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Animal and Plant Health Inspection Service

ArborGen, Inc. Petition (11-019-01p) for Determination of Non-regulated Status for Freeze Tolerant Eucalyptus Lines FTE 427 and FTE 435

Draft Environmental Impact Statement – April, 2017

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ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
°F	Degrees Fahrenheit
APHIS	Animal and Plant Health Inspection Service
AQI	Air Quality Index
BMP	Best Management Practices
BRS	Biotechnology Regulatory Services
CAA	Clean Air Act
CBF2	Cold-Binding Factor 2
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CP	Coastal Plain
CRP	Conversation Reserve Program
CWA	Clean Water Act
DBH	Diameter at Breast Height
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ET	Evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
FCCS	Fuel Characteristic Classification System
FDA	Food and Drug Administration
FERA	Fire and Environmental Research Applications Team
FFDCA	Federal Food, Drug, and Cosmetic Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FONSI	Finding of No Significant Impact
FR	Federal Register

FS	Forest Service
FTE	Freeze-tolerant *Eucalyptus*
GE	Genetically Engineered
GHG	Greenhouse Gas
HWC	Herbaceous Weed Control
LAI	Leaf Area Index
LTER	Long Term Ecological Research
MAV	Mississippi Alluvial Valley
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NO_2	Nitrogen Dioxide
NOI	Notice of Intent
NPS	Non-Point Source
NRCS	Natural Resources Conservation Service
O_3	Ozone
OSTP	Office of Science and Technology Policy
P	Precipitation
PB	Lead
PIP	Plant-Incorporated Protectant
PM	Particulate Matter
PPA	Plant Protection Act of 2000
PPRA	Plant Pest Risk Assessment
Q	Water yield
SCAN	Soil Climate Analysis Network
SO_2	Sulfur Dioxide
SPB	Southern Pine Beetle
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
US	United States
USDA	United States Department of Agriculture

VAM	Vesicular Arbuscular Mycorrhizae
VOC	Volatile Organic Compound
WRA	Weed Risk Assessment

EXECUTIVE SUMMARY

Regulatory Authority

APHIS regulates certain genetically engineered (GE) organisms under the authority of the PPA of 2000 as amended (7 U.S.C. §§ 7701–7772), and APHIS regulations codified in Title 7 part 340 of the U.S. Code of Federal Regulations (7 CFR part 340). 7 CFR part 340 governs a GE organism in the following circumstances: if it is a plant pest (such as certain microorganisms or insects that can cause injury or damage to plants); if it is created using an organism that is itself a plant pest; if APHIS does not have sufficient information to determine if the GE organism is or may be a plant pest.

When plant developers produce a certain plant through genetic engineering, the resulting GE plant is considered a regulated article under 7 CFR part 340 and developers must obtain permits from APHIS to grow the plant anywhere within the U.S. or to ship it across state or territorial borders. Once a developer of the regulated GE plant has obtained a reasonably sufficient body of information to conclude that the regulated GE plant is unlikely to cause injury, damage, or disease to plants or plant products (i.e., pose a plant pest risk), the developer may submit a petition to APHIS seeking "non-regulated status" so that it is no longer regulated. If APHIS approves a petition for non-regulated status, then APHIS will no longer require permits or notifications to grow the plant within the United States or to ship it across U.S. state or territorial borders; the plant will no longer be subject to regulations pursuant to 7 CFR part 340.

Any party can petition APHIS for non-regulated status of a GE organism through the procedures described in 7 CFR§ 340.6. APHIS regulates such a GE organism until a request for non-regulated status is made and approved. Once receiving the request, the agency evaluates it based on whether it meets the Plant Pest Act's (PPA) definition of a plant pest. The evaluation is based on scientific evidence and assesses whether the GE organism is unlikely to pose a plant pest risk; that is to say that the potential for the GE organism to cause plant disease or damage is unlikely. The petitioner must provide data, including information obtained from confined field tests regulated by APHIS, to help inform Agency decision makers. APHIS analyzes the data from the petitioner, researches current scientific findings, and prepares a Plant Pest Risk Assessment (PPRA) that documents whether or not the GE organism is likely to cause disease or damage. If APHIS concludes that the GE organism does not pose a plant pest risk, APHIS must then issue a regulatory decision of non-regulated status, since the Agency does not have regulatory authority to regulate organisms that are not plant pests. When a determination of non-regulated status has been issued, the GE organism may be introduced into the environment without APHIS regulatory oversight under 7 CFR part 340. In the case of the two GE lines of *Eucalyptus* tree that are the subject of this Environmental Impact Statement (EIS), if non-regulated status is determined to be appropriate for them, ArborGen will be allowed to sell the GE seedlings to tree plantation owners, and growers will be able to grow, harvest, and move their tree crops into commerce without the requirement of authorization from APHIS.

Two other federal agencies, the Federal Drug Administration (FDA) and the Environmental Protection Agency (EPA), provide oversight of GE plants. The relative roles of the USDA (through APHIS), the FDA, and the EPA are described by the "Coordinated Framework," a 1986 policy statement from the Office of Science and Technology Policy that describes the comprehensive Federal policy for ensuring the safety of biotechnology research and products (US-OSTP, 1986).

The FDA's regulation of GE plants is based upon its authority to regulate food safety under the Federal Food, Drug, and Cosmetic Act (FFDCA) 21 U.S.C. §§ 301 – 399. The FDA implements a voluntary consultation process to ensure that human and animal food safety issues or other regulatory issues, such as labeling, are resolved before commercial distribution of food derived from GE products.

The EPA regulates the use, sale, and labeling of pesticides pursuant to its authority under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7 U.S.C. §§ 136–136y). The EPA's actions under FIFRA directly affect the production methods used on herbicide-resistant (HR) GE plants. An herbicide must first be "registered" by the EPA before it can be distributed or sold in the U.S. (7 U.S.C. §§ 136a(a), 136j(a)(2)(F)). The EPA registration process starts with the herbicide manufacturer providing the EPA with information about the herbicide (7 U.S.C. § 136a(c)(1)(C), (F)). The agency then evaluates the effects it may have on humans and the environment in accordance with the proposed label. On the basis of this evaluation, the EPA then determines if it will allow use of the herbicide on a plant, and, if so, under what conditions and in what quantity. The EPA sets the conditions for herbicide use and places them in labeling instructions that a user must follow (*See* 7 U.S.C. 136j(a)(2)(G)). The EPA reevaluates all pesticides, which includes herbicides, every fifteen years (or shorter) to ensure they meet current standards for continued safe use (7 U.S.C.§ 136a(g)(1)(A)(iv)). Under FIFRA, the EPA also regulates plant-incorporated protectants (PIPs) which are pesticidal substances produced by plants and the genetic material necessary for the plant to produce the substance.

The GE *Eucalyptus* lines that are the subject of this draft Environmental Impact Statement (dEIS) have not been engineered to be resistant to a specific herbicide or produce plant incorporated protectants (PIP). Consequently, EPA is not required to review any proposed changes in the registered use of pesticides or to regulate FTE 427 and FTE 435 *Eucalyptus* lines on the basis of PIP.

Purpose of FTE 427 and FTE 435 Lines

Commercially viable planting of non-GE *Eucalyptus* varieties is currently limited to central and southern Florida, which is warm enough to cultivate tropical *Eucalyptus* varieties (*Eucalyptus* present in California are different *Eucalyptus* species than those that are commercially cultivated in central and southern Florida.) ArborGen developed FTE 427 and FTE 435 events to exhibit freeze-tolerance and male sterility. The primary purpose of FTE 427 and FTE 435 is to provide growers with additional planting options by expanding the geographic range for plantings of commercially grown *Eucalyptus* in the United States, while reducing the likelihood of pollen movement from these GE *Eucalyptus* lines.

If APHIS approves the petition for non-regulated status and ceases to regulate FTE 427 and FTE 435, these two GE *Eucalyptus* lines would be available for cross-breeding with all other non-GE *Eucalyptus* or GE varieties that are no longer regulated by APHIS. For the technical details on these two GE plant lines, see the petition submitted by ArborGen which is available on the APHIS website.[1]

Purpose and Need for Agency Action

APHIS regulations require APHIS to evaluate and make decisions on the complete petitions it receives for non-regulated status. The Agency can choose to approve a petition in whole or in part, or APHIS can deny the petition. As previously mentioned, APHIS decisions are based on a PPRA for the GE plants that are the subject of the petition. Plant pest risks are those risks caused by plant pests that can cause injury, damage, or disease to plants or plant products. Consistent with the APHIS authority under the PPA, market acceptance of a product is not an aspect of PPRA.

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[1] See http://www.aphis.usda.gov/biotechnology/petitions_table_pending.shtml

The purpose of the petition process and the decisions made under the regulations is to protect plant health. If developers can demonstrate through this process that their products do not pose plant pest risks, they can enter their products into commerce without restrictions. APHIS conducts evaluations and must makes decisions that are consistent with APHIS' statutory and regulatory authorities.

In response to ArborGen's petition submitted January 17, 2011, APHIS prepared a preliminary PPRA to assess the plant pest risk for FTE 427 and FTE 435. In addition to preparing a PPRA, APHIS must also prepare an environmental analysis consistent with its obligations under the National Environmental Policy Act (NEPA). Under NEPA regulations, an agency conducts an environmental assessment (EA) to determine if a major federal agency action will cause significant environmental impacts (40 CFR § 1501.4). If the agency concludes in its EA that its action will not significantly impact the environment, the agency issues a "Finding of No Significant Impact" (FONSI) and the agency can proceed with its proposed action without preparing a more thorough environmental impact statement (EIS). If the EA concludes that the proposed action may significantly affect the environment, the agency must prepare an EIS. However, an agency may determine that significant impacts are possible without formally preparing an EA and at its discretion proceed directly to the preparation of an EIS, as was the case for this petition.

The USDA's Forest Service (USDA-FS) has extensive experience with a wide range of issues concerning forests and production forestry. The USDA-FS is a cooperating agency in the production of this EIS. In addition to scientific and editorial assistance in the production of this draft EIS, USDA-FS also produced and submitted three technical reports for inclusion in this draft EIS. These include:

- *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B);
- *Implications for expansion of GE freeze-tolerant Eucalyptus plantations on water resources in the continental US* (Appendix C); and
- *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States* (Appendix D).

Public Involvement

APHIS routinely seeks public comment on EISs prepared in response to petitions seeking a determination of non-regulated status of a regulated GE organism. APHIS does this through a notice published in the *Federal Register*. Scoping for this EIS began on February 27th, 2013, when USDA-APHIS published its Notice of Intent (NOI) to prepare an EIS on this subject in the *Federal Register* (78 FR 13309). The scoping process included a 60-day comment period on the APHIS Notice of Intent (NOI) and two virtual public meetings.

The comment period for the APHIS NOI ended on April 29th, 2013. APHIS received 37,307 total comments.[2] For a summary of these 37,307 comments, see Appendix A. Twenty people attended the virtual public meeting held on April 17th, 2013; four of these people spoke at the meeting. Thirty-six people attended the virtual public meeting held on April 18th, 2013; three of them spoke at the meeting. Transcripts and a summary of the two virtual public meetings may be found in Appendix A. Overall, an analysis of the comments received did not identify any additional broad issues beyond those enumerated

[2] Total comments include public comment records, attachments, and form letters.

in the NOI, but served to highlight the relative importance of certain issues already on the list of topics that were analyzed by the agency in the EIS. For a summary of these issues, see Appendix A.

Alternatives Analyzed

In this EIS, APHIS considered two alternatives for its response to the ArborGen petition for non-regulated status. The two alternatives are: 1) continue to regulate FTE 427 and FTE 435 *Eucalyptus* lines (i.e., No Action Alternative); and 2) approve the petition for non-regulated status of FTE 427 and FTE 435 *Eucalyptus* lines (i.e., Preferred Alternative). These alternatives are described here and in Chapter 2.

Alternative 1: No Action Alternative – Continuation as Regulated Articles

Under the No Action Alternative, APHIS would deny the petition and the FTE 427 and FTE 435 *Eucalyptus* lines would continue to be regulated by APHIS. Permits issued or notifications acknowledged by APHIS would still be required for the introduction of FTE 427 and FTE 435 *Eucalyptus* lines, and measures to ensure physical and reproductive confinement would continue to be implemented. Based on the conclusion in its preliminary PPRA that FTE 427 and FTE 435 do not pose plant pest risks (USDA-APHIS, 2015), APHIS is identifying Alternative 2 as its Preferred Alternative. Therefore, choosing Alternative 1 would not be consistent with the scientific evidence before the Agency regarding lack of plant pest risk and thus would not fully satisfy the purpose and need of making the required regulatory determination under the PPA and 7 CFR part 340.6.

Alternative 2: Proposed Action Alternative (Preferred Alternative) – Determination of Non-regulated Status of FTE 427 and FTE 435 *Eucalyptus* Varieties

Under the Proposed Action alternative, which is also the Preferred Alternative, FTE 427, FTE 435, and their progeny would no longer be subject to APHIS biotechnology regulations (7 CFR part 340) as they would have been determined unlikely to pose plant pest risk. Permits issued or notifications acknowledged by APHIS would no longer be required for introductions of these lines. This alternative would meet the purpose and need to respond appropriately to the petition for non-regulated status, the requirements in 7 CFR part 340, and the Agency's regulatory authority under the plant pest provisions of the PPA, because APHIS has concluded in its preliminary PPRA that these lines are unlikely to pose plant pest risk. Therefore, this would be the Preferred Alternative because approving the petitions for non-regulated status for both lines is consistent with the scientific evidence before the Agency regarding lack of plant pest risk and would satisfy the purpose and need of making the required regulatory determination under the PPA and 7 CFR part 340.6.

Affected Environment

To determine the extent of the potential environmental impacts that could result from any APHIS decision related to the regulation of FTE 427 and FTE 435 *Eucalyptus* lines, the USDA Forest Service (USDA-FS), a cooperating agency on this EIS, produced a technical report examining where these GE *Eucalyptus* lines could be commercially cultivated (Appendix B). The action area for this EIS includes Alabama (5 counties); Florida (53 counties); Georgia (61 counties); Louisiana (31 counties); Mississippi (20 counties); South Carolina (9 counties); and Texas (25 counties). Additional details regarding the identification of these 204 counties as the FTE action area may be found in Appendix B. The USDA-FS technical report also further narrowed the action area within those 204 counties to those land areas that are currently planted to pine[3] or naturally-regenerated plantation pine (Appendix B). As a result, the resource areas examined are analyzed within the context of planted or naturally-regenerated plantation pine. Additional details regarding the identification of land utilized for the production of plantation pine may be found in Appendix B.

Potential Environmental Impacts of Alternatives

Environmental issues are assessed individually in Chapter 4 (Potential Environmental Consequences). As stated previously, APHIS has regulatory authority based on the plant pest potential of FTE 427 and FTE 435 lines. The scope of this EIS analyzes the potential for direct and indirect impacts that might result from the cultivation and use of FTE 427 and FTE 435.

APHIS emphasizes that its decision to prepare an EIS in this case was discretionary. The agency's decision was based on a perceived need for the level of thoroughness afforded by the EIS process because of the complexity of issues that needed to be addressed. These issues included the potential environmental impacts associated with any land use changes caused by the commercial cultivation region of *Eucalyptus*. APHIS considers these issues in detail in Chapter 4, which discusses the environmental consequences that may result if APHIS determines non-regulated status for the FTE 427 and FTE 435 lines, and if FTE 427 and FTE 435 replace some planted pine acreage. Chapter 5 discusses potential cumulative impacts that may occur if APHIS recognized non-regulated status for FTE 427 and FTE 435 lines, and if FTE 427 and FTE 435 replace some planted pine and naturally-regenerated pine acreage.

APHIS determined that the potential environmental impacts from the cultivation of FTE 427 and FTE 435 lines would either not differ or may be slightly worse from those caused by the cultivation of planted plantation pine. Certain categories of potential environmental impacts do not differ between pine plantation and cultivation of FTE 427 and FTE 435 lines because the cultivation of both utilizes similar management strategies inherent in production forestry. Other types of potential environmental impacts are slightly greater from those caused by the cultivation of planted plantation pine due to the specific management practices used in the viable cultivation of any *Eucalyptus* variety, not necessarily because the FTE 427 and FTE lines were genetically engineered.

A summary of the potential environmental consequences resulting from a determination of non-regulated status for FTE 427 and FTE 435 lines is presented below. More detailed analyses may be found in Chapters 4 through 8.

<u>Potential Environmental Impacts on Land Use</u>

To determine FTE adoption rates, APHIS coordinated with USDA-FS to model the potential adoption of FTE plantations. The model started by limiting the range where FTE can be commercially grown to a portion of the Southeastern United States from eastern Texas to South Carolina. The study then examined the economics of timber markets and FTE to project the potential extent of adoption as well as any potential shifts in land use to support commercial FTE production.

FTE may be potentially adopted by pine plantation land managers across 204 counties in South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. Additionally, FTE was found to be

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[3] i.e., artificially-regenerated pine grown in plantation

[4] See USDA Forest Service: https://www.fs.fed.us/psw/topics/urban_forestry/products/cufr562_Newsletter_Jan05_Special_Edition.pdf

potentially competitive with pine plantations especially in the western part of the Southeastern United States (Texas, Louisiana, and Mississippi). This competitive feature derives from strong growth in real hardwood pulpwood prices over the past two decades. In contrast, FTE would not be competitive with cropland, as current cropland returns exceed projected FTE returns by an order of 3 to 5 times, making it unlikely that growers will convert cropland to FTE plantations.

USDA-FS models yield a potential conversion of around 5 to 9 percent of the current 16 million acres of planted pine, equivalent to about 0.8 to 1.4 million acres of FTE. If it is assumed that the eligible area also included the area of naturally-regenerated pine, then the total eligible area would be about 27 million acres. Under this scenario, the projected area of adoption is estimated to range from around 1.4 to 2.8 million acres by year 30 (Appendix B).

Adoption of FTE in the study area is not anticipated to affect overall land use patterns described in the No Action Alternative. Conversion of other land use types, such as agricultural lands, to FTE plantations is considered highly unlikely because FTE is not competitive with other agricultural land uses. High returns from cropland would generally preclude transition to *Eucalyptus* because crop returns currently exceed *Eucalyptu*s returns by 3-5 times (Appendix B). Actual adoption of FTE will mostly depend on market demand and pricing for various timber products, including the potential development of a bioenergy market. Returns from *Eucalyptus* are driven by hardwood pulpwood prices, and strong price increases are consistent with an overall tightening of hardwood pulpwood supplies (Appendix B). According to USDA-FS analyses, costs to convert pine plantations to FTE could also have an appreciable effect on the areas and acreage that would ultimately be converted. An additional driver of adoption is the risk of public disapproval of the planting of genetically engineered trees. This societal concern could affect investment choices in the same way as biophysical risk – i.e., increased risk would reduce the rate of adoption.

Potential Environmental Impacts on Air Quality

Under the Preferred Alternative, planting FTE on some lands previously planted with commercial pine species in the action area may occur. The usage of vehicles and machinery in commercial forestry contribute air pollutants, and FTE will cause an increase in heavy equipment usage because of its shorter harvest cycle (six to ten years) compared to pine (twenty to twenty-five years). While emissions associated with plantation management may increase under the Preferred Alternative, this is unlikely to represent a significant source of air pollutants in the action area. FTE plantations are expected to be adopted on approximately 10 percent of the lands currently planted to pine. Hence, any increase in NAAQS emissions associated with a shorter harvest cycle of six to ten years are expected to be minor.

There is some evidence that *Eucalyptus* produces more volatile organic compounds (VOC) than pine species. VOCs interact with nitrogen oxides (NOx – produced via combustion of fossil fuels) and sunlight to produce ground-level ozone. High ground-level ozone can trap heat and exacerbate respiratory problems for people. This is generally more of a problem in urban areas that can have high levels of NOx. Where atmospheric concentrations of nitrogen oxides are low, such as rural and forest areas, unhealthy levels of ground-level ozone do not readily form. Although FTE and pine trees emit VOCs, trees in non-urban areas generally mitigate ozone formation due a reduction of direct sunlight under the tree canopy and cooling of air temperature.[4] Hence, the likelihood of FTE contributing to an increase in the development of ground-level ozone is considered low to negligible.

Potential Environmental Impacts on Soil Resources

Under the Preferred Alternative, the potential impacts on soil resources are likely to remain the same or be slightly worse than the No Action Alternative within the action area. The cultivation of FTE under the Preferred Alternative and the continued cultivation of plantation pine under the No Action Alternative both represent intensive production forestry operations. Consequently, both the No Action and Preferred Alternatives are likely to lead to similar impacts on soil quality, though the impact from cultivating FTE may be slightly worse, due to FTE physiology and its shorter rotation cycle. This impact on soil quality from the Preferred Alternative, when compared to the No Action Alternative, is likely to be minor because of management practices (e.g., BMPs and fertilization) currently used by managers of tree plantations to mitigate impacts to soil resources.

Additionally, the potential impact to mycorrhizal fungi is uncertain. While evidence suggests that FTE may form mycorrhizal associations within the action area, there is also an absence of information as to which native fungi species will be able to participate in this symbiosis. However, potential impacts on soil quality from fire or allelopathy under the Preferred Alternative are unlikely to be substantially different when compared to the No Action Alternative.

Potential Environmental Impacts on Water Resources

Under the Preferred Alternative, local and direct impacts may occur on water quantity and quality. However, these direct impacts on water quantity and quality are likely to be negligible at larger spatial scales, such as within individual watersheds or across all watersheds in the action area.

FTE is likely to use more water than other types of vegetation, including non-irrigated crops, deciduous hardwoods, and plantation pine. Consequently, FTE is likely to reduce the amount of water available for local streamflow compared to these other types of vegetation. The magnitude of this direct and local impact on streamflow is dependent on the type of vegetation that is replaced with FTE and the amount of precipitation received and other hydrological factors. Thus, the impact of FTE on local water quantity is site dependent.

FTE is likely to have local impacts on water quality through increased sediment loading from forest access systems (forest roads and stream crossings) into forest streams. While the cultivation of FTE is unlikely to increase the number of forest roads and stream crossings in the action area (i.e., FTE is anticipated to be planted on sites previously planted to plantation pine), these forest access systems are likely to experience more frequent disturbances related to FTE-related management. More frequent disturbances on these forest access systems may lead to increased sediment loading into forest streams. Current Best Management Practices (BMPs), however, are effective in reducing sediment loading into forest streams and may mitigate local and direct impacts from FTE-related management activities, so long as these BMPs are adopted by growers of FTE.

Potential Environmental Impacts on Pine-Associated Vegetation

[4] See USDA Forest Service: https://www.fs.fed.us/psw/topics/urban_forestry/products/cufr562_Newsletter_Jan05_Special_Edition.pdf

The replacement of planted pine plantations in the action area with FTE may result in a quicker shift to shade-tolerant vegetation in the understory. Additionally, the more intensive competition management may be used in the cultivation of FTE, potentially reducing the abundance and diversity of understory vegetation in sites where FTE is planted. However, it is prudent to mention that any tree plantation will generally have lower plant species diversity than natural forests due to overall common silvicultural practices.

FTE, like other *Eucalyptus* species under plantation management, grows quickly and reaches canopy closure within two years compared to pine canopy closure of 10-12 years. *Eucalyptus* harvest cycles are 6-10 years and four to six harvests can occur per planting. This equates to two or more harvest cycles within the period of one harvest cycle for planted pine. The machinery used during various management activities, particularly harvesting activities, would damage understory vegetation. In FTE plantations, this disturbance would occur every 6-10 years as opposed to 20-25 years for pine plantations.

Several studies indicate older pine and *Eucalyptus* plantations tend to have a higher level of plant diversity given the additional time to develop structural complexity. Furthermore, older plantations also tend to have more native plant species compared to younger plantations that tend to have light-demanding ruderal and exotic plant species. FTE likely will mimic a young plantation given the short harvest cycle. FTE plantations may require more management inputs compared to pine plantations, particularly in the stand establishment phase to control vegetation competition. Herbicide applications to manage vegetation competition are already common in pine plantations in the action area. FTE seedlings, like other *Eucalyptus* seedlings, are more sensitive to vegetative competition than pine seedlings. In the early stage of rotation, FTE plantations will likely have reduced herbaceous cover compared to planted pine plantations due to multiple applications of herbicides needed to control vegetation. The short harvest cycles for FTE will result in additional vegetation control since the canopy will reopen after harvest, encouraging the growth of understory plants until FTE trees sprout and attain canopy closure again. The suppression of vegetation competition in southern plantations, regardless of tree species, intentionally kills understory plants.

In general, tree plantations, including pine and *Eucalyptus* plantations, have lower plant species diversity than do natural forests, because they usually consist of a near monoculture. This is due to silvicultural practices, including vegetation management and harvesting, that disturb the understory and can reduce biodiversity.

Potential Environmental Impacts on Wildlife

The replacement of planted pine plantations in the action area with faster-growing and short-rotation FTE will likely reduce the available understory vegetation for wildlife. Since *Eucalyptus* seedlings are more sensitive to vegetative competition than are pine seedlings, it is expected that FTE growers within the action area will use more intensive management strategies than in pine plantations, thereby reducing available early succession food and habitat for mammalian species commonly associated with early growth forage, including small mammals and deer. The reduction in understory and increased disturbance from short rotation times also will reduce the number of bird species that would otherwise use this habitat for shelter and nesting. The reduction in bird species associated with FTE replacement of pine plantation is likely to be greater than the reduction in bird species associated with pine plantation management compared to natural forests.

FTE plantations will produce less nutritious, smaller seeds than pine plantations; however, insect-feeding birds will have similar opportunities in both FTE and pine plantations. Nectar-feeding birds, on the other hand, will benefit from the addition of FTE to the landscape. The number of amphibians and reptile species living in the FTE plantations will likely be minimal, further reduced from the trends described for reptile and amphibians in pine plantations. Invertebrate diversity and abundance will likely be reduced more quickly in FTE plantations compared to pine plantations due to the faster growth and shorter FTE rotation period, which subsequently reduces herbaceous cover.

In addition, intensive competition management could further reduce habitat available for invertebrates, such as butterflies. While *Eucalyptus* groves, including FTE, have the potential to be host to numerous wildlife species, the greatest biodiversity comes from old growth groves with an understory or *Eucalyptus* plantations that practice the non-traditional coppice method. As a result, FTE plantations within the action area are expected to host fewer wildlife and invertebrate species than planted pine plantations, though the specific amount of reduction is uncertain for some groups of wildlife species.

Potential Environmental Impacts on Insect and Disease Pests

Under the Preferred Alternative, there are a number of *Eucalyptus* insect and disease pests that can increase in prevalence within the action area. Additionally, the cultivation of FTE under the Preferred Alternative may allow the expansion of *Eucalyptus* insect and disease pests into the action area where *Eucalyptus* was not previously cultivated. Of these potential insect and disease pests, the insect pests that are most likely to become a substantial pest in FTE plantations are those insect pests already within the United States, such as Phoracantha wood borers, the eucalyptus weevil, and eucalyptus psyllids. Additionally, the disease pests most likely to become substantial pests in FTE plantations are also those disease pests already present in the United States, such as pink disease, eucalyptus rusk, and coniothyrium canker. This potential outcome is not surprising, considering the absence of cultivation or absence of large-scale cultivation of *Eucalyptus,* GE or non-GE, within the action area.

There are several factors which may play a role in the abundance of insect and disease pests of FTE *Eucalyptus*. These include: introduction potential, freeze tolerance and adaptation to environmental conditions, host specificity, and efficacy of control measures. Growers may be able to control the majority of the insect pests expected to infect FTE within the action. However, disease pests of FTE may be more difficult to control due to a more limited spectrum of available tools and control strategies compared to those available for insect pests. Monitoring for these pests and diseases should be conducted as part of good plantation management practices or part of an early detection and rapid response plan. Sufficient control methods would need to be put in place if disease pests of FTE were to increase in incidence or severity within the action area.

In spite of the potential increase in *Eucalyptus* insect and disease pests within the action area, it is unlikely that these pests will significantly damage other plant species. Many of the potential insect pests are host-specific herbivores that are unlikely to feed upon other plant hosts. Two disease pests, however, may affect other plants. Eucalyptus rust and pink disease may potentially infect other susceptible plants within the action area, as they are not host-specific pathogens. However, given the limited adoption of FTE and limited dispersal of these pathogens from FTE to other plant hosts, it is anticipated that potential impacts to other plant hosts from these two diseases will not be substantial. Monitoring for these pests and diseases should be conducted as part of good plantation management practices or part of an early detection and rapid response plan. With regard to the insect and disease pests of plantation pine discussed under the No Action Alternative, APHIS does not anticipate a significant impact under the Preferred Alternative, given the projected increase in planted plantation pine acreage that is already occurring independently of the regulatory status of FTE.

Potential Environmental Impact on Biological Diversity

Under the Preferred Alternative, biological diversity is likely to be reduced when compared to planted pine plantations within the action area, primarily due to the impacts from short-rotation management of FTE on vegetation and subsequent impacts on wildlife.

Tree plantations are likely to contribute to diversity when established on degraded lands, and when native tree species are planted. Also, management intensity and the age and structure of the stands determine the ability of plantations to harbor biodiversity. Neither planted pine nor *Eucalyptus* plantations are as biologically diverse as natural forest land, but they compare favorably to land used for agriculture or urbanization. However, the differences in management practices and biological traits of *Eucalyptus* will lead to an overall decrease in biodiversity in FTE plantations compared to planted pine plantations. Areas of FTE plantations have the potential to alter the diversity of plant and animal species across landscapes, but the reduction in biodiversity is expected to be less severe than if pine plantations were converted to other more intensive land uses, such as agricultural crops or to urban uses.

Potential Environmental Impact on Threatened and Endangered Species

Under the Preferred Alternative, there is the potential for direct and indirect impacts that may occur on threatened and endangered (T&E) species. Three main stressors that could lead to these impacts were identified: the potential to affect hydrology, the difference in growth habits between pine and FTE, and the more frequent harvest rotation and site activity, which in turn increases the potential for sedimentation.

FTE is likely to use more water than other types of vegetation, including non-irrigated crops, deciduous hardwoods, and plantation pine. Consequently, FTE is likely to reduce the amount of water available for local streamflow compared to these other types of vegetation. The magnitude of this direct and local impact on streamflow is dependent on the type of vegetation that is replaced with FTE and the amount of precipitation received and other hydrological factors. This effect on streamflow could impact water dependent species such as amphibians, reptiles, fish, and mussels. Reduced water in wetlands adjacent to or in a pine plantation may affect amphibians, reptiles and plants.

FTE, like other *Eucalyptus* species under plantation management, grows quickly and reaches canopy closure within two years compared to pine canopy closure of 10-12 years. This severely changes the light level in the understory and could affect species diversity and dominance. Species requiring a somewhat open canopy, such as certain plants, may be impacted. *Eucalyptus* harvest cycles are 6-10 years compared to 20-25 years for pine plantations. This equates to two or more harvest cycles within the period of one harvest cycle for planted pine. The machinery used during various management activities, particularly harvesting activities, would damage understory vegetation, and could directly affect any animal species present at the time of these activities, and indirectly affect them by altering habitat.

The shorter harvest cycle for FTE can potentially impact water quality through increased sediment loading from forest access systems (forest roads and stream crossings) into forest streams. While the cultivation of FTE is unlikely to increase the number of forest roads and stream crossings in the action area (i.e., FTE is anticipated to be planted on sites previously planted to plantation pine), these forest access systems are likely to experience more frequent disturbances related to FTE-related management. More frequent disturbances on these forest access systems may lead to increased sediment loading into forest streams. Current Best Management Practices (BMPs), however, are effective in reducing sediment loading into forest streams and may mitigate local and direct impacts from FTE-related management activities, so long as these BMPs are adopted by growers of FTE.

The stressors discussed above were used to analyze the potential effects that a determination of non-regulated status of FTE may have on federally-listed T&E species and species proposed for listing, as well as designated critical habitat and habitat proposed for designation. APHIS used the U.S. Fish and Wildlife Service (USFWS) database to identify all species and critical habitat within the action area, defined as the 204 counties where FTE is likely to be adopted. There were a total of 138 listed species and 2 species proposed for listing. Of the 140 species, APHIS has determined that 55 of the listed species and the 2 proposed species have the potential to be sufficiently collocated that they may be affected by conversion of pine plantations to FTE, although it is recognized that they may be currently impacted by existing plantations. Of these 57 species, 36 have the potential to be adversely affected, and 21 species may not be adversely affected. The species with the potential to be adversely affected include 3 amphibians, 1 fish, 11 mussels, 1 conifer, 16 flowering plants, and 4 reptiles. The species that may not be adversely affected species include 1 mammal, 7 mussels, 1 fish, 8 flowering plants, 1 crustacean, and 3 reptiles.

Of the 140 species, 39 have designated critical habitat and 2 species have proposed critical habitat. There is also one plant species that is not known to occur within the action area, but has an unoccupied critical habitat unit proposed for designation within the action area. As part of its species effects analysis, APHIS considered the effects that a determination of non-regulated status of FTE and likely adoption may have on the critical habitat of these species. Twenty-one of the species with critical habitat were determined to be "no effect" species, mainly because the species are far removed from pine plantations, have specific habitat requirements, and the primary constituent elements of the species' habitat are not found in pine plantations. No effects are expected on their critical habitat either. Of the 20 "may affect" species with critical habitat (18 designated and 2 proposed), the critical habitat for many would be unlikely to be affected. Conversion of pine to FTE would be unlikely to occur within critical habitat. In the majority of cases, pine plantations are unsuitable habitat for the species and conversion from pine to FTE would be unlikely to have any effect on habitat that would be different than pine. There may be some effect on critical habitat for amphibians and some mussel species in locations that have been susceptible to drought. During times of drought, the lack of water will likely be exacerbated by the increased water demand of FTE if a plantation were within the local drainage. Although such impacts may make the habitat unusable, they are likely to be temporary and long term impacts on the habitat are unlikely to be different than from those impacts resulting from periods of drought. The conclusions of the effects on critical habitat are in agreement with our determination for the species. That is, critical habitat for those species with a likely to adversely affect determination also have a similar determination for the critical habitat. The reason for this is that the species are affected by changes to their habitat (e.g. changes to water quality and quantity).

It is important to realize that these impacts would be local, site dependent (size of plantation, location in relation to populations of T&E species, presence of other stressors), and highly variable. There is a high level of uncertainty in the analysis because there is no way to know where FTE plantations will be established and how close in proximity to populations of T&E species and critical habitat. Recognizing this unknown, APHIS took a cautious approach for the analysis, and many species are identified as "may affect" species because of the potential for effects rather than the likelihood of effects. Some species, even those the analysis determined to be "likely to be adversely affected", may ultimately never be affected at all.

As a result of the determination that adoption of FTE may affect a number of species, APHIS submitted a Biological Assessment and this EIS to the USFWS, and requested a formal consultation with the Service under Section 7 (a)(2) of the Endangered Species Act. The consultation is currently ongoing. No final decision on the petition will be made until the consultation with USFWS is complete.

Potential Cumulative Impacts

Chapter 5 of this dEIS includes an environmental analysis of potential cumulative impacts, including how resource areas within the affected environment may change if FTE were to be cultivated on pine plantation sites, which could include either previously planted or naturally-regenerated pine plantation. See Sections 5.2 for a more detailed discussion of reasonable foreseeable events and assumptions that were included in the cumulative impact analyses.

APHIS determined that the potential cumulative impacts from the cultivation of FTE would either not differ or be slightly worse from those caused by the cultivation of planted or naturally-regenerated plantation pine. In cases where the cumulative impacts do not differ, it is because the cultivation of FTE and planted/naturally-regenerated plantation pine both utilized similar management strategies inherent in production forestry. In cases where the potential cumulative impacts are slightly worse from those caused by the cultivation of planted/naturally-regenerated plantation pine, it is because of the specific management practices used in the viable cultivation of any *Eucalyptus* variety, not necessarily because of the GE process used to produce FTE. It is prudent to mention, however, that some naturally-regenerated pine acreage is already shifting toward potentially more intensive planted pine within the action area; therefore, some of the potential environmental impacts described may occur on naturally-regenerated pine acreage within the action area, irrespective of a determination of non-regulated status for FTE.

A summary of the potential cumulative impacts resulting from a determination of non-regulated status for FTE is presented below. More detailed descriptions and analyses may be found in Chapter 5.

Potential Cumulative Impacts on Land Use

Given current trends of grower switching from naturally-regenerated pine to planted pine, it is reasonably foreseeable that some of those growers of naturally-regenerated pine may also switch to FTE as a result of the Preferred Alternative. Considering around 5 to 9 percent potential conversion to FTE, the projected area of adoption is estimated to range from around 1.4 and 2.8 million acres by year 30 (Appendix B). If we also included the area of naturally-regenerated pine to the eligible area that may switch to FTE, then the total eligible area would shift from about 16 million acres to 27 million acres. It can be assumed that similar patterns would be observed with naturally-regenerated pine plantations shifting to FTE as well. If we apply the 2 to 15 percent range for all of the model scenarios to the 27 million acres that includes planted pine as well as naturally-regenerated pine the adoption rates of FTE range from around 0.54 to 4.05 million acres.

The availability of FTE under the Preferred Alternative is not expected to have any direct or indirect effects on overall land uses in the action area. Consequently, there are no reasonably foreseeable cumulative impacts on land use patterns in the action area that would derive from cultivation of FTE. Any adoption and cultivation of FTE would be limited to current land uses for commercial forestry. An overall decreasing trend in forested land within the action area resulting from a net shift toward urban land uses is not anticipated to change (e.g., population growth in the action area).

Potential Cumulative Impacts on Air Quality

The Preferred Alternative analysis on air quality (Section 4.6.2) concluded that the conversion of planted pine plantations to FTE is not likely to impact air quality e more so than is already occurring under the No

Action Alternative. Within the action area, existing sources (mobile and industry sources) of air pollutants and the projected overall loss of trees to urban development and other land uses other than forestry are the primary emission sources affecting air quality in the action area (Sections 4.6.2). Given existing trends related to the loss of naturally-regenerated pine acreage (either to planted pine or urban land uses), additional shifts of naturally-regenerated pine to FTE is not likely to have an overall cumulative impact on air quality in the action area, primarily due to the relative magnitude of this conversion compared to other factors that impact air quality, such as overall losses in tree acreage (planted or naturally-regenerated pine) to urbanization. The use of fossil fuel burning vehicles and machinery in any production forestry contribute air pollutants, and it is expected that heavy equipment would be used more frequently on FTE plantations than on planted or naturally-regenerated pine plantations because of FTE's short harvest cycle (six to ten years) compared to pine (twenty to twenty-five years). Despite the shorter rotation of FTE plantations compared to planted or naturally-regenerated pine plantations, commercial forestry serves as an overall sink for CO_2 with limited CH_4 and N_2O emissions.

Cultivation of GE FTE lines in place of extant pine species would not contribute to any significant change in emissions sources or quantities associated with forestry management practices, or the wood, pulp, and paper industries. The project would not require a different type or increase in the use of equipment that emits NAAQS pollutants, nor increase the frequency or intensity of fires, including controlled burning. The GE FTE lines would not alter the beneficial effects of forests on removal of atmospheric pollutants. Cultivation of FTE in place of pine on an estimated 10 percent of pine plantations would contribute to cumulative NAAQS emissions, equivalent to intensifying the harvest cycle on 10 percent of pine plantations (from approximately twenty to ten years). However, at this scale, such conversion and any subsequent increase in NAAQS emissions would not be expected to result in the designation of additional areas as non-attainment, or challenge sustaining of current attainment areas. Any conversion would comprise about 0.54 to 4.05 million acres of pine plantations, most likely around 5 to 9 percent of planted pine forest area, which is equivalent to about 0.8 to 1.4 million acres of FTE. Hence, considering the six to ten year harvest cycle, and beneficial effects of forests on air quality from assimilation of atmospheric pollutants, any potential adverse cumulative impacts on emissions of NAAQS pollutants would be expected to be minimal.

Potential Cumulative Impacts on Soil Resources

The cultivation of FTE and the continued cultivation of plantation pine both represent intensive production forestry operations. Whether FTE is planted on some sites devoted to naturally-regenerated or planted plantation pine, it is likely to lead to similar impacts on soil quality as described in the Preferred Alternative (Section 4.6.3), though the immediate impact from cultivating FTE on naturally-regenerated pine may be slightly worse, due to its shorter rotation cycle and resulting increased frequency of disturbance. The overall impact on soil quality is likely to be minor, however, because of management practices (e.g., BMPs and fertilization) currently used by managers of tree plantations to mitigate impacts to soil resources.

As noted in the No Action analysis on soil resources (Section 4.3.3), soil quality within the action area is already considered poor due to past agricultural practices and the inherent characteristics of the soil itself. Modern production forestry uses intensive site preparation, fertilization, short rotation times, and high planting densities to maximize economic returns which generally impacts soil quality through changes in soil structure and nutrient balance. These current production practices substantially alter processes related to litter production and decomposition, thereby altering various aspects of soil structure and nutrient balance. FTE is likely to reduce soil organic matter and soil nutrient balance compared to planted or naturally-regenerated plantation pine, owing to the physiology of *Eucalyptus*, the quality of its leaf fall, and its shorter rotation time.

As noted in the No Action and Preferred Alternative analyses on soil resources (Sections 4.3.3 and 4.6.3), in order to mitigate the impacts on soil quality from modern forestry practices, all states in the action area have implemented Best Management Practices (BMPs). Forestry BMPs are voluntary conservation practices for growing a healthy, sustainable, and productive forest. These BMPs are designed to assist land owners in protecting State water resources as well as avoiding practices that will lead to soil erosion, compaction, runoff and loss of nutrients. BMPs are also effective in maintaining site productivity by preventing damage to soil structure and the loss of soil nutrition if put into place.

Potential Cumulative Impacts on Water Resources

USDA-FS analyses indicate that at a local level, FTE may reduce the amount of water available for streamflow compared to other types of vegetation. The magnitude of this reduction, however, is dependent on the type of vegetation that is replaced with FTE and the amount of precipitation received. While planted pine plantations and naturally-regenerated plantations contain the same species of trees, the distribution and density of pine seedlings in naturally-regenerated pine plantations is irregular due to natural seeding. Tree density may impact the amount of water used within a forest system. However, since naturally-regenerated pine would be thinned within the first 5 years to densities similar to planted pine, their water use is anticipated be similar to planted pine over the course of the rotation. Consequently, if FTE were to be adopted on lands previously in naturally-regenerated pine, APHIS expects similar impacts to local water quantity as found under the Preferred Alternative analysis on water resources (Section 4.6.3).

A significant impact on watershed water availability from FTE adoption is not anticipated unless a 50 percent adoption rate of FTE is reached (Appendix C). Additionally, potential regional impacts on either available water, percent change in available water, or groundwater recharge is anticipated to be negligible at less than 20 percent (Appendix C). As indicated in the cumulative impacts analysis on land use (Section 5.4.1), FTE may replace some planted and naturally-regenerated pine acreage, leading to a projected 2 to 15 percent adoption rate by year 30; however, the most likely adoption rate is 5 to 9 percent (Appendix B). In order for any observable impact to occur on the watershed level, greater than 20 percent of vegetation would need to be replaced by FTE. However, a scenario where greater than 20 percent of vegetation is replaced represents a dramatic conversion of vegetation to FTE, and based on the socioeconomic analysis of FTE adoption (Appendix B), is unlikely to occur. Thus, under the most likely adoption rate of 5 to 9 percent, FTE is unlikely to significantly impact streamflow and groundwater recharge.

However, given projected climate variability, especially an increased frequency and severity of drought, some areas could be more sensitive to the potential impacts of FTE on local water quantity, primarily due to decreased amounts of precipitation and soil moisture (Appendix C). At the same time, decreased precipitation could also limit the adoption of FTE as there may be insufficient water resources available to cultivate FTE (Section 5.4.1).

As discussed in the No Action and Preferred Alternative analyses (Sections 4.3.4 and 4.6.4, respectively) plantation forestry in the action area primarily impacts surface water quality through the generation of sediments from the use of forest access systems. The cultivation of FTE on the previous sites of plantation pine, whether planted or naturally regenerated, is unlikely to increase the formation of forest access systems, as these sites and their respective forest access systems are already in place for plantation forestry. However, because the rotation cycle of FTE is shorter than plantation pine, it is likely that these forest access systems will be subject to more frequent use associated with FTE-related management.

While more frequent disturbances on forest access systems may lead to increased sediment loading into forest streams, current BMPs are effective in reducing sediment loading into forest streams and may mitigate local and direct impacts from FTE-related management activities, so long as these BMPs are adopted by growers of FTE. As discussed in the No Action analysis on water resources (Section 4.3.4), BMPs are commonly utilized by foresters and growers in the action area to mitigate sediment loss from forest roads and stream crossings into surface waters. Though voluntary, these BMPs are likely to be effective in reducing sediments from forest access systems that are utilized in the production of FTE as these BMPs were designed for general use in production forestry. Furthermore, the potential cumulative impact of FTE on water quality is likely to be negligible at larger spatial scales within the action area when compared to other more significant sources of sediments (e.g., agriculture and urbanization).

Potential Cumulative Impacts on Pine-Associated Vegetation

In the scenario that some naturally-regenerated pine plantations convert to FTE plantations, we expect similar impacts to understory and bordering vegetation as described in the Preferred Alternative analysis of pine-associated vegetation (Section 4.6.5), in spite of differences in the timing of site preparation, rate of growth from seed or seedling establishment, intensity of competition control, and rotation length between naturally-regenerated pine and FTE plantations.

FTE plantations are likely to alter conditions within the site, favoring shade-tolerant understory plant species, primarily due to more rapid canopy closure than naturally-regenerated pine. Additionally, FTE requires more intensive site preparation and management activities. This, coupled with the shorter rotation cycles of FTE relative to naturally-regenerated pine, suggests that potential impacts to pine-associated vegetation may be worse than the potential impacts that may result if FTE were only planted on acreage previously devote to planted pine. However, it is prudent to mention that any tree plantation is typically a monoculture. Tree monocultures (i.e., tree plantations) generally possess reduced plant understory diversity compared to natural forests. Furthermore, the management of competing vegetation, which occurs in tree plantations of any type, reduces the density and diversity of understory and bordering vegetation. The goal of vegetation management is to eliminate the understory vegetation to reduce competition for nutrients, water, and light. Understory vegetation management ultimately reduces the density and diversity of plants found in the understory of any production forest, irrespective of planted pine, naturally-regenerated pine, or FTE plantations. As a result, the cultivation of FTE on some lands currently devoted to naturally-regenerated pine would have an overall similar impact as the replacement of some planted pine acreage with FTE. FTE plantations would alter the ecosystem within the plantation, favoring shade-tolerant understory plant species, and may represent a less favorable habitat for native plant and animal species that are more likely to be adapted to native trees.

With respect to tree plantation abandonment, abandonment does occur in the action area and may occur with FTE plantations. Based on data from the petition, the literature, and weed risk assessments, one cannot rule out the possibility that the FTE hybrid will become naturalized in the long term (approximately ≥ 75 years) if it were to be widely planted. Although it is not likely to become highly invasive, the APHIS preliminary PPRA found that over time FTE might escape from cultivation, naturalize, and perhaps become a minor invader (with high uncertainty). The APHIS PPRA recommends management and oversight of FTE in order to minimize the establishment and spread of seedlings outside of plantations, particularly in areas close to waterways. Lorentz (2013) recommends the use of buffer zones around plantings for the purpose of limiting seed dispersal as well as providing surface water protection by limiting the proximity of trees to waterways. Where *Eucalyptus* (not specific to FTE) has already invaded Forsyth et al. (2004) recommends removing trees from riparian areas (where water use is likely to be excessive) and nature reserves where all eucalypts have undesirable impacts on biodiversity. Again, the likelihood of abandonment and FTE naturalization is uncertain, due to the length of time required for *Eucalyptus* species to escape and naturalize in other areas where it has been planted in the world.

Potential Cumulative Impacts on Wildlife

As described in the Preferred Alternative analysis on wildlife (Section 4.6.6), a conversion of some planted pine acreage in the action area to FTE may reduce wildlife abundance and diversity. Therefore, conversion of even greater acreage to FTE through the switching of some naturally-regenerated pine acreage may result in a similar or slightly greater reduction of wildlife within the action area.

Compared to planted pine, naturally-regenerated pine often includes less soil disturbance, possibly lower intensity of treatments, and no period of time when the land is clear of all vegetation since a few mature seed trees are left on site to provide seed for the new crop. Those wildlife species that utilize mature trees may benefit from trees being left on site during seed establishment on naturally-regenerated sites, when compared to planted pine or FTE. Additionally, the replacement of pine plantations, whether planted or naturally regenerated, in the action area with FTE will likely reduce the available understory for wildlife, primarily due to the shorter rotation schedule and rapid canopy closure of FTE. Species abundance and diversity are similar on naturally-regenerated and planted pine plantations and vary with stand age; therefore, whether FTE is planted on sites devoted to naturally-regenerated or planted pine plantations, it is likely to lead to similar or slightly worse impacts on wildlife abundance and diversity as described under the Preferred Alternative, given that naturally-regenerated pine plantations typically have the least level of disturbance when compared to planted pine.

Potential Cumulative Impacts on Insect and Disease Pests

As described in the Preferred Alternative analysis on insect and disease pests (Section 4.6.7), a conversion of some planted pine acreage in the action area to FTE may reduce insect and disease pests for pine, though it may increase the occurrence of *Eucalyptus* insect and disease pests. Therefore, conversion of even greater acreage to FTE through the switching of some naturally-regenerated pine acreage may result in a similar potential effect, through the increased acreage of FTE adoption. The potential increased presence of these *Eucalyptus* insect and disease pests, however, is not anticipated to cause damage to other tree species.

Potential Cumulative Impacts on Biological Diversity

As described in the Preferred Alternative analysis on biological diversity (Section 4.6.8), a conversion of some planted pine acreage in the action area to FTE may reduce wildlife abundance and diversity. Therefore, conversion of even greater acreage to FTE through the switching of some naturally-regenerated pine acreage may result in a similar or slightly greater reduction of biological diversity within the action area.

Biological diversity in naturally-regenerated pine is similar to planted pine, although the degree and frequency of disturbance of the two plantation management types may be slightly different. Compared to planted pine, natural regeneration often includes less soil disturbance and no period of time when the land is clear of all vegetation, and therefore may result in some minor differences in biodiversity between the two types. Compared to planted or naturally-regenerated pine, the shorter rotation schedule, rapid canopy closure, and more intensive management activities of FTE may reduce the structurally complex understory, thereby potentially reducing the habitat that is suitable for wildlife species. As was concluded in the Preferred Alternative analysis on biological diversity (Section 4.6.8), conversion of 1.4 million acres (10 percent) of pine plantation in the action area to FTE will likely reduce biodiversity across the region; thus, conversion of even greater acreage if FTE were to replace some planted and naturally-regenerated pine sites would result in even greater reduction of biodiversity in the action area. Large areas of FTE plantations have the potential to alter the diversity of plant and animal species across landscapes.

1 PURPOSE AND NEED

This document is intended to ensure compliance with the National Environmental Policy Act (NEPA). NEPA requires agencies to prepare an environmental impact statement (EIS) to be included in "every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment" (42 U.S.C. §4332(2)(C)).

The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) is currently engaged in decision-making relevant to its statutory authority to regulate two genetically engineered (GE) varieties as potential plant pests. The document is prepared in order to inform the decision about the environmental impacts associated with each alternative. Therefore, this document has been prepared as part of this APHIS decision-making process.

1.1 Introduction

Summarized as "Protecting American Agriculture," the mission of USDA APHIS[5] is: "To protect the health and value of American agriculture and natural resources." To achieve its mission, APHIS regulates potential effectors of plant and animal health. It integrates these regulatory functions to protect and promote United States domestic agricultural production, commodities, and trade in agricultural products in a manner that prevents or minimizes impacts on the environment.

To implement its plant protection mission, the Agency establishes policies and measures to prevent the introduction of plant pests into the United States. It also promotes management of those plants, animals, and microorganisms that currently occur within the United States and cause economic losses to the United States agriculture, including commercial and non-commercial production of crops and ornamental plants. Its mission encompasses all practices and technologies that have the potential to impact plant pest risks, either by increasing or reducing them.

One practice overseen by the APHIS plant protection mission is the use of genetic engineering to modify plant agronomic properties. The Agency has regulatory authority to ensure that the products of genetic engineering are unlikely to pose a plant pest risk.

Principles of biochemistry and molecular biology underlie the current understanding of genetic inheritance. The mechanisms involved provide the theoretical framework for modern biotechnology. Genetic engineering is one application of biotechnology. It enables the precise manipulation (insertion or deletion) of one or more selected genetic traits (genes) into the genome of an organism without sole dependence on the sexual compatibility of traditional breeding (cross-breeding principles of classical Mendelian genetics of inheritance). As a result, modern biotechnology makes possible the transfer of highly specific, individual, beneficial genetic traits between unrelated species. As part of its statutory and regulatory authority to regulate plant pests, APHIS must examine and determine that a certain GE (genetically engineered) organism or product, which is a plant pest or which there is reason to believe is a plant pest, is unlikely to pose a greater plant pest risk than the unmodified organism from which it was derived.

The APHIS regulatory authority (see Section 1.2 for a general summary) over GE organisms is limited to those with the potential to be plant pests. The Agency performs extensive, science-based analyses to evaluate the plant pest potential of each organism regulated for which a petition for non-regulated status has been submitted. Results are documented in a plant pest risk assessment (PPRA). If the conclusion of the PPRA is that a GE organism is unlikely to pose a plant pest risk, the Agency must determine that it does not regulate that organism as a plant pest.

Regardless of its decision (either not to regulate or continue regulating) for a particular article (i.e., organism) that has not been released previously into the environment, the Agency also assesses whether or not its decision is likely to cause an environmental impact(s), and if so, examines the environmental impacts of its determination to comply with regulations codified under NEPA. The results of the examination APHIS has performed, relevant to two new GE organisms it currently regulates, are the subject of this document.

1.2 APHIS Regulatory Authority

The Plant Protection Act of 2000 (PPA), as amended (7 U.S.C. §§ 7701–7772), provides the legal authorization for the APHIS plant protection mission. It authorizes the Agency to regulate the introduction of potential plant pests into the territorial boundaries of the United States, and their interstate movement within U.S. boundaries by establishing quarantine, eradication and control programs. Implementing rules, regulations and guidelines for this enabling legislation (PPA) are codified in Title 7 of the U.S. Code of Federal Regulations (CFR). Rules that implement this authority specific to GE organisms have been published in 7 CFR part 340.

1.2.1 Requirements for this Document

When APHIS receives a petition for non-regulated status of an article currently regulated under its PPA authority codified in 7 CFR part 340, the Agency is required to make a decision. As a Federal agency, APHIS must also comply with applicable U.S. environmental laws and regulations because a decision on a petition for non-regulated status, whether positive or negative, is a final Agency action that might cause environmental impact(s).

This document addresses both of these requirements relevant to decision making on a petition submitted by ArborGen Inc. of Summerville, South Carolina (hereinafter referred to as ArborGen). This ArborGen petition seeks a determination of non-regulated status of two genetically engineered (GE) *Eucalyptus* events, FTE 427 and FTE 435 (collectively referred to as freeze-tolerant *Eucalyptus* or FTE hereinafter [6]). Both of these events are genetically engineered to exhibit both freeze tolerance and male sterility. The purpose of FTE and its regulatory history are described in Section 1.3 and Section 1.4, respectively.

FTE is currently regulated under 7 CFR part 340. Interstate movement and field trials of FTE have been conducted under notification and permits since 2005. Data from the field trials are analyzed in the ArborGen petition (2011) and a PPRA prepared by APHIS (2015).

If APHIS makes a determination of non-regulated status for FTE, then FTE will cease to be subject to the PPA and regulations in 7 CFR part 340. If FTE is no longer regulated, non-regulated status will extend to crosses between these varieties and conventional (non-GE) cultivars, and other biotechnology-derived

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[6] Freeze-tolerant *Eucalyptus* is a collective term that refers to hybrid *Eucalyptus* events 427 and 435. Hybrid *Eucalyptus* events FTE 427 and FTE 435 represent two discreet transformation events using the same construct and thus exhibit similar phenotypes. See the APHIS Plant Pest Risk Assessment (2013) for details on these two hybrid *Eucalyptus* events.

varieties classified previously by APHIS as not subject to regulation as plant pests under the PPA and 7 CFR part 340. Those not subject to regulation are those for which a petition for non-regulated status was submitted, and which were classified as non-regulated, and those for which a letter of inquiry was submitted and APHIS concluded after a review the agency had no jurisdiction[7].

1.3 Purpose of Freeze-Tolerant Eucalyptus

At present, despite its productivity and desirable wood qualities for the pulp industry, cultivation of *Eucalyptus* species in the United States is limited to USDA plant hardiness zone 9b or higher due to cold sensitivity (Figure 1). FTE is intended to be marketed as a tool to expand the range north where *Eucalyptus* can be commercially cultivated in the United States. FTE is genetically engineered to exhibit freeze tolerance and male sterility. Freeze tolerance is conferred through the insertion of a gene into the *Eucalyptus* genome that encodes for the protein cold-binding factor 2 (CBF2) during cold stress (Arborgen, 2011). Male sterility is conferred through the insertion of a gene into the *Eucalyptus* genome that encodes for the protein barnase during pollen development (Arborgen, 2011). The insertion of the gene that encodes for barnase production has been suggested as a means to mitigate pollen-mediated gene flow associated with large-scale deployment of transgenic trees (Zhang et al., 2012). With insertion of the barnase and CBF2 genes, FTE will allow growers to plant *Eucalyptus* in USDA plant hardiness zones 8b or higher (Figure 1).

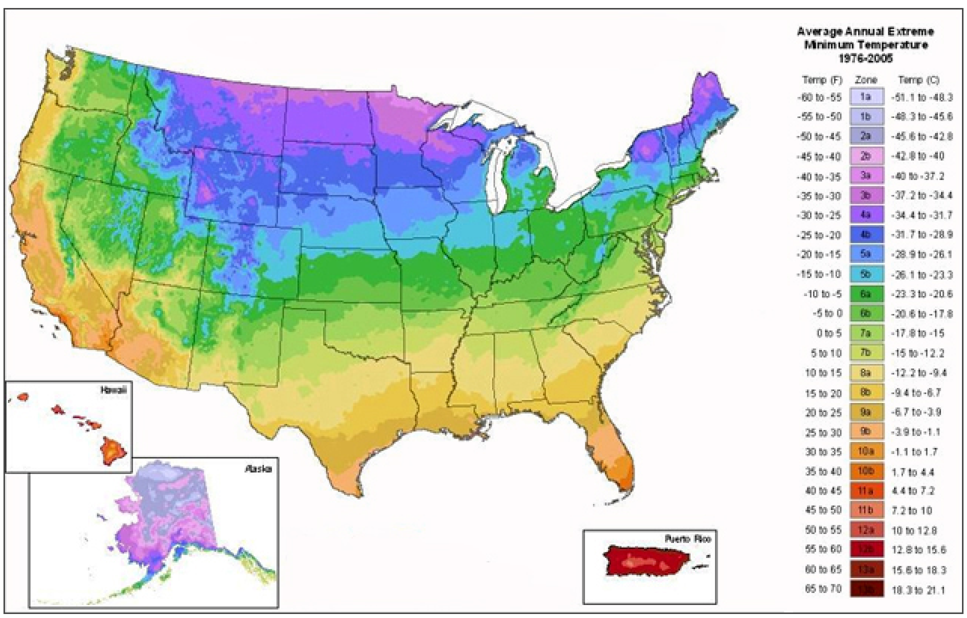

Figure 1. USDA Plant Hardiness Zone Map
Modified from USDA-ARS (2012)

[7] At the time of publication of this EIS, there are no non-regulated GE *Eucalyptus* species commercially cultivated in the United States.

1.4 Regulatory History of Freeze-Tolerant Eucalyptus

ArborGen first started field testing FTE in the United States in 2005 (Arborgen, 2011). As a result of ArborGen's requests to permit flowering and increase field test acreage of FTE, APHIS published three Environmental Assessments (EAs). These EAs and their publications dates are listed below (USDA-APHIS, 2013c):

- 06-325-111r was published on June 27th, 2007;
- 08-011-116rm and 08-014-101rm were published on May 12th, 2010; and
- 11-052-101rm was published on June 6th, 2012.

On January 17th, 2011, APHIS received a petition request from ArborGen seeking a determination of non-regulated status of FTE. The petition stated that APHIS should no longer regulate FTE, because it does not present a plant pest risk. On February 27th, 2013, APHIS published a notice in the *Federal Register* (see 78 *Federal Register* (FR) 13309 – 13313, Docket No. APHIS-2012-0030) announcing the receipt of the petition from ArborGen requesting a determination of non-regulated status under 7 CFR part 340, and a Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS) for the proposed determination of non-regulated status;

Additionally, APHIS is also publishing a PPRA for FTE concurrently with this EIS. Though specific information can be found in the PPRA, the general conclusion is that FTE is unlikely to pose a plant pest risk.

1.5 Eucalyptus District Court Litigation History

Numerous APHIS permits have been issued to ArborGen for the importation, movement, and field testing of GE *Eucalyptus* in the Southern United States since 2006. As stated in Section 1.4, on June of 2007 and 2010, APHIS published final EAs that both reached a Finding of No Significant Impact (FONSI) for GE permits for the field testing of GE *Eucalyptus* trees in the Southern United States.

On July 1, 2010, the Center for Biological Diversity, Center for Food Safety, and other groups filed suit against the USDA in the Southern District of Florida, challenging APHIS' decisions and approvals authorizing ArborGen to plant and allow flowering of GE *Eucalyptus* trees in field tests. Subsequently, plaintiffs amended their complaint on August 8th and October 11th, 2010.

Plaintiffs alleged that APHIS violated: the National Environmental Policy Act (NEPA) by failing to conduct an EIS; § 10204 of the 2008 Farm Bill by failing to implement the field testing safeguard directives it contains; and the Endangered Species Act (ESA) by failing to ensure that the permits would not jeopardize threatened and endangered (T&E) species and by lacking a program to conserve T&E species.

The plaintiffs sought to compel APHIS to prepare an EIS to address the overall, cumulative environmental impacts of all ArborGen permits concerning GE *Eucalyptus* and its introduction to the Southern United States and asked that any current permits (at the time) be rescinded pending completion of the EIS.

On October 19th, 2010, the Southern District of Florida issued an order requiring the parties to brief the issue of whether plaintiffs had standing to litigate the case. On May 19th, 2011, Judge Moore ruled that plaintiffs had standing to challenge the active permits, but could not challenge the expired permits, raise claims pursuant to § 10204 of the 2008 Farm Bill, or proceed with claims that APHIS was required to consider the potential environmental impacts of ArborGen's pending petition for deregulation of the GE *Eucalyptus* in its NEPA analysis.

The parties completed briefing on the cross-motions for summary judgment on August 26th, 2011. On October 6th, 2011, the Southern District of Florida ruled in favor of APHIS, denying plaintiffs' motion for summary judgment and granting defendants' motions for summary judgment. The Southern District of Florida found that:

- It was not arbitrary for APHIS to consider only two alternatives in its EA, given the very limited impact and scope of the permits;
- APHIS' cumulative impacts analysis was adequate and the agency did not need to address the potential environmental impacts that might occur in the event a deregulation petition was filed with APHIS and ultimately approved;
- APHIS's discussion of the public comments was appropriate, not arbitrary and capricious, as the plaintiffs' argued, and the record demonstrated that APHIS adequately responded, either directly or indirectly, to the issues raised by other agencies and organizations; and
- There was "no substantial basis for real controversy" requiring APHIS to prepare an EIS and, even if there were, the existence of "controversy" is only one of several factors in weighing whether or not to prepare an EIS.

1.6 Coordinated Regulatory Framework for Genetically-Engineered Organisms

The U.S. government has regulated GE organisms since 1986 under existing Federal regulations described in the *Federal Register* (51 FR 23302; 57 FR 22984) entitled "The Coordinated Framework for the Regulation of Biotechnology" (henceforth referred to here as the Coordinated Framework).

The Coordinated Framework, published by the Office of Science and Technology Policy (OSTP), describes the comprehensive Federal regulatory policy for ensuring the safety of biotechnology research and products. It also explains how Federal agencies will use existing Federal statutes to ensure public health and environmental safety while maintaining regulatory flexibility to avoid impeding the growth of the biotechnology industry.

Three central guiding principles form the basis for the Coordinated Framework:

- Agencies should define those transgenic organisms subject to review to the extent permitted by their respective statutory authorities;
- Agencies are required to focus on the characteristics and risks of a biotechnology product, not the process by which it was created;
- Agencies are mandated to exercise oversight of GE organisms only when there is evidence of "unreasonable" risk.

The Coordinated Framework explains the regulatory roles and authorities for the three major agencies involved in regulating GE organisms: APHIS, the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA). A summary of each role follows.

1.6.1 APHIS

As noted in Section 1.2, the PPA authorizes APHIS to regulate, manage and control plant pests. The PPA includes regulatory authority over the introduction (i.e., importation, interstate movement, or release into the environment) of certain GE organisms and products. A GE organism is considered a regulated article if the donor organism, recipient organism, vector, or vector agent used in engineering the organism belongs to one of the taxa listed in the regulation (7 CFR part 340.2) and is also considered a plant pest. A GE organism is also regulated under 7 CFR part 340, when APHIS has reason to believe that the GE organism may be a plant pest, or APHIS does not have sufficient information to determine if the GE organism is unlikely to pose a plant pest risk. A GE organism is no longer subject to the plant pest provisions of the PPA or to the regulatory requirements of 7 CFR part 340, when APHIS determines that it is unlikely to pose a plant pest risk.

An individual may petition the Agency for a determination that a particular regulated article is unlikely to pose a plant pest risk, and should not be regulated under the plant pest provisions of the PPA or the regulations at 7 CFR part 340. Under §340.6(c)(4), the petitioner must provide information related to plant pest risk that the Agency can use to determine whether or not a regulated article is a plant pest risk. A GE organism or other regulated article is subject to the regulatory requirements of 7 CFR part 340 of the PPA until APHIS determines that it is unlikely to pose a plant pest risk.

1.6.2 Environmental Protection Agency

The EPA is authorized under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7 U.S.C. 136 et seq.) to regulate the sale, distribution, and use of pesticides. Its authority includes herbicides and those that are expressed by an organism modified using techniques of modern biotechnology. The latter are classified by the EPA as plant-incorporated protectants. The EPA also regulates certain biological control organisms under the Toxic Substances Control Act (15 U.S.C. 53 et seq.). Before planting a crop containing plant-incorporated protectants, an individual or company must seek an experimental use permit from EPA. Commercial production of crops containing plant-incorporated protectants for purposes of seed increase and sale requires a FIFRA Section 3 registration with the EPA.

Under FIFRA (7 U.S.C. 136 et seq.), the EPA requires registration of all pesticide products for all specific uses prior to distribution for sale. Before granting a registration, the EPA evaluates the following: toxicity of the ingredients of a pesticide product; the particular site or crop on which it is to be used; the amount, frequency, and timing of its use; storage and disposal requirements. Prior to registration for a new use for a new or previously registered pesticide, the EPA must determine through specified test protocols conducted by the applicant that the pesticide does not cause unreasonable adverse effects on humans, the environment, and non-target species, when used in accordance with label instructions. The EPA is authorized under FIFRA to make these determinations on the basis of benefits exceeding associated risks of a pesticide. The EPA establishes restrictions that ensure that this test is met by approving specific language used on the pesticide label in accordance with 40 CFR part 158.

Once registered, a pesticide may only be legally used in accordance with directions and restrictions on its label. The purpose of the label is to provide clear directions for effective product performance, while minimizing risks to human health and the environment. The Food Quality Protection Act (FQPA) of 1996, (Pub. L. No. 104 – 170) amended FIFRA, requiring the EPA to implement periodic registration reviews of pesticides to ensure they are meeting current scientific and regulatory standards of safety and continue to have no unreasonable adverse effects (US-EPA, 2011).

The EPA also sets tolerances (maximum residue levels) or establishes an exemption from the requirement for a tolerance, under the Federal Food, Drug, and Cosmetic Act (FFDCA). A tolerance is the amount of pesticide residue that can remain on or in food for human consumption or animal feed. Before establishing a pesticide tolerance, the EPA is required to reach a safety determination based on a finding of reasonable certainty of no harm under the FFDCA, as amended by the FQPA.

EPA did not review FTE because it does not require use of any new pesticides that otherwise would not be used on other non-GE *Eucalyptus* species.

1.6.3 Food and Drug Administration

The FDA enforces pesticide tolerances set by EPA. The FDA also oversees market introduction of GE foods under the authority of the FFDCA (21 U.S.C. 301 et seq). The FDA published its policy statement concerning oversight for products derived from new plant varieties, including those derived from genetic engineering, on May 29, 1992 (57 FR 22984). Under this policy, the FDA implements a voluntary consultation process to ensure that human food and animal feed safety issues or other regulatory issues, such as labeling, are resolved before commercial distribution of food derived from GE products. This voluntary consultation process provides a way for developers to receive assistance from the FDA to comply with obligations under Federal food safety laws prior to marketing.

In June 2006, the FDA also published recommendations in "Guidance for Industry: Recommendations for the Early Food Safety Evaluation of New Non-Pesticidal Proteins Produced by New Plant Varieties Intended for Food Use" (US-FDA, 2015). This establishes voluntary food safety evaluations for new non-pesticidal proteins produced by new plant varieties intended to be used as food, including GE plants. Early food safety evaluations help ensure that potential food safety issues related to a new protein in a new plant variety are addressed early in development. These evaluations are not intended as a replacement for a biotechnology consultation with the FDA, but the information may be used later in the biotechnology consultation.

ArborGen did not undergo this voluntary consultation with FDA because FTE is not anticipated to be used for food or feed purpose.

1.7 Purpose and Need for this APHIS Action

APHIS is required to respond, consistent with its regulations at 7 CFR part 340.6, to the petition from ArborGen. In its submissions, the petitioner has provided information consistent with that described in §340.6(c)(4), which is required to inform APHIS of the full range of biological and chemical properties of the plant, so that APHIS can assess the plant pest risk of each of these events to determine if they are unlikely to be a greater plant pest risk than the unmodified organisms from which they were derived. Therefore, APHIS must respond to this petition from ArborGen, who request a determination of non-regulated status for FTE. If the Agency determines that a regulated article is unlikely to be a plant pest risk, a GE organism is no longer subject to the regulatory provisions of the PPA or the regulations of 7 CFR part 340.

As noted in Section 1.1, under the provisions of NEPA as amended (42 U.S.C. 4321 et seq), prior to implementation, Federal agencies must examine the potential impacts of proposed major actions that may significantly affect the quality of the human environment. In accordance with NEPA, regulations of the Council on Environmental Quality (CEQ) for implementing the procedural provisions of NEPA (40 CFR parts 1500-1508), USDA regulations implementing NEPA (7 CFR part 1 b), and the NEPA Implementing Procedures (7 CFR part 372) of APHIS, the Agency has considered how to properly examine the potential environmental impacts of its decisions for petitions for determination of non-regulated status.

For most petitions for a determination of non-regulated status of GE organisms that APHIS has evaluated previously, it has prepared an environmental assessment (EA) to provide the APHIS decision maker with a review and analysis that identifies whether there may be any significant environmental impacts. If the Agency makes a finding of no significant impact (FONSI), the NEPA process stops and a decision is issued. If significant environmental impacts are identified, the process continues with the preparation of an EIS before a determination is made.

For FTE, APHIS did not decide, *a priori*, to prepare an EIS based on the finding of significant environmental impact. Instead, as noted in the Notice of Intent to Prepare an EIS, the decision was discretionary on the part of APHIS based on public concerns about the potential environmental impacts from the cultivation of *Eucalyptus* in areas where it was not previously cultivated. An EIS provides APHIS decision makers with a mechanism for examining the potential impacts on the quality of the environment[3] that may result from a determination of non-regulated status of FTE.

1.8 Lead and Cooperating Agency Roles

1.8.1 Lead Agency: APHIS

As noted in Section 1.2, the PPA authorizes APHIS to regulate, manage and control plant pests. 7 CFR part 340 gives APHIS the regulatory authority over the introduction (i.e., importation, interstate movement, or release into the environment) of certain GE organisms and products. A GE organism is considered a regulated article if the donor organism, recipient organism, vector, or vector agent used in engineering the organism belongs to one of the taxa listed in the regulation (7 CFR § 340.2) and is also considered a plant pest. A GE organism is also regulated under 7 CFR part 340, when APHIS has reason to believe that the GE organism may be a plant pest, or APHIS does not have sufficient information to determine if the GE organism is unlikely to pose a plant pest risk. A GE organism is no longer subject to the plant pest provisions of the PPA or to the regulatory requirements of 7 CFR part 340, when APHIS determines that it is unlikely to pose a plant pest risk.

An individual may petition the Agency for a determination that a particular regulated article is unlikely to pose a plant pest risk, and should not be regulated under the plant pest provisions of the PPA or the regulations at 7 CFR part 340. Under § 340.6(c)(4), the petitioner must provide information related to plant pest risk that the Agency can use to determine whether or not a regulated article is a plant pest risk. A GE organism or other regulated article is subject to the regulatory requirements of 7 CFR part 340 until APHIS determines that it is unlikely to pose a plant pest risk.

In response to the receipt of the ArborGen petition, APHIS prepared a preliminary PPRA to assess the plant pest risk for FTE. In addition to the PPRA, APHIS must also prepare an environmental analysis consistent with its obligations under the National Environmental Policy Act (NEPA). Under NEPA regulations, an agency conducts an environmental assessment (EA) to determine if a major federal agency action will cause significant environmental impacts (40 CFR § 1501.4). If the agency concludes in its EA that its action will not significantly impact the environment, the agency issues a “Finding of No Significant Impact” (FONSI) and the agency can proceed with its proposed action without preparing a more thorough EIS. If the EA concludes that the proposed action may significantly affect the environment, the agency must prepare an EIS. However, an agency may determine that significant impacts are possible without formally preparing an EA and proceed to the preparation of an EIS, as was the case for this EIS.

1.8.2 Cooperating Agency: USDA, Forest Service

USDA's Forest Service (USDA-FS) has the responsibility to manage the resources of National Forest System lands (National Forests and National Grasslands) for multiple uses including timber production, recreation, and wildlife habitat, while recognizing the State's authority to manage wildlife populations. The USDA-FS recognizes the potential environmental impact from cultivating FTE on forest lands and resources. For this reason, USDA-FS entered into a Memorandum of Understanding (MOU) with APHIS to facilitate a cooperative relationship.

USDA-FS is listed as a cooperating agency in the preparation of this EIS, due to its extensive experience with various aspects of forests and production forestry in the United States. In addition to scientific and editorial assistance in the preparation of this EIS, USDA-FS also produced three technical reports for inclusion into this EIS. These three technical reports include:

- *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B);
- *Implications for expansion of GE freeze-tolerant Eucalyptus plantations of water resources in the continental U.S.* (Appendix C); and
- *Evaluation of potential fire behavior in genetically engineered freeze-tolerant (FTE) plantations of the Southern United States* (Appendix D).

1.9 Scoping and Public Involvement

APHIS seeks public comment on petitions it receives that request a decision of non-regulatory status for GE organisms. When the Agency decides to prepare an EIS as part of its decision-making process for a petition, prior to preparation, it also seeks public comments as part of its advance scoping process. Public scoping is required for an EIS under NEPA (see 42 U.S.C. §§ 4321 – 4327), Council of Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR parts 1500-1508), the USDA regulations for implementing NEPA (see 7 CFR part 1b), and the APHIS NEPA Implementing Procedures (7 CFR part 372). Details about the public involvement process for the petitions that are the subject of this document follow.

Scoping for this EIS began on February 27th, 2013, when USDA-APHIS gave notice in the *Federal Register* (78 FR 13309). A 60-day comment period on the APHIS NOI, in addition to two virtual public meetings, was announced as part of the scoping process.

1.9.1 Scoping Analysis and Documentation

The comment period for the APHIS NOI ended on April 29th, 2013. APHIS received 37,307 total comments[8]. For a summary of these 37,307 comments, see Appendix A.

Twenty people attended and four people spoke at the virtual public meeting held on April 17th, 2013. Thirty-six people attended and three people spoke at the virtual public meeting held on April 18th, 2013. Transcripts and a summary of the two virtual public meetings may be found in Appendix A.

[8] Total comments include public comment records, attachments, and form letters. See Appendix C for more details.

In general, an analysis of the comments received did not identify any additional broad issues outside of those enumerated in the NOI, but highlighted important issues within the existing list of issues that were analyzed by the agency in the EIS. For a summary of these issues, see the next section.

1.10 Issues Considered

In the *Federal Register* (see 78 *Federal Register* (FR) 13309 – 13313, Docket No. APHIS-2012-0030), several topics to be addressed in the EIS were presented:

- Alteration in the susceptibility to disease or insects – Potential of FTE lines 427 and 435 to harbor plant pests or diseases and the impacts of these pests or diseases on natural resources, forestry, or agriculture within the range of FTE lines 427 and 435;
- Alteration in weediness characteristics – Potential of FTE lines 427 and 435 to be invasive in certain environments and the impacts to natural resources and sociocultural resources if it is invasive;
- Potential impacts of growing FTE lines 427 and 435 on soil hydrology and water resources and how potential changes in soil hydrology or water use may affect natural resources and sociocultural resources;
- Potential impacts of FTE lines 427 and 435 on fire incidence and ecology and how this may affect natural resources and sociocultural resources;
- Potential impacts of allelopathy of FTE lines 427 and 435 on forestry practices or land use;
- Potential direct or indirect effects of FTE lines 427 and 435 on human health; and
- Potential direct or indirect effects of FTE lines 427 and 435 on wildlife and their habitats.

2 ALTERNATIVES

This document analyzes the potential environmental consequences of a determination of non-regulated status of FTE. In responding to the petitions, APHIS must assess the plant pest risks associated with FTE. Based on its preliminary PPRA (USDA-APHIS, 2015), APHIS has concluded that FTE is unlikely to pose plant pest risks. Following the conclusion of the plant pest risk analysis process, APHIS considered possible alternatives and selected those appropriate for further evaluation in this EIS.

2.1 Alternatives Considered and Selected for Further Evaluation in this EIS

This EIS analyzes in detail the two reasonable and appropriate alternative approaches for APHIS to make the required regulatory response to the petition from ArborGen seeking a determination of non-regulated status of FTE. The two alternatives were selected for analysis based on the APHIS conclusion that FTE is unlikely to pose a plant pest risk (USDA-APHIS, 2015). This EIS informs the APHIS Administrator of the potential impacts on the human environment resulting from the selection of each of the two alternatives. Each of the alternatives poses potential environmental impacts that differ in context and intensity. Additional alternatives (described in Section 2.2) were considered but eliminated from further consideration because they were either unreasonable or inappropriate since they failed to meet the regulatory program's legally authorized purpose and need.

2.1.1 Alternative 1 – No Action Alternative: Continuation as Regulated Articles

Under the No Action Alternative, APHIS would deny the petition, because the FTE 427 and FTE 435 *Eucalyptus* varieties present a plant pest risk. Therefore, they would continue to be regulated by APHIS. Permits issued or notifications acknowledged by APHIS would still be required for the introduction of FTE 427 and FTE 435 *Eucalyptus* varieties, and measures to ensure physical and reproductive confinement would continue to be implemented. This alternative is not the Preferred Alternative because, APHIS has concluded in its preliminary PPRA that FTE 427 and FTE 435 are unlikely to pose plant pest risks (USDA-APHIS, 2015). Choosing this alternative would not satisfy the purpose and need of making a determination of plant pest risk status and responding to the petition for non-regulated status.

2.1.2 Alternative 2 – Preferred Alternative: Determination of Non-regulated Status

Under this alternative FTE and their progeny would no longer be subject to APHIS biotechnology regulations (7 CFR part 340) as they have been determined unlikely to pose plant pest risks. Permits issued or notifications acknowledged by APHIS would no longer be required for introductions of these varieties. This alternative meets the purpose and need to respond appropriately to the petitions for non-regulated status (Arborgen, 2011), the requirements in 7 CFR part 340, and the Agency's regulatory authority under the plant pest provisions of the PPA, because APHIS has concluded in its preliminary PPRA that these varieties are unlikely to pose plant pest risks (USDA-APHIS, 2015). Therefore, this is the Preferred Alternative because approving the petitions for non-regulated status for both varieties is consistent with the scientific evidence before the Agency regarding lack of plant pest risk and would satisfy the purpose and need of making the required regulatory determination under the PPA and 7 CFR part 340.6.

2.2 Alternatives Considered but not Selected for Further Evaluation

APHIS assembled a list of alternatives considered for FTE. The Agency evaluated these alternatives in accordance with its authority under the plant pest provisions of the PPA and the regulations at 7 CFR part 340. In this evaluation APHIS considered environmental safety, efficacy, and practicality to identify those alternatives the agency would further consider for FTE. Based on this evaluation, APHIS rejected several alternatives. These alternatives are described briefly below with the specific reasons for rejecting each.

2.2.1 Prohibit FTE from Being Released

In response to public comments that stated a preference that no GE organisms enter the marketplace, APHIS considered prohibiting the release of FTE, including denial of any permits associated with field testing. APHIS determined that this Alternative is not appropriate because APHIS has concluded that FTE is unlikely to pose a plant pest risk (USDA-APHIS, 2015). Therefore, there is no scientific basis for prohibiting the release of these varieties under the regulations at 7 CFR part 340.

In enacting the PPA, Congress included findings in Section 402(4) that: “decisions affecting imports, exports, and interstate movement of products regulated under this title [i.e., the PPA] shall be based on sound science; …”

On March 11, 2011, in a Memorandum for the Heads of Executive Departments and Agencies, the White House Emerging Technologies Interagency Policy Coordination Committee established principles consistent with Executive Order 13563 to guide agencies in the development and implementation of policies for oversight of emerging technologies such as genetic engineering that included the following guidance:

“Decisions should be based on the best reasonably obtainable scientific, technical, economic, and other information, within the boundaries of the authorities and mandates of each agency; …”

Consistent with this guidance and based on the findings and scientific data evaluated for the preliminary PPRA (USDA-APHIS, 2015), APHIS has concluded that FTE is unlikely to pose a plant pest risk. Therefore, there is no scientific basis for prohibiting the release of these varieties under the regulations at 7 CFR part 340.

2.2.2 Approve the Petition in Part

APHIS considered an alternative where APHIS would not regulate the interstate movement or importation of FTE, but would continue to regulate the field release of FTE under part 340. APHIS considered, but rejected this alternative based on the conclusion of the APHIS PPRA.

APHIS concluded that FTE is unlikely to pose a plant pest risk (USDA-APHIS, 2015). This conclusion of the APHIS preliminary PPRA presents APHIS with no regulatory basis under the plant pest provisions of the PPA for approving a petition request for a partial deregulation of FTE. An approval in part would be inconsistent with the Agency’s purpose and need to respond appropriately to petitions for non-regulated status as set forth in the requirements in 7 CFR part 340 and the Agency’s authority under the plant pest provisions of the PPA and regulations in 7 CFR part 340.

2.2.3 Production/Geographical Restrictions to Isolate FTE from non-GE Eucalyptus

In response to public concerns of gene movement between GE and non-GE plants, APHIS considered requiring geographic restrictions separating FTE from non-GE *Eucalyptus*. However, because APHIS concluded that FTE is unlikely to pose a plant pest risk (USDA-APHIS, 2015), an alternative based on requiring isolation distances would be inconsistent with the Agency’s statutory authority under the plant pest provisions of the PPA and regulations in 7 CFR part 340.

Based on the consideration listed directly above, the imposition of geographic restrictions would not meet the APHIS purpose and need to respond appropriately to petitions for non-regulated status as set forth in the regulatory requirements of 7 CFR part 340 and the Agency's statutory authority under the plant pest provisions of the PPA. Individual land managers may choose on their own to geographically restrict their non-GE *Eucalyptus* from FTE, or use isolation distances to minimize gene movement between non-GE *Eucalyptus* and FTE.

2.3 Comparison of Potential Impacts by Alternative matrix

Table 1 is a summary of the potential environmental consequences associated with each of the Alternatives evaluated in this EIS. The environmental consequences assessment is presented in Chapter 4 of this EIS. The cumulative impacts are presented in Chapter 5.

Table 1. Alternatives Matrix

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
Meets Purpose and Need and Objectives	No	Yes
Land Use	Under the No Action Alternative, planted pine acreage is anticipated to continue increasing within the action area, primarily at the expense of naturally-regenerated pine acreage. Overall forested acreage (i.e., planted pine and naturally-regenerated pine) is anticipated to decrease over time within the action area, along with overall decreases in crop land uses, primarily due to shifts toward urban land uses. Both of these trends are well described within the action area, and are anticipated to continue under the No Action Alternative.	Under the Preferred Alternative, FTE may be potentially competitive with planted pine, and may potentially be planted across 204 counties in South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. As a result, FTE may be planted on approximately 0.8 million to 1.4 million acres of land that would otherwise be planted to planted pine within the action area. FTE is not anticipated to be competitive with crop or urban land uses within the action area. Thus, FTE is not anticipated to influence overall land uses within the action area. Declining trends in net forested land and cropland uses as a result of overall shifts toward urban land uses are not anticipated to change if FTE were granted non-regulated status, as the primary drivers of these shifts (i.e., government policy and economics related to urbanization) are not anticipated to change under the Preferred Alternative.
Air Quality	Under the No Action Alternative, air quality is generally improving, primarily due to Federal and State policies related to the Clean Air Act and the National Ambient Air Quality Standards. Though intensive production forestry may	Under the Preferred Alternative, potential air quality impacts is not anticipated to be greater than is already occurring under the No Action Alternative, particularly in the context of existing sources of air pollutants in the study area and the

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
	positively or negatively affect air quality, its contribution to overall air quality is anticipated to be minor due to the substantially larger influences of other industries, such as energy and transportation, within the action area. Under the Preferred Alternative, the action area, with expected variations in localities, is forecasted to experience warmer and drier temperatures in the foreseeable future. Production forestry can serve as a sink and source of carbon. Projections of forest carbon pools in the action area suggest a decrease, primarily due to overall losses in forested acreage. The harvest of trees may not immediately release stored carbon within the trees. The contribution of forest machinery to overall emissions (air quality) is considered minor relative to the transportation and energy industries within the action area.	projected overall loss of trees from urban development. In general, trees remove pollutants from the air and reduce adverse impacts to the atmosphere, but the rate of removal depends on the pollutant type, tree type, precipitation levels, and other local site characteristics. In the action area, the main sources for air pollutants are mobile sources and industry. The usage of vehicles and machinery in commercial forestry contribute air pollutants, and FTE will cause an increase in heavy equipment usage because of its short harvest cycle compared to pine. Despite this, commercial forestry of any kind is generally considered an overall sink of the contribution of air pollutants from forestry operations is small in comparison to the other sources of air pollutants in the study area.

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
Soil Resources	Under the No Action Alternative, soil resources within the action area are anticipated to generally remain poor, as typical forestry operations may continue affecting soil resources in a neutral or negative manner. Modern production forestry uses intensive site preparation, fertilization, short rotation times, and high planting densities to maximize economic returns. The use of these modern forestry practices in the present day generally impacts soil quality through changes in soil structure and nutrient balance. Due to the desire to maximize tree yields and returns from any given area of land, this cycle of site preparation, fertilization, and harvesting is likely to continue under the No Action Alternative. Accordingly, soil quality will continue to be impacted by modern forestry practices under the No Action Alternative. However, forestry best management practices may assist land owners in mitigating impacts on soil quality if adopted.	Under the Preferred Alternative, the potential impacts on soil resources are likely to remain the same or be slightly worse than that already occurring under the No Action Alternative. The cultivation of FTE under the Preferred Alternative and the continued cultivation of plantation pine under the No Action Alternative both represent intensive production forestry operations. Consequently, both the No Action and Preferred Alternatives are likely to lead to similar impacts on soil quality, though the impact from cultivating FTE may be slightly worse, due to FTE physiology and its shorter rotation cycle. This impact on soil quality from the Preferred Alternative, when compared to the No Action Alternative, is likely to be minor because of common and already-utilized best management practices currently used by managers of tree plantations to mitigate impacts to soil resources.

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
Water Resources	Under the No Action Alternative, water yield and water quality have been and continue to be impacted by plantation pine in the action area. Compared to some other common types of vegetation, including herbaceous plants and some hardwood trees, pine planted in plantation can utilize more water due to a variety of physiological and anatomical factors. As a result of this greater water use, plantation pine will continue to impact water quantity on the site and landscape levels. However, the magnitude of impact is directly modulated by precipitation, a variable that may differ substantially across time and space. Plantation pine growing on wetter sites is more likely to cause little or no impact on water quantity; conversely, plantation pine growing on drier sites is likely to cause more of an impact on water quantity compared to those wetter sites. With regard to water quality, plantation pine may impact water quality primarily through its contribution of sediments from poorly designed or maintained forest access systems. However, best management practices exist and demonstrate that the contribution of sediments to forested surface waters can be substantially and economically reduced to the benefit of the environment, if adopted and properly maintained.	Under the Preferred Alternative, local and direct impacts may occur on water quantity and quality. However, these potential impacts on water quantity and quality are likely to be negligible at larger spatial scales, such as within individual watersheds or across all watersheds in the action area. FTE is likely to use more water than other types of vegetation, including non-irrigated crops, deciduous hardwoods, and plantation pine. Consequently, FTE is likely to reduce the amount of water available for local streamflow compared to these other types of vegetation. The magnitude of this direct and local impact on streamflow is dependent on the type of vegetation that is replaced with FTE and the amount of precipitation received. Thus, the impact of FTE on local water quantity is site dependent. FTE is likely to have local impacts on water quality through increased sediment loading from forest access systems (forest roads and stream crossings) into forest streams. While the cultivation of FTE is unlikely to increase the number of forest roads and stream crossings in the action area, these forest access systems are likely to experience more frequent disturbances related to FTE-related management. Current best management practices, however, are applicable to many species of plantation trees and are effective in reducing sediment loading into forest streams and may mitigate local and direct impacts from FTE-related management activities, so long as these best management practices are adopted by growers of FTE.

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
Water Resources (continued)	It is prudent to note, however, that while pine planted in plantation may impact water quantity and quality in the action area, its impact is minimal relative to other common land uses, such as production agriculture and urbanization. Under the No Action Alternative, it is anticipated that this impact will remain minimal across the landscape, due to the sizable impact that urbanization and agriculture already exert on water quantity and quality.	It is prudent to note, however, that while FTE may impact water quantity and quality in the action area, its impact is minimal relative to other common land uses, such as production agriculture and urbanization. Under the Preferred Alternative, it is anticipated that this impact will remain minimal across the landscape, due to the sizable impact that urbanization and agriculture already exert on water quantity and quality.
Pine-Associated Plant Communities	Under the No Action Alternative, the diversity and abundance of plantation pine-associated vegetation will generally be less within the stand than in areas adjacent to the stand due to common pine plantation management activities intended to maximize timber production and canopy closure of the planted pine species. The geographic region, plantation management practices, and unpredictable events are factors that affect vegetation associated with pine plantations. In spite of these factors, common trends occur and may be used to describe the biological richness and abundance of pine-associated vegetation within a planted pine plantation. Relative to the plant community within stands of less intensively managed pine species (e.g., longleaf pine), the plant community in intensively managed plantation pine stands is usually more reduced in terms of plant richness and abundance. Over the course of a typical 20-year pine pulpwood rotation, positive response in planted pine growth are associated with intensive management of competing vegetation within the stand, strongly suggesting that land managers will continue common and intensive management practices to maximize wood	Under the Preferred Alternative, the replacement of some planted pine plantations in the action area with FTE may result in a quicker shift to shade-tolerant vegetation in the understory, primarily due to the more rapid canopy closure of FTE. Additionally, more intensive competition management may be used in the cultivation of FTE, potentially reducing the abundance and diversity of understory vegetation in sites where FTE is planted compared to planted plantation pine. However, it is prudent to mention that any tree plantation will generally have lower plant species diversity than natural forests due to monoculture and overall common silvicultural practices that aim to reduce vegetative competition and maximize wood production.

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
	production in stands of planted pine. Additionally, over the course of a typical 20-year pine pulpwood rotation, site preparation and site establishment activities will generally reduce the richness and abundance of plantation pine-associated vegetation early in the rotation (i.e., approximately year 0 – 5). Following this initial period of competition repression, plantation pine-associated vegetation may recover somewhat in terms of richness and abundance, but will almost always be reduced again upon canopy closure of the planted pine species (i.e., approximately year 10). By the end of the rotation cycle (i.e., approximately year 20), shade-tolerant plant species may be present in the plantation pine understory, but will generally not represent a large or substantial plant community within that plantation pine understory. The plantation pine-associated vegetation in areas adjacent to a plantation pine stand is generally greater in abundance than the vegetation within a plantation pine stand. This increase in plant diversity is primarily attributed to the openness of adjacent areas, facilitating greater access to light and precipitation than would occur inside of the plantation pine stand.	
Wildlife	Under the No Action Alternative, the presence of plantation pine within the action area has impacted and will continue to impact wildlife.	Under the Preferred Alternative, The replacement of planted pine plantations in the action area with fast-growing and short-rotation FTE will generally reduce wildlife habitat, and thus, some wildlife abundance and diversity.

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
Wildlife (continued)	In general, the diversity and richness of large and small mammals will mirror the development of understory vegetation development. Accordingly, large and small mammal diversity and richness is greatest early in a pine plantation rotation, followed by a corresponding decrease in diversity and richness as the pine plantation develops. The avian community may also be substantially affected by the age and structure of a pine plantation. In general, following a substantial reduction in the bird community immediately after common site preparation/establishment activities, breeding bird density and diversity may increase as the understory vegetation develops; however, the bird community commonly decreases as the pine plantation reaches mid-rotation in age and experiences simplification of understory structures as the canopy closes. In stands of older plantation pine, the bird community may return to high levels if several layers of canopy foliage are present to provide a sufficiently stratified habitat. In general, amphibians and reptiles are positively associated with leaf litter, herbaceous cover, course woody debris, and streamside management zones since they need a cool moist environment to thrive. However, the response of reptiles and amphibians over the life of a typical plantation pine rotation is often species specific.	Since *Eucalyptus* seedlings are more sensitive to vegetative competition than pine seedlings, it is expected that FTE growers within the action area will use more intensive management strategies than in pine plantations, thereby reducing available early succession food and habitat for mammalian species commonly associated with early growth forage, including small mammals and deer. The reduction in understory and increased disturbance from short rotation times also will reduce the number of bird species that would otherwise use this habitat for shelter and nesting. This reduction is likely to be greater than the reduction in bird species associated with pine plantation management. FTE plantations will produce less nutritious, smaller seeds than pine plantations; however, insect-feeding birds will have similar opportunities in both FTE and pine plantations. Nectar-feeding birds, on the other hand, will benefit from the addition of FTE to the landscape. The number of amphibians and reptile species living in the FTE plantations will likely be minimal, further reduced from the trends described for reptile and amphibians in pine plantations. Invertebrate diversity and abundance will likely be reduced more quickly in FTE plantations compared to pine plantations due to the faster growth and shorter FTE rotation period, which subsequently reduces herbaceous cover.

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
Insect and Disease Pests	Under the No Action Alternative, insect and disease pests of plantation pine will continue affecting plantation pine species, with the magnitude of pest damage generally mirroring the extent of plantation pine plantings. It is anticipated that plantation pine acreage will increase in the foreseeable future; consequently, the potential impact from insect and pest diseases of plantation pine may also increase. In spite of this, however, currently-adopted pest management practices are likely to be effective in managing the majority of these pests under the No Action Alternative.	Under the Preferred Alternative, there are a number of FTE pests that can appear or increase in prevalence within the action area. Of these potential insect and disease pests, the insect and disease pests that are most likely to become a substantial pest in FTE plantations are those pests already within the United States, such as Phoracantha wood borers, the eucalyptus weevil, eucalyptus psyllids, pink disease, eucalyptus rusk, and Coniothyrium canker. This potential outcome is not surprising, considering the absence of cultivation or absence of large-scale cultivation of *Eucalyptus*, GE or non-GE, within the action area. In spite of the potential increase in *Eucalyptus* insect and disease pests within the action area, it is unlikely that these pests will significantly damage other plant species. Many of the potential insect pests are host-specific herbivores that are unlikely to feed upon other plant hosts. Eucalyptus rust and pink disease, however, may potentially infect other susceptible plants within the action area, as they are not host-specific pathogens. However, given the limited adoption of FTE and limited dispersal of these pathogens from FTE to other plant hosts, it is anticipated that potential impacts to other plant hosts from these two diseases will not be substantial. Monitoring for these pests and diseases should be conducted as part of good plantation management practices or part of an early detection and rapid response plan.

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435
Insect and Disease Pests (continued)		With regard to the insect and disease pests of plantation pine discussed under the No Action Alternative, APHIS does not anticipate a significant impact under the Preferred Alternative, given the projected increase in planted plantation pine acreage that is already occurring independently of the regulatory status of FTE.
Biological Diversity	Under the No Action alternative, the presence of planted plantation pine, and more specifically, its management-related activities, has impacted and will continue to impact biodiversity within the action area. Planted pine plantations typically consist of intensively managed and even-aged stands of a single pine species. The biodiversity within an individual pine plantation is substantially affected by the management conditions subjected onto that particular stand; in general, however, the intensity of management to improve timber production and increase economic returns may often occur at the expense of biodiversity within the pine plantation itself. While planted plantation pine stands are not as structurally diverse as natural forests within the action area, biodiversity often compares favorably to other common land uses such as crop land and urban land uses. Compared to plantation pine, these landscape-scale factors may result in more substantial impacts on biodiversity than plantation pine.	Under the Preferred Alternative, biological diversity is likely to be reduced when compared to planted pine plantations within the action area, primarily due to the impacts from short-rotation management of FTE on vegetation and subsequent impacts on wildlife. Areas of FTE plantations have the potential to alter the diversity of plant and animal species across landscapes, but the reduction in biodiversity is expected to be less severe than if pine plantations were converted to other more intensive land uses, such as agricultural crops or to urban uses. Neither planted pine nor FTE plantations are as biologically diverse as natural forest land, but they compare favorably to land used for agriculture or urbanization.
Compliance with Other Laws		
CWA, CAA, EOs	Fully compliant	Fully compliant

Attribute / Measure	Alternative 1: No Action Alternative - Deny the petition request	Alternative 2: Preferred Alternative: - Determination of Non-regulated Status for FTE 427 and FTE 435

3 AFFECTED ENVIRONMENT

3.1 Introduction

Internationally, tree species of the genus *Eucalyptus* are a preferred fiber source for the pulp and paper industry utilized in various end products such as tissue, printing and writing paper, carton boards, and industrial filters (Arborgen, 2011).

Eucalyptus possesses several characteristics that facilitate its desirable use for the production of paper products. These desirable characteristics are attributed to its rapid growth rate and intrinsic attributes of its wood, including bulk, opacity, formation, softness, porosity, smoothness, absorbency, and dimensional stability (Arborgen, 2011). The growth rate of *Eucalyptus* ranks it among the fastest growing tree species in the world, with yields potentially exceeding 20 green tons acre^{-1} year^{-1} (Arborgen, 2011).

The rapid growth rate of *Eucalyptus*, coupled with desirable wood qualities, makes *Eucalyptus* an ideal raw material for potential production in the United States particularly the Southern United States; where the bulk of domestic pulp production is undertaken (Wear and Greis, 2012). However, the sensitivity of *Eucalyptus* to cold and freezing temperatures limits its commercial viability (Arborgen, 2011). Commercial *Eucalyptus* production in the United States is limited to USDA plant hardiness zones 9b and higher, a small area that covers central and southern Florida and the southern-most region of Texas.[9]

On January 17th, APHIS received a petition request from ArborGen Inc. of Summerville, South Carolina, seeking a determination of non-regulated status for two genetically engineered (GE) *Eucalyptus* lines, freeze-tolerant *Eucalyptus* (FTE) lines 427 and 435[10] (USDA-APHIS, 2013d). FTE is genetically engineered to expand the cultivation range of *Eucalyptus* from USDA plant hardiness zone 9b or higher to 8b or higher (Arborgen, 2011). Additionally, FTE is also genetically engineered to reduce the likelihood that FTE would cross-pollinate with existing populations of *Eucalyptus* (Arborgen, 2011). Further details about the genetic modifications in FTE are described by APHIS in its PPRA (2015).

This section aims to describe the action area and the human environment considered in this FTE EIS. Collectively, the geographical boundaries and the considered aspects of the human environment will make up the Affected Environment of this FTE EIS.

3.2 FTE Action Area

The FTE action area represents the geographic areas of the United States most likely to adopt and cultivate FTE. Additionally, the FTE action area also represents the geographic boundaries of analyses in this EIS.

Based on a technical report produced by the United States Department of Agriculture's Forest Service (USDA-FS) for APHIS, the FTE action area is limited to 204 counties across portions of seven Southern U.S. states (Figure 2). The FTE action area includes Alabama (5 counties); Florida (53 counties); Georgia (61 counties); Louisiana (31 counties); Mississippi (20 counties); South Carolina (9 counties);

[9] It is worth noting, however, that naturalized *Eucalyptus* occurs in California. It, however, is not a commercially cultivated tree species in California.

[10] Hereafter described as FTE.

and Texas (25 counties). The use of environmental filters relevant to commercial production[11] and economic modeling was utilized to determine not only where FTE may grow, but also where it is likely to be commercially cultivated as a source of wood pulp. Additional details regarding the identification of these 204 counties as the FTE action area may be found in Appendix B.

These 204 counties total approximately 131,168 square miles (USA Counties, 2013). This total land area approximately includes 4,535 square miles in Alabama; 38,444 square miles in Florida; 25,728 square miles in Georgia; 23,681 square miles in Louisiana; 10,691 square miles in Mississippi; 6,643 square miles in South Carolina; and 21,445 square miles in Texas. In total, these 204 counties represents 27 percent of total land area in FTE states and 3.7 percent of land area in the continental United States (USA Counties, 2013).

The USDA-FS technical report also further narrowed the action area within those 204 counties to those land areas that are currently planted to planted plantation pine[12] (Appendix B). As a result, any resource area identified in the next subsection will be analyzed within the context of planted plantation pine in Sections 4.3 – 4.4. Additional details regarding the identification of land utilized for the production of plantation pine may be found in Appendix B.

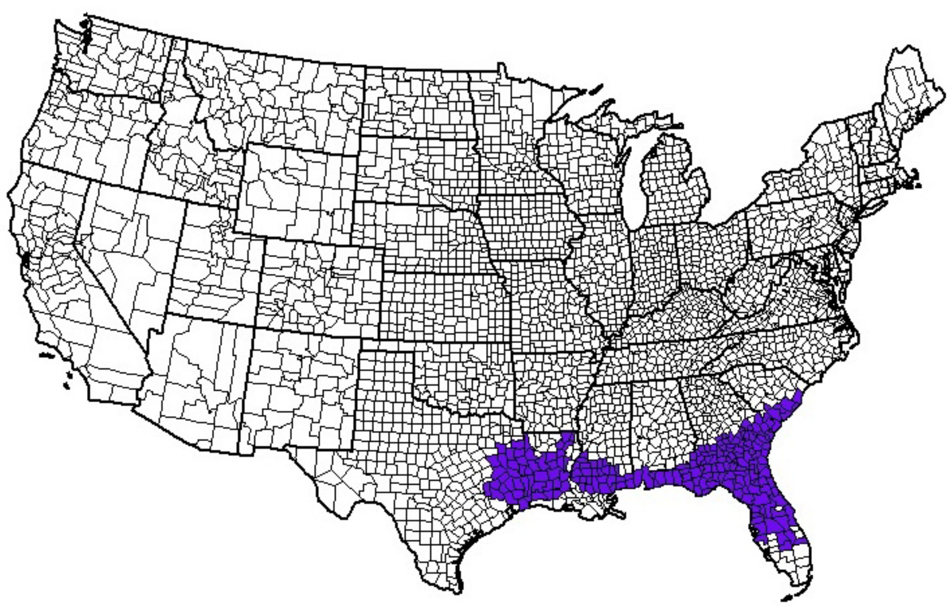

Figure 2. FTE Action Area

Figure and additional information for how this action was identified and derived may be found in Appendix B.

3.3 Resource Areas

In this FTE EIS, a resource area is a relevant component of the human environment. The human environment may include, but not be limited to, aspects of the natural (e.g., soil, water, wildlife, etc.) and

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[11] Environmental filters included: minimum average annual precipitation; minimum annual solar radiation; and minimum daily temperature.

[12] i.e., artificially-regenerated pine grown in plantation

human (e.g., economics, social values, etc.) environment. However, in order for any meaningful environmental analysis to be undertaken within this EIS; the resource areas must be narrowed down to those areas that are mostly likely to be impacted by an agency decision and/or those resource areas that concern the general public.

Based on three previous EAs for GE *Eucalyptus* lines produced by APHIS (USDA-APHIS, 2006; USDA-APHIS, 2010; USDA-APHIS, 2012) and an analysis of comments received on the APHIS NOI to prepare an EIS (Appendix A), the resource areas that will be examined in this FTE EIS includes:

- Land use;
- Air quality;
- Soil resources;
- Water resources;
- Pine-associated vegetation;
- Wildlife;
- Insect and disease pests; and
- Biological diversity.

In the following subsections, brief descriptions will be provided for each resource area. Analysis of each resource area under the Alternatives will be undertaken in Section 4, Environmental Consequences.

3.3.1 Land Use

Land use across a landscape details the interactions of humans and their environment, both natural and human-induced (BCAP, 2010). Land use, in its most general sense, may be characterized by the function or purpose of that land to produce goods or services (FAO, 1998). Furthermore, a parcel of land may not necessarily be exclusive to one use; the FAO (1998) indicates that several uses may occur on a single piece of land.

The primary land uses in the FTE action area and the rest of the Southern United States include urban, crop, and forested land types (Wear and Greis, 2002a).

Urban land use may be defined as any area that is densely developed, and are generally characterized as residential, commercial, and non-residential land types. Examples include residential, industrial, commercial, and institutional land; construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary landfills; sewage treatment plants; water control structures and spillways; other land used for such purposes; small parks (less than 10 acres) within urban and other built up areas; and highways, railroads, and other transportation facilities if they are surrounded by urban areas (Wear, 2013a). Additionally, this also includes land tracts of less than 10 acres that do not meet the above definition but are completely surrounded by urban or other built-up areas (Wear, 2013a).

Cropland is any land that is used to grow row or closely-sown plants. Row or closely-sown crops may include crops that are grown in rows and crops that are closely-sown such as certain crops grown for hay and silage. Cropland may also be planted to tree fruits, small fruits, berries, and tree nuts, vegetables and melons and other crops (USDA-ERS, 2013). Cropland may also be lands that are planted and harvested, planted and not harvested due to various reasons, left fallow in the summer, or otherwise not planted currently (USDA-ERS, 2013).

A forest is an ecosystem characterized by a plant community consisting predominantly of trees or other woody vegetation growing together (Schwarz et al., 1976). USDA-FS defines a forest as a land cover type that is at least 10 percent stocked by single stemmed forest trees of any size that will be at least 4 meters tall at maturity (Wear, 2013a). Additionally, when viewed vertically, a forest generally presents a 25 percent or greater canopy cover than a land stocked by single stemmed forest trees of at least 4 meters (13 feet) tall at maturity (Wear, 2013a). Included in this definition of forest are areas bearing evidence of natural regeneration of tree cover (cutover forest or abandoned farmland) and not currently developed by non-forest use (Wear, 2013a).

3.3.2 Air Quality

Air quality may be defined as the capability of the atmosphere to sustain life, enabling living organisms to respire, and to buffer life on earth from the extremes of temperature variations (BCAP, 2010). Air quality is directly and indirectly affected by air pollution from a variety of sources, including industrial plants, machinery, or windblown dust (EPA, 2013a).

Air quality within the United States is overseen by the Environmental Protection Agency (EPA) pursuant to the Clean Air Act (CAA) and the National Ambient Air Quality Standards (NAAQS). Accordingly, the EPA has established standards for six criteria pollutants: ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), lead (Pb), and inhalable particulates (coarse particulate matter [PM] greater than 2.5 micrometers and less than 10 micrometers in diameter [PM_{10}] and fine particles less than 2.5 micrometers in diameter [$PM_{2.5}$]) (BCAP, 2010). Under the CAA, the respective states are required to achieve and maintain the NAAQS and to prepare a State Implementation Plan identifying strategies to achieve and maintain the national standard of air quality within the state (BCAP, 2010).

3.3.3 Soil Resources

Soils are composed of a variety of organic and inorganic materials, such as weathered minerals, organic matter, air and water (USDA-NRCS, 2004). Soils are formed mainly by the weathering of rocks, the decaying of plant matter, and the deposition of materials such as chemical and biological fertilizers that are derived from other origins (USDA-NRCS, 1999).

Soils are classified taxonomically into soil orders based on observable properties such as organic matter content and degree of soil profile development (BCAP, 2010). Additionally, soil functions primarily to provide habitat to a wide variety of organisms, and thus, directly plays a key role in determining the productivity of a particular site. This body of inorganic and organic matter is home to a wide variety of fungi, bacteria, and arthropods, as well as the growth medium for terrestrial plant life (USDA-NRCS, 2004). Soils play a key role in determining the capacity of a site for biomass vigor and production in terms of physical support, air, water, temperature moderation, protection from toxins, and nutrient availability (USDA-NRCS, 1999).

Soil properties and functions, however, are not static. Dependent on conditions, soil properties change over time: temperature, acidity or alkalinity (pH), soluble salts, amount of organic matter, the carbon-nitrogen ratio, and numbers of microorganisms and soil fauna all change seasonally as well as over extended periods of time (USDA-NRCS, 1999). The net description of soil properties and functions may be described as soil quality, and like properties, may also change over time.

3.3.4 Water Resources

Southern forests[13] are exceptionally diverse and represent relatively stable ecosystems compared to other vegetative land covers that are subject to continuous cycles of cultivation and harvest (Wear and Greis, 2012). While relatively stable, Southern forests are also dynamic, as are its impacts on water resources in the action area (Chang, 2013).

Surface and groundwater resources are key outputs of forests. These water resources are essential to processes and functions across the action area. Surface waters, such as rivers, lakes, and estuaries provide habitat for plant and animal life (Sun et al., 2002; Wear and Greis, 2002a). Coinciding with these water resources in the action area is a prolific timber industry that produced approximately 55 percent of the nation's forestry products in 2007 (Wear and Greis, 2012). Furthermore, Southern forests facilitate a stable and abundant surface water supply for a variety of other anthropogenic uses, including drinking water, recreation, and power generation (Jackson et al., 2004; Sun et al., 2004; Vose, 2013b).

Forest hydrology is the study of water movement, distribution, and quality as regulated by forests (NRC, 2008). The overarching importance of water resources in the Southern United States, coupled with natural, societal, and industrial values of Southern forests, generated intensive examination of how structural and functional changes in Southern forests affects forest hydrology (Jackson et al., 2004; NRC, 2008; Lockaby et al., 2012a). Many of these studies examined the impact of plantation pine on Southern Forest water resources, due to the dramatic increase and relative importance of plantation pine in the Southern United States (West, 2002; Jackson et al., 2004; Sun et al., 2004).

Due to its chemical properties and role in ecosystem processes, water quality plays a central role in Southern Forests. Water, however, is more than simply two molecules of hydrogen and one molecule of oxygen. All water in the action area, including those waters yielded by plantation pine to streamflow on adjacent forested lands, also contains organic matter, inorganic matter, and dissolved gases derived from the environment, organisms, and anthropogenic activities. The concentrations of all these substances, in addition to their biological, physical, and chemical impacts, are the basic criteria of water quality (Chang, 2013).

Water quality is considered impaired if it is classified as partially supporting or not supporting its intended use(s), as determined by individual states (EPA, 2000a). Intended uses may include drinking, recreation, irrigation, industry, or aquatic life (Chang, 2013). Within the action area, surface waters are most likely to be impaired in comparison to groundwater due to the filtering effect of soils on moving water (Chang, 2013).

3.3.5 Vegetation

Vegetation is the totality of plants in a particular area, including native, introduced, desirable, and undesirable plants (BCAP, 2010). The plant species in the FTE action area represents a diverse variety of plant species, ranging from understory grasses to overstory trees. Additionally, plant species may be found in a variety of habitats, ranging from wetlands to plantation forests (USDA-APHIS, 2013a).

[13] Southern forests, as defined here, may consist of natural or commercial production forests.

Plant species in a particular area may be generally characterized as forbs, vines, succulents, ferns, grasses, shrubs, and trees (BONAP, 2013a). The plant classification descriptions below are derived from the Biota of North America Project[14] (BONAP, 2013a) unless otherwise stated:

- Forbes - Herbaceous plants most commonly with relatively broad, usually pinnately veined leaves (contrasted with parallel-veined in "grass or grass-like" plants), with all perennating or overwintering organs at or below ground level. The forb category, which was originally established in an agricultural context to contrast with grass and grass-like plants, includes a wide range of herbaceous growth habits, especially if aquatic plants are added. Vining, creeping, and trailing herbs also are included within this broad category (in the BONAP system). Plants with annual stems becoming woody at the base are included as forbs. Primarily herbaceous plants bearing terminal buds at the tips of woody caudex branches at or near ground level are referred to the forb category; "cushion plants" belong with these.
- Vines -Perennial plants with woody, above-ground stems that bear overwintering buds and do not die back to a basal stem or rhizome in winter. Trees usually have a single main stem, are at least 4 meters tall, and have a more or less distinct and elevated crown. A few species produce normally short-lived but rapidly growing plants that occasionally attain tree-like proportions (e.g., *Ricinus communis*).
- Succulents – Plants with stems and leaves that are very soft, fleshy, and often filled with juice or sap.
- Ferns - The pteridophytes as traditionally treated: spore-producing but flowerless and seedless vascular plants that are usually differentiated into roots, stems, and leaf-like fronds (Nishino, 2013).
- Grasses - Herbaceous plants with long, narrow, entire, parallel-veined leaves, often produced in a basal cluster, with all perennating or overwintering organs below the ground. The flowers of these plants usually are reduced in complexity and thus inconspicuous. Grasses and grass-like plants include all members of the monocot families Cyperaceae, Juncaceae, Juncaginaceae, and Poaceae, some members of the Liliaceae, and all members of the pteridophyte family Isoetaceae, but similar leaved-species occurring in numerous dicot families were not scored.
- Shrubs - Perennial plants with woody, above-ground stems that bear overwintering buds relatively evenly positioned on the stems and do not die back to a basal stem or rhizome in winter. Shrubs are multi-stemmed from the ground, generally attaining a low stature (variable in size but usually under 5 meters tall), and producing a poorly-defined crown. Some shrubs may be creeping (e.g., *Juniperus horizontalis*, *Gaultheria hispidula*); others may be "mat-like" or "mound-like" (e.g., *Arctostaphylos nevadensis*). Various exceptional species are also placed here (e.g., *Coreopsis gigantea*, a "fleshy-stemmed shrub"; *Coreopsis maritima*, a "hollow-stemmed shrub"; *Leucanthemum nipponicum*, a "soft shrub"), and some primarily shrubby species that occasionally reach tree size are also characterized as trees.
- Trees - Perennial plants with woody, above-ground stems that bear overwintering buds and do not die back to a basal stem or rhizome in winter. Trees usually have a single main stem, are at least 4 meters tall, and have a more or less distinct and elevated crown. A few species produce

[14] Additional information on plant classes can be found on the BONAP website: http://www.bonap.org/ Last accessed January, 2014.

normally short-lived but rapidly growing plants that occasionally attain tree-like proportions (e.g., *Ricinus communis*).

3.3.6 Wildlife

Like vegetation, wildlife refers to the totality of all animals in a specific area, including those wildlife species that are native, introduced, desirable, and undesirable (BCAP, 2010). The wildlife in the FTE action area represents a variety of types, ranging from invertebrate mollusks to vertebrate mammals; this list also includes non-migratory and migratory wildlife (USDA-APHIS, 2013b).

Wildlife species may be generally characterized as mammals, birds, reptiles, amphibians, fish, and molluscs (NatureServe, 2013). The following definitions are from Cambell (1999):

- Mammals – Members of the vertebrate class Mammalia, characterized by body hair and mammary glands that produce milk to nourish the young.
- Birds – Members of the class Aves, characterized by feathers and other flight adaptations.
- Reptiles – Members of the vertebrate class of Reptilia, represented by lizards, snakes, turtles, and crocodilians.
- Amphibians – Members of the class Amphibia, represented by frogs, salamanders, and caecilians.
- Fish – Members of the class Osteichthyes, represented by bony skeletons and jaws.
- Mollusks – Members of the Phylum Mollusca, including the classes Gastropoda and Bivalvia. Members of the class gastrapoda may or may not have a shell, and generally possess a radula and a foot for locomotion. Members of the class Bivalvia generally possess a flattened shell with two halves, reduced head, and are filter feeders.

3.3.7 Insect and Disease Pests

Insect and disease pests are those pest species that can impact forests in a variety of ways: they can kill trees, reduce tree health and growth; degrade or otherwise impact wood products from forests; affect water quality and quantity; create safety hazards; increase fire risk; or reduce the quality or the landscape (Ward and Mistretta, 2002).

The effect of an insect or disease pest in a forest is dependent on the intended use of that forest. In a "natural forest," native insect and disease pests are simply part of an ecological system that functionally contributes to and maintains a variety of stand ages and conditions; recycles elements back into the forest from dead or dying trees; and functions in maintaining forest health by removing the weakest trees in any particular forest (Ward and Mistretta, 2002). However, in a production forest (e.g., pine plantation), insect and disease pests may impact tree growth and development, and thus, volume and profit from the wood of the tree (Ward and Mistretta, 2002). With regard to production forestry, an impact is often described in terms of number of trees killed, volume of timber lost, area of defoliation, or amount of growth loss resulting from pest activity (Ward and Mistretta, 2002).

Native insects or disease-causing microbes are natural components of ecosystems. As part of a biological system, these native insects or diseases contribute to biological diversity, improve habitat for various flora and fauna, facilitate decomposition of plant material, and encourage ecological succession of the forest (Ward and Mistretta, 2002). Non-native insect and disease pests, on the other hand, have generally permanantly changed forest ecosystems and efforts to control them have costs hundreds of millions of dollars. With regard to intensive forestry in the Southern United States, an impact is often described in terms of "number of trees killed, volume of timber lost, area of defoliation, or amount of growth loss resulting from pest activity (Ward and Mistretta, 2002). Once established, populations of non-native insect and disease pests can substantially increase, due to an absence of natural control agents that would otherwise be present.

3.3.8 Biological Diversity

Biological diversity refers to the variety and variability of living organisms and the ecosystems where they occur (BCAP, 2010). Biological diversity, a multidimensional property of natural systems that includes organisms or traits across all levels of life, may be estimated through one of several different indices that generally include can be estimated using one or more indices that generally incorporate the number of different species of all taxa and their relative frequencies (BCAP, 2010). Within the context of biological diversity, these organisms are organized at many different levels, ranging from whole ecosystems to the molecular structures that are the basis of heredity (BCAP, 2010). Thus, the term encompasses different ecosystems, species, genes, and their relative abundance; it also encompases behavior patterns and interactions (BCAP, 2010).

Biological diversity and ecosystems it comprises contribute to ecosystem services through their function. Ecosystem services include numerous important items, including: pollination, genetic introgression, biological control, nutrient recycling, competition against natural enemies, soil structure, soil and water conservation, disease suppression, control of local microclimate, control of local hydrological processes, and detoxification of noxious chemicals (Altieri, 1999). In general, the loss of biological diversity may result in a need for costly management practices in order to provide these functions (Altieri, 1999).

4 POTENTIAL ENVIRONMENTAL CONSEQUENCES

This chapter examines the impacts of two Alternative actions on the resource areas described in the Affected Environment (Chapter 3). In its Alternative analyses, APHIS only examines the direct and indirect impacts of its action on the regulatory status of FTE. APHIS does not examine the impacts of our action combined with future actions that may occur in this Chapter. These cumulative impacts are discussed separately in The Cumulative Impacts Analysis (Chapter 5).

First, the potential impacts on the previously-described resource areas resulting from the No Action Alternative will be presented and discussed. Second, the potential impacts on the previously-described resource areas resulting from the Preferred Alternative will be presented and discussed.

4.1 No Action Alternative

The No Action Alternative represents the status quo, i.e., the situation that would occur if APHIS denies the ArborGen petition (Section 2.1.1). Under the No Action Alternative, APHIS would not approve the ArborGen petition. This section describes the impacts that are currently occurring on natural and biological resources in the FTE action area. The analysis examines the impacts of planted plantation pine[15] on natural and biological resources to allow for a comparison with APHIS' Action Alternative, which would allow for the introduction of FTE without restrictions.

4.2 Assumptions Used in the Analysis of the No Action Alternative

4.2.1 The FTE Action Area Consists of 204 Counties Across Seven Southern States

On February 27th, 2013, APHIS published a NOI to prepare an EIS for FTE (78 FR 13309). Along with this publication, a figure showing the potential FTE study region was also published by APHIS (Figure 3a). This potential FTE study region represented all of USDA plant hardiness zones 8b and higher, which included portions of the Southeastern, Southwestern, and Western United States.

Further refinement of the potential FTE study region shown in Figure 3a was undertaken by the USDA-FS in the technical report entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B). This additional refinement was undertaken because it was recognized that as commercial tree species, viable cultivation of *Eucalyptus* is limited not only by cold sensitivity, but also by other environmental factors that may affect its potential productivity (Appendix B). As another potential commercial tree species, FTE is no different from other cultivated non-GE *Eucalyptus* species in this regard.

USDA-FS, a cooperating agency on this EIS, utilized three additional important environmental factors[16] associated with *Eucalyptus* productivity to further refine the potential FTE study region. The use of these three additional environmental factors, in conjunction with an economic analysis of counties where FTE would most likely be cultivated, resulted in the geographic area identified in Figure 3b. Additional details about this refinement process and a description of the FTE action area itself can be found in Appendix B and Chapter 3, respectively.

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[15] See Section 4.2.1 and 4.2.2 for a summary of APHIS's decision to use plantation pine as the baseline in the No Action Analysis

[16] Mean annual precipitation, mean daily solar radiation, and mean annual daily temperature

As a result of the analyses described directly above and in Appendix B, it seemed likely that the most relevant areas to consider under the No Action Alternative were those general areas that would most likely cultivate FTE under the Preferred Alternative, as it would be those general areas that would be most affected by a decision to deny the ArborGen FTE petition.

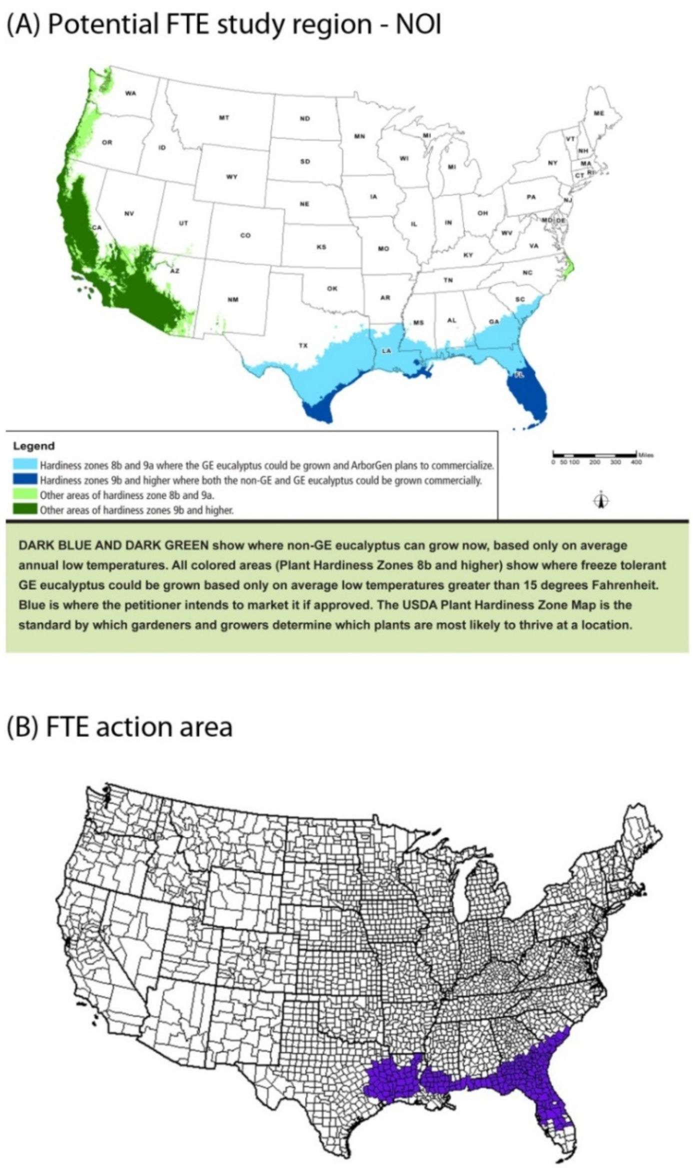

Figure 3. Potential FTE Study Region From the NOI versus the FTE Action Area Considered in this EIS

4.2.2 Planted Plantation Pine and Land Planted to Plantation Pine is the Appropriate Baseline for the No Action Alternative

As previously discussed in Section 4.2.1 directly above, USDA-FS, a cooperating agency on this EIS, used a series of environmental factors to further refine the potential FTE study region into the FTE action area (Figures 3a and 3b, respectively). In addition to these three additional environmental factors, USDA-FS also undertook an economic analysis to determine what, if any at all, common land uses in the refined area would be most likely shift to FTE[17].

In summary of the USDA-FS technical report entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B), planted plantation pine appears to be the land use most likely to shift to FTE under the Preferred Alternative. As a result of this economic analysis, this EIS assumes that planted plantation pine is the land use type that would be most affected by a decision to deny the ArborGen FTE petition under the No Action Alternative. Consequently, each resource area analyzed as part of the No Action Alternative will be considered within the context of planted plantation pine. Specific details regarding this economic analysis are described in Appendix B.

4.2.3 Herbicide Use is Under the Regulatory Purview of the EPA

Any herbicide (or any other pesticide) in the United States must be registered by the EPA prior to any specific use in the United States. EPA regulates pesticide use under broad authority granted by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (see 21 U.S.C. § 301 et seq.). EPA defines pesticide registration as:

> … a scientific, legal, and administrative procedure through which EPA examines the ingredients of the pesticide; the particular site or crop on which it is to be used; the amount, frequency, and timing of its use; and store and disposal practices. In evaluating a pesticide registration application, EPA assesses a wide variety of potential human health and environmental effects associated with the use of the product (EPA, 2013d).

EPA requires a variety of pre-defined tests in a pesticide registration package. The potential pesticide registrant must provide this data, according to EPA guidelines (EPA, 2013d). The data resulting from these tests is used by the EPA to produce an ecological risk assessment and human health risk assessment in order to:

> …evaluate whether a pesticide has the potential to cause adverse effects on humans, wildlife, fish, and plants, including endangered species and non-target organisms, as well as possible contamination of surface water or ground water from leaching, runoff, and spray drift. Potential human risks range from short-term toxicity to long-term effects such as cancer and reproductive system disorders (EPA, 2013d).

Following submission of a complete pesticide registration package, EPA may decide to register or not register a pesticide. If EPA decides to register a pesticide, then the pesticide can only be used:

> …legally according to the directions on the labeling accompanying it at the time of sale. Following label instructions carefully and precisely is necessary to ensure safe use (EPA, 2013d).

[17] Assuming APHIS determines non-regulated status for FTE, and ArborGen intends for commercial production of FTE

As a result of this pesticide registration process by EPA, any EPA-registered pesticide used in the United States:

> …if used in accordance with specifications, they will not cause unreasonable harm to the environment (EPA, 2013d).

With this established EPA oversight on pesticides and the pesticide registration process in place, this EIS assumes that end users of pesticides, such as land managers cultivating plantation pine, will follow the label and that no unreasonable harm will occur to the environment as a result of EPA-labeled pesticide use.

4.2.4 Resource Area-Specific Assumptions

The methodology in determining specific resource areas[18] for inclusion into this EIS was previously discussed in Section 3.3. For each resource area, a separate set of resource area-specific assumptions may have been used to facilitate the No Action Analysis for that particular resource area. For each resource area for which that was the case, the resource area-specific assumptions will be presented in text preceding the actual No Action Analysis for that particular resource area.

4.3 Potential Impacts Resulting from the No Action Alternative

4.3.1 Potential Impact on Land Use Resulting from the No Action Alternative

4.3.1.1 Summary of the No Action Analysis on Land Use

Under the No Action Alternative, forested acreage planted to plantation pine within the action area is anticipated to increase from 33 million acres in 2010 to 39 million in 2040, maintaining the overall current and historical trajectories of plantation pine acreage. While plantation pine acreage is anticipated to increase under the No Action Alternative, other forest types[19] are anticipated to shift toward urban land uses, resulting in a net loss in overall forested acreage. Additionally, cropland, another common land use type in the action area, is also anticipated to decrease as a result of acreage shifts toward urban land uses.

A variety of drivers are responsible for current trends in plantation pine acreage, though the primary drivers are represented by Federal policy and land use economics. Under the No Action Alternative, the Federal policies and land use economics are not anticipated to substantially change from the present day, strongly suggesting that current trends related to planted plantation pine acreage will also not change.

4.3.1.2 No Action Analysis on Land Use

<u>Introduction and Assumptions</u>

As described in Appendix B, Wear et al. (2013) assessed the area that would be most physiologically acceptable for FTE and then used other economic criteria to further limit this area[20]. These authors

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[18] Land use; Air quality ; Soil resources; Water resources; Vegetation; Wildlife; Insect and disease pests; and Biological diversity

[19] e.g., hardwoods or hardwood-pine mixed forest

[20] These authors first determined the regions likely to be within the appropriate USDA hardiness zone which was those above 8b. Solar irradiance and annual rainfall were also considered determinative for viable eucalyptus

compiled a list of 204 counties in seven Southern States (Figure 3b) that the analysis concluded would favor FTE planting. As a result of this analysis, portions of the Coastal Plain (CP) along the Southern and Eastern Coast regions and also the Mississippi Alluvial Valley (MAV) are included in the FTE action area (Figure 3b and Appendix B).

Because the data that provide the trends were collected over the full extent of the regions, this No Action analysis will discuss the larger area (that is, the entire CP and MAV) rather than the narrower area over which the data are assumed to apply. Wear (Personal Communication, 2013b) affirms that the counties that are most likely to be the areas of FTE adoption mirror the overall trends in the larger regions. In the No Action analysis, we propose to describe the trends of forest expansion and loss, the diversion of forests to agriculture and to urban areas, and planting of agricultural areas to forest, and we identify the types of forest management that are increasing or declining in acreage within the action areas. These trends were part of the data analyzed by Wear et al. (2013) in Appendix B.

The magnitude of past, present, and predicted forested land use changes in these locations will likely be one important driver channeling grower choice for planting FTE under the Preferred Alternative. In recognition of that driver, the focus of the No Action Alternative is on planted pine acres. The South still contains a widely diverse complement of physical, economic, and ecological conditions, where pine and other native habitats play an important role in supporting diversity of native plants and animals.

<u>Current Condition and Projections of Planted Pine in the Coastal Plain and Mississippi Alluvial Valley</u>

The Southern States forest resource that showed the greatest increase since the 1950s has been planted pine acreage (Figure 4) but upland hardwood acreage has also increased. In the entire South, planted pine acreage totaled only 2 million acres in 1952 (Conner and Hartsell, 2002). By 2010, total planted pine acreage had reached over 39 million acres in the U.S. Southeastern States (Huggett et al., 2013). This trend will likely continue through 2040, reaching a projected 59 million acres. By contrast, the largest decreases in forest acreage have been in natural pine acres in the period 1952 through 2010 and this is projected to continue through 2040. Losses of this forest type will be about 52 million acres (Huggett et al., 2013). To a far lesser extent, modest declines would be likely to continue in oak and pine land acres, upland hardwood acres, and lowland hardwood acres from 2010 through 2040 (Huggett et al., 2013).

About 33 million acres are planted to pine (Huggett et al., 2013) of about 102 million acres of total forest acres in 2010 in the Coastal Plain and Mississippi Alluvial Valley together (Wear et al., 2013). Future trends predicted by the U.S. Forest Service Southern Research Station show that planted pine in the Coastal Plain will increase to about 39 million acres (Figure 5) in 2040 from about 32.5 million in 2010 (Huggett et al., 2013). An increase of about 500,000 acres in planted pine in the Mississippi Alluvial Valley (MAV) during that same period is forecast and this area has about 5.6% of the acreage of the Coastal Plains (Huggett et al., 2013).

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production. They also took into account the necessary land quality as well as the economic opportunity factors that would encourage growers to choose this crop. The model generally integrated the land costs and desirability of crop switching. The authors concluded that the most plausible areas for planting would be those on which pine had previously been planted, with the potential addition of those areas in which pine had regenerated after a previous harvest. The counties within these regions are identified in Appendix B (Wear 2013) and are found in the following states: Alabama, Georgia, Florida, Louisiana, Mississippi, South Carolina, Texas (Eastern).

For other types of forest acres in the Coastal Plain, upland and lowland hardwoods and pine-oak forests are predicted to decline modestly between 2010 and 2040, while natural pine forests will show a considerable decline of 8 million acres (Figure 6). In the MAV, slight declines are predicted in upland and lowland hardwood with acreage of other types of forests maintaining relatively stable.

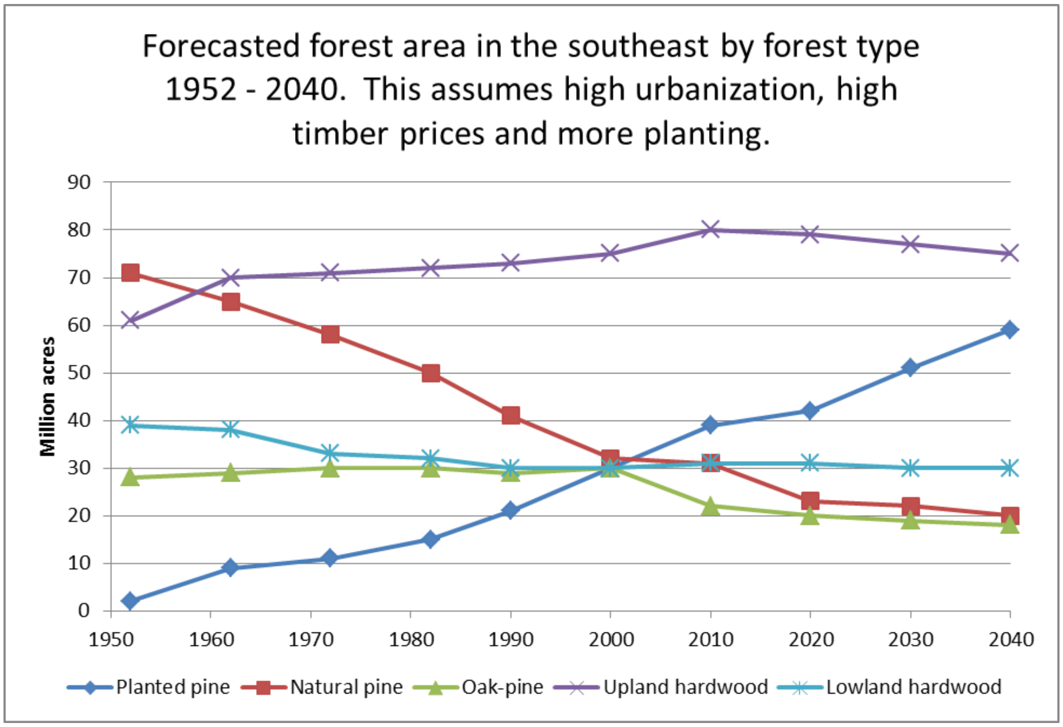

Figure 4. Forested Area by Type, 1952 – 2040

Figure derived from Huggett et al. (2013)

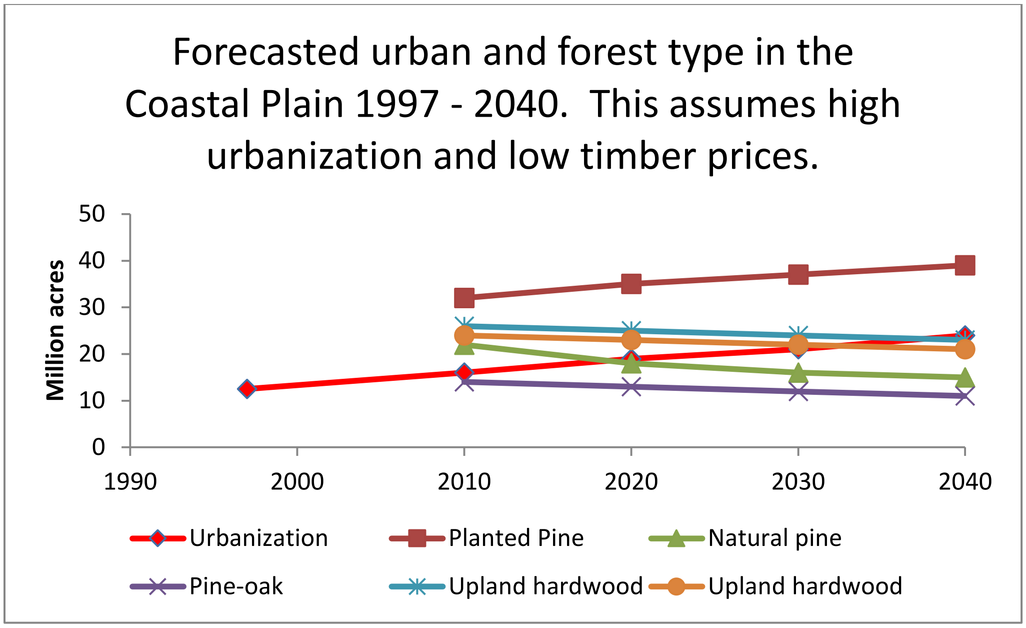

Figure 5. Coastal Plain Forest Area by Type, 1997 – 2040

Figure derived from Huggett et al. (2013)

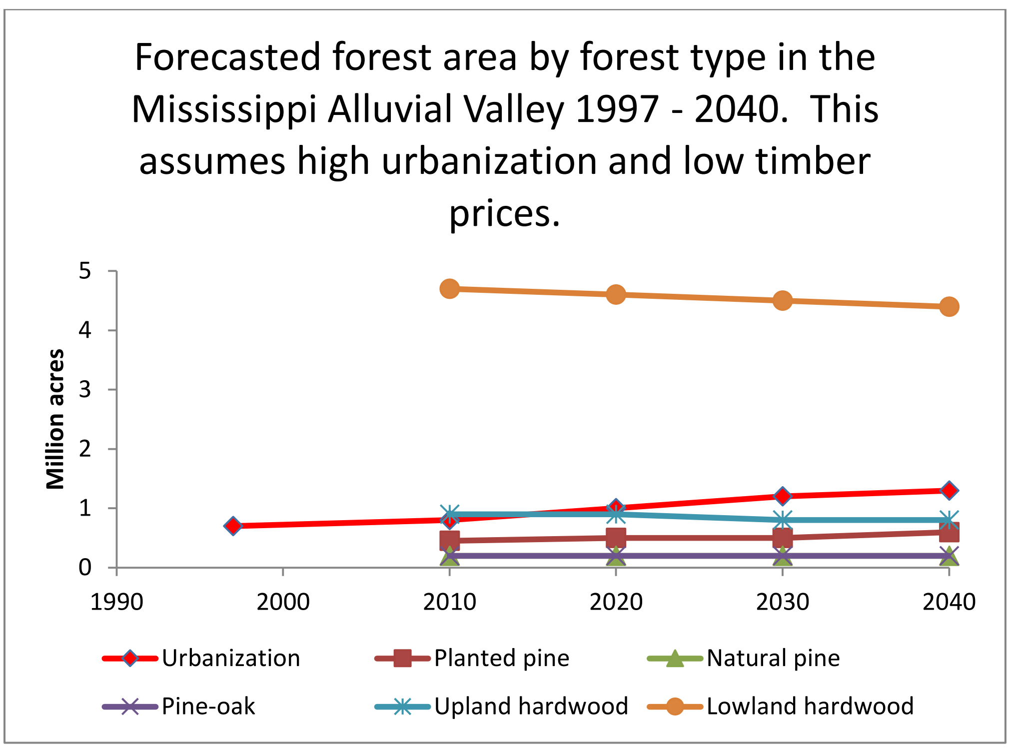

Figure 6. Mississippi Alluvial Valley Forest Area by Type, 1997 – 2040

Figure derived from Huggett et al. (2013)

Introduction to the Drivers of Amount of Planted Pine Acreage

The most significant change in forests in the period 1953 -1999 was a decline of 11.2 million acres in 13 Southern States (Conner and Hartsell, 2002). From projections of current acreage, the loss will continue into the period 2010 - 2060 (exclusive of Federal forest lands), and the decline is projected to be between 4.2 – 12.9 million acres (Huggett et al., 2013).

The Southern States economy and the status of agriculture and forestry in the United States gave rise to significant trends for forest management decisions and of land usage and also influenced the timelines of their development. The consequences of these trends have resulted in the extensive planting of southern pine in the Southern States. Wear (2002) and Hanson et al. (2010) distinguished at least four major eras that led to the current status of forests and allocation of lands to the several forest types in the Coastal Plain and Mississippi Alluvial Valley.

Era of Agricultural Exploitation (1630-1880): Land use in the affected region has been changing since the initial opening of the land to settlers from the east coast, whose agricultural operations began in the 17th century (Wear and Greis, 2002b). Between 1630 and 1880 about 35 million forested acres had been converted to crop agricultural uses (Hanson et al., 2010). Planting focused on cotton, but major pests such as boll weevil forced some adjustments in the area of planting, and other agricultural crops began to be planted. By the end of the 19th century, the cotton production area had reached its highest extent (Wear, 2002).

Era of Timber Exploitation (1880-1920): In the years following the Civil War, local use of forests for energy and fencing for farming continued, and deforested land was allocated to new agricultural uses, while tree harvests for industrial lumber production greatly increased (Hanson et al., 2010). As timber stocks were depleted in the Lake States, the timber industry moved to the Southern States (Wear, 2002). By 1920, southern forest acres reached their lowest point (Hanson et al., 2010).

Era of Recovery and Renewal (1920-1970): A combination of extensive tree harvest and depletion of soils by the start of the Great Depression led to large-scale abandonment of farms (Hanson et al., 2010). Owners began to reestablish forests with the planting of suitable forest trees. The era of modern southern forests began with growers taking account of the more economically viable uses for depleted land, along with impacts of increased crop agricultural pests, soil erosion, financial issues in agriculture and even the rise of available urban jobs (Hanson et al., 2010).

Era of Suburban and Urban Inroads (1970-Present): Various federal policies, economic trends, and particularly the land requirements of urban and suburban growth had major impacts on forest management decisions and trends in forest establishment. One of the foremost trends has been the planting of considerable acreage to pine, a process which began at the present rate in the 1950s (Frederick and Sedjo, 1991). These trends are reviewed in greater detail in the following sections. Planted pine acreage has increased in the Era of Suburban and Urban Inroads as a consequence of three principal factors, including Federal policy decisions, urbanization, and economics. Both the Coastal Plain and the Mississippi Alluvial Valley regions and their forests have been shaped by these factors.

Drivers of Planted Pine in the Coastal Plain and Mississippi Alluvial Valley – Federal Policy

At least three Federal policy decisions began and continue to underlie the changes in Southern Forests and the observed increases of planted pine, including the Soil Bank Program and the Conservation Reserve Program (CRP) (Conner and Hartsell, 2002). These programs affected land and management decisions across the Southern states, and specifically the Mississippi Alluvial Valley and the Coastal Plain regions.

The most important initial phase in the recovery was passage of the Soil Bank Act of 1956, which established the Conservation Reserve Program (Dangerfield et al., 1995b). Under its provisions, owners of agricultural lands were paid 80% of costs to convert the land to conservation uses (Dangerfield et al., 1995b). In addition, annual payments were made to the growers for 10 years. In the period 1956-1960, nearly 2 million acres were planted to trees in 12 Southern States. After 33 years, 80% of these Soil Bank program acres were still in forests (Dangerfield et al., 1995b). Between 1952 and 1962, natural pine acres in 12 Southern States declined from 72 million to 65 million acres, while planted pine acres increased from 1.8 million to 7.6 million acres (Wear, 2002). Oak-pine timberland increased also, but only slightly, from 27.1 million to 27.5 million acres.

A later version of the CRP was funded by the 1985 Farm Bill which authorized it in 1985. Across the Southeastern States, 1.69 million acres were placed in the program, and at the rate that Georgia growers signed up (91.4% were in tree crops), APHIS estimates that 1.54 million acres received cost sharing payments and annual maintenance fees (Dangerfield et al., 1995a). The purpose of the CRP was to place highly erodible lands into forest (Frederick and Sedjo, 1991) or into other uses such as permanent grass, forbs, or shrubs (Dangerfield et al., 1995a). The trend which began in the 1950s has continued to the present time, so that planted pine acres greatly exceed that of natural pine at least by 2010 in the Southeastern States (Figure 4).

Drivers of Planted Pine in the Coastal Plain and Mississippi Alluvial Valley – Urbanization

Besides Federal policies and programs, the other two factors driving change for the Southern forests include land use economics and urbanization, which have been prominent since the 1970s. The growth of population in the South increased 84% between 1970 and 2008, faster than the 50% growth rate for the rest of the United States (Hanson et al., 2010). Both urban growth and suburban growth had consequences for forests. The era of Suburban Inroads beginning in about 1970 initiated a time of low density suburban growth of one housing unit on 1.7 to 10 acres, and by 1984 urban and suburban growth was the cause of greater forest conversion than was conversion to agriculture (Hanson et al., 2010). High population increases coupled with low density growth can provide a larger loss of forest acres than to urban growth than either factor alone.

From 1968 through 1990, diversions of forest land to agriculture declined, from a high of over a million acres yearly to 400,000 acres in Southern States (Conner and Hartsell, 2002). At the same time, diversion of forest land to urban uses increased in 1968 from an annual rate of less than 400,000 acres yearly to about 550,000 acres in 1990 (Conner and Hartsell, 2002). As a consequence of these trends, by 1984, urban encroachment surpassed agriculture as the leading cause of forest loss in the South (Conner and Hartsell, 2002). Urbanization may also continue to contribute to steady loss of forest lands; urban lands will increase in the Coastal Plain region, by 11.5 million acres to a total of 24 million acres from 1997 to 2040 (Wear, 2013a). Similarly, urban acres in the Mississippi Alluvial Valley will also increase, by 300,000 acres to 1.03 million acres by 2040.

Drivers of Planted Pine in the Coastal Plain and Mississippi Alluvial Valley – Commodity Markets

Changing economic returns to growers from agriculture may, in certain circumstances, encourage new planting of forest trees (Wear, 2002). In general, however, the use of plantation timber for sale as pulp brings far less return to the landowner than commodity crop agriculture (Wear and Greis, 2013). As measured by the declining price of rent for agricultural land ($60-88/A to $25-44/A) in a five state area of the South (AR, GA, LA, TN, VA) from 1960-1994, declining productivity of commodity agriculture in that region would likely be one cause of the rent devaluation (Wear, 2002). In models produced to map the effects of a high timber price, shifts from agriculture to forestry were clearly indicated in areas of the

Coastal Plains and of the Mississippi Alluvial Valley between 1992 and 2020 (Wear, 2002), but these trends did not appear dependent upon price in some areas of the Southern States (Wear, 2002).

In general, "agriculture's returns have generally declined relative to forestry" (Wear, 2002), but these returns to agriculture and forestry depend importantly on land quality, climate, and location relative to markets (Wear, 2002). Wear (2013) also developed a model with specific assumptions about location and economics of existing pine and FTE adoption, in order to provide a clear conclusion about the location and size in acres of the potential adoption area of the FTE variety.

Wear (2002) has concluded that where agriculture has not attained preeminence in a geographic region of the Southern States, and where soil, weather and other economic conditions facilitate, landowners may choose to engage in timber production. One condition that encourages timber production is the proximity of production sites to a wood products processer. The Southern States have been ascendant in pulp processing, having five times the capacity of the U.S. West States in 2000, but having the largest U.S. capacity since at least 1961 (Wear et al., 2007). In 2006, the most softwood timber harvested in the U.S. was in the South, with 6.3 billion board feet, while the Pacific Coast was second with 2.2 billion and the Rocky Mountains with 500 million board feet (Smith et al., 2009). Southern softwood removals did not exceed that of the Pacific Coast and other regions until about 1986. Along with the economic encouragement for growers to prefer producing timber in some regions over crop agriculture, the South has concurrently developed as a dominant timber-producing region in the country (Wear, 2002).

Possible reversion of additional lands to forest from agricultural usage driven by new markets will be discussed in the Cumulative Impacts section. For example, the possibility of growth or development of forest biomass energy could be a relevant driver for future trends (Hanson et al., 2010). Otherwise, trends show that agricultural land for crop and pasture use declined in the Southeast states by 8 million acres between 1982 and 2007, while forest land increased only slightly (USDA-NRCS, 2013a).

Future projections of Planted Pine Trends in the Coastal Plain and Mississippi Alluvial Valley

The impetus to plant pine in the Southern United States has come from the net changes in several trends. In general, rural land in the Southern United States may transition between cropland and forests, depending on economic conditions.

As noted by Wear (2002), the trend from 1970 to 1990 was a declining level of conversion of forest land to agriculture, attaining about a 300,000 acre decline at the end of the period. Under the Conservation Reserve program however, the planting of forests on former agriculture lands began increasing, from about 800,000 acres per year to about 1.3 million acres. Net diversion of forest to urban areas or agriculture declined from 1.8 million acres per year to 850,000, and in 1987 the net forest gain became positive (Conner and Hartsell, 2002). In the period 1992-2001, forest cover lost totaled 1.4 million acres, while forest gained was about 550,000 acres and this included forest lands that had been harvested and then replanted to an additional forest plantation (Minnemeyer, 2010).

In the Coastal Plain, between 1997 and 2040, forest land is projected to lose about 4.1 million acres, and urban lands (moderate growth, increasing timber prices) will gain 11.6 million acres. In the Mississippi Alluvial Plain, 170,000 acres of forest will be lost, while 600,000 acres of urban area will be gained (Wear, 2013a; Wear et al., 2013). Under a high urbanization scenario with high timber prices Huggett et al. (2013) predicted that planted pine will continue an upward trajectory compared to most other forest types in the Southeast through 2040 (Figure 4). Likewise, in the Coastal Plains region from 2010 to 2040 growers will also be increasingly planting pine plantation acres, as will Mississippi Alluvial Valley growers (Figure 5 and Figure 6), except that pine-oak managed forest lands, rather than showing declining acreage as are all other types of forested land, seems to be more stable (Figure 6) (Huggett et al., 2013).

4.3.2 Potential Impact on Air Quality Resulting from the No Action Alternative

4.3.2.1 Summary of the No Action Alternative on Air Quality

Air quality is characterized through the quantitative measurement of primary and secondary pollutants[21]. Air quality has generally improved within the action area, primarily due to the Federal and state policies related to the Clean Air Act and the National Ambient Air Quality Standards. Historical and current trends in air quality within the action area closely mirror air quality trends on the national scale, emphasizing the substantial role the Clean Air Act and the National Ambient Air Quality Standards have played on both the National and state level. This current trend of improving air quality within the action area is anticipated to continue under the No Action Alternative as these Federal and state policies continue encouraging cleaner cars, industries, and consumer products. Though intensive production forestry may positively or negatively affect air quality, its contribution is anticipated to be minor due to the substantially larger influences of other industries, such as energy and transportation.

Within the action area, average annual temperatures range from 64 to 75 °F and average annual precipitation ranges from 36 to 70 inches. The action area, with expected variations in localities, is projected to experience warmer temperatures in the foreseeable future; however, projections are mixed for precipitation changes during the same time period.

Production forestry can serve as a sink and source of carbon dioxide . Projections of forest carbon pools in the Southern United States suggest a decrease in the next fifty years, primarily due to overall losses in forested acreage. As trees of most species grow larger, they increasingly fix carbon from atmospheric sources (Stephenson, 2014). While the harvest of trees may not immediately release stored carbon within the trees, the machinery used emits pollutants. However, the contribution of forest machinery to overall emissions is considered minor relative to the transportation and energy industries within the action area.

4.3.2.2 No Action Analysis on Air Quality

Introduction and Assumptions

The purpose of this section is to describe the current air quality in the action area as well as reasonably foreseeable future trends in air quality . This section will also describe the relative magnitude of plantation pine contributions to air quality when compared to other sources. The action area encompasses 204 counties across seven Southern States that are within plant hardiness zones 8b and above (Figure 3b). This includes five counties in Alabama, 53 counties in Florida, 61 counties in Georgia, 31 counties in Louisiana, 20 counties in Mississippi, 9 counties in South Carolina, and 25 counties in Texas.

In lieu of specific air quality data that cover each of the 204 counties in the action area, regional air quality data for the Southeast and South regions serve as a proxy to describe historical, current, and future air quality conditions. The U.S. National Oceanic and Atmospheric Administration's National Climatic Data Center defines these regions by their shared climatic conditions. The Southeast region includes Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia. The South region includes

[21] Including, but not limited to particulate matter, volatile organic compounds, and greenhouse gases

Arkansas, Kansas, Louisiana, Oklahoma, Mississippi, and Texas. These two regions cover a wider area than that defined by the study region.

Air Quality in the South and Southeast Regions

Primary and secondary pollutants affect air quality and, in turn, affect human health, and ecosystem health (including forests). Generation of primary pollutants such as particulate matter (PM), volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur oxides (SO_x) are directly from sources such as industrial facilities, electric utilities, autos and other mobile sources (Stern, 1977; EPA, 2012i). Secondary pollutants derive from the chemical transformation of primary pollutants, for example, exposure of VOCs and NO_x to sunlight forms ozone (EPA, 2012i). Agricultural and forestry practices can also contribute pollutants to the atmosphere. For example, the use of heavy equipment to harvest an area and prescribed burning contribute particulate matter, carbon, and nitrogen oxides to the atmosphere.

Federal, state, and local air regulatory agencies created laws, rules and regulations to control and reduce air pollutants. The Clean Air Act (CAA) (amended in 1990) requires States to comply with the National Ambient Air Quality Standards (NAAQS) established by the U.S. Environmental Protection Agency (EPA) for six principal pollutants, called criteria pollutants (EPA, 2012i). Each State may adopt requirements stricter than those of the national standard and each is required by the EPA to develop a State Implementation Plan that contains strategies to achieve and maintain the national standard of air quality within the State. The intention of these standards is to protect public health and the environment from these pollutants. Pollutants are easily transported long distances away from the point of origin, adding complexity to air quality restoration efforts. The six criteria pollutants are ground-level ozone (O_3), nitrogen oxides (NO_X), carbon monoxide (CO), sulfur dioxide (SO_2), lead (Pb), and inhalable particulate matter that are 10 micrometers in size or smaller. The EPA groups particulate matter into two categories: particles measuring 2.5 micrometers in diameter and smaller ($PM_{2.5}$), and particles larger than 2.5 micrometers and smaller than 10 micrometers in diameter (PM_{10}). Since the implementation of the Clean Air Act, air quality throughout the United States has improved (Table 2).

Air quality monitoring data is collected and reviewed by EPA, state, and local regulatory agencies, and is available to the public in the form of a local air quality index (AQI). The AQI is a measurement of the level of pollutants in the atmosphere. An AQI above 100 indicates that air quality conditions exceed health standards, while values below 100 indicate pollutant levels are within satisfactory levels. Between 2002 and 2010, major cities across the South and Southeast region saw a downward trend in the number of AQI days reported annually (EPA, 2012i).

Table 2. Regional Trends in Criteria Pollutant Levels Between 2000 and 2012

	Carbon monoxide	**Ground-level Ozone**	**Nitrogen dioxide**	**Sulfur dioxide**	**Lead[1]**	**$PM_{2.5}$**
Southeast Region[2]	63% decrease	17% decrease	35% decrease	66% decrease	No regional percentage available	41% decrease
South Region[3]	62% decrease	14% decrease	22% decrease	57% decrease	No regional percentage available	24% decrease

[1] Regional data for lead is unavailable. Lead levels decreased 91 percent nationally between 1980 and 2010
[2] The Southeast region includes Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia
[3] The South region includes Arkansas, Kansas, Louisiana, Oklahoma, Mississippi, and Texas
Data source: (EPA, 2012i)

In general, air quality is improving in the action area (Table 2), a trend reflected on the national scale. Emissions reductions were achieved through regulations and voluntary measures taken by industry (EPA, 2012i). Cleaner cars, industries, and consumer products have contributed to cleaner air for much of the United States (EPA, 2012i). Control programs for mobile sources and facilities such as chemical plants, dry cleaners, coke ovens, and incinerators are primarily responsible for these reductions (EPA, 2012i). Despite the downward trend in criteria pollutant levels observed across the Southeast and South regions in 2013, all counties in the action area reported nonattainment for one or more of the six criteria pollutants (EPA, 2013c).

Southern forests play a role in the improvement of local and regional air quality through the removal of pollutants from the air and the reduction of exposure of humans to these pollutants. Trees can absorb or trap nitrogen dioxide, sulfur dioxide, and particulate matter 10 microns or less in size (Beckett et al., 1998; Hanson et al., 2010). Rates of airborne pollution removal vary based on the pollutant type, leaf season length, and precipitation levels. In one estimate, a mature urban tree can intercept up to 50 pounds of particulates per year (Dwyer et al., 1992). In urban areas, ozone, sulfur dioxide, and nitrogen oxide are some of the most common pollutants, all of which can be absorbed by trees (Bell and Treshow, 2002).

Plantation pine can have adverse impacts on air quality, as well. Plantation pine pollen can be a lung irritant and can trigger allergies. Trees naturally release volatile organic compounds (VOCs), which can lead to the formation of ozone and carbon monoxide (Beckett et al., 1998). In a 2005 study, national VOC emissions from biogenic (natural) sources were larger than the VOC emissions from anthropogenic sources, accounting for approximately 74 percent of VOC emissions (EPA, 2010b). Anthropogenic sources of VOCs are from industrial processes and manmade products, such as power plants, chemical production, solvents, vehicles, and other machinery (EPA, 2010b; EPA, 2012i). On a national level, anthropogenic VOC emissions have been declining (EPA, 2010b).

Some forest production practices, including those used for commercial plantation pine in the South and Southeast regions, such as prescribed fires and the use of heavy equipment to harvest an area, contribute pollutants to the atmosphere. Prescribed fires in pine plantations prepare sites for seeding or planting, and reduce hazardous fuels to mitigate wildfires (USDA-FS, 2012b). In the Southern region of the United States, prescribed fires are applied annually to approximately eight million acres (3.2 million hectares) of land (Wear and Greis, 2013). Efforts in landscape restoration through the expansion of longleaf pine (*Pinus palustris*) forests are expected to increase the area burned annually as fire regimes are important to this ecosystem (Wear and Greis, 2013). During the conversion of lands in the South and Southeast to commercial plantation pine, the occurrence of wildland fires greatly diminished. “Air quality at the regional scale is affected only when many acres are burned on the same day” (USDA-FS, 2012a). Fires release criteria pollutants covered by the NAAQS, including significant amounts of $PM_{2.5}$and, while fires do not release ozone. Other chemicals released in wood smoke have known carcinogenic properties or are considered by the EPA as being hazardous air pollutants, including acetaldehyde, acrolein, 1,3 butadiene, formaldehyde, and polycyclic organic matter (Langmann et al., 2009; Wear and Greis, 2013). Vehicles and machinery used in commercial pine plantations contribute to emissions of criteria pollutants, but in the context of other mobile and industry sources in the South and Southeast, these are small contributions.

In 2010, planted pines comprised 19 percent of Southern forests (though not all are in zones 8b and above) (Wear and Greis, 2013). Over the next 50 years, models project that planted pines will comprise between 24 and 36 percent of the southern-forested area; this is the only tree type expected to increase and is expected to do so despite overall declines in forested areas (Wear and Greis, 2013). Overall forecasts project the South to lose millions of acres of forests to development (Wear and Greis, 2013). The prediction models vary in the degree of loss, but all models predict loss in the South, primarily due to a shift towards urban land uses (Wear and Greis, 2013). This loss of trees will affect air quality in the region and reduce the sequestration of CO_2; however, the greatest contribution to air quality improvements over the last decade is due to the reduction of mobile and industry emissions. "EPA expects air quality to continue to improve as recently adopted regulations are fully implemented and States work to meet current and recently revised national air quality standards" (Wear and Greis, 2013). Stricter air-quality regulations anticipated in coming years may add to the regulatory constraints on use of prescribed burning (Wear and Greis, 2013).

4.3.3 Potential Impact on Soil Resources Resulting from the No Action Alternative

4.3.3.1 Summary of the No Action Alternative on Soil Resources

Soil quality within the action area is generally considered poor due to the legacy of historical agricultural practices and inherent characteristics of the soil itself. Though soil quality has improved in recent times, modern forestry practices associated with production forestry (i.e., plantation pine) may cause changes in soil structure and nutrient balance. Under the No Action Alternative, modern silvicultural practices associated with production forestry are anticipated to continue impacting soil resources.

Modern production forestry uses intensive site preparation, fertilization, short rotation times, and high planting densities to maximize economic returns. The use of these modern forestry practices in the present day generally impacts soil quality through changes in soil structure and nutrient balance.

Due to the desire to maximize tree yields and returns from any given area of land, this cycle of site preparation, fertilization, and harvesting is likely to continue. Accordingly, under the No Action Alternative, soil quality will continue to be impacted by modern forestry practices. However, forestry best management practices may assist land owners in mitigating impacts on soil quality, if adopted.

4.3.3.2 No Action Analysis on Soil Resources

Introduction and Assumptions

As discussed in Appendix B and Section 4.2, the action area consists of plantation pine spread across 204 counties in the Southern United States. This analysis will discuss the impact of the No Action Alternative on soil resources within the action area, utilizing general, well-established trends related to plantation pine and soil resources across the Southern United States. Due to the abundance of plantation pine within the action area and a broad use of common plantation pine silvicultural practices across the entire Southern United States, these general trends are likely to be applicable within the action area.

The Southern United States region is generally considered to be the most eroded region in the country (Owen, 1975; USDA-NRCS, 2010), primarily due to the historical legacy of slash and burn agriculture (Owen, 1975; Johnston and Crossley, 2002). Additionally, the ultisol soil type commonly found in the action area (EPA, 2010a; EPA, 2012g; EPA, 2012b; EPA, 2012d; EPA, 2012c; EPA, 2012a; EPA, 2012f; EPA, 2012e) is generally considered low quality because of its acidity, poor drainage, and low nutrient holding capacity (NC State Soil Science, 2002; USDA-NRCS, 2013b).

The historical legacy of slash and burn agriculture and the inherent characteristics of soil types in the Southern United States led to large-scale planting of southern pine within the action area. Southern pine species, such as loblolly and shortleaf pine *(Pinus taeda* and *P. echinata*, respectively), are ideally suited to recolonize exposed and eroded areas (Jorgensen and Wells, 1986; Johnston and Crossley, 2002). The suitability of southern pine to grow well on poor soils helped facilitate an expansion of planted southern pine in the early 20th century to stabilize eroded soils, leading to modern production forestry in the present day (Wear and Greis, 2002a; Wear and Greis, 2012).

In comparison to other forest types, pine forests[22] are highly conservative ecosystems in that they are typified by a relatively slow rate of organic matter deposition/decomposition and nutrient cycling (Breymeyer, 1991; Knight, 1991; Johnston and Crossley, 2002). This slow rate of organic matter deposition/decomposition and nutrient cycling has significant implications for two primary aspects of soil quality, soil structure, and soil nutrient balance. Soil structure describes the physical arrangement of particles constituting the soil (Marshall and Holmes, 1979), while soil nutrient balance is a chemical representation of 14 essential nutrients that are important for plant growth (Barker and Pilbeam, 2010).

The structure and nutrient balance of soil within any forested ecosystem is primarily determined by the deposition and decomposition of litter on the forest floor. The metabolic activity of forest floor and soil biota, including fungi and other microorganisms, reduces litter to layers of simpler organic matter, eventually releasing nutrients contained within the litter into the soil (Johnston and Crossley, 2002). This production of organic matter and release of nutrients through litter decomposition represents two ecosystem processes that directly affect the structure and nutrient balance of soil, respectively (O'Connell and Sankaran, 1997). Accordingly, any forest event or activity that alters the deposition and decomposition or forest litter will also alter soil structure and soil nutrient balance.

Modern Production Forestry and its Potential Impacts on Soil Quality

Current forestry practices associated with the production of plantation pine, including shorter rotation times; higher stocking densities, and the use of machinery in all phases of stand management, are substantially more intensive than those of earlier in the 20th century (Vitousek and Matson, 1985; Johnston and Crossley, 2002). These current production practices, as performed today, substantially alter processes related to litter production and decomposition, thereby altering various aspects of soil quality (O'Connell and Sankaran, 1997).

Soil structure is substantially affected by plantation pine and its associated forestry practices. Mechanical site preparation activities, such as ripping, bedding, raking, and shearing (Barry et al., 2013; Cunningham et al., 2013) will generally use heavy machinery, resulting in the compaction of soil from the sheering of soil aggregates and the filling of pore spaces with solid soil components (Haines et al., 1975; Terry and Hughes, 1975). Compacted soil reduces plant growth by interfering with soil penetration, gas exchange, and water uptake by plant root systems (Marshall and Holmes, 1979; Johnston and Crossley, 2002). Furthermore, the relatively short rotation times associated with the cultivation of plantation pine generally lead to the removal of substantial amounts of plant material that would otherwise contribute to the generation of additional soil organic matter that would benefit overall soil structure (O'Connell and Sankaran, 1997; Johnston and Crossley, 2002).

Soil nutrient balance is represented by the macronutrients nitrogen (N); phosphorus (P), potassium (K); the three secondary macronutrients: calcium (Ca), sulfur (S), magnesium (Mg); and the

[22] Naturally-regenerated or planted

micronutrients/trace minerals: boron (B), chlorine (Cl), manganese (Mn), iron (Fe), zinc (Zn), copper (Cu), molybdenum (Mo), nickel (Ni) (Barker and Pilbeam, 2010). Within the action area where the easily-leachable ultisol soil types dominate (EPA, 2012g; EPA, 2012b; EPA, 2012d; EPA, 2012c; EPA, 2012a; EPA, 2012f; EPA, 2012e), there is often not enough of these plant nutrients to support healthy plant growth (NC State Soil Science, 2002; USDA-NRCS, 2013b).

Aspects of plantation pine biology and management interact to reduce soil nutrients within the action area. The *Pinus* species that collectively make up plantation pine possess rapid growth rates (Jokela, 2004); it is this rapid growth rate, in conjunction with high planting densities typical of pine grown in plantation, that facilitates a greater removal of nutrients from the soil than slower-growing tree species (Johnston and Crossley, 2002; Jokela, 2004). Furthermore, the removal of soil nutrients by plantation pine and its silvicultural practices is further compounded by the nature of plantation pine litter material and its removal. Needle fall represents the majority of litter within a pine plantation and is generally considered to be poorer in nutrients than trees not typically grown in plantation (O'Connell and Sankaran, 1997). Additionally, frequent harvesting of plantation pine woody material due to its relatively short rotation cycle (Johnston and Crossley, 2002), coupled with the immobilization of nutrients in pine needles that are slow to decompose (O'Connell and Sankaran, 1997), strongly suggests that removal of nutrients within a pine plantation exceeds the rate that nutrients can be restored from litter material. As a result, nutrient deficiencies, particularly nitrogen and phosphorus, are widespread in southern forests, partially as a result of these modern forestry practices (Johnston and Crossley, 2002; Fox et al., 2007). It is prudent to note, however, that nutrient losses that accompany pine harvests are partially dependent on the amount of pine material removed. Averaged over the life of a 16-year old pine plantation, stem-only harvesting reduces N by 7.2 kg ha^{-1}; however, whole tree N removals correspond to 16 kg ha^{-1} (Jorgensen and Wells, 1986).

Wildfire within the action area may also impact nutrient balance in the soil. Fire-induced deficiencies of nitrogen, iron, and copper have been reported following slash burning in lodge pole pine and white spruce stands in British Columbia. Significant nitrogen losses can occur in forests due to volatilization during intense burns such as uncontrolled forest fires. Additionally, prescribed burning may also reduce nutrient balances in the soil within a plantation pine site. However, cool prescribed burns in established pine stands in the South apparently have little impact on site nitrogen reserves (Allen, 1987; Albaugh et al., 2007).

Management of Impacts to Soil Quality by Forestry-Related Activities

In order to mitigate the impacts on soil quality from modern forestry practices, all states in the action area have implemented best management practices (BMPs) (Alabama Forestry Commission, 2007; Florida Department of Agriculture and Consumer Services, 2008; Mississippi Forestry Commission, 2008; Georgia Forestry Commission, 2009; Commission, 2013; Louisiana Forestry Association, 2013). Forestry BMPs are voluntary conservation practices for growing a healthy, sustainable, and productive forest. These BMPs are designed to assist land owners in protecting State water resources as well as avoiding practices that will lead to soil erosion, compaction, runoff and loss of nutrients. While many of these BMPs were initiated and adopted to comply with the Clean Water Act (CWA), [23] these BMPs are

[23] The concept of BMPs was first introduced in response to Federal legislation, the Clean Water Act, as a practical and effective means to reduce nonpoint source (NPS) pollution. Compliance with BMPs is required for forestry activities which involve discharge of dredge or fill materials into jurisdictional wetlands to qualify for the silvicultural exemption under Section 404 (f) of the Clean Water Act. Compliance with BMPs is recommended on

also effective in maintaining site productivity by preventing damage to soil structure and the loss of soil nutrition if put into place (Kelting et al., 1999; Johnston and Crossley, 2002).

Nutrient-poor soils are common throughout the action area, and common plantation pine practices may further impact soil nutrient balance in the soil. To address these nutrient poor soils, tree growers routinely use fertilization to counter nutrient deficiencies and to increase pine productivity at times of both planting and mid-rotation within the action area (Albaugh et al., 2007; Fox et al., 2007). In cases where fertilization is used, phosphorous and nitrogen are most often applied through fertilization. Phosphorus was identified as the primary limitation to forest growth at establishment, especially in poorly drained soils of the Coastal Plain in the late 1960s (Wells and Allen, 1985; Albaugh et al., 2007). And at some sites, early growth was also found to be nitrogen limited (Wells and Allen, 1985) so nitrogen is often applied as well. Also, in recent years, boron is being applied in areas where sandy soils are present, primarily due to studies showing that boron can be deficient in these soils. Applying boron serves two purposes in that it adds boron to the soil and also helps reduce nitrogen volatilization. In this case, boron-coated urea is applied and its use has increased significantly since 2000 (Albaugh et al., 2007).

Operational forest fertilization programs have been used for over 40 years in the Southern United States. Surveys taken since 1970 have shown a substantial increase in the acreage that is fertilized (Figure 7) (Albaugh et al., 2007). Two pine species commonly grown in plantation, loblolly (*Pinus taeda*) and slash pine (*Pinus elliottii*), are by far the species most often fertilized. Loblolly pine is the Southeast's primary commercial tree. Slash pine, with its smaller natural range, is still an important commercial species but is more geographically restricted than loblolly. Other species were fertilized beginning in 1997, including longleaf pine *(Pinus palustris* Mill.), sand pine *(Pinus clausa* Chapm. ex. Engelm.), shortleaf pine *(Pinus echinata* Mill.), and sweetgum *(Liquidambar styraciflua* L.); however, the acreage for these species represents less than 0.2 percent of the annual total (Albaugh et al., 2007).

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all sites on which there is a potential for violating water quality criteria. South Carolina Forestry Commission,: South Carolina's Best Management Practices for Forestry South Carolina Forestry Commission, "South Carolina's Best Management Practices for Forestry," (2013).

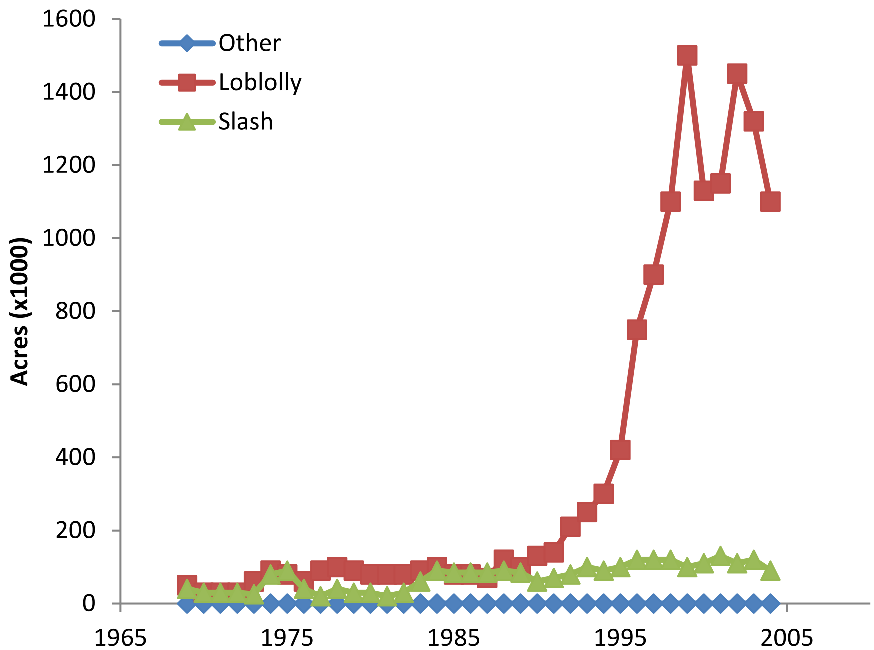

Figure 7. Acres of Forested Land Fertilized in the Southeastern United States
Estimated from Forest Nutrition Cooperative survey data collected from 1969 to 2004 from (Albaugh et al., 2007)

Maximum returns are realized when modern forestry practices are undertaken (Pritchett and Smith, 1975; Allen, 1987; Barry et al., 2013; Cunningham et al., 2013). In southern pine plantations in the Southeast, effective growth gains are obtained by combining intensive site preparation, vegetation control, and fertilization. Despite impacts on soil quality, these types of forestry activities are likely to continue under the No Action Alternative because the current condition of the soil necessitates that proper soil microsite conditions facilitate seedling establishment. Accordingly, soil quality is likely to continue being impacted by these modern forestry practices under the No Action Alternative.

4.3.4 Potential Impact on Water Resources Resulting from the No Action Alternative

4.3.4.1 Summary of the No Action Alternative on Water Resources

Under the No Action Alternative, water yield and water quality have been and continue to be impacted by plantation pine in the action area.

Compared to some other common types of vegetation, including herbaceous plants and some hardwood trees, plantation pine can utilize more water due to a variety of physiological and anatomical factors. As a result of this greater water use, plantation pine will continue to impact water quantity on the site and landscape levels. However, the magnitude of impact is directly modulated by precipitation, a variable that may differ substantially across time and space. Plantation pine growing on wetter sites is more likely to cause little or no impact on water quantity; conversely, plantation pine growing on drier sites is likely to cause more of an impact on water quantity compared to those wetter sites.

With regard to water quality, plantation pine may impact water quality primarily through poorly designed or maintained forest access systems, which contribute sediment to surface water. However, a plethora of strategies and best management practices exist and demonstrate that the contribution of sediments to forested surface waters can be substantially and economically reduced to the benefit of the environment, if adopted and properly maintained.

It is prudent to note, however, that while plantation pine (and other types of production forestry) may impact water quantity and quality in the action area, its impact is minimal relative to other common land uses, such as production agriculture and urbanization. Under the No Action Alternative, it is anticipated that this impact will remain relatively minimal across the landscape, due to the sizable impact that urbanization and agriculture already exert on water quantity and quality.

4.3.4.2 No Action Analysis on Water Resources

Introduction and Assumptions

Southern forests represent relatively stable ecosystems compared to other vegetative land covers that are subject to continuous cycles of cultivation and harvest (Wear and Greis, 2012). However relatively stable, Southern forests are also incredibly dynamic, as are their impacts on water resources in the action area (Chang, 2013).

Surface and groundwater resources are key outputs of Southern forests. These water resources are essential to processes and functions across the action area. Surface waters, such as rivers, lakes, and estuaries provide habitat for plant and animal life (Sun et al., 2002; West, 2002). Coinciding with these water resources in the action area is a prolific timber industry that produced approximately 55 percent of the nation's forestry products in 2007 (Wear and Greis, 2012). Furthermore, Southern forests facilitate a stable and abundant surface water supply for a variety of other anthropogenic uses, including drinking water, recreation, and power generation (Jackson et al., 2004; Sun et al., 2004; Vose, 2013b).

Forest hydrology is the study of water movement, distribution, and quality as regulated by forests (NRC, 2008). The overarching importance of water resources in the Southern United States, coupled with natural, societal, and industrial values of Southern forests, generated intensive examination of how structural and functional changes in Southern forests affect forest hydrology (Jackson et al., 2004; NRC, 2008; Lockaby et al., 2012b). Many of these studies examined the impact of plantation pine on Southern Forest water resources due to the dramatic increase and relative importance of plantation pine in the Southern United States (Jackson et al., 2004; Sun et al., 2004; Vose, 2013b).

This No Action Analysis of water resources will focus on the current condition of water quantity and quality resulting from plantation pine in the action area. With regard to water quantity, this analysis will infer impacts of plantation pine on water quantity in the action area from the published literature.

Water Balance and Water Yield

Within the Southern United States and worldwide, the impacts of plantation pine on water quantity have generated much discussion due to dramatic shifts toward plantation pine in recent decades (Lima, 2011; Wear and Greis, 2012) and the general function of plantation pine as the interface between water received and water available (Vose, 2013a). Prior to any discussion on water quantity, however, one must begin with a discussion about the amount of water yielded by plantation pine (Foti et al., 2013).

In any pine plantation, water yield may be described by the use of a water balance equation. A water balance equation is a mathematical representation of the relationship between water input, output, and storage that may be applied on a variety of spatial scales, including site[24], local[25], and landscape[26] scales (Chang, 2013). In a practical sense, application of a water balance equation to a pine plantation permits the determination of how much water is available for streamflow and groundwater recharge from that site (Vose, 2013b). In its simplest form, the water available from a plantation pine forest may be expressed as the following water balance equation[27]:

$$Q = P - ET$$

In this generalized water balance equation, Q represents water yield that is an estimate of available water that can potentially go into streamflow or groundwater recharge (Vose, 2013b). P (precipitation) is representative of the total of amount water received, while ET (evapotranspiration) is representative of the total amount of water lost (Farley et al., 2005; Vose, 2013a). For any given unit of time, Q (water discharge) is calculated to be the difference between precipitation (P) and evapotranspiration (ET) (Lockaby et al., 2012a).

Despite criticism that examining water yield will lead to an incomplete view of hydrology in any forest (Benyon et al., 2007; Dvorak, 2012), research and public interest have shown that water yield is a key metric in assessing overall hydrological impacts in natural or production forests. For example, recent research has shown that water availability is the most important resource in determining forest productivity (Stape et al., 2004; Stape et al., 2010). Additionally, water availability is a primary concern of government officials and the public (Andréassian, 2004; Dvorak, 2012), as demonstrated by numerous comments on the NOI for this EIS (See Issue 6 and 9 of Appendix A).

The remainder of this No Action Analysis on water quantity will examine water yield within the context of the water balance equation above, first examining the influence of plantation pine on ET. Next, the impact of plantation pine ET on Q will be presented, along with implications of altered Q for streamflow. Lastly, a discussion surrounding absolute and relative impacts will be presented, along with the modulating effect of P on Q in the action area.

Patterns and Drivers of Plantation Pine ET

As mentioned directly above, Q can be calculated as the difference between P and ET. Across any area where vegetation is dominant, ET is the parameter most likely to be influenced by vegetation (Sun et al., 2004; Farley et al., 2005; Lockaby et al., 2012a). Accordingly, before considering the impact of plantation pine on Q, one must first consider its impact on ET.

Plantation pine ET can be described in three ways: 1) annual ET over the course of a single year; 2) patterns of annual ET over the course of successive years; and 3) seasonal patterns of ET during the course of a single growing season.

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[24] Site = plantation

[25] Local = plantation + adjacent land

[26] Landscape = watershed or sub-watershed containing the plantation + adjacent land

[27] Typically, a water storage variable is included in water balance equations; however, over annual time scales typical of a plantation pine rotation, net water storage is typically considered to be negligible compared to the other terms and thus, assumed to be zero (See: G McIsaac, Nres 401: Watershed Hydrology, 2007, Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana-Chammpaign, Available: http://courses.nres.uiuc.edu/nres401/water%20balance%20&global%20hydro1.pdf.

During the course of a single year, plantation pine annual ET will generally be greater than other common vegetation of a comparable age, including deciduous forests and slower-growing conifers (Table 3). Plantation pine annual ET can range from 560 mm/yr to 1284 mm/yr, while pasture/grassland and deciduous forest annual ET can range from 360-650 mm/yr and 460-779 mm/yr, respectively. Natural pine forest annual ET ranges from 1077 mm/yr for pure natural pine forests to 1133 mm/yr for mixed pine/hardwood forests. The relatively greater ET values in plantation pine is well established in the literature, especially when compared to non-irrigated crops (Lima, 2011) and deciduous hardwood forests (Swank and Douglass, 1974; Ford et al., 2011; Chang, 2013).

Across successive years, plantation pine annual ET will generally increase as the plantation ages (Figure 8). This relationship between plantation age and Q is also well established in the literature, with confirmation of this trend spanning multiple syntheses in the peer-reviewed literature (Andréassian, 2004; Farley et al., 2005; Jackson et al., 2009; Sun and Liu, 2013).

Table 3. Comparison of ET Between Plantation Pine and Other Common Vegetation Types

Ecosystems	Evapotranspiration (mm)	Precipitation (*P*, mm)	ET/*P*	References
Loblolly pine plantation (CC), 4 year old, coastal North Carolina	838 (755-885)	1274	0.66	(Sun et al., 2010)
Loblolly pine plantation, 4 year old, Parker Track, North Carolina	895 (702–1078)	1152	0.78 (0.73–0.94)	(Diggs, 2004)
Loblolly pine plantation, 15 year old, Parker Track, North Carolina	988 938 (after thinning 1/3 of basal area)	1098	0.9	(Grace et al., 2006; Grace et al., 20006)
Loblolly pine plantation, 14-30 year old, Parker Track, North Carolina	997	1538 (947–1346)	0.65	(Amatya et al., 2006)
Loblolly pine plantation (LP) 16 year old, North Carolina	1087 (1011-1226)	1238	0.88	(Sun et al., 2010)
Loblolly pine plantation (PP), 25 year old, Piedmont North Carolina	658 (560–740)	1092 (930–1350)	0.6	(Stoy et al., 2006)

Ecosystems	Evapotranspiration (mm)	Precipitation (*P*, mm)	ET/*P*	References
Slash pine (*Pinus taeda* L.) plantation, clearcut, Florida	958 (869–1048)	959 (869–1048)	0.85 (0.84–0.86)	(Gholz and Clark, 2002)
Slash pine (*Pinus taeda* L.) plantation, 10-year old, Florida	1058 (994–1122)	1062 (877–1247)	1 (0.9–1.1)	(Gholz and Clark, 2002)
Slash pine (*Pinus taeda* L.) plantation, full-rotation, Florida	1193 (1102–1284)	1289 (887–1014)	0.93 (0.92–0.93)	(Gholz and Clark, 2002)
Slash pine (*Pinus taeda* L.) plantation, full-rotation, Florida (extreme drought years)	754 (676–832)	883 (811–956)	0.85	(Powell et al., 2005)
Mixed Pine and hardwoods, Santee Exp. Forest, South Carolina	1133	1382	0.82	(Lu et al., 2003)
Pine flatwoods, Bradford Forest, Florida	1077	1261	0.87	(Sun et al., 2002)
Deciduous hardwoods, Coweeta, North Carolina	779	1730	0.47	(Sun et al., 2002)
White pine (*Pinus strobus* L.), Coweeta, North Carolina	1291	2241	0.58	(Ford et al., 2007)
Deciduous hardwoods, Oak Ridge, Tennessee	567 (537–611)	1372 (1245–1682)	0.41	(Wilson and Baldocchi, 2000)
Deciduous hardwoods, Oak Ridge, Walker Branch watershed, Tennessee	575	1244	0.45	(Lu et al., 2003; Hanson et al., 2004)
Mature deciduous hardwoods (HW), Duke Forest, Piedmont North Carolina	573 (460–640)	1092 (930–1350)	0.52	(Stoy et al., 2006)

Ecosystems	Evapotranspiration (mm)	Precipitation (*P*, mm)	ET/*P*	References
Grass-cover old field (OL), Duke Forest, Piedmont North Carolina	508 (360–650)	1092 (930–1350)	0.46	(Stoy et al., 2006)

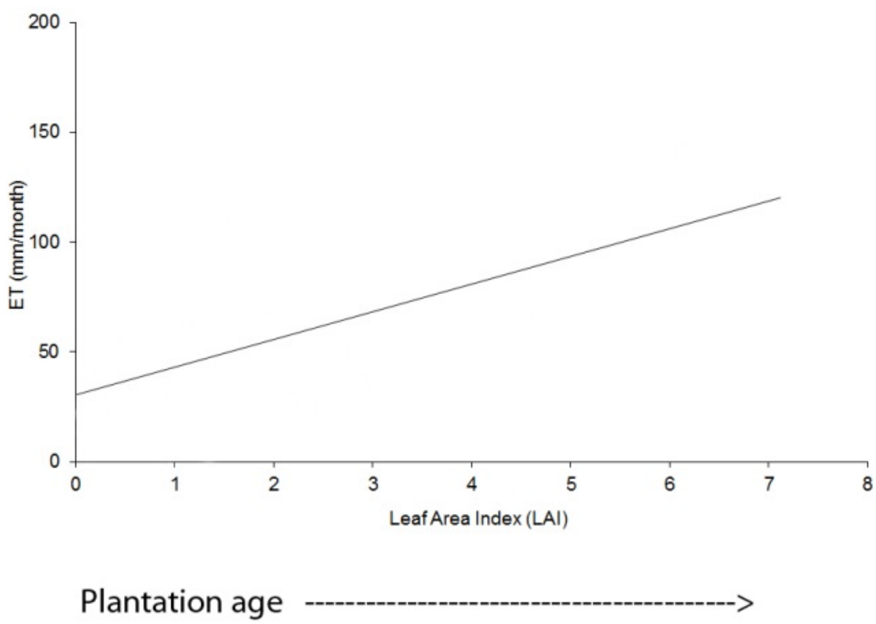

Figure 8. Plantation Age and Leaf Area Index (LAI) is a Major Control of Forest Evapotranspiration (ET)

Figure derived from Sun and Liu (2013)

While plantation pine annual ET generally increases as the plantation ages, plantation pine ET will also exhibit seasonal patterns, with maximum ET values generally occurring during the spring, summer, and autumn months in the Southern United States (Figure 9). During a three-year study in the lower coastal plain region of North Carolina, the maximum seasonal ET values in loblolly pine plantations were observed between the months of May and November (Sun et al., 2010).

Physiological and physical characteristics of plantation pine interact to drive annual patterns of ET (Farley et al., 2005). ET is calculated as the sum of transpiration and canopy interception/evaporation; consequently, factors that alter transpiration rate or canopy interception/evaporation will also alter ET (Ford et al., 2011).

Transpiration rates in plantation pine are primarily affected by its rapid growth rate (Lima, 2011) and its non-deciduous growth habit (Ford et al., 2011; Chang, 2013). A more rapid growth rate generally translates to greater transpiration rates in plantation pine (Lima, 2011). Additionally, the non-deciduous nature of plantation pine allows it to transpire year-round compared to other deciduous plants, albeit at lower rates during the colder months (Ford et al., 2011; Chang, 2013). Both factors facilitate plantation pine's higher ET rates, especially when younger, compared to many other types of vegetation.

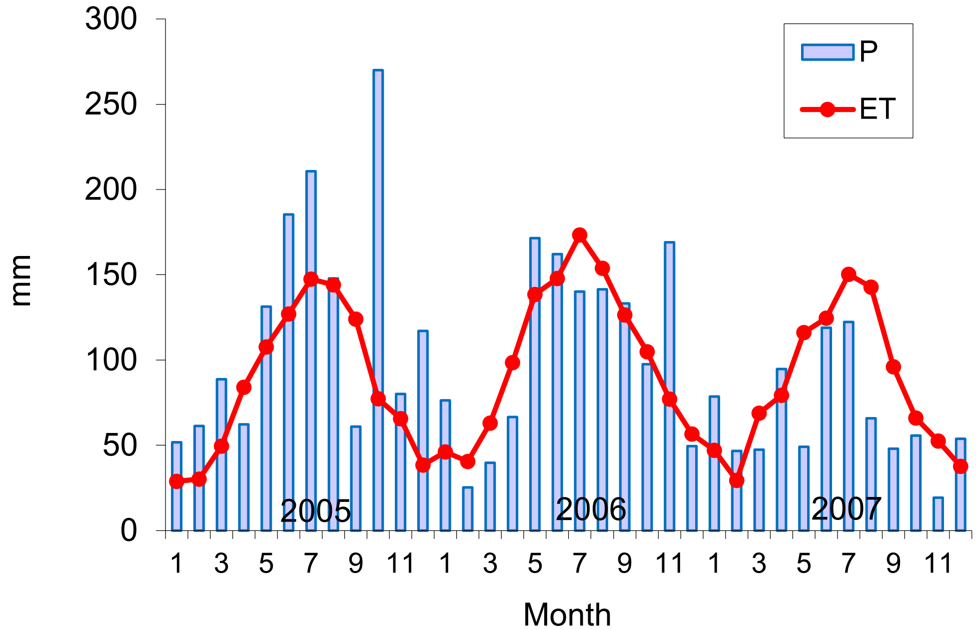

Figure 9. Seasonal Evapotranspiration Rates in a Mid-rotation Loblolly Pine Plantation, 2005 – 2007

Adapted from Sun et al. (2010)

Leaf area index (LAI), a measure of forest structure and canopy density, plays an important role in determining transpiration and canopy interception/evaporation rates, and thus, ET rates (Chang, 2013). In general, tall and evergreen conifer species possess the greatest LAI values, followed by deciduous hardwoods, shrubs, forbs, and grasses (Chang, 2013). The relatively high LAI value in plantation pine, coupled with its yearly increase, generally leads to greater transpiration and canopy interception/evaporation rates during a single year (Dvorak, 2012) and across successive years (Farley et al., 2005; McLaughlin et al., 2013; Sun and Liu, 2013).

While physiological and physical characteristics of plantation pine primarily drive annual ET values, seasonal patterns of plantation pine ET are primarily driven by precipitation. In general, water is necessary for ET processes to occur. Plantation pine ET will increase as precipitation increases; conversely, plantation pine ET will decrease as precipitation decreases (Ford et al., 2011; Chang, 2013). Consequently, plantation pine ET will generally peak when rainfall is greatest during a growing season (Lima, 2011). Figure 9 represents a three-year study in the lower coastal plain region of the Southeastern United States. In this region, precipitation is generally greatest between May and November; accordingly, this is also the period of time when plantation pine ET in this region is greatest (Sun et al., 2010). Further observations in peer-reviewed literature confirm this relationship between rainfall and plantation pine ET for the Southeastern United States (Sun et al., 2012).

Transpiration is considered the most important component of conifer ET; however, canopy interception/evaporation can also have large impacts on ET (Pearce and Rowe, 1979; Cannell, 1999). In conifers, canopy interception/evaporation values may be double that of deciduous trees (Sun et al., 2004), representing 15 – 40 percent and 10 – 20 percent, respectively (Le Maitre et al., 1999; Vose, 2013a). The relative importance of transpiration and canopy interception/evaporation may vary throughout the year and across multiple years (Ford et al., 2011). For example, when temperatures are high and precipitation is readily available in the summer months, transpiration will play a dominant role in determining ET values. However, during the winter months, when temperatures are low and precipitation is less, transpiration will also be lower, thereby increasing the relative importance of canopy interception/evaporation in determining ET.

In summary, a combination of physiological, physical, and environmental factors interact to not only produce relatively greater ET values in plantation pine compared to other vegetation types, but also to produce repeatable patterns of annual and seasonal ET. Plantation pine annual ET will increase as the plantation ages primarily due to increases in LAI, and seasonal patterns of plantation pine ET will follow precipitation patterns. These described patterns of plantation pine ET are likely to be similar in the action area, given the common and general trends that occur independent of geography in the peer-reviewed literature (Personal communication with J. Vose, 2013c).

Water Yield in the Action Area as a Function of Plantation Pine ET and Implications

As a general principle in forest hydrology, increases in ET will generally decrease Q (Figure 10). Intrinsically higher ET values of plantation pine, coupled with the substantial increase of plantation pine through afforestation[28] or reforestation[29] of land in the action area (Wear and Greis, 2002a; Wear and Greis, 2012), likely decreased water yield at those sites (Jackson et al., 2009; Chang, 2013).

If Q is reduced, then the amount of water available for streamflow or groundwater recharge on adjacent land is likely reduced (Andréassian, 2004). Consequently, if the amount of water for streamflow or groundwater recharge on adjacent land is reduced, then streamflow of surface waters is likely reduced (Jackson et al., 2009; Chang, 2013). This is an observable and common consequence of afforestation or reforestation with plantation pine.

Afforestation of land introduces relatively deep-rooted vegetation systems onto the land (Chang, 2013). In a synthesis of 14 catchment studies across a variety of climates, it was demonstrated that afforestation of grassland and shrubland universally reduced streamflow by approximately 165 mm, representing an approximate 30 to 40 percent reduction in streamflow compared to what it could have been if afforestation had never occurred (Table 4). While specific reductions are site-specific, this general reduction in streamflow following afforestation of grassland or shrubland is a well-established in the literature (Duncan, 1995; Dye, 1996a; Farley et al., 2004; Jobbagy and Jackson, 2004).

[28] Afforestation is the planting of trees on land that did not previously contain trees (e.g., conversion of agricultural land to plantation pine)

[29] Reforestation is the active planting of trees in an area that previously contained trees (e.g., conversion of natural pine to plantation pine)

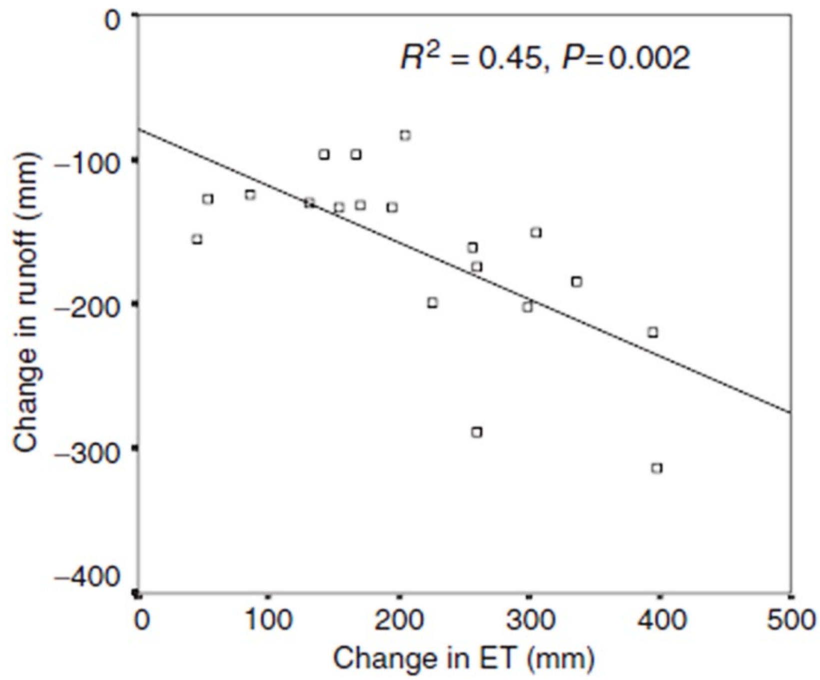

Figure 10. Change in Runoff as a Function of Change in Evapotranspiration (ET)
Derived from Farley et al. (2005)

Table 4. Mean Change in Runoff Following Afforestation with Planted Pine

Afforested from	Afforested to	Catchment number	Change in runoff (mm)	Change in runoff (%)	Mean annual precipitation (mm)
Grassland	Pines	9	- 167 (± 13)	- 40 (± 3)	1260 (± 18)
Shrubland	Pines	5	- 163 (± 9)	- 30 (± 2)	1226 (± 9)
Grassland or shrubland	Pines	14	- 165 (± 8)	- 35 (± 2)	1236 (± 10)

Adapted from Farley et al. (2005)

While the majority of trees share expansive root systems compared to non-woody vegetation, reforestation with plantation pine introduces a forest type with denser stocking and canopy patterns (Chang, 2013). Reforestation with plantation pine also leads to a reduction in surface water streamflow on adjacent lands (Figure 11). Multiple experiments at the Coweeta Hydrologic Laboratory in the Southern United States have demonstrated this trend, where conversion of natural forest to plantation pine increased ET and subsequently decrease Q at the study sites, consequently also reducing streamflow (Swank and Douglass, 1974; Jackson et al., 2004; Sun and Liu, 2013).

If afforestation or reforestation generally reduces streamflow, then the converse must be true; deforestation should generally increase streamflow. Again, this is a common and observable pattern in the literature (Figure 12), where removal of any forest results in decreased ET (i.e., lower LAI for transpiration, interception, and evaporation), thereby increasing streamflow in studied watersheds (Sun et al., 2012; Sun and Liu, 2013).

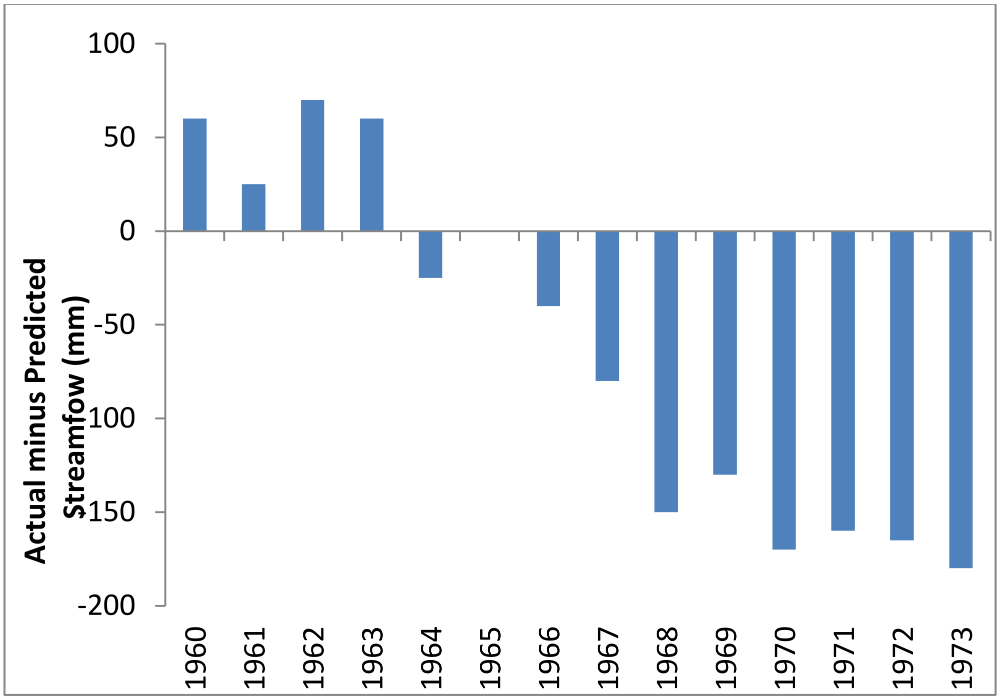

Figure 11. Annual Streamflow in a Coweeta Watershed After Planting White Pine, 1960 – 1973
Reproduced from Swank and Douglass (1974)

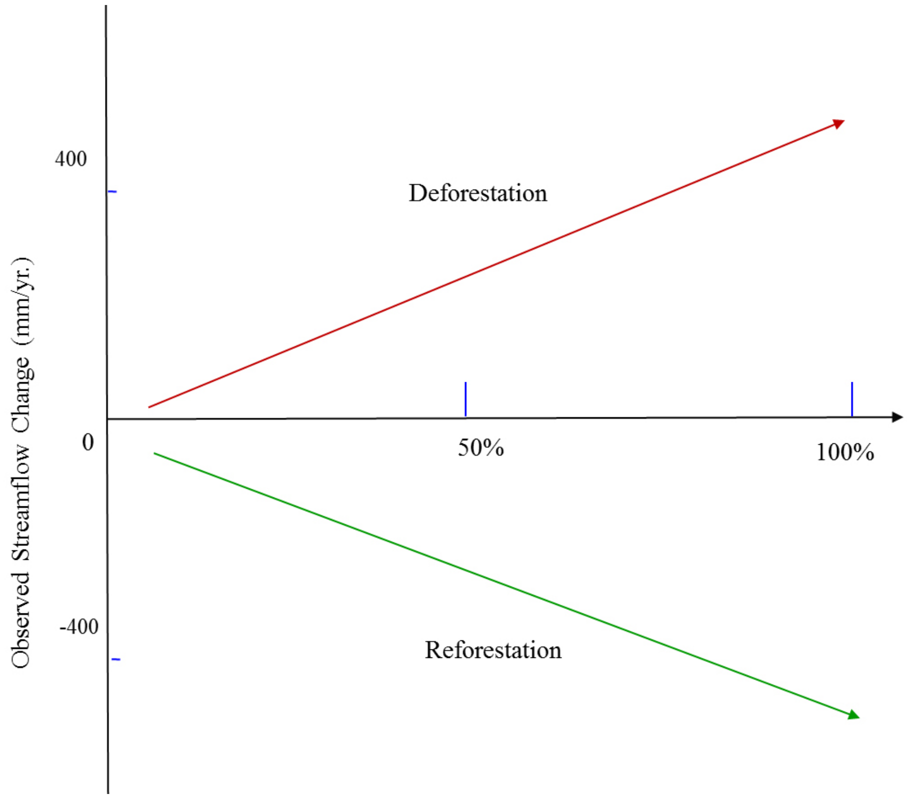

Figure 12. Effects of Deforestation and Reforestation on Watershed Water Yield
The x axis represents the percentage of area converted. Reproduced from Sun et al. (2012)

In a variety of reforestation and afforestation studies, plantation age is positively correlated with increasing reductions in streamflow, though specific patterns of this reduction may be site-specific (Farley et al., 2005). For example, in grassland sites afforested with plantation pine, reduction in runoff is generally found to continuously decrease with plantation age; the reverse pattern typically occurs over time when shrubland is afforested with plantation pine (Farley et al., 2005). Furthermore, in a natural forest site, reforestation with plantation pine can initially create an increase in streamflow, though this transient increase eventually amounted to a net decrease of 200 mm 16 years after pine planting occurred (Swank and Douglass, 1974). This transient increase in streamflow following reforestation is likely related to the length of time for plantation pine root systems and canopies to develop (Chang, 2013).

Reductions in streamflow at the local and landscape levels by plantation pine have important implications for annual and seasonal patterns of streamflow, with low flow being the factor that may be most substantially affected (Andréassian, 2004; Jackson et al., 2009). Low flow may be defined as the flow of water in a stream during prolonged dry weather (Smakhtin, 2001). For some aquatic species, low flow can be more important than annual stream flow, because there may be too little water during the dry season for aquatic species to survive (Findlay, 1995; Poff et al., 1997; Smakhtin, 2001; Jackson et al., 2009). In a worst-case scenario, perennial streamflow may shift to intermittent streamflow, where streams are capable of drying up (Andréassian, 2004; Farley et al., 2005; Chang, 2013). Low flow is most commonly observed in the summer months in the action area, when ET is highest and streamflow is lowest (Jackson et al., 2004).

In summary, afforestation or reforestation with plantation pine will generally increase ET and decrease the water yield from that site, functionally decreasing the amount of streamflow on adjacent land. Shifts in perennial streamflow to intermittent streamflow may occur as a result of this reduction in annual water availability, with streams sometimes drying up as a result of plantation pine cultivation. A multitude of peer-reviewed forest hydrology studies in the United States and world-wide have supported these general conclusions (Farley et al., 2005; Jackson et al., 2009; Kim et al., 2013; Sun and Liu, 2013) and it is likely that these conclusions are also applicable to the action area (Personal communication with J. Vose, 2013c).

<u>Absolute Versus Relative Impacts and the Modulation of Water Yield and Streamflow by Precipitation</u>

Following an examination of the literature and consultation with technical experts in forest hydrology, it is almost certain that substantial increases in plantation pine acreage within the action area decreased the amount of water available for streamflow. The magnitude of the impact associated with this decrease, however, is more uncertain. This uncertainty is likely due to the interaction of precipitation with plantation pine evapotranspiration and the resulting contrast between absolute and relative impacts on streamflow.

As mentioned previously, water discharge or stream flow (Q) is calculated to be the difference between precipitation (P) and evapotranspiration (ET) (Lockaby et al., 2012a); and Q is significantly influenced by ET (Sun et al., 2004; Farley et al., 2005; Lockaby et al., 2012a). For any given ET value, however, P functions to modulate the relative impact of Q (Figure 13).

In an examination of 14 afforested sites, proportional losses in low flow were closely correlated with, but even larger than, proportional losses in annual flow (Farley et al., 2005); therefore, dry season losses may be more severe than total losses, leading to shifts from perennial to intermittent flow in regions with less precipitation (Jackson et al., 2009). As a result, runoff reductions are most significant during the dry season, when stream channels may begin to dry; thus, the impact of planted pine on streamflow may be greater for low flows than for high flows (Chang, 2013). The reason for this contrast between absolute and relative differences on the impact of streamflow may be simply because there is less total water received, and thus available, for hydrological processes; for any vegetation-mediated increase in ET, the relative effect on streamflow in drier regions will be larger, because the amount of water available for streamflow is already low (Farley et al., 2005; Jackson et al., 2009). In short, drier areas (i.e., areas that receive less precipitation) will generally experience more of a relative impact from vegetation changes than wetter areas (Farley et al., 2005; Jackson et al., 2009).

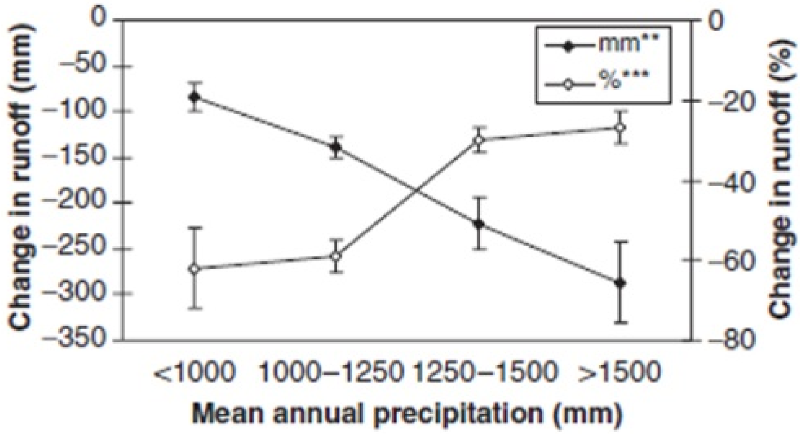

Figure 13. A Comparison of Absolute and Relative Changes in Runoff as a Function of Precipitation

Reproduced from Farley et al. (2005)

Introduction to Water quality in the Action Area

Due to its chemical properties and role in ecosystem processes, water quality plays a central role in Southern Forests. Water, however, is more than simply two molecules of hydrogen and one molecule of oxygen. All water in the action area, including those waters yielded by plantation pine to streamflow on adjacent forested lands, also contains organic matter, inorganic matter, and dissolved gasses derived from the environment, organisms, and anthropogenic activities. The concentrations of all these substances, in addition to their biological, physical, and chemical effects, are the basic criteria of water quality (Chang, 2013).

Water quality is considered impaired if it is classified as partially supporting or not supporting its intended use(s), as determined by individual states (EPA, 2000a). Intended uses may include drinking, recreation, irrigation, industry, or aquatic life (Chang, 2013). Within the action area, surface waters are most likely to be impaired in comparison to groundwater due to the filtering effect of Earth on moving water (Chang, 2013). Thus, the remainder of this No Action analysis on water quality will focus on surface waters in the action area.

The Nature and Contribution of Plantation Pine to Water Quality in the Action Area

Within the action area, surface waters span a total of approximately 570,569 miles (EPA, 2012h). As required by the Clean Water Act (CWA), state-level 305(b) reports illustrate that non-impaired surface waters averaged from 74 percent (AL) to 20 percent (FL and LA) during a six-year period between 2004 and 2010 (Table 5). Also during that six-year time period, impaired surface waters averaged from 80 percent (FL and LA) to 26 percent (AL) (Table 5).

Table 5. Non-impaired and Impaired Surface Waters in the Action Area, 2004 – 2010

	Total river and stream (miles)	**Average assessed river/stream miles (%), 2004 – 2010**	**Average non-impaired water (%),** 2004 – 2010*	**Average impaired water (%), 2004 – 2010***
AL	77242	14	74	26
FL**	51858	20	20	80
GA	70150	18	41	58
LA	66294	14	20	80
MS	84003	8	42	58
SC	29794	17	36	64
TX	191228	11	64	36

Information derived from EPA (2012h)

*As a percent of assessed water

**Only 2010 data was available for FL

Figure 14 shows annual changes from 2004 to 2010 in the percent of surface waters that were assessed as impaired and unimpaired in the seven Southeast states. Water quality trends in the action area between 2004 and 2010 demonstrate that the proportion of non-impaired surface waters generally increased in LA and MS, while non-impaired surface waters generally decreased in AL, SC, and TX, and remained roughly the same in GA over this period (Figure 14). Additionally, the percent of surface waters that qualified as impaired decreased in MS and LA, increased in SC and notably in TX, while remaining similar in GA and AL over this period (Figure 14). It is prudent to mention, however, that the classification of surface water as non-impaired or impaired is a complicated process that typically cannot be compared across states. In many cases, individual states do not use directly comparable criteria and monitoring strategies to examine water quality. As a result, states with more strict criteria for water quality are more likely to possess a higher proportion of impaired waters than states with less strict criteria (West, 2002). This suggests, for example, that TX may not necessarily possess higher water quality than SC, despite a higher proportion of non-impaired surface waters (Figure 14). Additional discussion of data limitations regarding water quality and water quality monitoring in the 305(b) reports may be found in West (West, 2002).

Within the action area, the most common cause of surface water quality impairment is likely non-point source (NPS) pollution (Neary et al., 1989). In contrast to point sources of pollution that have a single, locatable source, NPS sources of pollution are difficult to identify, are associated with rainfall and surface runoff, and possess routes that are intermittent and diffused through the landscape (Chang, 2013). NPS pollution is recognized as a major environmental concern in the action area and the rest of the Southern United States (EPA, 1984).

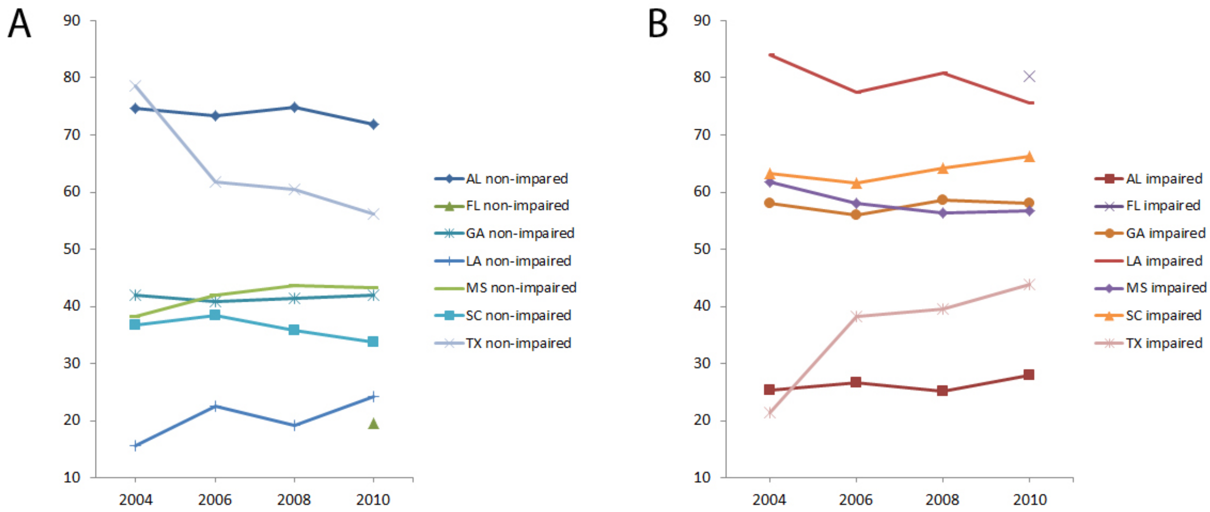

Figure 14. Non-impaired (A) and Impaired (B) Surface Waters as a Percent of Assessed Water in the Action Area, 2004 – 2010

Note that FL only has data available for 2010

Information derived from EPA (2012h)

Of the probable sources of water pollution in the action area, silviculture activities[30] are likely to contribute a smaller proportion relative to other common land use activities. On a national scale, silviculture activities ranked 13th overall in 2002 (Figure 15). Of the probable sources of surface water impairment, many were far greater than silviculture activities (e.g., modifications to hydrology, habitat modification, etc.); in fact, agriculture was responsible for surface water impairment that was an order of magnitude greater than silviculture activities (EPA, 2014b). There is reason to suspect that these national trends apply to the action area. For example, in 1984, silviculture contributed to less than 8 percent of all non-point source pollution in surface waters in the majority of Southern States (Neary et al., 1989). Furthermore, independent research corroborates this notion that other common land use activities, such as agriculture, generates far more surface water pollutants than silviculture; in a study of various silviculture activities in AK and OK, it was noted that the amount of sediments generated from forestry was 1/13 that of sediments produced from agriculture (Scoles et al., 1994).

[30] Silviculture activities include those activities related to the production of plantation pine

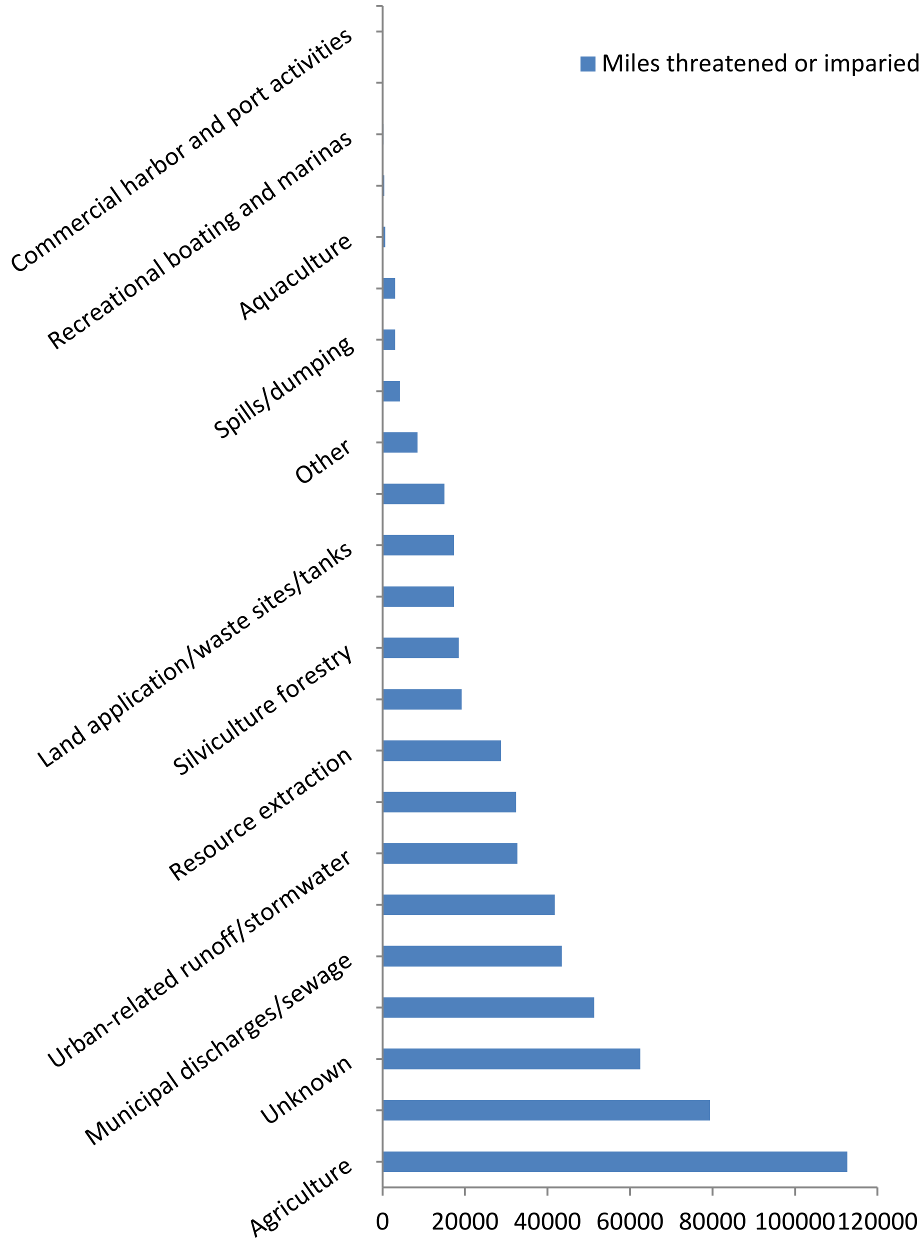

Figure 15. Probable Sources of Surface Water Impairment, 2002

Data derived from EPA (2014b)

Of the eight general types of pollutants (Table 6), surface water sediments likely represent the single largest source of pollutants from plantation pine in the action area (Neary et al., 1989; EPA, 1997; EPA, 2000b). Sediments are a non-point source of surface water pollution that may be organic or inorganic in nature, and generally originate from the land (Chang, 2013). This is likely, considering the vast acreage of production forestry in the action area (Wear and Greis, 2002a; Wear and Greis, 2012) and the observation that activities related to production forestry aim to eventually remove vegetation, disrupting the stabilizing force of growing forests on soils (Jackson et al., 2009; Lockaby et al., 2012a) and exposing the ground to disturbances and erosion (Chang, 2013).

The impacts of sediments can vary widely. Sediments can directly alter the turbidity, light penetration, energy exchange, taste, odor, temperature, and abrasiveness of water (Chang, 2013). Additionally, sediments can indirectly reduce reservoir activity, clog stream channels and drainage ditches, alter aquatic habitat, suffocate fish eggs and bottom-dwelling organisms, form alluvium, and increase flooding and flood damages (Chang, 2013).

Table 6. Descriptions of Eight Major Water Pollutant Types

Type of water pollutant	Description
Sediments	Inorganic or organic soil/mineral particles released by runoff, streamflow, wind, melting glaciers, rainfall, animals, or gravity. Chemically, many nutrients and chemicals can attach to soil particles and be carried into surface waters through sediments.
Heat	Increased water temperature may be caused by the summer sun, the reduction of flow volume, the removal of riparian plants, or the discharge of heated water from power plants and factories.
Oxygen-demanding wastes	These pollutants may include sewage, animal manure, and organic materials that can be decomposed by microorganisms; the decomposition of these materials by microorganisms are oxygen dependent and can result in the depletion of oxygen.
Plant Nutrients	Generally represented by nitrogen and phosphorus, plant nutrients may be derived from soil and water erosion; agricultural fertilizers; domestic sewage; livestock wastes; decomposition of plant material; and phosphate detergents. These nutrients stimulate growth of aquatic plants, including algae, which in turn interfere with water uses.
Disease-causing agents	Water discharges from urbanization, slaughtering plants, animal feedlots, or ships can carry pathogens capable of causing diseases in humans and animals.
Inorganic chemicals and minerals	These pollutants may include acids, salts, heavy metals, and toxic materials from industrial and municipal discharges.
Synthetic organic chemicals	These pollutants may include detergents, plastics, oils, septic-tank cleaners, phenols, pesticides, and other organic compounds of modern industrial technology. The stability of these chemicals vary widely; some may be broken down to harmless substances by natural processes, while others may be non-degradable.
Radioactive substances	Radioactive substances may be derived from naturally-occurring radioactive rocks and soils, from uranium mining and processing, nuclear power plants and weapons testing, and radioactive instruments.

Table derived from Chang (2013)

Contribution of Plantation Pine to Sediments in Forested Surface Waters

Sediments may originate from a variety of management activities related to the cultivation of plantation pine, such as site preparation (Riekerk, 1983; Blackburn and Wood, 1990; McBroom et al., 2008), harvesting/clear-cutting (Binkley and Brown, 1993; Bolstad and Swank, 1997; McBroom et al., 2008), and fire control (Kalabokidis, 2000). However, forest access systems, such as forest roads and stream crossings[31], are primarily responsible for production forestry-mediated stream sedimentation (Jackson et al., 2004; Chang, 2013). A plethora of information strongly suggests that this is the case in the action area. For example, the central role of forest access systems in stream sedimentation is demonstrated both by empirical data on a national scale (EPA, 2014c) and in the Southern United States (Swank et al., 2001) and its past and continuing presence as a primary concern in production forestry (Bengston and Fan, 1999; Gucinski et al., 2001). Furthermore, specifically in the action area, forest roads are the most likely source of sedimentation, not the plantation site itself (Swift, 1988). This is because the grade of the land at plantation sites in the action area is mostly flat, so disturbed sediments from site activities, like site prep and harvest, are unlikely to travel into surface waters (Personal communication with J. Vose, 2013c).

Forest access systems are essential in forest-management activities; however construction and use of forest access systems exposes land surfaces to accelerated erosion (Chang, 2013; EPA, 2014c). As identified by Chang (Chang, 2013), forest access systems, and in particular, forest roads, are responsible for deposition of sediment into surface waters because of:

- Low permeability of road surface;
- Alteration of natural surface drainage paths;
- Creation of concentrated overland flow by ditch systems and relief culverts;
- Susceptibility of cut-slopes and fill-slopes to soil erosion; and
- The construction and maintenance of stream crossings in developing a forest road system.

As a result of the factors directly above, forest roads can disrupt watershed systems and drainage patterns, becoming a convergence point of overland flow with greater potential to erode soil, delivering sediments to surface waters (Taylor et al., 1999; Chang, 2013).

Sediment deposition into forested surface waters from forest access systems may be substantial, representing 70 to 90 percent of all sediment lost from forested land (Grace, 2000). Often, the volume of sediment yield from these access systems is generally dependent on frequency and intensity of precipitation (Williams and Guy, 1973; Swift, 1984; Scoles et al., 1994), intensity of use (Jackson et al., 2004), and best management practices (BMPs) related to design and use (Chang, 2013).

<u>Prevention is for More Effective than Reclamation with Regard to Stream Sedimentation</u>

Production forestry, including the cultivation of plantation pine, need not unnecessarily degrade water quality through the deposition of sediments into forested surface waters. When the production of plantation pine is undertaken in an abusive manner, erosion and sedimentation can generally be substantial (Jackson et al., 2004). Conversely, when use of forest access systems is conducted in a way to preserve water quality, it may not cause substantial deposition of sediments into streams (Hewlett and Troendle, 1975).

Due to its NPS nature, sedimentation cannot generally be corrected using technology and treatments; preventative activities are more effective and cost-efficient in managing stream sedimentation and its respective hazards (Chang, 2013). Numerous studies have been undertaken examining sediment yield from forest access systems, specifically in the Southern United States (Table 7).

[31] Stream crossings may include bridges, culverts, and fords (stream-bottom crossings)

These studies have generally demonstrated that sediment yield from forest access systems is primarily related to the design of the forest access system itself. Studies have shown that for forest roads, the most common type of forest access system, sediment yield is related to road gradient, surface density, the diameter of materials, slope-length factor, percentage of forest cover over the fill, and road density (Burroughs and King, 1989; Brake et al., 1997). Consequently, studies and efforts that aim to minimize erosion on forest access systems, and thus minimize its impacts on water quality, are largely centered on forest road design (Swift, 1988).

In general, strategies in forest access systems design are focused on road placement, the reduction of sediment load from roads, and the control of sediment-containing runoff from roads. The distance between a road and a stream is a primary factor in determining stream sedimentation (Douglass, 1974; Swift, 1985).

Table 7. Summary of Findings Across a Range of Measures in Road-Related Sediment Studies Conducted at Coweeta

Research subject	Coweeta results
Soil loss from ineptly located and managed logging roads.	6,850 yd^3 of soil eroded from 2.3 miles of road.
Soil loss from well-located forest roads.	2-115 tons ac^{-1} yr^{-1}.
Flood frequencies and culvert sizes needed to convey flow beneath roads.	Results applicable to most of the southern Appalachian Region.
Distances soil eroded from roads, then was carried across forest floor.	Average distance ranged from 32 - 112 ft., with BMPs.
Principles of road design to minimize soil erosion.	Wide-ranging treatment in rather technical terms.
Unused roads stabilize soon after logging discontinued.	Easily reopened by clearing and re-vegetation.

Table reproduced and modified from Jackson et al., (2004)

Strategies focused on reducing sediment load from roads are largely centered on increasing durability of the road and controlling surface runoff over the road and adjacent areas. Road surface type is significant in reducing sediment loss from roads; in an additional study at Coweeta Long Term Ecological Research (LTER), it was determined that soil losses from bare roads were 8 times that from graveled beds (Swift, 1985). It was also determined that roads protected by layers of rock experienced less sediment loss, though thin layers of rock did not afford more protection than bare land (Swift, 1985). Additionally, paved roads were the best in reducing sediments (with paved roads at 150 total suspended solids [TSS, ppm]), followed by improved gravel (1470 TSS), routine gravel (1980 TSS), and unimproved gravel (3200 TSS) roads (Clinton and Vose, 2002).

Sediment increases off of roads due to increased channel flow (Williams et al., 1999). Consequently, the elimination of ditches, out-sloping of roads, and use of broad-based ditches permits runoff to form as a single sheet, rather than channels, reduces runoff and erosion that may impact surface waters (Jackson et al., 2004). These methods to facilitate runoff as a single sheet rather than channels was so effective in reducing runoff and erosion that they were adapted as standards for forest road construction by the national forests in Region 8 of the USDA Forest Service (Jackson et al., 2004).

Strategies that aim to control sediment-containing runoff from roads primarily include the use of vegetative buffer strips. The vegetative buffer strip effectively functions as a screen, mitigating the propagation of road sediments into streams (Jackson et al., 2004; Chang, 2013). While these vegetative buffer strips generally consist of growing plants, discarded plant material, such as mulch of woody slash material, are also capable of substantially decreasing the loss of sediments to forested surface waters (Hursh, 1935; Hursh, 1939; Hursh, 1942; Swift, 1988; Jackson et al., 2004). In a study of forested roads in NC, the benefits of filter strips in mitigating sediment flow was apparent; the average distance of transport in bare sites was 34 m, whereas grass cover reduced this distance by 40 percent (Swift, 1986).

Forest road designs, along with other forestry BMPs, have evolved over time and are all capable of reducing NPS pollution, such as sediments (Jackson et al., 2004). Although specific BMPs may vary from state to state in the action area, they all share the following basic recommendations: minimize bare ground coverage and soil compaction; separate bare ground from surface water; inhibit hydraulic connections between bare ground and surface water; avoid disturbance on steep convergent slopes; separate fertilizer and pesticide application from surface waters; provide a forested buffer around streams; and engineer stable road surfaces and stream crossings (Jackson et al., 2004). Studies of BMP effectiveness in the action area and other parts of the Southern United States almost all uniformly demonstrate that BMPs are capable of substantially reducing sediment loading into forested surface waters (Kochenderfer and Edwards, 1990; Adams et al., 1995; Arthur et al., 1998; Williams et al., 1999; Wynn et al., 2000; Vowell, 2001; Williams et al., 2001; Williams et al., 2002; Carroll et al., 2004).

Overall, the quality of water in areas that produce plantation pine is dependent on voluntary forestry-related BMPs to meet water quality protection standards outlined in the CWA (Jackson et al., 2004). This creates a non-regulatory solution that is intended to be flexible and better able to respond to relatively-ephemeral market conditions. To maintain this flexibility, the forest production industry (including those that cultivate plantation pine) must be able to demonstrate to the public and government agencies that forestry BMPs are reasonable to implement and are effective (Jackson et al., 2004). A long history of research and use has demonstrated that forestry BMPs are capable of reducing sediment, the primary NPS pollutant in surface waters, and its respective impacts on water quality (Jackson et al., 2004).

4.3.5 Potential Impact on Plantation Pine-Associated Vegetation Resulting from the No Action Alternative

4.3.5.1 Summary of the No Action Alternative on Plantation Pine-Associated Vegetation

Under the No Action Alternative, the diversity and abundance of plantation pine-associated vegetation will generally be less within the stand than in areas adjacent to the stand due to common pine plantation management activities intended to maximize timber production and canopy closure of the planted pine species.

The geographic region, plantation management practices, and unpredictable events are factors that affect vegetation associated with pine plantations. In spite of these factors, common trends occur and may be used to describe the biological richness and abundance of pine-associated vegetation within a planted pine plantation. Relative to the plant community within stands of less intensively managed pine species (e.g., longleaf pine), the plant community in intensively managed plantation pine stands is usually more reduced in terms of plant species richness and abundance.

Over the course of a typical 20-year pine pulpwood rotation, positive response in planted pine growth is associated with intensive management of competing vegetation within the stand, strongly suggesting that land managers will continue common and intensive management practices to maximize wood production in stands of planted pine. Additionally, over the course of a typical 20-year pine pulpwood rotation, site preparation and site establishment activities will generally reduce the species richness and abundance of plantation pine-associated vegetation early in the rotation (i.e., approximately year 0 – 5). Following this initial period of competition repression, plantation pine-associated vegetation may recover somewhat in terms of richness and abundance, but will almost always be reduced again upon canopy closure of the planted pine species (i.e., approximately year 10). By the end of the rotation cycle (i.e., approximately year 20), shade-tolerant plant species may be present in the plantation pine understory, but will generally not represent a large or substantial plant community within that plantation pine understory.

Unpredictable events, such as hurricanes, pest infestations, or catastrophic fires, will generally produce a mosaic pattern of open and closed spaces within a pine plantation due to potential localized mortality of planted pine trees. Successional plants may colonize these open spaces due to differences in the environment of that open space (e.g., more direct access to sunlight).

The plantation pine-associated vegetation in areas adjacent to a plantation pine stand is generally greater in abundance than the vegetation within a plantation pine stand. This difference in plant species abundance is primarily attributed to the openness of adjacent areas, facilitating greater access to light and precipitation than would occur inside of the plantation pine stand. Despite the likely lower plant species abundance, within the plantation pine stands, plant species composition may not differ between plantation-pine associated plant communities within and adjacent to the plantation pine stand, suggesting no net differences in understory species richness.

4.3.5.2 No Action Analysis on Plantation Pine-Associated Vegetation

Introduction and Assumptions

As identified by Wear et al. (2013), the action area consists of plantation pine within 204 counties spread across seven U.S. states (Appendix B). For this No Action analysis of pine-associated vegetation, we characterize the action area as *existing* pine plantations within the 204 counties.

The intent of this No Action analysis is to describe the interactions of plantation pine management and the vegetation within the stands and areas adjacent to stands located in the action area. This No Action analysis on pine-associated vegetation will also evaluate the interactions in response to unpredictable events across the action area. The following subsections will include background information describing the development of forests in the Southern United States, common pine plantation management practices within the action area and assumptions, and discussion centering on each of the objectives stated directly above.

South Pine Plantation Management- Development of Southern Pulpwood Markets

Timber production in the Southern United States has become a multi-billion dollar industry, with focused production of fiber (pulpwood along with pulp and paper products) provided by intensively managed pine (Miller and Miller, 2004a). Today, Southern pine forests are predominately privately owned and centered on loblolly pine production. Eleven percent of timberland (21.4 million acres) is managed by government agencies (Wear and Greis, 2004). The remaining 89 percent is privately owned: 22 percent of private timberland is owned by forest industry, 21 percent by farmers, 12 percent by other corporations, and 45 percent by other individuals (Wear and Greis, 2004).

Loblolly pine (*Pinus taeda*) grows in a wide range across the Southern United States. It grows mainly in early to middle successional periods of the forest ecosystem because it is shade intolerant (requiring light) to moderately shade tolerant (can survive in areas where canopy closure exists), has rapid juvenile growth, and is very adaptable, even in the periphery of its native range. The fastest growing of all southern pines, this species requires humid climates with extended hot summers and mild winters in areas with at least five months of freeze-free periods. Loblolly pine is a dominant pioneer arboreal species in secondary succession on the uplands; however, in later stages of succession it is commonly found with and often replaced by a broad spectrum of hardwood species when the successional trend is unchecked (Baker and Balmer, 1983).

Prior to the 1930s, loblolly was a minor component in the natural ecosystem across the Southeast. Much of the historic Southeast was in oak-hickory, longleaf pine and mixed hardwood forest and contained little to no component of loblolly pine. Timber production during this time focused around longleaf pine (*Pinus palustris*). A massive cutover of some 90 million acres of mature longleaf pine forest from the eastern to western Gulf Coast occurred during the early 1900s. It soon became clear that the massive cutover almost eliminated the opportunity for longleaf pine seed tree regeneration; however in North and South Carolina, loblolly pine (*P. taeda*) began to naturally regenerate in the longleaf pine cutover areas (Barnett, 2004). This extensive planting and natural regeneration of cutover forest land and abandoned farmland between 1930 and 1990 made loblolly the leading timber species in the United States (Schultz, 1999) due to its adaptability and requirements to produce successful amounts of wood volume (Miller et al., 2003).

Loblolly pine plantations grow in natural or planted stands, however, it produces higher overall growth on planted sites (Baker and Langdon, 2005). This feature shifted the composition of most loblolly pine forest in the Southern United States: pine forests moved away from naturally regenerated sites to large intensely managed areas of pine plantations on disturbed sites that focused mainly of optimizing yield, with little stand diversity or understory vegetation (Wear and Greis, 2004). Most pine plantations are in disturbed or highly disturbed sites, usually experiencing more than 30 years of various intensive management on previous agriculture sites. Plant species richness is typically lower on planted pine plantations compared to naturally regenerated tree plantations (Ramovs and Roberts, 2003) and pine forests (Brockerhoff et al., 2008), in general. Hedman et al. (2000) found that total species richness and herbaceous cover were negatively correlated with land-use history, particularly on old agricultural sites where native groundcover is already degraded, more so than forest management activities or pine cover type.

During the late 1970s to early 1990s, loblolly pine research helped to improve the performance in commercial loblolly pine production by improving tree genetics through conventional plant breeding and refining management practices including the optimum application time and amount of fertilizer, enhancing soil performance, and controlling vegetation competition through herbicides.

Recognizing that pine plantations provide other important ecosystem services, researchers are studying the impact of plantation practices on its surrounding ecosystem and developing best management practices to enhance plant and animal biodiversity, as well as soil and water quality (Hedman et al., 2000; NRCS, 2002; Rauscher and Johnsen, 2004; Lane et al., 2011b).

Commercial southern pine plantations rely on a four-step establishment process. These steps include: preparation of the site to remove of all competition on the planting site, fertilization of the site (if necessary), planting of pine in the site, and treatments to remove woody or herbaceous plants that would otherwise compete with the planted pine. Thinning of the stand may occur during mid-rotation to focus growth on dominant trees and increase the annual incremental growth for maximizing yield.

Overview of Typical Southern Pine Forest Management

This subsection will review typical southern planted-pine plantation practices. Studies conducted by Miller et al. (2003), Nilsson and Allen (2003), and Brockway et al. (1998) were the base documents used to develop assumptions and basic forest management treatments for the action area. This document will use the treatments discussed below as the assumptions for analysis.

Site Preparation Techniques: During the summer and early fall prior to planting, the existing mature stand (natural or artificially regenerated) is whole-tree harvested. Stand harvesting operations remove approximately 90 percent of the existing vegetation. Additional follow-up treatments like shearing, masticating, or drum chopping are used to cut all live trees and woody vegetation and start the drying process to build fuel loads for burning. In late fall to early winter (November to early December), the stand is burned to remove dead woody debris. Burning, for site preparation, releases pine from grasses and improves the control of hardwoods in the stand.

Complete stand clearing is usually accomplished through three methods: shear, burn, and herbicide spray; chop, burn, and herbicide spray; or burn and herbicide spray. Chemical site preparation (herbicide spraying) reduces vegetation competition prior to the planting of crop trees. Spraying is conducted depending on the site and composition of trees within the stand; however, most herbicide treatments occur at least seven weeks after clearing the stand (during the winter) to 2 weeks before planting (early spring).

Zhao et al. (2009) studied the growth response of loblolly pine on plantations in the southern United States 21 years after six site preparation treatments consisting of burning, mechanical only, burning with mechanical or chemical site preparation, a combination of all three, and double herbicide application with burning (fertilizing at 13 years) . Individual or combination of mechanical or chemical site preparation significantly changed pine growth. The burn-only treatment had significantly lower average pine growth compared to all other treatments. Double herbicides paired with burning increased growth yields and removed interspecific competition (Zhao et al., 2009).

Miller and Chamberlin (2008) examined two pine plantation site preparation techniques: burning (alone) and burning with a combination of two herbicides in which two herbicide applications occurred once by broadcast prior to or just after planting and once during the first growing season in the rows (but not between the rows). In their study, they found no changes in richness and presence between coupled techniques (herbicide and burning) and singular technique (burning only). In this study, herbicide treatments increased suppression of woody growth when used as a site preparation technique but promoted the growth of herbaceous plants, noted through the increase in forbs, legumes, and bluestem abundance. When only burning was used, woody species were predominately present in the understory.

Soil characteristics, such as the mineral composition, bulk density, nutrient levels, and water holding capacity, vary by location. Moderately to well-drained soils (from course to fine loams) are ideal for aggressive production of pine species. Pine plantations in areas with poor drainage and soil compaction usually require mechanical site preparation using subsoil plowing, disking and bedding prior to stand establishment (Barry et al., 2013). Poor soil conditions require a three pass site preparation technique: shearing, raking (or disking), and bedding on high intensive management sites, and, chop and bed on low intensive sites (Gresham, 2002). Soils are often nutrient deficient and require at least one application of phosphorus (P) fertilization for successful tree growth. Nitrogen (N) and P can also be added to help increase yield (Neary et al., 1990; Gresham, 2002; Nilsson and Allen, 2003).

Land managers of pine plantations in the Florida Flatwoods region typically follow site preparation techniques of double bedding, which involves bedding seven weeks post-harvest and again a few weeks before planting to increase the survival and performance rates of pines (Lauer and Zutter, 2001). The Flatwoods have a larger cover and diversity of shrub species compared to other plantations within the action area, so additional treatments (bedding or herbicides) focuses on reducing shrub competition. Zhao et al. (2008) compared various timing of bedding and pre-plant herbicide techniques with the addition of post plant herbaceous control. The study found greater pine (slash and loblolly pine) growth with early bedding and pre-plant herbicide application for shrub reduction and first year herbaceous control. The response to bedding times (early or late) and frequencies (single bedding or double-bedding) varied by site location; however, on all sites, shrub cover was reduced more with double bedding treatment than with single bedding alone treatments (Zhao et al. 2008). Lauer and Zutter (2001) (identical to Zhao's study and only reporting on the first 2 years after planting) saw the same response. The sites with double bedding saw greater overall growth on all study areas; however, not as much as the early bedding with herbicides. The post-harvest herbaceous weed control improved the growth of pines but not significantly (Zhao et al., 2008). To maximize production on pine plantations located in the Florida Flatwoods, the authors recommend site preparation to include early bedding with pre-plant herbicide applications to control woody shrubs while post-plant application for herbaceous weed control may or may not be needed (Zhao et al., 2008).

Planting Regime: Many of the pine seedlings come from cooperative nursery management programs across the Southeast. Plant breeders have bred pine seedlings to be more resistant to drought, disease, and pests, and exhibit proven height and diameter growth. Land managers plant pine seedlings in late winter to late spring. Seed establishment and survival is affected by weather conditions, soil moisture, seed conditions, seedbed age, and soil texture. Seedbed manipulation by scarification or burning can increase seedling survival. Pines are planted by hand or machine using bare root grown or containerized seedlings. Seedling spacing is usually between 500-800 trees per acres, depending on management objective and the requirements needed to improve survival.

Early Competition Control: Removing vegetation competition is done by both mechanical and chemical methods. Application times are critical, since following harvesting, intensive sprouting of new vegetation can begin before planting the next pine crop. The use of burning to slow down the reemergence of woody species (hardwood and other woody species) can be important for successful pine establishment. Mechanical options include slashing, shearing, piling, bedding, and chopping. In some locations, land managers apply pine straw (loose pine needles) to reduce competition from grass species and improve soil stability. Chemical methods usually rely on herbicides that attack the foliar surface of plants and have prolonged depletion in presence of species over rotation.

Jones et al. (2010b) analyzed pine seedling growth using combinations of mechanically and chemical site preparation treatments and herbaceous weed control. The analysis found that increasing intensive management treatments improved height and diameter (Jones et al., 2012). The treatment with the highest level of competition control (sub-soiling, disking, herbicide and 1st, 2nd year broadcast spraying) showed the greatest height and diameter response over the three year study period (Jones et al., 2010b). Broadcast herbaceous weed control produced better height and diameter growth. Chemical site preparation with banding herbicides performed better than mechanical only and the combination of all three treatments.

Land managers apply fertilizers to enhance seedling growth, particularly during the establishment period when seedlings are most susceptible to vegetation competition. Fertilization occurs in the first two growing seasons using a combination of nitrogen (N) and phosphorous (P) treatments or just P treatments alone (Haywood and Burton, 1989; Sword et al., 1998; Miller and Chamberlain, 2008).

Thinning Regime: Land managers thin trees to reduce competition among trees for light, water, and resources (Belanger et al., 1993). Timing and intensity of thinning depends on the age, density, and site quality. In pine plantations, thinning typically occurs mid-rotation, after crown closure but before excessive shortening of crowns and loss of residual diameter growth (Belanger et al., 1993). Thinning within pine stands improves and changes stand dynamic by: improving basal area, adjusting the sites carrying capacity, expanding the leaf area index, cycling the nutrient functions within the stand, increasing diameter and height, and increasing stem wood biomass. These are all factors that increase yield and volume production. Selective thinning provides an intermediate cash flow and shift future stand growth to larger, better quality trees (Amateis, 2000). Factors that affect the efficiency of thinning include precipitation, soil nutrient availability in the site, and the number of freeze-free days. In many of the studies that discussed thinning, fertilization to the stand was also compared to show the variation in production rates (Cain, 1996; Amateis, 2000; Baldwin Jr et al., 2000; Sword Sayer et al., 2004).

Thinning reduces tree stress by reducing competition. In areas where Southern Pine Beetle (SPB) is a problem, thinning is an effective strategy for managing this important insect pest, which is attracted to stressed trees. Residual basal areas of 80 to 100 ft^2/ac are normally recommended to reduce potential SPB attack in young stands (Belanger and Malac, 2006). The risk of insect spread increases considerably in stands with basal areas greater than 100 ft^2/ac (Coster and Searcy, 1981); when basal area is below 70 ft^2/ac SPB spread potential is very low.

Later Competition Control: Vegetation control within the first couple years of planting generally increases seedling survival, improves stand uniformity, and increases wood yield (Minogue et al., 1991). Grazing, mowing, herbicides, and prescribed burning are common practices for removing herbaceous plant and vine competition; however, of these methods, herbicide usage is more prevalent. Herbicides for herbaceous weed control are usually broadcast (used when planting are not evenly space), banded (used when impacts to soil or site conditions are sensitive), or direct sprayed (to remove vegetation from around the tree only). Herbicides can provide more lasting and complete vegetation control than other methods. The application of herbicides in mid- to late-rotation (later competition control) is not typical in southern pine-plantation management.

Rotation Age-Harvesting: Tree harvesting occurs when the maximum yield of the stand reaches the desired condition, which relates to the site index for the species. The harvest of pine trees in the study area is typically 20 years into the rotation.

Unpredictable Events: In the Southern United States, dealing with unpredictable events is unavoidable in pine management especially when applying intensive management practices. These unpredictable events may become a catapult for other diseases, infestations, or weather-related damage to trees because of increased susceptibility to damage or tree death. Two of the most frequent unpredictable events in the South are hurricanes (classified as extreme wind damage) and beetle infestations (usually by Southern Pine Beetle and bark beetles). Southern forest management has developed based on these occurrences and documented stand recovery and composition changes for both events. Additionally, catastrophic fire also has to be evaluated.

Overview of Pine-Associated Vegetation Response to Typical Southern Plantation Pine Management Regimes

Pine plantations in the study area have a diversity of herbaceous and woody plant species, including around 1,033 forb species, 607 grass species, 188 shrub species, and 203 tree species (BONAP, 2013b; BONAP, 2013c; BONAP, 2013d; BONAP, 2013e; BONAP, 2013f; BONAP, 2013g; BONAP, 2013h; BONAP, 2013i; BONAP, 2013j; BONAP, 2013k; USDA-APHIS, 2013e). The diversity, richness, and abundance of species present in a pine plantation depend on several factors including soil type and quality; water quantity; climate variations; surrounding vegetation including the pine species grown; and plantation management practices.

Pine-associated vegetation response to site preparation techniques: The site preparation techniques in planted-pine plantations significantly disturb understory vegetation by directly killing or damaging the plants. The intention of site preparation is to reduce vegetation competition and enable pine seedlings to establish and reach maximum yield.

Many plant species recover in terms of richness and abundance following site preparation activities by mid-rotation (i.e., approximately year 7); however, much of this richness and abundance is anticipated to significantly decrease as the pine plantation ages due to pine canopy closure (Miller et al., 2003). Although a recovery in plant richness occurs, it may not be equal to recovery in locations where no herbicides were applied, as found in one study where plant component richness remained significantly changed by year 15 by early treatments, particularly with fewer tree species after early woody control (Miller et al., 2003).

Brockway et.al. (1998) studied the variance in richness, abundance, and presence of vegetation in response to various mechanical and chemical site preparation treatments as it relates to soil properties. In this study, chemical treatment was part of one site preparation technique and involved the manual injection of an herbicide into trees remaining on a site after burning as opposed to broadcast or in-row herbicide treatment. No additional vegetation management occurred after site preparation. In this study, herbaceous production increased over pretreatment levels the first year after site preparation and remained constant through the third year following site preparation. Annual composites were the most abundant at sites where soil disturbance from site preparation was greatest. Forbs and grasses also increased in production. Early seral species such as annual threeawns, violet crabgrass, and gaping panicum were the most common on sites prepared using chop-disk, double-chop, and shear techniques - techniques that highly disturb the soil. By year three, the abundance of the herbaceous plant groups shifted substantially; the composites, and other forbs, and grasses declined by 50 percent on all treatments, primarily because of the reduction in early seral species like rough buttonweed, annual horseweed, bitter sneezeweed and annual threeawns. Other herbaceous groups like bluestem, panciums, paspalums, uniolas, rushes, sedges, and legumes increased 2- to 4-fold for the first three years (Brockway et al., 1998). The total above-ground herbaceous plant production declined substantially after seven growing seasons following site preparation, attributed to competition with trees and shrubs and to increased shade.

Plant community response to planting regime: The planting density of pine trees affects understory vegetation: the higher the density, the greater the competition for water and nutrients and the shorter the time to canopy closure which decreases light levels beneath the canopy. Planting pine trees at a wider spacing (6.1 x 1.5 m) increased the cover of grasses in the first year and deciduous woody species in years three and eight, but fewer forb species in year three (Lane et al., 2011b).

Plant community response to early vegetation competition control: Land managers actively control understory vegetation to reduce competition for light, water, and nutrients. Pine growth and yield usually increase with vegetation competition management. Shrub and hardwood control improved the success in diameter at breast height (DBH) and annual increment growth (Lauer and Glover, 1998; Nilsson and Allen, 2003) for loblolly pine.

The use of herbicides to control plant competition is common in Southern planted-pine plantations. Herbicide treatments, including the type of herbicide use, application time, application frequency, and application method, vary depending on the pine species, stage of vegetation development, weather, soils, and other environmental factors that can affect herbicide uptake and efficacy.

In an eight-year study of plant community responses following mechanical and chemical site preparation using varying spray techniques and herbaceous weed control (HWC) during the first season, Lane et al.

(2011b) found that all herbaceous plants were suppressed from the site two years following imazapyr in the form of Chopper at 3.51 L ha^{-1} mixed with 11.58 L ha^{-1} of methylated seed oil chemical treatments. However, herbaceous plants recovered after four years and forbs recovered after eight years. Vine and forb richness and cover were not affected by mechanical-only treatments in all years of the study (Lane et al., 2011b); however, chemical site preparation with HWC reduced vine richness in years 1-4, and banded HWC (spraying directly on planting columns) produced greater vine and forb richness in years 4-8. This is explained by the treatment type, banding, which leaves rows untreated and results in increased growth understory plant species.

Forbs and grasses showed the greatest differences in species richness due to varying levels of HWC; the occurrence was usually greatest during the season following treatments (Jones et al., 2009a). In years 3-5, forb response to herbicides decreased indicating resilience to the application levels for the selected herbicide. Grass richness was reduced by using broadcast HWC treatments the first few years, but like forbs, recovered in abundance from years 3-5 (Table 8). Vines and woody species were most affected by site preparation during all five years of the study (Jones et al., 2009a) (Table 8). Herbicides affected species richness, and banded herbicide chemical site preparation produced two times greater richness than broadcast chemical site preparation. Vines and hardwoods also decreased in response to treatments. Hardwoods decreased less with mechanical site preparation and vines decreased less with chemical site preparation. The addition of HWC further reduced vines and hardwoods, but encouraged the growth of herbaceous competition. Multi-herbicide application decreased total plant diversity consistently across all five years of the study (Jones et al., 2009a). Forbs and grass diversity were not affected by any treatment combination. Plant community composition changed over all treatments during the entire study (Jones et al., 2009a). In year five, community differences reflected clear establishment intensity gradients that indicated site preparation and HWC reduced most of the plant communities.

Table 8. Vegetation Species Cover and Richness for a Rotation of Loblolly Pine Plantation Using Mechanical Site Prep and Banded Hardwood and Herbaceous Control Using Herbicides

	Species	Post Site Prep	Pine Seedlings (Age 1-3)	Supp. Treatments (Age 3-5)	Thin (ca. age 7)	Rotation (Age ca. 20)
Loblolly		●	●	●	○	◊
Forb						
	Three-seed Mercy spp. (8)	○	●	○	○	◊
	Foxglove spp. (19)	○	●	○	○	◊
	Annual Ragweed	○	●	○	○	◊
	Laceleaf Ragweed	○	●	○	○	◊
	Cuman Ragweed	○	●	○	○	◊
	Peppervine spp. (2)	○	●	○	○	◊
	Wild Indigo spp. (7)	○	●	○	○	◊
	Spurred Butterfly Pea	○	●	○	○	◊
	Sensitive Pea spp. (3)	○	●	○	○	◊
	Tall Thistle	○	●	○	○	◊
	Soft Thistle	○	●	○	○	◊
	Yellow Thistle	○	●	○	○	◊
	Swamp Thistle	○	●	○	○	◊

	Species	Post Site Prep	Pine Seedlings (Age 1-3)	Supp. Treatments (Age 3-5)	Thin (ca. age 7)	Rotation (Age ca. 20)
	Bull Thistle	○	●	○	○	◊
	Tickseed spp. (14)	○	●	○	○	◊
	Ticktrefoil spp. (20)	○	●	○	○	◊
	Elephantsfoot spp. (4)	○	●	○	○	◊
	Fleabane spp. (12)	○	●	○	○	◊
	Thoroughwort spp. (18)	○	●	○	○	◊
	Bedstraw spp. (13)	○	●	○	○	◊
	Sunflower spp. (22)	○	●	○	○	◊
	Rosemallow spp. (5)	○	●	○	○	◊
	St. Johnswort spp. (15)	○	●	○	○	◊
	Sagebush spp. (9)	○	●	○	○	◊
	Goldenrod spp. (28)	○	●	○	○	◊
	Iris spp. (12)	○	●	○	○	◊
Vine						
	St. Johnswort spp. (15)	◊	○	●	○	○
	Tropical White Morning-glory	◊	○	●	○	○
	Swamp Morning-glory	◊	○	●	○	○
	Morning-glory spp. (19)	◊	○	●	○	○
	Senna spp. (5)	◊	○	●	○	○
	Rosinweed	◊	○	●	○	○
	Greenbrier spp. (11)	◊	●	●	●	●
	Harypea	◊	○	●	○	○
	E. Poison Ivy	◊	●	●	●	●
	Violet spp. (24)	◊	○	●	○	○
	Chainfern	◊	○	●	○	○
	Muscadine	◊	●	●	●	●
	Virginia Creeper	◊	●	●	●	●
	Yellow Jasmine	◊	○	●	○	○
	Sawtooth Blackberry	◊	●	●	●	●
	Blackberry spp. (10)	◊	●	●	●	●
Tree						
	Sugar Maple	○	●	●	●	○
	Chalk Maple	○	●	●	●	○
	Box Elder	○	●	●	●	○
	Red Maple	○	●	●	●	○
	Downy Serviceberry	○	●	●	●	○
	Serviceberry	○	●	●	●	○
	Pawpaw	○	●	●	●	○

	Species	Post Site Prep	Pine Seedlings (Age 1-3)	Supp. Treatments (Age 3-5)	Thin (ca. age 7)	Rotation (Age ca. 20)
	Ironwood	○	●	●	●	○
	Water Hickory	○	●	●	●	○
	Bitternut Hickory	○	●	●	●	○
	Pignut Hickory	○	●	●	●	○
	Pecan	○	●	●	●	○
	Hickory spp. (5)	○	●	●	●	○
	Nutmeg Hickory	○	●	●	●	○
	Sand Hickory	○	●	●	●	○
	American Chestnut	○	●	●	●	○
	Chinese Chestnut	○	●	●	●	○
	Chinkapin	○	●	●	●	○
	Iguana Hackberry	○	●	●	●	○
	Sugarberry	○	●	●	●	○
	Common Hackberry	○	●	●	●	○
	Dwarf Hackberry	○	●	●	●	○
	Flowering Dogwood	○	●	●	●	○
	Cockspur Hawthorn	○	●	●	●	○
	Hawthorn spp. (10)	○	●	●	●	○
	American Beech	○	●	●	●	○
	American Ash	○	●	●	●	○
	Carolina Ash	○	●	●	●	○
	Green Ash	○	●	●	●	○
	American Witchhazel	○	●	●	●	○
	Yaupon Holly	○	●	●	●	○
	Eastern Red Cedar	○	●	●	●	○
	Sweetgum	●	●	●	●	○
	Tulip Poplar	○	●	●	●	○
	Cucumber Tree	○	●	●	●	○
	Big Magnolia	○	○	●	●	○
	Sweetbay	○	○	●	●	○
	S. Crabapple	○	●	●	●	○
	Mulberry spp. (3)	○	●	●	●	○
	Water Tupelo	○	●	●	●	○
	Black Gum	○	●	●	●	○
	Sourwood	○	●	●	●	○
	Redbay	○	●	●	●	○
	Sycamore	○	●	●	●	○
	Chickasaw Plum	○	●	●	●	○

	Species	Post Site Prep	Pine Seedlings (Age 1-3)	Supp. Treatments (Age 3-5)	Thin (ca. age 7)	Rotation (Age ca. 20)
	Cherry Laurel	○	●	●	●	○
	Black Cherry	○	●	●	●	○
	White Oak	○	○	●	●	○
	Scarlet Oak	○	○	●	●	○
	S. Red Oak	○	○	●	●	○
	Laurel Oak	○	○	●	●	○
	Overcup Oak	○	○	●	●	○
	Blackjack Oak	○	○	●	●	○
	Chestnut Oak	○	○	●	●	○
	Water Oak	○	○	●	●	○
	Cherrybark Oak	○	○	●	●	○
	Willow Oak	○	●	●	●	○
	N. Red Oak	○	○	●	●	○
	E. Black Oak	○	○	●	●	○
	Live Oak	○	○	●	●	○
	Sassafras	○	○	●	●	○
	A. Snowbell	○	●	●	●	○
	Big Leaf Snowbell	○	●	●	●	○
	Chinese Tallow Tree	○	●	●	●	○
	Winged Elm	○	○	●	●	○
	A. Elm	○	○	●	●	○
	Cedar Elm	○	○	●	●	○
	Slippery Elm	○	○	●	●	○
	September Elm	○	○	●	●	○
	Persimmon	○	●	●	●	○
	Winger sumac	○	●	●	●	○
Graminoid						
	Bent Grass spp. (6)	◊	○	●	●	◊
	Silver Hairgrass	◊	○	●	●	◊
	Bluestem spp. (10)	◊	○	●	●	◊
	Threeawn spp. (15)	◊	○	●	●	◊
	Common Sedge spp. (95)	◊	○	●	●	◊
	Woodoats spp. (5)	◊	○	●	●	◊
	Flat Sedge spp. (55)	◊	○	●	●	◊
	Rosette Grass (24)	◊	○	●	●	◊
	Asian Crabgrass	◊	○	●	●	◊
	S. Crabgrass	◊	○	●	●	◊
	Fall Witchgrass	◊	○	●	●	◊

	Species	Post Site Prep	Pine Seedlings (Age 1-3)	Supp. Treatments (Age 3-5)	Thin (ca. age 7)	Rotation (Age ca. 20)
	Sourgrass	◊	○	●	●	◊
	Crabgrass spp. (7)	◊	○	●	●	◊
	Lovegrass spp. (24)	◊	○	●	●	◊
	Annual Rush	◊	○	●	●	◊
	Tapertip Rush	◊	○	●	●	◊
	Rush spp. (27)	◊	○	●	●	◊
	Japanese Honeysuckle	◊	○	●	●	◊
	Panicgrass spp. (10)	◊	○	●	●	◊
	Crowngrass spp. (24)	◊	○	●	●	◊
	Beaksedge spp. (51)	◊	○	●	●	◊
	Bristlegrass spp. (14)	◊	○	●	●	◊
	Droopseed spp. (11)	◊	○	●	●	◊
	Fluffgrass spp. (5)	◊	○	●	●	◊

Empty circles represent no species density or richness; empty diamonds represents some species cover but low density and richness; and darkened circles represent higher species cover, density, and richness. Numerical values in parentheses after species names represent number of species observed in that plant genus. The plant species in this table represents general plant species within the action area (BONAP, 2013b; BONAP, 2013c; BONAP, 2013d; BONAP, 2013e; BONAP, 2013f; BONAP, 2013g; BONAP, 2013h; BONAP, 2013i; BONAP, 2013j; BONAP, 2013k; USDA-APHIS, 2013e).

Pine plantations located in the Florida Flatwoods region typically require double bedding to manage vegetation competition prior to and shortly after planting. Vegetation was more persistent on sites with only one bedding treatment and fewer herbicide treatments. Pre-plant herbicide applications significantly reduced shrub cover on pine sites (Schultz and Wilhite, 1974; Lauer and Zutter, 2001). Schultz and Whilhte (1974) noted gallberry persistence through four years of their study, however bedding seemed to greatly decrease the presence of saw palmetto.

Using bedding alone does not completely release pine trees from vegetation competition or reduce competition as much as bedding with herbicide treatments in Flatwoods area. On bedding-only sites, when herbaceous cover was low, shrub cover was high; however, the degree of these impacts varied by location (Lauer and Zutter, 2001). Sites with double bedding increased herbaceous cover, so much so that single bedding and double bedding resembled one another two years post planting. In slash pine areas, the use of pre-plant herbicide treatments suppresses the development of bracken fern (*Pteridium aquilinum*) and red root amaranth (*Amaranthus retroflexus*) (late successional plants with heavy shade tolerance) (Lauer and Zutter, 2001). Overall, in Florida Flatwood sites, the efficiency of double bedding had been identified as successful but usually not as successful as pre-plant herbicide application.

Using the data on plant community responses described above, Table 9 describes the potential response of intra-stand pine-associated vegetation. In summary, many plant species recover in terms of richness and abundance following site preparation activities by mid-rotation (i.e., year 7); however, much of this richness and abundance is anticipated to significantly decrease as the pine plantation ages due to pine canopy closure (Miller et al., 2003).

Table 9. Plant Species Composition and Richness Over Eight Years Within a Pine Plantation, Using Common Management Practices

	Species	Post Site Preparation	Pine Seedlings (Ages 1-3)	Other Treatment (ca. Age 7)
Pine				
	Shortleaf Pine	○	◊	◊
	Slash Pine	●	●	●
	Spruce Pine	○	◊	◊
	Longleaf Pine	○	◊	◊
	Pond Pine	○	◊	◊
	E. White Pine	○	◊	◊
	Loblolly Pine	●	●	●
	Virginia Pine	○	◊	◊
Non-Pine Woody Trees				
	Sugar Maple	○	●	○
	Chalk Maple	○	●	○
	Box Elder	○	●	○
	Red Maple	○	●	○
	Downy Serviceberry	○	●	○
	Serviceberry	○	●	○
	Water Hickory	○	●	○
	Bitternut Hickory	○	●	○
	Pignut Hickory	○	●	○
	Pecan	○	●	○
	Hickory spp. (52)	○	●	○
	Nutmeg Hickory	○	●	○
	Sand Hickory	○	●	○
	Chinese Chestnut	○	●	○
	Chinkapin	○	●	○
	Sugarberry	○	●	○
	Common Hackberry	○	●	○
	Flowering Dogwood	○	●	○
	Cockspur Hawthorn	○	●	○
	Hawthorn spp. (9)	○	●	○
	American Beech	○	●	○
	American Ash	○	●	○
	Carolina Ash	○	●	○
	Green Ash	○	●	○
	American Witchhazel	○	●	○
	Yaupon Holly	○	●	○
	Eastern Red Cedar	○	●	○

	Species	Post Site Preparation	Pine Seedlings (Ages 1-3)	Other Treatment (ca. Age 7)
	Sweetgum	○	●	○
	Tulip Poplar	○	●	○
	Sweetbay	○	●	○
	S. Crabapple	○	●	○
	Mulberry spp.	○	●	○
	Water Tupelo	○	●	○
	Black Gum	○	●	○
	Sourwood	○	●	○
	Redbay	○	●	○
	Sycamore	○	●	○
	Chickasaw Plum	○	●	○
	Cherry Laurel	○	●	○
	Black Cherry	○	●	○
	White Oak	○	●	○
	Scarlet Oak	○	●	○
	Southern Red Oak	○	●	○
	Laurel Oak	○	●	○
	Overcup Oak	○	●	○
	Blackjack Oak	○	●	○
	Water Oak	○	●	○
	Willow Oak	○	●	○
	Northern Red Oak	○	●	○
	E. Black Oak	○	●	○
	Live Oak	○	●	○
	Sassafras	○	●	○
	A. Snowbell	○	●	○
	Big Leaf Snowbell	○	●	○
	Chinese Tallow Tree	○	●	○
	Winged Elm	○	●	○
	American Elm	○	●	○
	Cedar Elm	○	●	○
	Slippery Elm	○	●	○
Non-pine Woody Shrubs				
	Devils Walkingstick	○	●	○
	Slimleaf Pawpaw	○	●	○
	Smallflower Pawpaw	○	●	○
	Saltwater False Willow	○	●	○
	Silverling	○	●	○
	E. baccharis	○	●	○

	Species	Post Site Preparation	Pine Seedlings (Ages 1-3)	Other Treatment (ca. Age 7)
	American Beautyberry	○	●	○
	Purple Beautyberry	○	●	○
	New Jersey Tea	○	●	○
	Littleleaf Buckbush	○	●	○
	Alternateleaf Dogwood	○	●	○
	Cornus spp. (3)	○	●	○
	Stiff Dogwood	○	●	○
	Bountiful Hawthorn	○	●	○
	Hawthorn spp. (6)	○	●	○
	Swamp Rosemallow	○	●	○
	Rosemallow spp. (2)	○	●	○
	Coastal Plain St. Johnswort	○	●	○
	St. Johnswort spp. (14)	○	●	○
	Holly spp. (11)	○	●	○
	Japanese Privet	○	●	○
	Glossy Privet	○	●	○
	California Privet	○	●	○
	Privet spp. (3)	○	●	○
	Staggerbush spp. (5)	○	●	○
	S. Bayberry	○	●	○
	Wax Myrtle	○	●	○
	Scentless Bayberry	○	●	○
	Fragrant Sumac	○	●	○
	Winged Sumac	○	●	○
	Smooth Sumac	○	●	○
	False Poison Sumac	○	●	○
	Rose spp. (9)	○	●	○
	Sawtooth Blackberry	○	●	○
	Blackberry spp. (12)	○	●	○
	Jerusalem Cherry	○	●	○
	Tropical Soda Apple	○	●	○
	Atlantic Poison Oak	○	●	○
	Poison Sumac	○	●	○
	Blueberry spp. (12)	○	●	○
	Mapleleaf Viburnum	○	●	○
	S. Arrowwood	○	●	○
	Viburnum spp. (6)	○	●	○
	Switchcane	○	●	○
Herbaceous Forbs				

	Species	Post Site Preparation	Pine Seedlings (Ages 1-3)	Other Treatment (ca. Age 7)
	Three-seed Mercy spp. (6)	○	◊	●
	Foxglove spp. (18)	○	◊	●
	Annual Ragweed	○	◊	●
	Cuman Ragweed	○	◊	●
	Peppervine spp. (3)	○	◊	●
	Wild Indigo spp. (12)	○	◊	●
	Spurred Butterfly Pea	○	◊	●
	Sensitive Pea spp. (3)	○	◊	●
	Yellow Thistle	○	◊	●
	Swamp Thistle	○	◊	●
	Bull Thistle	○	◊	●
	Tickseed spp. (14)	○	◊	●
	Ticktrefoil spp. (21)	○	◊	●
	Elephantsfoot spp. (4)	○	◊	●
	Fleabane spp. (9)	○	◊	●
	Thoroughwort spp. (20)	○	◊	●
	Bedstraw spp. (13)	○	◊	●
	Sunflower spp. (24)	○	◊	●
	Rosemallow spp. (6)	○	◊	●
	St. Johnswort spp. (17)	○	◊	●
	Tropical White Morning-glory	○	◊	●
	Swamp Morning-glory	○	◊	●
	Morning-glory spp. (16)	○	◊	●
	Iris spp. (8)	○	◊	●
	Blazing Star spp.	○	◊	●
	Primrose-willow spp. (19)	○	◊	●
	Woodsorrel spp. (11)	○	◊	●
	Milkwort spp. (19)	○	◊	●
	Buttercup spp. (14)	○	◊	●
	Skullcap spp. (13)	○	◊	●
	Senna spp. (6)	○	◊	●
	Greenbrier spp. (11)	○	◊	●
	Goldenrod spp. (29)	○	◊	●
Herbaceous Vines				
	E. Poison Ivy	●	○	●
	Vervain spp. (11)	●	○	●
	Sagebush spp. (13)	●	○	●
	Violet spp. (20)	●	○	●
	Grape spp. (7)	●	○	●

	Species	Post Site Preparation	Pine Seedlings (Ages 1-3)	Other Treatment (ca. Age 7)
	Muscadine	●	○	●
	Rooting Chainfern	●	○	●
	Virginia Chainfern	●	○	●
Herbaceous Grasses				
	Bent Grass spp. (7)	○	●	●
	Silver Hairgrass	○	●	●
	Bluestem spp. (14)	○	●	●
	Threeawn spp. (16)	○	●	●
	Common Sedge spp. (91)	○	●	●
	Woodoats spp. (5)	○	●	●
	Flat Sedge spp. (48)	○	●	●
	Rosette Grass (22)	○	●	●
	S. Crabgrass	○	●	●
	Fall Witchgrass	○	●	●
	Sourgrass	○	●	●
	Crabgrass spp. (10)	○	●	●
	Lovegrass spp. (29)	○	●	●
	Annual Rush	○	●	●
	Rush spp. (28)	○	●	●
	Japanese Honeysuckle	○	●	●
	Panicgrass spp. (10)	○	●	●
	Crowngrass spp. (28)	○	●	●
	Beaksedge spp. (57)	○	●	●
	Bristlegrass spp. (11)	○	●	●
	Droopseed spp. (19)	○	●	●
	Fluffgrass spp. (4)	○	●	●

Empty circles represent no species density or richness; empty diamonds represents some species cover but low density and richness; and darkened circles represent higher species cover, density, and richness. Numerical values in parentheses after species names represent number of species observed in that plant genus. The plant species in this table represents general plant species within the action area (BONAP, 2013b; BONAP, 2013c; BONAP, 2013d; BONAP, 2013e; BONAP, 2013f; BONAP, 2013g; BONAP, 2013h; BONAP, 2013i; BONAP, 2013j; BONAP, 2013k; USDA-APHIS, 2013e); and trends in vegetation cover, richness, and density is based off of the conclusions of Lane et al. (2011).

Plant Community Response to Thinning Regime: Thinning activities will damage or kill some understory vegetation. The equipment used during thinning operations causes direct damage to plants as well as indirect damage through the disturbance and compaction of soil. The felling and removal of trees will have a similar effect. After thinning, the tree canopy may temporarily be more open, allowing more light to penetrate the forest floor. This would favor shade-intolerant plant species.

Plant Community Response to Later Competition Control: Vegetation management is usually limited to the first several years of a rotation. Sites under intensive management (e.g., removing all competition and applying herbicides for two years following planting) typically yield a higher tree volume at harvest. Herbaceous and woody vegetation control significantly increased diameter growth and individual tree volume, however this combination was no longer effective by age eleven (Haywood and Tiarks, 1990). Contributions to the change maybe due to interspecific competition and canopy closure (usually starting after age 7) which naturally decreases understory vegetation. Fifteen years after woody herbicide treatments, hardwood trees and shrubs remained suppressed on all sites, indicating that treatment during establishment limits reoccupation through mid-rotation (Miller et al., 2003). In the same study, herbaceous plants declined as tree canopies reached 50-60 percent cover about years 5-8 in the rotation (Miller et al., 2003).

Plant Community Response Summary: In summary, many plant species experienced substantial decreases in richness and abundance following site preparation activities, recovered to varying extents by mid-rotation, and decreased once again following canopy closure of the planted pine species (Table 9).

Response of the Plant Community to Unpredictable Events

Hurricanes

Hurricanes and other large storms can damage pine plantations. High winds and storm surges are associated with hurricanes, and excessive rainfall usually accompanies these storms (Stanturf et al., 2007). Hurricanes may cause patterns of patchy disturbance to pine plantations, potentially causing a significant loss in yield. The patchy disturbance can benefit successional plants by opening up the canopy.

In 1996, Hurricane Fran damaged long-term tree census plots (20 to 70 year-record) in the Duke Forest located in the North Carolina piedmont, enabling the comparison of pre- and post-hurricane forest composition (Xi et al., 2008). The major form of damage from the hurricane was the uprooting of many medium to large trees (greater than 10 cm DBH), including loblolly pine, causing a loss in basal area. The damage to understory trees was lower than expected. Many of the saplings and small trees were bent and pinned but less damaged than overstory trees, likely due to sheltering from winds by overstory trees. Large canopy pine trees, which normally have the lowest background mortality, had the highest mortality (19 fold) of all tree groups five years (delayed tree mortality) after the hurricane. The uprooting of trees caused an increase in the frequency and size of uneven canopy gap formations, enabling greater light penetration to the forest floor. Within five years, researchers saw an increase in the abundance of shade-intolerant *Ailianthus altissima*, *Carya ovalis*, and three deciduous *Viburnum* species in the pine stands, likely from the increase in light penetration. They also observed a loss of dominance of even-age pine trees and an increase in dominance of hardwood tree species already present in the understory. The formation of mounds and pits in the forest floor caused by the uprooted trees created microsites that could favor the growth of herbaceous species.

Southern Pine Beetle

The management of pests and the damage they cause is a necessity in southern pine management. One of the largest and most destructive pests in southern pine plantations is the Southern Pine Beetle (SPB) *Dendroctonus frontalis* (Gan, 2004). SPB, a bark beetle, damages and kills pines trees (Clarke and Nowak, 2009).

Environmental and plantation management factors affect the incidence and severity of pest and disease outbreaks, including outbreaks of SPB (Dixon et al., 1991). The current practice of planting a high density of closely related pine trees on private and industrial pine plantations favors SPB populations because of the availability of host material (Dixon et al., 1991). A high planting density can also lead to more competition and induce tree stress, particularly when drought conditions are present; making plantations more susceptible to SPB attack (Baldwin Jr et al., 2000; Nilsson and Allen, 2003).

Successful SPB management relies on selective approaches based on forest conditions. Most of these approaches involve the use of prevention, suppression, or resistant species replacement activities. Thinning is used to increase the vigor of the residual trees and increase the intra-tree spacing (Brown et al., 1987). It is also a preventive measure to help cease or slow down the occurrence of SPB within plantations.

Cutting infested trees (e.g., suppression treatments) decreases the rate of spread of the insect. Suppression treatments include cut-and-remove, cut-and leave, cut-and-hand spray, and pile-and burn (Clarke and Nowak, 2009). For cut-and-remove and cut-and-leave treatments, all infested trees are felled. Trees within a quarter acre or less (approximately a 59 foot radius) from infested trees are also felled to create a buffer to isolate beetles and prevent their spread (Clarke and Nowak, 2009). Cut-and-remove is the most effective method for reducing the spread of SPB, with an efficacy rate of 97% or higher. It is the most recommended method, as landowners benefit from the sale of harvested trees. The cut-and-leave method is used when cut-and-remove is not profitable. Cut-and-leave is most effective when used on smaller infestations (< 100 trees) in smaller diameter trees (Clarke and Nowak, 2009). Use of the cut-and-hand spray is rare because the appropriate insecticide use may not be available. Pile-and-burn may be used on infestations in pine plantations when the infested trees can be pushed into piles with a bulldozer and promptly burned (Clarke and Nowak, 2009).

The impacts to understory vegetation from suppression treatments for SPB are similar to those described under thinning impacts above.

Catastrophic Fire

The risk of catastrophic fire has been considered in plantation management strategies for over a century. Sometimes caused by human factors, and other times by unpredictable natural events (usually lightning), the occurrence of these fires reduces the amount of commercial timber products on public and private forests. To help control catastrophic fires, in the middle part of the 20^{th} century, national federal fire suppression initiatives were adopted. Fire suppression and education programs were started in efforts of getting the public to understand the dangers of catastrophic fire (forest fires) and help forest managers use management strategies that excluded fire. Since that time, forests have gone through extended periods (>50 years) without any fire activity.

Fire suppression essentially favored trees and vegetation that could survive without the presence of fire. Although fire suppression strategies reduced the occurrence of catastrophic fire, the severity of these fires has increased whereby causing complete elimination of stand vegetation and site composition. Site conditions that increase the potential for catastrophic fire in the Southeast has been due to Federal initiatives in the past. The fire suppression efforts since 1940’s have changed the forest ecosystem and altered the plant composition of forest landscapes across the south. In certain forest cover types, seral species, overstory species, and late successional understory trees that are fire dependent have almost disappeared for the landscape. Fire-adapted species have been managed to focus commercial forest practices. These practices created stands that targeted the growth of commercial timber and encouraged elimination of competing vegetation. The by-product of these activities slowly removed fire-adapted vegetation.

Also considered in the risk of catastrophic fire are the combinations of natural and anthropogenic occurrences during the growth of plantations. Over the last several decades, there was an increase in single-species plantation management to reduce stand rotations and increase economic benefit. Plantation management activities often favor the susceptibility of SPB infestations especially in stands with increased basal area. This leaves mosaic patches within large plantations of dried out standing dead trees. Lightning may strike these trees and initiate a catastrophic fire. Trees damaged or killed during hurricanes and other storms can serve as fuel for fire.

Vegetation Composition Along the Edge of Plantation

Vegetation on the edge of the plantation plays an important role in the development of the stand structure within the existing plantation but also in the adjacent stands that make up that forest ecosystem. The collective amount and composition of species along the edge of stands also influence the biological and physical characteristic of both the forested and the non-forested environment. Forest edges are the interface between forested and non-forested ecosystems or two forests of contrasting composition or structure (Harper et al., 2005). The influence of forest edges on forest structure has been a growing topic in forest management, mostly related to the size of the edge.

Forest edges can occur naturally, caused by a decline in forest species composition, natural succession of the stand, topography or soil type changes, weather damage and insect outbreaks. Forest edges create a marginal zone of altered microclimate and contrasting community structure distinct from the forest interior (Matlack, 1993). The size of forest edges can have great impacts on the creation of fragmented forest areas across the landscape. Forest fragmentation reduces the area of continuous forest and breaks it into isolated patches that have deleterious consequences on the native forest biota (Murcia, 1995). This can have both negative and positive relationships on the adjacent stands.

All forest edges share at least two commonalities: exchange or flow of energy, material, and/or organisms across the boundary and alterations in the biophysical process and ecosystem composition (Cadenasso et al., 2003; Harper et al., 2005). Forest edges are a zone that experiences the climate buffering effects of the tree canopy immediately above however, at the loss of lateral protection afforded by single aged stands (Matlack, 1993). In a study on the microenvironment variation within edges, Matlack (1993) examined how aspect, temperature, and humidity of the stand over time determine the effect on composition in the forest edges compared to those resources within the stand. The study compiled both newly created edges with older edges and embedded edges. The results indicated that compared to the understory within the forest stand, the forest edges received more light, more rainfall, and maintained high vapor pressure deficit when compared to the forested areas (Matlack, 1993). This is attributed mostly to the openness of the un-forested areas. Open canopies allow more light in, benefiting both understory and edge vegetation. The abundance of shrub cover increased as the light, temperature, and rainfall increased (Matlack, 1993). Unfortunately, the species composition of the shrub cover was not included in this study; however, some inferences can be drawn from this study. First, edges create their own habitat independent of the stand; this could lead to more diversity in plants growing at the forest edge. Second, forest edges receive more light, have greater temperature variation and receive more rainfall, elements essential in increasing species richness. Since the plants receive more of the necessary resources for growth, they will likely increase in height. Last, the study never identified a composition difference between the vegetation within the stand and on the forest edges, which could indicate that between the stand and forest edge there is no net loss of understory species presence.

4.3.6 Potential Impact on Plantation Pine-Associated Wildlife Resulting from the No Action Alternative

4.3.6.1 Summary of the No Action Alternative on Wildlife Associated with Plantation Pine

Under the No Action Alternative, the presence of plantation pine within the action area has impacted and will continue to impact wildlife.

Plantation pine represents a major forested land use type within the action area. In contrast to the natural and open pine stands that were once prevalent in the Southern United States, plantation pine provides less suitable habitat for wildlife; however, when compared to other major land uses in the action area, such as urban and crop land uses, intensively managed plantation pine stands may positively contribute to the biological diversity of wildlife both within and across the landscape.

Structural diversity of vegetation within the pine plantation is a substantial effector of wildlife within a plantation pine stand, as vegetation may provide habitat, cover, and/or food for wildlife. Within a typical plantation pine, a variety of activities, including common silvicultural activities and development of the plantation pine stand itself, generally impacts wildlife through the alteration of plant structural diversity.

In general, the diversity and richness of large and small mammals will mirror the development of understory vegetation development. Accordingly, large and small mammal diversity and richness is greatest early in a pine plantation rotation, followed by a corresponding decrease in diversity and richness as the pine plantation develops. An exception to this general rule may be bats, which prefer larger and thus older trees for roosting habitat.

The bird community may also be substantially affected by the age and structure of a pine plantation. In general, following a substantial reduction in the bird community immediately after common site preparation/establishment activities, breeding bird density and diversity may increase as the understory vegetation develops; however, the bird community commonly decreases as the pine plantation reaches mid-rotation in age and experiences simplification of understory structures as the canopy closes. In stands of older plantation pine, the bird community may return to high levels if several layers of canopy foliage are present to provide a sufficiently stratified habitat.

In general, amphibians are positively associated with leaf litter, herbaceous cover, course woody debris, and streamside management zones since they need a cool moist environment to thrive. However, the response of reptiles and amphibians over the life of a typical plantation pine rotation is often species-specific, making generalizations about the potential impact of pine plantation and its management difficult.

4.3.6.2 No Action Analysis on Wildlife Associated with Plantation Pine

Introduction and Assumptions

Historically, forest plantations have been linked to habitat fragmentation and have been characterized as biological deserts (Andreu et al., 2011). While natural open pine stands that were prevalent throughout the South had more wildlife than dense pine plantations (Wigley et al., 2000), pine plantations are favorable when compared to other land uses such as annual crop agriculture or human developments (Moore and Allen, 1999). Due to the prevalence of pine plantations in the Southern United States landscape (Hartley, 2002), these intensively managed forests positively contribute to the biodiversity of the landscape (Wigley et al., 2000).

A variety of different stand structures and age classes within a landscape provide the greatest variety of wildlife (Andreu et al., 2011). Structural diversity of vegetation is greater and subsequently more attractive to wildlife on previously forested sites versus old-field sites (Marion et al., 2011). Old-field sites are locations that were converted to fields for agricultural cultivation. Old-field sites generally have greater pine growth and less understory than non-cultivated sites due to a lack of seeds in the soil. Old-field sites lack plant diversity and are less attractive to wildlife than sites that were previously forested and have a substantial seed bank. Previously forested sites have a dense understory with wildlife foraging opportunities in 5- to 10-year-old plantations (Marion et al., 2011).

Wildlife diversity and abundance also can be achieved by retaining snags[32], course woody debris[33], and mature live trees (Andreu et al., 2011). Natural forest stands retained along intermittent and perennial streams, known as streamside management zones, also contribute to wildlife diversity, water quality, and habitat connectivity (Hurst et al., 1981; Baker and Hunter, 2002). Streamside management zones are a common component of landscapes dominated by pine plantations and protect water quality from nonpoint source pollution. Streamside management zones can increase wildlife diversity and abundance within plantations by providing habitat for species requiring mature forest structure and/or mature hardwoods, increasing habitat diversity (Miller et al., 2004).

Forest managers are increasingly expected to manage for fish and wildlife habitats that contribute to the conservation of biodiversity and the conservation of soil, water, and air through commitments such as the Sustainable Forestry Initiative (Sustainable Forestry Initiative Inc., 2004). Managed forests in the Southern United States support many terrestrial species of conservation concern, including the American burying beetle (*Nicrophorus americanus*), bald eagle (*Haliaeetus leucocephalus*), gopher tortoise (*Gopherus polyphemus*), Louisiana pine snake (*Pituophis melanoleucus ruthveni*), red-cockaded woodpecker (*Picoides borealis*), and red hills salamander (*Phaeognathus hubrichti*) (Miller et al., 2009). Also, some forest owners integrate hunt-lease programs into economic analyses and planning, which connects wildlife and timber management objectives (Mengak, n.d.).

Pulpwood rotations can be as short as approximately 18 years, limiting the amount of time that pine plantations spend in the later successional stages of growth (Andreu et al., 2011). Wildlife feed on plants and insects within pine plantations and some use the habitat within the plantations, as well as the surrounding habitat, for nesting and shelter. Between site preparation and planting, pine-associated grasses and seed-bearing annual plants attract feeding flocks of small birds, mice, and ground-nesting birds (University of Georgia, 1981). Between the seedling stage and 3-year-old pines, the open canopy allows sunlight to filter through the planted trees, and wildlife species with early successional vegetation habitat preferences will use the plantations. The species using the plantation during this time frame include: quail (*Coturnix coturnix*), rabbits (*Leporidae* spp.), cotton rats (*Sigmodon hispidus*), foxes (*Vulpes vulpes*), and sparrows (*Passer domesticus*). Young pine plantations also provide an abundant food supply for deer and turkeys. These species decline as the pine stand canopy closes (University of Georgia, 1981; Marion et al., 2011). In areas that have not undergone intensive management, 12- to 15-year-old pine stands will harbor shade-tolerant plants including shrubs and vines that attract deer, rabbits, foxes, and thicket-nesting birds (University of Georgia, 1981). For additional information, please refer to the No Action analysis on pine-associated vegetation (Section 4.3.5).

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[32] A standing dead or dying tree

[33] Dead branches and trees that are lying on the ground

While intensive site preparation benefits some species such as deer, less intensive site preparation is generally better for wildlife (Andreu et al., 2011) since high intensity site preparation can speed up the development of the canopy (Marion et al., 2011). Marion et al. (2011) compared high-intensity site preparation to low-intensity site preparation and found that low-intensity sites had a well-developed grass/saw palmetto understory and little growth of other woody shrubs. The understory supported a large number of insects, which was favorable for insect-feeding animals such as opossums, armadillos, and shrews (Marion et al., 2011). Soil disturbance, such as prescribed fire or disking, enhances habitat quality for quail and other grassland birds because it inhibits woody brush growth, promotes favored seed-producing plants, reduces plant residue, increases bare ground, and increases insect abundance (for additional information, please refer to the No Action analysis on pine-associated vegetation in Section 4.3.5). The subsequent plant communities also provide nutritious forage for deer, rabbits, turkeys, and other wildlife (Mississippi State University Forest and Wildlife Research Center, n.d.).

Fire changes the composition of the understory vegetation whereas herbicide application has a more significant effect on shrub and mid-story woody components. The forest industry is starting to replace fire with herbicide applications (Thompson et al., 2000). Selective hardwood herbicides such as imazapyr[34] can increase pine growth and survival and inhibit development of a dense brush layer, thereby increasing the length of time that the grass/forb plant community persists (Mississippi State University Forest and Wildlife Research Center, n.d.), benefitting certain grassland wildlife species.

Pine plantations that have been thinned, benefit numerous species such as deer, small mammals, turkeys, and birds (Andreu et al., 2011). Thinned stands have greater avian species richness compared to all stands before thinning (Wilson and Watts, 2000) due to an open canopy dominated by pine, dense understory vegetation, and variable density of mid-story hardwoods. The gradient between early successional and thinned stands is punctuated by stands that have a dense, closed canopy and an associated sparse understory (represented by 9- to 11-year-old stands in many areas) (Wilson and Watts, 2000).

The following subsections will discuss in more detail the categories of species most common in Southern United States pine plantations at varying age classes. These wildlife categories include mammals, birds, and reptiles and amphibians. These categories were selected after completing a literature review and consulting the NatureServe wildlife database for information on species that use pine stands for foraging or habitat purposes (or both). The subsections will not provide a detailed description of all of the species that may be present in the pine plantation at a given time but rather will focus on representative species from each category.

Mammals

White-tailed deer: White-tailed deer (*Odocoileus virginianus*) is the most frequently managed species on pine plantations leased for hunting (Iglay et al., 2010). Since deer abundance is directly correlated to forage availability, a loblolly plantation on pulpwood rotation of 20 to 25 years generally provides abundant forage for deer from the time of planting to crown closure. This occurs over an 8- to 10-year period depending upon pine spacing and site quality (Blair and Enghardt, 1976). One study found that deer forage on plantations in Mississippi increased progressively from the second to the fifth summer. Deer forage on the plantations in the seventh summer averaged less than in the second summer and declined thereafter, subsequently reducing the deer population in the plantation. Deer forage in late

[34] The potential environmental impact of herbicides, such as imazapyr, will not be discussed in this No Action analysis, as explained in Section 4.5

winter was greatest on 1-year-old plantations and generally declined with increases in plantation age (Hurst et al., 1981).

When prescribed fire is used mid-rotation in intensively managed pine plantations, plant species richness increases, which promotes deer habitat and timber production (Hurst et al., 1981; Mixon et al., 2009; Iglay et al., 2010). Deer forage on 6-, 11-, and 12-year-old plantations that had been burned one year earlier exceeded that on unburned plantations of the same age (Hurst et al., 1981). Without periodic disturbance, woody browse will grow beyond reach of deer and a fire-resistant hardwood mid-story will gradually re-emerge (Mixon et al., 2009).

Small Mammals: Small mammals are abundant during the early successional stages of the pine plantation. Least shrews (*Cryptotis parva*), house mice (*Mus musculus*), eastern harvest mice (*Reithrodontomys humulis*), rice rats (*Oryzomys palustris*), and cotton rats were found in pine stands with dense understory vegetation (Mitchell et al., 1995). White-footed mice (*Peromyscus leucopus*) were observed in greatest numbers in 1-year-old plantations and steadily declined through successive age classes. The percentage of pregnant adult female white-footed mice was highest (75%) in 1-year-old plantations and declined progressively on 2- to 4-year-old plantations (Atkeson and Johnson, 1979). House mice followed a similar pattern of succession. Cotton rats were present in stands of all ages and were most frequently captured in stands older than one year. They were at their greatest abundance in 3- and 4-year-old plantations and declined to low numbers after canopy closure. Pregnancy was most common among adult female cotton rats on 1- and 2-year-old plantations (Atkeson and Johnson, 1979). Harvest mice were observed in low numbers in stands of all ages but were captured most frequently in 1- to 3-year-old stands. A few golden mice (*Ochrotomys nuttalli*) were observed in each age plantation except for 3 years. They attained peak numbers in 7-year-old plantations (Atkeson and Johnson, 1979).

The abundance of small mammals on 2- to 4-year-old pine plantations is likely due to the vegetation changes associated with early succession. By the fifth year, pine canopy development and subsequent understory vegetation suppression may start reducing habitat quality for small mammals (Hanberry et al., 2013). However, mid-rotation management can enhance the understory vegetation enabling small mammals to recolonize the area. Pre-thinned stands in east-central Mississippi that were between 18- and 22-years-old were home to the cotton mouse, eastern harvest mouse, eastern mole (*Scalopus aquaticus*), golden mouse (*Ochrotomys nuttali*), hispid cotton rat (*Sigmodon hispidus*), house mouse, least shrew (*Cryptotis parva*), pine vole (*Microtus pinetorum*), rice rat, southern short-tailed shrew (*Blarina carolinensis*), and white-footed mouse (Hood et al., 2002). Management regimes in these mid-rotation pine stands consisted of prescribed burning, herbicide application, and herbicide application followed by prescribed burning. Small mammals responded favorably to prescribed burning and also to prescribed burning with herbicide due to an increase in food quality and quantity. The newly abundant understory grass/forb vegetation resulted in increased species richness within the older pine stands (Hood et al., 2002).

Abundance, richness, and diversity of small mammals was greatest for streamside management zones embedded within young, open canopy pine stands and thinned pine plantations. Abundance was least within streamside management zones surrounded by closed-canopy pine plantations (Miller et al., 2004). Reducing the time that plantations spend in the closed-canopy stage through management regimes such as wider row spacing of planted pine and early thinning help maintain small mammal populations (Miller et al., 2004).

Bats: A study in Georgia documented evening bats roosting in the bifurcated upper trunk of pines within middle-age (15-year-old) loblolly pine plantations (Miller, 2003). Seminole bats tend to roost in pine-dominated stands and prefer tall, large diameter trees as day roosts that are at least 20-years-old. The rapid growth of loblolly pine trees in intensively managed landscapes may produce taller, larger trees that are suitable for use as roosts at younger ages (Hein et al., 2008).

Birds

Southern pine plantations in the action area are located within three migratory bird flyways—the Atlantic flyway, Mississippi flyway, and the Central flyway (U.S. Fish and Wildlife Service, 2012). Hundreds of migratory bird species use these flyways each year and many of these species are now considered globally threatened. More than half of all Neotropical migrants have experienced substantial population declines in the last 40 years. Important habitat for migratory birds is under threat from infrastructure, housing, energy development, and agricultural expansion (BirdLife International, n.d.). Silviculture can impact migratory birds when hardwoods are converted to pine or when naturally occurring open habitats are lost (Baker and Hunter, 2002). However, conversion from hardwoods to pine or a pine-hardwood mix is better than no forested habitat. The current lack of hardwood forest structure due to fire suppression and other management regimes that subsequently reduce mid-successional and early successional forests help explain why pine plantations can provide valuable habitat for both migratory and resident birds[35] (Baker and Hunter, 2002).

Lane et al. (2011a) observed 76 bird species in the coastal plains of North Carolina over 8 years following pine plantation preparation. Of these species, 13 were resident, 32 were Neotropical migrants, and 31 were short-distance migrants. In addition, 24 species were classified as forest interior, 29 forest edge, and 12 pine-grassland species. In South Carolina, 72 species of birds were documented in intensively managed pine stands, including species of conservation concern (Wigley et al., 2000).

The structure of the bird community is influenced by stand age and structure (Wilson and Watts, 2000). Pine spacing has the greatest effect on bird abundance and species richness (Lane et al., 2011b). Residual trees also appear to be a critical stand element for many bird species (Hanberry et al., 2012a). Other than a few species such as the red-cockaded woodpecker (*Picoides borealis*), bird communities are mostly dependent upon non-pine vegetation within pine stands. Practices that promote grass, forb, and hardwood vegetation, such as wider spacing and thinning, benefit birds (Dickson et al., 1995). In intensively managed silvicultural practices, mid-rotation or pre-commercial thinning is required for optimal growth and yield in commercial harvesting and thus may benefit birds by promoting growth of additional vegetation in the understory (see the No Action analysis for vegetation in Section 4.3.5 for additional information about thinning).

In the following subsections, the general influences of pine plantation silvicultural practices and pine plantation age on the bird community will be presented and discussed.

Pine Plantation Management: All management regimes result in a short-term (1-year) reduction in bird species richness and total abundance. Mid-story species such as hooded warblers and white-eyed vireos decline after plantation management, whereas canopy species such as the great crested flycatcher (*Myiarchus crinitus*) and Eastern wood-pewee (*Contopus virens*) increase following this transient reduction in bird species richness and total abundance. By the second growing season following treatment, total bird abundance increases with combined herbicide and burn plots favored, as discussed below (Thompson et al., 2000).

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[35] Resident birds do not migrate

Sites with abundant herbaceous ground cover are selected by wild turkey females with broods, and broods used areas that have received some type of forest treatment such as clearcutting, thinning, or control burning. Broods also prefer an open canopy, which can be accomplished by moderate timber stocking and frequent thinning (Campo et al., 1989).

Chemical site preparation also often elicits positive bird community responses (Iglay et al., 2012). Hanberry et al. (2012b) observed greater species richness and total bird abundance in the chemical-only prepared stands versus mechanically prepared stands. Increased species richness and abundance in the chemical-only establishment likely was due to the presence of residual trees. Residual trees add an attractive structural element, particularly for birds that use trees as their primary substrate but also to a variety of songbirds for perching, singing, and mating display posts, and feeding and nesting opportunities (Hanberry et al., 2012a). Mechanical methods rearrange vegetation structure but rarely reduce woody encroachment, which would be beneficial for early successional wildlife species (Iglay et al., 2012). Industrial forests such as pine plantations that are managed using standard practices will most likely continue to provide value relative to conservation of avian communities, including species of conservation concern (Iglay et al., 2012).

In general, breeding bird density and diversity in pine stands are relatively high in young, rapidly growing stands with grasses, forbs, and shrubs, but decrease in middle-aged pine stands as pine canopies close and shade out other plants, and then increase to the highest level in structurally diverse older stands that have several layers of foliage (Dickson et al., 1995). Bird species associated with several age classes are discussed below.

Early Successional Pine Stands (0- to 6-years-old): Dickson et al. (1995) reported that the greatest bird abundance and number of species occurred during the second year after planting due to abundant fruits and seeds from grasses, forbs, and low shrubs that are available to foraging birds. As a result, young plantations are important for species such as the bobwhite quail (*Colinus virginianus*). Intensive management on loblolly pine plantations generally provided moderate levels of winter food and loafing cover, but inadequate nesting and brood-rearing cover for bobwhite during the first year (Jones et al., 2010a). Second and third year burn areas provide better nesting cover (Mississippi State University Forest and Wildlife Research Center, n.d.). Despite the use of early succession pine plantations by bobwhite, resident birds are least abundant in these stands because many of these species use mid- to late successional habitat not present in young pine plantations (Lane et al., 2011a).

Many of the short-distance migrants that may be encountered in early successional pine plantations were species that use forest edges or pine-grasslands such as the Eastern phoebe (*Sayornis phoebe*), Eastern towhee (*Pipilo erythrophthalmus*), mourning dove (*Zenaida macroura*), and field sparrow (*Spizella pusilla*). The Carolina chickadee (*Parus carolinensis*) and tufted titmouse (*Baeolophus bicolor*) were the most common forest interior birds that regularly ventured into young pine stands (Lane et al., 2011a).

Species such as the common yellowthroat (*Geothlypis trichas*) and gray catbird (*Dumetella carolinensis*) are commonly observed in early succession pine plantations (Wilson and Watts, 2000). Killdeer (*Charadrius vociferus*) are observed in pine stands during the first two growing seasons while Eastern bluebirds (*Sialia sialis*), Eastern kingbirds (*Tyrannus tyrannus*), blue grosbeak (*Guiraca caerulea*), indigo bunting (*Passerina cyanea*), and yellow-breasted chat (*Icteria virens*) are all associated with stands in the first 4 to 6 growing seasons (Dickson et al., 1993b; Wilson and Watts, 2000; Lane et al., 2011b). Indigo bunting and yellow-breasted chat also are frequently observed in stands 1 to 2 years after thinning (Dickson et al., 1993a; Wilson and Watts, 2000). The American goldfinch (*Spinus tristis*) is associated with stands in their first 6 growing seasons. Painted buntings (*Passerina ciris*), orchard orioles (*Icterus* *spurius*), and prairie warblers (*Dendroica discolor*) also prefer young, regenerating pine stands. Painted buntings were abundant in 3- to 7-year-old plantations and then declined rapidly (Dickson et al., 1993b). The prairie warbler appeared in pine plantations as young as 2 years old and peaked in numbers when the pine stands were 3- to 7-years-old (Wigley et al., 2000; Lane et al., 2011a). Yellow-rumped warblers (*Dendroica coronata*) are at low densities in year 2 but increase substantially by the 4th year (Dickson et al., 1995).

Aerial insectivores (e.g., barn swallow (*Hirundo rustica*), chimney swift (*Chaetura pelagica*), purple martin (*Progne subis*)) that use these habitats for foraging purposes only were associated with 1-year-old pine stands (Wilson and Watts, 2000; Lane et al., 2011a). Savannah sparrows (*Passerculus sandwichensis*), red-winged blackbirds (*Aqelaius phoeniceus*), and brown-headed cowbirds (*Molothrus ater*) are present in the early successional stages of the pine plantation (Dickson et al., 1995). Eastern meadowlarks (*Sturnella magna*) are present in low to moderate numbers during the first few years of a pine plantation (Dickson et al., 1995; Wilson and Watts, 2000). Dickson et al. (1995) observed that the song sparrow (*Melospiza melodia*) was the most abundant bird during the second year of growth in a pine plantation but decreased consistently in the plantation until it disappeared by age 7 as grass/forb vegetation was replaced by hardwood shrubs. Vesper sparrows (*Pooecetes gramineus*) were abundant for years 2 and 3 but declined from 4 to 6 years, after which they disappeared from the stand. Dark-eyed juncos (*Junco hyemalis*) were relatively abundant with the highest densities through year 8 (Dickson et al., 1995).

Middle-aged Pine Stands 6- to 15-years-old: As the plantation develops and shrubs become more dominant, bird communities change. Grass- and forb-associated birds reduce in number and shrub-associated birds become dominant. The closing pine canopy has a negative relationship with relative abundance of common yellowthroat, orchard oriole, prairie warbler, white-eyed vireo (*Vireo griseus*), and yellow-breasted chat (Hanberry et al., 2012a). Northern cardinals (*Cardinalis cardinalis*) and Carolina wren (*Thryothorus ludovicianus*) are consistently found in plantations during this time (Dickson et al., 1995). Flocks of American robins (*Turdus migratorius*) can be encountered during the winter months (Dickson et al., 1995).

As plantations develop from age 6 to 10 years, pines became more dominant, some hardwood shrubs diminish, and a few hardwood sprouts grow underneath the stand canopy. The golden-crowned kinglet (*Regulus satrapa*) may be found in the pine stand beginning in 7-year-old pine plantations. This species normally winters in conifer stands and is found regularly in middle-aged pine stands in Texas and Louisiana. The hermit thrush (*Catharus guttatus*) was present in small numbers from age 7 to 15. The Carolina chickadee can be occasionally detected in the shrub stage of plantations and usually more frequently after age 11. Pine warblers (*Dendroica pinus*) are permanent residents of a variety of middle-aged pine stands and have been detected in 12-year-old plantations and older as pine canopies dominate the stand (Dickson et al., 1995). Worm-eating warblers (*Helmitheros vermivorum*) begin to occupy plantations in the 10th growing season but attain the greatest density in thinned stands that have a dense understory (Wilson and Watts, 2000). Common yellowthroats (*Geothlypis trichas*), downy woodpeckers (*Picoides pubescens*), great-crested flycatchers (*Myiarchus crinitus*), and yellow-throated vireos (*Vireo flavifrons*) also reach maximum abundance in pine plantations that are 6- to 15-years-old (Wigley et al., 2000).

Dickson et al. (1993b) observed that in 10- to 11-years-old pine plantations, the few volunteer hardwood trees in the stand were sufficiently developed to permit colonization by species such as Kentucky warblers (*Oporornis formosus*) and hooded warblers (*Setophaga citrina*), normally associated with the understory of mature stands, and a few canopy dwelling species such as yellow-billed cuckoos (*Coccyzus* *americanus*), red-eyed vireos (*Vireo olivaceus*), and black-and-white warblers (*Mniotilta varia*) (Dickson et al., 1993b). From plantation age 12 to 17 years, the Neotropical breeding bird community often decreases in complexity (Dickson et al., 1993b).

Closed-canopy stands that are between the early successional stage and thinning tend to have the lowest bird densities due to their inferior habitat for both early successional and forest bird species (Wilson and Watts, 2000); however, some birds prefer middle-aged unthinned pine stands. Swainson's warblers (*Limnothlypis swainsonii*) can be found in loblolly pine plantations during the breeding season in several states including Texas, Louisiana, and North Carolina (Bassett-Touchell and Stouffer, 2006). The majority of observations occurred in unthinned, middle-aged (10-19 years) loblolly pine stands. Few Swainson's warblers were detected in thinned loblolly pine stands and there was no evidence of breeding in the thinned pine stands. Swainson's warblers in pine plantations are associated with sites with less live ground cover, complete canopy cover, dense understory vegetation, and higher densities of pine trees. Swainson's warblers will use stands beginning around the 7-year mark but will only persist if the stands remain unthinned (Bassett-Touchell and Stouffer, 2006).

Older Pine Stands 16- to 25-years-old : Pine stands 16-20 years old have reduced structural complexity and correspondingly also have the fewest species reaching maximum abundance (Wigley et al., 2000). Species reaching maximum abundance in pine 16-20 years old include the ovenbird (*Seiurus aurocapilla*) and pine warbler (Wigley et al., 2000). Birds present in 24-year-old pine plantations in Northern Florida include the red-bellied woodpecker (*Melanerpes carolinus*), blue jay (*Cyanocitta cristata*), summer tanager (*Piranga rubra*), chipping sparrow (*Spizella passerina*), and the great-crested flycatcher (Repenning and Labisky, 1985). Repenning and Labisky (1985) also observed that winter bird densities and species richness were lowest on 24-year-old pine plantations.

Thinned Pine Stands: As was previously mentioned, management practices such as thinning benefit birds, and thinning promotes the re-use of an area by birds that would not otherwise occur without managed succession of the pine plantation. Wilson and Watts (2000) observed that 80 percent of the species detected were observed in stands before thinning and 88 percent of species observed during the study were detected in thinned stands. Ten percent of the species were exclusively in stands before thinning and 16 percent of species were exclusively in thinned stands (Wilson and Watts, 2000). The downy woodpecker, Carolina wren (*Thryothorus ludovicianus*), blue-gray gnatcatcher (*Polioptila caerulea*), Acadian flycatcher (*Empidonax virescens*), ovenbird, and Carolina chickadee (*Poecile carolinensis*) were among the most abundant species distributed among all thinned stands. The Eastern wood-pewee (*Contopus virens*), great crested flycatcher, tufted titmouse, worm-eating warbler (*Helmitheros vermivorum*), pine warbler, summer tanager, and Northern cardinal were detected in high densities and distributed evenly among thinned stands. The hooded warbler was primarily associated with older stands and had a greater density in stands after a second thinning compared to stands after the first thinning. The brown-headed nuthatch (*Sitta pusilla*) was more abundant in stands 1 to 2 years after the first and second thinning compared to stands with increasing time since thinning (Wilson and Watts, 2000).

<u>Reptiles and Amphibians</u>

In South Carolina, 73 species of reptiles and amphibians were documented in intensively managed pine stands (Wigley et al., 2000). One of the most well-known species found in pine stands is the gopher tortoise (*Gopherus polyphemus*). Gopher tortoises generally inhabit upland ecosystems characterized by sandy soils, pine forests, and abundant herbaceous understory (Jones and Dorr, 2004). Tortoises select sites where soil conditions are conducive to good drainage, burrow construction, and adequate forage availability (Jones and Dorr, 2004). Burrow abandonment generally occurs in pine plantations with no intermediate management, such as stand thinning or prescribed burning. This condition was observed most frequently in stands 10- to 20-years-old when crown development of planted pine seedlings and the naturally colonizing mid-story caused canopy closure (Jones and Dorr, 2004; Diemer Berish et al., 2012). Gopher tortoises have the ability to dig out after forestry site preparation and have been observed to survive intensive forestry practices (Diemer, 1992). Some timber companies have a policy in which a protective buffer is retained around burrows where mechanized timber harvest and site preparation is restricted or limited (Jones and Dorr, 2004).

In general, amphibians are positively associated with leaf litter, herbaceous cover, course woody debris, and streamside management zones since they need a cool moist environment to thrive (LeGrand, 2005). Frogs and toads need a closed canopy for regulation of temperature and moisture (Bull and Wales, 2001). However, response to pine plantation succession appears to be species-specific, which limits the ability to make generalizations about the impact of pine plantation management on reptile and amphibian communities (LeGrand, 2005). To provide a better idea of the variability of habitat use within reptile and amphibian communities, species associated with several age classes of the stands are discussed below.

Early Successional Pine Stands: Frogs and toads observed in 0- to 3-year-old pine plantations with isolated wetlands, bottomland hardwood forests, or streamside management zones include the oak toad (*Bufo quercicus*), Southern toad (*Bufo terrestris*), Eastern narrow-mouthed toad (*Gastrophryne carolinensis*), gray treefrog (*Hyla chrysoscelis*), green treefrog (*Hyla cinerea*), squirrel treefrog (*Hyla squirella*), and southern leopard frog (*Rana utricularia*) (Wigley et al., 2000). Early successional pine stands are also home to the marbled salamander (*Ambystoma opacum*), Eastern mud turtle (*Kinosternon subrubrum*), stinkpot (*Sternotherus odoratus*), and pond slider (*Tarchemys scripta*) (Wigley et al., 2000). Lizards include the six-lined racerunner (*Cnemidophorus sexlineatus*), Southeastern five-lined skink (*Eumeces inexpectatus*), and the ground skink (*Scincella lateralis*) (Wigley et al., 2000). Snakes observed in young plantations include the copperhead (*Agkistrodon contortrix*), worm snake (*Carphophis amoenus*), southern hognose snake (*Heterodon simus*), common kingsnake (*Lampropeltis getulus*), and southern water snake (*Nerodia fasciata*) (Wigley et al., 2000).

Middle-aged Pine Stands: Frogs and toads observed in 10- to 15-year-old pine plantations with isolated wetlands, bottomland hardwood forests, or streamside management zones include the oak toad, Southern toad, Eastern narrow-mouthed toad, gray treefrog, green treefrog, green frog (*Rana clamitans*), and carpenter frog (*Rana virgatipes*) (Wigley et al., 2000). Middle-aged pine plantations also are home to Mabee's salamander (*Ambystoma mabeei*), marbled salamander, broken-striped newt (*Notophthalmus viridescens*), Eastern mud turtle, stinkpot, Eastern box turtle (*Terrapene carolina*), and pond slider (Wigley et al., 2000). Lizards include the Carolina anole (*Anolis carolinensis*), broad-headed skink (*Eumeces laticeps*), Southeastern five-lined skink, and the ground skink (Wigley et al., 2000). Snakes observed in middle-aged pine plantations include the copperhead, worm snake, canebrake rattlesnake (*Crotalus horridus*), rat snake (*Elaphe obsolete*), milk snake (*Lampropeltis Triangulum*), and coachwhip (*Masticophis flagellum*) (Wigley et al., 2000).

Older Pine Stands: In 18- to 22-year-old pine stands that were thinned in east-central Mississippi, the following reptiles and amphibians were captured: American toad (*Bufo Americana*), central newt (*Notophthalmus viridescens louisianensis*), Eastern narrow-mouthed toad, five-lined skink (*Eumeces fasciatus*), Fowler's toad (*Bufo woodhousii fowleri*), green anole (*Anolis carolinensis*), ground skink, midland brown snake (*Storeria dekayi wrightorum*), Mississippi ringsnake (*Diadophus punctatus stictogenys*), Mississippi slimy salamander (*Plethodon mississippi*), small-mouth salamander (*Ambystoma texanum*), southern black racer (*Coluber constrictor priapus*), copperhead, Southern leopard frog, speckled kingsnake (*Lampropeltis getula holbrooki*), spring peeper (*Pseudacris crucifer*), timber rattlesnake (*Crotalus horridus*), upland chorus frog (*Pseudacris feriarum*), and western pygmy rattlesnake (*Sistrurus miliarius streckeri*) (Hood et al., 2002).

Invertebrates

Invertebrates are an important component of the forest ecosystem. The third largest order of insects, Diptera, includes insects with individuals that are differentiated more by habitat type than by geographical location (Hughes et al., 2000). Allgood et al. (2009) examined Dipteran activities in open canopy, closed canopy, thinned, and unmanaged pine stands. Chloropids (fruit flies/grass flies) were more abundant in open stands than in closed stands, and the dipteran community was more diverse and even in stands with open canopies and at edges (Allgood et al., 2009). The amount of deciduous vegetation is an important habitat usage predictor for Diptera. As a result, dipteran diversity is greatest in young, open pine stands and declines as pine succession proceeds and the canopy closes (Allgood et al., 2009). Flying arthropods appear to be more abundant at the edge of pine stands, and chloropids and cecidomyiids (gall midges/gall gnats) also are abundant at edges. Thinned and closed canopy pine stands had an abundance of cecidomyiids (Allgood et al., 2009). Galling insects (insects that feed on plant tissues and cause abnormal plant growth) are more abundant in harsh conditions where their natural predators have lower survival rates (Price et al., 1998).

Trees in pine plantations are pollinated by wind currents; however, pollinators are needed for wildlife-managed understory development of some shrubs and hardwoods such as maples (Schowalter et al., 1997). Limited genetic diversity within monoculture pine plantations further reduces the charismatic invertebrate population in pine plantations while increasing the vulnerability of trees to pest outbreaks in unthinned pine stands as a result of competitive stress (Schowalter et al., 1997). As a result, we will discuss invertebrate pests extensively in section below, *Potential Impact on Insect and Disease Pests of Plantation Pine from the No Action Alternative* (Section 4.3.7).

4.3.7 Potential Impact on Insect and Disease Pests of Plantation Pine from the No Action Alternative

4.3.7.1 Summary of the No Action Alternative on Insect and Disease Pests of Plantation Pine

There are several major insect and disease pests of plantation pine in the action area that cause widespread economic damage. Under the No Action Alternative, insect and disease pests of plantation pine will continue affecting plantation pine species, with the magnitude of pest damage generally mirroring the extent of plantation pine plantings. It is anticipated that plantation pine acreage will increase in the foreseeable future; consequently, the potential impact from insect and pest diseases of plantation pine may also increase. In spite of this, however, currently-adopted pest management practices are likely to be effective in managing the majority of these pests now and in the foreseeable future under the No Action Alternative.

4.3.7.2 No Action Analysis on Insect and Disease Pests of Plantation Pine

Introduction and Assumptions

As identified by Wear et al. (2013), the action area consists of plantation pine within 204 counties spread across seven U.S. states (Appendix B). The action area includes the Southern Coastal Plain and the Mississippi Alluvial Valley of the Southern United States. The insect and disease pests discussed in this No Action analysis are those identified as major pests of plantation pine, are widespread, and cause significant economic damage according to work undertaken by the USDA-FS Southern Research Station[36].

In this No Action analysis, general trends related to insect and disease pests of plantation pine in the broader regions of the Southern Coastal Plain and the Mississippi Alluvial Valley are used to inform the analysis within the action area. As indicated by Wear (2013b), the action area mirrors overall trends in the Southern Coastal Plain and the Mississippi Alluvial Valley, suggesting that the broader region trends can be used to describe action area trends.

Major Pests in the FTE Study Region

The major pests of plantation pine, as determined by the USDA FS Southern Forest Research Station, in the FTE study region represent herbivorous insects, microbial diseases, or microbial diseases that are facilitated by insects. Table 11 represents a list of major insect and disease pests of plantation pine (with an emphasis on loblolly pine). Below is a brief summary of the information presented in Table 11, with emphasis on the pests that cause the most economic damage in plantation pine.

The Southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann, is one of the most destructive insect pests of pine in the Southern United States (Clarke and Nowak, 2009; Xi et al., Unknown). Loblolly, shortleaf, pitch, pond, and Virginia pines are the favored hosts in the southeast United States. During outbreaks, SPB may infest all pine species, and even marginal hosts such as spruce and hemlock may be killed (Clarke and Nowak, 2009). The SPB is generally in outbreak status every year somewhere within its range. A recent historical review estimated that SPB caused $1.5 billion of damage to pine forests during the outbreak of 1999 through 2002 (Duerr and Mistretta, 2012). Outbreaks of this insect tend to be cyclical in occurrence. Trees attacked by SPB often exhibit hundreds of resin masses (i.e., pitch tubes) on the outer tree bark. Consequently, once SPB have successfully colonized a tree, the tree cannot survive, regardless of control measures (Clarke and Nowak, 2009). Most of these pests are pests of pine that occur in native pine forests and are already present in the FTE study region. Other major and wide-spread insect pests of pine are bark beetles (*Ips avulsus, I. calligraphus, I. grandicolli*, and *Dendructonus terebrans*), Nantucket pine tip moth (*Rhyacionia frustrana*), and Pine reproduction weevils (*Hylobius pales* and *Pachylobius picivorus*) (Table 11). Texas leaf-cutting ant is also a major pest of planted pine; however, it is also very restricted in its distribution (Duerr and Mistretta, 2012).

Fusiform rust, caused by the fungus *Cronartium fusiforme,* is the most serious disease affecting pines in the Southern United States (Florida Forest Service, 2008). Infections by the fungus, which develops at or near the point of infection, result in tapered, spindle-shaped swells, definitive swellings called galls, on branches and stems of pines (Florida Forest Service, 2008). While the disease attacks several southern pine species, it is especially damaging and severely limits their management in high-hazard areas on slash pine (*Pinus elliottii* var. *elliottii* Englem.) and loblolly pine (*P. taeda* L.). Extensive planting of susceptible slash and loblolly pines since the 1930s has resulted in an epidemic of fusiform rust, which now extends throughout its available host range in the Southern United States; infected trees being found throughout the southern pine region (Ward and Mistretta, 2002). Losses are most serious on Coastal Plain sites from Louisiana to southeastern South Carolina. In 1978 annual losses from this disease were estimated at 562 million board feet of sawtimber and 194 million cubic feet of growth stock. Stumpage losses were valued at $28 million annually (Phelps and Czabator, 1978). Other wide-spread and major diseases of pine that are responsible for billions of U.S. dollar losses are Annosum root disease

[36] http://www.srs.fs.usda.gov/ Last accessed April, 2014

(*Heterobasidion annosum*), Brown spot needle disease (*Scirrhia acicola*), and Fusiform rust (*Cronartium fusiforme f. sp. Fusiforme*) (Table 11).

There are two diseases that are a complex of both insects and fungi. These are Loblolly pine decline (with at least one fungus (*Lophodermium* spp.) and an associated insect (*Hylastes* spp.) and the Sirex woodwasp (*Sirex noctilio*) with an associated fungus (*Amylostereum areolatum*) (Table 11). Loblolly pine decline is a disease complex resulting from the interactions of both biotic and abiotic stressors. The cause of decline is typically a complex of agents biotic and abiotic, which exacerbate or mitigate the extent of growth reduction and mortality differentially (Jurskis, 2005).

<u>Factors that Influence the Abundance of Insect and Disease Pests of Plantation Pine</u>

When pine trees cultivated in plantation are planted, harvested, and replanted on the same site in large blocks over many years, it can act as a natural sink for these pests and contribute to an increase in insect and disease pests impacts (Cock, 2003). It has been noted that monocultures of the same species tend to transform sporadic pests into more permanent problems (Cock, 2003). These two reasons explain why pests of plantation pine have become increasingly prevalent. As plantation pine acreage increased in the Southern United States, so did the number of hosts for these pine pests.

Plantation pine is subjected to a variety of disturbances caused by environmental conditions. Disturbances such as fire, drought, species invasions, insect and disease outbreaks, and storms such as hurricanes and windstorms are having notable impacts on plantation pine. They cause the damage by impacting their development, survival, reproduction, and by altering host defenses and susceptibility.

Drought is one of the most important climate-related events through which rapid ecosystem changes can occur as it affects the very survival of existing tree populations and increased susceptibility for certain pests. Drought can also elicit changes in plant and tree physiology which will impact pest disturbance dynamics and lead to increased susceptibility for certain pests. For example extensive periods of drought can lead to extensive damage to trees by engraver beetles and SPB (Duerr and Mistretta, 2013). Storm damage (hurricanes) and wildfire can lead to increased stress and an increase in insect and disease pests (Duerr and Mistretta, 2013). Trees that are damaged in storms or wildfire are often under stress and can be more susceptible to attacks by disease and insects. Both of these environmental events are common in the Southern Coastal Plain and Mississippi Alluvial Valley.

<u>Management of Insect and Disease Pests of Plantation Pine</u>

Common and accepted best management practices are methods currently used by plantation managers to control insect and disease pests of plantation pine (Table 10). These best management practices are summarized below from Table 10 are summarized below.

Control of these pests is primarily through management practices or the deployment of resistant germplasm. Good management practices including planting genetically improved stock (selected for resistance to a particular pest), lowering planting densities, thinning stands, and cutting and removing groups of infested trees) can reduce damage. Early detection and eradication of the pests can often be used as a method of control (Table 10). Lowering planting densities and thinning stands, representing the most commonly practiced methods of control, reduces the number of host, which in turn, reduces the number of pests.

For some of these pests, chemical control can be used (such as for the Nantucket tip moth or Texas leaf-cutting ant) (Table 10) but these are often cost-prohibitive on a very large scale. For this reason chemical control is not an option for many of these pests, even if they are available. The FAO has recommended that mixed plantings of native and exotic trees can be used as a method of minimizing pest problems by separating monocultures of existing plantations (Cock, 2003). This appears to be used little if at all in the southeastern United States for loblolly pine at this time.

Outlook of Insect and Disease Pests of Plantation Pine

Under the No Action Alternative, the potential impact on insect and disease pests of southern pine is likely to increase or stay the same in the action area, depending on the abundance of host trees and the particular pest in question. In response, growers will continue to rely on best management practices to control these pests.

Over the next 10 years, the planting of loblolly pine is projected to increase from around 39 million acres to between 42 and 50 million acres (Huggett et al., 2013) (see land use section of this draft EIS). In the Coastal Plain, planted pine is projected to increase from approximately 32 million to approximately 36 million acres (Huggett et al., 2013). The Mississippi Alluvial Valley is projected to see a slight increase in planted pine to around 500,000 acres (Huggett et al., 2013). As the amount of planted pine increases, there is projected to be an increase in many of these pests simply because there will be more acreage available for infestation (Duerr and Mistretta, 2013).

However, some of these pests are already so ubiquitous in the region that additional spread is unlikely. For example, Annosum root disease and Fusiform rust are already present across the entire region so additional spread is unlikely. Nonetheless, most of the other pests are likely to increase as pine acreage increases (Duerr and Mistretta, 2013). The Sirex woodwasp has not caused widespread mortality in the North American areas where it is established, nor have any populations been reported in the South. However within the next 50 years, it is very likely that natural or human-aided spread will introduce this pest to southern forests. Many of the South's most important pine species are susceptible to Sirex and many trees will succumb if attacks are as aggressive as they are in South America and Australia (Duerr and Mistretta, 2013).

Table 10. Major Insect Pests and Diseases of Southern Pine (with an emphasis on loblolly pine)

Common Name	Scientific Name	Susceptibility	Control
Annosum root disease	*Heterobasidion annosum*	All southern pines are susceptible but loblolly and slash pine are the most severely affected (Duerr and Mistretta, 2013). This disease produces significant losses of conifers across the South (Duerr and Mistretta, 2013).	Prevention and control strategies include stump treatment, timing of thinnings, prescribed burns, and the manipulation of planting density.
Bark beetles (other than Southern Pine Beetle)	*Ips avulsus, I. calligraphus, I. grandicolli, & Dendructonus terebrans*	Pine in the loblolly-shortleaf and longleaf–slash forest types are affected. These beetles are usually considered secondary pests because they normally infest only stressed, weakened, damaged, or downed pines. Large infestations develop only occasionally, usually after widespread environmental stress, such as that caused by drought, storm damage, or wildfire (Duerr and Mistretta, 2013).	The impact of these beetles depends largely on management activities. Prevention methods (such as lowering planting densities, thinning stands, and cutting and removing groups of infested trees) can reduce damage (Duerr and Mistretta, 2013). In unmanaged stands, they attack single trees or small groups of pines and reduce pine basal area (Duerr and Mistretta, 2013).
Brown spot needle disease	*Scirrhia acicola*	This is primarily a disease of Longleaf pine. But the fungus also infects seedlings of slash, loblolly, and white pines in nurseries within or slightly beyond the southern coastal plain.	Control methods include the use superior seed that is resistant to the disease. Also removal and destruction of all infected seedlings and infected pines growing in and around nursery areas. Good nursery practices include the remove clipped needles from nursery bed areas and the avoidance of pruning when it is raining or at any time when the seedlings are wet. Good control methods are available by spraying with fungicides registered for use on brown spot.
Fusiform rust	*Cronartium fusiforme f. sp. fusiforme*	Affects loblolly and slash pines. It is considered the most destructive disease of southern pines. Losses are most serious on Coastal Plain sites from Louisiana to southeastern South Carolina (Duerr and Mistretta, 2013).	Effective strategies are available for managing fusiform rust impact in plantations and forests. These include avoidance of over-fertilizing seedlings in the nursery, silvicultural manipulation of young stands to favor healthy saplings, and favoring the deployment of genetically screened resistant

			seedlings in areas of historic high rust incidence (Duerr and Mistretta, 2013).
Loblolly pine decline	*As a minimum: various fungi (Lophodermium spp.) and insects (Hylastes spp.)*	This is a tree decline complex of insect and fungi. It has been prevalent on upland sites of central Alabama since the 1960's. The causes and progression of the disease is still uncertain (Hess et al., 2002; Duerr and Mistretta, 2013).	Despite the uncertainties about the causes and progression of this disease complex, management strategies are in place that can be implemented with the expectation of improving resistance of future stands on affected sites. These strategies start with applying a risk rating model that uses digital elevation maps and mapped shape files for the sites in question combined with data on landform and root health of the trees in the stand. If the model predicts hazard to loblolly pine, the recommended alternative species is longleaf pine. For existing loblolly pine stands on high hazard sites, the recommendation is to thin them between ages 20 and 40 (Duerr and Mistretta, 2013).
Nantucket pine tip moth	*Rhyacionia frustrana*	The Nantucket pine tip moth, *Rhyacionia frustrana*, is one of the most common forest insects in the South. Although it is usually considered a southern pest, its range includes most of the eastern half of the United States. Most commercial pine species are susceptible to attack by the Nantucket pine tip moth, but there are considerable differences in relative susceptibility. Among the southern pines, longleaf nursery seedlings and all ages of shortleaf, loblolly, and Virginia pines are highly susceptible, while slash and older longleaf pines are highly resistant (Duerr and Mistretta, 2013). Tip moth infestations in loblolly pine stands are generally regarded as inevitable. However, as the acreage of intensively managed pine plantations is predicted to	Damage, while potentially serious, is normally transitory or negligible in forest stands. Tip moth damage (loss of growth and deformation) is most severe on seedlings and saplings, usually under 5 years old. A number of effective, chemical control options exist for this pest (Asaro et al., 2003). If population levels are monitored in a timely and regular fashion, and are followed up by appropriate insecticide applications, tip moth damage can be minimized. Chemical control options are effective, especially the new systemic insecticides. However, they are often prohibitively expensive (Duerr and Mistretta, 2013).

		increase, this tip moth should become a more common pest problem in the future (Ward and Mistretta, 2002).	
Pine reproduction weevils	*Hylobius pales, Pachylobius picivorus*	Pales weevil *(Hylobius pales)* and pitch-eating weevil *(Pachylobius picivorus*) are two of the most damaging insect pests of pine seedlings in the southeastern United States. Both species prefer loblolly, shortleaf, pitch and eastern white pine. Adult weevils of both species are attracted to newly harvested sites, where they breed in logging slash, stumps, and old root systems; they cause economic losses by feeding on the bark and often killing planted seedlings. If seedlings are planted on or adjacent to sites with fresh stumps or damaged trees, it is common to have 30 to 60 percent weevil-caused mortality among first-year seedlings, with instances of 90 percent or more mortality recorded (Duerr and Mistretta, 2013). Reproduction weevil impacts may increase in the future. Current trends suggest that forest industry will continue to shorten rotations and may be less willing in the future to delay replanting to avoid the weevils. This trend could lead to an increased risk of weevil-caused damage or an increased need for proactive control strategies (Ward and Mistretta, 2002)..	Only a few biological control agents that affect reproduction weevils have been reported. Very little is known about their effect in regulating field populations. Silvicultural and chemical strategies are available to reduce losses to reproduction weevils. A hazard rating system is available and should be used before scheduling pine planting (Ward and Mistretta, 2002).
Sirex woodwasp	*Sirex noctilio (insect), Amylostereum areolatum (fungus)*	Sirex woodwasp, *Sirex noctilio*, is native to Europe, Asia and northern Africa and has been introduced to North America. Sirex woodwasp has not caused widespread mortality in the North American areas where it is established, nor have any populations been reported in the South. However within the next 50	If the Sirex woodwasp becomes established in the South and acts as a primary tree killer, effective prevention and suppression techniques are available, including the current practice of thinning stands to increase growth and vigor and reduce susceptibility to bark beetles. In other countries, Sirex woodwasp has been

		years, it is very likely that natural or human-aided spread will introduce this pest to southern forests. Many of the South's most important pine species are susceptible to *Sirex* and many trees will succumb if attacks are as aggressive as they are in South America and Australia (Duerr and Mistretta, 2013).	successfully managed using biological control agents (Duerr and Mistretta, 2013).
Southern pine beetle	*Dendroctonus frontalis*	Southern Pine Beetle (SPB), *Dendroctonus frontalis,* is the most destructive insect pest of pine forests in the South (Thatcher and Connor, 2006). Populations build rapidly during periodic outbreaks and kill large numbers of trees. However, during periods of low activity, SPB populations may be so low that it is difficult to locate a single infested tree or capture beetles in pheromone traps (Duerr and Mistretta, 2013). SPB impacts over the next 50 years are expected to be significant, especially if the pine acreage increases in the South, high-susceptibility species are planted in dense plantations, and the plantations are left unthinned (Duerr and Mistretta, 2013).	Planting the proper species for a given site, lower planting densities, and thinning of pine stands can increase stand vigor and resiliency and possibly reduce SPB damage. When outbreaks do occur, damage can be minimized by early detection and monitoring of spots, followed by prompt direct suppression of active spots (Billings, 1980; Duerr and Mistretta, 2013).
Texas leaf cutting ant	*Atta texana*	The Texas leaf cutting ant, *Atta texana,* targets first- and second-year pine plantations in eastern Texas and west central Louisiana. This ant has a strong preference for well-drained, deep sandy soils. In areas where the ants are abundant, it is nearly impossible to establish pine plantations (Duerr and Mistretta, 2013).	The impact of this insect appears to be unaffected by management intensity or ownership (Waller, 1986; Ward and Mistretta, 2002). Chemical control is essential in highly infested areas (TAMU, 2013). A new fipronil control product was registered in 2009, and an insecticidal bait is on the horizon. Regular and consistent application of these products has the potential to reduce the impacts of Texas leaf cutting ants from historical levels (Duerr and Mistretta, 2013).

4.3.8 Potential Impact on Biodiversity Resulting from the No Action Alternative

4.3.8.1 Summary of the No Action Analysis on Biodiversity Associated with Plantation Pine

Under the No Action alternative, the presence of planted plantation pine, and more specifically, its management-related activities, has impacted and will continue to impact biodiversity within the action area.

Planted pine plantations typically consist of intensively managed and even-aged stands of a single pine species. The biodiversity within an individual pine plantation is substantially affected by the management conditions subjected onto that particular stand; in general, however, the intensity of management to improve timber production and increase economic returns may often occur at the expense of biodiversity within the pine plantation itself.

The biodiversity of wildlife within a planted plantation pine stand is generally affected by the vegetative structural diversity within that stand, which in turn is generally affected by common management practices intended to control plant competition and improve planted pine growth. In a typical plantation pine stand within the action area, overall biodiversity is often the most minimal shortly after site preparation and site establishment. Following site establishment, biodiversity will generally improve within the pine stand until canopy closure simplifies the vegetative understory and the wildlife that may use that vegetative understory. This general trend as it applies to wildlife may be class specific, however, as reptiles, amphibians, and invertebrates are less likely to follow this trend than mammals and birds.

Conservation of biodiversity within a planted plantation pine stand is increasingly becoming an important topic. Accordingly, a variety of practices are being identified and adopted to increase biodiversity. While many of these practices aim to increase the vegetative structural diversity that function as wildlife habitat within a stand, it is prudent to mention that land managers may or may not decide to adopt these practices in light of potential tradeoffs to timber production and economic returns.

While planted plantation pine stands are not as structurally diverse as natural forests within the action area, biodiversity often compares favorably to other common land uses such as crop land and urban land uses. Across the landscape, larger-scale activities and events are affecting biodiversity, including invasive species, and increasing urbanization. Compared to plantation pine, these landscape-scale factors may result in more substantial impacts on biodiversity than plantation pine.

4.3.8.2 No Action Analysis on Biodiversity in Plantation Pine

<u>Introduction and Assumptions</u>

The purpose of this section is to describe biodiversity in planted pine plantations in the action area, and management practices and factors that affect it. The action area encompasses 204 counties across seven Southern States that are within plant hardiness zones 8b and above (Figure 3b).

Biodiversity can be defined as the "variety of life in all its forms (plants, animals, fungi, bacteria, and other microorganisms) and at all levels of organization (genes, species, and ecosystems)" (Hunter, 1996). It also includes the functional processes through which these structural components interact with one another and their environment (Hunter, 1996). In a forest ecosystem, biodiversity can be affected by several factors including climatic and soil conditions, evolution, changes in species' geographical ranges, population and community processes, and natural disturbances or those caused by human activities (Carnus et al., 2006).

Carnus et al. (2006) describe four components of biodiversity relevant to plantation forests that can be applied at various scales and change over time. These are:

1) The genetic diversity within a population or a species.

2) The frequency and diversity of different species in a particular area.

3) The horizontal and vertical structure of the plant community (in plantation forests, this is continuously changing as stand development proceeds, and is particularly important for animal species diversity in an area).

4) The variation in functional characteristics of trees and other plant species. This includes characteristics such as evergreen versus deciduous, shade tolerant versus light demanding, deep-rooted versus shallow-rooted, and others.

Biodiversity in Pine Plantations

Planted pine plantations typically consist of intensively managed, regularly spaced, even-aged stands of a single pine species, and are characterized by relatively short rotations when compared with natural forests (Section 4.3.5). Biodiversity in plantation pines varies considerably depending on stand age. In intensively managed pine plantations, wildlife species diversity is greatest in stands less than 10 years old because of dense understory vegetation that provides wildlife habitat (Moorman and Hamilton, 2005). As a densely planted pine stand ages and the canopy closes, overall habitat quality declines; shaded understory vegetation dies, reducing wildlife food and cover (Moorman and Hamilton, 2005). Management practices in pine plantations have direct impacts on stand dynamics and structure and will greatly influence biodiversity (Carnus et al., 2006). Factors such as intensity of site preparation, stand establishment, control of competing vegetation, thinning, pruning, and timing of harvest largely determine the rate of stand development and changes in tree architecture and stand structure, all that affect biodiversity (Carnus et al., 2006). Clear cutting and short rotations favor early successional species and long-lived climax species may not be present while older stands can provide habitat for native shade-tolerant species typical of naturally-regenerated forests (Carnus et al., 2006).

Over the course of a typical 15-20-year pine pulpwood rotation, site preparation and site establishment activities will generally reduce the richness and abundance of plantation pine-associated vegetation early in the rotation (i.e., approximately year 0-5). Following this initial period of competition repression, plantation pine-associated vegetation may recover somewhat in terms of richness and abundance, but will almost always be reduced again upon canopy closure of the planted pine species (i.e., approximately year 8). By the end of the rotation cycle, shade-tolerant plant species may be present in the plantation pine understory, but will generally not represent a large or substantial plant community within that plantation pine understory (Section 4.3.5).

Similar to plant community diversity, the wildlife community in intensively-managed plantation pine stands is generally reduced in terms of richness and abundance compared to primary forest, although they are more beneficial to biodiversity than agricultural and other degraded lands (Carnus et al., 2006) (Section 4.3.6). Small mammals are abundant during the early successional stages of the pine plantation, before canopy closure. The abundance of small mammals on pine plantations, 2-4 years old, is likely due to the vegetative changes associated with early succession. As tree canopy development occurs and understory vegetation is suppressed, habitat quality for small mammals may be reduced (Hanberry et al., 2013). However, bats that roost in trees prefer older (15 years or more), tall and large-diameter pine trees.

Breeding bird density and diversity is high in young pine stands, where grasses, forbs, and shrubs compose a well-developed understory. Bird diversity decreases in middle-aged pine stands with closing canopies that shade out understory plants, and this effect increases to the highest level in structurally diverse older stands with several layers of foliage (Dickson et al., 1995) (Section 4.3.6).

Reptile and amphibian species present in pine plantations also change as the stand ages. These species are present within isolated wetlands, bottomland hardwood forests, or streamside management zones within the plantation. Gopher tortoises generally inhabit upland ecosystems characterized by sandy soils, pine forests, and abundant herbaceous understory.

Invertebrates are another important component of the forest biome. Diversity of dipterans (flies) is greatest in young, open pine stands and declines as pine succession produces a closed canopy (Allgood et al., 2009). In one Texas pine plantation study, the soil and litter arthropod community recovered rapidly from tree removal and site preparation disturbance. This indicated that silvicultural practices don't affect diversity of these species types (Bird et al., 2000). For syrphid flies and carabid beetles, no differences in species richness and diversity were recorded between semi-natural stands and plantations (Humphrey et al., 1999).

Another study compared arthropods in cleared and thinned pine plantations, comparing species richness, diversity, and community similarity. Arthropod diversity and richness were similar between a treated and an un-manipulated control treatment. However, different treatment groups supported different arthropod species assemblages, suggesting that different successional stages support communities containing different assemblages of arthropod species (Burkhalter et al., 2013).

Conservation of biodiversity in intensively managed forests has become an increasingly important topic to the public and scientists (Carnus et al., 2006; Brockerhoff et al., 2008; Miller et al., 2009). Approximately 90 percent of the forestland in the Southern United States today is in private ownership and much of it is dense plantations of fast-growing loblolly pine (Andreu et al., 2011). The management intensity of southern pine plantations has been increasing in recent decades (Stanturf et al., 2003). Landowners are facing increased demand from the public to conserve biodiversity on their lands, which can lead to conflict over forest management practices that balance between conservation and production (Palik et al., 2002; Lindenmayer et al., 2003; Zobrist, 2005; Andreu et al., 2011). Certain management practices associated with intensive pine management may have consequences on biodiversity. Some examples include mechanical site preparation using root-raking or chopping that may eliminate native plant species and may encourage invasive species (Van Lear et al., 2005). However, there are management practices used in pine plantations to increase biodiversity. These have been reviewed by (Zobrist, 2005). These practices are discussed below.

Management Practices to Increase Biodiversity in Pine Plantations

- Maintaining structural diversity throughout the landscape is recommended to increase biodiversity in plantations (Fischer et al., 2006). As mentioned in the No Action analysis of wildlife, structural diversity is often associated with increased wildlife richness and abundance (Section 4.3.6). A way to increase with-in stand structural diversity in pine plantations is to maintain an open canopy that allows a more diverse understory to develop that provides wildlife habitat (Andreu et al., 2011). Maintaining an open canopy with a productive understory makes plantations more similar to natural pine communities (Bragg, 2002; Zobrist, 2005; Andreu et al., 2011). Planting fewer trees per acre can achieve also this, using a wide spacing to delay canopy closure. Ober et al. (2009) suggest planting 300 to 500 trees per acre instead of 600 trees per acre to allow more sunlight to reach the forest floor, allowing for growth of understory and ground cover. Because wide spacing can result in poor wood quality, rather than decreasing planting density, trees can be planted at a high density and later thinned. Similar to reduced density planting, thinning increases biodiversity because it creates an open, diverse structure of the stand where more light reaches the forest floor. This allows for growth of an herbaceous understory that provides habitat for many species (Andreu et al., 2011).

- Managing timber on long rotations ensures that a greater number of stands will be producing quality habitat for a variety of wildlife species at any particular point in time (Ober et al., 2009). This would involve transitioning pine stands from pulpwood to other timber products. Increasing rotation length has been advocated as a means to enhance native biodiversity in plantations but can prove uneconomical because financial profitability decreases after a certain stand age (Brockerhoff et al., 2008).

- Promote cavities, snags, and logs (Ober et al., 2009). Snags are standing dead or dying trees and are important for many vertebrates for basking, nesting, foraging, perching, denning, and roosting (Jones et al., 2009b). Snag removal in older (40−50 year) loblolly pine plantations affected bird diversity (Lohr et al., 2002). When snags fall to the ground, they create log habitat for shelter, basking, navigational aids, and a food source for wildlife (Ober et al., 2009).

- Use herbicides to selectively control the hardwood mid-story that blocks light from getting to the ground and prevents herbaceous ground cover (Ober et al., 2009). However, in herbicide studies in loblolly pine plantations, controlling both woody and herbaceous vegetation provided the greatest increases in marketable wood volume compared to controlling only woody vegetation (Wagner et al., 2004), potentially resulting in a cost to producers that preserve the herbaceous ground cover. Herbicides may improve biodiversity of plant species in pine plantations when they are used for control of invasive plants that can outcompete native vegetation (Miller and Miller, 2004b). Miller and Miller (2004a) suggest herbicide practices that enhance diversity including varying herbicides among stands, leaving untreated areas, protecting special habitat features or habitat types, and use of alternative vegetation management techniques.

- Use fire to stimulate non-woody ground cover and to control hardwoods (Ober et al., 2009). Prescribed burning in combination with thinning can increase biodiversity to control hardwoods and maintain an open stand structure with a productive and diverse understory. Burning maintains a diverse groundcover characteristic of longleaf pine forests even on sites that have been planted to other *Pinus* species (Tucker et al., 1998). Palik et al. (2002) suggested that long-leaf pine stands should be under-burned every 1 to 3 years. However, fires in different seasons can benefit plant species differently (Hiers et al., 2000).

- Use longleaf pine (*Pinus palustris*) for pine plantations because it is more resistant to insects and diseases, allows more sunlight to reach the forest floor, is longer lived, and is preferred by red-cockaded woodpeckers (Ober et al., 2009). However, it should be noted that growers may be unwilling to use longleaf pines because of their slow growth characteristic compared to rapid-growing slash and loblolly pine. New plantations should use native tree species to increase within-plantation biodiversity, although exotic plantations do support some biodiversity (Bremer and Farley, 2010).

- Leave woody material behind after logging (Ober et al., 2009). Logging debris (slash) or coarse wood material can be a valuable food source and provides cover for wildlife (Ober et al., 2009). Small mammals use it for travel pathways to avoid predators, and birds use it for perching, nesting, foraging, and displaying for mating and territory defense purposes (Jones et al., 2009a).

- Maintain habitat diversity by providing diverse food sources in the areas next to managed pine stands, not converting drainages and bottomland to pine, and providing a diversity of cover options (Ober et al., 2009). The occurrence of multiple structural classes of loblolly pine forest benefitted both resident and early-successional Neotropical migrant birds (Wigley et al., 2000). Maintaining early successional habitats and deciduous woodland patches in a conifer plantation matrix can increase biodiversity by creating spatial heterogeneity (Barbaro et al., 2005; Barbaro et al., 2007).

- Create travel corridors where forest stands are isolated by planting 3−5 rows of trees to connect isolated stands to increase animal movement between stands (Ober et al., 2009). Besides being beneficial to wildlife, corridors can benefit native plant species. In a longleaf pine study, patches connected by corridors retained more native plant species than isolated patches, and corridors did not promote invasion by exotic species (Damschen et al., 2006).

- Protect riparian, aquatic, and wetland areas for drinking water and for vegetation growth (Ober et al., 2009). Wetlands in southern plantations are important habitat features for reptiles and amphibians such as toads and snakes (Ober et al., 2009).

Factors Affecting Biodiversity in Southern Forests

Although there are management practices that can contribute to increased biodiversity in pine plantations, there are several factors that can adversely impact biodiversity at a regional scale in the Southern United States.

Invasive species

Invasive species are one of the greatest threats to plant and animal communities and native species. Invasive species can cause extinction of certain species (Clavero and García-Berthou, 2005) and can modify ecosystems properties (Gordon, 1998). This can occur through habitat modification, competition for resources, predation, herbivory, and introduction of pathogens. The southern United States has the highest number of introduced plant species on the continent, many of which are in or near the longleaf pine ecosystem (Van Lear et al., 2005). For example, cogongrass (*Imperata cylindrica*) was accidentally introduced into the southeastern United States from Japan and is affecting both natural and planted forests (Jose et al., 2002). Cogongrass disrupts ecosystem functions, reduces wildlife habitat, decreases tree seedling growth and establishment success, and alters fire regimes and intensity. Japanese climbing fern (*Lygodium japonicum*) is another invasive plant species in pine plantations in Florida. The plant smothers native vegetation by blocking sunlight and increases fire risk by allowing fire to spread up trees along its vines (Minogue et al., 2009).

Urbanization

Urban development (urbanization) causes some of the greatest local extinction rates and frequently eliminates the large majority of native species because of habitat loss (Minogue et al., 2009). Wear and

Greis (2012) project "from the base year of 1997 to 2060, an additional 30 to 43 million acres of southern rural lands are forecasted to be converted into urban uses". They estimate total forest loss to range from 11 to 23 million acres, depending on the rate of population growth and the future of timber markets (Wear and Greis, 2011). Impacts from urbanization also include increased forest fragmentation, increased human presence in remaining forests, inability to use fire to manage forests, and reduced water quality protection (Wear and Greis, 2011). Urban development in areas of Texas and Louisiana could impact a large number of reptiles and birds, could imperil the diversity of salamanders in the southern Appalachian (Griep and Collins, 2013).

Expansion of pine plantations for pulpwood

Wear and Greiss (2011) project that planted pine could expand by as much as 28 million acres for bioenergy uses—from 39 million acres in 2010 to about 67 million acres in 2060, and most would come from conversions of natural pine forests after harvesting. They concluded that "forecasted levels of woody biomass harvests could lead to a reduction of stand productivity, deterioration of biodiversity, depletion of soil fertility, and a decline in water quality."

Conclusions

Pine plantations may not be as biologically diverse as natural forest land, but they compare favorably to land used for agriculture or urbanization (Moore and Allen, 1999; Lindenmayer et al., 2003; Brockerhoff et al., 2008; Bremer and Farley, 2010). Bremer and Farley (2010) found that the value of plantations for biodiversity depends on whether the original land cover was grassland, shrubland, primary forest, secondary forest, or degraded or exotic pasture, and whether native or exotic trees are planted. Study findings determined that plantations are more likely to contribute to biodiversity when established on degraded lands and when native species are used, but plantations do not restore biodiversity to levels found in primary forest (Bremer and Farley, 2010). However, where plantation forests are established on abandoned pastures or degraded land, they usually are more beneficial to biodiversity than such modified agricultural areas or urban areas (Carnus et al., 2006).

Establishing and maintaining a diversity of habitat within a plantation forest is important for maintaining biodiversity (Lindenmayer et al., 2003; Jones et al., 2009a). Biodiversity conservation in production landscapes such as pine plantations sustains vital ecosystem services and protects global biodiversity (Fischer et al., 2006). Plantations can contribute to biodiversity through habitat supplementation to forest species, improving connectivity between native forest remnants, and by buffering remnant forest from undesirable edge effects (higher sunlight, vapor pressure, wind, etc.) (Brockerhoff et al., 2008). Even minor management changes can conserve biodiversity in a pine plantation with little or no reduction in production (Hartley, 2002). However, other factors, including invasive species, urbanization, and conversion of primary forests can result in an overall reduction of biodiversity at a regional scale.

4.4 Preferred Alternative

Under the Preferred Alternative, APHIS would approve the ArborGen petition for non-regulated status. FTE and its progeny could be grown and shipped without a permit from APHIS BRS. This section analyzes the impacts of that decision. Here we consider the direct and indirect impacts of that decision on natural and biological resources (previously described in Section 2.1.2)

4.5 Assumptions used in the Analysis of the Preferred Alternative

4.5.1 The FTE Action Area Consists of 204 Counties Across Seven Southern States

On February 27th, 2013, APHIS published a NOI to prepare an EIS for FTE (78 FR 13309) in response to APHIS petition no. 11-019-01p from AborGen Inc., seeking a determination of non-regulated status for two FTE lines designated 427 and 435. Along with this publication, a figure showing the potential FTE study region was also published by APHIS (Figure 16(A)). This potential FTE study region represented all of USDA plant hardiness zones 8b and higher, which included portions of the Southeastern, Southwestern, and Western United States.

Further refinement of the potential FTE study region shown in Figure 16(B) was undertaken by the USDA-FS in the technical report entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B). This additional refinement was undertaken because it was recognized that as commercial tree species, viable cultivation of *Eucalyptus* is limited not only by cold sensitivity, but also by other environmental factors that may affect its potential productivity (Appendix B). As another potential commercial tree species, FTE is no different from other cultivated non-GE *Eucalyptus* species in this regard.

USDA-FS, a cooperating agency on this EIS, utilized three additional important environmental factors[37] associated with *Eucalyptus* productivity to further refine the potential FTE study region. The use of these three additional environmental factors, in conjunction with an economic analysis of counties where FTE would most likely be cultivated, resulted in the geographic area identified in Figure 16(B). Additional details about this refinement process and a description of the FTE action area itself can be found in Appendix B and summarized in Section 4.6.1.

[37] Mean annual precipitation, mean daily solar radiation, and mean annual daily temperature

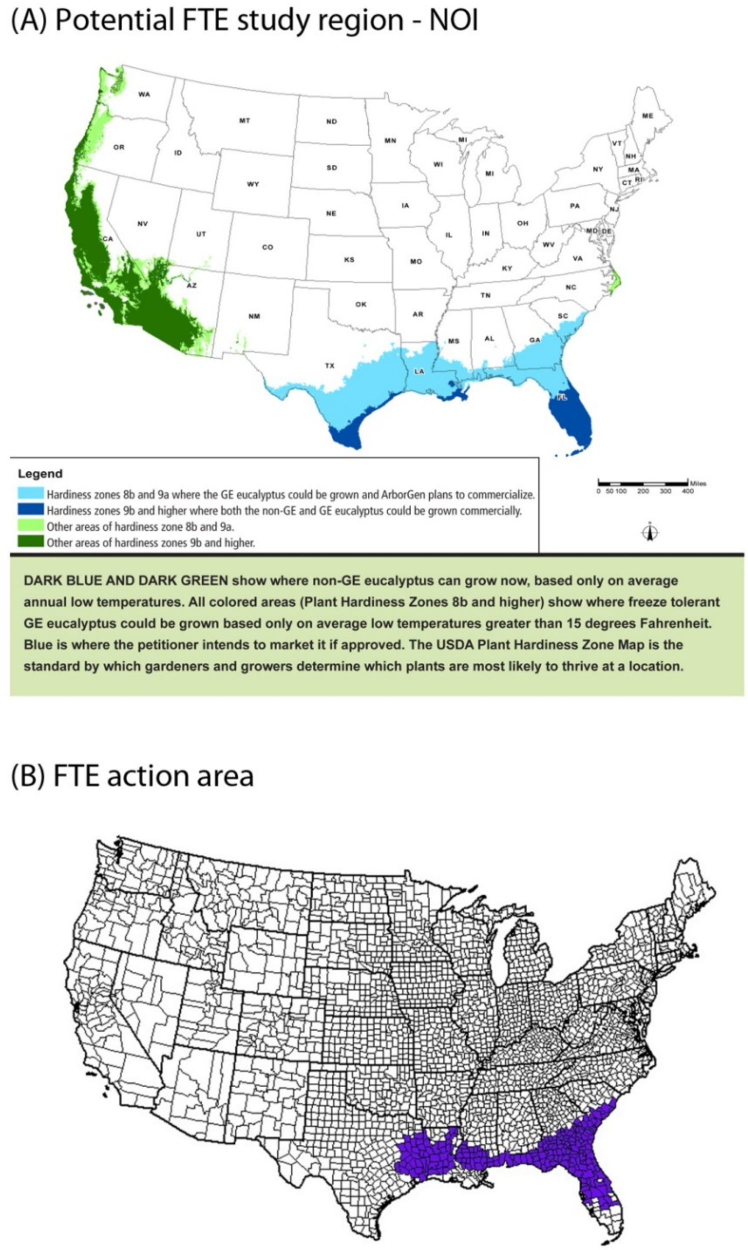

Figure 16. Potential FTE Study Region From the NOI Versus the FTE Action Area Considered in this EIS

4.5.2 The Baseline for Comparison of the Potential Impacts Resulting from the Preferred Alternative are Potential Impacts Resulting from the No Action Alternative

As previously discussed in Section 4.2.2 and Appendix B, FTE is likely to be planted on land previously planted to plantation pine under the Preferred Alternative. Accordingly, any potential impacts resulting from planting FTE (i.e., potential impacts resulting from the Preferred Alternative) is appropriately compared to potential impacts resulting from the continued planting of plantation pine (i.e., potential impacts resulting from the No Action Alternative).

As a result of these analyses, conversion of other land use types (e.g., fallow agricultural fields, publically-owned forests, etc.) to FTE plantations will not be considered under the scope of the Preferred Alternative analysis. Accordingly, potential impacts from the afforestation[38] or deforestation[39] of other land use types will not be considered as a baseline for comparison to the Preferred Alternative.

Additional information about the methodology used to establish plantation pine as the comparison baseline to FTE may be found in the USDA-FS technical report entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B). Additionally, this information will be summarized in Section 4.6.1 (Potential Impact on Land Use Resulting from the Preferred Alternative).

Furthermore, it is worth noting that the specific management conditions and rotation cycle length of FTE and/or southern plantation pine may slightly differ between the analyses presented in the USDA-FS technical reports (Appendices B through D) and the analyses presented here under the Preferred Alternative. These minor differences in specific management practices and rotation cycle length are largely reflective of geographic differences and individual objectives of the land owner. While there may exist minor differences in management conditions and rotations cycle lengths for FTE and/or southern plantation pine, what is crucially maintained in the various Preferred Alternative analyses is the ratio of rotation cycle length between FTE and southern plantation pine (i.e., 2:1, southern plantation pine to FTE).

4.5.3 The Fire Risk from Planting FTE is not Significantly Different than the Fire Risk from Planting Plantation Pine

Eucalyptus is a fire-adapted tree species in its native range (USDA-APHIS, 2006; USDA-APHIS, 2012), much like planted plantation pine is here within the Southern United States (Stanturf et al., 2002; Watts, 2013).

Due to the fire adaptation of *Eucalyptus* and the absence of large-scale commercial plantings of *Eucalyptus* in the FTE action area, the potential impact to fire risk within the FTE action area was uncertain. As a result, APHIS approached the Fire and Environmental Research Applications Team (FERA) of the Pacific Northwest Research Station to assess the potential fire risk of planting FTE within the FTE action area. Because no or very little quantitative data regarding the fire risk of *Eucalyptus* within the FTE action area was available, FERA undertook a mathematical modeling approach using the Fuel Characteristic Classification System (FCCS). FCCS was used to evaluate and compare the fire risk of planting FTE under various scenarios to other common land uses within the FTE action area. The FCCS was previously utilized to evaluate the fire risk of planting *Eucalyptus* in certain areas within the Southern United States by Stanturf et al. (2013b), though this current USDA-FS FERA effort can be considered more exhaustive of a study. The culmination of this effort is the USDA-FS FERA technical

[38] Afforestation is the planting of trees on land that did not previously contain trees
[39] Reforestation is the active planting of trees in an area that previously contained trees

report entitled *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States* (Appendix D)

Based on FCCS predictions contained within the USDA-FS FERA technical report, it was concluded that in general, FTE does not pose a substantially higher fire risk over the life of its rotation than Southern planted pine plantations or any other common land use type[40] within the FTE action area. While some individual component scores of FTE may be higher than planted plantation pine (e.g., spreading potential), these are often offset by other individual components scores that are actually lower than planted plantation pine (e.g., surface fire potential). Thus, the overall fire risk from planting FTE under the Preferred Alternative is not considered substantially different than the overall fire risk from planting plantation pine under the No Action Alternative (Appendix D). Considering that the overall fire risk from planting FTE is not considered substantially different than the overall fire risk from planting plantation pine, then there can also be no substantial impact on current fire regimes under the Preferred Alternative compared to the No Action Alternative.

During the comment period for previous APHIS EAs for the permitted field testing of GE *Eucalyptus*, comments were received suggesting that wildfire in unmanaged stands of California *Eucalyptus* provided evidence that GE *Eucalyptus* stands also presented a fire risk (USDA-APHIS, 2010; USDA-APHIS, 2012). However, it is prudent to mention that the understory of unmanaged (i.e., naturalized *Eucalyptus* species in California) and managed *Eucalyptus* (i.e., FTE plantations within the action area) stands differ in both content and structure. This is particularly relevant in the context of forested wildfires, as the understory of forested stands represent a primary fuel source. As noted in the USDA-FS FERA technical report entitled *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States* (Appendix D), understory vegetation and structure within short-rotation FTE stands is likely to be minimal, in contrast to the understory in unmanaged and older California *Eucalyptus* stands (USDA-APHIS, 2010). Thus, the primary source of fuel for wildfires in unmanaged and older California *Eucalyptus* stands is not likely to be present in the same amount as in FTE plantations within the action area.

Additional and more specific details regarding these fire risk conclusions may be found in the USDA-FS FERA technical report entitled *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States* (Appendix D).

4.5.4 FTE is Unlikely to Pose a Plant Pest Risk

Along with the publication of this EIS, APHIS is also publishing a preliminary Plant Pest Risk Assessment (PPRA) of FTE (USDA-APHIS, 2015). General conclusions regarding plant pest risk from the PPRA include:

- There is no plant pest risk from the inserted genetic material and there was no atypical responses to disease or plant pests in the field and indirect plant pest impacts on other agricultural products;
- There is the potential that if the trees are commercially successful and there are increased plantings of the *Eucalyptus* in areas of the Southeast where *Eucalyptus* trees are not currently grown, pest and diseases already present in the United States. could become more widespread as the plantings of *Eucalyptus* are expanded;

[40] Where vegetation is dominant

- Sufficient control methods would need to be put in place if there were an increase in the incidence and severity of insect or disease pests. Therefore management of plantations for pests would be needed, as for any other forestry species; and
- There is also no evidence of deleterious effects on non-targets or beneficial organisms in the agro-ecosystem due to the insertion and expression of the new genes.

In addition to an assessment of plant pest risk, the preliminary PPRA also performed a weed risk assessment (WRA) of FTE. General conclusions from this WRA include:

- There is a possibility, with high uncertainty, that the transgenic trees could become naturalized over time if widely planted and could become a minor invader if the plantations are not properly managed;
- Management and oversight of the plantations would be needed to ensure that plants do not inadvertently escape and persist beyond cultivation over time. Due to their slow ability to naturalize this should be easily done;
- The trees are not expected to impact the weediness of other plants with which they can interbreed because the formation of natural hybrids is considered unlikely. In the unlikely event that hybrids were to be formed, they would be in the vicinity of established plantations; and
- Abandoned plantations could be problematic and measures would need to be taken to either remove the trees or monitor for the escape of seedlings and remove them.

As a result of this preliminary PPRA, APHIS concludes that FTE is unlikely to pose a plant pest risk as long as there is proper management and oversight of FTE plantations during establishment and over the life of its rotation cycle (USDA-APHIS, 2015). More specific information regarding this plant pest risk assessment may be found in the APHIS preliminary PPRA for FTE (2015).

For the purposes of this Preferred Alternative analysis, APHIS will assume that land mangers that choose to cultivate FTE in plantation will follow typical management practices to maximize wood yield, and thus, economic returns. As a result of these typical management practices, scenarios (i.e., plantation abandonment) that could potentially lead to escape of FTE from plantation sites in the short term would likely be avoided.

However, APHIS recognizes that FTE stand abandonment could potentially take place. This potential aspect resulting from FTE cultivation will be presented and discussed in the Cumulative Impacts Analysis (Chapter 5) of this EIS.

4.5.5 FTE is not Anticipated to Present a Risk to Human Health

In previous comment periods for GE *Eucalyptus* EAs, some public concern was raised regarding the possibility of a causal relationship between the planting GE *Eucalyptus* trees and increasing incidences of *Cryptococcus gattii* infection in humans (USDA-APHIS, 2006; USDA-APHIS, 2010; USDA-APHIS, 2012). While APHIS responded to this concern in the Response to Comments and Finding of No Significant Impact (FONSI) documents for each of those EAs (USDA-APHIS, 2006; USDA-APHIS, 2010; USDA-APHIS, 2012), the information is summarized below for the purposes of establishing that FTE is not anticipated to present a risk to human health under the Preferred Alternative.

C. gattii is a fungal pathogen that can infect the pulmonary and central nervous system of humans and animals. Since being first identified within North America in the Pacific Northwest, more than 200 cases of *C. gattii* have been reported in humans (Datta et al., 2009). Despite its identification as a disease causal agent in this area in 1999, data from genetic studies suggests that this organism may have been present in the area for more than 30 years.

Despite its presence in the Pacific Northwest and its world-wide distribution, *C. gattii* is not a common fungus (Upton et al., 2007; Datta et al., 2009). Its inherent adaptability, coupled with a changing climate, may lead to its geographic spread in North America, though the extent of this spread is uncertain (Upton et al., 2007; Datta et al., 2009).

While *C. gattii* is an emerging pathogen that can have significant effects on those infected with the fungus, the extent of the association between it and *Eucalyptus* is much less certain. Ellis and Pfeiffer (1990) suggested that the sole source of *C. gattii* in *Australia* was *Eucalyptus camaldulensis* in Australia. However, since that publication, other publications have demonstrated that *C. gattii* may be associated with other tree species beyond *Eucalyptus* (Kidd et al., 2007; Datta et al., 2009). Furthermore, the non-GE hybrid that FTE is generated from does not represent a *Eucalyptus* species that *C. gattii* has been isolated from (Kidd et al., 2007; Datta et al., 2009; USDA-APHIS, 2015).

Based on available information, it appears that any increase in the occurrence of *C. gatti* as a result of planting of FTE would be negligible for several reasons. First, although *Eucalyptus* is present in many of the areas of the world known to have *C. gattii* cryptococcosis, the actual isolation of *C. gattii* from *Eucalyptus* trees is rare outside Australia, despite extensive sampling. By example, while *Eucalyptus* trees thrive in Southern California, *C. gattii*, has rarely been isolated from *Eucalyptus* trees in this area, and in the pacific northwest and British Columbia, where *C. gattii* was first identified in North America (Kidd et al., 2007; Springer et al., 2014). Most recently it was recently found that *C. gattii* in southern California was not associated with Eucalyptus, but three other species of trees; Canary Island pine, New Zealand pohutukawa, and American sweet gum (Springer et al., 2014). Second, *C. gattii* is associated with a variety of tree species (54 tree species); most (77%) are angiosperms; gymnosperms account for 23% of positive species (Springer and Chaturvedi, 2010). *C. gattii* exhibits associations with tree types such as *Abies* spp. (Firs); *Arbutus* spp. (Arbutus); *Cedrus* spp. (Cedar); *Picea* spp. (Spruce); *Pinus* spp. (Pine); *Pseudotsuga menziesii* var. (Douglas Fir); and *Thuja plicata* (Pacific redcedar). Angiosperms other than *Eucalyptus* spp. have been reported positive for *C. gattii* from North America, South America, Africa, and India. Two prominent examples are *Ficus* spp. (Ficus) and *Terminalia* spp. (almond) trees (Springer and Chaturvedi, 2010). As for other reservoirs for *C. gattii*, the predominant reservoir appears to be soil (Kidd et al., 2007; Springer and Chaturvedi, 2010).

Considering current data, *Eucalyptus* spp. does not appear to confer any special reservoir, or ecological niche, for hosting of *C. gattii*, and it is unlikely that the planting of FTE, particularly the supplanting of some planted pine plantation with FTE, will lead to an increase of *C. gattii* in the environment. As such, the likelihood that FTE will present any human health risk in the way of cryptococcosis, is negligible.

Additional information regarding *C. gatti* and GE *Eucalyptus* may be found in previous EAs and associated APHIS (2006; 2010; 2012) documents for the permitted field trials of GE *Eucalyptus*[41].

4.5.6 Herbicide Use is Under the Regulatory Purview of the EPA

Any herbicide (or any other pesticide) in the United States must be registered by the EPA prior to any specific use in the United States. EPA regulates pesticide use under broad authority granted by the

[41] http://www.aphis.usda.gov/brs/biotech_ea_permits.html

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (see 21 U.S.C. § 301 et seq.). EPA defines pesticide registration as:

> … a scientific, legal, and administrative procedure through which EPA examines the ingredients of the pesticide; the particular site or crop on which it is to be used; the amount, frequency, and timing of its use; and store and disposal practices. In evaluating a pesticide registration application, EPA assesses a wide variety of potential human health and environmental effects associated with the use of the product (EPA, 2013d).

EPA requires a variety of pre-defined tests in a pesticide registration package. The potential pesticide registrant must provide this data, according to EPA guidelines (EPA, 2013d). The data resulting from these tests is used by the EPA to produce an ecological risk assessment and human health risk assessment in order to:

> …evaluate whether a pesticide has the potential to cause adverse effects on humans, wildlife, fish, and plants, including endangered species and non-target organisms, as well as possible contamination of surface water or ground water from leaching, runoff, and spray drift. Potential human risks range from short-term toxicity to long-term effects such as cancer and reproductive system disorders (EPA, 2013d).

Following submission of a complete pesticide registration package, EPA may decide to register or not register a pesticide. If EPA decides to register a pesticide, then the pesticide can only be used:

> …legally according to the directions on the labeling accompanying it at the time of sale. Following label instructions carefully and precisely is necessary to ensure safe use (EPA, 2013d).

As a result of this pesticide registration process by EPA, any EPA-registered pesticide used in the United States:

> …if used in accordance with specifications, they will not cause unreasonable harm to the environment (EPA, 2013d).

With this established EPA oversight on pesticides and the pesticide registration process in place, this EIS assumes that end users of pesticides, such as land managers cultivating plantation pine, will follow the label and that no unreasonable harm will occur to the environment as a result of EPA-labeled pesticide use.

4.5.7 Resource Area-Specific Assumptions

The methodology in determining specific resource areas[42] for inclusion into this EIS was previously discussed in Section 3.3. For each resource area, a separate set of resource area-specific assumptions may have been used to facilitate the Preferred Alternative Analysis for that particular resource area. If that

[42] Land use; Air quality ; Soil resources; Water resources; Vegetation; Wildlife; Insect and disease pests; and Biological diversity

were the case, those resource area-specific assumptions will be presented in text preceding the actual Preferred Alternative Analysis for that particular resource area.

4.6 Potential Impacts Resulting from the Preferred Alternative

4.6.1 Potential Impact on Land Use Resulting from the Preferred Alternative

4.6.1.1 Summary of the Preferred Alternative on Land use

To determine FTE adoption rates, APHIS coordinated with USDA-FS to model the potential adoption of FTE plantations. The model started by limiting the range where FTE can be commercially grown to a portion of the Southeastern United States from eastern Texas to South Carolina. The study then examined the economics of timber markets and FTE to project the potential extent of adoption as well as any potential shifts in land use to support commercial FTE production.

FTE may be potentially adopted by pine plantation land managers across 204 counties in South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. Additionally, FTE was found to be potentially competitive with planted pine forests especially in the western part of the Southeastern United States (Texas, Louisiana, and Mississippi). This competitive position derives from strong growth in real hardwood pulpwood prices over the past two decades. In contrast, FTE would not be competitive with cropland, as current cropland returns exceed projected FTE returns by an order of 3 to 5 times, making it unlikely that growers will convert cropland to FTE plantations. The USDA-FS model projects between 0.8 million acres and 1.4 million acres of FTE to be planted on lands currently devoted to planted pine by year 30.

Adoption of FTE in the study area is not anticipated to affect overall land use patterns described in the No Action Alternative. Declining trends in net forested land and cropland uses are not anticipated to change as a result of adoption of FTE within the study region, as the primary drivers of government policy and economics are not anticipated to change under the Preferred Alternative.

4.6.1.2 Preferred Alternative Analysis on Land Use

<u>Introduction and Assumptions</u>

At present, FTE is not cultivated within the action area and *Eucalyptus* is not commercially cultivated on a large scale within the action area. Due to the absence of empirical FTE data in the action area, it was necessary to model FTE adoption rates in order to determine if any potential impacts on land use would occur. Modeling provides an alternative approach to determine potential impacts on land use, thus further informing any potential regulatory decision regarding FTE.

Any conclusions specifically related to FTE and its potential range and adoption rates may be considered a summary of results from the USDA-FS technical report produced for APHIS, entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations,* unless otherwise stated. This technical report may be found in Appendix B.

The USDA-FS analysis is based on several assumptions. These assumptions include:

- The freeze tolerance conferred by the FTE will be successful in preventing substantial freeze damage to planted trees within plant hardiness zone 8b and higher;

- Irrigation would not be used to grow *Eucalyptus* in arid regions of the southwestern United States;
- Productivity is essentially uniform across the southeastern United States;
- Forest areas likely to switch would be limited to the current area of planted pine because this is the portion of the region's forests that has demonstrated economic feasibility for tree plantations. This forested land use type was used as a starting point for the analysis, though other land use types were also considered; and
- The behavior of returns for each of the land uses will remain unchanged into the future (USDA-FS did not explicitly address the impacts of shifting timber supply on future market equilibrium).

Additional details regarding these assumptions may be found in the USDA-FS technical report, entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B). Unless otherwise stated, all data in this Preferred Alternative analysis on land use can be assumed to be derived from the USDA-FS technical report, *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B).

This analysis of the Preferred Alternative on land use will focus on the potential range where FTE can be commercially grown and the potential adoption rates for FTE. First, the method used to limit the action area will be discussed. Second, a description of the USDA-FS model used will be presented. Third, the growers most likely to adopt FTE as well as the adoption rates predicted by the USDA-FS model will be examined. Lastly, the impacts on land use in relation to those already occurring under the No Action Alternative will be discussed.

<u>Refinement of the FTE Study Region</u>

USDA-FS defined the action area in the technical report entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B). The refinement of the study area was necessary because it was recognized that as commercial tree species, viable cultivation of FTE would be limited not only by cold sensitivity, but also by other environmental factors that may affect its potential productivity (Appendix B).

The study area was limited initially by APHIS to USDA plant hardiness zones 8b and higher and implicitly assumes that an effective frost tolerance is conferred upon FTE through the genetic modification (Figure 17, shaded red). This zone encompasses a large area of the Southeastern United States, but also includes much of the Southwestern United States, in addition to California along with coastal areas of Oregon and Washington. Commercial FTE plantings would be limited not only by cold sensitivity, but also by potential productivity, which is influenced by availability of water inputs and solar insolation.

USDA-FS defined the areas where FTE could be a viable crop by screening out areas based on its commercial cultivation requirements for water and solar inputs. First, areas were screened out based on rainfall limitations of current and viable *Eucalyptus* plantations. USDA-FS used total annual rainfall to summarize water availability. USDA-FS screened out areas with average annual precipitation of less than 800 mm/year as unsuitable for plantings in the United States (Figure 17, shaded green). This eliminated the Southwestern United States, from central Texas westward and much of California.

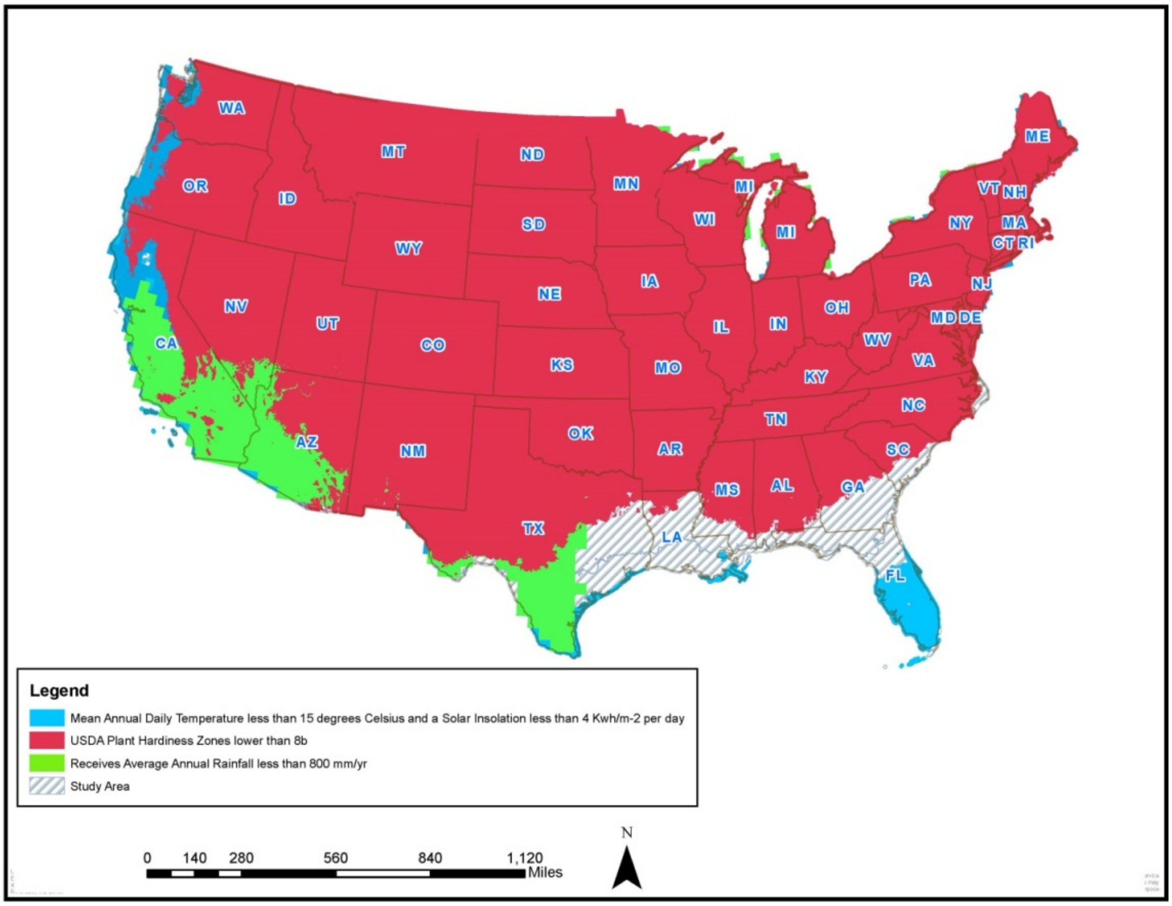

Figure 17. Areas Eliminated From the Study Area

USDA-FS then limited their analysis to areas with solar insolation[43] comparable to the current distribution of productive *Eucalyptus* plantations. They considered two metrics of solar input, mean annual daily temperatures and total solar radiation measured as annual kilowatt hours per square meter per day (Kwh/m^{-2} per day). USDA-FS defined the mean annual daily temperature cutoff as greater than 15 degrees Celsius (about 60 degrees F) and a solar insolation cutoff as 4 Kwh/m^{-2} per day (Figure 17, shaded blue). These screens eliminated from consideration the small section of plant hardiness zone 8b contained in Oregon, Washington, and the southern-most parts of the Southern United States. The action area is therefore limited to the Southeastern United States from East-central Texas to South Carolina.

Model Used to Determine FTE Adoption

The USDA-FS study, *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations,* asks whether and to what degree FTE might be adopted as a preferred land use based on anticipated productivity and economics. The analysis starts by examining the production technology and economics of *Eucalyptus* plantations to estimate potential returns and present net values of potential FTE adoption. These estimates depend on a full accounting of the costs, biophysical productivity, and revenues of management and are based largely on estimates from management of non-GE tree plantations. USDA-

[43] Solar insolation is the amount of solar energy received on a given surface area during a given time.

FS constructed implied historical returns by linking simulated profit functions to historical prices and compared these returns with returns for other land uses including other forest types and cropland. Adoption of FTE will depend not only on expected returns but also on the relative return risk associated with all land uses.

Understanding the potential adoption of FTE requires a model that addresses return risk and uncertainty as well as expected values of returns to determine switching between different possible land uses. Adoption of FTE would depend not only on expected returns but also on the relative return risk associated with all land uses. USDA-FS used a real options land use switching model[44] to compare FTE with existing major land uses to estimate adoption under modeled return and risk conditions. The model simulated land use choices by risk-neutral landowners using estimates of future returns and return variance (based on historical returns) and the costs of land use conversion. The analysis of several model variants regarding return risks, price levels, and productivity allowed USDA-FS to explore how the adoption of FTE could develop under various market conditions. The model anticipates that a risk-neutral decision maker chooses between retaining a current land use or adopting a new land use (FTE) based on a comparison of returns, conversion costs, and uncertainty regarding future returns and reflects profit-maximizing behavior on the part of private landowners. The model indicates that switching may be expected on a portion of planted pine forest land, as this land use has already been demonstrated to be amendable for plantation pine cultivation.

Economics of FTE and Potential Returns

USDA-FS examined the production technology and economics of non-GE *Eucalyptus* plantations to estimate potential returns and present net values of FTE adoption. These estimates depend on a full accounting of the costs, biophysical productivity, and revenues of management and are based largely on estimates from management of non-FTE. These return estimates were then used to determine which land use FTE would be most economically competitive with.

Forest uses dominate the rural landscape in the study area at 59.3 million acres. Pine forest types account for 27 million acres or 46 percent of that total forest area, with 16 million acres (27 percent) in a planted forest condition. Hardwood forest types account for 25 million acres (42 percent) with a majority (15 million acres) in lowland hardwood forest types. The 2012 Census of Agriculture indicates that 16.7 million acres of land was dedicated crop uses within the study region (USDA-NASS, 2015).

Conversion costs include mechanical and chemical site preparation, seedlings, and planting. Management costs include fertilization, herbicide treatments, and annual management costs. Revenues depend on biophysical production and prices. To estimate conversion to FTE the USDA-FS model assumes removals will be sold in hardwood pulpwood market, and use a 16 year management regime. USDA-FS applied historical hardwood prices to FTE return estimates. The steady increase in *Eucalyptus* returns visible in Figure 18 reflects a sustained growth in hardwood pulpwood prices. Values for planted pine, in contrast, have trended slightly downward, while crop returns have varied across most of the time period.

[44] Real option land use switching model uses both geometric Brownian motion and mean reverting models of stochastic returns. For more detailed information on these models refer to the USDA-FS technical report found in Appendix B

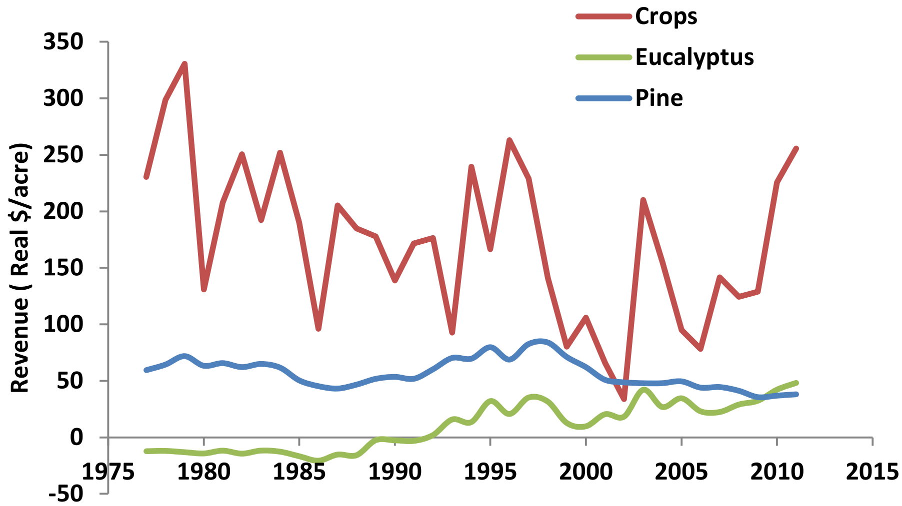

Figure 18. Southeast-Wide Regional Average Returns for Eucalyptus, Planted Pine, and Crop Composite (1977-2011)

FTE is not competitive with cropland. Current cropland returns exceed FTE and pine returns by 3 to 5 times. Land use switching from crops to FTE would be highly unlikely. Based on economic returns FTE could provide comparable returns to planted pine forests, especially in western parts of the study region (TX, LA, MS) (Figure 19). Since returns from *Eucalyptus* and planted pine have been comparable in the recent past, the most likely land use type to switch would be between pine and FTE. This competitive position derives from strong growth in real hardwood pulpwood prices over the past two decades.

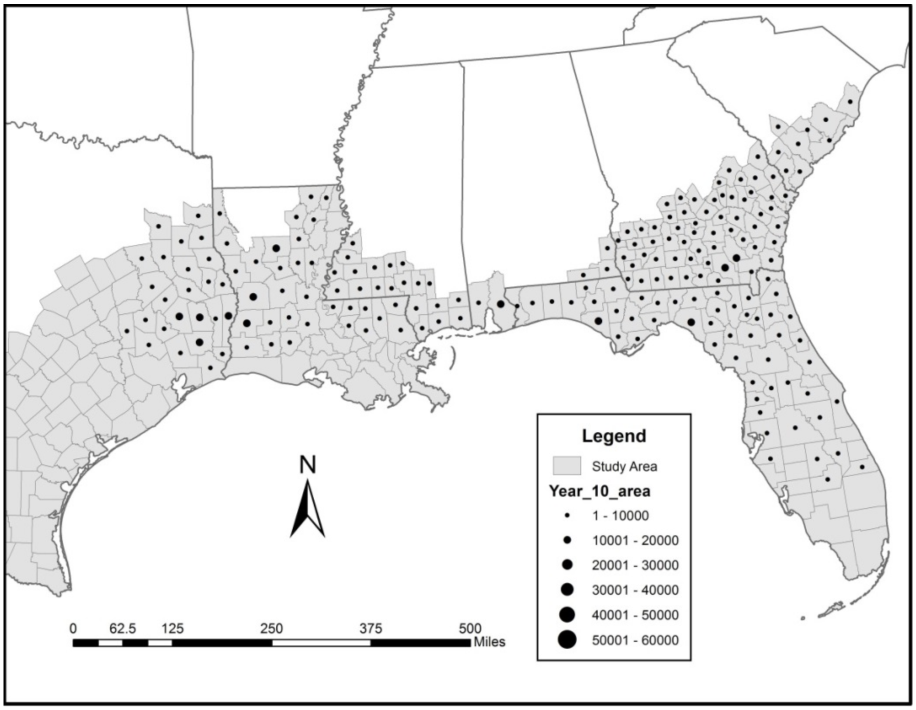

Figure 19. Forecasted Area of Eucalyptus in the Southeastern United States at Year 10 Using the USDA-FS Model

FTE Adoption Rate

FTE adoption was initially examined by USDA-FS using existing market situations and returns as determined above. The USDA-FS switching model uses returns from existing land uses and the constructed FTE returns based on production of hardwood pulpwood. USDA-FS examined a range of assumptions regarding return risks, price levels, and productivity. The model projects between 0.8 million acres and 1.4 million acres of FTE in production by year 30, a conversion of about 5 to 9 percent of planted pine forest area. This model is consistent with a scenario with mild expansion in demands for hardwood material.

To address potential changes to market demands USDA-FS also ran alternative adoption scenarios trough their model. These included: a) the base case scenario, b) higher initial returns for FTE, c) increased correlation between FTE and planted pine returns, d) reduced variance[45] term for FTE returns (equal to variance term for planted pine), and e) 50 percent reduced drift[46] term for FTE returns.

Results of the USDA-FS model, summarized in Figure 20, show that lowering the variance term for FTE returns allows the trend—i.e., an increasing spread between FTE and pine returns—to be more dominant in the projected return series, resulting in an increasing rate of land use switching. Adoption increases as land managers are more confident that markets will provide higher returns for *Eucalyptus* compared to pine. Reducing the drift term by 50 percent lowers adoption of FTE by about 20 percent. Adoption

[45] Amount of drift

[46] The change of the average value of a random process: For this model drift is the change in returns based on historic trends

decreases as returns for E*ucalyptus* are closer to returns for pine. Results further indicate that while FTE may be competitive in terms of expected returns, its higher return variance and conversion costs may limit the degree to which land is actually converted. Projected adoption rates ranged from 2 – 15 percent by year 30 or 0.5 – 2.5 million acres under these various scenarios (Figure 20 and Figure 21). Figure 21 shows that reducing the model drift results in high projections of area switched to *Eucalyptus* over the three decades.

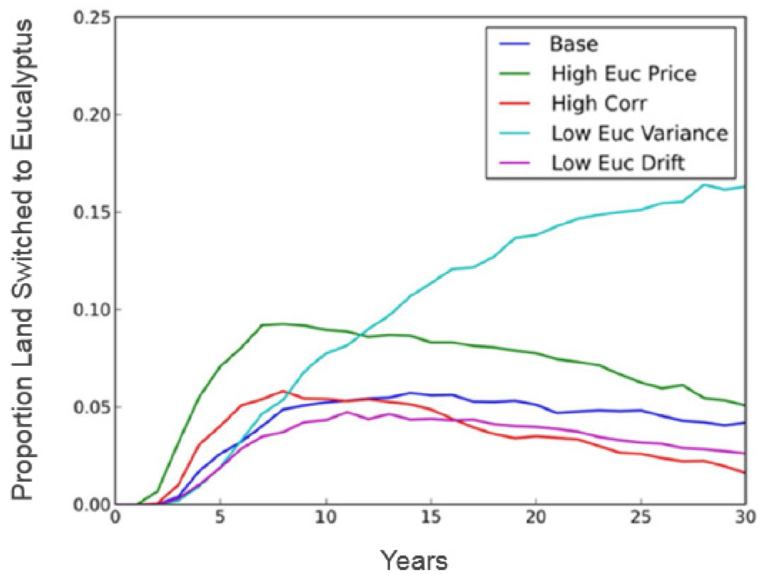

Figure 20. Projected Proportion of Planted Pine Land That Switches to FTE From Year 1 Through Year 30 for Several Modelled Scenarios

Modified from Wear et al., 2013

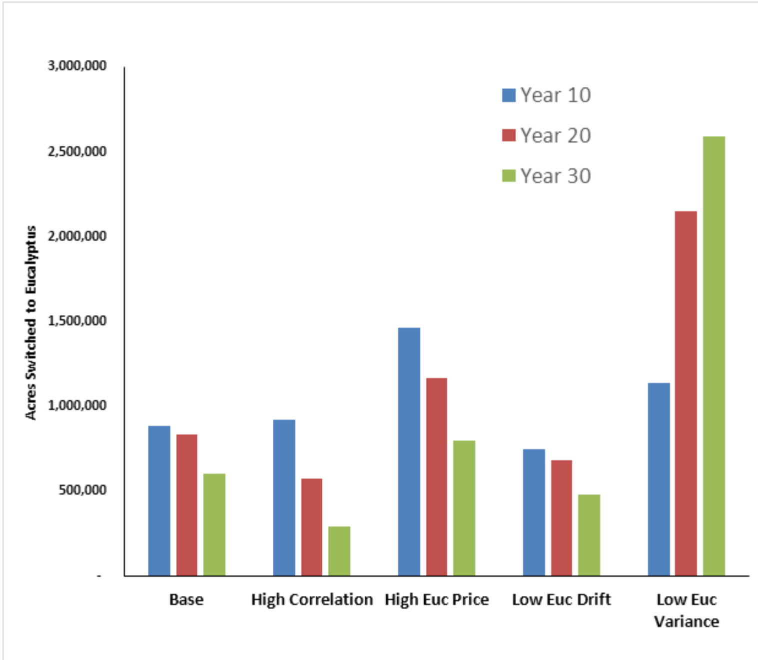

Figure 21. Projected Area of FTE Plantations by Scenario

Applying the model to naturally-regenerated pine in addition to planted pine would shift the projected area of adoption to between 1.35 and 2.75 million acres. This section is limited to the discussion of FTE adoption in areas currently devoted to planted pine. Further discussion of FTE adoption in areas of naturally-regenerated pine forests will be addressed in the Cumulative Impacts analysis (Section 5.4.1).

While the USDA-FS projections are not meant to be precise predictions of the area of FTE adoption, they do demonstrate that under current conditions, a risk-neutral and profit maximizing land owner could choose to adopt FTE as a preferred land use. The extent of that adoption will depend on the future of market prices for various timber products, including new bioenergy products, and on the demonstrated productivity and certainty of production from available FTE seedlings.

Potential Impacts of FTE on Land Use

Compared to the current and projected land use trends described in the No Action Alternative, the Preferred Alternative is unlikely to change these trends. As previously described in Section 4.3.1, acreage planted to plantation pine within the action area is anticipated to increase from 33 million acres in 2010 to 39 million in 2040, while overall forested acreage as well as cropland acreage is predicted to decline during the same time period. The Preferred Alternative is unlikely to have any influence on the overall decreasing trends in forested and cropland uses as both land use types are experiencing a net shift toward urban land uses primarily due to changes in population growth and economics (Section 4.3.1). Under the Preferred Alternative these drivers are not anticipated to change since population growth and economics within the study region are independent of FTE adoption, therefore the decline in overall forested land and cropland uses are also not anticipated to change.

4.6.2 Potential Impact on Air Quality Resulting from the Preferred Alternative

4.6.2.1 Summary of the Preferred Alternative on Air Quality

Under the Preferred Alternative, planting FTE on some lands previously planted with commercial pine species in the action area may occur. Trees remove pollutants from the air and reduce climate-changing greenhouse gases (GHG) in the atmosphere, although the rate of removal depends on the pollutant type, tree type, precipitation levels, and other local site characteristics. In the action area, the main sources for air pollutants are mobile sources and industry. The usage of vehicles and machinery in commercial forestry contribute air pollutants, and FTE will cause an increase in heavy equipment usage because of its short harvest cycle (six to ten years) compared to pine (twenty to twenty-five years). Despite this, the contribution of air pollutants from forestry operations is small in comparison to the other sources of air pollutants in the action area. There is some evidence that *Eucalyptus* produces more volatile organic compounds (VOC) than pine species. VOCs interact with sunlight to produce ozone. Although trees emit VOCs, trees usually result in an overall reduction for ozone because their shade cools temperatures. FTE air quality impacts will not be greater than is already occurring under the No Action Alternative, particularly in the context of existing sources of air pollutants in the action area and the projected overall loss of trees from urban development.

4.6.2.2 Preferred Alternative Analysis on Air Quality

Introduction and Assumptions

Under the Preferred Alternative, planting FTE on some lands previously planted with commercial pine species in the study area may occur. Growers may opt to grow FTE because it is fast growing which leads to shorter rotation cycles, and harvest can occur through coppice (re-sprouting from cut stumps) as opposed to full tree removal and replant.

Trees serve an important role in local and regional air quality through the removal of pollutants from the air (Dwyer et al., 1992; Beckett et al., 1998; Bell and Treshow, 2002; Hanson et al., 2010). Rates of airborne pollution removal vary depending on the pollutant type, leaf season length, and precipitation levels (Dwyer et al., 1992). Recognizing this, the commercial forestry industry develops best management practices for sustainability, and includes strategies for increasing forest carbon stocks through carbon sequestration (Joyce et al., 2014). Trees release stored carbon when burned or through the decay process. Conversion of trees to lumber or other non-combustible wood products does not immediately release carbon stores within the tree.

The purpose of this analysis is to evaluate the impacts to air quality through the replacement of some planted pine plantations with FTE. We consider the important aspects of FTE commercial production that may have potential impacts on air quality and determine if these impacts are substantially different from those already occurring under the No Action Alternative.

Several key assumptions underlay the analysis and frame the remainder of the FTE to pine plantation comparison. These are:

- FTE will be planted on land already designated to planted pine (Appendix B; Section 4.5)
- FTE will be planted on approximately 10 percent or less of the lands already dedicated to planted pine (Appendix B; Section 4.5)

- FTE plantations for pulpwood will grow in a 2:1 harvest time ratio compared to loblolly/slash pine pulpwood plantations (Appendices B and D)

Given the limited information available on *Eucalyptus* cultivation in the United States, including FTE, reliance on *Eucalyptus* research in other countries, technical information provided by ArborGen, Inc., and expert opinion is necessary to understand potential impacts to and from air quality if growers choose to plant FTE in place of some planted pine. Where appropriate, citations for these references occur throughout this section. As with the No Action Alternative, in lieu of specific air quality data that covers each of the 204 counties in the action area, regional air quality data for the Southeast and South regions serve as a proxy to describe the impacts of FTE on air quality.

Commercial *Eucalyptus* Plantation Management and the Potential Impacts to Air Quality

Under the Preferred Alternative, FTE may replace approximately 10 percent of the study area currently planted to pine. USDA-FS predicts expansion of planted pine in the southeast region. For example, planted pine in the Coastal Plain will increase to about 39 million acres by 2040 from about 32.5 million in 2010 (Huggett et al., 2013). Despite the expansion of pine plantations, predictions indicate an overall loss of trees in the southeast region from urbanization (Wear and Greis, 2013; see land use section 4.3.1).

Each tree on a plantation affects air quality. The rate of air pollutant removal by trees varies based on the pollutant type, leaf season length, and precipitation levels (Dwyer et al., 1992). One estimate infers that a mature urban tree can intercept up to 50 pounds of particulates per year (Dwyer et al., 1992).

The density of trees in a plantation is dependent on market factors and site characteristics. The dominant market for plantation pine and FTE in the study area is pulpwood production. In pine plantations, common spacing is between 2.4-m (8-ft) and 3.7-m (12-ft) between rows and 1.8-m (6-ft) and 2.4-m (ca. 8-ft) within rows (Londo and Dicke, 2006). The thinning of trees during mid-rotation in pine plantations reduces the density of trees within the pine stand (Cassidy, 2005). Based on a review of the literature, Schönau and Coetzee (1989) recommend a spacing of 3-m (ca. 10-ft) between rows x 2.5-m (ca. 8-ft) for *Eucalyptus* grown for pulpwood; Sein and Mitlöhner (2011) recommend a spacing of 2.5-m x 2.5-m (ca. 8-ft). The plant spacing recommended for *Eucalyptus* pulp wood production by the petitioner, ArborGen, Inc. (2014), is in line with these recommendations. Based on the literature, the spacing of trees in *Eucalyptus* plantations for pulpwood production in the action area may be slightly less than the spacing in typical southern pine plantations. The potential difference in tree density within the FTE stand versus the pine stand is unlikely to cause a significant change for the interception of pollutants in the commercial plantation. Rather, the overall loss of trees in the southeast region due to urbanization despite the expansion of pine plantations in certain areas (see land use section 4.3.1) will have a greater impact on the interception of air pollutants.

Volatile organic compounds (VOCs) play a role in the production of ozone and carbon monoxide in the atmosphere (Beckett et al., 1998). In the United States, VOC emissions from biogenic (natural) sources account for approximately 74 percent of the VOC emissions; anthropogenic sources, including industrial processes and manmade products, such as power plants, chemical production, solvents, vehicles, and other machinery account for the rest (EPA, 2010b; EPA, 2012i). The southeast region of the United States emits the largest volume of VOCs from anthropogenic sources compared to all other regions (EPA, 2010b). In the study area, biogenic sources of VOC include commercial pine plantations as well as other forest and vegetation areas. *Eucalyptus* species are classified as moderate to high emitters of VOCs compared to other tree species (this comparison does not include *Pinus* species) (Padhy and Varshney, 2005; Singh et al., 2011). In Portugal, *Eucalyptus* forests represent approximately 15 percent of the total forest area but have the same VOC (primarily isoprene and monoterpenes) emission potential of pine forests that occupy an area three times greater (Nunes and Pio, 2001). It is possible replacing 10 percent of pine plantations with FTE could result in an increase in VOC emissions in portions of the study area. On a national level, anthropogenic VOC emissions have been declining (EPA, 2010b) but how this balances the potential increase in VOCs from FTE is unknown. Although trees emit VOCs that can contribute to ozone formation, studies demonstrate that an increase in tree cover actually leads to reduced ozone formation because trees reduce direct sunlight under the tree canopy and cool air temperature at the ground level (Nowak and Dwyer, 2000).

In the United States, mobile sources are a main contributor of air pollutants (EPA, 2012i). The vehicles and machinery used in forestry operations for site establishment, management, harvest, transportation of felled wood, and other operation activities emit air pollutants, including VOCs, nitrogen oxides, $PM_{2.5}$, and carbon monoxide (EPA, 2012i). Forestry vehicles and machinery differ in their emission levels based on their mechanics but also in their workload, runtime duration, and site terrain (Berg and Karjalainen, 2003). For example, the equipment used to cut down a stand of trees during harvest will likely produce more emissions than the equipment used to apply topical applications of herbicide and fertilizer in the same stand. FTE is a rapidly growing *Eucalyptus* variety intended for cultivation under intensive management conditions (ArborGen, 2011). Its cultivation will lead to an increase in the use of heavy machinery compared to pine plantations, partly due to the expected increase in equipment usage during the site preparation stage, but mostly due to the short harvest cycle. FTE harvest cycle is much shorter than for pine; FTE harvest is every six to ten years (White, 1995; Sein and Mitlöhner, 2011; ArborGen, 2014; Rockwood and Peter, 2014), pine is every 20-25 years (Siry, 2004). This is at least two harvest cycles per one harvest cycle for pine, utilizing heavy machinery to cut trees (Personal communication with P. Minogue, 2013c; 2013b; 2013a). While machinery activity and emissions associated with plantation management may increase under the Preferred Alternative, this is unlikely to represent a significant source of pollutants to the atmosphere in the study area for several reasons. First, FTE will not replace all commercial forestry operations in the study area; rather FTE plantations are expected to occur on approximately 10 percent of the lands currently planted to pine. Secondly, in the study area the operation of forestry machinery is responsible for a small proportion of air pollutants in comparison to the contribution from the operation of millions of cars and other machinery that occur on a daily basis (EPA, 2012i; EPA, 2014a). Thirdly, other industrial facilities in the action area account for higher proportions of air pollutants compared to commercial forestry (EPA, 2012i; EPA, 2014a).

Fire is another management practice that can potentially affect air quality. However, given that prescribed burning is unlikely to occur in FTE plantations (Personal communication with R. Ottmar, 2013) and the conclusion that FTE does not pose a significantly higher fire risk than plantation pine (USDA-FS FERA technical report entitled *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States* (Appendix D), it is unlikely that fire in FTE will impact air quality any more than is already occurring under the No Action Alternative.

Conclusions

Under the Preferred Alternative, planting FTE on some lands previously planted with commercial pine species in the action area may occur. The usage of vehicles and machinery in commercial forestry contribute air pollutants, and FTE will cause an increase in heavy equipment usage because of its shorter harvest cycle (six to ten years) compared to pine (twenty to twenty-five years). While emissions associated with plantation management may increase under the Preferred Alternative, this is unlikely to represent a significant source of air pollutants in the action area. FTE plantations are expected to be adopted on approximately 10 percent of the lands currently planted to pine. Hence, any increase in emissions associated with a shorter harvest cycle of six to ten years are expected to be minor.

FTE plantations in the action area will also contribute air quality benefits through the assimilation of air pollutants and the sequestration of carbon dioxide. However, how these benefits offset the usage of heavy machinery during FTE's short harvest cycles is uncertain in terms of quantitative values.

4.6.3 Potential Impact on Soil Resources Resulting from the Preferred Alternative

4.6.3.1 Summary of the Preferred Alternative on Soil Resources

Under the Preferred Alternative, the potential impacts on soil resources are likely to remain the same or be slightly worse than the No Action Alternative within the action area.

The cultivation of FTE under the Preferred Alternative and the continued cultivation of plantation pine under the No Action Alternative both represent intensive production forestry operations. Consequently, both the No Action and Preferred Alternatives are likely to lead to similar impacts on soil quality, though the impact from cultivating FTE may be slightly worse, due to FTE physiology and its shorter rotation cycle. This impact on soil quality from the Preferred Alternative, when compared to the No Action Alternative, is likely to be minor because of management practices (e.g., BMPs and fertilization) currently used by managers of tree plantations to mitigate impacts to soil resources.

Additionally, the potential impact to mycorrhizal fungi is uncertain. While evidence suggests that FTE may form mycorrhizal associations within the action area, there is also an absence of information as to which native fungi species will be able to participate in this symbiosis. However, potential impacts on soil quality from fire or allelopathy under the Preferred Alternative are unlikely to be significantly different when compared to the No Action Alternative.

4.6.3.2 Preferred Alternative Analysis on Soil Resources

Introduction and Assumptions

This analysis of the Preferred Alternative on soil resources will focus on the potential direct and indirect impacts of cultivating FTE on soil resources, using the context of soil structure and soil nutrient balance already established in Section 4.3.3. First, important aspects of FTE physiology that is relevant to a discussion of soil resources will be presented. Second, this analysis of the Preferred Alternative will discuss potential impacts FTE may have on soil quality. Third, this analysis of the Preferred Alternative will examine if these impacts on soil resources are substantially different from those impacts on soil resources already occurring under the No Action Alternative.

At present, FTE is not cultivated within the action area (Appendix B). Thus, a direct examination of potential impacts under the Preferred Alternative is not possible. In lieu of direct examination, this Preferred Alternative analysis on soil resources will be undertaken through a literature review of *Eucalyptus* and relevant aspects of its physiology. The results of this literature review, in conjunction with likely management practices, will be considered within the context of the action area and the vegetation FTE is most likely to displace (i.e., plantation pine) under the Preferred Alternative (Appendix B) in order to determine potential impacts on soil resources.

Aspects of *Eucalyptus* Physiology Relevant to a Discussion on Soil Resources

In general, *Eucalyptus* nutrient use patterns are dependent on the developmental stage of the tree (Attiwill, 1979; Attiwill, 1980; Grove et al., 1996). The nutrient requirement of young and developing *Eucalyptus* to support canopy closure is met through soil uptake (Grove and Malajczuk, 1985; Cromer et al., 1993); however, after canopy closure, older-stage *Eucalyptus* generally rely more on internal nutrient cycling to satisfy nutrient requirements for growth of wood (Gholz et al., 1985; Grove et al., 1996). Internal nutrient cycling, otherwise known as nutrient redistribution, represents the movement of nutrients from one plant organ or tissue to another. For example, nutrient requirements for *Eucalyptus* wood growth following canopy closure is supported through the redistribution of nutrients (e.g., nitrogen, phosphorus, and other mobile elements) from senescent leaves or sapwood to actively-growing woody parts of the tree (Grove et al., 1996). This redistribution of nutrients from senescing leaves[47] to actively-growing *Eucalyptus* tissue represents a major component (i.e., 34-92 percent) of the internal cycling of nitrogen, phosphorus, and potassium in *Eucalyptus* (Attiwill, 1981; Baker and Attiwill, 1985; Turner and Lambert, 1996). A result of this internal nutrient cycling in older-stage *Eucalyptus* trees is a nutrient-poor litter layer in *Eucalyptus* plantations (Grove et al., 1996; O'Connell and Sankaran, 1997), where leaf fall represents the majority of *Eucalyptus* litter on the floor of the plantation (O'Connell and Sankaran, 1997; Johnston and Crossley, 2002; Du Toit, 2008).

In any forest, natural or artificial, the decomposition of leaf fall functions to return nutrients back to the soil (Attiwill, 1980; Attiwill, 1981; Baker and Attiwill, 1985). However, partially due to the evolutionary development of *Eucalyptus* on nutrient-poor soils (Beadle, 1962; Beadle, 1966), its internal nutrient cycling is very efficient, leading to leaf fall that is poorer in quality and slower to decompose than many other trees (Turner and Lambert, 1983; Bargali et al., 1993b; O'Connell and Sankaran, 1997; Goncalves et al., 1999; Bernhard-Reversat et al., 2001a).

Based on observation of poor leaf fall quality in other *Eucalyptus* species, FTE leaf fall is also likely to be poor. Consequently, the return of organic matter and nutrients to the soil is likely to be low in an FTE plantation.

The Potential Impacts of *Eucalyptus* on Soil Resources

As previously discussed in the No Action analysis on soil resources (Section 4.3.3), there are several factors that may potentially impact soil quality within any intensively-managed plantation forest. These factors include the soil type where the plantation forest is grown (USDA-NRCS, 2013b), the tree species cultivated within the plantation, and the silvicultural practices used to manage the plantation (Ewers. et al., 1996; Johnston and Crossley, 2002). The potential impact of FTE on each of these factors will be discussed below, followed by a discussion of the relative impact of the Preferred Alternative on soil quality when compared to the No Alternative.

First and foremost, baseline characteristics of the soil are unlikely to be different between the Preferred and No Action Alternatives. The soil type (i.e., ultisols) that generally makes up land planted with plantation pine is described in the No Action analysis on soil resources (Section 4.3.3). Under the Preferred Alternative, FTE is most likely to be planted on soil types that previously supported plantation pine (Appendix B). Consequently, no change in soil type is anticipated because FTE is likely to be planted on those soil types already supporting plantation pine and the tree is not capable of changing the soil type.

[47] i.e., dying leaves

FTE is a rapidly-growing *Eucalyptus* variety intended to be cultivated under intensive-management conditions (Arborgen, 2011). Aspects of *Eucalyptus* growth and development (Turner and Lambert, 1983; Bargali et al., 1993b; Grove et al., 1996; O'Connell and Sankaran, 1997; Goncalves et al., 1999; Bernhard-Reversat et al., 2001a), coupled with its likely silvicultural methods (Personal Communication with P. Minogue, 2013c; Minogue, 2013b; Minogue, 2013a), suggests that its cultivation will lead to a greater net removal of organic matter and soil nutrients than can otherwise be replenished by typical forest processes (Turner and Lambert, 1983; Judd, 1996; Laclau et al., 2000; Bernhard-Reversat et al., 2001b).

Compounding this low return of organic matter and nutrients is the relatively rapid rotation cycle that FTE is cultivated under (Arborgen, 2011).

When trees in any forest are harvested, nutrients are lost in harvested wood, bark, and other tree components; additionally, other nutrients are also lost in harvesting (Crane and Raison, 1980; Turner and Lambert, 1980; Wise and Pitman, 1981; Ellis and Graley, 1983; Leitch et al., 1983; Grove and Malajczuk, 1985; Stewart and Flinn, 1985; Hopmans et al., 1987; Cromer et al., 1993). Despite large quantities of leaf fall in *Eucalyptus* species, ranging from 3.4 – 7.8 ton ha^{-1} $year^{-1}$ (Ferreira, 1984; Turner, 1986; Cromer et al., 1993; Bernhard-Reversat et al., 2001a; Turner and Lambert, 2007), the overall amount of nutrients are contained within the harvestable biomass of a tree (Turner, 1986). Consequently, when this biomass is removed (i.e., harvested) at the end of a rotation cycle, so are the bulk of nutrients that would otherwise return back into the soil through decomposition/mineralization processes (Ewers. et al., 1996; Judd, 1996; Turner and Lambert, 2007).

If the harvesting of trees removes nutrient from a site that would otherwise return to the soil, then more frequent harvesting of woody material in the even shorter rotations associated with FTE is likely to increase this rate of nutrient removal (Ewers. et al., 1996; Judd, 1996; Turner and Lambert, 2007). In particular, phosphorus, nitrogen, and calcium may be reduced from the soil, due to the sequestration of these plant nutrients in plant material that is harvested and taken off site (O'Connell and Grove, 1985; Dell et al., 1987; Mulligan, 1988; Judd, 1996; Laclau et al., 2000; Bernhard-Reversat et al., 2001b; Turner and Lambert, 2007). Compounding this is the potential impact on the structure of the soil, due to the more frequent use of heavy machinery in typical plantation silvicultural practices, such as site preparation and harvesting, that is associated with a shorter rotation cycle (Personal Communication with P. Minogue, 2013c; Minogue, 2013b; Minogue, 2013a).

Beyond soil structure and soil nutrient balance, the microbial fauna of soil is also an indicator of soil quality. Ectomycorrhizal fungi form highly diverse communities in temperature forests. Ectomycorrhizal species diversity is particularly important for liberation of N from recalcitrant organic compounds (OECD, 2014)), but contributions of individual ectomycorrhizal species or genera to soil processes is not clear. In particular, ectomycorrhizal association between *Eucalyptus* and fungi can occur, indicating that *Eucalyptus* is a mycorrhizal species (Malajczuk and Hingston, 1981; Brundrett and Abbott, 1991), as in Pinus spp.. Mycorrhizal associations are formed between *Eucalyptus* and a range of mycorrhizal species (e.g., *Cortinarius* or *Hysterangium*) (Malajczuk et al., 1987; Castellano and Trappe, 1990; Castellano and Trappe, 1992). The occurrence of mycorrhizae between FTE and ectomycorrhizae is uncertain within the action area, due to an absence of information examining the rhizosphere. However, in other areas where *Eucalyptus* species are introduced, mycorrhizal symbioses have been noted to form between *Eucalyptus* and native ectomycorrhizae (OECD, 2014).

Further, while there is considerable overlap in the mycorrhizal communities of *Eucalyptus* spp. and *Pinus* spp., some Pinaceae-associated fungi (*Suillus* spp. and *Rhizopogon* spp.) do not associate with *Eucalyptus*

(Malajczuk et al., 1982). Differences in leaf litter can lead to changes in ectomycorrhizal community structure and to changes in nutrient cycling and decomposition (OECD, 2014) (), so the production of large quantities of eucalyptus litter may change some patterns in ECM community structure and diversity.

Conversion of pine plantations to *Eucalyptus* may have local negative effects on pine-specialist mycorrhizal fungal populations, but as these genera are native fungi of North America, they would still remain present within the larger landscape. When pines arrive in a habitat, co-invasion of their mycorrhizal community occurs (OECD, 2014) so it is unlikely that the mycorrhizal community of eucalyptus would prevent potential success of later pine plantations or forest. In addition, *Eucalyptus* have been observed to use ectomycorrhizae from their new habitat (OECD, 2014), so some additional pine-associated ectomycorrhizal species may remain on site after conversion from pine plantation to FTE. With conversion of pine plantation to *Eucalyptus*, there is reason to believe there may be a change in mycorrhizal community structure, but there is no evidence that this conversion would lead to changes in soil community function in the larger landscape (OECD, 2014).

Additionally, Eucalyptus species such as FTE have been reported to be allelopathic (Ong, 1993; Davidson, 1995; Sunder, 1995; White, 1995; Espinosa-Garcia et al., 2008). However, as described in the most recent APHIS EA (USDA-APHIS, 2012) for GE *Eucalyptus*, the state of knowledge of *Eucalyptus'* allelopathic characteristics is currently limited: it is inconclusive as to whether compounds produced by *Eucalyptus* are exclusively responsible for reported allelopathic effects. While potential allelopathy from *Eucalyptus* remains to be substantiated, given the fact that *Eucalyptus* growers commonly use mechanical/chemical understory control, any potential allelopathic effects from *Eucalyptus* are likely to be relatively minimal (USDA-APHIS, 2012). Furthermore, reports from the field where non-GE *Eucalyptus* is grown indicate that plant growth in former *Eucalyptus* fields is normal, strongly suggesting that even if *Eucalyptus* were to exhibit potential allelopathy, the effects would not persist over time (Personal Communication with P. Minogue, 2013c).

In summary of the potential impacts of *Eucalyptus* on soil resources, FTE is likely to substantially reduce soil organic matter and soil nutrient balance where it is planted, owing to the physiology of *Eucalyptus* and its short rotation times. The particular composition of mycorrhizal associations that would exist in FTE plantations is uncertain but may overlap with that of pine plantations, and the impact from potential *Eucalyptus* allelopathy is likely to be insignificant compared to other typical forestry practices to control vegetation.

<u>The Relative Potential Impacts of the Preferred Alternative on Soil Resources</u>

As discussed directly above, cultivation of FTE under the Preferred Alternative will likely lead to the substantial reduction of nutrients and organic matter from sites, despite the addition of fertilizer. While this describes the absolute (potential) impact of cultivating FTE under the Preferred Alternative, the relative (realized) impact of FTE on soil resources is dependent on the current condition of soil resources, as described in the No Action Alternative analysis on soil resources (Section 4.3.3).

Compared to the current and projected condition of soil quality described in the No Action Alternative analysis on soil resources (Section 4.3.3), the Preferred Alternative is likely to lead to the same or slightly worse impacts.

As previously described in Section 4.3.3, the cultivation of plantation pine for pulpwood and its associated intensive management practices are already impacting soil quality with regard to structure and nutrient balance. And, as described in Section 4.3.3, growers are already managing these soil quality impacts through BMPs to preserve soil structure and fertilization to address soil nutrient deficiencies.

The shorter rotation cycle of FTE is likely to lead to more frequent use of heavy machinery in site preparation and harvesting activities (Personal Communication with P. Minogue, 2013c; Minogue, 2013b; Minogue, 2013a). However, the use of BMPs to preserve soil structure is not species-specific, and is often typical of intensively-managed plantation forests, in general. The use of BMPs, in conjunction with the relatively low anticipated adoption of FTE (Appendix B), suggests that impacts on soil structure are expected to be the same or slightly more than is already occurring under the No Action Alternative.

Additionally, while FTE is anticipated to lead to greater removal of nutrients from the soil than plantation pine, it is prudent to acknowledge that plantation pine under the No Action Alternative is already removing a substantial amount of nutrients from sites within the action area (Section 4.3.3). And as described in Section 4.3.3, it is a typical practice for tree growers to fertilize sites prior to/shortly after planting to facilitate optimal performance of the plantation because of these nutrient deficiencies. While the pattern of nutrient losses may be different between the No Action and Preferred Alternatives, owing to the physiology of the trees grown (Fife and Nambiar, 1982; Fife and Nambiar, 1984; Dell et al., 1987; Grove et al., 1996; Cobb et al., 2008), growers of plantation pine and growers of FTE are both likely to incur overall nutrient losses and respond with fertilization regimes at plantation sites. Under both alternatives, the future sustainability of the soil is uncertain, as both plantation pine and *Eucalyptus* are considered to produce litter that is poorer in nutrients and slower to decompose and release those nutrients back into the soil compared to other trees (Grove et al., 1996; O'Connell and Sankaran, 1997). In general, it is already well recognized that short rotations of any plantation tree species will lead to reductions in nutrients and to declines in productivity of plantations, despite fertilization regimes (Judd, 1996).

Fire is another management practice that can potentially impact soil quality. Most southern pine (slash, longleaf) and many other pines are fire dominated, so the forests they evolved in have had high fire risk. However, given that prescribed burning is unlikely to occur in FTE plantations (Personal Communication with R. Ottmar, 2013) and the conclusion that FTE does not pose a significantly higher fire risk than plantation pine (Appendix D), it is unlikely that fire in FTE will impact soil nutrient balance any more than is already occurring under the No Action Alternative.

The relative impact of FTE on mycorrhizal species, as compared to the No Action Alternative, is uncertain. While the mycorrhizal associations between plantation pine and FTE are different (i.e., vesicular arbuscular mycorrhizae [VAM] in plantation pine and ectomycorrhizae in *Eucalyptus*), the long-term impact on mycorrhizal fungi is uncertain, owing to the potential but unknown colonization of FTE by both VAM and ectomycorrhizae (Malajczuk and Hingston, 1981; Lapeyrie and Chilvers, 1985; Brundrett and Abbott, 1991) and the observation that fertilization with phosphorus in any plant is likely to decrease mycorrhizal colonization phosphorus (Marx et al., 1977; Harley and Smith, 1983; Abbott and Robson, 1984; Thomson et al., 1994).

4.6.4 Potential Impact on Water Resources Resulting from the Preferred Alternative

4.6.4.1 Summary of the Preferred Alternative on Water Resources

Under the Preferred Alternative, local and direct impacts may occur on water quantity and quality. However, these direct impacts on water quantity and quality are likely to be negligible at larger spatial scales, such as within individual watersheds or across all watersheds in the action area.

FTE is likely to use more water than other types of vegetation, including non-irrigated crops, deciduous hardwoods, and plantation pine. Consequently, FTE is likely to reduce the amount of water available for local streamflow compared to these other types of vegetation. The magnitude of this direct and local impact on streamflow is dependent on the type of vegetation that is replaced with FTE, the amount of precipitation received, and other local factors. Thus, the impact of FTE on local water quantity is site dependent.

FTE is likely to have local impacts on water quality through increased sediment loading from forest access systems (forest roads and stream crossings) into forest streams. While the cultivation of FTE is unlikely to increase the number of forest roads and stream crossings in the action area (i.e., FTE is anticipated to be planted on sites previously planted to plantation pine (Appendix B)), these forest access systems are likely to experience more frequent disturbances related to FTE-related management. More frequent disturbances on these forest access systems may lead to increased sediment loading of forest streams. Current BMPs, however, are effective in reducing sediment loading of forest streams and may mitigate local and direct impacts from FTE-related management activities, so long as these BMPs are adopted by growers of FTE.

4.6.4.2 Preferred Alternative Analysis on Water Resources

Introduction and Assumptions

The development of FTE plantations in the Southern United States has raised concerns regarding a variety of environmental and biological factors, and in particular, water resources (Stanturf et al., 2013b). This Preferred Alternative analysis on water resources will focus on the potential impacts of FTE on two aspects of water resources, water quantity and water quality.

This Preferred Alternative analysis will examine the potential impact of FTE on water quantity, using the water balance framework (further discussed in the following section) that was described in Section 4.3.4: Potential Impact on Water Resources Resulting from the No Action Alternative. Any conclusions specifically related to FTE and its potential impact on water quantity may be considered a summary of results from the USDA-FS technical report produced for APHIS, entitled *Implications for expansion of GE freeze-tolerant Eucalyptus plantations of water resources in the continental US,* unless otherwise stated. This technical report may be found in Appendix C.

This Preferred Alternative analysis on water quantity will first address the need to model potential water quantity impacts from FTE within the action area. This will be followed by a summary of FTE model results and its implications for streamflow over a range of spatial scales in the action area.

After a discussion of potential impacts to water quantity, this Preferred Alternative analysis will examine the potential impacts of FTE cultivation on water quality in the action area, using the information initially presented in Section 4.3.4: Potential Impact on Water Resources Resulting from the No Action Alternative.

Eucalyptus and the Need to Model Potential Impacts on Water Balance in the Action Area

Concerns regarding the potential impacts of *Eucalyptus* plantations are based on peer-reviewed studies of *Eucalyptus* water use from across the world (Farley et al., 2005; Ferraz et al., 2013; King et al., 2013). However, these published studies were not undertaken in the action area, primarily due to an inability to grow *Eucalyptus* beyond its current cultivation range.

Assessing the potential impacts of FTE on water quantity requires an analysis of all water budget components at multiple spatial levels. As previously discussed in the No Action analysis on Water Resources (Section 4.3.4), a water balance equation can help facilitate discussion on water use. A generalized water balance equation can be presented as:

$$Q = P - ET$$

In this generalized water balance equation, Q represents water balance; P represents precipitation or the total amount of water input; and ET represents evapotranspiration or the total amount of water used. Similar to other common plantation tree species, cultivation of FTE is not expected to impact local P or net soil water storage at annual time scales (Section 4.3.4); hence, the focus of this Preferred Alternative analysis on water quantity will be primarily on how changes in Q impact streamflow and groundwater recharge.

However, due to the absence of empirical FTE ET data in the action area, it was necessary to model FTE ET in order to determine its potential impacts on Q. P and other climate data used in the model were obtained from five open-field climate stations within the action area (Figure 22). These five climate stations are maintained by the Natural Resources Conservation Service (NRCS) as part of the Soil Climate Analysis Network (SCAN[48]) and represent sites with diverse climatic conditions where FTE may be cultivated under the Preferred Alternative.

In lieu of empirical FTE water use within the action area, modeling provides an alternative approach to determine potential impacts on water use, thus further informing any potential regulatory decision regarding FTE. However, the following results should be considered an approximation of potential impacts until empirical data resulting from direct measurement are available.

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[48] http://www.wcc.nrcs.usda.gov/scan/ Last accessed January, 2014

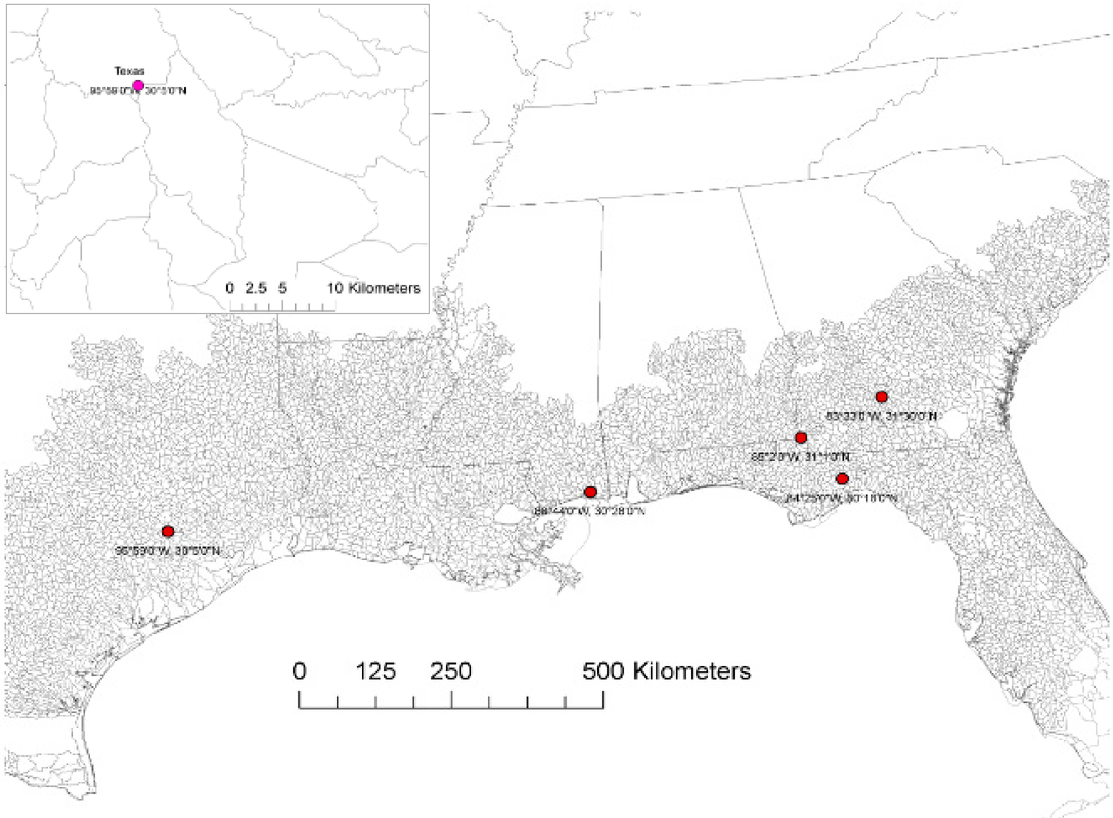

Figure 22. Location of Sites Used to Model the Impact of FTE on Water Quantity

The sites included: Koptis Farms, Alabama; Little River, Florida; Wakulla, Florida; Fort Bayou, Mississippi; and Texas. Adapted and reproduced from Appendix C

<u>Patterns and Drivers of Simulated FTE ET</u>

In order to determine the potential impact on Q, FTE ET must be determined. This subsection will summarize simulated[49] values of FTE ET from the FS technical report (Appendix C) and discuss its primary and likely drivers within the context of the model and the action area.

Simulated FTE ET is generally comparable to plantation pine ET in some areas, though greater than other common vegetation types within the action area, including deciduous hardwoods and non-irrigated crops (Table 11). Additionally, the values calculated for simulated FTE ET are similar to observed non-GE *Eucalyptus* ET values found within the peer-reviewed literature. Simulated FTE ET ranged from approximately 500 mm yr^{-1} to 1200 mm yr^{-1}, whereas observed non-GE *Eucalyptus* ET values ranged from approximately 949 mm yr^{-1} to 1364 mm yr^{-1} (Table 11).

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[49] Within this Preferred Alternative analysis on Water Resources, a value described as simulated can be considered a value resulting from mathematical modeling. Accordingly, a value described as observed can be considered a value resulting from empirical observation/measurement

Table 11. Comparison of ET Between FTE, Non-GE Eucalyptus, and Other Common Vegetation Types in the Southern United States

Ecosystems	Evapotranspiration (mm)	Precipitation (*P*, mm)	ET/*P*	References
FTE, action area	500–1200	1250 (779-1553)	0.51-0.77	Appendix C
Eucalyptus Plantation (clonal *Eucalyptus grandis* x *Eucalyptus urophylla*), 2-4 years old, São Paulo State, Brazil	1179 (1124–1235)	1329 (1280–1377)	0.88 (0.82–0.96)	(Cabral et al., 2010)
Eucalyptus Plantation (hybrid of *E. urophylla* and *E. grandis*), 2-6 years old, spacing of 3.00 × 2.75m, São Paulo State, Brazil	1101 (943–1364)	1308 (1150–1601)	0.84 (0.81–0.89)	(Lima et al., 2012)
Eucalyptus Plantation (hybrid of *E. urophylla* and *E. grandis,* different clone), 0-2 years old, spacing of 6.00 × 1.40 m. São Paulo State, Brazil	1099 (949–1240)	1601 (1537–1716)	0.69 (0.55–0.80)	(Lima et al., 2012)
Loblolly pine plantation, 15 year old, Parker Track, North Carolina	988 938 (after thinning 1/3 of basal area)	1098	0.9	(Grace et al., 2006; Grace et al., 20006)
Loblolly pine plantation, 14-30 year old, Parker Track, North Carolina	997	1538 (947–1346)	0.65	(Amatya et al., 2006)
Loblolly pine plantation (LP) 16 year old, North Carolina	1087 (1011-1226)	1238	0.88	(Sun et al., 2010)
Loblolly pine plantation (PP), 25 year old, Piedmont North Carolina	658 (560–740)	1092 (930–1350)	0.6	(Stoy et al., 2006)
Slash pine (*Pinus taeda* L.) plantation, clearcut, Florida	958 (869–1048)	959 (869–1048)	0.85 (0.84–0.86)	(Gholz and Clark, 2002)

Ecosystems	Evapotranspiration (mm)	Precipitation (*P*, mm)	ET/*P*	References
Slash pine (*Pinus taeda* L.) plantation, 10-year old, Florida	1058 (994–1122)	1062 (877–1247)	1 (0.9–1.1)	(Gholz and Clark, 2002)
Slash pine (*Pinus taeda* L.) plantation, full-rotation, Florida	1193 (1102–1284)	1289 (887–1014)	0.93 (0.92–0.93)	(Gholz and Clark, 2002)
Slash pine (*Pinus taeda* L.) plantation, full-rotation, Florida (extreme drought years)	754 (676–832)	883 (811–956)	0.85	(Powell et al., 2005)
Mixed Pine and hardwoods, Santee Exp. Forest, South Carolina	1133	1382	0.82	(Lu et al., 2003)
Pine flatwoods, Bradford Forest, Florida	1077	1261	0.87	(Sun et al., 2002)
Deciduous hardwoods, Coweeta, North Carolina	779	1730	0.47	(Sun et al., 2002)
White pine (*Pinus strobus* L.), Coweeta, North Carolina	1291	2241	0.58	(Ford et al., 2007)
Deciduous hardwoods, Oak Ridge, Tennessee	567 (537–611)	1372 (1245–1682)	0.41	(Wilson and Baldocchi, 2000)
Deciduous hardwoods, Oak Ridge, Walker Branch watershed, Tennessee	575	1244	0.45	(Lu et al., 2003; Hanson et al., 2004)
Mature deciduous hardwoods (HW), Duke Forest, Piedmont North Carolina	573 (460–640)	1092 (930–1350)	0.52	(Stoy et al., 2006)
Grass-cover old field (OL), Duke Forest, Piedmont North Carolina	508 (360–650)	1092 (930–1350)	0.46	(Stoy et al., 2006)

Adapted and reproduced from Appendix C

FTE ET may vary across multiple growing seasons and within an individual growing season. These temporal patterns of FTE ET play a role in long-term and seasonal water availability, and thus, are important to determine.

A typical FTE rotation cycle is anticipated to span 7 – 9 years (Arborgen, 2011). Simulated FTE ET increased with each passing year at all five sites (Figure 23). Part of this pattern is a direct result of the assumption of an increase in leaf area index (LAI) equal to 0.5 m^2m^{-2} per year. In actual field settings, LAI development may occur differently. For example, maximum LAI (and hence greater ET) may be attained quickly on higher quality sites. Simulated FTE ET at the Florida site increased the least (approximately 500 - 850 mm yr^{-1} by year 7), and simulated FTE ET at the Alabama and Mississippi sites increased the most (approximately 650 - 1200 mm yr^{-1} by year 7). The remaining sites (Little River, Georgia; and Texas) yielded simulated FTE ET increase rates that were intermediate to the Florida, Alabama, and Mississippi sites (Figure 23).

In terms of seasonal ET patterns within a single growing season, simulated FTE ET peaked between late spring and early fall, regardless of stand age or location (Figure 24), for the years of climate data used. Accordingly, simulated FTE ET was lowest during the winter months, regardless of stand age or location (Figure 24).

Within the action area, other common plantation tree species (e.g., loblolly pine) have ET values and patterns (across multiple growing seasons and within a single growing season) that are similar to ET values simulated for FTE (Section 4.3.4 and Appendix C). The model used to simulate FTE ET values is based on environmental, physiological, and anatomical factors that influence tree ET in the field. Consideration of these two observations in conjunction with the peer-reviewed literature on the drivers of ET of plantation tree species (Chang, 2013) suggests that FTE ET is likely to be influenced by characteristics that also determine ET in other common plantation tree species if it were to be grown in the action area.

A relatively rapid growth rate, its resulting influence on plant LAI and sapwood area, and climate are the primary determinants of ET values and patterns (Chang, 2013). A relatively rapid growth rate and increases in plant LAI necessitates that FTE ET be sufficiently high enough to viably maintain this growth rate. Indeed this is the case in vegetation with relatively-rapid growth rates, including FTE, non-GE *Eucalyptus*, and plantation pine species (Table 11).

Patterns of FTE ET across multiple growing seasons and within individual growing seasons are likely driven by anatomical or climatic characteristics. The increase in simulated FTE ET in each successive year of a typical rotation cycle is dependent on LAI, where increases in LAI will generally lead to concurrent increases in ET (Figure 24). This relationship between LAI and ET is generally well-accepted across tree species, where increases in LAI lead to increase in characteristics (e.g., transpiration and canopy interception/evaporation) that in turn, lead to increases in ET (Chang, 2013). In contrast to the pattern of simulated ET across multiple growing seasons, the pattern of simulated FTE ET within a single year is dependent upon precipitation and available energy, where ET will rise or fall in accordance with the availability of precipitation and energy (Lima, 2012). Thus, the results presented in Figure 24 are not surprising, as the summer months generally reflect the wettest and warmest time of the year in the action area (Sun et al., 2010).

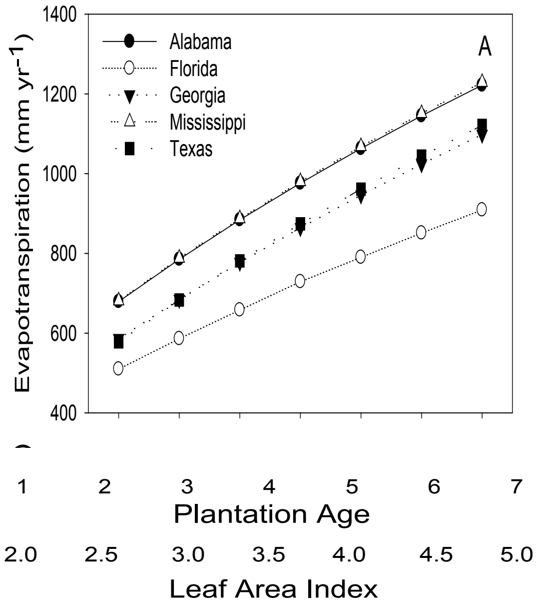

Figure 23. Annual ET From Process Based Model for the Five Intensive Study Locations
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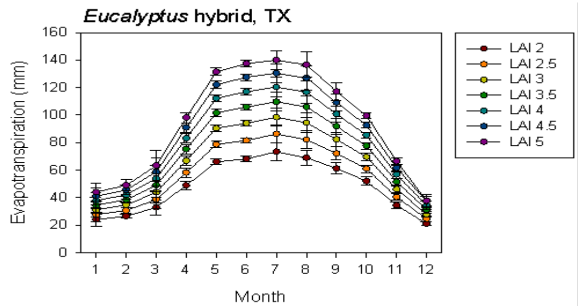

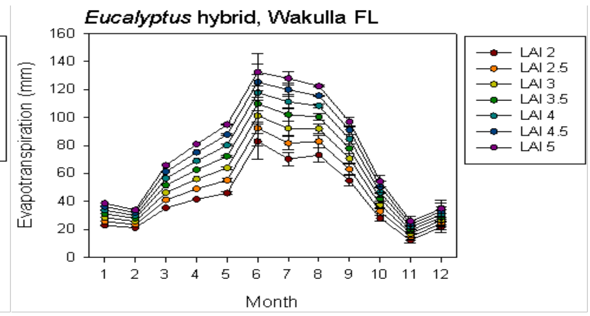

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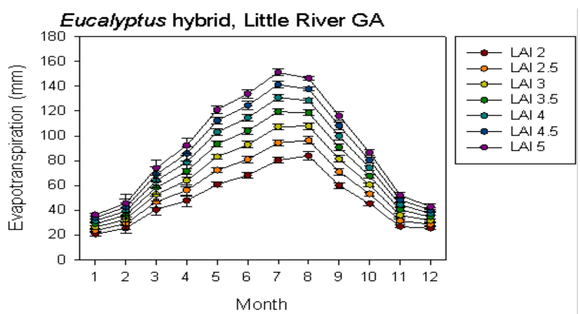

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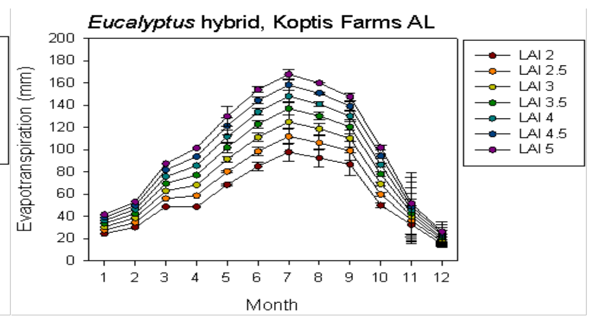

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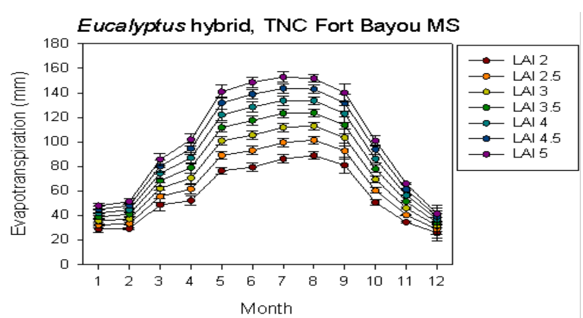

Figure 24. Monthly Total Evapotranspiration Simulated Across all Years of Climate and Over Seven Years of Stand Age for Five Sites

Stand age is represented as increases in leaf area index (LAI) from 2–5 $m^2\ m^{-2}$, as LAI typically will increase as any plantation ages – figure was reproduced from Appendix C

Potential Impact of FTE on Q

As described in Lockaby et al. (2012b) and Section 4.3.4, Q is calculated to be the difference between P and ET[50]. Additionally, Q is primarily determined by ET in any given area of land where vegetation is

[50] i.e., Q = P - ET

dominant (Sun et al., 2004; Farley et al., 2005; Lockaby et al., 2012a). This relationship between Q and ET is generally independent of spatial scale (Sun et al., 2004; Farley et al., 2005; Lockaby et al., 2012a) and may be used to determine potential impacts on water availability, streamflow, and groundwater recharge on a local level[51] and across the landscape[52].

Based on the general water balance equation, Q and ET share an inverse relationship, where an increase in one value causes a decrease in the other value. This indeed is the case, as simulated Q decreased as simulated FTE ET increased across all five sites (Figure 25). This inverse relationship, however similar, was not uniform across the five sites. In the Georgia and Texas sites, Q decreased toward zero[53] as the FTE plantation matured. At the remaining sites in Alabama, Florida, and Mississippi, Q also decreased with FTE plantation age, though Q did not approach zero (Figure 25).

At the individual watershed level and anticipated adoption level, cultivation of FTE did not substantially impact streamflow in that individual watershed (Figure 26). With regard to these landscape-level results on streamflow, it is prudent to mention that these results assumed a standard adoption level of FTE. Landscape-scale analyses on streamflow defined standard adoption as a ≤ 10 percent or less conversion of plantation pine to FTE. This standard adoption value was determined by a socioeconomic analysis of FTE adoption (Appendix A). For all five individual watersheds, the maximum absolute reduction in streamflow was less than 6 mm $year^{-1}$, representing less than 1.5 percent of streamflow under baseline conditions. Additionally, across all watersheds in the Southern United States, cultivation of FTE[54] also did not yield a substantial impact on collective streamflow (Figure 27) or groundwater recharge (Figure 28). This result is not surprising, considering that streamflow in individual watersheds within the action area was not substantially affected by cultivation of FTE.

If FTE were to replace 50 percent of plantation pine or 100 percent of all vegetation, then landscape-scale impacts to streamflow can be expected (Figure 26 and Figure 27). However, these scenarios representing dramatic conversion rates of vegetation or a subset of vegetation (e.g., plantation pine) to FTE are not likely based on a socioeconomic analysis of FTE adoption (Appendix B). Thus, under standard adoption levels on and across the landscape, FTE is unlikely to significantly impact streamflow and groundwater recharge.

The results summarized directly above and initially presented in Appendix B strongly suggests that cultivation of FTE under the Preferred Alternative will reduce local streamflow (Figure 25). This likely local impact on streamflow, however, does not equate to likely impacts on streamflow/groundwater recharge on and across the landscape at anticipated adoption levels (Figure 27 and Figure 28, respectively). Thus, any further discussion of potential impacts to water availability and streamflow will

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[51] Within this Preferred Alternative analysis on water resources, the local level is represented by the site where FTE is grown and the lands directly adjacent to it

[52] Within this Preferred Alternative analysis on water resource, the landscape is represented by individual watersheds within the action area or all watersheds within the Southern United States. Like the sites, these watersheds represent a variety of climatic conditions where FTE may be cultivated. Additionally, these watersheds also contain a variety of land use patterns (Figure 9 in Appendix C), representing areas within the landscape that may be adjacent to or near FTE plantations

[53] As seen in Figure 25, negative values for runoff occurred at the Texas site by year 3 and the Georgia site by year 7. However, negative runoff is not possible in real-world situations; accordingly, negative data should be interpreted as runoff = 0. See Appendix C for more details

[54] The anticipated adoption level of FTE is > 10 percent, where FTE is planted in lieu of plantation pine. Further details regarding the socioeconomic analysis of FTE adoption can be found in Appendix B

focus on the local level. Additionally, the potential indirect impacts of local streamflow on plant and wildlife communities will not be discussed here, but in the Cumulative Impacts analysis (Section 5).

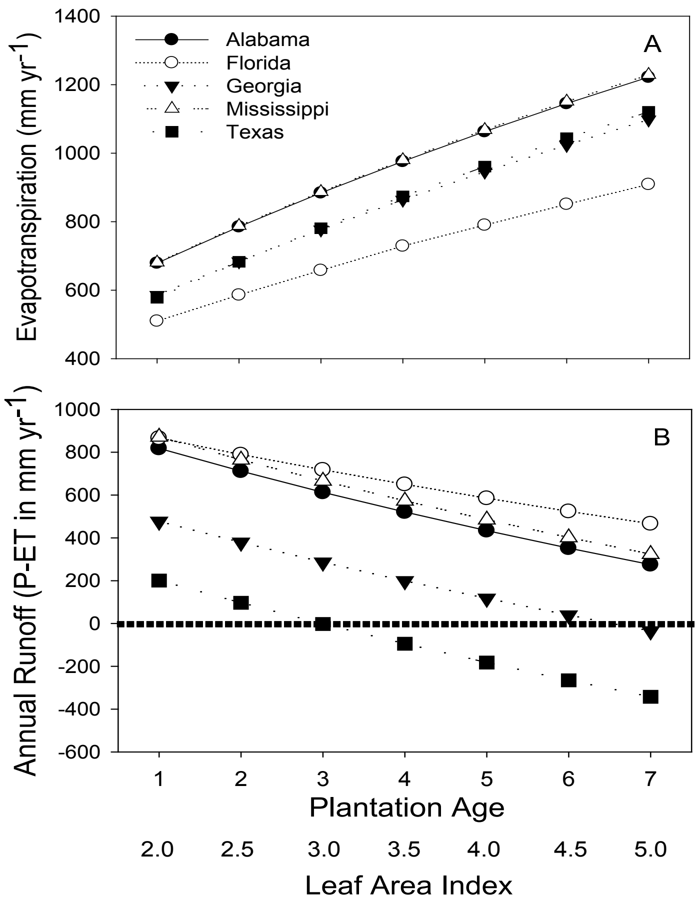
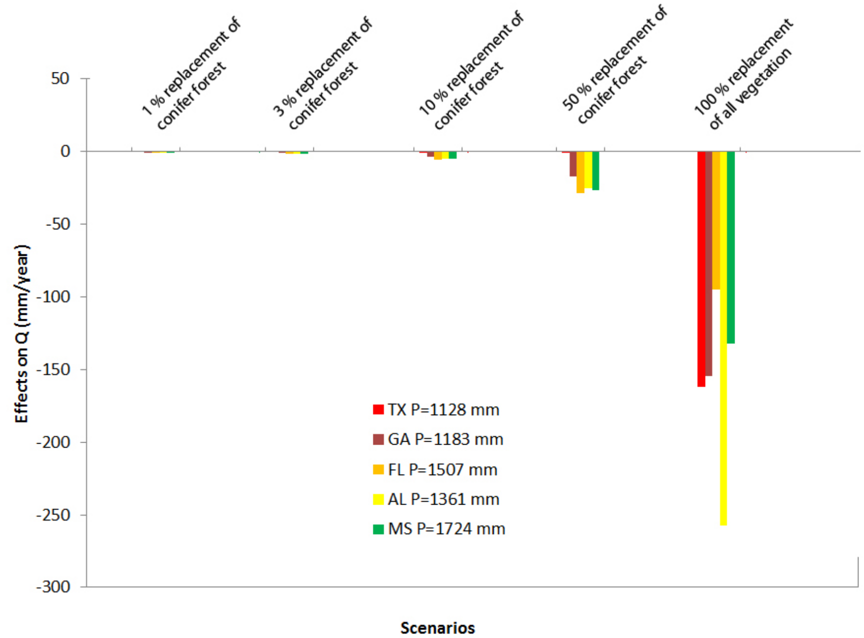


Figure 25. Annual ET (A) and Runoff (B) Predicted From Process Based Model for the Five Intensive Study Locations

The model does not incorporate physiological or structural adjustments that occur when annual ET exceeds P (*i.e.*, leaf area reduction, access to deep soil water, etc.) so predicted runoff is negative for the Texas site when LAI > 3.0. Because "negative runoff" is not possible, these data should be interpreted as runoff = 0. Reproduced and derived from Appendix C



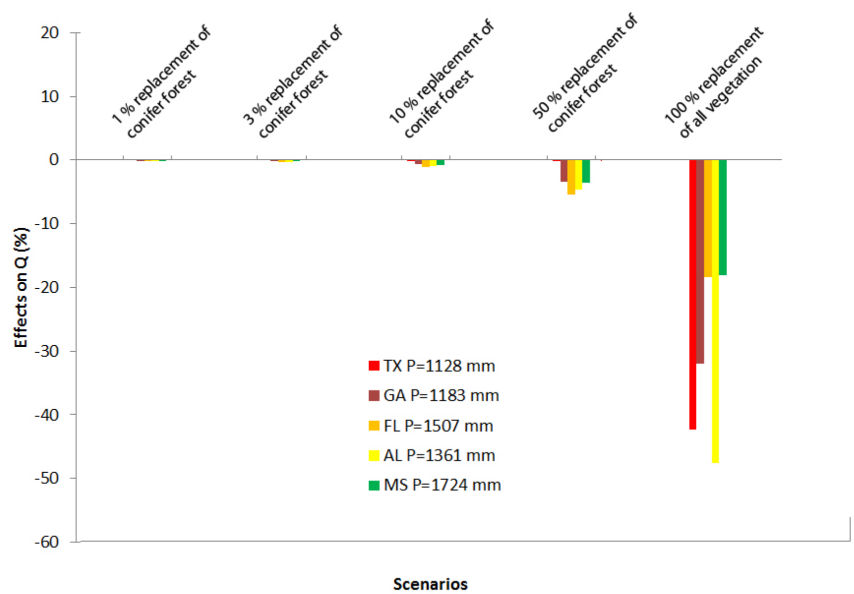


Figure 26. Modeled Impacts of FTE on Streamflow Under Multiple Scenarios

(A) represents reductions in Q; and (B) represents reductions in Q as a percentage of the baseline – Figure modified and reproduced from Appendix C

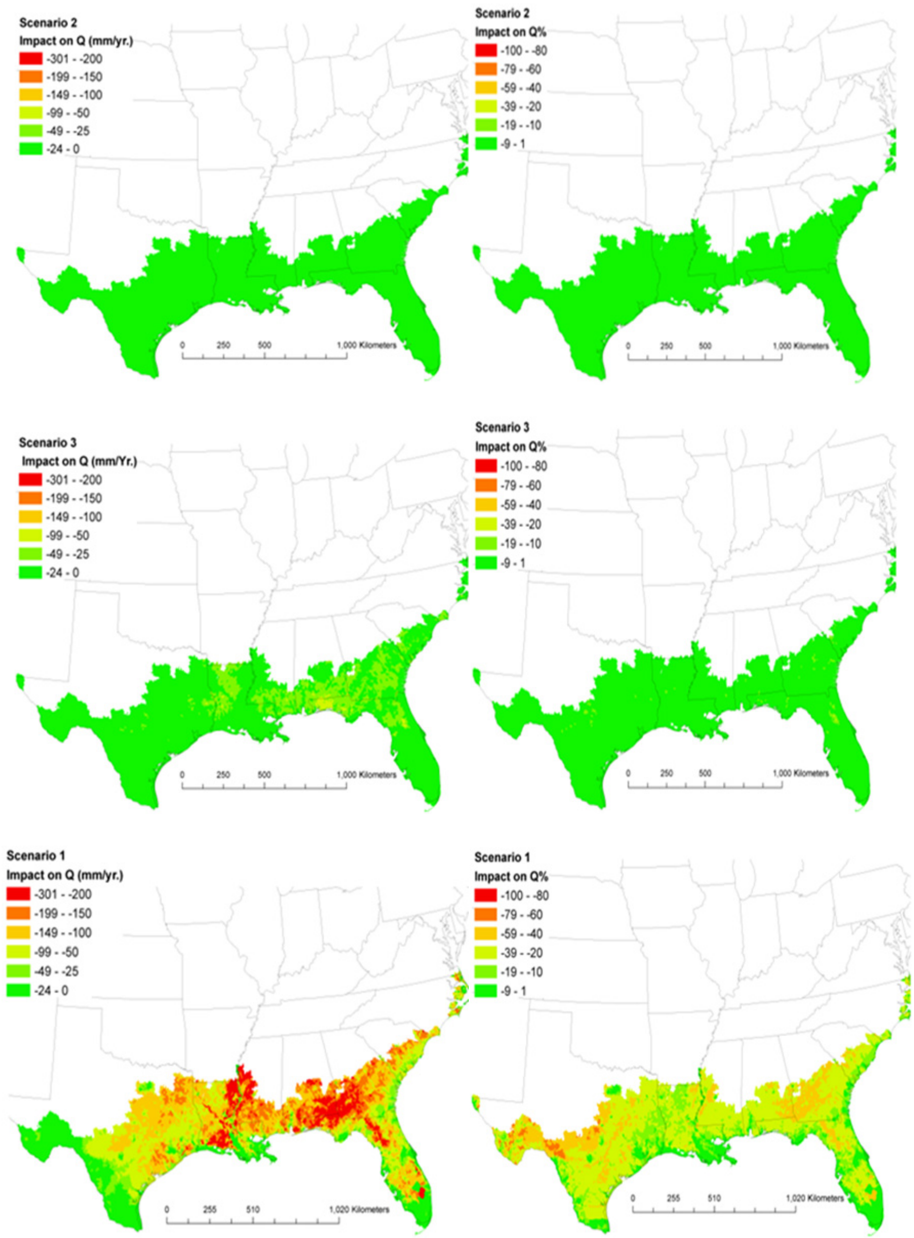


Figure 27. Regional Analysis Simulating the Impact on Q

Regional analysis simulated the impact of Q (absolute change in mm yr^{-1} and percent change in) of replacing 10% of the conifer cover (Scenario 2), 50% of the conifer cover (Scenario 3), and 100% of all vegetation (Scenario 1) with FT *Eucalyptus* for all of the 12-digit HUCS in the southern region of hardiness zones 8b and greater – Figure modified and reproduced from Appendix C

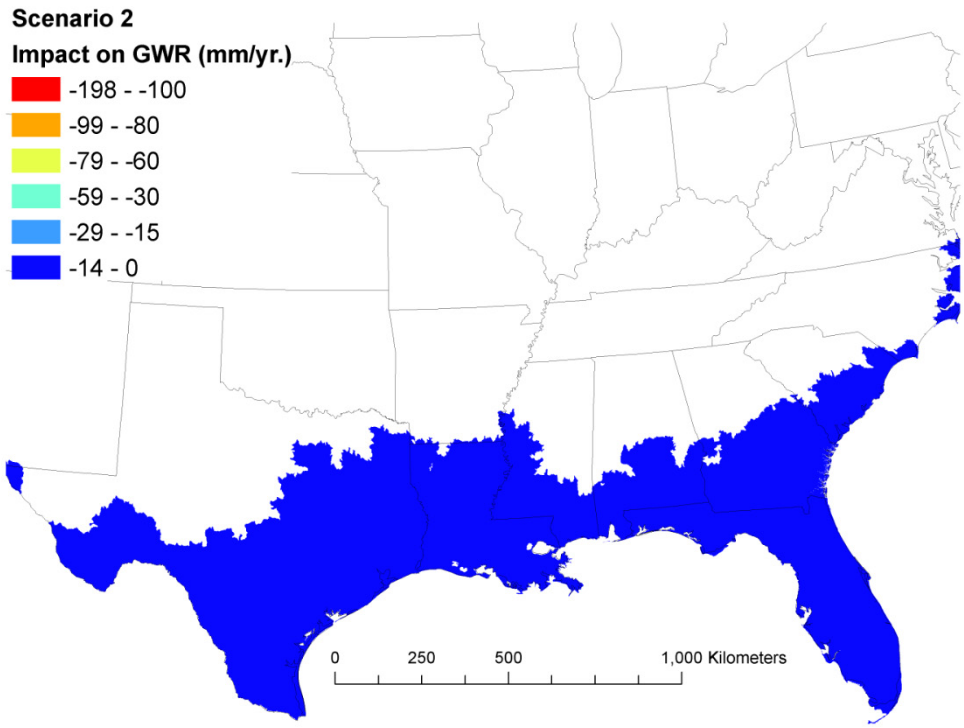


Figure 28. Spatial Distribution of Modeled Impacts on Groundwater Recharge Across 17,000 Watersheds Under Standard FTE Adoption Levels (10 percent)

Figure modified and reproduced from Appendix C

Potential Implications for Local Streamflow Under the Preferred Alternative

Based upon simulated ET values, FTE will likely utilize a substantial amount of water at the local level (Figure 23). These simulated FTE ET values also suggests that FTE is capable of reducing local Q, and thus, contribution of water toward local streamflow (Figure 25). In a worst-case scenario, as streamflow approaches 0, perennial streamflow on local land may shift to intermittent streamflow, potentially causing streams to dry during certain parts of the year. It is important to note that the impacts in Figure 23 and Figure 25 represented averages, and thus, impacts during drought years may be more significant. Within a season, this potential scenario is most likely to occur when FTE ET is the highest in the action area, meaning between spring and fall. This potential impact on local streamflow is supported by observations of non-GE *Eucalyptus* from the peer-reviewed literature and are to be expected from any rapidly growing, non-deciduous tree species (Sun et al., 2004; Farley et al., 2005; Sun et al., 2010; Chang, 2013).

These results, summarized above and presented in Appendix C, represent FTE-mediated absolute impacts on local streamflow under the Preferred Alternative. In order to determine the significance of this absolute impact, the relative impact must be determined through comparison to an appropriate reference point. As presented in the discussion of Potential Impacts on Water Resources Resulting from the No Action Alternative (Section 4.3.4) and the USDA FS technical report entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* (Appendix B), this appropriate reference point is plantation-grown loblolly pine, as it is the land use and cover type most likely to be replaced by FTE. The difference in local impacts on streamflow between plantation pine and FTE helps to determine the relative impact of FTE on local streamflow, and thus, the significance of this impact.

As discussed in the Potential Impacts on Water Resources Resulting from the No Action Alternative (Section 4.3.4), plantation pine has the capacity for high water use (up to 100 percent of precipitation), as demonstrated by observed ET values for pine in many areas of the southern United States. Compared to plantation pine, simulated FTE ET was comparable to the "higher-end" estimates for pine, but greater than others, and showed a similar pattern of ET across multiple growing seasons and within a single growing season (Figure 23 and Figure 24). Considering the relationship between Q and ET (Lockaby et al., 2012a), similar ET values between plant species would suggest similar effects on Q, and thus, similar impacts on local streamflow (Sun et al., 2004; Farley et al., 2005; Lockaby et al., 2012a). A comparison of observed plantation pine ET and simulated FTE ET suggest that these tree species may use similar amounts of water in some settings, with similar consequences for local water balance and local streamflow. Based on this comparison, it would appear that FTE may not significantly reduce local streamflow any more than plantation pine in some regions of the action area.

Mathematical models incorporate a large number of parameters to accurately describe a system. The mathematical model used to simulate potential FTE ET, and thus, determine its potential impacts on local streamflow, incorporates a plethora of biophysical variables to determine overall ET. However, this mathematical model does not directly incorporate all anatomical differences[55] between plant species and the resulting impacts on plant physiological processes. In short, a comparison of observed plantation pine ET and simulated FTE ET[56] may not truly indicate a similar impact on local Q and local streamflow.

One anatomical difference between FTE and plantation pine that may affect ET is the structure of the root system. In contrast to plantation pine, FTE (like any non-GE *Eucalyptus*) possesses a dimorphic root system[57] (Stape et al., 2004; Stape et al., 2010; Lima, 2011). When compared to the shallow root system of plantation pine (Johnston and Crossley, 2002), this anatomical difference may permit FTE greater access to water when compared to plantation pine. This anatomical difference may be particularly relevant, given observed physiological responses of tree species when water is limited. In general, when subject to water stress, tree species will generally increase root growth at the expense of aboveground tissue growth. This is particularly true in *Eucalyptus* species, where its dimorphic root system may permit an increased capacity to exploit water resources deeper in the soil than plantation pine (Dye, 1996b).

As a result of this observation regarding the limitations to consider differential access to water in plant species, it is difficult to conclude that FTE will yield similar impacts on local streamflow in comparison to plantation pine. If one takes into account the function of a dimorphic root system to permit greater access to water, and the general consensus that FTE grows faster than plantation pine, it is likely that FTE will be able to access more water and use more water than plantation pine. Accordingly, as a result of this anatomical rooting structure and intrinsic characteristics to maintain its rapid growth, it is likely that FTE

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[55] The USDA-FS model incorporates LAI and Gc declines; see Appendix C for further details

[56] Recall that observed values are represented by direct measurement in the field; in contrast, simulated values result from mathematical modeling exercises. The USDA-FS technical report, Implications for expansion of GE freeze-tolerant Eucalyptus plantations of water resources in the continental US, made comparisons of observed pine plantation water balance values and simulated FTE water balance values

[57] FTE (and non-GE Eucalyptus) possesses a dimorphic root system. This means that the root system consists of both a taproot and a system of lateral roots. The taproot facilitates access to sources of water deeper in the soil, while lateral roots facilitate acquisition of water just below the surface of the soil. This is in contrast to a monomorphic root system, a root system that consists of either a taproot or a system of lateral roots. In plantation pine, a system of lateral roots is present.

will reduce streamflow even further than plantation pine. A synthesis of peer-reviewed studies examining the observed impact of plantation pine and plantation *Eucalyptus* on water balance appears to support this general conclusion (Figure 29), where *Eucalyptus* species generally decrease local streamflow more than plantation pine at numerous locations and under a variety of climatic conditions (Farley et al., 2005; Jackson et al., 2009; Chang, 2013).

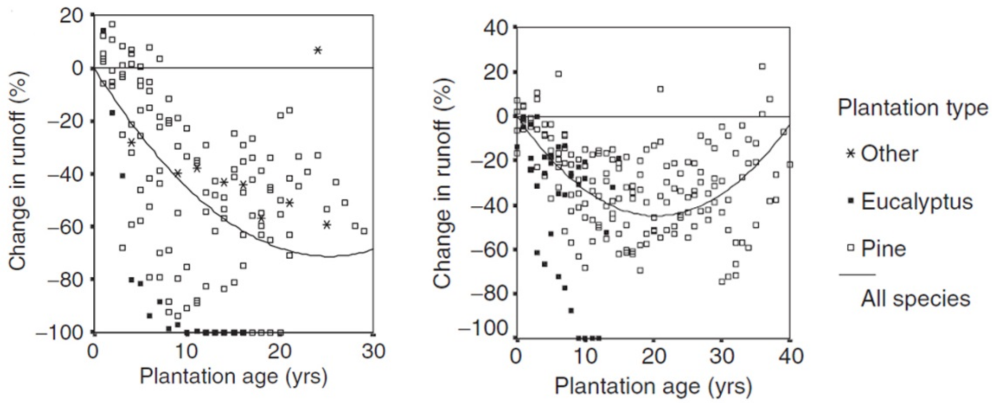

Figure 29. Percent Change in Runoff at a Variety of Grassland (A) and Shrub Land (B) Sites Afforested with Plantation Pine

Reproduced from Farley et al. (2005)

Additionally, while FTE may reduce streamflow more than plantation pine, it is prudent to recall that precipitation modulates the impact vegetation on streamflow (Section 4.3.4). Once again, consider the general water balance equation originally presented in Section 4.3.4:

$$Q = P - ET$$

While ET represents the amount of water that is taken out of a system, P represents the amount of water that is added to a system. Within the action area, P is represented as rainfall. The modulating effect of P on Q, and therefore, local streamflow is apparent when simulated FTE ET is used to determine Q. In an examination of impacts on local Q by FTE, the largest net decrease in site water balance is associated with sites that received the least amount of precipitation. For example, in Figure 25, the Georgia and Texas sites experienced the greatest reduction in Q relative to the remaining sites in Alabama, Florida, and Mississippi. In the Georgia and Texas sites, annual precipitation averaged 1063 and 779 mm year^{-1}, respectively. This is in contrast to greater precipitation levels at the Alabama (1479 mm year^{-1}), Florida (1375 mm year^{-1}), and Mississippi (1553 mm year^{-1}) sites (Table 3 in Appendix C). The modulating effect of precipitation on streamflow is well documented in the literature, where lower precipitation levels exert larger relative impacts on streamflow reductions than greater precipitation levels (Farley et al., 2005; Jackson et al., 2009; Chang, 2013). This is primarily due to the observation that under lower precipitation levels, there is less water overall to participate in hydrological processes, thereby increasing the relative impact of any hydrological processes that use water.

In summary, FTE is likely to use more water than plantation pine, and thus, reduce local streamflow more than plantation pine within the action area. The magnitude of this reduction, however, is dependent on site precipitation levels, suggesting that any overall impact on streamflow is ultimately site dependent.

Potential Impacts of FTE on Water Quality

As presented in the discussion of Potential Impacts on Water Resources Resulting from the No Action Alternative (Section 4.3.4), plantation forestry in the action area primarily impacts surface water quality through the generation of sediments. These forestry sediments are derived from the use and generation of forest roads and stream crossings (Bengston and Fan, 1999; Gucinski et al., 2001; Swank et al., 2001; Jackson et al., 2004; Chang, 2013).

FTE is likely to be cultivated on sites previously planted to plantation pine (Appendix B). Consequently, the cultivation of FTE on the previous sites of plantation pine is unlikely to increase the generation of forest access systems, as these sites and their respective forest access systems are already in place for plantation forestry.

However, because the rotation cycle of FTE is shorter than plantation pine (Arborgen, 2011), it is likely that forest roads and stream crossings (forest access systems) that service the plantation site will be subject to more frequent disturbances associated with FTE management activities (e.g., site preparation and harvesting). As a result of more frequent disturbances, sediment load from these forest access systems are likely to increase, thereby potentially impacting local water quality. However, as mentioned in presented in the discussion of Potential Impacts on Water Resources Resulting from the No Action Alternative (Section 4.3.4), BMPs are commonly utilized by foresters and growers in the action area to mitigate sediment loss from forest roads and stream crossings into surface waters. Though voluntary, these BMPs are likely to be effective in reducing sediments from forest access systems that are utilized in the production of FTE as plantation pine, as these BMPs were designed for general use in production forestry (Kochenderfer and Edwards, 1990; Adams et al., 1995; Arthur et al., 1998; Williams et al., 1999; Vowell, 2001; Williams et al., 2001; Williams et al., 2002; Carroll et al., 2004).

At larger spatial scales within the action area, the potential impact of FTE on surface sedimentation is likely to be negligible compared to other potential sources of sediments. As discussed in Section 4.3.4, production forestry and related silvicultural activities contribute a relatively small proportion of sediments into surface waters when compared to other sources of sediment (e.g., urbanization and conventional row agriculture) (EPA, 2000b; EPA, 2014c). Considering that FTE is projected to replace ≤ 10 percent of plantation pine (Appendix B), the relative contribution of FTE to landscape-scale sediment generation is also likely to be negligible, as the overall contribution of production forestry to surface water sedimentation is already low (EPA, 2000b; EPA, 2014c).

Additionally, as a result of likely reductions in water balance by FTE at the site level, it is possible that nutrient concentration increases may occur in streams in and adjacent to sites where FTE is cultivated due to the concentrating effect of local water reduction (Jackson et al., 2004; Chang, 2013). These effects, however, are uncertain, as these concentration increases have been noted to be nutrient dependent and sometimes only transiently observed in plantations as noted in the peer-reviewed literature (Jackson et al., 2004; Chang, 2013).

In summary, FTE may impact local water quality through an increased contribution of sediments from forest roads and stream crossings in the action area. However, this local impact on water quality is unlikely to change landscape-scale impacts from production forestry, considering the relatively low contribution of sediments from production forestry and the relatively small projected adoption level of FTE.

4.6.5 Potential Impact on Plantation Pine-Associated Vegetation Resulting from the Preferred Alternative

4.6.5.1 Summary of the Preferred Alternative on Plantation Pine-Associated Vegetation

The replacement of planted pine plantations in the action area with FTE likely may result in a quicker shift to shade-tolerant vegetation in the understory. FTE, like other *Eucalyptus* species under plantation management, grows quickly and reaches canopy closure within two years compared to pine canopy closure of 10-12 years. Other environmental factors, including soil bulk density, soil moisture holding capacity, and soil organic content, contributed to understory species diversity and dominance, but not as much of a role as that of light level. *Eucalyptus* harvest cycles are 6-10 years and four to six harvests can occur per planting. This equates to two or more harvest cycles within the period of one harvest cycle for planted pine. The machinery used during various management activities, particularly harvesting activities, would damage understory vegetation. In FTE plantations, this disturbance would occur every 6-10 years as opposed to 20-25 years for pine plantations. Several studies indicate older pine and *Eucalyptus* plantations tend to have a higher level of plant diversity given the additional time to develop structural complexity. In addition, older plantations also tend to have more native plant species compared to younger plantations that tend to have light-demanding, ruderal and exotic plant species. FTE likely will mimic a young plantation given the short harvest cycle. FTE plantations may require more management inputs compared to pine plantations, particularly in the stand establishment phase to control vegetation competition. Herbicide applications to manage vegetation competition are already common in pine plantations in the action area. FTE seedlings, like other *Eucalyptus* seedlings, are more sensitive to plant competition than are pine seedlings. In the early stage of rotation, FTE plantations will likely have reduced herbaceous cover compared to planted pine plantations due to multiple applications of herbicides to control vegetation. The short harvest cycles for FTE will result in additional vegetation control since the canopy will reopen after harvest, encouraging the growth of understory plants until FTE trees sprout and attain canopy closure again. The suppression of vegetation competition in southern plantations, regardless of tree species, intentionally kills understory plants. In general, tree plantations, including pine and eucalyptus plantations, have lower plant species diversity than natural forests because they usually consist of a monoculture, and silvicultural practices, including treatment for vegetation competition and harvesting, disturb the understory. However, due to the short cycle and increased frequency of application of herbicides, FTE plantations may have lower plant diversity than pine plantations do.

4.6.5.2 Preferred Alternative Analysis on Plantation Pine-Associated Vegetation

<u>Introduction and Assumptions</u>

Under the Preferred Alternative, planting FTE on lands previously planted with commercial pine species in the study area may occur. FTE may provide equivalent or superior quality pulpwood compared to plantation pine. Growers may opt to grow FTE because it is fast growing which leads to shorter rotation cycles, and (unlike with pine) harvest can result in coppice (re-sprouting from cut stumps) as opposed to full removal and the need to replant individuals.

The purpose of this analysis is to evaluate impacts on vegetation associated within and adjacent to FTE plantations previously planted with pine. Understory vegetation in commercial tree plantations serves an important role in ecosystem health and biodiversity (Ramovs and Roberts, 2003; Duan et al., 2010). It serves an important role in nutrient cycling as well as contributions to soil and water quality within the plantation and areas surrounding the plantation (Yarie, 1980). Many vertebrate and invertebrate species depend on understory vegetation (Koide and Wu, 2003; Pineda et al., 2005; Mboukou-Kimbatsa et al., 2007; Duan et al., 2010). These roles emphasize the importance of the vegetative understory and adaptation of plantation practices are occurring to account for these services. This section touches upon plant diversity within and adjacent to a commercial tree stand; see Section 4.6.8 for a discussion on biodiversity across the broader landscape.

Several key assumptions underlay the analysis and frame the remainder of the FTE to pine plantation comparison. These are:

- FTE will be planted on land already designated as planted pine plantation (Appendix B);
- FTE will be planted on approximately 10 percent or less of the lands already dedicated to plantation pine (Appendix B);
- Species richness is lower in plantations compared to natural forests (Bremer and Farley, 2010) and pine plantations in the action area already have reduced species richness (Section 4.3.5);
- FTE plantations for pulpwood will grow in a 2:1 time to harvest ratio compared to loblolly/slash pine pulpwood plantations (Appendices B and D); and
- Issues relating to allopathic tendencies for FTE plantations are not expected (Section 4.6.3).

Given the limited information available on *Eucalyptus* cultivation in the United States, including FTE, reliance on *Eucalyptus* research in other countries, technical information provided by ArborGen, Inc., and expert opinion is necessary to understand potential impacts to understory vegetation. Where appropriate, citations for these references occur throughout this section.

Commercial *Eucalyptus* Plantation Management and the Impacts to Understory and Bordering Vegetation

Management of tree plantations occurs throughout the rotation cycle. The strategies used to carry out the management practices depend on numerous factors including the species of tree cultivated, site location, intended market, and environmental factors.

Pine and *Eucalyptus* plantation management in the action area both involve reducing vegetation competition, bed preparation for seedlings, fertilization, and harvesting (Schönau, 1984; Sein and Mitlöhner, 2011). The frequency and timing for these activities is dependent upon the local site conditions.

The key differences in *Eucalyptus* management practices result from several biological traits of the tree and may cause different impacts on understory vegetation compared to that of pine plantations. In particular, *Eucalyptus* trees, including FTE, are 1) more sensitive to vegetation competition during seedling establishment than pine (Schönau, 1985; Schönau and Coetzee, 1989; ERDB, 2009; Rockwood and Peter, 2014); 2) faster growing than pine leading to a shortened time interval to canopy closure and harvest (Baker and Hunter, 2002; Arborgen, 2011); and 3) undergo multiple harvests from one planting (coppice) whereas pine is cut and replanted (White, 1995; Siry, 2004; Sein and Mitlöhner, 2011; ArborGen, 2014; Rockwood and Peter, 2014). A discussion of these differences and their impacts to understory and bordering vegetation follows.

Vegetation Competition Management and its Impacts on Understory and Bordering Vegetation

Competing vegetation is a major problem on recently planted forest sites as it can grow overtop newly planted trees and compete for light, water, and nutrients resulting in slower growth and seedling mortality (Miller et al., 1995; Fox et al., 2004; Siry, 2004). Impediment of *Eucalyptus* and pine seedlings by competing vegetation, especially hardwood trees that regenerate faster than pine, affects establishment of plantations (Fox et al., 2004). Species of *Eucalyptus* are intolerant of competition and overhead cover from other plants, including weeds, grasses, and trees (Schönau, 1985; Schönau and Coetzee, 1989; ERDB, 2009; Rockwood and Peter, 2014). The goal of vegetation management in both pine and *Eucalyptus* plantations is to kill the understory as well as vegetation along the stand borders to prevent the influx of weeds and invasive plant species. This reduces the density and diversity of plants found in the understory.

Vegetation management occurs throughout the rotation of both pine and *Eucalyptus* plantations. The removal of weeds and sprouting hardwood trees through mechanical and/or herbicide applications is standard management practice during the site preparation phase for both pine and *Eucalyptus* plantations (Siry, 2004; Jones et al., 2009b; Sein and Mitlöhner, 2011; Personal Communication with P. Minogue, 2013b; ArborGen, 2014). Herbicide applications in pine and *Eucalyptus* plantations during site preparation are becoming more common given the recent trends towards minimal soil disturbance through burning, ploughing, and harrowing (Jones et al., 2009a; Sein and Mitlöhner, 2011). Establishing *Eucalyptus* on the footprint of pine plantations in the action area requires removal of existing pines, including stumps and roots, and all other vegetation. One company that produces *Eucalyptus* varieties in the United States indicates that the control of competition at the site preparation phase is more important for *Eucalyptus* trees than for pine tree establishment (ArborGen, 2014). In one site preparation plan for *Eucalyptus*, after the first herbicide application, mechanical site preparation follows, including controlled burning on sites with substantial woody debris (ArborGen, 2014).

In pine plantations in the southern United States, vegetation management typically occurs during site preparation, two to five years after planting, and after thinning which usually occurs 12 to 18 years after planting (Miller et al., 1995; Cassidy, 2005). The use of herbicides to control herbaceous weeds and hardwood trees in pine plantations is a widespread practice throughout the South (Fox et al., 2004; Siry, 2004; Jones et al., 2009b). The succession of understory plants in southern pine plantations varies depending on the type and time of treatment. Control of herbaceous plants early in the rotation of pine results in a decrease of herbaceous plants and woody shrubs, the latter likely outcompeted by growing pine and other tree species (Miller et al., 2003; Miller and Chamberlain, 2008). Herbaceous plant control in pine plantations removes competition for nutrients and water, and leads to an increase in hardwood dominance (Miller et al., 1995). A rebound in herbaceous plants (dominantly grasses) to 60-80 percent coverage within the first year of rotation occurred after no vegetation control or treatment for woody species during site preparation (Miller et al., 1995; Miller et al., 2003). Controlling woody plant species extends the presence of herbaceous plant species through year eight of the pine rotation; however, without woody plant control herbaceous plant cover drops much earlier (year six) in the rotation due to increase shade from shrubs and pine canopy closure (Miller et al., 1995; Miller et al., 2003). Forbs peak at 1-2 years into rotation and decline as the stand ages. In contrast, vine cover began to increase by year six (Miller et al., 1995).

In *Eucalyptus* plantations, the application of herbicide typically occurs during site preparation followed by multiple applications within the first year of establishment. This is slightly more intensive than vegetation management during the first year in a pine plantation, but is essential to control grasses and herbaceous weeds, as these compete with young *Eucalyptus* seedlings resulting in crop failure (Rockwood, 1997; Rockwood and Peter, 2014). In *Eucalyptus* plantations in Florida, growers typically apply two or more applications of herbicides until stand establishment 2-3 months after planting (Personal Communication with P. Minogue, 2013b). In Hawaii, guidelines specify two herbicide applications within six months after planting *Eucalyptus* to control vegetation competition (Whitesell et al., 1992). After the first year, the application of herbicides in *Eucalyptus* plantations occurs as needed (ArborGen, 2014). After canopy closure in a *Eucalyptus* plantation, typically by the end of the second year, weed control is usually not needed (ArborGen, 2014). *Eucalyptus* plantations, including FTE, are ready for harvest within six to ten years, undergoing two to four harvest cycles per one pine rotation. *Eucalyptus* trees re-sprout after the first harvest to produce the next crop rotation. The vegetation management process begins all over again after harvest and until canopy closure. This may result in a higher number of herbicide applications in *Eucalyptus* plantations to control herbaceous and woody vegetation compared to one rotation of a pine plantation (Figure 30). The understory succession in *Eucalyptus* plantations will likely differ from pine plantations. The multiple herbicide treatments within the first six months will reduce the rebound of herbaceous plants. The short rotation cycles and vegetation management may outpace the growth of the understory plants. For example, in pine plantations, forbs peak 1-2 years in rotation when the canopy is still open and woody vines eight years into rotation, which is about the time of *Eucalyptus* harvest. Canopy cover (discussed later in this section) is a factor in succession, but other microclimate factors and vegetation management early in rotation influence the succession of understory plants.

Plant diversity in both pine and *Eucalyptus* plantations declines in response to vegetation control (Jones et al., 2009a). Vegetation diversity was lower within *Eucalyptus* plantations compared to a second-generation natural forest in the Congo (Loumeto and Huttel, 1997). Approximately 75 percent of the species found in the forest were absent in the plantation. This is expected since reducing vegetation competition is an important management strategy, and in contrast to likely competition management in the action area, competition management in the Congo occurs during the first three years after planting (Loumeto and Huttel, 1997).

The borders around tree plantations are also subject to vegetation management. However, less vegetation management occurs with increasing distance from the edge of the tree plantation. Managing vegetation along the borders of a plantation is undertaken to reduce the influx of invasive species into plantations. In pine plantations in the southern United States, invasive species are on the rise (Miller et al., 2003). In a study on vegetation within *Eucalyptus* plantations, the authors note lower species diversity 50 – 100 meter (m) from the edge of the plantation stand compared to 10-m from the edge of the natural forest (Loumeto and Huttel, 1997). The reduced species diversity is not entirely due to vegetation management; other management and biological factors contribute to diversity.

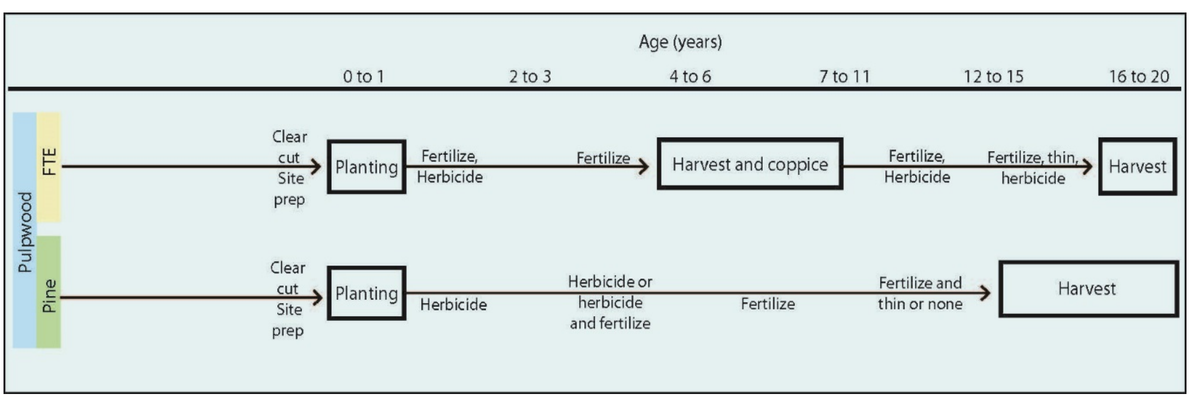

Figure 30. Timing of Management Activities in FTE and Pine Plantations for Pulpwood Production

Time to Canopy Closure and its Impacts on Understory Vegetation

Canopy cover influences understory plant composition, structure, and diversity (Michelsen et al., 1996; Hartley, 2002; Bremer and Farley, 2010; Duan et al., 2010). In the typical course of forest succession, understory plant diversity is relatively high at the stand initiation stage through the mid-successional stages as plant species with varying levels of shade tolerance occupy the site at the same time (Baker and Hunter, 2002). As the stand matures, shade levels increase as the canopy gap closes, resulting in a decline in plant diversity and a shift to shade-tolerant species (Oliver and Larson, 1996; Baker and Hunter, 2002; Bremer and Farley, 2010). Tree plantations reach crown closure and enter stem-exclusion stage sooner than naturally-regenerated forests (Ramovs and Roberts, 2003). General patterns in plant succession in pine plantations in the action area reflect this more rapid closure, partly because of an impact of single-species planting (Shultz, 1997).

In younger, dense tree stands, overlapping crowns are more common (Oliver and Larson, 1996), and this pertains to both *Eucalyptus* forests and plantations (Schönau and Coetzee, 1989). However, in older tree stands, overlapping crowns are less common (Oliver and Larson, 1996); *Eucalyptus* tree buds are sensitive to abrasion that occurs when branches interlock (Schönau and Coetzee, 1989), likely leading to the greater light penetration observed in the 22-year *Eucalyptus* stands when compared to plantations planted to a mix of tree species (Duan et al., 2010).

The degree of shade in an older *Eucalyptus* plantation may not be as great as in a pine plantation. In a literature review by Bauhus et al. (2001), light transmission beneath older (natural) *Eucalyptus* forest canopies range from 30 to 47 percent, which is higher than the light transmission measured beneath northern hemisphere conifer and hardwood forests (0.5 to 15 percent). This is likely due to *Eucalyptus* canopies having an open nature and lacking interlocking branches in older age *Eucalyptus* stands.

The difference in time to canopy closure between a *Eucalyptus* plantation and pine plantation will likely have an impact on the understory. In pine plantations, canopy closure occurs 10 to 12 years after establishment (Baker and Hunter, 2002). In *Eucalyptus* plantations, including FTE, canopy gap closure occurs approximately 24 months after establishment (about eight years sooner than in pine plantations) (ArborGen, 2014).

As the pine canopy closes, a decline in herbaceous plant cover and an increase in shade-tolerant shrubs and woody vines may occur (Miller, 2003; Miller and Chamberlain, 2008). After vegetation management in the first 3-5 years of rotation in southern pine plantations, woody shrubs regrowth began in years 6-8. Herbaceous cover declines when the pine canopy reaches 50-60 percent closure, approximately around year eight (Miller, 2003). In pine plantations, the canopy may open up for a short time after tree thinning which may occur 12 to 18 years into the rotation (Cassidy, 2005). Thinning reduces canopy cover and allows light to penetrate the forest floor, encouraging growth of understory plants (Baker and Hunter, 2002). As the canopy gap closes, shade-intolerant species are edged out.

In Florida, crown closure in *Eucalyptus* stands suppresses the growth of understory vegetation because of shading (Personal Communiation with P. Minogue, 2013b). In FTE plantations, an emergence of shade-tolerant plant species, such as vines, may occur earlier than that observed in pine plantations due to more rapid canopy closure (Table 12) (Miller et al., 1995; Miller et al., 2003). Herbaceous cover will likely decline within two years with the onset of canopy closure in FTE plantations, as opposed to around eight years in pine plantation. The onset of woody shrub growth 6-8 years into rotation in pine plantations may indicate a potential reduction in diversity and composition of woody shrub in FTE plantations, as FTE is ready for harvest within six to ten years.

Along with potential changes in plant succession, a reduction in plant diversity may occur in FTE plantations that replace pine plantations in the action area. Wang et al. (2011) reported lower species diversity in the understory of 7-year-old *Eucalyptus* plantations compared with 10-year-old secondary evergreen forests. Loumeto and Huttel (1997) noted *Eucalyptus* plantations lacked consistent undergrowth when they reached the harvesting age of 6-7 years. Calviño-Cancela et al. (2012) observed a drop in species diversity between young (5-8 year old) low-managed *Eucalyptus* plantations and intermediate (15-18 year old) plantations followed by an increase in diversity with the entrance of shade-tolerant species in older (over 25 years old) *Eucalyptus* plantations, likely because of the more open canopy in older *Eucalyptus* plantations (Schönau and Coetzee, 1989). The young *Eucalyptus* plantations had significantly less herbaceous and tree biovolume, measured in the height and width of species present, but significantly more shrub biovolume compared with pine plantations over 60 years of age (Calviño-Cancela et al., 2012). Woody plants invaded *Eucalyptus* stands over twelve years of age (Loumeto and Huttel, 1997). In a comparison study of six 22-year-old plantations in China, three planted with native species and three with nonnative species (two with *Eucalyptus*) at a tree spacing of 2.5-m x 2.5-m, light was the most limiting factor contributing to composition and structure of understory vegetation in all plantations (Duan et al., 2010). Other environmental factors, including soil bulk density, soil moisture holding capacity, and soil organic content, contributed to understory species diversity and dominance, but not as much of a role as that of light level. The two *Eucalyptus* plantations contained the lowest number of understory species. The mixed native species plantations had the highest diversity of understory plant species, but less grass coverage compared to the *Eucalyptus* plantations. In the *Eucalyptus* plantations, the composition of understory species was homogenous compared with the other plantation types. The composition of the vegetation was mostly grass species and tall shrubs, with minimal to no presence of woody species (Duan et al., 2010). Drought-tolerant plants were more common in the understory of *Eucalyptus* compared to native tree plantations, attributed to the possible higher level of evapotranspiration with greater light penetration and the greater uptake of water by fast growing tree species (Duan et al., 2010). These patterns were explained by the composition of the *Eucalyptus* species; generally fast growing, tall with relatively thin crown coverage when more mature that would allow more light to reach the forest floor, causing an increase in grass and shrub species, which flourish under these understory conditions (Duan et al., 2010).

Tree spacing in plantations affects the time to canopy closure (Schönau and Coetzee, 1989). The spacing of trees in a plantation is dependent on market factors and site characteristics. In pine plantations, common spacing is between 2.4-m (8-ft) and 3.7-m (12-ft) between rows and 1.8-m (6-ft) and 2.4-m (8-ft) within rows (Londo and Dicke, 2006). Plantings of *Eucalyptus* trees are typically at a higher density for pulpwood than for other markets, such as sawtimber (Schönau and Coetzee, 1989). Based on a review of the literature, Schönau and Coetzee (1989) recommend a spacing of 3-m between rows x 2.5-m for *Eucalyptus* grown for pulpwood; Sein and Mitlöhner (2011) recommend a spacing of 2.5-m x 2.5-m. The plant spacing recommended for *Eucalyptus* pulp wood production by the petitioner, ArborGen (2014), is in line with these recommendations. “Closely spaced pines cause even greater reductions in understory development” compared with eucalypt species, although eucalypts' faster growth rate will shade out native vegetation of the same age regenerating below them (Davidson, 1995). Wide spacing in *Eucalyptus* plantations delays canopy closure and increases weeding costs (Schönau and Coetzee, 1989). Based on the literature, the spacing of trees in *Eucalyptus* plantations for pulpwood production in the action area may be slightly less than the spacing in typical southern pine plantations. This spacing difference may a factor in the time to crown closure; however, the growth rate of *Eucalyptus* is the main contributor to the time to crown closure.

Eucalyptus plantations grown for pulpwood undergo thinning after harvest to reduce competition between shoots sprouting from the same tree stump. In contrast, thinning in pine plantations involve the removal of pine trees from the stand. Removal of trees during thinning increased the percent coverage of forbs (herbaceous flowering plants that are not grasses) but did not alter the species richness or diversity in the understory, nor did it result in an increase in understory cover (Bauhus et al., 2001). The increase in forbs may indicate suppression by shade prior to thinning. The impacts of reducing overhead canopy on the vegetative understory observed by Bauhus et al. (2001) contrasts with other studies (discussed in the next section). The authors speculate that there is a time lag in the vegetative understory response, and that light levels under the *Eucalyptus* canopy may not favor dense-shade tolerant plants given the open nature of the canopy. In their study, the site location and characteristics, as well as the age and species composition of the *Eucalyptus* forest could also be factors influencing the response of the vegetative understory to increased light transmission. FTE plantations in the southern United States will undergo harvest every six to ten years, and may not experience a more open canopy as observed in older *Eucalyptus* plantations, although in a study by Loumeto and Huttel (1997), canopy density was always light beneath canopies of *Eucalyptus* plantations ranging in stand age of six to 20 years.

Table 12 highlights shade-tolerant plants present on pine plantations in the study area. Switching from pine to FTE will likely cause a shift to shade-tolerant species in the understory sooner than that observed in pine plantations, due to the shorter time interval to canopy gap closure.

Table 12. Plantations in the Action Area That May Also Be Found in FTE Plantations*

Scientific Name	Common Name	Reference
Tree		
Acer saccharum *A. rubrum*	Maple, sugar Maple, red	(Hedman et al., 2000; Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)
Asimina triloba	Pawpaw	(Jones et al., 2009a; USDA-NRCS, 2014)
Celtis laevigata *C. occidentalis* *Celtis* sp.	Sugarberry Common hackberry Dwarf hackberry	(Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)
Cornus alternifolia *C. florida*	Alternateleaf dogwood Flowering dogwood	(Hedman et al., 2000; Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)
Fagus grandifolia	American beech	(Lane et al., 2011b; USDA-NRCS, 2014)
Fraxinus caroliniana *F. pennsylvanica*	Carolina ash Green ash	(Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)
Oxydendrum arboreum	Sourwood	(Hedman et al., 2000; Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)
Persea borbonia	Redbay	(Lane et al., 2011b; USDA-NRCS, 2014)
Ulmus alata *U. rubra* *U. serotina*	Winged elm Slippery elm September elm	(Hedman et al., 2000; Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)
Amelanchier sp.	Serviceberry	(Hedman et al., 2000; Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)

Magnolia virginiana	Sweet bay	(Hedman et al., 2000; Russ, 2004; Jones et al., 2009a; Lane et al., 2011b)
Nyssa sylvatica	Black gum	(Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)
Herbaceous, forb, vine, or grass		
Ampelopsis arborea	Peppervine spp.	(Hedman et al., 2000; Jones et al., 2009a; Lane et al., 2011b; USDA-NRCS, 2014)
Chamaecrista fasciculata	Partridge pea	(Hedman et al., 2000; USDA-NRCS, 2014)
Lonicera japonica	Japanese honeysuckle	(Hedman et al., 2000; Jones et al., 2009a; USDA-NRCS, 2014)
Parthenocissus quinquefolia	Virginia creeper	(Russ, 2004; Jones et al., 2009a)
Shrub		
Ceanothus americanus	New Jersey Tea	(Hedman et al., 2000; Lane et al., 2011b; USDA-NRCS, 2014)
Hamamelis virginiana	American witchhazel	(Russ, 2004; Jones et al., 2009a; Lane et al., 2011b)
Ilex sp.	Holly	(Lane et al., 2011b; USDA-NRCS, 2014)
Ligustrum japonicum	Japanese Privet	(Lane et al., 2011b; USDA-NRCS, 2014)
Morella inodora	Scentless Bayberry	(Hedman et al., 2000; Lane et al., 2011b; USDA-NRCS, 2014)
Rhus aromatica	Fragrant Sumac	(Hedman et al., 2000; Russ, 2004; Lane et al., 2011b)
Viburnum acerifolium	Mapleleaf Viburnum	(Hedman et al., 2000; Lane et al., 2011b; USDA-NRCS, 2014)

*this is not a comprehensive list

Harvesting and its Impacts on Understory and Border Vegetation

Rotation cycles and harvest methods differ greatly between pine plantations and *Eucalyptus* plantations. The average rotation cycle for pine plantations is approximately 25 years (Siry, 2004). In contrast, the rotation cycle for *Eucalyptus* plantations is six to ten years, including FTE plantations grown for pulpwood production (Figure 30) (White, 1995; Sein and Mitlöhner, 2011; ArborGen, 2014; Rockwood and Peter, 2014).

Harvest of pine plantations is through cutting, followed by the replanting of seedlings. Harvest of *Eucalyptus* is also through cutting; however, trees regenerate by coppice, i.e., producing shoots from cut stumps. This allows for more than one rotation per planting; up to four to six rotations for some plantings (Sein and Mitlöhner, 2011; Rockwood and Peter, 2014). Coppice rotations may be ready for harvest earlier, by at least one year, than the first rotation (Rockwood and Peter, 2014).

In the southern United States, even-age stand management is very common since most commercially desirable tree species are shade intolerant (Baker and Hunter, 2002). Under this management type, the harvesting of trees in a stand occurs during the same cycle. In contrast, uneven stand management involves cutting a subset of trees in a stand as opposed to the entire stand. Uneven stand management does occur in some forest stands in the south (Baker and Hunter, 2002). The management of FTE for pulpwood production in the southern United States will likely follow the even-age stand management (e.g., continuous cropping system) since FTE will be planted on former pine plantation sites that likely used this cropping system. This would reduce the shading of *Eucalyptus* stumps, which can reduce sprout growth and cause stump mortality (Ferraz-Filho et al., 2014). However, the use of uneven stand management could occur, especially if trees are destined for another market beside pulpwood (Ferraz-Filho et al., 2014). The trees left behind after uneven-age harvests continue to grow in diameter and height during subsequent coppice cycles (Ferraz-Filho et al., 2014). In *Eucalyptus* plantations that follow un-even stand management, only a low density of trees (referred to as standard trees) remain to reduce competition to the coppice understory as it regenerates. Other advantages to leaving standard trees is the maintenance of a layer of tree vegetation that serves as a habitat to wildlife and addresses some needs surrounding recreational function and nature conservation (Ferraz-Filho et al., 2014). Regardless of the stand management type followed, the impacts to the vegetative understory will likely be similar since harvest will occur every six to ten years, disturbing the understory vegetation and forest floor and causing canopy gaps. In addition, other management practices, such as the application of herbicides to prevent vegetation competition, would follow harvests (Figure 30). Loumeto and Huttel (1997) observed (but did not study) a rapid regrowth of understory plants in *Eucalyptus* plantations after harvest compared to the first rotation stands.

In one study, a comparison of the vegetative understory between a first rotation *Eucalyptus* plantation (previously planted to a 23-year-old Chinese fir trees) and a second rotation *Eucalyptus* plantation found lower species diversity and more herbaceous than woody species in the second-rotation plantation (Wen et al., 2010). Based on this study, the authors conclude that the repetitive damage from short-rotation harvest cycles leads to a reduction in plant diversity and composition. The machinery used during harvest and the harvesting process disturbs the plantation forest floor and damages the vegetative understory (Wen et al., 2010). Clear-cutting changes the microclimate and alters soil conditions (Wen et al., 2010).

In a review of peer-reviewed literature, Bremer and Farley (2010) found a higher level of plant diversity in older plantations, including those planted to *Pinus caribaea* Morelet and *Eucalyptus*, established on previously forested lands given the additional time to develop structural complexity. Older plantations also tend to have more native species compared to younger plantations that tend to have light-demanding ruderal (the first plants to colonize a disturbed area) (Loumeto and Huttel, 1997) and often exotic species. Wang et al. (2011) reported a reduction in plant diversity as well as a decline in the quality of the regenerated vegetative understory within a 7-year-old *Eucalyptus* plantation compared to a 10-year-old secondary evergreen forest. They also observed *Eucalyptus* trees outcompete native and endemic plants, impeding their growth in the understory (Wang et al., 2011). Loumeto and Huttel (1997) found greater species diversity in *Eucalyptus* stands over 10 years of age and more woody species in stands over 12 years of age, which are a few years beyond the harvest cycles expected for FTE in the action area. In contrast to the Loumeto and Huttel (1997) study, as the *Eucalyptus* stand aged, Bauhus et al. (2001) noted an overall decrease in the composition of the vegetative understory. Calviño-Cancela et al. (2012) reported a higher level of species diversity in low maintenance young (5-8 year old) and old (greater than 25-year-old) *Eucalyptus* plantations compared to intermediate (15-20 year old) *Eucalyptus* plantations, attributing the shift to shade-tolerant species in older plantations. The six to ten year harvest cycle may cause FTE plantations to mimic “young” plantations. Although canopy closure is one factor observed in maturing plantations, there are other factors contributing to structural complexity such as the accumulation of organic matter and the succession time for plant development. Thus, *Eucalyptus* plantations that reach canopy closure within two years are not necessarily structurally complex.

Tree harvesting creates edges. Harper et al. (2005) defines forest edge as the "interface between forested and non-forested ecosystems or between two forests of contrasting composition or structure". In a recently created edge, canopy cover, tree density, and biomass decreases, and physical disturbance to vegetation and soil can occur during harvest (Harper et al., 2005). In response to these changes, sapling density and understory cover increases and a change in species composition, particularly in the increase in abundance of saplings, herbs, and shrubs, occurs at the edge (Harper et al., 2005). At the edge, compositional changes in plant species typically involve an increase in exotic and shade-intolerant species and a lower abundance of shade-tolerant species (Harper et al., 2005). The influence of edge is typically less in forest with more open and diverse canopies (Harper et al., 2005), which may apply in *Eucalyptus* plantations that have more open canopies.

In one study evaluating the floristic and structural characteristics of the boundary between *Eucalyptus* forest and a rainforest, grass (shade-intolerant) species dominate the understory of the *Eucalyptus* forest and fewer plant species occur in the understory (Turton and Duff, 1992). Across the boundary gradient from the *Eucalyptus* forest to rainforest, a decrease in grass species and an increase in shrub (shade-tolerant) species as well as overall number of plant species occur in the understory of the rainforest. The floristic patterns follow the light levels from higher light levels under the *Eucalyptus* canopy to diminished light levels under the rainforest canopy (Turton and Duff, 1992).

Plantations of native tree species established on exotic or degraded pastures had more species richness in the understory compared to plantations of non-native tree species established on the same land type (Bremer and Farley, 2010). The authors speculate the reasons for this observation may be because plantations of native tree species closely resemble natural forests and they may favor faunal diversity due to masting cycles and the quality of fruit and nectar (Bremer and Farley, 2010). The impacts to fauna from plantation management practices are also likely to affect the diversity and composition of the vegetative understory as numerous species play a role in seed dispersal and pollination (Oliver and Larson, 1996). Forest edge habitat supports an abundance and diversity of game species; conversely, it affects breeding of some songbirds (Harper et al., 2005).

See Section 4.6.6 for a discussion on wildlife interactions with pine and *Eucalyptus* plantations.

Conclusions

Pine plantations in the action area already have low diversity, composition, and density of understory vegetation. Pine and *Eucalyptus* plantations, including FTE plantations, are typically monocultures, which have reduced understory diversity compared to natural forests (Loumeto and Huttel, 1997; Wang et al., 2011). In addition, the management of competing vegetation reduces the density and diversity of understory and bordering vegetation. During site establishment, FTE plantations may receive more herbicide applications than pine plantations, affecting plant succession in the understory. Soil amendments are part of pine and *Eucalyptus* plantation management and affect understory vegetation; however, application regime is site specific and distinct impacts to understory vegetation cannot be drawn between the two plantation types (Baker and Hunter, 2002; Fox et al., 2004; Personal Communication with P. Minogue, 2013b; ArborGen, 2014). Several studies indicate an increase in plant diversity and composition as plantations age while others indicate this is not the case. The short-rotation of FTE plantations in the action area may lead to less plant diversity, possibly with a plant composition mostly composed of grass and ruderal species, compared with pine plantation stands of 25 years of age. The short harvest cycles for FTE will result in changes to understory vegetation every six to ten years, compared to every twenty-five years for pine.

4.6.6 Potential Impact on Plantation Pine-Associated Wildlife Resulting from the Preferred Alternative

4.6.6.1 Summary of the Preferred Alternative on Plantation Pine-Associated Wildlife

The replacement of planted pine plantations in the action area with fast-growing and short-rotation FTE will likely reduce the available understory for wildlife. Since *Eucalyptus* seedlings are more sensitive to vegetative competition than pine seedlings, it is expected that FTE growers within the action area will use more intensive management strategies than in pine plantations, thereby reducing available early succession food and habitat for mammalian species commonly associated with early growth forage, including small mammals and deer. The reduction in understory and increased disturbance from short rotation times also will reduce the number of bird species that would otherwise use this habitat for shelter and nesting. This reduction is likely to be greater than the reduction in bird species associated with pine plantation management. FTE plantations will produce less nutritious, smaller seeds than pine plantations; however, insect-feeding birds will have similar opportunities in both FTE and pine plantations. Nectar-feeding birds, on the other hand, will benefit from the addition of FTE to the landscape. The number of amphibians and reptile species living in the FTE plantations will likely be minimal, further reduced from the trends described for reptile and amphibians in pine plantations. Invertebrate diversity and abundance will likely be reduced more quickly in FTE plantations compared to pine plantations due to the faster growth and shorter FTE rotation period, which subsequently reduces herbaceous cover. In addition, intensive competition management could further reduce habitat available for charismatic invertebrates. While *Eucalyptus* groves, including FTE, have the potential to be host to numerous wildlife species, the greatest biodiversity comes from old growth groves with an understory or *Eucalyptus* plantations that practice the non-traditional coppice with standards method. As a result, FTE plantations within the action area are expected to host fewer wildlife and invertebrate species than planted pine plantations, though the specific amount of reduction is uncertain for some wildlife classes.

4.6.6.2 Preferred Alternative Analysis on Plantation Pine-Associated Wildlife

<u>Introduction and Assumptions</u>

Under the Preferred Alternative, FTE may be planted on lands previously planted to pine plantations where it is expected that no more than 10 percent of current planted pine plantations will change over to *Eucalyptus* (Appendix B). Producers may select FTE instead of pine due to its fast growth and short rotation cycles (Arborgen, 2011). FTE, like other *Eucalyptus* species under plantation management, grows quickly and reaches canopy closure within two years compared to pine canopy closure of 10-12 years. *Eucalyptus* harvest cycles are 6-10 years and up to four harvests can occur per planting through coppice. Due to the short rotations, it is likely that FTE grown for pulp will be harvested twice as often as plantation pines grown for pulp (Section 4.6.5). More frequent harvesting is likely to lead to more disturbance of wildlife in FTE plantations.

In general, repetitive damage from short-rotation harvest cycles leads to a reduction in the understory plant community. The machinery used during harvest and the harvesting process disturbs the plantation forest floor and damages the vegetative understory (Wen et al., 2010). Clear-cutting changes the microclimate and alters soil conditions (Wen et al., 2010). In addition, vegetation management, including the use of herbicides, appears to be more important for *Eucalyptus* trees than for plantation pines (ArborGen, 2014). An increased use in herbicides to control grasses and herbaceous weeds will limit the vegetative community with a corresponding decrease in wildlife abundance and diversity.

Impacts of non-native *Eucalyptus* on wildlife are viewed as positive and negative in the peer-reviewed literature. The following represents a literature summary of wildlife-related impacts associated with short-rotation and mature[58] *Eucalyptus*.

Eucalyptus generally causes larger proportional changes in annual runoff than pines, especially when precipitation is limited (Section 4.6.4), potentially impacting fish, invertebrates, reptiles, and amphibians. In California, mature *Eucalyptus* groves tend to have limited native ground vegetation with shallow-rooted plants such as poison oak favored (Bean and Russo, 1989). Further limiting plant growth in *Eucalyptus* groves are potentially germination-inhibiting chemicals produced in the leaves of mature *Eucalyptus* trees. However, poison oak and non-native plants such as Cape Ivy and English Ivy are not susceptible to these reported chemicals (Williams, 2002). The potential impacts of allelopathic compounds from *Eucalyptus* are further discussed in Section 4.6.3

Leaf litter build-up also limits the amount of native vegetation that is able to thrive in the area (Bean and Russo, 1989; Williams, 2002), but some wildlife species actually benefit from the leaf litter that accumulates on the floor of a *Eucalyptus* grove. Brown towhees and golden-crowned sparrows (*Zonotrichia atricapilla*) have been observed using debris on the ground for shelter during rains (Bean and Russo, 1989).

Eucalyptus plantations in the Iberian Peninsula also are considered to be low biodiversity ecosystems as a result of no or poor understory vegetation (Carneiro et al., 2008). A study conducted in Portugal in a 5-year-old *E. globulus* plantation showed a general decrease of species richness over time in all treatment plots (control, fertilization, harrowing, and harrowing/fertilization) that may be related to competition for light, water, and nutrients with *Eucalyptus* trees (Carneiro et al., 2008). This reduced and less diverse understory minimizes the number of wildlife species that are able to inhabit *Eucalyptus* groves.

Further supporting the importance of understory in *Eucalyptus* groves, Sax (2002) noted that understory plants appear to be the foundational element of species assemblages in woodlands and therefore are important in determining diversity and composition of wildlife in *Eucalyptus* groves in California. His study demonstrated that the mean species richness values of native woodlands (oak and bay trees) and *Eucalyptus* groves were similar for understory plants, leaf-litter invertebrates, amphibians, and birds. Rodents were the only group with a significant difference between the two sites, with fewer rodents in the *Eucalyptus* sites. While *Eucalyptus* groves have the potential to be host to numerous wildlife species, the greatest biodiversity comes from old growth groves with an understory or *Eucalyptus* plantations that practice the non-traditional coppice with standards method[59]. In the United States, *Eucalyptus* growers would harvest their trees every 6-10 years, eliminating the opportunity for an understory to become established. It is unclear how many growers would use the coppice with standards method; however, they are unlikely to use the non-traditional coppice with standards method. Therefore, *Eucalyptus* plantations in the action area would not likely see their full potential for biodiversity.

Given the limited information available on *Eucalyptus* cultivation in the United States and its impact on wildlife, reliance on *Eucalyptus* research in other countries and expert opinion is necessary to understand

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[58] Older than 25 years of age (See: María Calviño-Cancela, Margarita Rubido-Bará and Eddie J. B. van Etten, "Do Eucalypt Plantations Provide Habitat for Native Forest Biodiversity?," Forest Ecology and Management 270.0 (2012).)

[59] i.e., scattered individual stems are allowed to grow continuously through several coppice cycles

potential impacts to understory vegetation. Where appropriate, these references are cited throughout the analyses of FTE in this section.

The following subsections will discuss in more detail the categories of species that could be found in *Eucalyptus* stands and how they may be impacted by the Preferred Alternative. These wildlife categories are the same as those discussed in the No Action Alternative (Section 4.3.6), and include mammals, birds, and reptiles and amphibians. The subsections will not provide a detailed description of all of the species that may be present in a *Eucalyptus* stand at a given time in specific areas (Shultz, 1997), but rather will focus on representative species from each wildlife category previously discussed in the No Action analysis of wildlife (Section 4.3.6).

Mammals

Similar to pine plantations, the population size of small mammals in *Eucalyptus* plantations is generally inversely correlated to the age of the plantation. In agroforestry plantations (primarily *E. camadulensis* with boundary strips of 1 to 9 rows of casuarina (*Casuarina cunninghamiana*)) in the San Joaquin Valley of California, deer mice (*Peromyscus maniculatus*) comprised 82 percent of rodent captures while California voles (*Microtus californicus*), house mice, and western harvest mice (*Reithrodontomys megalotis*) made up the remaining captures (Dyer et al., 1990). In California *Eucalyptus* plantations with understory, deer can be found in the plantations. Moles, gophers, and fox squirrels also have been observed in these plantations (Bean and Russo, 1989).

Since *Eucalyptus* seedlings are more sensitive to vegetative competition than pine seedlings, it is expected that Southern United States FTE growers will use more intensive management strategies than in pine plantations (Section 4.6.5), thereby reducing available early succession food and habitat for mammalian species commonly associated with early growth forage, including deer. As a result of increased vegetative competition control and shorter rotation length (2:1 harvesting strategy) in FTE plantations as compared to planted pine plantations, it is expected that mammalian species richness will decrease in the Preferred Alternative compared to the No Action Alternative, as it is anticipated that there will be less understory habitat and food available for mammalian use during the course of the FTE rotation.

Birds

The habitat quality of *Eucalyptus* groves for birds varies as a result of numerous factors including tree size, stand density, canopy closure, understory development, and the presence of adjacent natural habitats and other exotic trees. Habitat quality is greatest for birds in groves with a diversity of ages that include large and mature trees. Low to moderate tree densities are preferred while dense growths of small stems or even closely-spaced mature trees are undesirable. Low to moderate tree densities with some mature trees tend to have a well-developed understory that provides important food and habitat for birds (Suddjian, 2004). Birds also use *Eucalyptus* stands in areas where natural woodland habitats and other exotic tree species (especially conifers) occur adjacent to them. Stands adjacent to bodies of water also are valuable (Suddjian, 2004).

Varying opinions exist about the benefits and hazards associated with *Eucalyptus* trees planted in non-native areas. Some reports indicate that while native birds in California use *Eucalyptus* groves, species diversity can be decreased by up to 70 percent when compared to native landscapes (Williams, 2002). In addition, there has been reports that leaf-gleaning birds such as kinglets, vireos, and wood warblers can suffocate or end up starving as a result of *Eucalyptus* gum buildup on their faces and bills from feeding upon flowers (Williams, 2002). These statements, however, are now considered myths. No analysis was ever done on the material that suffocated the birds (only a few carcasses were ever found), and leafgleaners take insects off of leaves and not from flowers (Hovland, 2010). Even if the gum build-up theory was correct, the species grown under the Preferred Alternative are a hybrid of *E. grandis* and *E. urophylla* not *E. globulus*, the species associated with the theory (USDA-APHIS, 2015). Further description regarding this may be found in the APHIS (2015) PPRA for FTE. There have been no reports of avian mortality in field-testing of these hybrids (USDA-APHIS, 2015).

The chestnut-backed chickadee (*Poecile rufescens*) and dark-eyed junco (*Junco hyemalis*) have been observed feeding on seeds in *Eucalyptus* trees while song sparrows, fox sparrows (*Passerella iliaca*), and mourning doves have been observed feeding on ground seeds (Bean and Russo, 1989). While birds do feed on *Eucalyptus* seeds, they are small and contain little nutritional value (Personal Communication with P. Minogue, 2013c). Additionally, FTE is anticipated to produce less seed than non-GE *Eucalyptus* trees as a result of the male sterility trait (Arborgen, 2011).

On the other hand, seeds from pine plantations are an important food source. Loblolly pine, for example, produces seed as early as 10 years, and seed is produced annually with abundant crops every 3- to 5-years (Walterscheidt, n.d.). As a result, implementing the Preferred Alternative would result in a decrease of an important source of food for birds in the action area, such as Carolina chickadees and pine warblers (Audubon, 2014; Cornell Lab of Ornithology, n.d.,). This reduction could lead to a decrease in bird abundance or diversity over the life of the FTE rotation.

More than 90 species of birds regularly use mature *Eucalyptus* groves in the Monterey Bay region, and several rare migrants also have been observed in the region. Of the species known to nest in this region, 68 percent of them frequently nest in *Eucalyptus*. As is the case with pine plantations, many of the species that do nest in *Eucalyptus* appear to do so at lower densities than in native habitats (Suddjian, 2004). In the Monterey Bay region, the nesting bird community in *Eucalyptus* is most closely associated with the region's native conifer and mixed evergreen forests due to their tall growth and similarities in shading and understory development (Suddjian, 2004).

Allen's hummingbird (*Selasphorus sasin*), Bullock's oriole (*Icterus bullockii*), red-winged blackbirds, and black-headed grosbeaks (*Pheucticus melanocephalus*) use the nectar from the *Eucalyptus* blossoms or feed upon insects that are attracted to the nectar in California. FTE also is likely to produce nectar since other parts of the flower appear to develop normally (Personal Communication with L. Pearson, 2013). In contrast, pine trees have inconspicuous flowers (Gilman and Watson, 1994) that are unlikely to attract nectar feeders. While birds such as the red-winged blackbird, grosbeaks, and orioles will use young, regenerating pine stands, it is the understory vegetation that they are relying upon versus the pine tree flowers (Dickson et al., 1993a; Dickson et al., 1995).

Species that fly after insects or hunt for them on the bark of limbs and trunks also are well-represented in *Eucalyptus* groves. Two of these species, the olive-sided flycatcher (*Contopus cooperi*) and western wood pewee (*Contopus sordidulus*), are Neotropical migrants of conservation concern that have been observed nesting in tall groves of *Eucalyptus* (Suddjian, 2004).

Other birds that use *Eucalyptus* trees for nest sites include the brown creeper (*Certhia americana*), robin, downy woodpecker, and red-shafted flicker (*Colaptes auratus cafer*). However, the downy woodpecker and the red-shafted flicker, species that prefer dead or dying *Eucalyptus* trees to form their nests, are not likely to be present in short-rotation FTE unless coppice with standards is followed as a management practice (Bean and Russo, 1989).

Species such as the red-shouldered hawk, red-tailed hawk, great-horned owl, great blue heron, great egret, and double-crested cormorants are not likely to nest in Southern FTE plantations because nesting suitability for these species is determined by tree height and diameter (Suddjian, 2004). Mature *Eucalyptus* trees are often selected by these species due to the taller, broader-limbed nature of *Eucalyptus* compared to native trees (Rottenborn, 2000), a condition not likely to occur in FTE stands within the action area. Therefore, the use of FTE trees for nesting by raptors is expected to be similar to the use of trees by raptors in pine plantations.

Despite the attractiveness of mature *Eucalyptus* groves to a variety of bird species, bird species richness of *Eucalyptus* plantations is often considered poor when compared to native forests. For example, bird species richness in a *Eucalyptus* plantation in Brazil was considered poor as a result of intensive understory management (Marsden et al., 2001).

Vegetation management occurs throughout the rotation of both pine and *Eucalyptus* plantations with an associated decrease in the vegetative understory. It is expected that under the Preferred Alternative, FTE plantation management in the action area (see Section 4.6.5 for more information) will result in little to no vegetative understory and short rotation times, thereby reducing the number of bird species that would otherwise use this habitat. This reduction is likely to be greater than the reduction in bird species associated with pine plantation management. When compared to the No Action Alternative, FTE plantations will produce less nutritious, smaller seeds and will likely result in less available and consistent habitat for shelter and nesting than pine plantations. Insect-feeding birds will have similar opportunities in both FTE and planted pine plantations, while nectar-feeding birds may benefit from the addition of FTE to the landscape.

<u>Reptiles and Amphibians</u>

The presence of reptiles and amphibians in FTE plantations will likely be determined by the status of the understory. In 3- to 4-year-old *Eucalyptus* plantations with an understory of annuals and small trees in the Brazilian Amazon, habitat generalists took up residence. The amphibian community formed a subset of primary forested species while the lizard community was distinct and dominated by open-area species (Gardner et al., 2007). In a study conducted by Trimble and van Aarde (2014), in a biodiversity hotspot in eastern South Africa, *Eucalyptus* plantations were small-scale with vegetated understories and coppiced trees. These plantations hosted high species richness and diversity but the amphibian and reptile communities were structurally distinct compared to the native forest. In and the plantations hosted high species richness and diversity. In another South African study, but on large-scale *Eucalyptus* plantations, Russell and Downs (2012) observed few amphibians species, suggesting that *Eucalyptus* cultivation had disturbed or replaced habitats needed by the reptiles and amphibians due to the management conditions required by *Eucalyptus* cultivation. It is expected that FTE plantation management will mimic the conditions observed in this latter study.

In mature *Eucalyptus* groves or those with undisturbed, vegetated understories, numerous reptiles and amphibians can be found. Amphibians such as the arboreal salamander (*Aneides lugubris*), California slender salamander (*Batrachoseps attenuates*), California newt (*Taricha torosa*), rough-skinned newt (*Taricha granulosa*), and Pacific tree frog (*Pseudacris regilla*) have all been observed in California Eucalyptus groves, primarily under fallen logs and other debris (Bean and Russo, 1989). Several snakes also have been observed in mature *Eucalyptus* groves including ring-necked snakes (*Diadophis punctatus*), rubber boas (*Charina bottae*), and sharp-tailed snakes (*Contia tenuis*). Other reptiles common to mature Eucalyptus groves include northern (*Elgaria coerulea*) and southern alligator lizards (*Elgaria multicarinata*) (Bean and Russo, 1989).

Reptiles and amphibians need leaf litter, herbaceous cover, course woody debris, and streamside management zones to thrive (LeGrand, 2005). Given the variability of these characteristics in a pine plantation and the species-specific response to them, it is difficult to make a direct comparison about the impact of pine plantations to the impact of FTE plantations on reptiles and amphibians. However, both pine and FTE plantations can be host to several reptiles and amphibians.

Under the Preferred Alternative, it is expected that the full spectrum of the potential amphibian and reptile community will not be realized in a FTE stand given the short rotation cycle and intensive understory vegetation management. Therefore, the number of species of amphibians and reptiles living in the FTE plantations will likely be minimal, further reduced from the trends described for reptile and amphibians under the No Action Analysis (Section 4.3.6).

<u>Invertebrates</u>

While invertebrate response to coppicing, regardless of rotation length, is poorly understood, several generalities can be made about invertebrate use of a FTE plantation. In the first year after cutting, the invertebrate population is characterized by a large number of a few species such as ground beetles and wolf spiders. Similar to the No Action Alternative, larger densities of more species occurs in years 2 to 5 after cutting, with invertebrate numbers decreasing as the canopy closes. Invertebrates are most likely to thrive in young FTE plantations that have diverse ground vegetation (Fuller and Warren, 1993).

The western monarch butterfly (*Danaus plexippus* L.) overwinters in California and uses *Eucalyptus* trees, in addition to native conifers (Griffiths and Villablanca, 2013). Monarch butterflies have specific requirements for overwintering sites, and this includes habitats with extensive canopy cover and some gaps to allow sunlight to filter in. The overwintering sites must also have a developed understory that includes saplings or mid-level canopy as well as ground vegetation (Bell et al., 1993). As monarchs make their way south for the winter, it is possible that they could use Southern FTE plantations with a closed canopy as a stopover point, especially if the FTE trees were flowering. Pine trees are also sometimes selected as a roost site if the trees have thick canopies with some sunlight filtering through (USDA-FS, n.d.,).

Bees have been observed in the vicinity of FTE field trials during the flowering season most likely collecting nectar (the flowers do not produce pollen) (Arborgen, 2011). In pine plantations, bees can be observed in young plantations with open canopies and some ground cover. Bees, however, do not typically use pollen from pine trees because they produce protein-poor pollen (Ellis et al., n.d.,).

Similar to pine plantations, the limited plant community within monoculture FTE plantations with minimal to no understory reduces the charismatic invertebrate populations. In a study conducted in South Africa, species richness was slightly greater in *Eucalyptu*s plantations (19 species) versus pine plantations (17 species) (Ratsirarson et al., 2002). Under the Preferred Alternative, while species richness is statistically similar between pine and *Eucalyptus* plantations, invertebrate diversity and abundance will likely be reduced more quickly in FTE plantations versus the No Action Alternative due to the shorter FTE rotation. In addition, intensive competition management could further reduce habitat available for charismatic invertebrates, though this will likely be dependent on the specific charismatic invertebrate species considered.

4.6.7 Potential Impact on Insect and Disease Pests of Plantation Pine Resulting from the Preferred Alternative

4.6.7.1 Summary of the Preferred Alternative on Insect and Disease Pests of Plantation Pine

Under the Preferred Alternative, there are a number of FTE pests that can appear or increase in prevalence within the action area. These include 18 insect pests and 23 microbial diseases. Of these potential insect and disease pests, the insect pests that are most likely to become a substantial pest in FTE plantations are those insect pests already within the United States, such as Phoracantha wood borers, the eucalyptus weevil, and eucalyptus psyllids. Additionally, the disease pests most likely to become substantial pests in FTE plantations are also those disease pests already present in the United States, such as pink disease, eucalyptus rusk, and Coniothyrium canker. This potential outcome is not surprising, considering the absence of cultivation or absence of large-scale cultivation of *Eucalyptus,* GE or non-GE, within the action area.

There are several factors which may play a role in the abundance of insect and disease pests of FTE. These include: introduction potential, freeze tolerance and adaptation to environmental conditions, host specificity, and efficacy of control measures. Overall, the majority of the insect pests expected to infect FTE within the action area may be relatively well controlled by growers. On the other hand, disease pests of FTE may be more difficult to control due to a more limited spectrum of control strategies when compared to insect pests. Monitoring for these pests and diseases should be conducted as part of good plantation management practices or part of an early detection and rapid response plan. Sufficient control methods would need to be put in place if disease pests of FTE were to increase in incidence or severity within the action area.

In spite of the potential increase in *Eucalyptus* insect and disease pests within the action area, it is unlikely that these pests will significantly damage other plant species. Many of the potential insect pests are host-specific herbivores that are unlikely to feed upon other plant hosts. Two disease pests, however, may affect other plants. Eucalyptus rust and pink disease may potentially infect other susceptible plants within the action area, as they are not host-specific pathogens. However, given the limited adoption of FTE and limited dispersal of these pathogens from FTE to other plant hosts, it is anticipated that potential impacts to other plant hosts from these two diseases will not be substantial. Monitoring for these pests and diseases should be conducted as part of good plantation management practices or part of an early detection and rapid response plan.

With regard to the insect and disease pests of plantation pine discussed under the No Action Alternative (Section 4.3.7), APHIS does not anticipate a significant impact under the Preferred Alternative, given the projected increase in planted plantation pine acreage that is already occurring independently of the regulatory status of FTE.

4.6.7.2 Preferred Alternative Analysis on Pine Insect and Disease Pests of Plantation Pine

<u>Introduction and Assumptions</u>

The FTE action area includes the Southern Coastal Plain and the Mississippi Alluvial Valley of the Southern United States. The insect and disease pests discussed in this Preferred Alternative analysis are those identified as major pests of eucalyptus already present in this area, in other states, or in other countries. Control strategies for potential FTE pests will be addressed. In addition, this section will discuss the probability of non-GE eucalyptus and FTE causing damage to non-eucalypts in the action area. Also considered is the response of plantation pine pests to replacement of part of the currently planted pine areas with FTE.

As discussed in Section 4.5, Assumptions of the Preferred Alternative, APHIS makes several assumptions for the purposes of analysis of the Preferred Alternative, including: FTE is unlikely to pose a plant pest risk as long as there is proper management and oversight of FTE plantations (USDA-APHIS, 2015); FTE is likely to be planted on land previously planted to plantation pine (Appendix B); FTE does not pose a substantially higher fire risk over the life of its rotation than do southern pine plantations or any common land use type within the FTE (Appendix D); and FTE will respond to pests in the same manner as non-GE eucalyptus (USDA-APHIS, 2015).

Major Pests in the FTE Study Region

Table 13 presents a list of major insect pests of *Eucalyptus*, and Table 14 lists major disease pests of *Eucalyptus* projected to be problems in the FTE action area.

Below is a brief summary of the information presented in Tables 13 and 14, with emphasis on the pests that may cause the most economic damage in FTE, based on the damage they cause within their current geographic distribution

Potentially, the most significant insect pests of FTE are likely to be those which are already in the United States, including the two Phoracantha wood borers (the eucalyptus longhorned borer, *P. semipunctata,* and the yellow phorocantha borer, *P. recurva*), the eucalyptus weevil *Gonipterus scutellatus*, and the psyllids *Glycaspis brimblecomei*, *Ctenarytaina spatulata* and *Ctenarytaina eucalypti*. If these insects were to become present in FTE plantations in the action area where these trees could be grown, they could cause significant damage to the trees. These pests cause significant damage in their current geographic distributions (Dahlsten and Rowney, 2000; Paine et al., 2011).

Phorocantha borers (the eucalyptus longhorned borer, *Phorocantha semipunctata*, and the yellow phorocantha borer, *P. recurva*) are attracted to volatile chemicals from stressed or injured trees, which they then colonize and attack (Paine and Millar, 2002; Paine et al., 2009; Wotherspoon et al., 2014). Longhorned borers have been known to kill even healthy trees (FAO, 2007). *Phorocantha* is also attracted by freshly cut wood (Paine et al., 2009). Paine et al. (2009) note that one of the parents of the FTE hybrid, *E. grandis,* is considered more susceptible to *Phorocantha* damage than some other species of eucalyptus. It is not known in Florida yet, but its high potential for spread is an important factor in determining its pest status. Adults are good fliers and can disperse fairly widely (FAO, 2007). *Phorocantha* has been introduced into many other countries around the world, and spread from southern California northward to the San Francisco Bay area within five years (Kliejunas et al., 2001). It is ubiquitous in California wherever *Eucalyptus* is grown (Paine et al., 2009). Effective biological control has been achieved in California by the egg parasitoid *Avetianella longoi* (Paine et al., 2011). *P. recurva* has been more difficult to manage than *P. semipuncta*, because it emerges earlier and so has a greater potential to spread, and because *A. longoi* is not as effective against *recurva* since the wasp preferentially parasitizes *semipunctata* eggs (Kliejunas et al., 2001; Paine and Millar, 2002).

The eucalyptus snout beetle, *Gonipterus scutellatus*, is considered to be a major defoliator of eucalyptus, and causes serious damage, which can eventually lead to tree mortality (Garrison, 2001). As with *Phorocantha*, *E. grandis* is an identified host. The probability of *G. scutellatus* becoming a pest in the FTE action area is also increased by the fact that it is easily dispersed, by flight and by adults dropping from trees onto vehicles and passersby (Garrison, 2001), adults are relatively long-lived (3-6 mos.), and its habit of resting under bark so that detection may be difficult (Kliejunas et al., 2001). Kliejunas et al.

(Kliejunas et al., 2001) rate *G. scutellatus* as a seriously invasive pest. Good control of this pest has been achieved with the use of the egg parasitoid *Anaphes nitens* (Paine and Millar, 2002; Paine et al., 2011).

Psyllids have had a serious impact on eucalyptus in California (Jones et al., 2011). At high population densities, psyllid larvae cause great damage to young eucalyptus shoots and foliage (Hodkinson, 2007). In addition, psyllid adults are very mobile, which leads to greater dispersal (Halbert et al., 2003), and have multiple generations per year (Paine et al., 2006). Of the Eucalpytus psyllids, *Glycaspis brimblecomei*, *Ctenarytaina eucalypti* and *Ctenarytaina spatulata* are expected to cause problems in the FTE action area.

The red gum psyllid, *G. brimblecomei*, is known to feed on eucalyptus in Florida, and is considered to be the most damaging eucalyptus psyllid in North America (Halbert et al., 2003; Paine et al., 2006). Because of its characteristic protective lerp covering (a waxy shield), *G. brimblecomei* populations can be difficult to target and control, especially with insecticides. In many countries within its geographic range, *G. brimblecomei* is responsible for eucalyptus tree mortality (de Quieroz Santana and Burckhardt, 2007). A moderate degree of control by the parasitoid *Psyllaephagus bliteus* has been achieved in California (Jones et al., 2011).

The blue gum psyllid, *Ctenarytaina eucalypti,* is a eucalyptus pest of important economic concern in Brazil, and has been known to be a vector of plant viruses (de Quieroz Santana and Burckhardt, 2007). It is present in California, where it is considered to be a serious eucalyptus pest (Paine et al., 2011), but is successfully controlled by *Psyllaephagus pilosus* (Jones et al., 2011; Paine et al., 2011). This psyllid has not yet been detected in Florida.

Drought conditions appear to favor *Ctenarytaina spatulata*, the rose gum psyllid, attack in *E. grandis*, and infestation levels are not necessarily visually apparent, making control more difficult (Santana et al., 2010). Dispersal is favored by continuous planting of eucalyptus trees such as in a plantation setting (Santana et al., 2010).

The major fungal pathogens that may cause concern in the FTE action area are pink disease (*Erythricium* (=*Corticium*) *salmonicolor*), eucalyptus rust (*Puccinia psidii*) and Coniothyrium canker (*Coniothyrium zuluense*). They are already present in the United States or Mexico and could become more widespread as the plantings of eucalyptus are expanded.

Pink disease is currently distributed from the southeastern United States westward to Texas (Kliejunas et al., 2001). This pathogen, considered as one of the most important diseases of eucalyptus (Jacobs, 1979), can cause stem girdling and tree mortality (Gezaghne et al., 2003). Young trees appear to be more susceptible. In India, pink disease has been reported to infest young eucalyptus plantations and to build up over time during which trees suffer repeated dieback, until the disease reaches epidemic proportions in plantings between 2 and 5 years old (Jacobs, 1979). In addition to *E. grandis* (Kliejunas et al., 2001), pink disease has a wide host range, including some within the FTE action area, such as grapefruit, orange, apple (Akrofi et al., 2014), *Cercis canadensis* (redbud), *Ficus carica* (fig), and *Pyrus communis* (pear) (Kliejunas et al., 2001). Florida was noted by Kliejunas et al. (2001) as a potential geographic area for colonization because of its high rainfall and warm temperatures, and was also rated as likely to escape detection by inspectors.

Eucalyptus rust is currently distributed in Florida (Ghini et al., 2014), within the FTE action area, and in Hawaii (Uchida and Zhong, 2006; Ghini et al., 2014). It is considered to be a very serious eucalyptus pathogen, causing epidemics in some areas of the world (Booth et al., 2000b). *P. psidii* has a wide host range, and is considered a threat to eucalyptus and other members of the Myrtaceae worldwide (Kliejunas et al., 2001; Graca et al., 2013; Ghini et al., 2014). Some non-eucalyptus members of the Myrtaceae occurring in Florida are also susceptible to this disease, such as *Myrcianthes fragrans* (Simpson's stopper or twinberry, which is a threatened species in Florida), *Callistemon viminalis* (weeping bottlebrush), *Myrtus communis* (crape myrtle), *Syzium paniculata* (brush cherry) and *Syzium jambos* (rose apple), and the range of host species appears to be increasing in Florida (Glen et al., 2007). Pathogenicity of this disease appears to vary within populations, with rust genotypes adapted to distinct hosts, thus making prediction of its impact on non-eucalypt hosts more difficult (Graca et al., 2013).

Coniothyrium canker is considered to be one of the most significant diseases in eucalyptus plantation forestry (Gezaghne et al., 2003), including those areas outside Australia with a tropical or subtropical climate (van Zyl et al., 2002). This disease has only been detected in Hawaii thus far (Cortinas et al., 2004), but Kliejunas et al (2001) notes that south Florida has a favorable climate for its cultivation. *E. grandis* is a host of this disease in South Africa (Kliejunas et al., 2001). The typical stem infections caused by *Coniothyrium* interfere with bark-peeling and increases production costs in preparation of wood for pulping (Cortinas et al., 2004). Dispersal is by wind and rain (Wingfield et al., 1997).

Table 13. Insect Pests of Eucalyptus Under the Preferred Alternative

Common and Scientific Names	Pest Status	Feeding Habits and Symptoms	Control	U.S. Distribution	Sources
Eucalyptus longhorned borer, *Phorocantha semipunctata* (Coleoptera: Cerambycidae)	Serious: adults attracted to stressed trees by volatiles, but can kill even healthy trees; infestation heightened by trees with water deficit; adults disperse by flight	Larvae feed on bark, leaving characteristic staining and holes; epicormic sprouting; prefers moist wood for oviposition	Pretreatment of *Eucalyptus* wood products before U.S. entry; biological: egg parasitoid *Avetianella longoi*; maintain regular irrigation	California (1984)	(Paine and Millar, 2002; FAO, 2007; Paine et al., 2009; Paine et al., 2011) (Paine and Millar, 2002; FAO, 2007; Paine et al., 2009; Paine et al., 2011)
Yellow phorocantha borer, *Phorocantha recurva* (Coleoptera: Cerambycidae)	Serious: infestation heightened by trees with water deficit; adults disperse by flight	Larvae feed on bark, leaving characteristic staining and holes; prefers moist wood for oviposition	Pretreatment of *Eucalyptus* wood products before U.S. entry; biological: egg parasitoids *Avetianella longoi*	California (1994)	(Paine et al., 2000; Paine et al., 2009)
Eucalyptus tortoise beetle, *Trachymela sloanei* (Coleoptera: Chrysomelidae)	Moderate: stressed trees at greater risk; adults disperse by flight	Defoliator: notches leaves	Development of biological control program ongoing; proper tree maintenance and water management	California (1998)	(County of Los Angeles, 1998; Palik et al., 2002; Paine et al., 2009; Paine et al., 2010)
Eucalyptus leaf beetle, *Chrysophtharta m-fuscum* (Coleoptera: Chrysomelidae)	Serious on *E. pulverulenta*	Defoliator: notches leaves	Proper tree maintenance and water management	California, South Carolina (2003)	(Millar et al., 2009; Paine et al., 2011; Clemson University, 2012)
Eucalyptus snout beetle, *Gonipterus scutellatus* (Coleoptera: Curculionidae)	Moderate: some *Eucalyptus* spp. more susceptible than others; newly expanded leaves and shoots preferred; severe infestations can reduce growth, kill trees; dispersal by flight; movement of infested trees and by attachment to foreign objects	Defoliator, characteristic notches on leaves; larval stage is most damaging; eats only 1 surface of leaves	Biological: *Patasson nitens*; *Anaphes nitens* (Hymenoptera: Mymaridae)	California (1994)	(County of Los Angeles, 1998; Paine and Millar, 2002; FAO, 2007; Paine et al., 2011)

Common and Scientific Names	Pest Status	Feeding Habits and Symptoms	Control	U.S. Distribution	Sources
Ambrosia beetles (Coleoptera: Curculionidae)	Moderate: Intercepted in shipments of *Eucalyptus* to U.S.; damage positively correlated with number of spp. present; dispersal by adult flight	Excavate tunnels in wood of dead or dying trees; may be more of a problem in drier areas;	Use alternative to wood packaging; survey with traps baited with attractants such as ethanol	Nationwide, including Florida and Hawaii (native)	(Bowersox, 1990; Flechtmann et al., 2001; Brockerhoff et al., 2006; Wotherspoon et al., 2014)
Scarab beetles (Coleoptera: Scarabaeidae)	Minor: Larvae develop as grass root feeders in understory, as adults, defoliate leaves	Defoliator: pattern varies with species	Limit fertilizer application to reduce population growth of larvae	Nationwide (native)	(Urqhart, 1995; Frew et al., 2013)
Eucalyptus psyllid, *Blastopsylla occidentalis* (Hemiptera: Psyllidae)	Minor	Honeydew secretions may lead to mold	Biological control potential: *Psyllaephagus pilosus* (Hymenoptera: Encyrtidae); syrphids, lacewings, coccinellids; monitor by sticky traps	California, Florida (1984)	(Halbert et al., 2001; Halbert et al., 2003; de Quieroz Santana and Burckhardt, 2007; Paine et al., 2011)
Tristania psyllid, *Ctenarytania longicauda* (Hemiptera: Psyllidae)	Minor	Honeydew secretions may lead to mold		California (1984)	(Paine et al., 2011)
Rose gum psyllid or eucalyptus psyllid, *Ctenarytaina spatulata* (Hemiptera: Psyllidae)	Serious: in Brazil, prefers *E. grandis*	Larvae damage young shoots and foliage; deformation; premature leaf drop; crown thinning; honeydew secretions may lead to mold; damage may be exacerbated by drought conditions	Biological control: *Psyllaephagus pilosus*, coccinellids, lacewings, syrphids, spiders, fungus *Verticilium lecanii;* chemical control difficult due to overlapping generations ; monitor by sticky traps	California (1991)	(Brennan and Weinbaum, 2001; de Quieroz Santana and Burckhardt, 2007; Hodkinson, 2007; Santana et al., 2010)

Common and Scientific Names	Pest Status	Feeding Habits and Symptoms	Control	U.S. Distribution	Sources
Blue gum psyllid, *Ctenarytaina eucalypti (*Hemiptera: Psyllidae)	Serious: on *E. pulverulenta* in California	Larvae damage young shoots and foliage; dieback; leaf curling and discoloration; honeydew secretions may lead to mold	Biological: *Psyllaephagus pilosus* (Hymenoptera: Encyrtidae); chemical control difficult due to overlapping generations; monitor by sticky traps	California (1990)	(Brennan and Weinbaum, 2001; de Quieroz Santana and Burckhardt, 2007; Hodkinson, 2007)
Red gum lerp psyllid, *Glycaspis brimblecombei* (Hemiptera: Psyllidae)	Serious on *E. camuldulensis* in California	Honeydew secretions may lead to mold; leaf damage and drop; branch dieback and tree mortality	Biological: *Psyllaephagus bliteus*, also predation by coccinellids, anthocorids, chrysopids, hemerobiids, syrphids, spiders, and birds; provide adequate, regular irrigation; limit fertilizers; insecticides; monitor by sticky traps	Arizona, California, Florida, Hawaii, Louisiana (1998)	(Dahlsten and Rowney, 2000; Halbert et al., 2001; Halbert et al., 2003; Paine et al., 2006; de Quieroz Santana and Burckhardt, 2007; Jones and Paine, 2012)
Lemon gum psyllid, *Cryptoneossa triangula* (Hemiptera: Psyllidae)	Minor on *E.citriodora* and *E. maculata* in California	Honeydew secretions may lead to mold; uses lerps of *E. maideni*; defoliation; dieback	Biological: *Psyllaephagus bliteus*	California (2000)	(Jones et al., 2011)
Spotted gum lerp psyllid, *Eucalyptolyma maideni* (Hemiptera: Psyllidae)	Minor: on *E.citriodora* and *E. maculate*	Honeydew secretions may lead to mold; forms feather-shaped lerp; defoliation; dieback	Biological: *Psyllaephagus bliteus*	California (2000)	(County of Los Angeles, 1998; Paine and Millar, 2002; Jones et al., 2011; Jones and Paine, 2012)
Acacia psyllid, *Acizzia uncatoides (*Hemiptera: Psyllidae)	Occasional: primarily a pest of *Acacia* spp.	Severe chlorosis; dieback	Biological control: coccinellids, lacewings	California, Hawaii (1954)	(Dreistadt and Hagen, 1994; Paine et al., 2010)

Common and Scientific Names	Pest Status	Feeding Habits and Symptoms	Control	U.S. Distribution	Sources
Blue gum chalcid, *Leptocybe invasa (*Hymenoptera: Chalcidae)	Moderate: forms galls; reproduce by parthenogenesis; eggs laid inside leaves	Growth stunting, weakening, gnarled appearance, dieback, eventual mortality; dispersal by eucalyptus seedling movement	Biological control potential: *Quadrastichus mendeli* and *Selitrichodes kryceri*	California, Florida (2008)	(Kim et al., 2008; Wiley and Skelley, 2008; Gaskill et al., 2009; Sankaran, No Date)
Lemon gum gall wasp, *Epichrysocharis burwellii* (Hymenoptera: Eulophidae)	Minor: pest of *Eucalyptus* in India	Forms blister-like galls on leaves		California, Hawaii (1991)	(Schauff and Garrison, 2000; Ramanagouda et al., 2010)
Argentine ant, *Linepithema humile* (Hymenoptera: Formicidae)	Minor: infests eucalyptus in New Zealand	Recruits nestmates by trail pheromone; tends hemipteran pests	Forages on trees; generally associated with hemipteran pests	Far west, southeast, eastern seaboard (native)	(Lester et al., 2003; Jones and Paine, 2012)

Table 14. Fungal pathogens of Eucalyptus under the Preferred Alternative

Common and Scientific Names	Pest Status	Symptoms	Control	U.S. Distribution	Sources
Heart rot (various spp.)	Minor to moderate: young trees grown in plantations may suffer	Wood in center of trunk and limbs decays	Protect trees from injuries; prune regularly	Nationwide	(Kile and Johnson, 2000; Hickman et al., 2011)
Eucalyptus leaf spot, *Pestalotia disseminta* (Amphisphaeriaceae)	Serious	Spots on leaves and petioles	Quarantine; protect trees from injury; water management; sanitation; fungicides	Not currently in U.S.	(USDA, 2007; Elliott, 2013)

Common and Scientific Names	Pest Status	Symptoms	Control	U.S. Distribution	Sources
Aulographina leaf spot, *Aulographina eucalypti* (Asterinaceae)	Moderate to serious: sporulation greatest in spring and summer and after rain; dispersal by splashing rain and blowing wind	Defoliation; circular, necrotic, corky leaf, petiole, and twig spots; spots only halfway through leaf tissue	No effective control available	Hawaii	(Wall and Keane, 1984; Kliejunas et al., 2001)
Bot canker (Botryosphaericeae)	Serious in Ethiopia and South Africa: affects environmentally stressed trees subject to high rainfall and temperatures		Use resistant clones; pretreatment of *Eucalyptus* wood products required before U.S. entry	Southern US	(Barnard et al., 1987; FABI, 2001; Gezaghne et al., 2003; Hodkinson, 2007)
Diplodia, *Diplodia australiae* (Botryosphaericeae)	Serious in South Africa: stressed trees more susceptible	Cankers; dieback; some members of this family have been shown to switch hosts from grape to eucalyptus	Fungicides	California	(Kliejunas et al., 2001; Perez et al., 2010; Billones-Baaijens et al., 2012)
Ceratocystis canker, *Ceratocystis fimbriata* (Ceratocystidaceae)	Minor, but serious in other tree taxa, serious in Brazil and Ethiopia, where it reduces yield; dispersal by insects , contaminated equipment, or rain	Infections start in base of tree or roots and move up to stem, causing dark staining of xylem; wilting; may be associated with beetle attack and with wound colonization	Use resistant clones; pretreatment of eucalyptus wood products required before US entry	California	(Gezaghne et al., 2003; Zauza and Alfenas, 2004; Ferreira et al., 2013; Harrington, 2013; Mafia et al., 2013)
Eucalyptus canker, *Cryphonectria cubensis* (Cryphonectriaceae)	Serious: important in South America and Ethiopia, particularly in plantations; able to switch hosts in Colombia	Failure of trees to coppice and regenerate; stem girdling and cambium death, leading to tree mortality; sunken, cracked areas of stem or bark; canker forms when large	Use resistant clones; monitor for disease	Southern Florida	(Barnard et al., 1987; Wingfield et al., 1997; Kliejunas et al., 2001; Roux et al., 2002; Gezaghne et al., 2003; da Silva Guimaraes et al., 2010; van der Merwe et al., 2013)

Common and Scientific Names	Pest Status	Symptoms	Control	U.S. Distribution	Sources
		cambium section dies			
Cryphonectria gyrosa (Cryphonectriaceae)			Use resistant clones	Southern Florida	(Hodges et al., 1979; Barnard et al., 1987)
Cryptosporiopsis leaf spot, *Cryptosporiopsis eucalypti* (Dermataceae)	Serious: has had major impact on plantations in Vietnam and Thailand; can reduce yield; favored by high humidity; dispersal by rain and wind	Infection through wounds or stomata; defoliation of leaves and shoots; irregular brown leaf spots; cankers on woody tissue; crown damage; dieback; stem girdling; may lead to invasion of secondary pathogens	Use resistant clones	Hawaii	(Kliejunas et al., 2001; Old et al., 2002; Cheewangkoon et al., 2010)
Powdery mildew, including rose powdery mildew, *Sphaerotheca pannosa* (Erysiphaceae)	Moderate in nurseries and greenhouses; dispersal negatively correlated with high humidity	Preferentially attacks saplings in greenhouses and nurseries; white powdery spots on leaves and stems; can cause significant loss if not adequately treated	Fungicides; phytosanitary measures in greenhouses and nurseries; some plant extracts and oils effective	Nationwide	(Brown and Ferreira, 2000; Glawe, 2008; da Silva Guimaraes et al., 2010)
Anthracnose diseases, *Colletotrichum gloeosporiodes* (Glomerellaceae)	Moderate in seed or cutting propagation nurseries	Preferentially infests young tissue; dark, sunken lesions; expanding leaves and developing shoots affected; infected leaves drop prematurely; twig dieback	Manage trees to minimize excess moisture; fungicides may control in nurseries, but less effective in field	Nationwide	(Smith et al., 1998; Brown and Ferreira, 2000; Crump, 2009)
Cercospora leaf spot, *Cercospora epicoccoides* (Mycosphaerellaceae)	Minor on *E. cinerea*	Small circular leaf spots, center of spots brown/gray	Fungicides	Florida	(Alfieri and McRitchie, 1975; Mangandi and Peres, 2012)

Common and Scientific Names	Pest Status	Symptoms	Control	U.S. Distribution	Sources
Mycosphaerella leaf spot, *Mycosphaerella suttoniae* and *M. walkeri* (Mycosphaerellaceae)	Minor to serious: important in Ethiopia	Defoliation; leaf spots; reduced growth	Fungicides; develop resistant varieties	California	(Kliejunas et al., 2001; Carnegie and Ades, 2003; Gezaghne et al., 2003)
Leaf spot disease, *Pseudocercospora eucalyptorum (* Mycosphaerellaceae)	Minor	Leaves disfigured, but growth unaffected	Fungicides, but not considered necessary	Florida	(Kliejunas et al., 2001; Farm Forestry New Zealand, No Date)
Cylindrocladiella root rot, *Cylindrocladiella camelliae* (Nectriaceae)	Moderate	Root rot	Fungicides	Florida	(Crous et al., 1991; van Coller et al., 2005)
Cylindrocladium leaf spot and blight, *Cylindrocladium* spp. (Nectriaceae)	Serious: dominant pathogen in Colombia	Leaf spots which coalesce into necrotic lesions; crown and stem deformation; girdling and shoot blight; potential mortality; infection from spores in soil and leaf litter; favored by high rainfall and temperatures in trees with closed canopies	Resistant clones being developed	California, Florida	(Booth et al., 2000a; Kliejunas et al., 2001; Rodas et al., 2005; Mohan and Manorkan, 2013)
Coniothyrium canker, *Coniothyrium zuluense* (Phaeosphaericeae)	Serious: yield reduction in plantations in South Africa and Ethiopia	Necrotic branch and stem spots; stunting; wood quality deterioration; may lead to girdling and death; stem malformation; epicormic sprouts	Use resistant clones, although in some clones, resistance is being overcome	Hawaii	(Wingfield et al., 1997; Kliejunas et al., 2001; Roux et al., 2001; van Zyl et al., 2002; Gezaghne et al., 2003; Cortinas et al., 2004)
Pink disease, *Erythricium salmonicolor* (Phanerochaetaceae)	Serious; *E. grandis* is a host; favored by high rainfall	Stem and branch canker; epicormic roots; potential for girdling and mortality	Pretreatment of eucalyptus wood products required before US entry	Texas to southeastern US	(Jacobs, 1979; Kliejunas et al., 2001; Gezaghne et al., 2003; Mohan and Manorkan, 2013)

Common and Scientific Names	Pest Status	Symptoms	Control	U.S. Distribution	Sources
Alternaria leaf spot, *Alternaria alternata* (Pleosporaceae)	Minor: damage mostly cosmetic	Causes minute greyish brown leaf spots which may coalesce into necrotic lesions	Monitor for disease symptoms; fungicides	Nationwide	(Crous et al., 1989; Adaskaveg et al., 2012)
Eucalyptus rust, *Puccinia psidii* (Puccinaceae)	Serious: particularly in *E. grandis;* decreases productivity in Brazil; higher temperatures worsen attack; epidemics in plantations related to leaf wetness; wind-dispersed	Attacks young trees; leaves deformed and shriveled; pustules or lesions; stunting	Fungicides in nurseries; use of resistant clones; potential biological control methods being investigated; increased atmosphere CO_2 concentration reduces disease; quarantine in Australia	Florida, Hawaii	(Booth et al., 2000b; Kliejunas et al., 2001; Glen et al., 2007; Perez et al., 2010; USDA-FS, 2010; Ghini et al., 2014)
Phytophora cinnamomi (Pythiaceae)	Serious: impeded by low winter temperatures, dry conditions, and in soils rich in organic matter	Attacks roots, resulting in poor growth and mortality	Monitor trees for symptoms; irrigate regularly; fungicides	Nationwide	(Shearer and Smith, 2000; Rhoades et al., 2003; Crone et al., 2013; Thompson et al., 2014)
Shelf fungus, *Stereum albomarginatum* (Stereaceae)	Minor: mostly on dead tissue, rarely causes serious decay on live trees	Thin, leathery bracketlike structures	Not necessary	California	(Kliejunas et al., 2001; Hickman et al., 2011)
Root rot fungus, *Gymnopilus spectabilis* (Strophariaceae)	Minor: associated with older ornamental eucalyptus trees; young, commercial plantations not adversely impacted	Enters through wounds; may cause root failure	Survey and remove damaged trees	Nationwide	Kliejunas et al (2001), USDA-FS (2009)

Factors that Influence the Abundance of Insect Pests and Pathogens of *Eucalyptus*

There are several factors which may play a role in the abundance of insect and disease pests of FTE. These include: introduction potential, freeze tolerance and adaptation to environmental conditions, host specificity, and efficacy of control measures.

For those identified pests not already in the action area, movement into that area is a critical factor in their establishment, abundance, and consequent pest status. Dahlsten et al. (2000) state that since the first detection of a eucalyptus pest in the United States in 1985, new pests are being detected at a rate of about one a year. The import of infested wood products or eucalyptus nursery stock is responsible for the introduction of many exotic pests of eucalyptus, including those originally associated with eucalyptus in Australia (Brockerhoff et al., 2008; Paine et al., 2010; Paine et al., 2011). USDA has several phytosanitary measures and regulations in place specifically to guard against accidental entry of these pests (Kliejunas et al., 2001), but some pests are difficult to detect upon inspection, such as the eucalyptus snout beetle, which frequently rests under bark, and is cryptically colored (Kliejunas et al., 2001). Fungal pathogens are also accidentally introduced into the United States via import (Billones-Baaijens et al., 2012; Ferreira et al., 2013; Harrington, 2013).

The ability of pests to adapt to a climate in which occasional freezing temperatures occur is an important factor in influencing population densities of eucalyptus pests. There are a number of insects and diseases of *Eucalyptus* that are already present in the continental U.S.; primarily in Florida and California. There are also pests of *Eucalyptus* grown in Mexico. These pests could possibly expand to new *Eucalyptus* plantings where the freeze tolerance trait could allow the establishment of plantings in areas of the Southeast where trees have not been previously grown. However, field tests of FTE by ArborGen over a period of 3-5 years show that there has been no incidence of increased risk of pests and diseases (Appendix C, ArborGen)

Because using pesticides is usually cost prohibitive in large-scale forestry operations, it is likely that at some point breeding for pest- and disease-resistant selections would have to be made with these freeze-tolerant clones in order to find resistant clones as part of a mitigation strategy; as has been practiced in other parts of the world when eucalyptus has been grown for a number of years (van Heerden and Wingfield, 2002; Zauza and Alfenas, 2004; Kulkarni, 2010). In addition, success of eucalyptus pests, especially those not already located in the FTE action area, will depend on adaptation to local environmental conditions such as prevalence and quantity of rainfall and drought. For example, higher rainfall appears to be correlated with greater population levels of longhorned borers (Wotherspoon et al., 2014), and pink disease severity increases with increased rainfall (Kliejunas et al., 2001). Drought-affected roots of *E. grandis* are preferentially attacked by *Ctenarytaina spatulata* (Santana et al., 2010), and eucalyptus trees stressed by drought conditions are preferred hosts for *Phorocantha* (Paine et al., 2009).

Particular characters of host eucalyptus trees have also been shown to affect probability of attack or infestation by insects. For example, leaf epicuticular waxes may confer resistance to some insect pests if the waxes impair leaf settling or adhesion to the leaf surface, or by deterring or stimulating feeding or oviposition (Ohmart and Edwards, 1991; Brennan and Weinbaum, 2001). Abundance levels of pests may vary with age of leaves, in part because of these characters.

As mentioned in the section below on management of pests, the most significant insect pests identified here have been well controlled by parasitoids and/or predators in California. Therefore, the degree to which these pest insect population levels can be controlled depends on introducing and establishing the biological control organisms into the action area. Control of fungal diseases that may afflict eucalyptus appears to be more of a challenge.

Management of Insect and Disease Pests of *Eucalyptus*

Management practices for the expected insect and disease pests of FTE eucalyptus currently used by plantation managers are summarized in Tables 13 and 14.

In order to prevent the introduction of insects and diseases of eucalyptus that currently do not occur in the United States, or to prevent the further introduction of pests that are already present, the USDA has imposed conditions for the importation of wood products of eucalyptus (Federal Register (69 FR 2289–2295, Docket No. 02–097–2); USDA, 20040).

Cultural control of insect pests includes protecting trees from injury, and removing infested branches and trees as soon as possible since damaged and dying eucalyptus trees are primary sites for breeding of some insects (Paine et al., 2006; Paine et al., 2009). Infested trees and wood should be buried or burned promptly (Paine et al., 2009). Because moist wood is more attractive to some insects than drier wood (e.g., ovipositing *Phorocantha* sp.), attempts should be made to shorten drying times of eucalyptus logs used for firewood (Paine et al., 2009). Growers should avoid overfertilizing trees (Paine et al., 2009) since the nitrogen addition stimulates new plant growth, which is attractive to insect pests such as psyllids (Paine et al., 2006) and scarab beetle larvae (Frew et al., 2013).

Monitoring insect presence and population levels via traps is a viable management technique for some eucalyptus insect pests such as psyllids (Dahlsten and Rowney, 2000; de Quieroz Santana and Burckhardt, 2007) and ambrosia beetles (Flechtmann et al., 2001; Wotherspoon et al., 2014).

As shown in Table 13, the most important of the identified eucalyptus insect pests are fairly well regulated by biological control methods: e.g., *Avetianella longoi* for *Phorocantha* spp.(Paine et al., 2009); *Anaphes nitens* for *Gonipterus scutellatus* (County of Los Angeles, 1998); *Ctenarytaina eucalypti* by *Psyllaephagus pilosus* (Jones et al., 2011; Paine et al., 2011); and *Glycaspis brimblecomei* by *Psyllaephagus bliteus* (de Quieroz Santana and Burckhardt, 2007; Jones et al., 2011).

Control with insecticides is usually considered a last resort because it is difficult to achieve good coverage in populations of some pest insects with overlapping generations, such as psyllids (Dahlsten and Rowney, 2000; de Quieroz Santana and Burckhardt, 2007) and because natural enemies and beneficial species are eliminated along with pests (Garrison, 2001; FAO, 2007; Millar et al., 2009; Paine et al., 2009).

As shown in Table 14, for disease pathogens of eucalyptus, control methods include cultural methods such as proper tree maintenance and protection from injury, as well as sanitation of areas around tree plantings (Hickman et al., 2011; Elliott, 2013; Harrington, 2013), water management (Crump, 2009; Crone et al., 2013; Elliott, 2013), monitoring for the presence of disease by scouting (Gezaghne et al., 2003; da Silva Guimaraes et al., 2010), and treatment with fungicides (Carnegie and Ades, 2003; Glen et al., 2007; Glawe, 2008; Crump, 2009; da Silva Guimaraes et al., 2010; Mangandi and Peres, 2012; Elliott, 2013). Removal of infected trees may be warranted in some severe cases, such as with infestation by *Puccinia psidii* (Glen et al., 2007), and *Ceratocystis* (Harrington, 2013). In the case of planting of non-GE eucalyptus, the use of resistant varieties of eucalyptus is recommended to control for many of the pathogens identified in Table 14 (Wingfield et al., 1997; Harrington, 2013; Wingfield et al., 2013). Quarantine and inspection regulations for nursery stock and wood packing materials are in place to prevent entry of some diseases such as *Ceratocystis* wilts (Harrington, 2013). In contrast to insect management, there are virtually no currently recommended biological control organisms for disease pathogens of eucalyptus at present, particularly for plantation management (Glen et al., 2007; Wingfield et al., 2013). Sufficient control methods would need to be put in place if their incidence and severity of infection were to increase.

The presence of the transgene is not expected to affect the susceptibility of the trees to these insects and diseases (USDA-APHIS, 2015). Monitoring for these pests and diseases should be conducted as part of good plantation management practices or part of an early detection and rapid response plan. Should these diseases become present in new areas of the United States on *Eucalyptus*, control methods would need to be established, for both transgenic and non-transgenic trees.

Outlook of Insect and Disease Pests of FTE

Most of the insects expected to infest FTE in the action area are relatively well controlled by parasitoids and predators. Currently, there are active control and management programs in place in the state of California for the exotic pests of eucalyptus. Therefore, there are both biological and chemical means to control these pests, and these could be applied to new trees being established in the FTE action area should the pests also become established in this region, provided that the chemicals are or can be registered for use there or appropriate approvals are granted for use of biological control agents. On the other hand, few of the eucalyptus pathogens predicted to be problematic have such biocontrol programs. It appears that diseases of FTE may be more difficult to manage than insect pests. The major fungal pathogens of concern are pink disease, eucalyptus rust and *Coniothyrium* canker. They are already present in the United States or Mexico and could become more widespread as the plantings of eucalyptus are expanded. Sufficient control methods would need to be put in place if their incidence and severity of infection were to increase. The presence of the transgene is not expected to affect the susceptibility of the trees to these insects and diseases. Differences in species and clonal susceptibility would be a much more important factor to consider. Monitoring for these pests and diseases should be conducted as part of good plantation management practices or part of an early detection and rapid response plan. Should these diseases become present in new areas of the United States on *Eucalyptus*, control methods would need to be established, for both transgenic and non-transgenic trees.

Potential for FTE Pests to Switch to Other Hosts in the Action Area

Approximately ten percent of the action area which is currently planted in planted plantation pine may be displaced by FTE. Since the primary insect pests on FTE identified in this EIS do not survive on non-eucalyptus hosts e.g., (Hanks et al., 1995; de Quieroz et al., 2010), APHIS does not expect that these insects will move onto plantation pine or any other associated flora. Many of them are host-specific feeders: for example, feeding and oviposition tests indicate that the rose gum psyllid, *Ctenarytaina spatulata*, has a low probability of adapting to feeding on other non-myrtaceous hosts (de Quieroz et al., 2010; Santana et al., 2010).

There is some potential that two of the identified disease pests could affect other nearby plants. For example, as mentioned above, eucalyptus rust may affect other hosts in the FTE action area (Glen et al., 2007). Kliejunas et al. (2001) also report that this pathogen has been damaging to broad-leaved paperbark, *Melaleuca quinquenervia*, in Florida. Pink disease may affect other hosts in the action area (Kliejunas et al., 2001; Akrofi et al., 2014). However, dispersal will probably be localized, due to the pathogen's high rainfall preference, with predicted limited impact on other hosts (Kliejunas et al., 2001). Management of FTE plantings will need to consider potential locations of alternate hosts for pink disease and eucalyptus rust, and control these pathogens accordingly.

With these two exceptions, the introduction of the transgenic eucalyptus should not alter the plant pest relationships between *Eucalyptus* and the surrounding vegetation and crops; compared to what currently exists for trees already grown in Florida and California. The USDA has imposed conditions for the importation of wood products of eucalyptus to prevent the introduction of other insects and diseases of eucalyptus that currently do not occur in the United States or to prevent the further introduction of pests that are already present (Federal Register (69 FR 2289– 2295, Docket No. 02–097–2); USDA, 2004).

Potential Impact of the Preferred Alternative on Insect and Disease Pests of Planted Plantation Pine

Since approximately 10 percent of the geographic area currently planted in plantation pine is expected to be displaced by FTE plantings (Appendix B) and considering that the acreage of plantation pine is anticipated to increase over time (Wear and Greis, 2012; Wear, 2013a; Wear and Greis, 2013), APHIS projects that the remainder of the plantation pine area may experience increased abundance of insect and disease pests that have been identified as pests under the No Action Alternative, at least until the carrying capacity of that area is exceeded. This is likely a function of the increasing plantation pine acreage within the acreage described in the No Action Alternative analysis on land use (Section 4.3.1) and is independent on the Preferred Alternative. APHIS does not anticipate that displacement of some planted plantation pine will have a substantial impact on the host plant-pest relationships in the action area.

4.6.8 Potential Impact on Biological Diversity Resulting from the Preferred Alternative

4.6.8.1 Summary of the Preferred Alternative on Biological Diversity

Under the Preferred Alternative, biodiversity is likely to be reduced when compared to planted pine plantations within the action area, primarily due to the impacts from short-rotation management of FTE on vegetation and subsequent impacts on wildlife.

Tree plantations are likely to contribute to diversity when established on degraded lands, and when native tree species are planted. Also, management intensity and the age and structure of the stands determine the ability of plantations to harbor biodiversity. Neither planted pine nor *Eucalyptus* plantations are as biologically diverse as natural forest land, but they compare favorably to land used for agriculture or urbanization. However, the differences in management practices and biological traits of *Eucalyptus* will lead to an overall decrease in biodiversity in FTE plantations compared to planted pine plantations. Areas of FTE plantations have the potential to alter the diversity of plant and animal species across landscapes, but the reduction in biodiversity is expected to be less severe than if pine plantations were converted to other more intensive land uses, such as agricultural crops or to urban uses.

4.6.8.2 Preferred Alternative Analysis on Biological Diversity

Introduction and Assumptions

Biodiversity can be defined as the "variety of life in all its forms (i.e., plants, animals, fungi, bacteria, and other microorganisms) and at all levels of organization (i.e., genes, species, and ecosystems)" (Hunter, 1996). The purpose of this Preferred Alternative analysis is to describe potential impacts on biodiversity on both the stand and landscape levels if some planted pine plantations are replaced with FTE plantations in the action area.

As described elsewhere in this document, several key assumptions underlay the analysis and frame the remainder of the FTE to pine comparison. These analysis-specific assumptions are:

- The action area encompasses 204 counties across seven Southern States (Appendix B). The purpose of this analysis is to evaluate impacts on biodiversity through the planting and management of FTE for commercial purposes;
- FTE will be planted on approximately 10 percent or less of the lands already dedicated to planted plantation pine. This translates into approximately 1.4 million acres of FTE cultivated across the action area (Section 4.6.1 and Appendix B);
- FTE plantations for pulpwood will grow in a 2:1 time to harvest ratio compared to loblolly/slash pine pulpwood plantations (Section 4.6.5);
- Species richness is lower in planted pine plantations compared to natural forests (Bremer and Farley, 2010) and pine plantations in the action area already have reduced species richness (Appendices B and D);
- Allopathic and invasive tendencies of FTE are not expected (Section 4.6.3); and
- FTE grows quickly and reaches canopy closure within two years compared to pine canopy closure of 10-12 years. *Eucalyptus* harvest cycles, including FTE harvest cycles, are 6-10 years and up to four harvests can occur per planting (Section 4.6.5).

These differences in *Eucalyptus* management practices and biological traits compared to those of planted pine can have impacts on the biodiversity of plant and animal species in *Eucalyptus* plantations and are discussed below. Given the limited information available on FTE cultivation within the action area, direct comparison of biodiversity in FTE plantations to biodiversity in pine plantations is not possible. Thus, reliance on *Eucalyptus* research in the United States and other countries where it is cultivated as an exotic (non-native) crop must be relied upon to understand potential impacts of FTE plantations on biodiversity in the action area.

Biodiversity in Exotic *Eucalyptus* Plantations

Eucalyptus species are the most widely planted hardwood species in the world, used mainly for paper production (Calviño-Cancela et al., 2012). Characteristics such as fast growth, coppicing ability, wide adaptability to soils and climate, and valuable wood properties are the reasons for the success of eucalypts (Turnbull, 2000). However, the expansion of *Eucalyptus* plantations has raised concerns regarding loss of biodiversity (Calviño-Cancela et al., 2012). Large expanses of *Eucalyptus* plantations, unlike small areas, have greater potential to alter the diversity of plant and animal species at the stand level and across landscapes (Lugo, 1997).

There are few studies on the impacts of *Eucalyptus* plantations on biodiversity, but many studies suggest lower biodiversity in *Eucalyptus* plantations (Calviño-Cancela et al., 2012). There are also studies that indicate that *Eucalyptus* plantations can have a positive impact on biodiversity, but this occurs in low-management plantations (Calviño-Cancela et al., 2012), old, undisturbed plantations with a well-developed plant understory (Sax, 2002), or when *Eucalyptus* is planted on degraded land or wasteland, agricultural land, or deforested areas (Tyynelä, 2001; Yirdaw and Luukkanen, 2003).

Like planted pine, *Eucalyptus* plantations typically consist of intensively managed, regularly spaced, even-aged stands of a single species. Cultivation of *Eucalyptus* requires management that concentrates resources of water, nutrients, and light into *Eucalyptus* growth (Binkley and Stape, 2004). However, there are key differences in *Eucalyptus* management practices and biological traits compared to planted pine that can impact biodiversity, and are described below.

- Hydrological impacts in *Eucalyptus* plantations from increased erosion and higher water use. In India, erosion studies indicated that soil detachment from rainfall beneath *Eucalyptus camadulensis* is greater than beneath *Pinus caribaea* (Calder et al., 1993). *Eucalyptus* plantations use substantial quantities of water; intensively managed plantations in Brazil consume 300 to 600 cubic meters of water for every cubic meter of wood produced (Stape et al., 2004). Hydrological studies carried out in South Africa showed a decrease in stream flow from tree plantations, and this decrease was greater with *Eucalyptus* than with pine (Bouillet and Bernhard-Reversat, 2001). Further discussion on the potential impacts of FTE on hydrology within the action area can be found in Section 4.6.4.
- *Eucalyptus* is disturbed through management practices more frequently than pine. In *Eucalyptus* plantations, disturbance may occur every 6–10 years as compared to 15–20 years for pine plantations. *Eucalyptus* harvests can occur up to four times per planting. This equates to two or more harvest cycles within the period of one harvest cycle for pine. The machinery used during various management activities, particularly harvesting activities, would damage understory vegetation. Understory vegetation is one of the most important elements of biodiversity in plantations, and can be the best predictor of animal diversity (Hartley, 2002). Further discussion on the potential impacts of FTE on vegetation within the action area can be found in Section 4.6.5.
- The canopy closes more rapidly in *Eucalyptus* plantations than in pine plantations. As a densely planted pine stand ages and the canopy closes, overall habitat quality declines; shaded understory vegetation dies which reduces wildlife food and cover (Moorman and Hamilton, 2005). However, canopy closure occurs more rapidly (within two years) in *Eucalyptus* plantations, shading out understory vegetation more rapidly than in pine plantations where canopy closure does not occur for approximately eight years. Further discussion on the potential impacts of FTE on vegetation within the action area can be found in Section 4.6.5.
- Competition management, including herbicide use, is more intensive in *Eucalyptus* plantations than in pine plantations. The suppression of vegetation competition in southern plantations, regardless of tree species, intentionally kills understory plants. Effective management of woody vegetation and fast-growing herbaceous plants (primarily using herbicides) has been demonstrated to increase wood volume gains by 30-450% in U.S. forests (Wagner et al., 2004). Because *Eucalyptus* seedlings are more sensitive to vegetative competition than pine seedlings, it is expected that FTE growers in the action area will use more herbicide applications than in pine plantations, thereby reducing understory that provides food and habitat for animal species and potentially affecting water quality of aquatic species. Further discussion on the potential impacts of FTE on vegetation within the action area can be found in Section 4.6.5.
- *Eucalyptus* is not native to the United States while the pine species generally used in southern plantations are (e.g., loblolly pine). Native plant and animal species in the plantation area are more likely to be adapted to native trees (Hartley, 2002). Plantations of exotic species (such as *Eucalyptus*) generally have a less diverse flora and fauna than plantations of indigenous species (such as pines) (Poore et al., 1985). Stephens and Wagner (2007) found that biodiversity is decreased in exotic-species plantations compared to natural/native forest, while native-species plantation forests show similar to only slightly lower biodiversity when compared to natural forests. Further discussion on the potential impacts of FTE on vegetation within the action area can be found in Section 4.6.5.

Plants

- Biodiversity in plantation pines varies considerably depending on stand age. The short-rotation of FTE plantations may lead to less plant diversity, possibly with a plant composition mostly composed of grass and ruderal species, compared with pine plantation stands of 25 years of age (Section 4.6.5). Repetitive damage from short-rotation harvest cycles of *Eucalyptus* leads to a reduction in plant diversity and composition (Wen et al., 2010). The machinery used during the harvesting process disturbs the plantation forest floor and damages the vegetative understory (Wen et al., 2010). Clear-cutting changes the microclimate and alters soil conditions (Wen et al., 2010).
- Calvino-Cancela *et al*. (2012) attribute low understory diversity in *Eucalyptus* plantations "to several factors including allelopathic compounds of *E. globulus* (Souto et al., 2001; Zhang and Fu, 2009), soil degradation, with a decrease in fine soil particles, moisture retention capacity, organic matter and nutrient concentration (Bargali et al., 1993a), and factors associated with management, such as understory clearing (Wang et al., 2011), short rotations (Bargali et al., 1993a), and low structural and micro-environmental heterogeneity typical of tree monocultures (Duan et al., 2010)". However, of these factors, the Preferred Alternative analysis for soil (Section 4.6.3) concluded that allelopathy from FTE is not likely a concern in the action area.
- Besides low understory diversity, *Eucalyptus* can outcompete native plant species (Wang et al., 2011). Once established, fast-growing species such as *Eucalyptus* can replace native forest tree species because of their natural invasive potential, as has been observed in northwestern Spain and Portugal (Carnus et al., 2006). However, the pest risk assessment (USDA-APHIS, 2015) indicated that FTE is not likely to become invasive in the action area. Although pines are known to be invasive in the southern hemisphere where they are exotic species (Richardson, 1998), plantation pine is not reported to be invasive in the action area.

Wildlife

Eucalyptus species are highly unpalatable for native animals in most areas where they have been introduced (Paine et al., 2011). Due to the unpalatability of *Eucalyptus* for native animals, the understory is very important to sustain biodiversity as the base of the food web (Calviño-Cancela et al., 2012).

The following paragraphs summarize the potential impact of the Preferred Alternative on wildlife groups in the action area. Further discussion can be found in Section 4.6.6.

Mammals

Similar to pine plantations, abundance of undergrowth is likely to determine the diversity of mammals present in a FTE plantation. In intensively-managed pine plantations, wildlife species diversity is greatest in stands less than 10 years old because of dense understory vegetation that provides wildlife habitat (Moorman and Hamilton, 2005). However, because *Eucalyptus* seedlings are more sensitive to vegetative competition than pine seedlings, it is expected that FTE growers in the action area will use more intensive management strategies to eliminate competing vegetation than would be used in pine plantations, reducing available early succession food and habitat for mammalian species commonly associated with early growth forage (Section 4.6.6). In addition, more rapid canopy closure in *Eucalyptus* than in pine results in shading and death of understory vegetation, thereby reducing wildlife food and cover. Because of the intensive management of understory vegetation and more rapid canopy closure than pine plantations the diversity of mammal species present in FTE plantations would be reduced compared to pine plantations in the action area (Section 4.6.6).

Birds

The diversity and density of bird populations in *Eucalyptus* plantations is dependent on the amount of understory (Brosset, 2001). In plantations where there is little or no undergrowth, few bird species are present (Loumeto and Huttel, 1997; Marsden et al., 2001). In addition, reduced numbers of insects in exotic *Eucalyptus* plantations to serve as a food source may also contribute to lower bird densities in *Eucalyptus* stands (Pina, 1989). However, nectar-feeding birds may benefit from the addition of FTE to the landscape.

It is expected that FTE plantation management in the action area will result in little to no vegetative understory, thereby reducing the number of bird species that would otherwise use this habitat. When compared to planted pine plantations, FTE plantations will provide reduced food sources, and will likely result in less available and consistent habitat for shelter and nesting than pine plantations (Section 4.6.6).

Reptiles and Amphibians

The presence of reptiles and amphibians in *Eucalyptus* plantations will likely be determined by the status of the understory vegetation (Section 4.6.6). In mature (25 years or older) *Eucalyptus* groves or those with undisturbed, vegetated understories, numerous reptiles and amphibians can be found. In contrast, intensively-managed short rotation *Eucalyptus* plantations have reduced understory due to competition control and rapid canopy closure. In addition, increased water usage and reduced water quality in FTE plantations may impact amphibian species in the action area; immature stages of amphibians are dependent on aquatic habitats and poor water quality may have an impact on them. Therefore, the number of species of amphibians and reptiles living in FTE plantations will likely be minimal, reduced compared to reptile and amphibian species diversity in pine plantations (Section 4.3.6).

Arthropods

Arthropods are an important component of the forest ecosystem. Response of arthropods to FTE plantations vary. For instance, in Portugal, native ants were less likely to colonize exotic *Eucalyptus* than indigenous pine and oak habitats, allowing the invasive, non-native ant *Linepithema humile* to spread unimpeded in *Eucalyptus* (Cammell et al., 1996). In studies in Brazil, Lepidopteran abundance was greater in *Eucalyptus* while Hymenopteran abundance was reduced in *Eucalyptus* (Bragança et al., 1998). Lepidopteran abundance increased with age of the plantation due to increased vegetation heterogeneity after year two (Zanuncio et al., 1998). In a study in Portugal, few insects were observed in *Eucalyptus* (Pina, 1989). Arthropods are most likely to thrive in young *Eucalyptus* plantations that have diverse ground vegetation (Fuller and Warren, 1993). However, this condition is not expected to exist in FTE plantations or other short rotation *Eucalyptus* plantations where intensive control of competitive understory vegetation will occur. Other arthropods such as bees or butterflies may take advantage of nectar in FTE flowers (Arborgen, 2011).

Non-native pest insects of *Eucalyptus* may add to the arthropod species diversity in the action area. More than 15 different Australian *Eucalyptus*-feeding insect species have been introduced into California, Florida, or Hawaii (including two borers, three leaf-eating beetles, several species of gall wasps and psyllids) (Paine et al., 2011), and these may establish on FTE.

In planted pine plantations, different successional stages support communities containing different assemblages of arthropod species (Burkhalter et al., 2013). For FTE plantations, this trend may be similar, although fewer arthropod species in the action area would likely be adapted to non-native FTE. These species would likely be limited to generalist arthropod species, while arthropod species with specialized niches and adaptations will not. Native plant feeding insects that have become pests of eucalypts outside of Australia generally are adapted to feed on many hosts (polyphagous) or have native Myrtaceae as their native hosts (Paine et al., 2011). Myrtaceae is the plant family to which *Eucalyptus* belongs.

Freshwater Mussels

Potential reductions in water quality and quantity under the Preferred Alternative, particularly at the local scale (Section 4.3.4), may impact freshwater mussel species in the action area. Degraded water quality from siltation and contaminants as well as drought are important factors in the decline of freshwater mussels in the United States (Williams et al., 1993; Haag and Warren, 2008). Thus, the diversity of mussel species in FTE plantations is expected to be reduced when compared to pine plantations, though it is prudent to mention that this is already occurring under planted pine plantations under the No Action Alternative.

Management Practices to Increase Biodiversity in *Eucalyptus* Plantations

Fischer et al. (2006) described principles for conserving biodiversity in production landscapes, including maintaining structural complexity, creating buffers around sensitive areas, creating corridors, maintaining landscape heterogeneity, etc. For *Eucalyptus* plantations, steps can be taken by managers to increase biodiversity within plantations. Low-managed *Eucalyptus* plantations with reduced disturbance can provide substantial understory that provides habitat for early-successional species (Calviño-Cancela et al., 2012), although species composition may differ between native pines and exotic *Eucalyptus* (Sax, 2002). Methods to reduce soil and vegetation disturbance from clear-cutting and mechanical plowing that will protect the understory should be introduced to conserve species composition and diversity in *Eucalyptus* plantations. However, practices for conserving biodiversity in *Eucalyptus* plantations would likely result in economic tradeoffs, and may not be practiced in FTE plantations.

Potential Landscape-scale Biodiversity Impacts of FTE Plantations

Factors affecting biodiversity in plantations as described under the No Action Alternative, such as invasive species, urbanization, and conversion of primary forests can result in an overall reduction of biodiversity at a regional scale regardless of whether the No Action or Preferred Action alternatives are implemented. However, the differences in management practices and biological traits of *Eucalyptus,* and that it is a species not native to the United States, will lead to an overall decrease in biodiversity in FTE plantations compared to pine plantations. Conversion of 1.4 million acres (10 percent) of pine plantation in the action area to FTE will likely reduce biodiversity across the region, but it is difficult to quantify the significance of this reduction. Large areas of *Eucalyptus* plantations have the potential to alter the diversity of plant and animal species across landscapes (Lugo, 1997). However, the reduction in biodiversity is expected to be less severe than if pine plantations were converted to agricultural crops or to urban uses.

5 CUMULATIVE IMPACTS

5.1 Introduction

Cumulative impacts are defined as the "impact on the environment, which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions" (40 CFR 1508.7).

This section analyzes current and reasonably foreseeable future impacts if APHIS chooses the Preferred Alternative described in Section 2.1.2. APHIS considers the impacts of the Action Alternative on the specific resource areas described in Section 3.3, combined with past, present, and reasonably foreseeable future actions as well as those actions of others, in this section.

Impacts on natural and biological resources were considered in the analyses contained within this section. Possible implications of how these impacts might affect the availability of those resources for human use were also analyzed. The initial phase in this process was an analysis of the potential impacts to specific resource areas as a result of the Action Alternative. In the second phase, potential impacts to specific resource areas, in conjunction with other reasonably foreseeable actions, were considered. The result of this second phase is this Cumulative Impacts analysis.

During the first phase, environmental consequences for each specific resource area were assessed individually in Section 4.6. From those analyses, APHIS determined that potential impacts to local surface water resources (Section 4.6.4), pine-associated plant communities (Section 4.6.5), wildlife (Section 4.6.6), and biological diversity may occur (Section 4.6.8). It is prudent to mention, however, that the potential impacts described in Sections 4.6.4, 4.6.5, 4.6.6, and 4.6.8 are not directly a result of the genetic modification used to produced FTE; rather, those potential impacts are a result of physiological factors and silvicultural practices specific to short-rotation *Eucalyptus* species such as FTE.

This section is a review of the findings of the second phase of APHIS's analysis, which includes a presentation of the past, present, and reasonably foreseeable future actions that are considered as Cumulative Impacts. A presentation of the assumptions used in this Cumulative Impacts section will then be presented, followed by a presentation of an analysis of the specific resource area identified in Section 3.3 and analyzed in Section 4.6 for which there are possible cumulative impacts.

5.2 Past, Present, and Reasonably Foreseeable Future Actions Considered in this Cumulative Impacts Section

5.2.1 The Potential Displacement of Naturally-Regenerated Plantation Pine with FTE Plantations

The forested landscape of the Southern United States represents an ever-changing landscape. Since the colonial era, Southern forests have primarily transitioned to and from agricultural land uses, culminating in an overall net transition to urban land uses in the present day (Wear and Greis, 2002a; Wear, 2013a).

Planted pine is primarily responsible for dramatic increases in the reforestation and afforestation of the Southern United States (Wear and Greis, 2002b; Wear, 2013b). Historically, both non-forested and forested acreage were shifted to planted pine in the Southern United States. However, as non-forested land became less available later in the twentieth century, forested land began to represent the majority of land transitioning to planted pine. In particular, land containing naturally-regenerated plantation pine acreage began shifting toward planted pine acreage primarily for economic reasons later in the twentieth century, a trend that still continues and is anticipated to continue into the foreseeable future within the Southern United States (Wear and Greis, 2002b; Wear, 2013b).

Past and current trends in conjunction with future projections strongly indicate that southern land managers cultivating naturally-regenerated plantation pine will continue shifting toward planted plantation pine as long as economic conditions remain favorable(Wear and Greis, 2002b; Wear, 2013b). If FTE becomes economically competitive with planted plantation pine, as it is projected to do under the Preferred Alternative (Appendix B and Section 4.6.1), then it is reasonably foreseeable that some land managers in the southern United States who currently cultivate naturally-regenerated plantation pine may shift to the cultivation of FTE.

As a result of this potential shift away from naturally-regenerated plantation pine, in addition to already-described shifts away from plantation pine, in this section APHIS will focus on the potential cumulative impacts that may occur if FTE is planted on land previously planted with cultivated or naturally-regenerated pine.

5.2.2 The Baseline for Comparison of Potential Cumulative Impacts is the Potential for Impacts Resulting from the Displacement of Plantation Pine

As reviewed in Appendix B and Section 4.6.1, FTE may be planted on 10 percent or less of current plantation pine acreage. As a result, the Preferred Alternative analyses of physical and biological resource areas utilized this as a context for individual analyses (Section 4.6). However, considering past, current, and future trends related to the displacement of naturally-regenerated plantation pine with planted plantation pine (Wear and Greis, 2002a; Wear and Greis, 2002b; Wear and Greis, 2012; Wear, 2013b), it is reasonably foreseeable that following a determination of non-regulated status, FTE may also be planted on land previously planted to naturally-regenerated plantation pine (Appendix B). Section 5.3.2.1 below briefly describes naturally- regenerated pine production forests, with respect to general site preparation/management conditions and outcomes.

As a result of these past, current, and future trends related to the displacement of naturally-regenerated plantation pine, for this Cumulative Impacts section, it was assumed that those growers that may shift from naturally-regenerated plantation pine to planted pine may also decide to shift from naturally-regenerated plantation pine to FTE. Based on this assumption, APHIS focused on the potential cumulative impacts that may take place if FTE is planted on land previously planted to planted and naturally-regenerated pine where appropriate in this Cumulative Impacts Section. Conversion of other land use types (e.g., fallow agricultural fields, publically-owned forests, etc.) to FTE plantations will not be considered within the scope of the cumulative impacts analysis. Therefore, potential impacts from the afforestation[60] or deforestation[61] of other land use types were not considered as a baseline for this Cumulative Impacts analysis.

Furthermore, it is important to recognize that the specific management conditions and rotation cycle lengths for FTE and/or southern plantation pine may have differed slightly differ for the analyses presented in the USDA-FS technical reports (Appendices B through D) and the analyses presented here under the Preferred Alternative. These minor differences in specific management practices and rotation cycle length are largely reflective of geographic differences and individual objectives of the land owner. While there may exist minor differences in management conditions and rotations cycle lengths for FTE and/or southern plantation pine, the approximate ratio of the rotation cycle length for FTE and southern plantation pine (i.e., 2:1, southern plantation pine to FTE), which was critical for making meaningful comparisons, was maintained for the Cumulative Impact analyses reviewed in this document.

5.2.2.1 Naturally-regenerated Production Forests

Plantation forests are established by planting or seeding one or more indigenous or introduced tree species for afforestation or reforestation. Trees in stands are typically even-spaced and of the same age. Many plantations are intensively managed often with short rotations using improved tree varieties and silvicultural methods that may involve site preparation (e.g., ploughing, harrowing, use of fertilizers, and herbicides, thinning, and clear-cut harvesting), often with short rotations.

Common pine regeneration methods include natural regeneration or planting on cut-over sites following timber harvests. In 1988, there were 182 million acres of commercial forest in the South (Moorhead and Dangerfield, 1997). In 2010, the South contained 39 million acres of planted pine (about 19 percent of total forest area) and 31.5 million acres of naturally-regenerated pine (Huggett et al., 2013).

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[60] Afforestation is the planting of trees on land that did not previously contain trees

[61] Reforestation is the active planting of trees in an area that previously contained trees

Natural regeneration of loblolly pine is a common practice across the South. Landowners may harvest pine from their lands with the goal of allowing natural regeneration to establish the new stand. Naturally regenerating a loblolly pine stand involves utilizing the seed fall from the existing trees within a stand. Typically a seed tree or shelterwood method is used, leaving mature seed-producing pines after harvest to provide seed for the new crop (Moorhead and Dangerfield, 1997). The seed tree regeneration method is a modified clearcut practice because some trees are left on the site to provide seed, but essentially such sites are as fully exposed as clearcut ones (Clatterbuck and Hay, 2005). Ten to twelve trees are left per acre as a seed source following harvest to regenerate new seedlings (Cunningham et al., 2013). Seed trees are typically mature, healthy, without deformities and with a DBH (diameter breast height) of at least 14 inches. Leaving the best trees in the stand as seed producers offers some genetic improvement by ensuring the best seedling quality (Chandler, no date).

Prior to harvest, plans are made for harvesting the present forest stand and leaving some trees to provide seed (Duryea, 2000). Before a site is logged, seed trees must be selected and marked. Selection is designed to choose the best trees for seed trees. These are the tallest, straightest, largest crowned and highest vigor trees with no evidence of disease (Duryea, 2000; Cunningham et al., 2013). Trees should be well-spaced over the site to allow even distribution of seed dispersal (Duryea, 2000).

Site preparation for natural regeneration differs from that for artificial regeneration but has the same goals (Cunningham et al., 2013). One difference is that site preparation for natural regeneration begins two to three years before harvest (Cunningham et al., 2013). When a good seed crop is available, the site must be prepared prior to promote seed dispersal. The small, winged seeds must come into direct contact with the soil on the forest floor to adequately germinate and grow. A thick litter deposit of leaves, branches, grasses, and weeds serves as a barrier against such contact (Chandler, no date). Some site preparation options include burning, mechanically scarifying, and/or spraying with herbicides (Duryea, 2000). Prescribed burning is an excellent method to remove this barrier. Often, it is necessary to conduct a prescribed burn following harvest to remove slash and expose the mineral soil to the falling seed, which improves germination (Cunningham et al., 2013; Chandler, no date). A prescribed burn before seedfall will also remove most vegetative competition, but often leaves large diameter hardwoods. This hardwood competition must be removed if the seedlings are to survive and develop properly (Chandler, no date). Sometimes the logging operation provides sufficient disturbance to expose the soil. However, the completeness and intensity of the site preparation may improve seedling establishment (Duryea, 2000).

Pine stands grow best where all trees are of the same age, so they receive the same amount of sunlight. Therefore, once adequate seedlings are established and reach 1 to 2 years of age, the large seed trees should be removed (Duryea, 2000). Shrubs, small trees, and herbaceous vegetation will compete with small seedlings for nutrients, water, and sunlight causing mortality or slower growth. For the first few years, the planting site should be observed to see if this unwanted vegetation is affecting seedling growth and survival and measures should be taken to control the weeds. Chemical control, hand-cutting, and mowing are three possible methods of control (Duryea, 2000).

While natural regeneration methods can provide low cost and effective means to establish new stands, overstocking is common when favorable weather and seedbed conditions occur. Mechanical strip thinning is a recommended practice usually by age 3 to 5 years (Moorhead and Dangerfield, 1997).

The following is a list of advantages and disadvantages of naturally-regenerated pine (Duryea, 2000).

Advantages

- Lower initial cost of establishing a forest stand is required, especially if site preparation is not necessary.
- Less heavy equipment and labor is required.
- Seedlings have a naturally shaped root system unlike nursery-grown seedlings.
- Risk of tip moth damage is reduced.

<u>Disadvantages</u>

- A seed crop must be available and seed dispersal must be timed correctly with site preparation, so that a suitable seedbed is available for seed germination.
- Moisture in the soil is necessary for the seeds to germinate; exceptionally dry years or sites may result in poor germination or seedling mortality.
- Insects and other small seed-eating animals may consume all or most of the seed.
- Competing vegetation may be a problem for survival and growth for a longer time period than with planting because seedlings are smaller or seed may not be disseminated in the first year.
- If the seed is abundant and a dense stand results, a pre-commercial thinning may be necessary to decrease the number of trees per acre. This thinning may be accomplished by hand-cutting or plowing up rows of seedlings and leaving the remaining rows about 10-12 feet apart.
- Because the site is planted with seed versus 1-year-old seedlings, the rotation length (time until harvest) may be increased by one or more years.
- The seed coming from the seed trees is not genetically improved as when the seed comes from a seed orchard.

5.2.3 The Fire Risk from Planting FTE is not Substantially Different than the Fire Risk from Plantation Pine

Eucalyptus is a fire-adapted tree species in its native range (USDA-APHIS, 2006; USDA-APHIS, 2012), much like plantation pine is within the Southern United States (Stanturf et al., 2002; Watts, 2013).

Due to the fire adaptation of *Eucalyptus* and the absence of large-scale commercial plantings of *Eucalyptus* in the FTE action area, the potential impact of fire risk within the FTE action area was uncertain. As a result, APHIS approached the Fire and Environmental Research Applications Team (FERA) of the Pacific Northwest Research Station to assess the potential fire risk of planting FTE within the FTE action area. Because no or very little quantitative data regarding the fire risk of *Eucalyptus* within the FTE action area was available, FERA undertook a mathematical modeling approach using the Fuel Characteristic Classification System (FCCS). FCCS was used to evaluate and compare the fire risk of planting FTE under various scenarios to other common land uses within the FTE action area. The FCCS was previously utilized to evaluate the fire risk of planting *Eucalyptus* in certain areas within the Southern United States by Stanturf *et al*. (2013b), though this current USDA-FS FERA effort can be considered a more exhaustive of a study. The culmination of this effort is the USDA-FS FERA technical report entitled *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant Eucalyptus (FTE) Plantations of the Southern United States* (Appendix D).

Based on FCCS predictions contained within the USDA-FS FERA technical report, it was concluded that in general, FTE does not pose a substantially higher fire risk over the life of its rotation than Southern planted pine plantations or any other common land use type[62] within the FTE action area. While some individual component scores of FTE may be higher than planted plantation pine (e.g., spreading potential), these are often offset by other individual components scores that are actually lower than planted plantation pine (e.g., surface fire potential). Thus, the overall fire risk from planting FTE under the Preferred Alternative is not considered substantially different than the overall fire risk from planting plantation pine under the No Action Alternative (Appendix D). Considering that the overall fire risk from planting FTE is not considered substantially different than the overall fire risk from planting plantation pine, then there can also be no substantial impact on current or projected fire regimes under the Preferred Alternative compared to the No Action Alternative. While it is likely that the fire season may be extended in the Southern United States over time, any potential effect this may have on FTE is likely to be similar or the same as its effect on plantation pine.

During the comment period for previous APHIS EAs for the permitted field testing of GE *Eucalyptus*, comments were received suggesting that wildfire in unmanaged stands of California *Eucalyptus* provided evidence that GE *Eucalyptus* stands also presented a fire risk (USDA-APHIS, 2010; USDA-APHIS, 2012). However, it is important to note that the understory of unmanaged (i.e., naturalized *Eucalyptus* species in California) and managed *Eucalyptus* (i.e., FTE plantations within the action area) stands differ in both content and structure. This is particularly relevant in the context of forested wildfires, as the understory of forested stands represents a primary fuel source. As noted in the USDA-FS FERA technical report entitled *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States* (Appendix D), understory vegetation and structure within short-rotation FTE stands is likely to be minimal, in contrast to the understory in unmanaged and older California *Eucalyptus* stands (USDA-APHIS, 2010). Thus, the amount of primary source fuel for wildfires in unmanaged and older California *Eucalyptus* stands is not likely to be same as in FTE plantations within the action area.

Additional and more specific details regarding these fire risk conclusions may be found in the USDA-FS FERA technical report entitled *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant Eucalyptus (FTE) Plantations of the Southern United States* (Appendix D).

5.2.4 FTE is Unlikely to Pose a Plant Pest Risk

In conjunction with this EIS, APHIS is also publishing a preliminary Plant Pest Risk Assessment (PPRA) of FTE (USDA-APHIS, 2015). General conclusions regarding plant pest risk from the PPRA include:

- There is no plant pest risk from the inserted genetic material, no atypical responses to disease or plant pests in the field, and no indirect plant pest effects on other agricultural products;
- There is the potential that if the trees are commercially successful and there are increased plantings of *Eucalyptus* in areas of the Southeast where *Eucalyptus* trees are not currently grown, pests and diseases already present in the United States could become more widespread as the plantings of *Eucalyptus* are expanded;
- Sufficient control methods would need to be put in place if there were an increase in the incidence and severity of insect or disease pests. Therefore management of plantations for pests would be needed, as for any other forestry species; and

[62] Where vegetation is dominant

- There is also no evidence of deleterious effects on non-targets or beneficial organisms in the agro-ecosystem due to the insertion and expression of the new genes.

In addition to an assessment of plant pest risk, the preliminary PPRA also included a weed risk assessment (WRA) of FTE. General conclusions from this WRA include:

- There is a possibility, with high uncertainty, that the transgenic trees could become naturalized over time if widely planted and could become a minor invader if the plantations are not properly managed;
- Management and oversight of the plantations would be needed to ensure that plants do not inadvertently escape and persist beyond cultivation over time. Due to their slow ability to naturalize this should be easily done;
- The trees are not expected to impact the weediness of other plants with which they can interbreed because the formation of natural hybrids is considered unlikely. In the unlikely event that hybrids were to be formed, they would be in the vicinity of established plantations; and
- Abandoned plantations could be problematic and measures would need to be taken to either remove the trees or monitor for the escape of seedlings and remove them.

As a result of this preliminary PPRA, APHIS concluded that FTE is unlikely to pose a plant pest risk with the expected management and oversight of FTE plantations during establishment and over the life of its rotation cycle.

For the Preferred Alternative analysis, APHIS assumed that land mangers that choose to cultivate FTE in plantations will follow typical management practices to maximize wood yield, and thus, economic returns. As a result of these typical management practices, scenarios (i.e., plantation abandonment) that could potentially lead to escape of FTE from plantation sites would likely be avoided.

Accordingly, APHIS also assumed, based on its analyses for the preliminary PPRA (USDA-APHIS, 2015), that FTE is unlikely to pose a plant pest risk.

For the purposes of this Cumulative Impacts analysis, APHIS recognized that FTE-stand abandonment could potentially take place and that some *Eucalyptus* species may represent a "slow invader" (USDA-APHIS, 2015). See Section 5.4.5 (Cumulative Impacts Analysis of Pine-Associated Vegetation) for a review of the possible ramifications of these two observations.

5.2.5 FTE is not Anticipated to Present a Risk to Human Health

Historically, there has been some concern expressed during public comment periods regarding the EA's for GE *Eucalyptus,* especially the potential causal relationship between the planting of GE *Eucalyptus* trees and the increased findings of *Cryptococcus gattii* infections in humans (USDA-APHIS, 2006; USDA-APHIS, 2010; USDA-APHIS, 2012). The information is summarized below for the purposes of establishing that FTE is not anticipated to present a risk to human health under the Preferred Alternative.

C. gattii is a microscopic fungus that grows preferentially in soil around various tree species in several tropical and subtropical regions of the world, including British Columbia, the Pacific Northwest of the United States, and Hawaii (CDC, 2015; Franco-Paredes et al., 2015). *C. gattii* infects humans via inhalation of microscopic spores (CDC, 2015). Although cases of *C. gattii* meningoencephalitis were previously reported in otherwise healthy individuals, recent reports from the United States have demonstrated that most infections occurred in immunosuppressed individuals (Franco-Paredes et al., 2015). There have been few cases of human infection reported from individuals living in these regions of

North America, indicating that it is unlikely that these individuals would become infected by the pathogen without traveling outside of these regions (CDC, 2015). Since 1999, more than200 cases of human *C. gattii* fungal infections have been reported in North America. However, data from genetic studies indicate that this pathogen may have been present within these regions for over 30 years (Upton et al., 2007; Datta et al., 2009).

Although *C. gattii* is widely distributed world-wide, it is an uncommon fungus and recognized as a unique species (Upton et al., 2007). Its increased fitness has allowed it to adapt and create various environmental niches within the temperate regions of North America. The resiliency of *C. gatti* has allowed it to withstand a variety of environmental factors such as extreme temperatures. *C. gattii* has been reported in California, Hawaii and the southeastern United States (CDC, 2015). The extent of its distribution is uncertain.

The species of *C. gattii* are divided into four unique molecular types (variety *gattii*; VGI-IV). VGI and VGII strains are in Australia; VGII and VGIII strains are in South America; the VGI strain is in India, and the VGIV strain is in Africa. The cases of outbreak within the Pacific Northwest of the United States involve the VGII strain. Since 2009, there have been more than 25 cases of *C. gattii* in other parts of the United States involving the VGI or VGIII strains (Paredes et al., 2015). Studies have demonstrated that there is a positive correlation with *Eucalyptus* trees and the spread of *C. gattii* to different parts of the world (Springer and Vishnu, 2010), as host species such as *Pinus radiate, Cedrus deodara, Cupressus sempervirens, Cupressus lusitanica,* and *Terminalia catappa* have been widely exported from their native ranges. Although there is limited evidence that supports that *C. gattii* is dispersed by wind and air currents, fungal isolations from air samples have been obtained from positive trees in Canada and India (Springer and Vishnu, 2010).

Since 2004, *C. gattii* has become more prevalent in the Pacific Northwest and other temperate regions of North America. Most cases have been in individuals with chronic lung disease, or other chronic diseases associated with immunosuppression. Ellis and Pfeifer reported the first environmental isolation of *C. gattii* in 1990 from Australian wood, bark, leaves, and plant debris of *Eucalyptus* trees (Springer and Vishnu, 2010). Although found in several *Eucalyptus* trees in Australia, isolated environmental instances of *C. gattii* outside of Australia have been rare. However, there are several other tree species with reported isolated instances of *C. gattii* including angiosperms (77%), and gymnosperms (23%). Reported tree species include: *Abies spp*., *Arbutus menziesii var. menziesii*, *Cedrus spp., Abies grandis, Picea spp., Pinus spp., Pseudotsuga menziesii var. menziesii*, and *Thuja plicata* in Canada; *Pinus radiate* (Monterey Pine) and *Cupressus lusitanica* in Columbia; *Cedrus deodara* and *Cu. sempervirens* in Argentina, and *Ficus spp*. and *Terminalia spp.* (almond) trees. Infected trees show signs of decayed hollows, a different biochemical composition, available nutrients, presence of water, microbial communities, and fungal associations (Springer and Vishnu, 2010). As stated in section 4.5.5, non-GE hybrids used to develop FTE, do not represent *Eucalyptus* hosts of *C. gattii.*

As stated in section 4.5.5, any increase in the occurrence of *C. gatti* as a result of planting of FTE would be negligible because *Eucalyptus* spp. do not appear to confer any special reservoir or ecological niche for hosting of *C. gattii*, making it unlikely that the planting of FTE, (i.e., supplanting planted pine plantation with FTE) will lead to an increased dispersion of *C. gattii* in the environment. Therefore, the likelihood that FTE will present any human health risk related to cryptococcosis, is negligible.

5.3 Potential Cumulative Impacts

5.3.1 Potential Cumulative Impacts on Land Use

Land use changes can result in cumulative effects on soil, air and water quality, watershed function, the extent and quality of wildlife habitat, climate, and human health. This section addresses potential cumulative impacts on land uses in the action area, specifically. Potential cumulative effects on the physical and biological environment, human health, and forestry products markets are addressed separately in the sections that follow.

Under the Preferred Alternative, the planting of FTE on lands currently planted with commercial pine species in the action area (Section 3.2) could occur. USDA-FS analyses indicate that *Eucalyptus* is potentially competitive with planted pine over a range of future conditions, with net return variance and conversion costs limiting the degree to which land would actually be converted. Lowering the return variance parameters for *Eucalyptus* strongly increases the potential for adoption.

As discussed in Appendix B, USDA-FS models examining various scenarios predict FTE adoption rates ranging from 2 – 15 percent in 30 years, which would result in 0.5 – 2.5 million acres of FTE. Most of the models yield a conversion of around 5 to 9 percent of planted pine forest area, equivalent to about 0.8 to 1.4 million acres of FTE. If it is assumed instead that the eligible area also included the area of naturally-regenerated pine, then the total eligible area would be about 27 million acres. Under this scenario, the projected area of adoption is estimated to range from around 1.4 and 2.8 million acres by year 30.

Actual adoption of FTE will mostly depend on market demand and pricing for various timber products, including the potential development of a bioenergy market. Returns from *Eucalyptus* are driven by hardwood pulpwood prices, and strong price increases are consistent with an overall tightening of hardwood pulpwood supplies (Appendix B). According to USDA-FS analyses, costs to convert pine plantations to FTE could also have an appreciable effect on the areas and acreage that would ultimately be converted. An additional driver of adoption is the risk of public disapproval of the planting of genetically engineered trees. This societal concern could affect investment choices in the same way as biophysical risk—i.e., increased risk would reduce the rate of adoption.

Acreage planted to plantation pine within the action area is anticipated to increase from 33 million acres in 2010 to 39 million acres by 2040, while overall forested acreage is predicted to continue to decline during the same time period. From 1997 to 2060, the South is forecasted to lose between 11 million acres (7 percent) and 23 million acres (13 percent) of forests, nearly all to urban uses (Wear, 2013a).

As previously described in Sections 4.3.1 and 4.6.1, adoption of FTE in the study area is not anticipated to affect overall land use patterns described in the No Action Alternative. Conversion of other land use types to FTE plantations, such as agricultural lands, is considered highly unlikely because FTE is not competitive with other agricultural land uses. High returns from cropland would generally preclude transition to *Eucalyptus* because crop returns currently exceed *Eucalyptu*s returns by 3-5 times (Appendix B). Declining trends in forested land and cropland uses are not anticipated to change as a result of adoption of FTE within the study region. It is assumed that forest areas switched to cultivation of FTE would be limited to the current area of planted pine because this is the portion of the region's forestland that has demonstrated economic advantages for tree plantations. Because any adoption of FTE would result in supplanting of current pine plantation lands, and forest management practices for both FTE and pine plantations would not substantially differ (e.g., Best Management Practices, harvesting/rotation, pesticide use, transportation and processing), any potential cumulative impacts on land uses would be the same as or similar to those under the No Action Alternative. While FTE would be harvested more frequently than pine (every 6 to 10 years compared to 20 to 25 years for pine) there are no identifiable cumulative impacts on land uses associated with a more frequent harvesting schedule.

5.3.2 Potential Cumulative Impacts on Air Quality

This section includes a review of how a shift in planted and naturally-regenerated pine to FTE may contribute to cumulative impacts related to emission of NAAQS pollutants in the action area. Cumulative effects could derive from a change in the scale and/or intensity of pine and FTE production, management practices utilized in cultivation of pine and FTE, and the scale and/or intensity of production wood, pulp, and paper products.

5.3.2.1 Potential Cumulative Impacts on Air Quality

As described above, during the next 30 years, adoption rates for FTE under various scenarios range from 2 to 15, which would result in an estimated potential conversion from pine to FTE on 0.54 to 4.05 million acres. Most of the models yield a conversion of around 5 to 9 percent of planted pine forest area, equivalent to about 0.8 to 1.4 million acres of FTE. This latter range considered under the Preferred Alternative, approximately 10 percent or less, is assumed to be a reasonable estimate of FTE that could potentially be planted on lands already dedicated to pine plantations (Appendix B).

The vehicles and machinery used in forestry operations for site establishment, management, harvest, transportation of felled wood, and other operational activities result in direct emissions of air pollutants, including VOCs, nitrogen oxides, $PM_{2.5}$, and carbon monoxide (EPA, 2012i). Sources of indirect emissions include the wood, pulp, and paper industries.

Because of the shorter harvest cycle for FTE (six to ten years) relative to pine (twenty to twenty-five years), cultivation of FTE would result in a modest increase in heavy equipment usage, and thereby increase emissions of NAAQS pollutants. Hence, there would be a minor contribution to cumulative emissions of NAAQS pollutants. The potential cumulative effects of silviculture in general, and the wood, pulp, and paper industries specifically, on NAAQS emissions would be the same under both the No Action and Preferred Alternatives. Neither alternative is expected to contribute to any cumulative impacts on NAAQS emissions from these industries; any increase or decrease in production, and consequently potential emissions, would be determined by market demand for pine- and *Eucalyptus*-based products.

The USDA-FS concluded that FTE does not pose a substantially higher fire risk during the entire rotational cycle of southern pine plantations (Appendix D). The conversion of pine plantations to FTE will not increase the fire risk. Therefore, there are no potential cumulative impacts associated with fire risk.

While cultivation of FTE in lieu of pine would yield a small increase in the cumulative emissions of NAAQS pollutants (e.g., equivalent to intensifying the harvest cycle on 10 percent on pine plantations from approximately twenty to ten years), commercial forestry serves as a sink for air pollutants. Trees reduce air pollution by decreasing air temperature (the formation of several pollutants is temperature dependent, such as ozone), and removing gaseous and particulate pollutants (Vose et al., 2012; Wear and Greis, 2013). The rate of removal depends on the pollutant type, tree type, precipitation levels, and other local site characteristics (Dwyer et al., 1992). Published scientific studies were not available to enable a comparison between pine species and *Eucalyptus* in their removal of pollutants from the air. However, in general, all trees are involved in the uptake, transport, and assimilation (and in some cases decomposition) of various gaseous and particulate pollutants, mediating some of the adverse effects of atmospheric pollutants.

For example, computer simulations conducted by trees per county in 2010 revealed that forests in the conterminous United States removed 17.4 million tonnes[63] (range: 9.0–23.2 million tonnes) of air pollution (i.e., NO_2, O_3, $PM_{2.5}$, SO_2) that contributed to improved human health effects valued at 6.8 billion U.S. dollars (range: \$1.5–13.0 billion). During 2010, the estimated removal per square kilometer of land of all pollutants was estimated to be greatest (3.4 to 8.4 tonnes km^2) in the southeastern United States, where the majority of commercial forestry occurs. The greatest amount of pollution removal was for O_3, NO_2, and $PM_{2.5}$.

A higher tree density also promotes greater reduction in air pollutants. As reviewed for the Preferred Alternative (Section 4.6.5), the spacing for *Eucalyptus* trees for pulpwood production may be slightly less (higher density) than for planted pine and likely for naturally-regenerated pine. As found in the Preferred Alternative analysis, the potential difference in tree density within the FTE stand versus the planted and naturally-regenerated pine stand is unlikely to cause a substantial change in the amount of pollutants produced from commercial plantation. In contrast, the overall loss of trees in the action area from urbanization (Section 4.3.1) will likely have a greater impact on the amount of air pollutants.

As discussed for the Preferred Alternative in Chapter 4, there is some evidence that *Eucalyptus* produces more volatile organic compounds (VOC) than pine species (Nunes and Pio, 2001). VOCs interact with nitrogen oxides (NOx – produced via combustion of fossil fuels) and sunlight to produce ground-level ozone. High ground-level ozone can trap heat and exacerbate respiratory problems for people. The potential increase in the number of FTE trees in the action area through the conversion of naturally-regenerated pine plantations could increase the amount of VOCs. However, where atmospheric concentrations of nitrogen oxides are low, such as rural and forest areas, unhealthy levels of ground-level ozone do not readily form. Although FTE and pine trees emit VOCs, trees in non-urban areas generally mitigate ozone formation due a reduction of direct sunlight under the tree canopy and cooling of air temperature (Nowak and Dwyer, 2000). Hence, the likelihood of FTE contributing to any cumulative increase in the development of ground-level ozone in the action area is considered low to negligible.

In summary, cultivation of GE FTE lines in place of extant pine species would not contribute to any significant change in emissions sources or quantities associated with forestry management practices, or the wood, pulp, and paper industries. The project would not require a different type or increase in the use of equipment that emits NAAQS pollutants, nor increase the frequency or intensity of fires, including controlled burning. The GE FTE lines would not alter the beneficial effects of forests on removal of atmospheric pollutants. Cultivation of FTE in place of pine on an estimated 10 percent of pine plantations would contribute to cumulative NAAQS emissions, equivalent to intensifying the harvest cycle on 10 percent of pine plantations (from approximately twenty to ten years). However, at this scale, such conversion and any subsequent increase in NAAQS emissions would not be expected to result in the designation of additional areas as non-attainment, or challenge sustaining of current attainment areas. Any conversion would comprise about 0.54 to 4.05 million acres of pine plantations, most likely around 5 to 9 percent of planted pine forest area, which is equivalent to about 0.8 to 1.4 million acres of FTE. Hence, considering the six to ten year harvest cycle, and beneficial effects of forests on air quality from assimilation of atmospheric pollutants, any potential adverse cumulative impacts on emissions of NAAQS pollutants would be expected to be minimal.

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[63] A tonne (also called metric ton) is a non-SI unit of mass, accepted for use with SI, defined as: 1 tonne = 1000 kg.The short ton is a unit of mass equal to 2000 lb (exactly 907.18474 kg). In the United States it is often called simply "ton" without distinguishing it from the metric ton (or tonne)

5.3.3 Potential Cumulative Impacts on Soil Resources

Cumulative impacts on plantation pine and its associated intensive management practices are already impacting soil quality with regards to structure and nutrient balance. Growers are already managing these soil quality impacts with BMPs to preserve soil structure and fertilization to address soil nutrient deficiencies.

5.3.3.1 Potential Cumulative Impacts on Soil Resources

As noted in the Cumulative Impacts analysis on land use (Section 5.4.1), an increase in demand for FTE may expand the adoption area to include naturally-regenerated pine in addition to planted pine plantations. While the same species of trees will be found on both plantation types, the degree and frequency of disturbance may be slightly different. Compared to artificial regeneration, natural regeneration often includes less soil disturbance and no period of time when the land is clear of all vegetation as 10 to 12 mature seed trees are left per acre for the first 2 years (Shultz, 1997; Duryea, 2000; Chandler, no date). Soil disturbance is often limited to that created during logging (Chandler, no date). Therefore, the conversion of naturally-regenerated pine plantations to FTE may result in even greater soil disturbance compared to the conversion of planted pine plantations.

Mechanical site preparation involves operations such as ripping, bedding, raking, shearing and others designed to prepare the soil, provide site access and provide some competition control (Cunningham et al., 2013). Site preparation for natural regeneration differs from that for artificial regeneration in that less heavy equipment and labor is required for site preparation (Duryea, 2000). Soil disturbance, an unavoidable result in preparing planting sites, can initiate soil erosion. Less soil disturbance in plantations could potentially decrease the chances of erosion. Minor soil disturbance can be beneficial in exposing the soil for seed germination and seedling establishment. When natural regeneration is used, 10 to 12 dominant trees remain per acre in the landscape and soil disturbance is often limited to that created during logging (Chandler, no date). While there may be fewer disturbances from naturally-regenerated pine plantations during site preparation and planting, management activities to reduce densities and control competition within the first five years may be increased in comparison to planted pine plantations (Shultz, 1997; Duryea, 2000; Cunningham et al., 2013).

The cultivation of FTE on the previous sites of plantation pine, whether planted or naturally-regenerated, is unlikely to increase the generation of forest access systems, as these sites and their respective forest access systems are already in place for plantation forestry. However, because the rotation cycle of FTE is shorter than plantation pine (Arborgen, 2011), it is likely that these forest access systems will be subject to more frequent disturbances associated with FTE-related management.

While these sites are already subject to frequent disturbance, the shorter rotation cycle of FTE is likely to lead to more frequent use of heavy machinery in harvesting activities (Personal communication with P. Minogue, 2013c; Minogue, 2013b; Minogue, 2013a). While the frequency of disturbance may increase due to the shorter rotation cycle of FTE, that disturbance may be less intense due to the use of coppicing, which allows for subsequent crops with disturbances limited to those from harvesting and not from site preparation and planting (Arborgen, 2011). This increased disturbance could lead to impacts on soil resources. However, the use of current BMPs to preserve soil structure may be adopted by FTE growers. These BMPs are designed to assist land owners in avoiding practices that will lead to soil erosion, compaction, runoff and loss of nutrients. Though voluntary, BMPs are likely to be effective in reducing soil impacts that result from the production of FTE as these BMPs were designed for general use in production forestry. The use of BMPs, in conjunction with the relatively low anticipated adoption of FTE

(Appendix B), indicate that impacts on soil structure are likely to be the same or slightly worse than those already reviewed under the Preferred Alternative.

As noted in the No Action analysis on soil resources (Section 4.3.3), soil quality within the action area is generally considered poor due to past agricultural practices and the inherent characteristics of the soil itself. Modern production forestry uses intensive site preparation, fertilization, short rotation times, and high planting densities to maximize economic returns which generally impacts soil quality through changes in soil structure and nutrient balance (Vitousek and Matson, 1985; Johnston and Crossley, 2002). These current production practices substantially alter processes related to litter production and decomposition, thereby altering various aspects of soil structure and nutrient balance (O'Connell and Sankaran, 1997).

Planted pine as described under the No Action Alternative is already removing a substantial amount of nutrients from sites within the action area (Section 4.3.3). Short rotations of any plantation tree species will lead to reductions in nutrients and lead to declines in productivity of plantations, in spite of fertilization regimes (Judd, 1996). To address nutrient poor soils, tree growers routinely use fertilization to counter nutrient deficiencies and to increase pine productivity at both planting and mid-rotation within the action area (Albaugh et al., 2007; Fox et al., 2007).

Forestry practices for naturally-regenerated pine differs only slightly from that of planted pine, but are aimed at accomplishing the same goals (Cunningham et al., 2013). The main difference is the timing of management practices, especially within two to three years before harvest and the first five years following harvest (Cunningham et al., 2013). Site preparation for natural regeneration should begin two to three years before harvest (Cunningham et al., 2013) and includes removing the thick litter deposit of leaves, branches, grasses, and weeds so seeds come into direct contact with the soil on the forest floor (Chandler, no date). Some site preparation options are to burn, mechanically scarify, and/or spray with herbicides (Duryea, 2000) to remove the vegetative or litter barrier. Once adequate seedlings are established and about 1 to 2 years old, the large seed trees are removed (Duryea, 2000). Management activities within the first five years are directed at reducing densities and controlling competition, and may be increased in comparison to planted pine plantations (Shultz, 1997; Duryea, 2000; Cunningham et al., 2013). Natural regeneration methods can lead to overstocking when favorable weather and seedbed conditions occur. Thinning stands to decrease the number of trees per acre is a recommended practice within the first 3 to 5 years (Moorhead and Dangerfield, 1997). Shrubs, small trees, and herbaceous vegetation compete with small seedlings for nutrients, water, and sunlight causing mortality or slower growth. For the first five years, the planting site is observed to see if this unwanted vegetation is affecting seedling growth and survival and chemical control, hand-cutting, or mowing are used to control any unwanted vegetation (Duryea, 2000).

As described in the Preferred Alternative analysis on soil resources (Section 4.6.3), FTE leaf fall is likely to be poor, based on observations of poor leaf fall quality in other *Eucalyptus* species. As a result, the return of organic matter and nutrients to the soil is likely to be low in an FTE plantation. Compounding this low return of organic matter and nutrients is the relatively rapid rotation cycle that FTE is cultivated under (Arborgen, 2011). The more frequent harvesting of woody material in the even shorter rotations associated with FTE is also likely to increase this rate of nutrient removal (Ewers. et al., 1996; Judd, 1996; Turner and Lambert, 2007). Growers of FTE are likely to incur overall nutrient losses and respond with fertilization regimes at plantation sites.

As noted in the No Action and Preferred Alternative analyses on soil resources (Sections 4.3.3 and 4.6.3), to mitigate the impacts on soil quality from modern forestry practices, all states in the action area have implemented BMPs (Alabama Forestry Commission, 2007; Florida Department of Agriculture and Consumer Services, 2008; Mississippi Forestry Commission, 2008; Georgia Forestry Commission, 2009; Commission, 2013; Louisiana Forestry Association, 2013). Forestry BMPs are voluntary conservation practices for growing a healthy, sustainable, and productive forest. These BMPs are designed to assist land owners in protecting State water resources, and for avoiding practices that will lead to soil erosion, compaction, runoff and loss of nutrients. These BMPs are also effective in maintaining site productivity by preventing damage to soil structure and the loss of soil nutrition if put into place (Kelting et al., 1999; Johnston and Crossley, 2002). BMPs are not species specific and so could also be applied to FTE plantations.

The cultivation of FTE under the Preferred Alternative and the continued cultivation of plantation pine under the No Action Alternative both represent intensive production forestry operations. Whether FTE is planted on sites devoted to naturally-regenerated or planted plantation pine, it is likely to have similar impacts on soil quality as described in the Preferred Alternative, though the impact from cultivating FTE on naturally-regenerated pine may be slightly worse because of its shorter rotation cycle and resulting increased frequency of disturbance. This impact on soil quality is likely to be minor because of management practices (e.g., BMPs and fertilization) currently used by managers of tree plantations to mitigate impacts to soil resources.

5.3.4 Potential Cumulative Impacts on Water Resources

As reviewed previously in Chapter 4, local direct and indirect impacts may occur on water quantity (especially in areas with lower rainfall) and quality. However, these impacts are likely to be negligible at larger spatial scales, such as within individual watersheds or across all watersheds in the action area. This section reviews how potential shifts in adoption of FTE may contribute to cumulative impacts on water quantity and quality in the action area.

5.3.4.1 Potential Cumulative Impacts on Water Quantity

Eucalyptus has among the highest ET rates of all tree species and is extremely fast growing. While *Eucalyptus* has a high water use efficiency (WUE = kg biomass produced/kg water transpired), substantial reductions or elimination of streamflow as a result of increased water use by *Eucalyptus* could have detrimental cumulative impacts on water resources and associated aquatic ecosystems, especially at local scales.

As reviewed under the Preferred Alternative analysis on water resources (Section 4.6.4), in low rainfall areas, FTE is likely to use more water than other types of vegetation, including deciduous hardwoods and plantation pine. FTE may reduce the amount of water available for local streamflow compared to these other types of vegetation. The magnitude of this reduction is dependent on the type of vegetation that is replaced with FTE, the percent area of the watershed planted to FTE, and the frequency and volume of precipitation. In general, the potential impact of FTE on local water quantity is site dependent. For example, in areas with plentiful rainfall and saturated soils (i.e., where evapotranspiration is limited) water use by FTE may be comparable to plantation pine. Where precipitation is more scarce, local cumulative impacts on water resources are possible.

As reviewed in the above analysis on land use, estimates of adoption rates during a 30-year period under various scenarios range from 2 to 15 percent (0.54 to 4.05 million acres) with the most likely adoption rate being about 5 to 9 percent (0.8 to 1.4 million acres). Hence, cumulative impacts analyses of FTE adoption on water resources assume a more probable metric of ≤ 10 percent. At the anticipated adoption levels of approximately 10 percent, potential impacts of FTE on water resources are likely to be negligible at larger spatial scales, such as within individual watersheds or across all watersheds in the southern United States. If only 1% of the vegetative cover in the action area were converted to FTE, changes in Q (amount or %) would be very small (e.g., < 5 mm and <1%) across all watersheds.[64] At this level of adoption, changes in Q would likely not be measurable at the watershed scale, and unlikely to negatively impact streamflow or groundwater recharge. However, measurable local scale impacts may still occur immediately downstream of FTE plantations. At intermediate levels of adoption (e.g., 10% *vs*. 50%), impacts varied depending upon the land cover being replaced. Simulations assuming a 10% replacement of conifer land cover with FTE indicated that the impacts on Q would be minimal; about 0 - 24 mm/year; < 10% change in percent Q. At a 20% replacement of conifer cover with FTE, simulations projected a reduction in Q of approximately 0 - 50 mm/year; < 20% change in percent Q.

In general, at the scale of conversion considered in USDA-FS analyses (e.g., <20% conversion of conifer cover to FTE); models indicate that the regional impacts on either Q, percent change in Q, or groundwater recharge at the watershed scale will be negligible. However, local scale impacts may occur immediately downstream of FTE plantations even at low land cover conversion rates. Conditions that might result in a negative impact would include:

- Planting in areas where precipitation is limited or where dry years are likely.
- Planting in areas where the ratio of P/potential evapotranspiration is low.
- Planting in headwater areas or planting large acreages in close proximity to streams that have low annual base-flow.

Considering the factors discussed at the scale of conversion indicated by the economic analysis (*e.g*., <20% conversion of conifer to FTE), the USDA-FS analyses (Appendix C) indicate the regional impacts, such as within individual watersheds or across all watersheds in the Southern United States, on either Q, percent change in Q, or groundwater recharge will be negligible. Consequently, potential cumulative impacts on water resources at the regional scale are unlikely. Potential cumulative impacts on water resources at the local level from reductions in streamflow are possible, although they are expected to be limited and localized to areas of limited precipitation and downstream of FTE plantations. For local cumulative impacts: at the anticipated levels of FTE adoption of $\leq$ 10 percent, USDA-FS models predict reductions in Q of about 0 - 24 mm/year; < 10% change in percent Q. Considering that ET varies from around 480 mm/year in hardwoods to approximately 1,200 mm/year in slash and loblolly pine plantations, and that mean annual precipitation (averaged over the years used for simulation) has ranged from about 780 mm/year for pine plantation in Texas to about 1,550 mm/year for pine plantation in Mississippi, the potential for significant cumulative impacts on stream flow, groundwater recharge, and aquatic ecosystems would likely be limited to unusual circumstances such as prolonged drought, and to areas downstream of FTE plantations.

5.3.4.2 Potential Cumulative Impacts to Water Quality

As analyzed for the No Action and Preferred Alternatives (Sections 4.3.4 and 4.6.4, respectively), forestry activities in the action area primarily impact surface water quality by the generation of sediments. These sediments derive from the use of forest access systems such as the use and generation of forest roads and stream crossings (Bengston and Fan, 1999; Gucinski et al., 2001; Swank et al., 2001; Jackson et al., 2004; Chang, 2013).

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[64] Q = precipitation – ET, where a positive Q results in streamflow and/or groundwater recharge

The cultivation of FTE on the previous sites of plantation pine, whether planted or naturally regenerated, is unlikely to increase the formation of forest access systems, as these sites and their respective forest access systems are already in place for plantation forestry. However, because the rotation cycle of FTE is shorter than plantation pine (Arborgen, 2011), it is likely that these forest access systems will be subject to more frequent use associated with FTE-related management activities (e.g., site preparation and harvesting). As a result of more frequent disturbances over time, cumulative increases in sediment loading into forest streams are possible, which could potentially impact local water quality. However, BMPs are effective in reducing sediment loading into forest streams expected to help mitigate the potential cumulative impacts associated with more frequent FTE harvesting and management activities, as long as these BMPs are adopted by growers of FTE. As considered in the No Action analysis on water resources (Section 4.3.4), BMPs are commonly utilized by foresters and growers in the action area to mitigate sediment loss from forest roads and stream crossings, and sediment loading into surface waters. Though voluntary, these BMPs are likely to be effective in reducing sediments from forest access systems that are utilized in the production of FTE, as BMPs were designed for general use in forestry and silviculture (Kochenderfer and Edwards, 1990; Adams et al., 1995; Arthur et al., 1998; Williams et al., 1999; Vowell, 2001; Williams et al., 2001; Williams et al., 2002; Carroll et al., 2004).

Compared to artificial regeneration, natural regeneration often includes less soil disturbance, perhaps less intensity of treatments (e.g., competition control), and no period of time when the land is clear of vegetation (i.e., no clear cutting/site prep) (Shultz, 1997; Chandler, no date). While there may be fewer disturbances from naturally-regenerated pine plantations during site preparation and planting, management activities to reduce densities and control competition within the first five years may introduce soil disturbances similar to planted pine plantations (Shultz, 1997; Duryea, 2000; Cunningham et al., 2013). Harvest activities in all plantations disturb the soil. FTE harvest occurs every 6-10 years as compared to 20-25 years for pine plantations. The frequency of FTE harvests has the potential to create greater soil disturbance compared to pine plantations, however, the disturbance may be less intense due to the use of coppicing[65] instead of replanting after each harvest. Coppicing allows for subsequent crops without disturbances from site preparation and planting (Arborgen, 2011); the only disturbance would be from harvesting.

The potential for FTE cultivation to contribute to adverse cumulative impacts on surface water sediment loading is likely to be negligible at larger spatial scales within the action area. As described in the No Action Alternative analysis on water resources (Section 4.3.4), forestry and related silvicultural practices, these activities contribute a small proportion of sediments to surface waters relative to other sources such as urbanization and conventional row agriculture (EPA, 2000b; EPA, 2014c). Considering that FTE is projected to replace less than 10 percent of plantation pine, whether planted pine or naturally-regenerated (Appendix B), the relative contribution of FTE to landscape-scale sediment generation is likely to be negligible, as the overall contribution of forestry to surface water sedimentation is relatively limited.

5.3.5 Potential Cumulative Impacts on Plantation Pine-Associated Vegetation

Due to the short harvest cycle of *Eucalyptus* as compared to that of planted pine, understory vegetation has a higher risk of being damaged because of the constant use of heavy machinery. The BMP when dealing with FTE requires added layers of contribution mainly in the stand establishment phase to control vegetation competition.

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[65] Coppicing involves repetitive cutting of the same stump, close to ground level, and allowing shoots to regrow from that main stump, which provides for the continual harvest of wood from the same tree stump

5.3.5.1 Potential Cumulative Impacts on Understory and Bordering Vegetation from Planting FTE on Naturally-regenerated Pine Plantations

Understory vegetation within and bordering commercial tree plantations serves an important role in ecosystem health and biodiversity (Ramovs and Roberts, 2003; Duan et al., 2010). It has an important role in nutrient cycling and contributes to soil and water quality within the plantation and surrounding areas (Yarie, 1980). Many vertebrate and invertebrate species depend on understory vegetation (Koide and Wu, 2003; Pineda et al., 2005; Mboukou-Kimbatsa et al., 2007; Duan et al., 2010).

In the scenario that some naturally-regenerated pine plantations convert to FTE plantations, APHIS expects similar impacts to understory and bordering vegetation as described in the Preferred Alternative analysis of pine-associated vegetation (Section 4.6.5). Pine plantations in the action area already have low diversity, composition, and density of understory vegetation. Planted pine, naturally-regenerated pine, and *Eucalyptus* plantations, including future FTE plantations, are typically monocultures, which have reduced understory diversity compared to natural forests (Loumeto and Huttel, 1997; Wang et al., 2011). In addition, the management of competing vegetation, which occurs in plantations of any type, reduces the density and diversity of understory and bordering vegetation. The goal of vegetation management is to eliminate the understory vegetation to reduce competition for nutrients, water, and light. Understory vegetation management ultimately reduces the density and diversity of plants found in the understory.

Management of naturally-regenerated pine plantations has a few differences compared to planted pine plantations and *Eucalyptus* plantations, but APHIS expects the impact to understory vegetation to be similar as described in the Preferred Alternative analysis on pine-associated vegetation (Section 4.6.5). As described in Section 5.3.2.1, the site preparation step to control understory vegetation in naturally-regenerated pine plantations occurs two to three years before harvest to clear the forest floor and allow falling pine seeds to contact the soil (Cunningham et al., 2013). In contrast, site preparation for both planted pine and *Eucalyptus* plantations occurs before planting or after harvest of *Eucalyptus* stands left to sprout. Naturally-regenerated pines grow from seed in the soil, starting the rotation with sprouting seeds which must compete with faster growing vegetation. For the first few years after regeneration, land managers may need to control unwanted vegetation using chemical control, hand-cutting, or mowing (Duryea, 2000). This is similar to planted pine plantations and *Eucalyptus* plantations, where vegetation management occurs early in the rotation (Miller et al., 1995; Cassidy, 2005; Personal communication, P. Minogue, 2013c; Minogue, 2013b). In *Eucalyptus* plantations, the application of herbicide typically occurs during site preparation followed by multiple applications within the first year of establishment. This is slightly more intensive than vegetation management during the first year in a planted pine plantation and possibly in a naturally-regenerated pine plantation (Rockwood, 1997; Rockwood and Peter, 2014). Early in the rotation, FTE plantations will likely have reduced herbaceous cover compared to pine plantations due to multiple applications of herbicides to control vegetation.

Another difference between naturally-regenerated pine plantations and planted pine plantations, and *Eucalyptus* plantations is the removal of large seed trees 1 to 2 years after seedling establishment (Duryea, 2000) and thinning 3 to 5 years into the rotation for naturally-regenerated pine plantations to remove any overstock of trees (Dangerfield et al., 1995b). Thinning in planted pine plantations usually occurs mid-rotation (12 to 18 years after planting) (Miller et al., 1995; Cassidy, 2005); a mid-rotation thinning in naturally-regenerated pine plantations could also occur if necessary. As described in the Preferred Alternative analysis of pine-associated vegetation (Section 4.6.5), thinning of *Eucalyptus* occurs within the first year of rotation and involves the removal of sprouts from a tree trunk or stump as opposed to the removal of an entire stump. Thinning activities in these three types of plantations disturb the forest floor, affecting understory vegetation, and change the canopy cover and time to canopy closure.

Naturally-regenerated pine plantations reach canopy closure later than planted pine plantations because the trees start from seed as opposed to a planted seedling. As described in the Preferred Alternative analysis of pine-associated vegetation (Section 4.6.5), *Eucalyptus* plantations reach canopy closure within two years resulting in a more rapid shift to shade-tolerant vegetation compared to both planted and naturally-regenerated pine plantations, which reach canopy closure after 10 to 12 years (Baker and Hunter, 2002; ArborGen, 2014).

The harvesting practices on naturally-regenerated pine plantations are a modified clear-cut, in that some trees remain to provide seed, but essentially the exposure on the site is the same as that of a clear-cut (Clatterbuck and Hay, 2005). Ten to twelve trees are left per acre as a seed source following harvest to regenerate new seedlings (Cunningham et al., 2013). APHIS expects the impacts to understory vegetation from harvesting a naturally-regenerated pine plantation to be similar to that of a planted pine plantation. As described in the Preferred Alternative, harvest of FTE plantations will damage understory vegetation at more frequent intervals than on planted pine and naturally-regenerated pine plantations. *Eucalyptus* harvest cycles are 6-10 years and four to six harvests can occur per planting. This equates to two or more harvest cycles within the period of one harvest cycle for pine. In FTE plantations, this disturbance would occur every 6-10 years as opposed to 20-25 years for pine plantations.

In addition, management practices (site preparation, stand management, and harvest) in planted pine, naturally-regenerated pine, and FTE plantations affect not just vegetation, but also vertebrates and invertebrates. As discussed in the Preferred Alternative, the availability of suitable habitats and food sources will change with the conversion to FTE for some vertebrates and invertebrates (see Preferred Alternative Analysis on wildlife, Section 4.6.6). This may change the composition of vertebrate and invertebrate species, which can change the composition of the vegetative understory as numerous species play a role in seed dispersal and pollination (Oliver and Larson, 1996).

In summary, the cultivation of FTE on lands currently devoted to naturally-regenerated pine would have similar impacts as discussed in the Preferred Alternative. FTE plantations would alter the ecosystem within the plantation, favoring shade-tolerant understory plant species, and may be a less favorable habitat for native plant and animal species that are more likely to be adapted to native trees (Hartley, 2002).

5.3.5.2 Potential Cumulative Impacts from FTE Plantation Abandonment

As described in the Preferred Alternative analysis, *Eucalyptus* trees directly and indirectly alter the habitat for vertebrates and invertebrates, as well as plants (Section 4.6.5, Section 4.6.6, and Section 4.6.8). Abandonment of tree plantations does occur in the action area and may occur in FTE plantations in the long term.

The abandonment of FTE plantations may alter ecosystem within the plantation area. FTE is likely to use more water than other types of vegetation; consequently, FTE may reduce water available for amphibians, fish, mussels, and other aquatic species. FTE may reduce the amount of water available to other vegetation (Section 4.6.4) possibly favoring the growth of drought-tolerant plants (Duan et al., 2010). Best management practices in commercial forestry include those directed at reducing sedimentation and impacts to water resources. A reduction in sedimentation of water resources within and around the abandoned plantation may occur because of the absence of harvesting and other activities that disturb the soil. FTE is likely to reduce substantially soil organic matter and soil nutrient balance, owing to the physiology of *Eucalyptus* (Section 4.6.3). The restoration of nutrients through fertilization would not occur on an abandoned FTE plantation. Allelopathic tendencies of FTE are not expected (Section 4.6.3).

The Preferred Alternative analysis on wildlife (Section 4.6.6) found that FTE plantations produce less nutritious, smaller seeds and intensive management practices will likely result in less available and consistent habitat for shelter and nesting than pine plantations. In contrast to an intensively-managed FTE plantation, an abandoned FTE plantation will likely see an increase in wildlife and invertebrate species as the understory vegetation recovers. Growth of other tree species and the development of a mid-level canopy in the abandoned FTE plantation may improve the habitat as well as the availability of more nutritious seeds for wildlife. Increases in understory vegetation and diversity may allow some accumulation of soil organic matter. An abandoned plantation would have less fragmentation and less edge effect. In a succession study on experimental plantation plots in Puerto Rico, which included plots planted with *Eucalyptus robusta*, no management other than weed control six months after planting occurred. Researchers found a diversity of understory plants including 19 native and naturalized trees and shrubs growing 4½ years after *Eucalyptus* seedling establishment (Parrotta, 1995). The majority of the plant species growing within the plots were bird-dispersed. Fewer species and lower seedling densities occurred in understories of plots with greater litter accumulation (Parrotta, 1995). As the abandoned plantation ages and the canopy cover increases, changes in the type and diversity of species will occur.

The point in the FTE rotation cycle at which abandonment occurs may be important to future successional changes. Abandonment of an FTE plantation after planting seedlings or after a harvest through coppice could diminish the survival of some FTE trees due to vegetation competition as FTE is intolerant of competition and overhead cover (Schönau, 1985; Schönau and Coetzee, 1989; ERDB, 2009; Rockwood and Peter, 2014). Abandonment of an FTE plantation when the trees are mature will likely not cause an immediate loss of FTE trees from competition.

In a review of peer-reviewed literature, Bremer and Farley (2010) found a higher level of plant diversity in older plantations, including those planted to Caribbean pine (*Pinus caribaea* Morelet) and *Eucalyptus*, established on previously forested lands given the additional time to develop structural complexity. Older plantations also tend to have more native species compared to younger plantations that tend to have light-demanding ruderal (the first plants to colonize a disturbed area) (Loumeto and Huttel, 1997) and often exotic species. In India, a study evaluated the regeneration of a forest 15 years after the abandonment of an *E. tereticornis* plantation after clearcut (George et al., 1991). The forest regenerated with a mix of shade tolerant and intolerant species, including evergreen and deciduous species indicating an eventual development into a semi-evergreen forest type. These studies indicate that abandoned FTE plantations, including those abandoned later in their rotation cycle will likely develop a greater level of plant diversity over time.

<u>Naturalization of FTE May Occur in the Presence of Abandoned FTE Plantations</u>

Based on data from the petition, the literature, and weed risk assessments, one cannot rule out the possibility that the FTE hybrid will become naturalized (approximately $\geq$ 75 years) if it were to be widely planted (USDA-APHIS, 2015). Although it is not likely to become highly invasive, the APHIS preliminary PPRA (2015) found that FTE might escape from cultivation, naturalize, and perhaps become a minor invader (with high uncertainty) in the long term, especially if abandoned FTE plantations are present to function as an unmanaged propagule source. Contributing to this uncertain long-term naturalization of FTE is research and experience demonstrating that the long distance dispersal of *Eucalyptus* seed and seedling establishment is very rare (da Silva et al., 2011; Callaham et al., 2013; Lorentz, 2013). In cases where *Eucalyptus* species naturalize and are invasive, it has done so slowly and does not appear to go far beyond established plantations. *Eucalyptus* is generally not very competitive with native vegetation (da Silva et al., 2011; Lorentz, 2013).

Existing Mechanisms to Mitigate FTE Naturalization

To mitigate the uncertain naturalization of FTE in the action area, the APHIS preliminary PPRA (2015) recommends management and oversight of FTE to minimize the establishment and spread of seedlings outside of plantations, particularly in areas close to waterways (Le Maitre et al., 2002; Forsyth et al., 2004; Beater et al., 2008; Lorentz, 2013). The most problematic escapes for *Eucalyptus* appear to be along waterways where seeds get distributed near water (Kirkpatrick, 1977; Rejmanek and Richardson, 2011). This is particularly true in South Africa (Forsyth et al., 2004; Booth, 2012a) and has also been found to occur in California (M and Yost, 2009). Lorentz (2013) recommends the use of buffer zones around plantings for the purpose of limiting seed dispersal as well as providing surface water protection by limiting the proximity of trees to waterways. Where *Eucalyptus* (not specific to FTE) has already invaded Forsyth et al. (2004) recommends removing trees from riparian areas (where water use is likely to be excessive) and nature reserves where all eucalypts have undesirable impacts on biodiversity.

It is important to mention, however, that APHIS does not have the authority to regulate types of management practices. Other Federal and State-level mechanisms exist and may potentially be utilized to mitigate any potential spread of FTE, particularly if FTE were to be grown as a feedstock for cellulosic biofuels.

An example of a Federal-level condition that may be required for growers of FTE for use in biofuels can be found in the EPA Final Rule Approving Renewable Fuel Pathways for Giant Reed (*Arundo donax)* and Napier Grass (*Pennisetum purpureum*) (78 FR 41703). While not specific for FTE, this EPA Final Rule does represent an example of a Federal-level tool to mitigate potential FTE naturalization.

In summary, the EPA Final Rule mentioned directly above requires that any grower of giant reed or napier grass for renewable fuel under the Renewable Fuel Standard (RFS) program submit and adhere to an EPA-approved Risk Mitigation Plan (RMP). The RMP is specifically designed to mitigate the risk of spread beyond the planting area of the feedstock used for the production of renewable fuel under the RFS program. The RMP would be required to include practices and approaches that are already recognized as effective in mitigating the risk of spread of a particular feedstock, such as Hazard Analysis Critical Control Point (HACCP), best management practices (BMPs), Early Detection and Rapid Response (EDRR) plans, and monitoring/reporting components. As a result of measures contained within this RMP, it is anticipated that the likelihood of spread, and thus invasiveness, is substantially reduced[66] (78 FR 41703).

Potential FTE naturalization may also be controlled on the State level. For example, the Florida Department of Agriculture, Division of Plant Industry, regulates the planting of non-native species[67] through the Non-native Species Planting Permitting process, as described in FL Rule 5B-57.011[68]. The

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[66] Alternatively, under this same condition, the grower of giant reed or napier grass may demonstrate that a RMP is not needed, because of specific circumstances that preclude a significant likelihood of spread or invasiveness from a planting area of a feedstock used for the production of renewable fuel under the RFS program (e.g., when giant reed or napier grass is grown in an area outside of the United States where it is native and unlikely to spread)

[67] On an area greater than two contiguous acres

[68] https://www.flrules.org/gateway/ruleno.asp?id=5B-57.011&Section=0 Last accessed January, 2015

intent of this permitting process is to ensure the introduction and field release of non-native plant species in an environmentally-responsible manner, through the control of inter/intrastate movement and cultivation of non-native plant species within Florida (FL Department of Agriculture, 2013). One central aspect of this Florida permitting process that ensures the eradication of any permitted planting is the requirement of an applicant to submit a proof of bond or certificate of deposit to cover the costs[69] of permitted planting eradication prior to permit approval (FL Department of Agriculture, 2013). By requiring this proof of bond or certificate of deposit, the Florida Department of Agriculture, Division of Plant Industry, ensures that any permitted planting may be eradicated, thereby precluding any long-term abandonment of that permitted planting.

5.3.6 Potential Cumulative Impacts on Plantation Pine-Associated Wildlife

As previously discussed under the Preferred Alternative analysis on wildlife (Section 4.6.6), FTE plantations within the action area are expected to host fewer wildlife and invertebrate species than planted pine plantations, though the specific amount of reduction is uncertain. The reason for the reduction in wildlife is mainly due to FTE plantation management in the action area, which will result in less vegetative understory and shorter rotation times, thereby reducing the abundance and diversity of species that would use this habitat.

5.3.6.1 Potential Cumulative Impacts on Plantation Pine-associated Wildlife as a Result of Switching from Naturally-Regenerated Pine

Forestry practices for naturally-regenerated pine differs only slightly from that of planted pine, but are aimed at accomplishing the same production goals (Cunningham et al., 2013). The main difference is the timing of management practices, (especially within two to three years before harvest) and the first five years following harvest (Cunningham et al., 2013). While these pine plantations grow the same species of trees, the degree and frequency of disturbance may be slightly different which may result in some minor differences in wildlife presence between the two plantation types.

Compared to artificial regeneration, natural regeneration often includes less soil disturbance, possibly less intensity of treatments, and no period of time when the land is clear of all vegetation since a few mature seed trees are left on site to provide seed for the new crop (Moorhead and Dangerfield, 1997; Shultz, 1997; Chandler, no date). Those wildlife species that utilize mature trees may benefit from trees being left on site during seed establishment on naturally-regenerated sites.

While there may be fewer disturbances from naturally-regenerated pine plantations during site preparation and planting, management activities to reduce densities and control competition within the first five years may be increased in comparison to planted pine plantations (Shultz, 1997; Duryea, 2000; Cunningham et al., 2013). Site preparation intensity affects cover, mast crop, and populations of arthropods, birds, and some mammals (Mengak et al., 1989). While important vegetation for a variety of wildlife species, shrubs, small trees, and herbaceous vegetation also compete with small seedlings for nutrients, water, and sunlight causing mortality or slower growth. Therefore, for the first few years, the planting sites are monitored for this unwanted vegetation and managed to control the weeds, which in turn, may affect wildlife due to a reduction in understory habitat. Chemical control, hand-cutting, and mowing are three possible methods of control (Duryea, 2000).

[69] Specifically, 150 percent of the cost of eradication of a permitted planting

Because *Eucalyptus* seedlings are more sensitive to vegetative competition than pine seedlings, it is expected that FTE growers within the action area will use more intensive management strategies than in pine plantations (Section 4.6.5); generally reducing understory vegetation available for food and habitat for wildlife such as the various mammalian species commonly associated with early growth forage. More frequent harvesting is likely to lead to more disturbance of wildlife in FTE plantations and a corresponding overall decrease in wildlife abundance and diversity. While the frequency of disturbance may increase, that disturbance may be less intense due to the use of coppicing, which allows for subsequent crops with disturbances only from harvesting and not from site preparation and planting (Arborgen, 2011). The replacement of pine plantations, whether planted or naturally-regenerated, in the action area with fast-growing and short-rotation FTE will likely reduce the available understory for wildlife. In general, short-rotation harvest cycles lead to a reduction in the understory plant community. The machinery used during harvest and the harvesting process disturbs the plantation forest floor and damages the vegetative understory (Wen et al., 2010). Compared to planted or naturally-regenerated pine, the shorter rotation schedule and rapid canopy closure of FTE can reduce the structurally complex understory that is suitable for many wildlife species (Carnus et al., 2006).

As described under the Preferred Alternative (Section 4.6.6), species diversity and abundance will likely be reduced in FTE plantations versus pine plantations due to the shorter FTE rotation and understory management. Species abundance and diversity are similar on naturally-regenerated and planted pine plantations and vary with stand age; therefore, whether FTE is planted on sites devoted to naturally-regenerated or planted pine plantations, it is likely to lead to similar impacts on wildlife abundance and diversity as described under the Preferred Alternative. The impacts to wildlife from cultivating FTE on naturally-regenerated pine may be slightly worse as naturally-regenerated pine plantations typically have the least level of disturbance of the two plantation types.

5.3.7 Potential Cumulative Impacts on Insect and Disease Pests

Potential impacts of the Preferred Alternative on insects and disease pests were discussed in Section 4.6.7. Anticipated major insect pests are the *Phorocantha* borers, eucalyptus weevil, and eucalyptus psyllids, all of which are currently found in the United States. Similarly, the major potential disease pests, eucalyptus rust, pink disease, and *Coniothyrium* canker, are all currently found in the United States. Factors such as introduction potential, adaptation to changing environmental conditions, host specificity and efficacy of control measures affect insect and disease pest profiles. If introduced into the FTE action area, these pests and pathogens are capable of causing substantial damage to *Eucalyptus* and managers will need to consider appropriate control measures, such as use of biocontrol organisms. When pests and pathogens are separated in time and space from their natural enemies, damage to hosts can be more severe (Wingfield et al., 2008). This section examines potential cumulative impacts on insect pests and diseases.

Changes in shipping and trade procedures may affect the rate of introduction of new insect and disease pests into the FTE area. As discussed in the Preferred Alternative analysis of pest and insect diseases (Section 4.6.7), movement of insects and diseases in nursery stock and container packaging (e.g., wood chips, wood pallets) is a significant source of introduction (Brockerhoff et al., 2006; Brasier, 2008; Paine et al., 2010; Paine et al., 2011; Roy et al., 2014). Although USDA implements phytosanitary regulations to prevent accidental entry of pests during trade, small or cryptic pests or disease symptoms may be difficult to diagnose (Kliejunas et al., 2001; Brasier, 2008; Roy et al., 2014). Worldwide introduction of invasive pests and diseases is positively correlated with numbers of imports and total GDP, so that countries such as the United Kingdom and the United States, with greater numbers of imports and higher GDP, also experience greater numbers of accidental introductions (Roy et al., 2014). It is conceivable that sanitary measures may become more tightly regulated in the foreseeable future, which may delay the introduction of new pests and diseases into the action area, or the volume of imported products may become so great that numbers of introduced species will increase. Should additional nonnative pests and diseases be introduced into the United States via shipping and or accidental introduction, there is a potential for diseases which are currently considered serious in other parts of the world, but are not currently found in the United States, to be introduced and gain a foothold in the FTE action area. One potential example is *Eucalyptus* leaf spot (*Pestalotia disseminta*) (Elliott, 2013).

The most important insect pests identified here have been well controlled by parasitoids and/or predators in California. Therefore, the degree to which these pest insect population levels can be controlled depends on introducing and establishing the biological control organisms into the action area. Because there are currently few biocontrol methods available for *Eucalyptus* diseases, more reliance on methods such as fungicides may be necessary.

As discussed in the Preferred Alternative analysis of pest and insect diseases (Section 4.6.7), there is some potential for two diseases, eucalyptus rust (Glen et al., 2007) and pink disease to spread to other host plants in the FTE action area. In particular, eucalyptus rust can be damaging to broad-leaved paperbark, *Melaleuca quinquenervia*, in Florida (Kliejunas et al., 2001). Pink disease may also affect other hosts in the action area (Kliejunas et al., 2001; Akrofi et al., 2014). Potential cumulative impacts of drier conditions may decrease spread of these two diseases to non-*Eucalyptus* hosts since lower rainfall depresses/slows dispersal in general (Kliejunas et al., 2001).

5.3.7.1 Potential Cumulative Impacts on Biological Diversity from Switching from Naturally-regenerated Pine to FTE

This section will focus on the potential cumulative impact on biological diversity that may take place if FTE is planted on land previously planted to pine or naturally-regenerated pine.

As described in the Cumulative Impacts analysis on land use (Section 5.4.1), if demand for FTE increases, the eligible area may increase to include the area of naturally-regenerated pine. This would shift the total eligible area from about 16 million acres to about 27 million acres. Applying the model for switching to naturally-regenerated pine in addition to planted pine would shift the projected area of FTE adoption to up to 2.75 million acres (Appendix B).

Biological diversity in naturally-regenerated pine would be similar to planted pine, although the degree and frequency of disturbance of the two plantation management types may be slightly different. Compared to planted pine, natural regeneration often includes less soil disturbance and no period of time when the land is clear of all vegetation, and therefore may result in some minor differences in biodiversity between the two types.

FTE grows quickly and reaches canopy closure within two years compared to pine canopy closure of 10-12 years. FTE harvest cycles are 6-10 years, and up to four harvests can occur per planting, a shorter rotation and harvest cycle compared to pine plantations. These characteristics of FTE cultivation would reduce biodiversity compared to plantation pine, whether planted or naturally-regenerated. Compared to planted or naturally-regenerated pine, the shorter rotation schedule and rapid canopy closure of FTE can reduce the structurally complex understory that is suitable for wildlife species (Carnus et al., 2006). Repetitive damage from short-rotation harvest cycles of FTE would also lead to a reduction in plant diversity and composition (Wen et al., 2010).

As was concluded in the Preferred Alternative analysis on biological diversity (Section 4.6.8), conversion of 1.4 million acres (10 percent) of pine plantation in the action area to FTE will likely reduce biodiversity across the region. Thus, conversion of even greater acreage (up to 2.75 acres) would result in even greater reduction of biodiversity in the action area. Large areas of *Eucalyptus* plantations have the potential to alter the diversity of plant and animal species across landscapes (Lugo, 1997).

6 OTHER IMPACTS AND MITIGATION MEASURES

This section describes other potential impacts associated with the implementation of the Action Alternatives, including unavoidable impacts; short-term versus long-term productivity of the environment; and irreversible/irretrievable commitments of resources. This section also describes potential impact mitigation measures, as applicable, in addition to those already described in the Alternatives.

6.1 Unavoidable Impacts

Unavoidable environmental impacts are those that are inevitable if a proposed action is implemented (40 CFR § 1502.16).

Production of any short-rotation tree species in a monoculture (e.g., plantations planted in pine; non-GE eucalyptus or FTE) using conventional silvicultural has the potential to impact the environment (i.e., air quality and climate; soil resources; water resources) and biological resources [e.g., vegetation; wildlife; insect and disease pests; and biological diversity]). Selection of either of the Alternatives considered and reviewed in this document will result in unavoidable impacts on the environment.

Growers of short-rotation tree species in monocultures may mitigate the rate or magnitude of these unavoidable impacts through the adoption and proper use of best management practices. APHIS does not have the authority to regulate grower management practices.

6.2 Short-Term Versus Long-Term Impacts

In the short term, growers who adopt FTE are likely to experience more costly establishment and weed control costs than pine-tree growers. These higher costs associated with FTE, however, may be offset by the long-term effect of higher profits from the increased productivity of FTE relative to pine plantation from the more rapid maturation of FTE resulting in more frequent harvests.

In the long term, as production forestry of any type continues within the action area, environmental resources may continue to be impacted, as described in the analyses of the No Action and Preferred Alternatives. Under both Alternatives, these long-term potential impacts will be primarily due to the silvicultural practices of short-rotation tree species in monocultures (e.g., pine, non-GE eucalyptus, or FTE grown in plantations) using conventional silvicultural practices.

Under the No Action and Preferred Alternatives, tree growers may mitigate the rate or magnitude of these unavoidable impacts through the adoption and proper use of best management practices. APHIS does not have the authority to regulate grower management practices.

6.3 Irreversible Resource Commitments

Irreversible resource commitments represent a loss of future options. This applies primarily to the use of nonrenewable resources and to factors that are renewable only over long time spans, or to impacts that cannot be reversed. An irretrievable commitment of resources represents opportunities that are lost for the period of the proposed action. It also includes the use of renewable resources, such as timber or human effort, as well as other utilization opportunities that are forfeited in favor of the proposed action.

No irreversible or irretrievable commitments of resources were identified with either the Action Alternatives.

6.4 Mitigation Measures

As defined in the CEQ regulations for implementing NEPA (40 CFR § 1508.20) mitigation includes:

- Avoiding the impact altogether by not taking a certain action or parts of an action;
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and
- Compensating for the impact by replacing or providing substitute resources or environments.

APHIS does not have the authority to regulate types of management practices. Nevertheless, mitigation of environmental impacts can occur through the adoption and proper use of best management practices. These silvicultural best management practices are discussed throughout this EIS. Voluntary adoption of these best management practices are anticipated to mitigate many of the environmental impacts presented in this section and described elsewhere in this EIS. APHIS acknowledges that there is no binding legal enforcement mechanism to ensure that growers follow these best management practices.

Best management practices oversee the proper cultivation of tree species in production forestry to limit impacts on environmental and biological resources. Adherence to these best management practices is anticipated to reduce the environmental impacts associated with production forestry.

7 THREATENED AND ENDANGERED SPECIES

The Endangered Species Act (ESA) of 1973, as amended, is one of the most far-reaching wildlife conservation laws ever enacted by any nation. Congress passed the ESA to prevent extinctions facing many species of fish, wildlife and plants. The purpose of the ESA is to conserve endangered and threatened species -- and the ecosystems on which they depend -- as key components of America's heritage. To implement the ESA, the U.S. Fish & Wildlife Service (USFWS) works in cooperation with the National Marine Fisheries Service (NMFS), other federal, state, and local agencies, Tribes, non-governmental organizations, and private citizens. Before a plant or animal species can receive the protection provided by the ESA, one of the Services (NMFS or USFWS) must first add it to the federal list of threatened and endangered wildlife and plants. Threatened and endangered (T&E) species are plants and animals at risk of becoming extinct throughout all or part of their geographic range (endangered species) or species likely to become endangered in the foreseeable future throughout all or a significant portion of their ranges (threatened species).

The Services add a species to the list when they determine it is endangered or threatened because of any of the following factors or a combination thereof:

- The present or threatened destruction, modification, or curtailment of its habitat or range;
- Overuse for commercial, recreational, scientific, or educational purposes;
- Disease or predation;
- The inadequacy of existing regulatory mechanisms; or
- The natural or manmade factors affecting its survival.

Once an animal or plant is added to the list, in accordance with the ESA, protective measures apply to the species and its habitat. These measures include protection from adverse effects of federal activities.

7.1 Requirements for Federal Agencies

Section 7(a)(2) of the Endangered Species Act requires that each federal agency, in consultation with the Services and with the assistance of the relevant Secretary, ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of a listed T&E species, or result in the destruction or adverse modification of designated critical habitat. You can find implementing regulations in 50 CFR part 402, Interagency Cooperation Regulations.

When analyzing potential effects of a proposed regulatory action on T&E species and critical habitat, under Section 7(a)(2), agencies must use the best available scientific information to consider direct, indirect, interrelated, interdependent, and cumulative effects as defined in the implementing regulations of the ESA (50 CFR §402.02).

An effects analysis results in either a "may affect" or "no effect" determination. "May affect" is an appropriate determination when an action may have an effect on any individual(s) of a listed species or designated critical habitat. A "no effect" determination is appropriate when an action will have no effect on any individual(s) of listed species or designated critical habitat. In accordance with Section 7 of the ESA, APHIS consults with the Services for any "may affect" determination. The ESA does not require consultation with the Services for "no effect" determinations.

When actions may affect listed or proposed T&E species, or designated or proposed critical habitat, agencies must prepare biological assessments (BAs). A BA analyzes potential effects and describes any protective measures an agency proposes to use to protect affected species and/or their habitats. The agency submits findings of a BA for review by the appropriate Service. This review is followed by a consultation process between the participating agencies to formalize limitations on allowable effects on T&E species and establish protective measures to mitigate effects.

If the federal agency reaches a "may affect" determination, it must determine whether the action is likely or not likely to adversely affect the listed species or designated critical habitat.

> A ***"may affect, not likely to adversely affect"*** determination is appropriate when effects on listed species or designated critical habitat are expected to be discountable, insignificant, or completely beneficial. If the determination is "may affect, not likely to adversely affect," the agency initiates an informal consultation with the Services. Failure to obtain the Services' concurrence with this determination requires formal consultation.
>
> A ***"may affect, likely to adversely affect"*** determination is appropriate when the agency does not expect effects on listed species, or designated critical habitat to be discountable, insignificant, or completely beneficial; the overall effect is beneficial, but is also likely to cause some adverse effects; or if the agency expects a "take" to occur as a result of the action. If the determination is "may affect, likely to adversely affect," the agency initiates a formal consultation with the Services. The formal consultation process ends with a decision by the Services (usually written in a Biological Opinion) on whether the action will result in jeopardy/non-jeopardy to the continued existence of the species if the action will adversely modify designated critical habitat.

To facilitate their ESA consultation requirements, APHIS met with the USFWS from 1999 to 2003 to discuss factors relevant to APHIS' regulatory authority and effects analysis for petitions for non-regulated status and developed a process for conducting an effects determination consistent with the PPA (Title IV of Public Law 106-224). APHIS uses this process to help fulfill its obligations and responsibilities under Section 7 of the ESA for biotechnology regulatory actions.

The APHIS regulatory authority over GE organisms under the PPA is limited to those GE organisms for which it has reason to believe might be a plant pest or those for which APHIS does not have sufficient information to determine that the GE organism is unlikely to pose a plant pest risk (7 CFR §340.1). After completing a similarity assessment, if APHIS determines that seeds, plants, or parts of eucalyptus lines FTE 427 and FTE 435 do not pose a plant pest risk similar to its antecedents, then this article would no longer be subject to the plant pest provisions of the PPA or to the regulatory requirements of 7 CFR Part 340, and therefore, APHIS must reach a determination that this article is no longer regulated. As part of its EA analysis, APHIS analyzed the potential effects of eucalyptus lines FTE 427 and FTE 435 on the environment including any potential effects to T&E species and critical habitat. As part of this process, APHIS thoroughly reviews GE product information and data related to the organism to inform the ESA effects analysis and, if necessary, the biological assessment. For each transgene(s)/transgenic plant the following information, data, and questions are considered by APHIS:

- A review of the biology, taxonomy, and weediness potential of the crop plant and its sexually compatible relatives;
- Characterization of each transgene with respect to its structure and function and the nature of the organism from which it was obtained;

- A determination of where the new transgene and its products (if any) are produced in the plant and their quantity;
- A review of the agronomic performance of the plant including disease and pest susceptibilities, weediness potential, and agronomic and environmental impact;
- Determination of the concentrations of known plant toxicants (if any are known in the plant); and
- Analysis to determine if the transgenic plant is sexually compatible with any T&E species or a host of any T&E species.
- Any other information that may inform the potential for an organism to pose a plant pest risk.

USDA-APHIS met with USFWS officials on June 15, 2011, to discuss and clarify whether USDA-APHIS has any obligations under the ESA regarding analyzing the effects on T&E species that may occur from use of pesticides associated with GE crops. As a result of these joint discussions, USFWS and USDA-APHIS have agreed that it is not necessary for USDA-APHIS to perform an ESA effects analysis on pesticide use associated with GE crops because EPA has both regulatory authority over the labeling of pesticides under FIFRA, and the necessary technical expertise to assess pesticide effects on the environment. USDA-APHIS has no statutory authority to authorize or regulate the use of pesticides by growers. Under USDA-APHIS' current Part 340 regulations, USDA-APHIS only has the authority to regulate eucalyptus lines FTE 427 and FTE 435 or any GE organism as long as USDA-APHIS believes they may pose a plant pest risk (7 CFR § 340.1). USDA-APHIS has no regulatory jurisdiction over any other risks associated with GE organisms including risks resulting from the use of pesticides on those organisms.

7.2 Threatened and Endangered Species Analysis

Based upon the scope of the EIS and production areas identified in the Affected Environment section of the EIS, APHIS developed a T&E species lists (listed and proposed) for the geographic area that encompasses each county where freeze tolerant eucalyptus (hereafter referred to as "FTE") is likely to be grown. The species list was obtained by using the USFWS database, and includes all species federally listed or proposed for listing in the counties identified in the action area. Appendix F of the EIS provides a list of these species and indicates if they have critical habitat. APHIS, as described below, has evaluated the potential effects that a determination of non-regulated status of FTE may have on federally-listed T&E species and species proposed for listing, as well as designated critical habitat and habitat proposed for designation within the action area.

7.2.1 Assumptions used for the T&E Species Analysis

There are numerous assumptions used for the T&E species analysis for FTE. These are discussed in detail in Section 4.5 - Assumptions Used in the Analysis of the Preferred Alternative of this EIS. These assumptions are used to define the extent of the action area, and assist in the identification of stressors that could affect the reproduction, numbers, or distribution of a listed T&E species or species proposed for listing, and designated critical habitat or habitat proposed for designation. These assumptions are:

- The FTE Action Area is within the boundaries of 204 counties in 7 Southern States (Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, and South Carolina) (see Appendix F – list of counties, and Figure 3 – map of action area). The refinement of the action area is based on limitations by environmental factors (cold sensitivity) and economic factors that would make planting FTE unprofitable compared to the current and projected land use (see Sections 4.5.1 and 4.6.1 and Appendix B).

- The baseline for comparison of the potential impacts resulting from the Preferred Alternative is potential impacts resulting from the no action alternative, which is the continued planting of pine in pine plantations (see Sections 4.2.2 , 4.5.2, 4.6.1, and in Appendix B - the USDA-FS Economic Adoption Technical Report). FTE will be expected to replace pine in pine plantations, and is not expected to be planted in areas currently devoted to row cropping or in natural areas. As discussed in Cumulative Impacts (see Section 5.2.2), it is reasonably foreseeable that managers of plantations growing naturally regenerated pine may convert to growing FTE. However, this factor's importance is reduced when one considers the ongoing trend is conversion of naturally generated pine to plantation pine and that this trend is expected to continue into the foreseeable future within the Southern United States (Wear and Greis, 2002b; Wear and Greis, 2013).
- Forest Service (FS) modeling points toward an adoption (conversion of pine plantations to FTE) rate of between 5-9 percent by year 30; between 0.8 and 1.4 million acres (see Section 4.6.1 and Appendix B). If one includes conversion of naturally generated pine at this rate, the total acreage would be between 1.35 and 2.75 million acres. However, a foreseeable possibility is that market forces could increase demand for wood products, and demand could increase for FTE, as well, especially with development of biomass markets. The FS model adoption rates under such scenarios suggest that for planted pine as well as naturally regenerated pine, the adoption acreage of FTE could range up to 4.05 million acres.
- The rotation interval between harvests for FTE compared to pine is much shorter; 6-10 years compared to 20-25 for pine plantations (see Section 4.6.5).
- FTE may undergo up to four harvests from one planting (due to coppice) whereas pine is cut and then either naturally regenerated or replanted (see Section 4.6.5).
- FTE, like other *Eucalyptus* species under plantation management, grows quickly and reaches canopy closure within two years compared to pine canopy closure of 10-12 years (see Section 4.6.5).
- Compared to pine, FTE has increased evapotranspiration and is likely to use more water. This could affect wetlands and vernal pools habitats. At the local level, with high adoption, there is the potential to change permanent streams into intermittent streams. Impacts to streams and rivers at the landscape and watershed level cannot be generalized as these impacts are ultimately site dependent. (see Section 4.6.4 and Appendix C).
- FTE plantations will have substantially less organic matter and nutrients in soil compared to the baseline pine plantation (see Section 4.6.3).
- The impact of potential allelopathy of FTE will be insignificant compared to other typical forestry practices used to control vegetation in plantations (see Section 4.6.3).
- There is a potential, with high uncertainty, that FTE could naturalize in the environment. However, such an occurrence would be slow. The FTE hybrid is male sterile and in addition, any seedlings that would occur as a result of pollination from other *Eucalyptus* species would produce hybrids that are not likely to be very competitive with other vegetation (see Section 5.3.4 and PPRA).

- Abandoned plantations could be problematic and measures would need to be taken to either remove the trees or monitor for the escape of seedlings and remove them (see Section 5.3.4). There is no current regulatory mechanism that requires this.
- The fire risk from planting FTE is not substantially different than the fire risk from plantation pine (see Section 4.5.3).
- FTE is unlikely to pose a Plant Pest Risk (see Section 4.5.4) (USDA-APHIS, 2015).
- FTE is not expected to present a risk to human health (see Section 4.5.5).
- Pesticide use including herbicides associated with silviculture, including growing FTE, is under the regulatory purview of the EPA (see Section 4.5.6).

7.2.2 Identification of Stressors

From the assumptions and information presented in the draft EIS, several potential stressors have been identified:

- As discussed thoroughly in Section 4.6.4 and in Appendix C, FTE has the potential to affect hydrology on a local level. This has the potential to affect water dependent species both within the FTE plantation and beyond. Plants within the plantation or in close proximity may be affected by removal of water from the ground which would make it unavailable to them. Impacts may also occur to species that use vernal pools for part of their lifecycles such as reptiles and amphibians. Vernal pools and other wetlands must have water during the critical breeding period and long enough to support the larval stages of vernal-pool dependent species or they will be unsuitable as breeding habitat. In addition, FTE has the potential to reduce the flow in local streams potentially causing some permanent streams to become intermittent streams. This change could make this habitat unsuitable for fish, mussels, or other organisms that require a permanent aquatic habitat of suitable quality.
- The much quicker canopy closure for FTE compared to pine may be detrimental to plant species found within plantations that require direct sunlight. Some species that are currently found in pine plantations benefit from the open canopy that is present from the time of planting until the canopy eventually closes by year 10. In contrast, the canopy for FTE closes in two years, greatly reducing the timeframe during which the site would be exposed to direct sunlight. This change in canopy closure would have impacts on species requiring direct sunlight but may be beneficial to species that prefer shade. However, because of the shorter harvest rotation, these species may be impacted when the canopy reopens in four to eight years rather than in 10 to 15 years for pine.
- Several studies indicate an increase in plant diversity and composition as plantations age while others indicate this is not the case. The shorter harvest cycle for FTE will result in damage to understory vegetation and the forest floor every six to ten years, compared to every 25 years for pine. This may lead to less plant diversity compared with pine plantation stands of 25 years of age, possibly with a plant composition mostly composed of grasses and species that typically are the first to establish in disturbed soil. This may be unsuitable habitat for some animal species, and may also be detrimental to some plant species that require more than six to ten years without disturbance. These characteristics of FTE cultivation would reduce biodiversity compared to plantation pine, whether planted or naturally-regenerated. Compared to planted or naturally-regenerated pine, the shorter rotation schedule and rapid canopy closure of FTE can reduce the structurally complex understory that is suitable for wildlife species (Carnus et al., 2006). Repetitive damage from short-rotation harvest cycles of FTE would also lead to a reduction in

plant diversity and composition (Wen et al., 2010). However, one must consider the baseline conditions which for pine plantations are low diversity, composition, and density of understory vegetation. Pine and *Eucalyptus* plantations, including FTE plantations, are typically monocultures, which have reduced understory diversity compared to natural forests (Loumeto and Huttel, 1997; Wang et al., 2011).

- The shorter harvest cycle will increase the frequency of activities associated with the harvesting and removal of the biomass. However, the intensity of disturbance would likely be less than what occurs under management of both planted and naturally regenerated pine plantations. This is because regeneration of FTE is typically accomplished by coppicing, where a shoot from the cut stump is allowed to grow to produce the next crop. Under this growing regimen, up to four harvests are completed from one planting. This production method results in less soil disturbance over time and is less likely to result in soil loss from the production site when compared to pine production. However, FTE could potentially have local impacts on water quality through increased sediment loading from forest access systems (forest roads and stream crossings) into forest streams. While the cultivation of FTE is unlikely to increase the number of forest roads and stream crossings in the action area (i.e., FTE is anticipated to be planted on sites previously planted to plantation pine (see Appendix B), these forest access systems are likely to experience more frequent disturbances related to FTE harvesting. More frequent disturbances on these forest access systems increases the potential for sediment loading into forest streams. Current BMPs, however, are effective in reducing sediment loading into forest streams and may mitigate local and direct impacts from FTE-related management activities, so long as these BMPs are adopted by growers of FTE. Best management practices (BMPs) are protective of water quality and mussel habitat, and industrial forestry activities generally do a good job of implementing BMPs (US-FWS, 2012). However, BMPs are voluntary and, therefore, are not always implemented. In addition, some harvesting operations fail to use BMPs adequately, and localized impacts can and do occur (US-FWS, 2012). In the case of FTE production, it is reasonable to expect that most growers who decide to pay a premium for the trees and venture into growing a new crop would be likely to adopt BMPs.
- As discussed in Section 4.3.4, production forestry and related silvicultural activities contribute a relatively small proportion of sediments into surface waters when compared to other sources of sediment (e.g., urbanization and conventional row agriculture) (EPA, 2000b; EPA, 2014b) . Considering that FTE is projected to replace ≤ 10 percent of plantation pine (see Appendix B), and the overall contribution of production forestry to surface water sedimentation is already low, the potential increase in sediment contribution compared to pine production at the landscape level is unlikely to be substantial. At larger spatial scales within the action area, the potential impact of FTE on surface sedimentation is likely to be negligible compared to other potential sources of sediments (see Section 4.6.4). The potential for increased sedimentation was the stressor triggering many of the “may effect” concerns. However, for many species, any increases in sedimentation from conversion to FTE would be negligible, insignificant, or otherwise discountable, and thus resulted in a final “may affect, not likely to adversely affect” determination.

The stressors discussed above were considered when analyzing the potential impacts that a determination of non-regulated status of FTE may have on federally-listed T&E species and species proposed for listing, as well as designated critical habitat and habitat proposed for designation. It is important to realize that these impacts would be local, site dependent (size of plantation, location in relation populations of T&E species, presence of other stressors), and highly variable. There is a high level of uncertainty in the analysis. There is no way to know where FTE plantations will be established and how close in proximity to populations of T&E species and critical habitat. Recognizing this unknown, APHIS took a cautious approach for the analysis, and many species are identified as “may affect” species because of the potential for effects rather than the likelihood of effects. Some species, even those the analysis determined to be likely to be adversely affected, may ultimately never be affected at all.

The action area includes 204 counties within the states of Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina, and Texas (see Figure 3 and Appendix E). The action area is restricted by the limitations of the engineered phenotype, and the economics of silviculture. The species list was obtained by using the USFWS database, and includes all species federally listed or proposed for listing in the counties identified in the action area. Appendix F provides a list of these species and indicates if they have critical habitat. There are a total of 138 listed species and 2 proposed species within the action area. USDA-APHIS analyzed the possible impacts that a determination of non-regulated status and the subsequent commercialization of FTE could have on these species. Of the 140 species, APHIS has determined that 55 of the listed species and the 2 proposed species have the potential to be sufficiently collocated that they may be affected by conversion of pine plantations to FTE. Of these 57 species, 36 are likely to be adversely affected, and 21 species are not likely to be adversely affected. The species likely to be adversely affected include 3 amphibians, 11 mussels, 1 fish, 1 conifer, 16 flowering plants, and 4 reptiles. These species are listed in Table 15. The species not likely to be adversely affected include 1 mammal, 7 mussels, 1 fish, 1 crustacean, 8 flowering plants, and 3 reptiles. These species are listed in Table 16.

Of the 140 species, 39 have designated critical habitat and two species have proposed critical habitat. There is also one plant species that is not known to occur within the action area, but has an unoccupied critical habitat unit proposed for designation within the action area. As part of its species effects analysis, APHIS considered the impacts that a determination of non-regulated status of FTE and likely adoption may have on the critical habitat of these species. Twenty-one of the species with critical habitat were determined to be “no effect” species, mainly because the species are far removed from pine plantations, have specific habitat requirements, and the primary constituent elements of the species’ habitat are not found in pine plantations. No effects are expected on their critical habitat either. Of the 20 “may affect” species with critical habitat (18 designated and 2 proposed), the critical habitat for many would be unlikely to be affected. Conversion of pine to FTE would be unlikely to occur within critical habitat. In the majority of cases, pine plantations are unsuitable habitat for the species and conversion from pine to FTE would be unlikely to have any effect on habitat that would be different than pine. There may be some effect on critical habitat for amphibians and some mussel species in locations that have been susceptible to drought. During times of drought, the lack of water will likely be exacerbated by the increased moisture requirement of FTE if a plantation were within the local drainage. Although such impacts may make the habitat unusable, they are likely to be temporary and long term impacts on the habitat are unlikely to be different than from those impacts resulting from periods of drought.

The conclusions of the effects on critical habitat are in agreement with our determination for the species. That is, critical habitat for those species with a likely to adversely affect determination also have a similar determination for the critical habitat. The reason for this is that the species are affected by changes to their habitat (e.g. changes to water quality and quantity).

Table 15: Species That May Be Affected, and Are Likely to Be Adversely Affected

Common Name	Scientific Name	Listing Status	States Known to Occur – (within action area)	Critical Habitat
Frosted Flatwoods salamander	*Ambystoma cingulatum*	Threatened	FL, GA, SC	Yes - Likely to be adversely affected
Dusky gopher frog	*Rana sevosa*	Endangered	MS	Yes - Likely to be adversely affected
Reticulated flatwoods salamander	*Ambystoma bishopi*	Endangered	FL, GA	Yes - Likely to be adversely affected
Choctaw Bean	*Villosa choctawensis*	Endangered	Al, FL	Yes - Likely to be adversely affected
Fuzzy pigtoe	*Pleurobeama strodeanum*	Threatened	AL, FL	Yes, - Likely to be adversely affected
Gulf moccasinshell	*Medionidus penicillatus*	Endangered	AL, FL, GA	Yes - Likely to be adversely affected
Louisiana pearlshell	*Margaritifera hembeli*	Threatened	LA	No
Narrow pigtoe	*Fusconaia escambia*	Threatened	AL, FL	Yes – Likely to be adversely affected
Oval Pigtoe	*Pleurobema pyriforme*	Endangered	AL, FL, GA	Yes - Likely to be adversely affected
Shinyrayed pocketbook	*Lampsilis subangulata*	Endangered	AL, FL, GA	Yes - Likely to be adversely affected
Southern kidneyshell	*Ptychobranchus jonesi*	Endangered	AL, FL	Yes – Likely to be adversely affected
Southern Sandshell	*Hamiota (=Lampsilis) australis*	Threatened	AL, FL	Yes - Likely to be adversely affected
Suwannee moccasinshell	*Medionidus walker*	Threatened	FL, GA	No
Tapered pigtoe	*Fusconaia burkei*	Threatened	AL, FL	Yes, Likely to be adversely affected
Florida torreya	*Torreya taxifolia*	Endangered	FL, GA	No

Pearl Darter	*Percina aurora*	Proposed Threatened	MS	No
American chaffseed	*Schwalbea americana*	Endangered	AL,GA,FL,LA,SC	No
Apalachicola rosemary	*Conradina glabra*	Endangered	FL	No
Canby’s dropwort	*Oxypolis canbyi*	Endangered	GA, SC	No
Chapman rhododendron	*Rhododendron chapmanii*	Endangered	FL	No
Cooley's meadowrue	*Thalictrum cooleyi*	Endangered	FL, GA, NC	No
Florida skullcap	*Scutellaria floridana*	Threatened	FL	No
Gentian pinkroot	*Spigelia gentianoides*	Endangered	AL, FL	No
Godfrey's butterwort	*Pinguicula ionantha*	Threatened	FL	No
Hairy rattleweed	*Baptisia arachnifera*	Endangered	GA	No
Harperella	*Ptilimnium nodosum*	Endangered	GA	No
Harper's beauty	*Harperocallis flava*	Endangered	FL	No
Louisiana quillwort	*Isoetes louisianensis*	Endangered	AL, LA, MS	No
Pondberry	*Lindera melissifolia*	Endangered	AL, GA, MS, SC	No
Rugel's pawpaw	*Deeringothamnus rugelii*	Endangered	FL	No
Telephus spurge	*Euphorbia telephioides*	Threatened	FL	No
White birds-in-a-nest	*Macbridea alba*	Threatened	FL	No
Gopher tortoise	*Gopherus Polyphemus*	Threatened	AL, LA, MS	No
Black pine snake	*Pituophis melanoleucus lodingi*	Threatened	AL, MS	Proposed CH - Likely to be adversely affected
Louisiana pinesnake	*Pituophis ruthveni*	Proposed Threatened	LA, TX	No
Eastern indigo snake	*Drymarchon corais couperi*	Threatened	AL, GA, FL	No

Table 16: Species That Are Likely to Be Affected, but Are Not Likely to Be Adversely Affected

Common Name	Scientific Name	Listing Status	States Known to Occur – (within action area)	Critical Habitat
Alabama heelsplitter	*Potamilus inflatus*	Threatened	AL, LA, MS	No
Chipola slabshell	*Elliptio chipolaensis*	Threatened	AL, FL	Yes - Not likely to be adversely affected
Fat threeridge	*Amblema neislerii*	Endangered	FL, GA	Yes - Not likely to be adversely affected
Ochlockonee moccasinshell	*Medionidus simpsonianus*	Endangered	FL, GA	Yes - Not likely to be adversely affected
Purple bankclimber	*Elliptoideus sloatianus*	Threatened	AL, FL, GA	Yes - Not likely to be adversely affected
Rabbitsfoot	*Quadrula cylindrica*	Threatened	MS	Proposed CH - Not likely to be adversely affected
Round ebonyshell	*Fusconaia rotulata*	Endangered	FL	Yes – Not likely to be adversely affected.
Squirrel Chimney cave shrimp	*Palaemonetes cummingi*	Threatened	FL	No
Bayou Darter	*Etheostoma rubrum*	Threatened	MS	No
Beautiful paw	*Deeringothamnus pulchellus*	Endangered	FL	No
Florida bristle fern	*Trichomanes punctatum* ssp. *floridanum*	Proposed Endangered	FL	No
Fringed campion	*Silene polypetala*	Endangered	FL, GA	No
Miccosukee gooseberry	*Ribes echinellum*	Threatened	FL	No
Navasota ladies'-tresses	*Spiranthes parksii*	Endangered	TX	No

Neches River rose-mallow	*Hibiscus dasycalyx*	Threatened	TX	Yes - Not likely to be adversely affected
Relict trillium	*Trillium reliquum*	Endangered	AL, GA	No
Texas trailing phlox	*Phlox nivalis ssp. texensis*	Endangered	TX	No
Bluetail mole skink	*Eumeces egregius lividus*	Threatened	FL	No
Sand skink	*Neoseps reynoldsi*	Threatened	FL	No
Yellow-blotched map turtle	*Graptemys flavimaculata*	Threatened	MS	No
Northern Long-Eared Bat	*Myotis septentrionalis*	Endangered	AL, GA, LA, MS, SC	No

As a result of the determination that adoption of FTE may affect, and is likely to adversely affect several species, and may adversely affect designated critical habitat, APHIS prepared and submitted a Biological Assessment and this EIS to the US Fish and Wildlife Service, and requested a formal consultation with the Service under Section 7 (a)(2) of the Endangered Species Act. The consultation is currently ongoing. No final decision on the petition will be made until the consultation with USFWS is complete.

8 SPECIAL CONSIDERATIONS AND CONSIDERATION OF EXECUTIVE ORDERS, STANDARDS, AND TREATIES RELATING TO ENVIRONMENTAL IMPACTS

8.1 Special Considerations in the USDA-FS Technical Reports

8.1.1 Introduction to Uncertainty and Limitations

As mentioned throughout this draft EIS, *Eucalyptus* spp. have not been commercially-cultivated on a large scale within the United States. As a result, there is a substantial absence of empirical field data about its effects on land use, hydrology, and fire risk within the United States.

APHIS and USDA-FS determined that in the absence of empirical field data regarding *Eucalyptus* spp. within the United States, computer modeling provides the next best option for analyses on land use, hydrology, and fire risk. Each of the specific models utilized in the various analyses of land use, hydrology, and fire risk represent established or modifications to established models that have withstood the scrutiny of academic peer review.

The modeling efforts undertaken for land use, hydrology, and fire risk represent the current state of the science, and culminated in the technical reports presented as appendices to this FTE draft EIS. Each technical report was peer-reviewed by teams of technical experts and represents considerable effort by APHIS and USDA-FS to address issues related to land use, hydrology, and fire risk in lieu of empirical field data for the United States.

However, computer modeling is not without its limitations or uncertainties. The subsections immediately below detail these aspects of uncertainty and limitation with respect to each of the modeling efforts utilized in the technical reports for land use, hydrology, and fire risk. In each subsection, the illustration of uncertainty and limitations are presented with the interpretation of the technical experts who developed the three models used for this FTE EIS.

8.1.2 Uncertainty and the Technical Report – Projecting Potential Adoption of Genetically Engineered Freeze-Tolerant Eucalyptus Plantations

The technical report entitled *Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations* is based on a normative simulation analysis of potential land owner behavior and depends on a set of critical assumptions. Most fundamental is the set of behavioral assumptions behind the analysis. It is assumed that private landowners behave as maximizing entities. According to the theory outline in the report, the ". . . switching model anticipates that a risk-neutral decision maker chooses between retaining a current land use or (reversibly) adopting a new land use (FTE) based on a comparison of returns, conversion costs, and uncertainty regarding future returns." Inter-temporal value comparisons depend on time preferences which is approximated with a discount rate of 8 percent.

The analysis of land use data requires processing a large amount of data, often with incongruent boundaries. Nearly all land use and production data were organized by counties. Counties were considered to be a part of plant hardiness zone 8B and higher if a majority of the land area was within the zonal boundary. A further restriction of the study area is based on the environmental range of *Eucalyptus grandis*, which represents an important assumption and source of uncertainty. The relationship between environmental variables and productivity and commercial viability for the modified hybrid is not fully knowable prior to field experience.

The analysis also assumes that the forest land base that would be plausible for transition to FTE is limited to planted pine. This is based on the assumption that these lands have already been selected or deemed suitable for intensive forest management. The managed condition of these forests also defines lower conversion costs compared to those associated with naturally-regenerated forests. Analysis by Wear et al (2013a) also indicates that rates of tree planting following harvest are very high for natural pine in this region, but are low for upland and lowland hardwoods. The possibility that naturally-regenerated pine could be a source in the future was explored in accordance with this observation, but does not consider hardwoods as a potential source based on current and anticipated economics.

The analysis is also based on several assumptions about future market trends and risks. One important assumption is that the freeze tolerance trait in FTE will be successful in preventing substantial freeze damage to planted trees within plant hardiness zone 8b and higher. Mortality and productivity are however important stochastic elements of overall return estimates which would influence return risk. In general, higher return variance would reduce adoption of FTE as demonstrated by our sensitivity analyses. This analysis also assumes that productivity is essentially uniform across the Southeastern United States. This is a necessary assumption because of the lack of data regarding these factors in the Southeastern United States, but incorporating location specific productivity and damage functions could provide additional insights into the likely location of future FTE plantations. Another unknown is the actual cost of FTE seedlings. According to the analysis presented here, the conversion costs between land uses could have an appreciable impact on the area that would ultimately be changed to FTE plantings. An additional source of risk that extends beyond the scope of this analysis is the risk of some public backlash against the planting of genetically modified trees. This societal risk could affect investment choices in the same fashion as biophysical risk (i.e., increased risk would reduce the rate of adoption).

8.1.3 Uncertainty and the Technical Report – Implications for Expansion of GE Freeze-tolerant Eucalyptus Plantations of Water Resources in the Continental United States

The technical report entitled *Implications for Expansion of GE Freeze-tolerant Eucalyptus Plantations of Water Resources in the Continental U.S.* is a model-based analysis of the potential impacts of the expansion of FTE that represents the best approximation based on currently available data. Because physiological and structural data for FTE do not exist, the following was assumed:

1. Physiological (*e.g*., stomatal conductance) and stand structure data (*e.g*., leaf area index amount, season dynamics, and development over time) from *Eucalyptus grandis* (and other *Eucalyptus* spp.) growing in other regions of the world are applicable to FTE growing in USDA plant hardiness zone 8b and higher.
2. The stand level model was a sufficient representation of how FTE would respond to climatic and soil driving variables at the five study locations.
3. The empirical AET model (equation 7) developed from an eddy covariance tower in Brazil was applicable to FTE growing in USDA plant hardiness zone 8b and higher.
4. A stand LAI = 4 is a reasonable value for commercial stands of FTE growing in USDA plant hardiness zone 8b and higher.

In addition to these assumptions, biophysical models at all scales are limited by imperfect knowledge and simplifications of processes, parameters, and driving variables, and by limits to the accuracy and precision of climate driving variables such as precipitation and air temperature. Furthermore, these results must be viewed in the context of the hydrologic setting of the area of the plantation. Key physical features such as soil texture, topography, existing drainage networks and road systems, and groundwater depth can either mitigate or exacerbate responses. Future climate variability, especially an increased frequency and severity of drought may make some areas much more sensitive to the impacts of higher ET in the future. The models applied here were not appropriate for simulating the potential impacts of extreme drought due to a lack of model sophistication and data on physiological and structural responses from FTE. These assumptions and uncertainties reinforce the need to obtain empirical measurements to validate (or reject) model projections.

8.1.4 Uncertainty and the Technical Report – Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States

The technical report entitled *Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States* represents a model-based projection of FTE, plantation pine, and other forested/agricultural land uses.

Because actual stand exam and surface fuel survey data for the FTE fuelbeds were lacking, these results and interpretations should be considered preliminary. The fuelbeds are intended to provide a logical and systematic exploration of potential fire risks in FTE plantations in the southern United States. The following are key assumptions made in fuelbed construction that could have substantial impacts on our fire hazard assessment for FTE plantations.

Understory species composition was assumed to be comparable to typical southern pine plantations. However, if individual sites have flammable understory shrubs such as gallberry or wax myrtle, predicted surface fire behavior would be considerably higher.

To remain consistent with standard FCCS fuelbed development, 0-1 year old FTE and loblolly pine plantations were represented as short tree canopy layers in this report. However, if trees less than a year old were considered as shrubs, they were treated as flammable shrub layers by FCCS and the predicted surface fire behavior increases dramatically. The recommendation for the most conservative estimate of fire risk is to use fuelbeds constructed with 0-1 year FTE as a shrub layer.

Decomposition rates were assumed to be high in the southern United States, so accumulations of litter over time were considered to be low.

Although FTE bark does not slough off in large strips as in some *Eucalyptus* spp., substantial sloughing of bark flakes in photographs of FTE plantations was not noted. The contribution of FTE bark to litter reaction intensity has not been fully accounted for in fuelbeds examined. Incorporation of a litter and/or bark layer would require some field sampling to accurately reflect the bulk density and decomposition rates of the fuels.

Fine woody fuel surveys would be required to more accurately represent this fuelbed component. Because it was assumed that FTE plantations would have similar woody fuel loads as loblolly plantations, there was no expectation of any difference in predicted surface fire behavior.

<u>Data gaps</u>

The following data would be needed to improve characterization of FTE fuels and provide more reliable predictions of fire hazard:

1. Forest inventory plots to provide important canopy inputs including tree height, height to live crown, tree density and forest cover across management scenarios and plantation ages.

2. Understory vegetation surveys including shrub and herbaceous species, relative cover, height, percent cover by ground projection, and fuel loading.
3. Downed woody fuel inventories by size class with particular emphasis on fine wood (1-hr, 10-hr, and 100-hr fuels for surface fire behavior prediction).
4. Forest floor inventories to measure litter depth, bark slough, percent cover and bulk density.

8.2 Executive Orders with Domestic Implications

The following executive orders require consideration of the potential impacts of the Federal action to various segments of the population.

- **Executive Order (EO) 12898 (US-NARA, 2013), "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,"** requires Federal agencies to conduct their programs, policies, and activities that substantially affect human health or the environment in a manner so as not to exclude persons and populations from participation in or benefiting from such programs. It also enforces existing statutes to prevent minority and low-income communities from being subjected to disproportionately high and adverse human health or environmental effects.

- **EO 13045 (US-NARA, 2013), "Protection of Children from Environmental Health Risks and Safety Risks,"** acknowledges that children may suffer disproportionately from environmental health and safety risks because of their developmental stage, greater metabolic activity levels, and behavior patterns, as compared to adults. The EO (to the extent permitted by law and consistent with the Agency's mission) requires each Federal agency to identify, assess, and address environmental health risks and safety risks that may disproportionately affect children.

- **Executive Order 13175 (US-NARA, 2013), "Consultation and Coordination with Indian Tribal Governments,"** pledges agency communication and collaboration with tribal officials when proposed Federal actions have potential tribal implications.

The No Action and Preferred Alternatives were analyzed with respect to EO 12898 and EO 13045. None of the Alternatives are expected to have a disproportionate adverse impact on minorities, low-income populations, or children.

The No Action and Preferred Alternatives were also analyzed with respect to EO 13175. Any silvicultural activity that may be taken by growers on tribal lands would only be conducted at the tribe's request. Thus, the tribes would have control over any potential conflict with cultural resources on tribal properties. APHIS sent letters to Tribal entities when this petition was declared complete and made available to the public. There were no comments received from any tribal entities. There are no alternatives that have potential Tribal implications.

The following executive order addresses Federal responsibilities regarding the introduction and impacts of invasive species:

- **EO 13112 (US-NARA, 2013), "Invasive Species,"** states that Federal agencies take action to prevent the introduction of invasive species, to provide for their control, and to minimize the economic, ecological, and human health impacts that invasive species cause.

Table 17 presents the results of several weed risk assessments (WRAs) conducted and presented in the APHIS preliminary PPRA for FTE (2015).

Table 17. Summary of Aphis Preliminary PPRA WRA Results of Select Eucalyptus Species

Score type	*E. grandis*	***E.** urophylla*	***E. grandis x E. urophylla***	**GE** *E. grandis x E. urophylla*
% Probability Major-invader	35.0	0.6	1.9	1.2
% Probability Minor-invader	59.7	15.9	37.1	27.4
% Probability Non-invader	5.3	83.5	61.0	71.4
* Establishment/ Spread Potential (Uncertainty index)	7 (0.29)	- 7 (0.35)	-2 (0.41)	-4 (0.45)
* Impact Potential (Uncertainty index)	3.1 (0.24)	1.1 (0.13)	1.1 (0.70)	1.1 (0.70)
Model Result	Evaluate Further	Low Risk	Low Risk	Low Risk
Secondary Screening	High Risk	N/A	N/A	N/A

* The Establishment/Spread potential in the model can range from -20 to 25. The Impact Potential can range from 1 to 5. Uncertainties range from 0 to 1. Average uncertainty, as defined in the model, is a score of 0.17 (e.g., the average uncertainty among the set of 204 species used to develop the WRA model was 0.17). See the APHIS preliminary PPRA (2015) for more details.

Based on the WRA results from Table 17 and available evidence, the analyses indicates that FTE or its non-GE parent variety is not likely to escape, establish, and cause harm (USDA-APHIS, 2015). The WRA results for the non-GE parent are similar to other WRA results conducted for the non-GE parent (Gordon et al., 2012; IFAS, 2012).

One of the parents of the hybrid, *E. grandis*, has shown significant impacts due to its invasiveness, particularly in South Africa. In contrast, the other parent, *E. urophylla*, has not shown evidence of invasiveness or other impacts despite having been grown in a number of countries for more than 75 years. The scores above show that while both parents are very different, the hybrid is likely to be similar to *E. urophylla*. However, there was much uncertainty with this analysis because of the relatively short duration that the non-GE and GE hybrids have been present in the environment, which leads to a less knowledge about how the hybrid will behave over time (USDA-APHIS, 2015).

Due to this uncertainty, one cannot rule out the possibility that the GE hybrid could eventually become naturalized if it were widely planted. Although it is not likely to become highly invasive, it could escape from cultivation and become naturalized and perhaps become a minor invader (with high uncertainty). In cases where *Eucalyptus* has become naturalized and has become invasive, it has done so slowly (≥ 75 years). It also does not appear to spread far beyond established plantations (USDA-APHIS, 2015). The most problematic escapes appear to be along water courses where seeds have become distributed by water (Rejmanek and Richardson, 2011). This is particularly true in South Africa (Forsyth et al., 2004; ARC, 2011; Booth, 2012b) and has also been found to occur in California (Ritter and Yost, 2009). Trees will tend to spread from failed or abandoned plantations where there appears to be little or no oversight of the trees (Knadler and Sinimbu, 2011). Therefore, the concerns would be for GE hybrid plantings in areas close to waterways that occur in areas where there is bare mineral soils or for those in plantations that are subsequently abandoned, so left unmanaged.

In Brazil, Knadler and Sinimbu (2011) found that eucalyptus species are not a threat to the adjacent undisturbed Cerrado areas, and it is hypothesized that the native grasses inhibit the successful dispersal and germination of eucalyptus seeds in this type of habitat. A similar situation would occur in the southeastern United States where grasses and other vegetation would likely shade out any seeds that are released from the plantation. However, management and oversight of any plantations that are established would be advisable to ensure that trees don't escape and become naturalized in unwanted areas where undesired impacts could occur. As Stanturf et al. (2013a) noted, because Callaham et al. (2013) found seedlings in less intensively managed areas such as partially wooded sites, it is important to monitor for potential spread of *Eucalyptus* seedlings into unmanaged areas. Given the slow process by which this occurs with *Eucalyptus*, this would not be particularly labor intensive.

Eucalyptus plantations in general require adequate oversight and management to ensure high productivity (Whitesell et al., 1992; Rejmanek and Richardson, 2011). As a part of this oversight, best management practices can be implemented that would reduce invasion risk. Examples for eucalypts may be to avoid cultivation near waterways and cultivation and monitoring practices to control the slow spread from cultivation sites (Gordon et al., 2012). As noted above, Lorentz (2013) recommends the use of buffer zones around plantings for the purpose of limiting seed dispersal as well as providing surface water and wildfire protection by limiting the proximity of trees to waterways and by establishing a firebreak around the stand. Where *Eucalyptus* has already invaded Forsyth (2004) recommends removing trees from riparian areas (where water use is likely to be excessive) and nature reserves where all eucalypts have undesirable impacts on biodiversity). Rejmanek and Richardson (2011) note that because *Eucalyptus* seed do not have dormancy, it would make local eradication an achievable goal. Therefore oversight and management of plantations established with these GE trees, to monitor for any escape of seedlings, would effectively eliminate any inadvertent escape and persistence beyond cultivation. Any seedlings that appear in the vicinity of plantations could be easily controlled with the use of appropriate herbicides.

Due to the short period of time that the hybrid and the GE hybrid have been in cultivation, there was a high level of uncertainty in the results of the analysis. As noted above it is important to understand that uncertainty is not the same as risk because the unforeseen results may be neutral or beneficial. Therefore uncertainty does not lead to harm (Raybold, 2012). The uncertainty estimates in the WRA are not due to any calculation errors or limitations in the underlying model, but rather stem from the availability and robustness of the relevant biological and ecological data to run the model.

The following executive order requires the protection of migratory bird populations:

- **EO 13186 (US-NARA, 2013), "Responsibilities of Federal Agencies to Protect Migratory Birds,"** states that Federal agencies taking actions with a measurable impacts on migratory bird populations need to develop and implement a Memorandum of Understanding with the USFWS that promotes the conservation of migratory bird populations. On August 2, 2012, a Memorandum of Understanding between APHIS and the USFWS was signed to facilitate the implementation of this Executive Order. The Memorandum of Understanding provides APHIS with guidance to avoid and minimize, to the extent practicable, detrimental migratory bird habitat alteration or unintentional take during management activities.

As described in the Preferred Alternative analysis of plantation-pine associated wildlife (Section 4.6.6), a few migratory birds, primarily nectar-feeding birds, may benefit from the addition of FTE to the landscape while others, including insect-feeding birds, will have similar opportunities in both FTE and pine plantations. Still some migratory birds may be impacted by the reduction in understory and increased disturbance from relatively short FTE rotation times. Increased use of herbicides to control grasses and herbaceous weeds will limit the vegetative community with a corresponding decrease in migratory bird abundance and diversity. Birds such as red-winged blackbirds, grosbeaks, and orioles that rely on understory vegetation (Dickson et al., 1993a; Dickson et al., 1995) may experience the most significant impacts from the reduced available habitat for breeding, sheltering, and feeding.

To assist Federal agencies with their environmental impact analyses when proposing an action, the U.S. Fish and Wildlife Service identified stressors[70] that can impact the migratory bird community. An impact occurs when there is an increase in light, human presence, chemical release, invasive species (Section 8.2), noise, ground structures, and aerial structures. An impact occurs when there is a decrease in vegetation quantity (complete loss) or vegetation quality (altered structure). Stressor management is a proactive approach that provides solutions to the problem before it occurs rather than managing the impacts of an action. These stressors, with the exception of aerial structures, are already present in the pine plantation migratory bird community. These stressors are likely to occur more frequently in the Preferred Alternative due to the shorter rotation time for FTE compared to plantation pine.

The use of machinery is common in production forestry, so the level of noise will remain the same between pine plantations and FTE plantations. It is expected, however, that this noise, and the associated human presence, vegetation removal, and temporary addition of equipment to the landscape, would occur more frequently in FTE plantations because of FTE's short rotation period (six to ten years) compared to pine (twenty to twenty-five years).

The impacts of using herbicides (chemical release stressor) could be greater in FTE plantations compared to pine plantations because they require different vegetation manipulation schemes than pine plantations. FTE seedlings, like other *Eucalyptus* seedlings, are more sensitive to vegetative competition than pine seedlings. In the early stage of rotation, FTE plantations will likely have reduced herbaceous cover compared to planted pine plantations due to multiple applications of herbicides to control vegetation. The short rotation period for FTE will result in additional vegetation control relative to plantation pine, since the canopy will reopen after harvest, encouraging the growth of understory plants until FTE trees sprout and attain canopy closure again.

In general, comprehensive forestry management includes best management practices to limit disturbance from these stressors (NRCS, 2002). APHIS will encourage FTE growers to consider the migratory birds that frequent their area and develop a management plan that is beneficial to migratory birds before impacts from an action take place. In some areas, forestry managers may create edge habitat that will produce quality habitat for edge-generalist species. Some growers may choose to plant bordering vegetation or buffers to help maintain biodiversity too (NRCS, 2002). To reduce the impact of stressors on migratory birds, conservation measures should be integrated into the forestry management scheme, and best management practices should be followed. Landowner compliance with best management practices is high (NRCS, 2002), however, it is important to note that the use of best management practices and conservation measures are strictly voluntary.

8.3 Executive Orders with International Implications

The following executive orders require consideration of the international implications of Federal actions.

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[70] A stressor is any alteration of or addition to the environment that affects birds and/or their resources

- **EO 12114 (US-NARA, 2013), "Environmental Impacts Abroad of Major Federal Actions"** requires federal officials to take into consideration any potential environmental impacts outside the United States, U.S. territories, and other U.S. possessions that result from actions being taken.

APHIS has given this EO careful consideration and does not expect any major environmental impacts outside the United States in the event of a determination of non-regulated status of FTE. All existing national and international regulatory authorities and phytosanitary regimes that currently apply to introductions of new plant cultivars internationally apply equally to those covered by an APHIS determination of non-regulated status under 7 CFR part 340.

Any international trade of FTE subsequent to a determination of non-regulated status of the product would be fully subject to national phytosanitary requirements in accordance with phytosanitary standards developed under the International Plant Protection Convention (IPPC) (International-Plant-Protection-Convention, 2011). The purpose of the IPPC "is to secure a common and effective action to prevent the spread and introduction of pests of plants and plant products and to promote appropriate measures for their control" (International-Plant-Protection-Convention, 2011). The protection it affords extends to natural flora and plant products, and includes both direct and indirect damage by pests, including weeds.

The IPPC establishes a standard for the reciprocal acceptance of phytosanitary certification among the nations that have signed or acceded to the Convention (172 countries as of March 2010). In April 2004, a standard for PRA of living modified organisms (LMOs) was adopted at a meeting of the governing body of the IPPC as a supplement to an existing standard, International Standard for Phytosanitary Measures No. 11 (ISPM-11, Pest Risk Analysis for Quarantine Pests). The standard acknowledges that all LMOs will not present a pest risk and that a determination needs to be made early in the PRA for importation as to whether the LMO poses a potential pest risk resulting from the genetic modification. APHIS pest risk assessment procedures for GE organisms are consistent with the guidance developed under the IPPC. In addition, issues that may relate to commercialization and trans-boundary movement of particular agricultural commodities produced through biotechnology are being addressed in other international forums and through national regulations.

The *Cartagena Protocol on Biosafety* is a treaty under the United Nations Convention on Biological Diversity (CBD) that established a framework for the safe trans-boundary movement, with respect to the environment and biodiversity, of LMOs, which include those modified through biotechnology. The Protocol came into force on September 11, 2003, and 160 countries are Parties to it as of December 2010 (CBD, 2012). Although the United States is not a party to the CBD, and thus not a party to the Cartagena Protocol on Biosafety, U.S. exporters will still need to comply with those regulations that importing countries which are Parties to the Protocol have promulgated to comply with their obligations. The first intentional trans-boundary movement of LMOs intended for environmental release (field trials or commercial planting) will require consent from the importing country under an advanced informed agreement (AIA) provision, which includes a requirement for a risk assessment consistent with Annex III of the Protocol and the required documentation.

LMOs imported for food, feed, or processing (FFP) are exempt from the AIA procedure and are covered under Article 11 and Annex II of the Protocol. Under Article 11, Parties must post decisions to the Biosafety Clearinghouse database on domestic use of LMOs for FFP that may be subject to trans-boundary movement. To facilitate compliance with obligations to this protocol, the U.S. Government has developed a website that provides the status of all regulatory reviews completed for different uses of bioengineered products (NBII, 2010). These data will be available to the Biosafety Clearinghouse.

APHIS continues to work toward harmonization of biosafety and biotechnology consensus documents, guidelines, and regulations, including within the North American Plant Protection Organization (NAPPO), which includes Mexico, Canada, and the United States, and within the Organization for Economic Cooperation and Development (OECD). NAPPO has completed three modules of the Regional Standard for Phytosanitary Measures (RSPM) No. 14: *Importation and Release into the Environment of Transgenic Plants in NAPPO Member Countries* (NAPPO, 2003).

APHIS also participates in the *North American Biotechnology Initiative (NABI)*, a forum for information exchange and cooperation on agricultural biotechnology issues for the United States, Mexico, and Canada. In addition, bilateral discussions on biotechnology regulatory issues are held regularly with other countries including Argentina, Brazil, Japan, China, and Korea.

8.4 Compliance with the Clean Water Act and Clean Air Act

This EIS evaluated the potential changes in plantation tree production (planted pine or FTE) if the petition for a determination of non-regulated status to FTE is approved, and determined that the potential impact on water and air quality under the Preferred Alternative is similar to the impact on water and air quality under the No Action Alternative (Section 4.6.4 and Section 4.6.2). The similar impacts on water quality and air quality between the two alternatives are primarily due to common and well-adopted forestry best management practices, and the relative magnitude of them, when compared to other more substantial impacts on water and air quality within the action area from other sources (e.g., agriculture and urbanization) (Section 4.6.4 and Section 4.6.2).

Based on these analyses, APHIS concludes that an extension of a determination of non-regulated status to FTE would comply with the Clean Water Act and the Clean Air Act.

8.5 Impacts on Unique Characteristics of Geographic Areas

Approving the petition for a determination of non-regulated status to FTE is not expected to impact unique characteristics of geographic areas such as parklands, prime farmlands, wetlands, wild and scenic areas, or ecologically critical areas. This is because FTE is likely to be cultivated on land already under silvicultural management (i.e., land previously planted to planted pine) and is not anticipated to expand the cultivation of FTE to new, natural areas.

Under the Preferred Alternative, FTE is not likely to cause any major ground disturbances, new physical destruction or damage to property, or any alterations of property, wildlife habitat, or landscapes outside of the action area. Likewise, no prescribed sale, lease, or transfer of ownership of any property is expected as a direct result of a determination of non-regulated status for FTE. This action would not convert land use to non-silvicultural uses. Standard silvicultural practices for land preparation, planting, maintenance, and harvesting of trees would be used on silvicultural lands planted to FTE

Based on these findings, including the assumption that pesticide label use restrictions are in place to protect unique geographic areas and that those label use restrictions are adhered to, approving the petition for a determination of non-regulated status to FTE is not expected to impact unique characteristics of geographic areas such as park lands, prime farm lands, wetlands, wild and scenic areas, or ecologically critical areas any more than production forestry already does.

8.6 National Historic Preservation Act (NHPA) of 1966 as Amended

The NHPA of 1966 and its implementing regulations (36 CFR 800) require Federal agencies to: 1) determine whether activities they propose constitute "undertakings" that have the potential to cause impacts on historic properties; 2) if so, to evaluate the impacts of such undertakings on such historic resources and consult with the Advisory Council on Historic Preservation (i.e., State Historic Preservation Office, Tribal Historic Preservation Officers), as appropriate.

The APHIS proposed action, a determination of non-regulated status of FTE, is not expected to adversely impact cultural resources on tribal properties. Any silvicultural activity by growers on tribal lands would only be conducted at the tribe's request. Thus, the tribes would have control over any potential conflict with cultural resources on tribal properties. APHIS sent letters to tribal entities when this petition was declared complete and made available to the public. There were no comments received from any tribal entities.

The APHIS Preferred Alternative would neither impact districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places, nor would it likely cause any loss or destruction of important scientific, cultural, or historical resources. This action is limited to a determination of non-regulated status of FTE.

The APHIS proposed action is not an undertaking that may directly or indirectly cause alteration in the character or use of historic properties protected under the NHPA. In general, common silvicultural activities conducted under this action do not have the potential to introduce visual, atmospheric, or noise elements to areas in which they are used that could result in impacts on the character or use of historic properties. For example, there is potential for increased noise on the use and enjoyment of a historic property during the operation of mechanical equipment on silvicultural sites. A built-in mitigating factor for this issue is that virtually all of the methods involved would only have temporary impacts on the audible nature of a site and can be ended at any time to restore the audible qualities of such sites to their original condition with no further impacts. These cultivation practices are already being conducted throughout the action area. The cultivation of FTE is not expected to change any of these silvicultural practices that would result in an impact under the NHPA.

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In addition to the contacts in the above distribution list, APHIS notified all of its stakeholders of the availability of this EIS.

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12 INDEX

ArborGen, Inc. Petition (11-019-01p) for Determination of Non-regulated Status for Freeze Tolerant Eucalyptus Lines FTE 427 and FTE 435

Draft Environmental Impact Statement, April, 2017

Appendix A: Summary of Comments Received on the Notice of Intent and During the Two Public Virtual Meetings

Summary of Comments Received on the Notice of Intent and During the Two Public Virtual Meetings

On February 22, 2013, APHIS published a notice in the Federal Register (78 FR pages 13309-13312, Docket no. APHIS-2012-0030) announcing the availability of the ArborGen petition for a 60-day public review and comment period. In this notice, APHIS announced its intention to prepare an environmental impact statement (EIS) on the action with regard to the petition for non-regulated status. Comments were required to be received on or before April 29, 2013. APHIS convened two public meetings to collect public input for this EIS. These two public meetings were convened on-line, as web-based virtual meetings. The first meeting was convened on April 17, 2013, at 7:00pm EDT, and the second public meeting was convened on April 18, 2013, at 4:00pm, EDT. Both public meetings provided an open forum for the general public to submit verbal comments on the project. All comments were carefully analyzed to identify potential environmental and interrelated economic issues and impacts that APHIS may determine should be considered in the evaluation of the petition. A total of 6,546 comments were received during the comment period[71]. Three of the comments were petitions containing a total of 30,764 signatures. The issues that were raised in the public comments which were related to the ArborGen FTE lines 427 and 435 petition included:

ISSUE 1:

A number of commenters identified similar issues related to potential increase in fire frequency and intensity from FTE plantations. Concerns were raised that the introduction of a new fuel source would change the regime of frequency and severity of fire in the southeast. Many noted that eucalyptus species are known to be highly flammable trees. Concern was raised that the highly flammable nature of the leaves may threaten surrounding forests and communities with extreme wildfires. Commenters noted incidents of fire involving eucalyptus in California and Australia, "wildfires in Oakland California in 1991 and in Australia in 2009 both fueled by eucalyptus trees-killed scores of people and caused billions in losses." It was suggested that extensive modeling be conducted to quantify the uncertainty surrounding the potential for increased fire risks.

ISSUE 2:

A number of commenters raised concerns of the effects FTE would have on water quality. Multiple commenters noted that eucalyptus leaves contain oils that are highly toxic and that their decomposition in rivers and groundwater will impact aquatic and other organisms in the surrounding communities. One commenter noted "it has been found that rain run-off from a GE eucalyptus plantation in Tasmania has poisoned the waters of the George River, causing harm to the eco-system, and decimating oyster farms in the ocean at the river's end."

ISSUE 3:

One commenter noted that other species of eucalyptus are already cold tolerant and so GE is not necessary. There are already existing cold/ snow tolerant Eucalyptus species available. These species include E. pauciflora, E. stellulata, E. viminalis, E. dalrympleana, E. amygdalina, E. gunnii, and E. ovata – and there are many more. These species naturally occur in alpine regions of Australia and in Tasmania.

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[71] Comment documents may be viewed at http://www.regulations.gov/#!docketDetail;D=APHIS-2012-0030

Genetic manipulation of Eucalyptus species has not been necessary. Another commenter noted that there are native trees that could just as easily fill the niche for which FTE was developed.

ISSUE 4:

Several commenters stated that approval of FTE could result in gene flow or pollen contamination that will transmit the FTE transgene to naturalized species of eucalyptus noting that pollen is minute and can be carried inter-continentally by birds, insects, people, and even wind.

ISSUE 5:

Several commenters raised several concerns about the impacts of FTE on native species, including impacts from land conversion to FTE plantations, displacement of native species, impacts to biodiversity, and impacts on TES.

Several commenters raised the issue of decreased biodiversity within FTE plantations. Noting that "plantations of eucalyptus have been described as "green deserts" because of their total lack of biological diversity." Several commenters also noted that conversion of land from other land uses to FTE plantations would decrease "habitat amount and quality for native plants and animals throughout the prospective planting area– including threatened and endangered species –compared to natural forests or plantations of native trees, wetlands, conservation reserve lands, and other uses." Concerns were also raised that as demand for FTE increases more land will be converted to plantations.

Other issues were raised concerning the impacts related to the management of FTE plantations, specifically the use of pesticides for understory management. Both because wildlife require food and shelter provided by diverse undergrowth and because pesticides can directly and indirectly harm plants and animals.

Several issues were raised on the impacts of eucalyptus trees on native wildlife. These include the polyphenols released from the decomposition of eucalyptus leaves and concerns for native bird species from toxins and gums produced by eucalyptus trees. It was also noted that animal species will be unable to find suitable food, nest sites, germination sites and other habitat features within eucalyptus plantations.

ISSUE 6:

Several commenters raised issues concerning the increased water use and impacts on stream flow, groundwater, and on hydrology from FTE. Several commenters raised the issue that eucalyptus plantations use more water than native forests and noted this concern in light of current drought conditions in much of the South. One commenter citing that "the U.S. Forest Service has stated that large-scale plantings of eucalyptus lower water tables, and affect groundwater recharge and local stream flows, in some cases eliminating seasonal streams." Many commenters were also concerned that climate change could exacerbate these problems.

ISSUE 7:

Several commenter raised issues related to the pests and diseases of eucalyptus and whether those pests or diseases could infect native or crop species. Concerns were raised that native members of the Myrtaceae family may be susceptible to diseases that FTE plantations could harbor. Commenters cited examples of disease infection passing from eucalyptus to Myrtaceae members in Uruguay.

ISSUE 8:

Several commenters raised concerns related to the potential invasiveness of FTE including that eucalyptus is a genus that contains many invasive species; both parent species of the FTE have been reported as invasive within similar climatic zones such as South Africa, New Zealand and Ecuador. Many commenters also note that eucalyptus has become so established in California that it is now listed as an invasive species. Concerns were raised that cold tolerant varieties grow in a wider range of areas than non-cold tolerant varieties and that this may increase the likelihood of establishment and spread of non-native species and contribute to their invasiveness. Another concern raised was that trees are long living and can live for decades to centuries in the wild, unsupported by human intervention. Their escape into the wild can be extremely difficult to eradicate.

Another issue raised with invasiveness is that propagule pressure is directly related to the size of the planting. Concerns have been raised that if given non-regulated status this crop will be planted in much larger acreages. This change in scale could significantly alter propagule pressure and could increase the potential that either or both translines might become invasive, expand the area at risk to such invasions, and expose new locations to the risk of such invasions.

ISSUE 9:

Issues related to the contamination of soil and changes to soil characteristics caused by FTE were raised by several commenters. Root exudates, decaying roots, leaf and bark litter, and other plant parts from FTE 427 and 435 will be different from those of other plants in the planting area, and may change soil dynamics in ways that impact subsequent land uses. Concerns were raised about alteration of soil characteristics (microbial communities, nutritional characteristics, secondary compound profiles) from allelopathy. Another concern raised was due to the nature of eucalyptus to draw extreme amounts of water and nutrients out of surrounding soil. Commenters noted that research conducted on the effects of Eucalyptus timber stands on soil properties and adjacent maize crops shows that Eucalyptus decreased soil nutrients and maize yields within 20 meters of the trees in Ethiopia.

ISSUE 10:

Several commenters raised concerns about the effects of agrochemical use on human health, groundwater, and soil noting that the use of GE trees, especially in industrial plantations, is likely to increase the application of dangerous chemical fertilizers, herbicides and pesticides.

ISSUE 11:

Several issues related to climate change were raised, including the effects of climate change on FTE plantations and the effects of FTE on climate change. Several commenters noted that climate change could cause or exacerbate plant pest risks and environmental impacts associated with FTE and that climate change will extend the predicted range of Eucalyptus within North America. Several commenters noted that forests play an important role in mitigating and impacting climate change and that FTE will worsen climate change through the destruction of carbon rich native forests for carbon poor plantations, noting that one study found that timber plantations contain about one-quarter the carbon of a native forest.

ISSUE 12:

One commenter raised concerns related to the stability of the inserted genes and possible pleiotropic effects stating "Trees activate and de-activate genes at different stages of their lives. An introduced gene may have minimal pleiotropic effects under "normal" field conditions. However, once climatic factors, insect pests, shifts in nutrient availability, and other stressors occur, the genetically active profile in various cells of the plant shifts. When these shifts occur, it is possible that the introduced genetic material interacts with the new active genes in ways that were not predictable before those genes became active."

ISSUE 13:

Several commenters raised concerns that FTE is a potential host for the fungal pathogen *Crytococcus gattii*. They noted that the fatal fungal pathogen, *C. gattii* has been found in the U.S., and can cause fatal fungal meningitis among people and animals that inhale its spores. They also note that although APHIS has looked at the relationship between *C. gattii* and eucalyptus in previous risk assessments the issue needs to be addressed again, given the scale-up and increase in planting range that approval of non-regulated status would trigger.

ISSUE 14:

The Nature Conservancy raised the issue that APHIS should consider use of BMP as an alternative in our analysis noting that "Best Management Practices (e.g., sufficient separation of cultivated stands from other eucalypts to preclude pollination of the GM lines), or monitoring of potential invasiveness or alterations to local hydrology would alleviate many of the potential issues associated with this specific case, and likely future proposals for deregulation of GM trees."

ISSUE 15:

Several commenters were concerned that approval of the petition would set a precedent for other GE tree approvals stating that "it would set a dangerous precedent that could enable the approval of GE poplar, pine, and other native species native to this continent. And the release of these genetically engineered versions of native species would lead to the inevitable and irreversible genetic contamination of native forests throughout the continent."

ISSUE 16:

The Center for Food Safety noted that APHIS should consider future scenarios that include non-GE freeze-tolerant eucalyptus and other lines or species of GE freeze-tolerant eucalyptus that may be expected to someday overlap the range of FTE 427 and 435, particularly when looking at cumulative and other impacts.

ISSUE 17:

Several commenters noted that ArborGen is likely under-estimating the potential range increase. Noting that "ArborGen does not include suitable regions of the Pacific Northwest." They also note that only biological-based constraints and not market-based constraints should be used because market based constraints are subject to rapid change. In addition, climate change will extend the predicted range of Eucalyptus within North America and the corresponding area where the FTE could grow.

ISSUE 18:

One comment raised concerns about the impacts of FTE on pollinators. Noting that, "honeybees may be attracted to the nectar-producing flowers but because of lack of pollen in male-sterile FTE 427 and 435, and absence of other flowering plants from undergrowth suppression, the bees may not be able to get adequate nutrition within the landscape."

ISSUE 19:

Several commenters stated that because 12 dockets for petitions were posted on the same day, that the public was not afforded enough time to review the documents.

ISSUE 20:

One commenter noted that plantings of FTE may lead to land use conflicts with wood for other purposes such as wood for building, veneer, and other products.

ISSUE 21:

One commenter raised the concern of adverse health effect associated with biofuel production. Citing that "throughout the Southeast and in the Pacific Northwest, citizens are objecting to the building of biomass energy and biofuels facilities; one of their main concerns is an increase in air and water pollution, with health impacts."

ISSUE 22:

One commenter noted that APHIS must critically analyze information from a variety of sources. Whenever possible, APHIS should consult high-quality independent peer-reviewed research, up-to-date reports in the press and extension bulletins, government studies, and other sources of relevant information. APHIS must not rely on the "Environmental Report" embedded in the Petition that was commissioned by ArborGen and is strongly biased towards finding no significant impacts. APHIS must also consult with all other federal and state agencies with relevant expertise in these issues and regarding potential impacts, such as the Fish and Wildlife Service. Another commenter noted that APHIS should consult with DOI and National Invasive Species Council to further expand the already established APHIS weed-initiated pest risk assessment.

ISSUE 23:

One commenter supports the use of bioconfinement by inclusion of a male sterility gene to reduce the risk of spread.

ISSUE 24:

Several commenters noted that FTE would fill the increased demand for wood, fiber and pulp while using land more efficiently. They also note that it offers a promising alternative to foresters and landowners interested in a fast-growing hardwood for certain areas of the South and can be a positive contribution to rural development. Commenters also note that "highly productive trees, such as the FTE hybrid can produce more wood on a smaller footprint, lessening the need to harvest from native stands of trees."

Jennifer Wood: Good evening, I'm Jennifer Wood, your technical support for this broadcast. Welcome to the first of two virtual public meetings sponsored by the U.S. Department of Agriculture Animal and Plant Health Inspection Service.

First, I would like to go over a few housekeeping items. This virtual meeting uses audio broadcast technology. As an attendee, you will be able to hear the panelists and presenters but we are not able to hear you. If you are registered to speak today, you have received separate instructions on how to connect to the meeting so that you will be heard when it is your turn to provide your public comment. You should see a welcome sign on the left side of your screen. On the right side, you will see the panelists via webcam, the names of the panelists who will be conducting the meeting, and your name. You will not see the names of other attendees. There are several blue bars, called panels, all on the right side of the screen – participants, chat, and media viewer. You can open and close these panels by using the small half arrows next to the panel title. If you experience technical difficulties joining the WebEx session, please contact WebEx technical support at 1-866-229-3239. This number will also appear on all slides used in this meeting.

If you are registered to speak on today's call, please be sure you are dialed in via a phone line. You will see a phone icon next to your name in the participant panel. If you do not see a phone icon, please disconnect with your phone line only, and redial in. Please make sure to enter your attendee ID slowly. You must have a phone next to your name in order to provide a public comment.

If you are having difficulty during this meeting, such as with your panels, please use the chart panel located in the center of your panel to send me a communication. You can also use the green toolbar at the edge of your screen if viewing in full screen mode. Please type your question in the text field and hit "send." Please keep the send to default as all panelists. I will respond as promptly as possible. I may also contact you via the chat panel if you're speaking today and I see you are not dialed in currently.

With that, we invited you to sit back, relax, and enjoy today's presentation. Without further delay, I would like to hand the broadcast off to Dick George.

Dick George: Welcome and thank you for joining us. I'm Dick George, Communications Branch Chief of Biotechnology Regulatory Services, or BRS. BRS is part of APHIS, the Animal and Plant Health Inspection Service, an agency of the U.S. Department of Agriculture. Soliciting public comments is a very important part of our process. We value your input and are pleased that you've chosen to be with us today either to make a public comment or to listen to the comments of others. Technicians are standing by to assist anyone having difficulty in accessing this meeting. Please call 1-866-229-3239 for help. This number is at the bottom of each slide.

On the left side of your screen, you should see the slide that's currently displayed for the meeting. On the right side, you should see the projection of me and my colleague, Rebecca Stankiewicz Gabel. You will also notice that there are other panels you can navigate, such as the media viewer. To access closed captioning for this meeting, open the media viewer to the right of your screen.

The purpose of this meeting is to solicit your comments on a notice of intent to do an environmental impact statement – or EIS – for a line of eucalyptus that has been genetically engineered to be tolerant of freezing temperatures. For more information on this eucalyptus, go to www.APHISVirtualMeeting.com. This site contains background information and also links to other documents and websites. In the past, we've traveled around the country to conduct meetings where interested parties can make public comments on our regulatory actions. Today, for the first time, we're holding an online virtual public meeting to allow more people the opportunity to comment.

Joining me is Dr. Rebecca Stankiewicz Gabel, my colleague at BRS. Rebecca is the supervisor of our Biotechnology Environmental Analysis branch.

Dr. Rebecca Stankiewicz Gabel: Before we start taking comments from our online audience, we'd like to go over some of the specifics for the virtual meeting. We will be taking only spoken comments today. If you'd prefer to make a written comment, you can do so by going to Regulations.gov. Enter the word "eucalyptus" in the search box. This will take you to a link for the freeze-tolerant eucalyptus comment site. The public comment period ends on April 29, 2013. You can go to Regulations.gov any time between now and the 29th and leave a written comment, which will become part of the public record. Or you can make a spoken comment here tonight at this meeting, which will go until 9:00 p.m. Eastern. Those of you wishing to speak will be recognized in the order in which you were registered. Today we are here to receive your input, not to answer questions about eucalyptus. For background information, please go to www.APHISVirtualMeeting.com. If you haven't already registered to speak and wish to do so, please click on the raised hand icon. This will indicate that you wish to speak and you will be placed in a queue. You will be provided with instructions on how to proceed via the chat feature.

The statements received during the public comment period, whether spoken today or submitted in writing to Regulations.gov, will be considered in the development of the draft EIS for freeze-tolerant eucalyptus. After we have published the draft EIS, we will solicit and receive comments on it. Those comments will be considered in the development of a final EIS. After the final EIS is published, there will be a decision on the regulatory status of freeze-tolerant eucalyptus.

We welcome your comments today because they will help us to determine what issues to consider as we prepare our draft Environmental Impact Statement.

Dick George: You should see a list of commenters in the order in which they will speak on your screen, so you will know when your turn is approaching. We ask that you keep your comments to three minutes or less. A recording of this meeting will be available within forty-eight hours on our site, www.APHISVirtualMeeting.com, and written transcripts will be available there within a few weeks.

At the conclusion of the virtual meeting, a survey will appear on the screen. Please complete it before you log off. Your feedback is very important to us. If you would like to be seen, as well as heard today, please turn on your webcam when it's your turn to speak and click on the camera icon next to your name on the screen. If you're experiencing technical difficulties, again, the number to call, the WebEx Technical Support team, is 1-866-229-3239. As a reminder, we're here to receive your comments only, not to answer questions on eucalyptus or to discuss or debate biotechnology.

At that, we will hear from our first commenter, who is Nancy Beecham. It may take a moment to unmute her phone so that she can speak so please bear with us just for a second. Okay, Nancy, are you there? No. In that case, we'll move ahead to our second commenter, who is William Bennington. Can we unmute his phone, please?

William Bennington: Hello.

Dick George: Yes, hello, William.

William Bennington: Yes.

Dick George: Yes, please go ahead with your comment.

William Bennington: Alright, I'll try to keep it under two minutes. It would've been good to know about that ahead of time. So my name's Will Bennington. I'm a small-scale farmer in Vermont and I have a background in forest ecology, ecological forest management. And I'm on the call today to bring up two important issues pertaining to ArborGen's petition to deregulate its freeze-tolerant GE eucalyptus.

First, I think it's a problem of widespread non-native invasive plants in this country and across the world is a serious issue that I've dealt with in my work. I think there are far too many cases of unintentional introduction of non-invasive species that has led to widespread invasion, oftentimes resulting in ecosystem level impacts. And a lot of times, these different plants and animals that are introduced are introduced under the assumption that there will be no impact and that they will not become invasive. But the reality of it is the science really can't ever dictate whether or not it's going to happen, especially when we're talking about trees, which have a much longer lifecycle than many other plants and can persist in ecosystems for a very long time.

The only way that APHIS and the USDA can do its job to serve the public and ensure the highest level of protection against highly invasive species like GE eucalyptus and to protect our forest resources is by outright banning their release. And unfortunately, the agency failed to protect the public interest several years ago when they allowed ArborGen to release several field trials of GE eucalyptus in the U.S. South. So I'm here to demand that the USDA correct their past mistakes and stop this pending ecological disaster before it's too late. And absolutely consider to be the utmost importance the fact that there is no way to tell that eucalyptus will not be invasive and that it is more likely than not that genetically engineered eucalyptus will become highly invasive.

I'm also concerned about this issue because GE eucalyptus has been likened to flammable kudzu. It's invasive and it's highly flammable. And planting vast plantations of eucalyptus in the U.S. South, which is a drought-stricken region that's very prone to wildfires, is only going to increase the risk of catastrophic wildfires, which are going to become an increasing problem as we face the impact of global warming over the coming decade.

So basically, we're looking at a highly invasive, non-native plant that is incredibly flammable, like an explosive firecracker in a drought-stricken region. So it's just about the worst combination of factors you could imagine.

And then, one final thing that I want to bring up is this, what many people call a revolving door between ArborGen and biotech giant, Monsanto. ArborGen was initially envisioned in 1999 by Fletcher Challenge Forests, International Paper, Westvaco, and biotech giant, Monsanto. Before beginning the sixty-million-dollar venture that was actually ArborGen, Monsanto backed out. However, several CEOs and other upper level management of ArborGen have come from Monsanto and ArborGen frequently cites itself as the next Monsanto and the Monsanto of the forest industry. And if what Monsanto has done to the agricultural section in the United States and across the world is any example of what ArborGen is planning to do to the forest product industry, that is a serious problem. Monsanto and their products have caused massive ecological degradation, the destruction of local agricultural systems, and the increased use of pesticides and herbicides, the privatization of genetic matter in seeds, mounting economic problems for farmers. And it's abundantly clear that this is the direction ArborGen is intending to go.

So as countries across the world are banning Monsanto's products and banning Monsanto from doing business in the country, I think it's about time that the United States follows suit. And we have a real opportunity to do that with ArborGen by saying no to their GE products today so that they cannot pursue the kind of model of economic domination and ecological destruction that Monsanto has pursued throughout the world.

And I'm sure I've gone well over three minutes, so I'll just wrap up by saying that I demand the USDA and APHIS deny ArborGen's petition to deregulate cold-tolerant genetically engineered eucalyptus, and I hope that you will consider all the concerns I brought up while preparing the environmental impact statement. Thank you.

Dick George: Thank you so much for your comment. Our next speaker is Orin Langelle. Please forgive me if I have butchered your name. Please go ahead.

Orin Langelle: Yes, hello, can you hear me?

Dick George: Yes, thank you.

Orin Langelle: Okay, yeah, you didn't butcher me. Actually, you said it in the correct way. The international pronunciation is Lon-gell. Anyway, I've worked on the study of genetically engineered trees, and written on them, since 1999. And I'm going to start out with a harsh paragraph here. "If ArborGen is allowed to sell genetically-engineered eucalyptus in the Southeastern United States, it will be potentially a criminal action that should lead to the prosecution and incarceration of ArborGen's board of directors and its parents companies of IP, – that's International Paper – MeadWestvaco, and Rubicon, Ltd. They are knowingly allowing health risks to the human and non-human inhabitants of the region, furthering global warming and decreasing the ecological sustainability of that region.

The USDA should pay attention to that scenario, in case they are not listening to all the arguments against genetically engineered trees. Traditionally, eucalyptus trees are extremely flammable and invasive. They require extreme amounts of water to grow. The U.S. South is suffering from a major drought. As Mr. Bennington stated, if they're allowed, they'll become the flammable kudzu of the South."

And now, we're going to get into some stuff by the United States Environmental Protection Agency, who stated that, "The average annual temperatures in the region are projected to increase by four to nine degrees by 2080.

Higher temperatures, longer periods between rainfall events, and greater demand for water will likely strain water resources in the Southeast. Incidents of extreme weather, increased temperatures, and flooding will likely impact human health. Higher temperatures will likely affect the growth and productivity of crops and forests in the region.

The EPA continues on the impact on water resources, stating, "Water resources scarcity can affect many sectors of the Southeast economy, as well as the region's natural ecosystems. Periodic droughts, overconsumption of water resources, and other factors can create water shortages. Managing water resources will likely become more challenging with projected climate changes and anticipated population and economic growth; higher temperatures increase in that duration and water loss from plants. Projected increases in temperature will likely increase the frequency, duration, and intensity of droughts in the area. Projected changes in the surface water runoff to the coast and groundwater recharge will likely allow saltwater to intrude and mix with shallow aquifers in sub-coastal areas in the Southeast, particularly in Florida and Louisiana. If the region increases groundwater pumping to offset water shortfalls, then aquifers will be further depleted. In the long term, the depletion of groundwater supply would place additional strain on surface water resources. Growth and demand will also likely strain water resources.

The Southeast region is attracting a great deal of people, investment, and industry. The population of Florida has more than doubled during the past thirty years. Growth rates in most other Southeastern states are forty-five to seventy-five percent over the same period. Decreased water availability will challenge future growth and the quality of lives of residents in the region."

Now, from another radical organization here, the National Wildlife Federation, whose report will, I'm going to quote the global warming and drought stage that… "The Southeast drought, as historic records show, that regular droughts are more typical through the Southeast. Global warming suggests that more is yet to come. Continued climate changes will potentially cause both more extremely dry periods and more heavy rainfall events. And sea level rise could contaminate critical underground freshwater reserves. The Southeast should take the following actions to plan for increasing variability in water supply, improved water use, efficiency, and conservation. Take global warming into account when choosing water management strategies to meet multiple demand. Maintain and restore a natural forest and wetland systems that store floodwaters and provide efficient water storage…"

Dick George: I have to ask you to please complete your thought and wrap it up, please.

Orin Langelle: Okay, I will. "…a rapidly expanding population, irrigation, and power generation have increased water demand. In the states in the National Wildlife Federation for some of the states slated for GE trees, it would be increased water (inaudible) from 1950 to (inaudible). Florida, one hundred and ninety-six percent. Alabama, a hundred and ninety-six percent. Mississippi, two hundred and twenty-three percent. Florida, two hundred and fifty-nine percent. And ArborGen's home base, South Carolina, a whopping nine hundred and forty-seven percent. And I have not even gotten into Florida's water aquifer, which is polluted and it probably will be, it's going to be a major health and economic hazard for the entire Southeastern region, especially the citizens of Florida. Thank you.

Dr. Rebecca Stankiewicz Gabel: Thank you for your comments. The next caller on the phone is Anne Peterman.

Anne Peterman: Hello, can you hear me?

Dick George: Yes, we can.

Dr. Rebecca Stankiewicz Gabel: Yes, we can.

Dick George: Please go ahead.

Anne Peterman: Okay, great. I guess I jumped the queue. I just wanted to add onto what has been reported already, that another concern that I have regarding genetically engineered eucalyptus trees – and I am, incidentally, the International Coordinator of the Stop Genetically Engineered Trees Campaign and have been working on this issue since 1999. I have spoken at United Nations meetings, including the Convention of Biological Diversity, the UN Forum on Forests, and the UN Climate Convention all over the world. One of the things that I'm additionally concerned about with regard to genetically engineered eucalyptus approval is that it would set a dangerous precedent that could enable the approval of GE poplar pine and other native species native to this continent. And the release of these genetically engineered versions of native species would lead to the inevitable and irreversible genetic contamination of native forests throughout the continent. It was for this reason, and many others, that we have been campaigning to stop the release of genetically engineered trees.

In 2008, we traveled to Bonn, Germany for the Conference of the Parties of the US Convention on Biological Diversity where we had the unanimous agreement of all of the NGOs that were there, all of the indigenous people's organizations that were there, the entire African delegation, and many countries in Latin America who agreed that the release of genetically engineered trees should be totally suspended. And they weren't just talking about commercial release, they were talking about test plots, as well. In fact, the decision that the entire conference made was that the conference of the parties recognizing the uncertainties related to potential environmental and socioeconomic impact, including long-term and transplantation-boundary impacts of genetically engineered trees on global forests, biological diversity, as well as all the livelihoods of indigenous and local communities and given the absence of reliable data and the capacity of some countries to undertake risk assessments and to evaluate those potential impacts, recommends parties to take a precautionary approach when addressing the issue of genetically modified trees.

The reason why this is so important is because these freeze-tolerant eucalyptus are not just being grown for release in the United States but they would be released all over the world. And eucalyptus plantations are already a disaster in countries like Brazil and Chile and South Africa, and many other places where they're being grown. And if they are developed to be freeze-tolerant, they will be able to spread further north, further south, higher in elevation, and spread the disaster of eucalyptus plantations to new locations that are yet untouched by them.

So this is not just about the United States. This is about what these trees could do all over the world where they would be released, endangering communities, endangering forest ecosystems, biodiversity, and so on.

So I wanted to just point out the international implications of this decision and how the US Convention on Biological Diversity recommends a precautionary approach, which means proving they're safe before they're released which clearly cannot happen with a tree as invasive and dangerous as eucalyptus. So that's good for me.

Dr. Rebecca Stankiewicz Gabel: Thank you very much for your comments.

Dick George: Our next commenter is Lillian Kui. Excuse me I've mispronounced your name. Are you there?

Lillian Kui: Hi, hello?

Dick George: Yes, hi. Please go ahead.

Lillian Kui: Okay, it's Lillian Kui, but no problem. It's not something you come across every day.

Basically, like the previous speakers before me, I'm just not even sure why genetically engineered trees are even being considered to be planted amongst natural trees, natural ecology. I mean, if USDA wants to find a cold-hardy plant, there are plenty of other natural trees that are not genetically modified or genetically engineered. We do not know the potential harm that these genetically engineered trees will potentially wreak havoc on the ecosystem of not just the United States, but around the world, like previous speakers just spoke of.

There are so many things we do not know of that can endanger hundreds of different kinds of species, wildlife, not excluding us ourselves. You know, in ecology, everything is connected. If you introduce an invasive species, everything else is going to be affected. It won't be just insects or birds or any other species that we might not think will affect us because we live in cities or whatever the idea may be. You know, genetically engineering anything should not be considered something that… I can't even get the words. Because it's so absurd for me to even consider something like this. I just want the USDA to really, really consider not approving this at all. I think it will have very, very, very dangerous effects – very, very, probably irreparable ramification if this species is released. Please consider the dangers that you are potentially putting everyone in – not just in these small forests or whatever states. It's going to affect everyone. Please, please reconsider. Thank you.

Dr. Rebecca Stankiewicz Gabel: Thank you for your comment.

Dick George: Thank you, Lillian. I'm looking for the next commenter and it doesn't look like we have another commenter ready to speak at the moment. If Nancy Beecham is there or ready, we can hear from her, and we have a couple others. So what we'll do is we'll take a pause. I will remind folks that if you're listening in on this call and you've changed your mind and would like to make a comment, you could still do so. Click on the raised-hand icon and you will receive instructions via the chat feature of what you need to do to call in and to make a comment. We welcome your comments and hope that if you do have something to say that you would call.

So until we have another person who's lined up and ready to make a comment, we're just going to take a pause. We do intend to stay here until 9:00, as advertised, so if people come onto the call late or if they're on the call and they change their mind and would like to make a comment, we're here to receive that comment. So until we have another person lined up and ready to make a comment – we're getting some notes here from our producer that there's nobody set at the moment to do so – we're going to take a pause until someone does. And again, if anybody who's listening in cares to make a comment, please use the raised-hand icon if you haven't signed up to make a comment already, and we'll be happy to receive your comment. Thanks.

Dr. Rebecca Stankiewicz Gabel: Thank you.

[Pause]

Dr. Rebecca Stankiewicz Gabel: Mr. Bennington, are you on the line?

William Bennington: I believe so.

Dr. Rebecca Stankiewicz Gabel: Okay, we can hear you.

Dick George: Please go ahead.

William Bennington: Great. Thank you so much for doing a second chance. I didn't want to leave you both hanging there for another hour and fifteen minutes. Thank you.

So I just wanted to make a couple more quick comments. First, I just want to talk about the importance that forests play in mitigating and impacting climate change and particularly, the importance that the role of native biodiverse – by biodiverse, I mean species-diverse and age class numbers for it – so not monoculture plantations, though, they're, in fact, not forest and do not serve the same function that forests do. And I'm sure you're aware, worldwide forests sequester anywhere between eleven and twelve, or more conservative, up to twenty percent of carbon is released in the atmosphere. So they're incredibly important to the global carbon cycle. And rates of deforestation that has been happening worldwide are causing serious problems with the amounts of release of C02. And one driver of this deforestation is, in fact, the increased use of forest monocultures; in particular, species like pine and eucalyptus in South America and increasingly so. If ArborGen's request to deregulate GE eucalyptus is granted, we'll start seeing that happen more in the South. And as several speakers commented on earlier, eucalyptus is incredibly flammable so that risk of forest loss is even greater.

And then, another point I wanted to make is that you both, and the USDA and APHIS, have a real opportunity here to do the right thing and to make a quite historic decision that can impact the future, all future generations on this planet. You can say no to this. The science is out there. The social, the public opposition is out there. You can say no to this and it will be okay, and it will be the right choice. And it's not very frequently that you have such an amazing opportunity to make such an important decision. And as Ms. Peterman pointed out before, this decision is going to have implications far beyond the borders of the seven states in the U.S. South. It's far beyond borders of the United States. This decision is going to have implications worldwide, and so I just hope that in making their decision to hopefully not allow the deregulation of commercial sale of genetically engineered eucalyptus that you'll consider that. And consider that this is a decision that is going to potentially negatively impact generations to come well into the future, and I certainly wouldn't want to have that on the weight of my shoulders. But I would love to be on the right side of history, and I really encourage the USDA and APHIS to stand on the right side of history and stand up to the interest that ArborGen is presenting in trying to release genetically engineered eucalyptus across the U.S. South. Thank you very much.

Dr. Rebecca Stankiewicz Gabel: Thank you for your comment. Is there anyone else that wants to make an additional comment? If anyone does, they should raise their hand. Or if any of the people that are on that haven't made a comment wish to make a comment, if you could please raise your hand, we can get you the instruction for how to call in.

Dick George: Since there are none in queue at the moment, we'll take another pause. And if there are others who change their mind or people who have spoken already and they'd like to say a little more, we certainly have time for that. So we're going to take a pause and we'll keep an eye… We're getting prompted by the producer when people become available and ready to speak, and so we'll accept those comments when and if they come. In the meantime, we'll take another pause. Thank you very much.

Dr. Rebecca Stankiewicz Gabel: Thank you.

Dick George: Well, we see that we have Orin Langelle, who already spoke and would like to say a little more. So we will get his phone unmuted and as soon as we do, we'll be happy to take more comments.

Orin Langelle: Hello?

Dick George: Yes, hello. Orin, go ahead.

Orin Langelle: Okay, thank you. Thank you for letting me finish up. I know I went a little bit longer. I want to echo what the first gentleman was just talking about, to do the right thing. And remind everybody that in a lot of indigenous cultures that people plan seven generations ahead of time. It's not just for the present, it's not just for money. It's about not just our children, our grandchildren, about their grandchildren. It's further down the line.

I was actually starting to talk about the Florida aquifer system. It's one of the most productive aquifers in the world. It underlies an area of about a hundred thousand square miles and it provides water for several large cities including Savannah and Brunswick in Georgia and Jacksonville, Tallahassee, Orlando, and St. Petersburg in Florida. It's a *(inaudible)* system and it underlies the states that I just mentioned. And one of the things about it, it's a very kind of a shallow aquifer so water gets into it very easily compared to the Ogallala Aquifer, which is really a large aquifer, elsewhere. And that means if it rains a lot or whatever, you'll get a lot of water going into the aquifer.

While it may seem good because it is shallow, you don't get the same kind of filtration you do when you have a deeper aquifer. So what's going to happen – and what's already happening – is toxic waste and runoff is already getting into Florida, and it's polluting things down… as things go further south. And there have been major studies done upon this. And I have a really bad feeling that when ArborGen and the other companies start putting more and more chemicals and whatever they're going to put on these things. It's going to get into that system and it's going to hurt people a whole lot more, including the species that need to be alive, the humans that need to be alive.

And I'll leave it like that but again, I'll ask you to do the right thing. I think a lot of us are very sad that we're in this situation of global warming and the way the world is going right now. So let's not make it worse, okay? Thank you very much.

Dr. Rebecca Stankiewicz Gabel: Thank you very much for your comment. Is there anyone else that would like to make an additional comment or anyone that is on that would like to make a comment? If you'd like to make a comment, please raise your hand.

Dick George: Well, we have no other speakers ready at the moment and so we will encourage those who are listening in who might have a comment, who might want to make a comment, to do so and we'll take another pause. Thanks.

Dr. Rebecca Stankiewicz Gabel: Thank you.

Dick George: Another speaker, apparently Lillian would like to expand her comment, which we're happy to do. So are you there?

Lillian Kui: Yes, hi.

Dick George: Hi, please go ahead.

Lillian Kui: Okay, great. Thanks for letting me speak again. Yeah, just to continue onto what I was saying. I think any time you introduce an invasive species into the environment or the ecological system that is not its native ecology, it's never good for the environment that it's being placed in and probably even for the species itself, which is not what its native environment is supposed to be. And I know these are genetically engineered trees so supposedly they're supposed to be freeze-tolerant but it's not natural. It's just not natural. And I want to stress the word "natural."

The earth has been *[inaudible]* for billions of years. It didn't need our intervention to come to where it is today which is full of life, full of diversity, full of biodiversity. It didn't need our intervention. It doesn't need our intervention now. You know, for us to intervene like this, it's just wrong. I don't think it needs any other evidence to support that creating a genetically engineered product, it's just wrong. It is playing God. It is not something that the earth has evolved. It is not something that is naturally evolved into. It did not evolve into a plant that wants to grow in the environment that ArborGen wants to place it in.

You know, it's just too many unnatural things going on. Like Mr. Bennington had said, Monsanto was a potential partner before. I mean, if ArborGen is anywhere close to Monsanto, it's not going to be good. It's not going to be good. From the GMO soybeans and corn, we don't need any more of that stuff. It's just bad for us, bad for the environment, and like my previous speaker said, the effect of this will reverberate to generation to generation to generation. You guys really do have the opportunity right now to do something right, to do something that will stop this. All these big companies out there that are just pushing these agendas for its profits. Whatever ArborGen's agenda is or Green Energy, all that stuff, it's got to stop at some point. And I think enough is enough. You know, for whatever profits, whatever industry; it's got to be enough. It's got to stop, okay? That's just, you know, I don't think it takes a rocket scientist to understand that introducing invasive species into an ecosystem that would not benefit from it. If history has taught us anything, any time an invasive species is introduced into an environment that is not native to it, it wreaks havoc. It just does. From other native species dying off from it or making it ill to toxins, pollutants. I understand that this GE eucalyptus tree is going to be herbicide resistant so that just means more herbicides would be sprayed, more polluting, more toxins.

I mean, really, do we really need to say more? I know there's only been a few speakers here but what we're saying makes a whole lot of sense and GE eucalyptus does not make any sense at all. It is completely, absolutely unnecessary. That's it for now. Maybe I'll come back.

Dr. Rebecca Stankiewicz Gabel: Thank you for your comment.

Dick George: Thank you for your comment.

Dr. Rebecca Stankiewicz Gabel: And you're welcome to come back.

Lillian Kui: Okay, thank you.

Dr. Rebecca Stankiewicz Gabel: Is there anyone else that is on the line that would like to make a comment? Please raise your hand if you'd like to make a comment.

Dick George: Since we have no other calls lined up at the moment, we'll take another pause. Again, encouraging anyone who may be having second thoughts or may decide to make a comment, please feel free to do so. Click on the raised-hand icon and we'll get instructions to you on how to do that. In the meantime, we'll take another pause. Thanks so much.

Dr. Rebecca Stankiewicz Gabel: Thank you.

[Music]

Dick George: Okay, *[music playing over speaking]*… we still have some speakers lined up to speak. We're still here. We'll be here until 9:00 and we welcome any comments. Again, encourage you, if you'd like to make a comment, to use a raised hand icon to let us know and we'll get instructions to you so that you can do so. So basically, we'll take another pause. We'll come back on every five or ten minutes or so just to let folks know that we're still here and we're glad to take any comments. So having said that, I see we still have no speakers lined up and so we shall take another pause.

Dr. Rebecca Stankiewicz Gabel: Thank you.

Dick George: Thanks so much.

Dick George: Okay, so seeing that we have no one else scheduled to speak, we're going to bring the meeting to a close. We'd like to thank everyone who participated today in our virtual meeting for freeze-tolerant eucalyptus. The PowerPoint and the audio of this virtual meeting will be available at our website, www.APHISVirtualMeeting.com within forty-eight hours. Please do not log off before completing the survey. It will appear on your screen after the… immediately following the meeting. Please fill it out and then click the submit button. We will be posting information, including dates and times of future virtual meetings, at www.APHISVirtualMeeting.com. Our next virtual meeting is tomorrow from 4:00 to 6:00 Eastern time. To register, to attend, or to speak, please go to www.APHISVirtualMeeting.com.

So having said that, for Rebecca and myself, we'd like to thank you for participating in our virtual meeting, and this meeting is now concluded. Thanks so much.

Dr. Rebecca Stankiewicz Gabel: Good night.

Susan Wheatley: Good evening, my name is Susan Wheatley, your technical support for this podcast. Welcome to the second of two virtual public meetings, sponsored by the U.S. Department of Agriculture Animal Implant Health Inspection Service. First I would like to go over a few housekeeping items. This virtual meeting uses audio broadcast technology. As an attendee, you will be able to hear the panelists and presenters, but we are not able to hear you. If you are registered to speak today, you have been sent separate instructions on how to connect to this meeting so that you will be heard when it is your turn to provide your public comment.

You should see a welcome slide on the left side of your screen; on the right side you will see the panelists via webcam, the names of the panelists who will be conducting the meeting and your name. You will not see the names of the other attendees.

There are several blue bars called panels along the right side of your screen. (Inaudible) chat and media viewer. You can open and close these panels by using the small half arrows next to the panel title. If you experience difficulty joining the WebEx session, please contact WebEx Technical Support at 1-866-229-3239. This number will also appear on all the slides used in this meeting. If you are registered to speak on today's call, please be sure you are dialed in via a phone line. If you see a phone icon next to your name in the participant panel. If you do not see a phone icon, please disconnect with your phone only and redial in, making sure to enter the attendee ID slowly. You must have a phone next to your name in order for you to provide a public comment.

If you are having a technical difficulty during the meetings, such as with your panels, please use the chat panel located in the lower right corner of your screen to send me a communication. You can also use the green toolbar on the edge of your screen if viewing in full screen mode. Type in your questions in the text field and hit send. I will respond as promptly as possible. Please keep the send to default as all panelists. With that, we invite you to sit back, relax, and enjoy today's presentation. Without further delay, I will hand the broadcast off to Dick George.

Dick George: Thank you, welcome and thank you for joining us. I am Dick George, Communications Branch Chief at Biotechnology Regulatory Services, or BRS. BRS is part of APHIS, the Animal Plant and Health Inspection Service, an agency of the U.S. Department of Agriculture. Soliciting public comments is a very important part of our process. We value your input and are pleased that you have chosen to be with us today, either to make a public comment or to listen to the comments of others. Technicians are standing by to assist anyone having difficulties in accessing this virtual meeting. Please call 1-866-229-3239 for help. This number is at the bottom of each slide. On the left side of your screen you should see the slide that is currently displayed for the meeting. On the right side you should see the projection of me and my colleague, Rebecca Stankiewicz Gabel. You will also notice that there are other panels that you can navigate such as the media viewer. To access closed captioning for this meeting, open the media viewer to the right of your screen. I will repeat that, to access closed captioning, open the media viewer to the right of your screen.

The purpose of this meeting is to solicit your comments on a notice of intent to do an Environmental Impact Statement or EIS for a line of eucalyptus that has been genetically engineered to be tolerant of freezing temperatures. For more information on this eucalyptus go to www.APHISVirtualMeetings.com. This slide contains background information, and also links to other documents and websites.

In the past, we have traveled around the country to conduct meetings where interested parties can make public comments on our various regulatory actions. Now, for the first time, we are holding online virtual public meetings to allow more people the opportunity to comment. Joining me is Dr. Rebecca Stankiewicz Gabel my colleague at BRS. Rebecca is the supervisor of our Biotechnology Environmental Analysis Branch.

Dr. Rebecca Stankiewicz Gabel: Before we start taking comments from our online audience, we would like to go over some of the specifics for the virtual meeting. We are taking only spoken comments today. If you prefer to make a written comment, you can do so by going to www.regulations.gov. Enter the word "eucalyptus" in the search box. This will take you to a link for the freeze tolerant eucalyptus comment site. The public comment period ends on April 29, 2013. You can go to regulations.gov anytime between now and the 29th and leave a written comment, which will become part of the public record. Or you can make a comment here at our meeting which will go until 6:00 p.m. tonight eastern time.

Those of you wishing to speak today will be recognized in the order in which you were registered. Today we are here to receive your input, not to answer questions about eucalyptus. For background information, please go to www.APHISVirtualMeeting.com. If you did not already register to speak and you wish to do so, please click on the raised hand icon. This will indicate that you wish to speak and you will be placed in the queue. You will be provided with instructions on how to proceed through the chat feature.

The statements received during the public comment period, whether spoken here today, or provided in writing to regulations.gov, will be considered in the development of the draft EIS for freeze tolerant eucalyptus. After we have published the draft EIS, we will solicit and receive comments on it. Those comments will be considered in the development of the final EIS. After the final EIS is published, there will be a decision on the regulatory status of freeze tolerant eucalyptus. We welcome your comments today because they will help us to determine what issues to consider as we prepare our draft and environmental impact statement.

Dick George: You should see a list of commenters and the order in which they will speak on your screen so you will know when your turn is approaching. We ask that you keep your comments to three minutes or less. Once everyone who wants to speak has done so, if we have extra time and you would like to say more, we will glad to afford you that opportunity. A recording of this meeting will be available within 48 hours on our site which is www.APHISVirtualMeeting.com. And written transcripts will be available there within a few weeks.

At the conclusion of the meeting, a survey will appear on the screen. Please complete it before you log off. Your feedback is very important to us. If you would like to be seen as well as heard today, please turn on your webcam when it is your turn to speak, and click on the camera icon next to your name. If you are having technical difficulties call the technical support team at 1-866-229-3239. As a reminder, we are here to receive your comments only, not to answer questions on eucalyptus or to discuss or debate biotechnology. With that, we are ready to hear from any commenter who is ready to speak and the first person on our list I think, I am looking at the screen here to get a queue as to whether we have a commenter who is ready quite yet to speak. Do we have Madelynn Frazier or Michael Portereiko. If we could – Michael Portereiko, if your mic is open, you can go ahead. It may take a moment to unmute his phone.

Dr. Rebecca Stankiewicz Gabel: Michael, are you on the line?

Dick George: Michael Portereiko, are you there?

Michael Portereiko: Yes we are here actually, we were just on the list to listen. We do not have any prepared comments at this time.

Dick George: Okay, thank you. Is there anyone else who would like to comment? Ann Peterman, are you there, if so let us know.

Ann Peterman: Yes, can you hear me?

Dick George: Yes, we certainly can.

Dr. Rebecca Stankiewicz Gabel: Yes we can.

Dick George: If you would like to go ahead with your comment, please do.

Ann Peterman: Okay, just one moment. Alright, I guess I would like to point out that this environmental impact statement for this genetically engineered eucalyptus represents the first time that APHIS has prepared a full environmental impact statement on a genetically engineered plant without being forced to by litigation. And it is only the fourth time that APHIS has prepared an environmental impact statement for any GE plant. Previously the agency was forced by litigation to prepare an environmental impact statement for alfalfa, beets and bent grass. And I think what that means is that APHIS is aware that this genetically engineered eucalyptus is potentially very dangerous and could have severe environmental impacts, and that is the fact that there is overwhelming public opposition to them. So I hope that that means that APHIS will take this very seriously and not rubber stamp these genetically engineered eucalyptus.

They are not native to the United States, eucalyptus of any kind, and they are also a documented invasive species. They are highly flammable, they are known to deplete ground water, and the freeze tolerant eucalyptus will be able to escape into ecosystems that previously have been too cold for them. So that makes them very dangerous in addition to the very – the other impacts that eucalyptus plantations already have as we know from the impacts that eucalyptus plantations have had elsewhere in the world, which all the impacts include clear cutting of bio-diverse forests for conversion to industrial eucalyptus plantations in Brazil. These are called green deserts because they have no bio-diversity at all. In Chile they are called green soldiers because they are constantly increasing and on the march forward, taking over more and more land. In South Africa they are called green cancer because people cannot control their spread, they are constantly being found in ecosystems where they were not planted.

They are documented as invasive in Florida and California. They increase the danger of firestorms. They contain a highly volatile oil and are explosively flammable. They displace wildlife that cannot use the eucalyptus trees for habitat or food and in addition, some eucalyptus trees are known to actually glue the beaks of birds together and kill them. They contaminate soil and ground water with the toxic agro chemicals that are used on them. And they are worse in droughts, they have deep tap roots and monopolize ground water and dry up soils. And all of this put together means that they will worsen climate change through the destruction of carbon rich native forests for carbon poor plantations. One study found that timber plantations actually contain about one-quarter the carbon of a native forest. So that is good for my comments for now.

Dr. Rebecca Stankiewicz Gabel: Thank you for your comments.

Dick George: Thank you, we have Keith Brunner on the line, Keith, are you there.

Keith Brunner: Hello Dick, can you hear me?

Dick George: I sure can, please go ahead.

Keith Brunner: Great, so my name is Keith Brunner, I am here today to call on the USDA to deny this permit from ArborGen. Eucalyptus trees are introduced organisms here in the U.S. and they are documented as invasive pests in parts of California and Florida. This cold tolerant trait that we are discussing today, would vastly expand the range of GE eucalyptus trees. And so hence it would enhance its ability to invade native ecosystems which is seriously problematic for bio-diversity as well as for ecosystem resiliency in the face of catastrophic climate change that we are facing.

Our experience in California and other parts of the world has shown that when eucalyptus escapes it is near impossible to eradicate them. And I wanted to include a quote from the renowned geneticist David Suzuki, I quote. "We have no control over the movement of insects, birds and mammals, wind and rain that carry pollen and seeds, genetically engineered trees with the potential to transfer pollen for hundreds of miles carrying genes for tracing, including insect resistance, herbicide resistance, sterility and released lignin, thus have the potential to wreak ecological havoc throughout the world's native forests." And as was mentioned, approval of GE eucalyptus would open the door for other GE tree species.

Also as was mentioned, GE trees are green deserts. They are an industrial plantation of trees, tree plantation, especially of GE trees, is like an industrial army of trees that will wipe out all of the life around them. These have major impacts on bio-diversity, particularly, these trees the cold-tolerant eucalyptus trees are being targeted for the forests of the southern U.S., and these are some of the most bio-diverse forests in the world. They have species found nowhere else including the Louisiana Black Bear, the Golden Cheeked Warbler, and the Red-Cockaded Woodpecker. These are species that could be pushed over the edge if millions of acres of GE Eucalyptus plantations are developed. They are also – eucalyptus trees are known to soak up more water than the forest that evolves naturally here, which threatens creeks and rivers. And the endangered freshwater species that live in them.

I also wanted to talk about the fact that there is enormous public opposition, not only in the United States, but internationally, to genetically engineered trees as well as to eucalyptus plantations. The last time that APHIS took comments on the test plots, there were tens of thousands of comments opposed to the field trials, and there were only 50 in favor. So that tells if it is something about where the public stands, and in this democracy of course, it should be a participatory process and it should be absolutely included in our decision making. I also wanted to highlight in 2006 this sort of, this story sort of encapsulates some of their resistance to eucalyptus plantations that occurs internationally. In 2006, on March 8, 2000 women from La Via Campesina, occupied the plantation of Aracruz Celulose which is now Fibria in Brazil, and Rio Grande do Sul on a Wednesday, and they occupied this plantation to denounce the social and environmental impacts of these green deserts created by eucalyptus monoculture. Now this was a massive even in Brazilian politics caused by the expansion of eucalyptus monocultures. And I quote from La Via Campesina from the women, "We are against green deserts, the enormous plantations of eucalyptus that cover thousands of hectáreas in Brazil and Latin America when the green desert advances, bio-diversity is destroyed, soil deteriorates, and rivers dry up. Moreover, these plants pollute air and water and threaten human health." So that is what we will see here in the U.S. South is what has happened internationally, and that is why I am calling on APHIS to not submit – to deny this permit to Arbor Gen Corp cold tolerant eucalyptus trees. Thank you, I am done.

Dr. Rebecca Stankiewicz Gabel: Thank you for your comments. Do we have anyone else on the line?

Dick George: We have no one else lined up at the moment to speak. I would mention to those who are listening in if perhaps you have decided that you would like to make a comment, you could still do so. You need to click on the raised hand icon on your screen, and you will receive instructions through the chat feature on how to make a comment. So since we have no others signed up at the moment, we do receive a signal from our WebEx producer when someone is on the line and ready to speak. So what we will do, we will take a pause. We encourage those listening, if you have a comment, please do so the way I just described. And in the meantime, we will take a pause, and if we have no others who come on, we will come back on every five minutes or so just to let folks know that we are still here. We plan on being here until 6:00 p.m. today, so if someone comes on this meeting late, they will still have the opportunity to make a comment.

So having said that, I will take a pause and if we get a signal that we have someone else who is ready to speak, we will come back on and receive that comment. So we will take a pause right here, thank you.

Dr. Rebecca Stankiewicz Gabel: Thank you.

Dick George: Okay, we have someone who would like to make a comment. It is Rachel Smolker, please forgive me if I have mispronounced your name, Rachel are you there?

Rachel Smolker: Hi, I am here.

Dick George: Terrific, go ahead with your comment.

Rachel Smolker: Okay. I had a little trouble getting onto the call so I am not sure what had already been said or not. But I wanted to comment on two things. First of all, the organization that I work with does a lot of work on the impacts of large scale bio-energy on climate and on human rights and on food and we do not support the position that was in this petition that this is – that large scale bio energy is a great socio-economic benefit to people. Because in fact the demand for land, to produce enough biomass to make any kind of significant contribution to our energy demand as it is right now, is astronomical. And we cannot meet more than a very small portion of our energy demand from trees or any other source that requires large amount of land and water like eucalyptus would. So that is one point, the other point I would like to bring up, in the petition, the issue of Cryptococcus, which is a fungal pathogen that causes fungal meningitis and is becoming global epidemic at this point. It is a major cause of death for a lot of patients with AIDS. It also infects people who are immunocompetent that does not have any compromised immune system in different places.

It was initially discovered in Australia associated with eucalyptus species, and we brought this up in the process where decision about field testing these eucalyptus, and it was dismissed because it was found that there are other trees that also host this Cryptococcus fungus. That is not a good basis for dismissing it in my opinion because just because there are other trees that are also host, Cryptococcus is not a plant of favored host over wide swathes of the United States. It is rather foolhardy actually.

In a letter to the USDA at that time, Dr. Heitman who is from Duke University, wrote, in summary there is a possibility that exporting or planting large numbers of eucalyptus trees could create a novel environmental niche for human pathogen that causes infections of the lungs and the central nervous system that can be difficult to treat, exhibit drug resistance and can be fatal. So I think it is immature to be dismissing the issue of Cryptococcus setting the possibility of setting up widespread habitat for that fungal pathogen by planting eucalyptus over a much extended range with these genetically engineered trees.

The other issue I wanted to bring up was is around pests, having looked a little bit at what was here in the petition about the various test species. I just want to say that I really want to say that it was really quite impossible to predict what kinds of pests will be attracted to massive plantings of eucalyptus in the United States. Plantings elsewhere are not necessarily indicative because there are different plants and plant pests traveling around in different parts of the world. I just want to read a brief portion from an abstract of a paper that was published in 2010 which was about the introduction of pests to eucalyptus in California. The paper that this was from was published in the journal of economical entomology, accumulation of pest insect on eucalyptus in California, random process or smoking gun. Timothy Paine, Jocelyn Millar, and Kent, M. Daane. These are folks from the University of California. The main point is that between 1983 and 2008, an additional 16 Australian insect pests of eucalyptus have become established in that state. Others prior to that. The modes or routes of introduction have never been established, and I just highlight that. We do not know, we cannot tell, there is no way of controlling the travel and transport of these pests. However, examinations, different temporal spatial patterns suggest the introductions were non random processes. And it goes on to say that the precautionary approach to these things and the risks associated with large scale planting of something like that.

And so, one of my questions is what are the environment impacts going to be of having large areas planted with this eucalyptus if we have no idea really what kinds of pests, we cannot really pretend that we know, and what kinds of controls are going to be used, what kinds of chemicals will have to be sprayed in order to control those pests when they inevitably do arrive. So that is my comments, thank you.

Dick George: Thank you so much for your comment. We do not have another speaker scheduled to speak at the moment, but we will, as I said before, we are here until 6:00 so if anyone else would like to speak, perhaps someone who is on the line who has been listening in, just click on the raised hand icon to do so, you will get instructions on the chat feature. And if someone does decide they would like to make a comment, we will come back online as quickly as we can to receive that comment. So otherwise, we will see you, if we do not hear from anyone else, we will close the meeting right before 6:00, so we will see you in about 15 minutes if not before. And if we have someone who wants to speak in the meantime, we will be back on as quickly as we can. Thank you so much.

We would like to thank everyone who participated today in our virtual meeting on freeze tolerant eucalyptus. Our PowerPoint and audio of this virtual meeting will be available on our website, www.APHISVirtualMeeting.com within 48 hours. Please do not log off before completing our survey, it will appear on your screen following the meeting. Please fill it out and then click the submit button. We will be posting information, including dates and times of future virtual meetings at our website, www.APHISVirtualMeeting.com. Thanks again for joining us for this virtual meeting. For Rebecca and myself, we appreciate you being here and your comments. And also those who just attended. As of now, this virtual meeting is now concluded, thanks so much.

Dr. Rebecca Stankiewicz Gabel: Good night.

ArborGen, Inc. Petition (11-019-01p) for Determination of Non-regulated Status for Freeze Tolerant Eucalyptus Lines FTE 427 and FTE 435

Draft Environmental Impact Statement, April, 2017

Appendix B: USDA-FS Technical Report on the Potential Adoption of Freeze-Tolerant Eucalyptus in the United States

See Attached: Wear, D.N., Dixon, E., Abt, R.C., and Singh, N. Projecting Potential Adoption of Genetically Engineered Freeze-Tolerant Eucalyptus Plantations, August, 2013

Projecting potential adoption of genetically engineered freeze-tolerant Eucalyptus plantations

Authors: David N. Wear[1]; Ernest Dixon IV[2]; Robert C. Abt[3]; Navinder Singh[4]

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Date: August 2, 2013

Abstract

Development of Eucalyptus plantations has been limited in the United States due mainly to the species' sensitivity to freezing temperatures. Recently developed genetically engineered clones of a Eucalyptus hybrid which confer freeze tolerance could expand the range of commercial plantations. This study asks whether and to what degree the freeze tolerant Eucalyptus might be adopted as a preferred land use based on comparative returns and a real options land use switching model. Climate factors other than freezing (rainfall and average temperatures) are assumed to limit potential adoption to the southeastern region of the United States. Comparison of returns indicates that Eucalyptus would not likely compete with cropland in this region but could be competitive with forest uses, especially planted pine. Real options analysis, using both geometric Brownian motion and mean reverting models of stochastic returns indicates that switching could be expected on a portion of planted pine forest land. Models predict about .8 to 1.4 million acres of Eucalyptus plantations or 5 to 9 percent of the current area of planted pine. Extending the analysis to also consider the current area of naturally regenerated pine results in as much as 2.8 million acres of Eucalyptus. Actual adoption will likely depend on uncertain future markets for cellulose, especially for bioenergy feedstock, and a set of model variants explore the potential range of responses.

Introduction

Planted forests provide an increasing share of fiber supply throughout the world and their area expanded at a rate of 5 million ha yr^{-1} between 2000 and 2010 (FAO 2012). *Eucalyptus*, a highly productive genus native to Australia and Indonesia, has been planted across large areas of Asia, Africa, and Brazil but its application in the United States has been limited by environmental factors, especially sensitivity to freezing temperatures. In the southeastern United States, the 16 million ha of planted forests are almost exclusively pines (*Pinus spp*.) and are an important source of softwood forest products. Hardwood forest products in the region are mostly sourced from natural stands and have become somewhat scarce, especially in some localized markets (Wear et al. 2007). As a result, a freeze-tolerant *Eucalyptus* established in plantations could have commercial application in the region for industries currently using hardwood forest products as an input and may make novel industrial applications economically viable.

Recent efforts to modify the genetics of *Eucalyptus* hybrids to confer freeze tolerance could expand the range of *Eucalyptus* in the United States. In particular, ArborGen LLC has developed two genetically engineered clones of a *Eucalyptus* hybrid: *Eucalyptus grandis X Eucalyptus urophylla,* with genetic modifications targeting freeze tolerance and male sterility. The company has petitioned the USDA Animal and Plant Health Inspection Service (APHIS) for a determination of nonregulated status of this freeze tolerant (FT) *Eucalyptus* under regulations 7 CFR part 340 under the authority of the Plant Protection Act of 2000 (Public Law 106-224—June 20, 2000). In response to the ArborGen petition, USDA APHIS has decided to prepare an Environmental Impact Statement (EIS) to consider the potential environmental effects of an agency determination of nonregulated status consistent with Council of Environmental Quality's (CEQ) National Environmental Policy Act of 1969 and subsequent amendments (NEPA) regulations and the USDA and USDA-APHIS NEPA implementing regulations and procedures (40 CFR Parts 1500-1508, 7 CFR Part 1b, and 7 CFR Part 372). If the petition is granted, it would allow ArborGen to plant these freeze-tolerant clones without permit in unconfined conditions. Our assignment, in support of the EIS conducted by APHIS, is to explore the potential adoption of these clones in light of anticipated productivity and economics. The overarching question is how much land area might be occupied by FT-*Eucalyptus* plantations if these clones receive nonregulated status. The answer would necessarily derive from the willingness of landowners to adopt this new land use in lieu of existing land uses. This paper compares returns to existing land uses with those accruing to potential FT-

Eucalyptus management regimes within an anticipated viable range in the United States to determine where returns to *Eucalyptus* management could compete with existing land uses.

The analysis starts by examining the production technology and economics of *Eucalyptus* plantations to estimate potential returns and present net values of *Eucalyptus* adoption. These estimates depend on a full accounting of the costs, biophysical productivity, and revenues of management and are based largely on estimates from management of non-FT *Eucalyptus*. We construct implied historical returns by linking simulated profit functions to historical prices and compare these returns with returns to other land uses. Adoption of *Eucalyptus* would depend not only on expected returns but also on the relative return risk associated with all land uses. A real options land use switching model compares FT-*Eucalyptus* with existing major land uses to estimate adoption under modeled return and risk conditions. The use of disaggregated county and sub-regional data allows for the mapping of potential land use changes. The analysis of several model variants allows us to explore how the expansion of Eucalyptus plantations could develop under various market futures.

This document is organized as follows: The next section of this paper describes land use theory, first in a deterministic setting and then with a consideration of risk and uncertainty using real options and includes specifics regarding estimation of the land use switching models. The data section describes the geographic region viable for FT-*Eucalyptus* and the compilation of data on the extent and net returns for the existing agriculture and forest land uses within this region, as well as the predicted returns for *Eucalyptus* management. The third section describes the results of model estimation, comparisons of *Eucalyptus* returns with returns to existing land uses, and projections of potential *Eucalyptus* adoption in the future for a set of scenarios. The concluding section describes key findings and discusses important uncertainties associated with the analysis.

Land Use Theory

Understanding the potential expansion of FT-*Eucalyptus* plantations requires a model of switching between different possible land uses. For example, under a deterministic land use switching model, the existing distribution of land uses is assumed to reflect profit-maximizing behavior on the part of private landowners so that the quasi-rent accruing to the selected land use exceeds the quasi-rents accruing to all other possible uses (e.g., Hardie et al 2000):

$$R^* = \max\left(R^{*1}, \dots, R^{*J}\right) \tag{1}$$

where j=1, …, J represents the possible land use categories. These quasi-rents are defined by profit functions which account for all the relevant costs of management as well as the returns to harvest for different rural land uses—we treat urban land uses as fixed. Anticipated rents therefore vary across demand futures—i.e., they depend on the prices of known and anticipated products—but also depend on the qualities of the site that determine productivity and operating costs. If land is of homogenous quality then we would expect one land use to dominate all others everywhere; heterogeneous land quality accounts for a diversity of land use outcomes within an analysis area. A more explicit accounting follows:

$$R^{*j}(P,Q)=Px^{*j}(P,Q)' \tag{2}$$

Where quasi-rent for land use j depends on a vector of input and output prices (P) and the quality of the parcel indexed by Q. The product of prices with the vector of input/output quantities (which likewise depend on P and Q) define the profit associated with land use j. Equation (2) indicates that the rent accruing to any land use would change in response to exogenous changes in input (energy, labor, or capital) prices or in output (corn, wheat, other crops, timber) prices and also implies that the ranking of rents for a given parcel may change in response. Rent reordering explains rural land use changes in this formulation.

Introduction of a new land use alternative—for example, *Eucalyptus* plantations—would require a reevaluation of relationship (1) with J+1 (rather than J) alternatives. Because the current distribution of land uses across an analysis area represents the optimal allocation of land across economic and land quality conditions, the potential for reallocation depends on comparing the quasi-rent for *Eucalyptus* plantations with the quasi-rent accruing to each land use currently occurring within the analysis area. With a deterministic model, once the returns to *Eucalyptus* have been estimated, this reduces to evaluating the following inequality:

$$R^{*J+1} - C > R^* = \max(R^{*1}, \cdots, R^{*J}) \tag{3}$$

Where C accounts for the one-time cost of converting to a *Eucalyptus* plantation. If the inequality holds, then the land use would be expected to switch from the current optimal alternative to a *Eucalyptus* plantation.

Landowners face uncertainty regarding future returns and the structure of that uncertainty along with costs of conversion have been shown to influence switching decisions (e.g., Schatzki 2003). To address uncertainty and conversion costs we apply real options methods to estimate the potential for adoption of *Eucalyptus*. In general, the inclusion of uncertainty and conversion costs into the decision model tends to reduce the likelihood of conversion compared to the predictions of the deterministic model (Dixit and Pindyk 1994). The approach changes the switching calculus from an "all or nothing" proposition to one which accounts for portfolio balancing among uses.

A real options land use switching model

Our switching model anticipates that a risk-neutral decision maker chooses between retaining a current land use or (reversibly) adopting a new land use (*Eucalyptus*) based on a comparison of returns, conversion costs, and uncertainty regarding future returns. Modern investment theory highlights the limitations of discounted cash flow as a decision rule where returns are not known with certainty and investments are at least costly to reverse (Dixit and Pindyck 1994). The ability to switch land use is an option which is lost when the decision is made—i.e., the landowner foregoes the option to further delay the timing of the investment and therein benefit from future information. The costs (as well as the benefits) of exercising the option factor into the decision, therein defining a real options problem. We adopt the modeling approach of Song et al. (2011) to define switching models to compare the *Eucalyptus* land use with current land uses. Their analysis addresses the potential adoption of perennial switchgrass over a corn-soybean land use in the Midwest US and allows for two-way switching, a question directly analogous to our research question.

Following Song et al. (2011), assume that a risk-neutral landowner is considering the current use of a unit of land, denoted by i, that can be converted to another use, j, at a lump sum cost of C_{ij}. The return to the current land use i ($\pi_i[t]$) in a given time period t is assumed to evolve by a stochastic process of the form:

$$d\pi_i(t) = \alpha_i \pi_i dt + \sigma_i \pi_i dz_i \tag{4}$$

where α_i, the drift term, and σ_i, the variance term, are both constants and dz_i is the increment to a Wiener process. Equation (4) defines a geometric Brownian motion model of the returns to the land use which is nonstationary—a positive α indicates an upward drift in revenues.

To compare returns between two land uses requires estimating a GBM model for each and accounting for the correlation of the return series due to the influence of common factors (for example, all land based returns in a region may be similarly influenced by drought). The joint GBM models for both land uses can be expressed as follows:

$$d\pi_1(t) = \alpha_1(\pi_1, t)dt + \sigma_i(\pi_1, t)dz_1$$

$$d\pi_2(t) = \alpha_2(\pi_2, t)dt + \sigma_2(\pi_2, t)(\rho dz_1 + \sqrt{1-\rho^2}dz_2) \quad (5)$$

where ρ is the correlation coefficient between the two return series and other variables are defined as above.

The GBM model with positive drift implies increasing scarcity. In the case of renewable resources a long term stability in commodity returns may be more consistent with theory. Accordingly, we also examine a mean-reverting stochastic return model that allows for short run fluctuations but anticipates a tendency for prices to be drawn back to a long run mean value, consistent with a stock adjustment process (i.e., planting more or less crops) that responds to increasing or decreasing scarcity. This model is defined as:

$$d\pi_i(t) = \eta(\bar{\pi}_i - \pi_i)\pi_i dt + \sigma_i \pi_i dz_i \quad (6)$$

where n is the speed of reversion back to the mean (and is expected to be positive) and the other parameters are as defined for the GBM model. While the GBM is more tractable and is the standard form applied to the real options analysis of financial instruments, the mean reverting (MR) model may be preferable for describing returns to land-based commodity production. It is difficult to select mean reversion or to allow for drift *a priori*. We instead investigate the implications of both formulations.

The expected present-value payoff in time period t due to the landowner following optimal conversion is a function of the returns to both possible land uses and is denoted as $V^i(\pi_{cur}(t), \pi_{alt}(t))$, with cur and alt denoting the current and *alternative (e.g.,Eucalyptus)* land use respectively. Letting r be the landowner's discount rate, the conversion decision is defined by:

$$V^i\left(\pi_{cur}(t), \pi_{alt}(t)\right) = \max\begin{Bmatrix} \pi_{cur}(t)dt + e^{-rdt}EV^{cur}(\pi_{cur}(t+dt), \pi_{alt}(t+dt)), \\ V^{alt}\left(\pi_{cur}(t),\ \pi_{alt}(t)\right) - C_{cur,alt} \end{Bmatrix}. \quad (7)$$

The first term in the maximum operator is the return to the landowner from staying in the current land

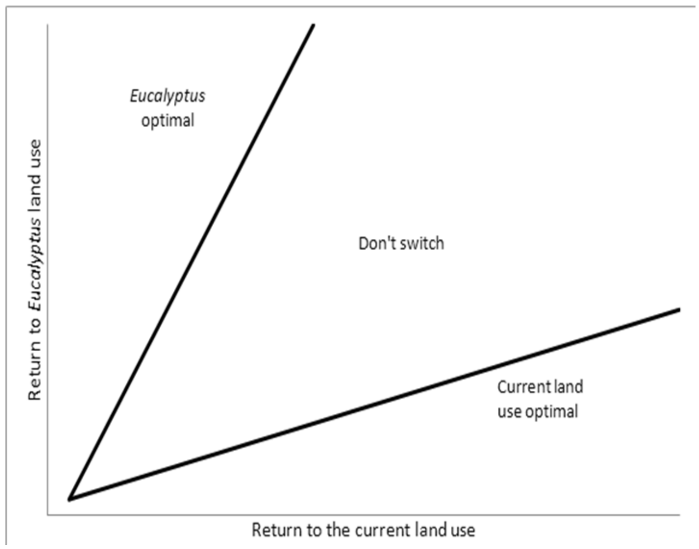


Figure .1 Idealized switching boundaries for a real options based land use switching model.

use i and is the sum of the immediate profits from the current land use and the discounted value of the expected profits at the end of the time period $[t + dt]$. The second term in the maximum operator is the return from converting to *the alternative use* net of the switching cost $C_{cur,alt}$.

This present value function can be redefined to describe optimal decision rules incorporating the option value of the current land use based on different realizations of relative returns in the two possible land uses. Figure 1 shows a graphical representation of idealized switching boundaries for the current problem (equation 7) with returns to current use and *Eucalyptus* use on the horizontal and vertical axes respectively. Where relative returns occur above the upper switching boundary, returns to *Eucalyptus* exceed returns to the current use enough to justify switching from the current land use to *Eucalyptus*. Where relative returns occur below the lower switching boundary, returns to the current land use exceed *Eucalyptus* returns enough to justify switching from *Eucalyptus* back to the original use.

The region where relative returns fall between the two lines corresponds to the condition in which it is not optimal for the landowner to make a switch, even if current returns for the existing land use are lower than the alternative (due to conversion costs and/or risk). Note that land use hysteresis is expected with this model specification—i.e., following a land use switch a return to a pre-switch price pair may not induce switching back to the original land use. More information about the mathematical procedure and proofs underlying the conversion of the present value function to the optimality conditions can be found in Song et al. (2011) and Brekke and Øksendal (1994).

Model Specification

The land use switching model described above is too complex to be solved analytically and is instead solved by numerical approximation. In this procedure, the model is reformulated as a series of piecewise linear basis functions and then solved for a subset of possible values by a process called collocation. This produces an approximation of the location of the switching boundaries between the two land uses demonstrated in Figure 1 (Fackler 2004; Miranda and Fackler 2002). The probability of conversions through time may be estimated by simulating switching behavior over a large set of simulations for the return paths determined by equations (5) and the correlation between returns. For each year in each simulation, switches to and from *Eucalyptus* are tallied to predict the total proportion of land that would be allocated to *Eucalyptus*. We construct pairwise comparisons of existing rural land uses with *Eucalyptus* management in each of several sub-regions where distinct estimates of revenue time series can be constructed.

For each pairing between a current land use and the *Eucalyptus* land use, we use OSSOLVER, a MATLAB utility developed by Fackler (2004) for solving switching problems (to and from Eucalyptus) by numerical approximation, to solve for the optimality conditions and develop the conversion boundaries between land uses for each county. The switching boundaries estimated in this step define a mapping between revenue pairs and the optimal decision, incorporating the option value of the current land use and conversion costs between all pairs of land uses.

Monte Carlo simulations were done in the Python programming language, applying 100,000 realizations of equations (4) over a 30 year time period and calculating the switching between the *Eucalyptus* and alternate land use based on the OSSOLVER switching boundaries. *Eucalyptus* adoption is examined initially for the existing market situation, that is, with the estimated stochastic revenue functions for existing land uses and a constructed *Eucalyptus* revenue function based on production of hardwood pulpwood. To address altered demands for cellulosic fiber, for example, from anticipated thermal and biochemical bioenergy uses, we also consider scenarios with higher initial prices for both *Eucalyptus* and other wood producing land uses.

Study Area and Data

The study area is limited initially by USDA plant hardiness zones 8b and higher as shown in Figure 2. This is defined by the parameters of the environmental analysis conducted by USDA APHIS and implicitly assumes that an effective frost tolerance is conferred upon the Eucalyptus hybrid through genetic modification[1]. This zone encompasses a large area of the southeastern United States, but also includes much of the southwestern US and California along with coastal areas of Oregon and Washington. Intolerance to cold (freeze damage) has restricted the small area of commercial plantings of non-FT *Eucalyptus* to zone 9 (generally zone 9a) and FT hybrids could expand the range to this broader area. USDA plant hardiness zones are defined by bands of average annual minimum temperatures and can be useful for defining limits based on frost or cold tolerance. Commercial *Eucalyptus* plantings would be limited not only by cold sensitivity, but also by potential productivity, which is influenced by availability of water inputs and solar insolation. We define the areas where Eucalyptus could be a viable crop by screening out areas based on the plants minimum requirements for water and solar inputs. First we screen out areas based on rainfall limitations. While vapor pressure deficit, seasonal rainfall distribution, and other factors affecting water balance play a role, total rainfall is used to summarize water availability. Schonau (1984) cites 800 mm/year as a threshold for E. *grandis* plantations around the globe (900 mm/year for commercial success). Stape et al. (2004) observe productive *E*. *grandis* x *urophylla* plantations in Brazil on sites where precipitation ranges from 853-1164 mm/year, while Gonçalves et al. (2012) cite a range of 1000-3000 mm/year for *Eucalyptus* plantations in Brazil. A global climate envelop for E. *grandis*, based on data from Austrailia and Africa (Booth 1989), includes a mean annual rainfall requirement of 700-2500 mm yr^{-1}. We screen out areas with average annual precipitation of less than 800 mm/year as unsuitable for plantings in the U.S. This eliminates the southwestern United

[1] This is clearly a strong assumption given that freeze damage is influenced by minimum temperatures and the time of year at which the stand is subjected to freezing temperatures (e.g., before or after hardening).

States, from central Texas westward and much of California—and also assumes that irrigation would not be used to grow *Eucalyptus* in arid regions of the southwestern United States (Figure 3)[2].

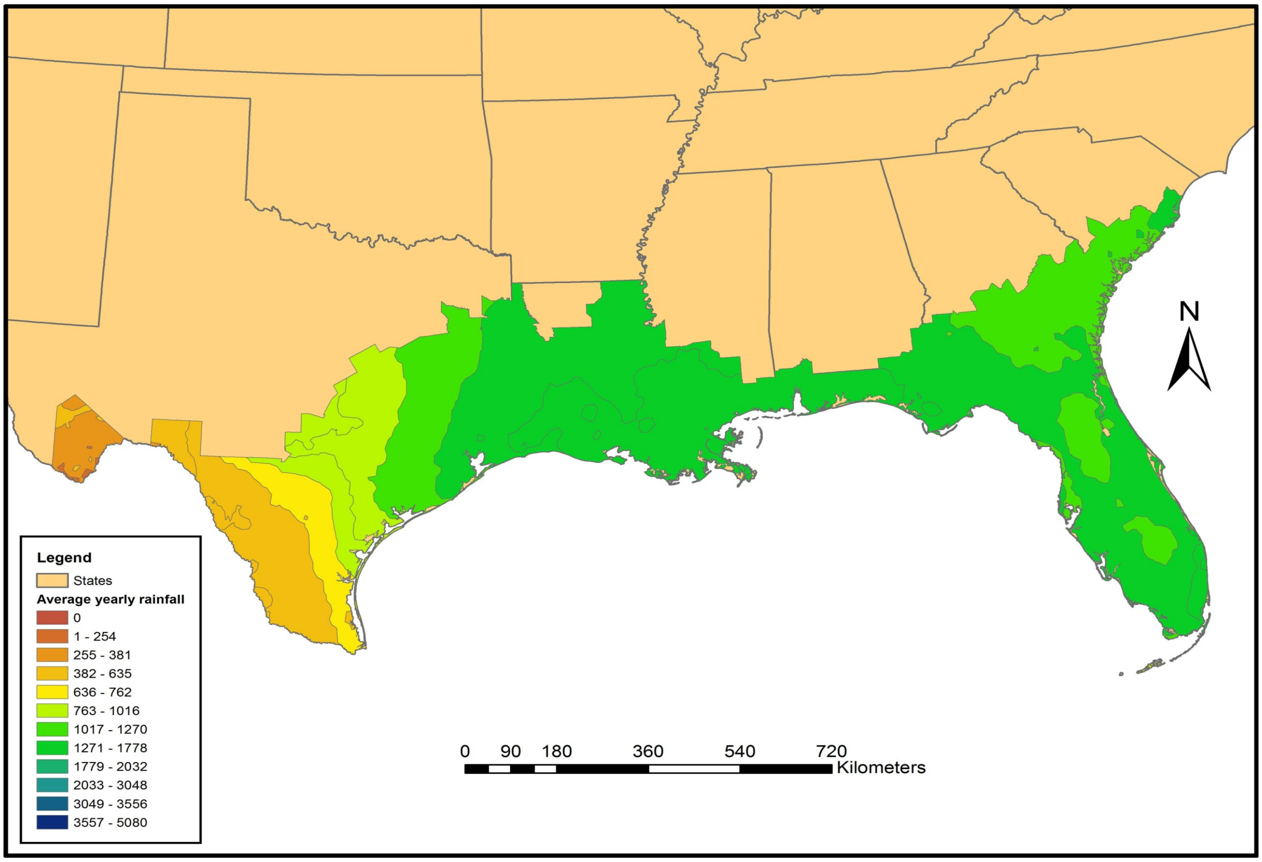


Figure 2A. Plant hardiness zones 8b and higher intersected with precipitation zones for the South.

[2] Assuming that Eucalyptus would need the equivalent of 900 mm of rainfall to produce a viable crop equates to about 3 ac. ft. of water input from irrigation, a quantity that is consistent with irrigation delivery in Arizona (average of 5.4 ac. ft.) and California (average of 3.1 ac. ft.; USDA 2009). However, the costs of irrigation would be prohibitive: the average costs of irrigation from off-farm suppliers in 2008 was $140/ac/year and $143/ac/year in Arizona and California respectively. As demonstrated later in this paper, these costs far exceed potential returns from Eucalyptus.

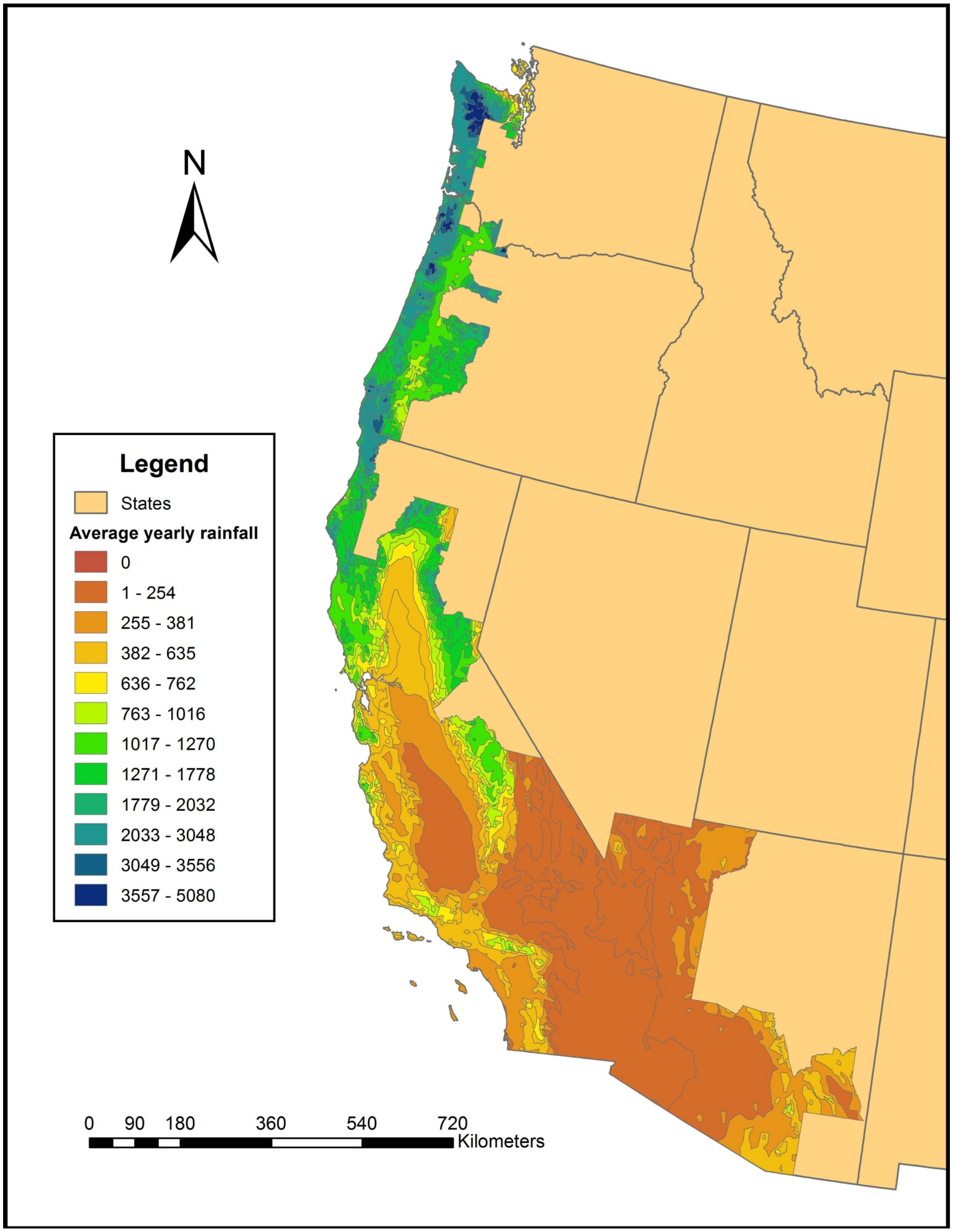


Figure 3B. Plant hardiness zones 8b and higher intersected with precipitation zones for (A) the South (showing Timber Mart-South Zones) and (B) the West

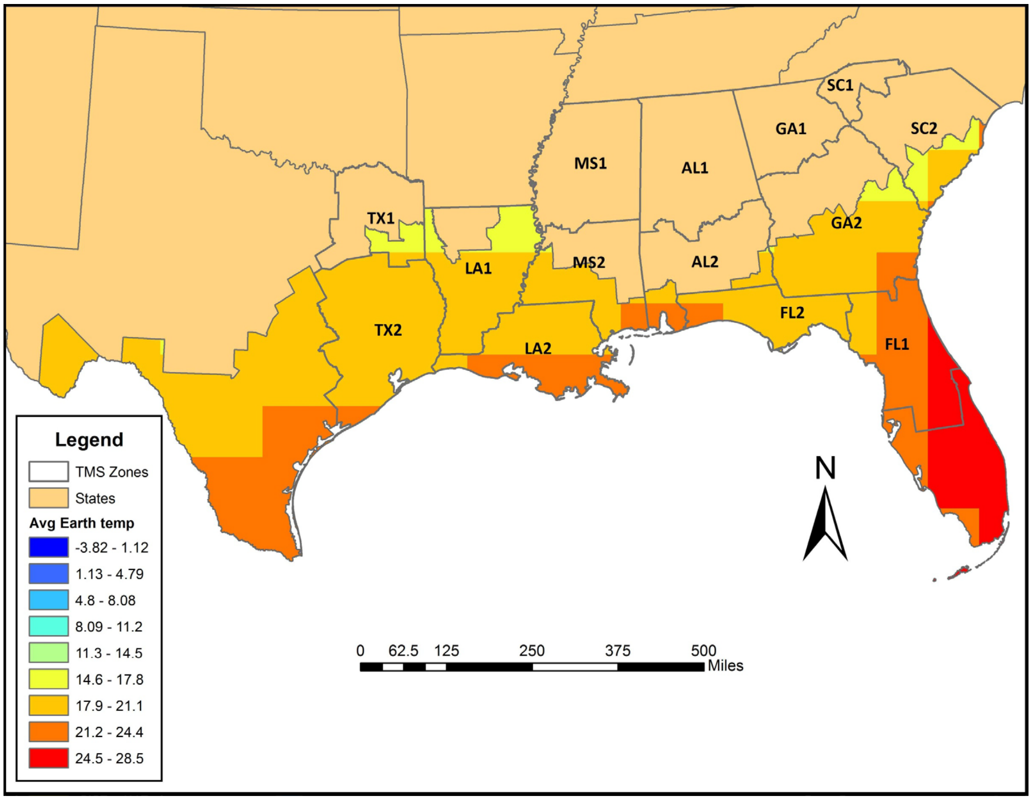


Figure 3A. Earth temperature intersected with plant hardiness zones 8b and higher for the South. Timber Mart-South zones are defined within each State.

We also limit our analysis to areas with solar insolation comparable to the current distribution of productive *Eucalyptus* plantations. We consider two metrics of solar input, mean annual daily temperatures and total solar radiation measured as annual kilowatt hours per square meter per day (Kwh/m^{-2} per day). In Brazil, Stape (2004) finds productive *Eucalyptus* plantations over a range of average daily temperatures from 19.4 – 23.6º C and Gonçalves et al (2012) reports a range of 13-26º C. Booth's climate envelop for E. *grandis* identifies a mean annual temperature range of 14-25^{o} C. Also in Brazil, Almeida et al. (2004) observe productive *Eucalyptus* across a solar radiation range of 4.5-5.1 kwh/year. We define the mean annual daily temperature cutoff as greater than 15 degrees Celsius (about 60 degrees F) and a solar insolation cutoff as 4 Kwh/m^{-2} per day. These screens eliminate from consideration the small section of plant hardiness zone 8b contained in Oregon and Washington (see

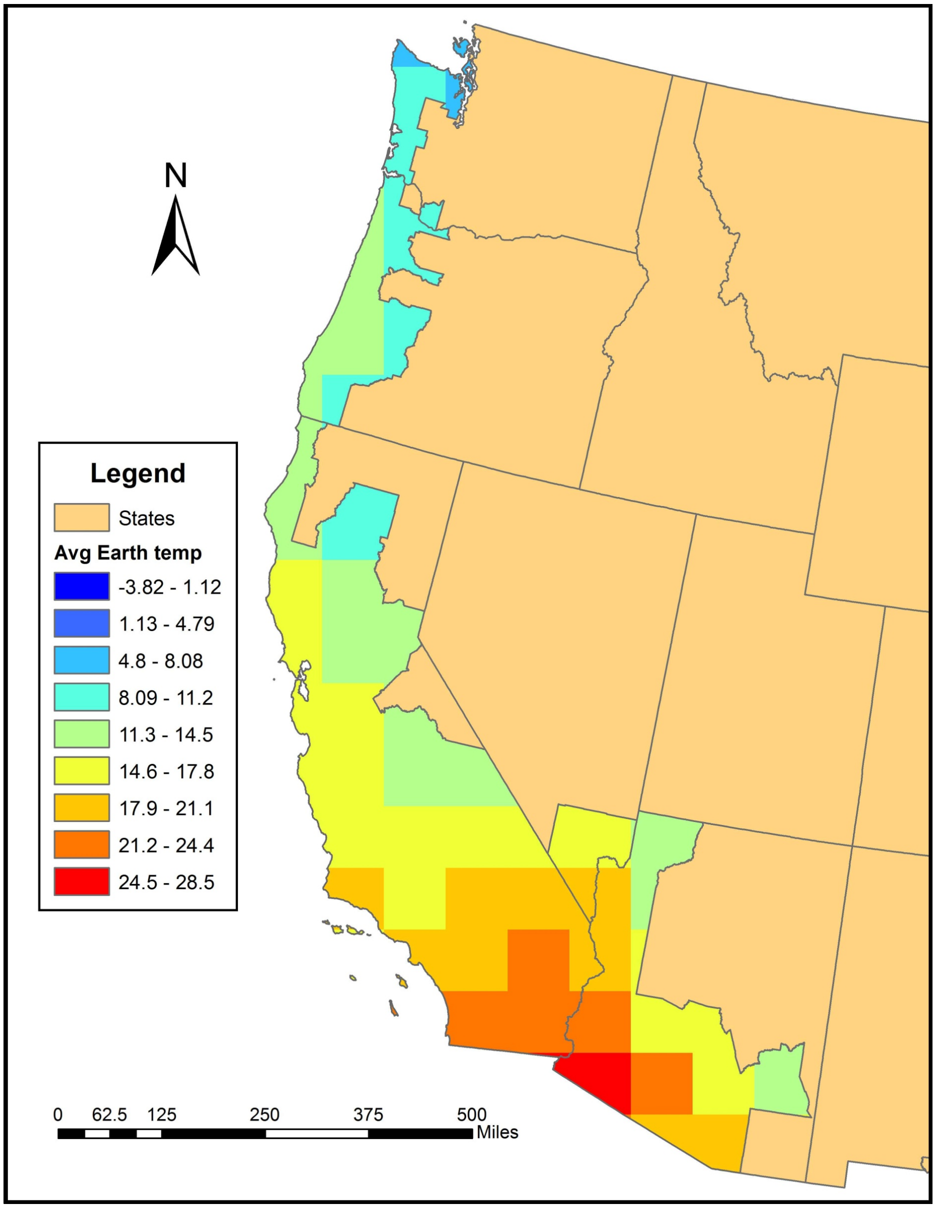


Figure 3B. Earth temperature intersected with plant hardiness zones 8b and higher for the West.

Figures 3 and 4). Our study area is therefore limited to the southeastern United States from east-central Texas to South Carolina as shown by the areas with green shading in Figure 2. [3]

[3] For the most part, these literature-derived environmental constraints define clear boundaries for commercial viability. However, a small area of northern California while excluded from our analysis by these constraints, is close to the margins for rainfall and solar insolation.

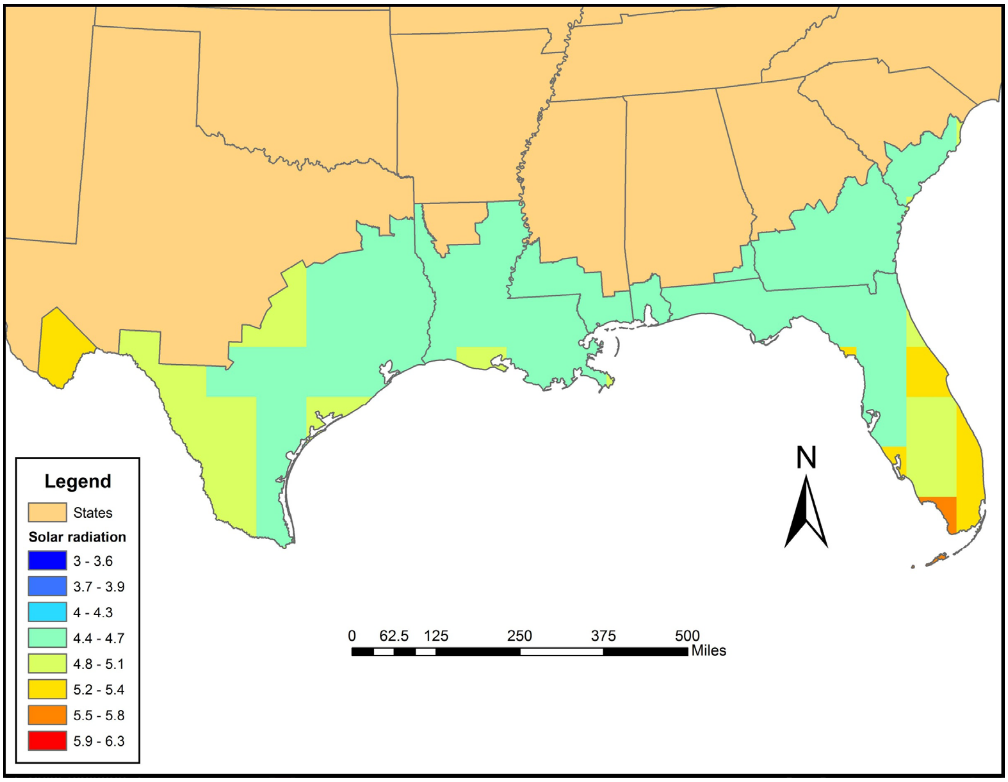


Figure 4A. Solar radiation intersected with plant hardiness zones 8b and higher for the South.

To examine the potential adoption of *Eucalyptus* plantations in zone 8b requires data on the current rural land use distributions across forest management types and crop types, net returns accruing to each of these existing land uses, the costs of converting from existing land uses to *Eucalyptus* and vice versa, and the potential rents accruing to *Eucalyptus*. Data were compiled at county and sub-regional levels. Returns data are organized by the one or two Timber Mart-South (TMS) sub-regions within each state (see Figure 2). Crop returns are compiled across broader regions defined by the USDA and crop were linked to TMS sub-regions. Where more than one crop return region is associated with the TMS sub-region an average return is constructed by weighting the respective crop returns by crop acreage. Data (land uses, conversion costs, and returns) are assembled for each sub-region in the study area from the following sources:

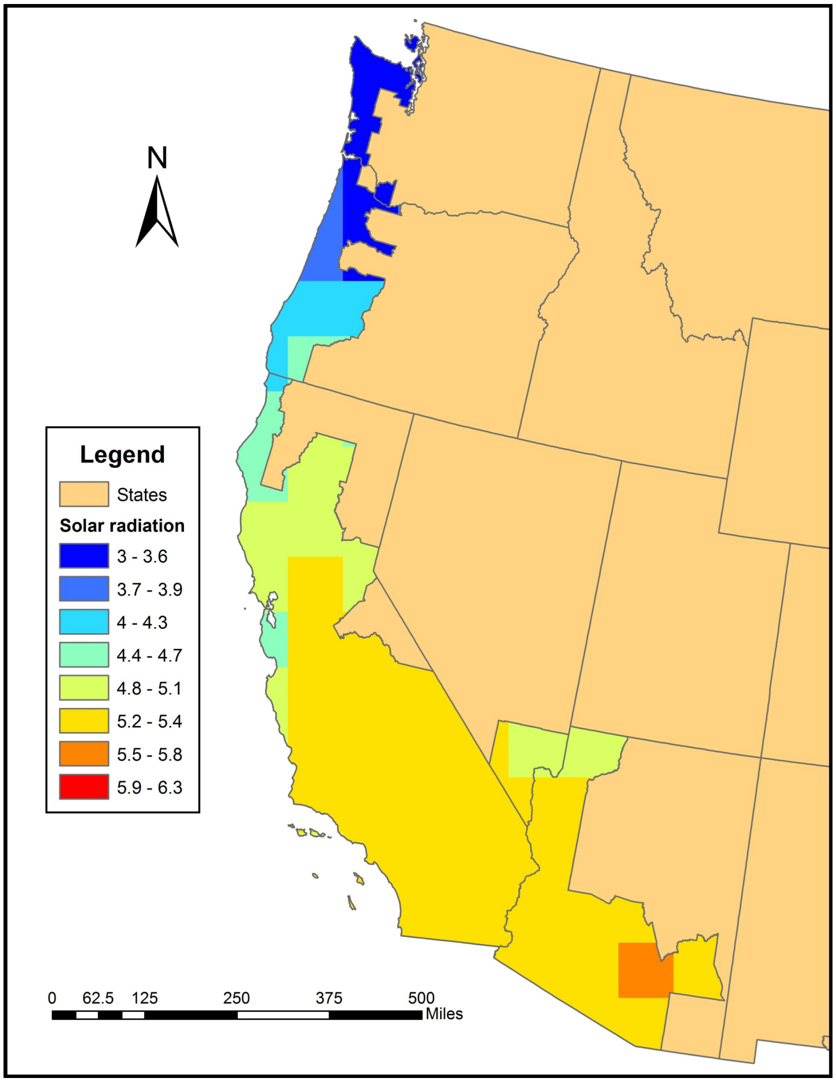


Figure 4B. Solar radiation intersected with plant hardiness zones 8b and higher for the South.

Area of Land Uses: Cropland by crop type and pastureland area are taken from the 1997, 2002, and 2007 Census of Agriculture (USDA 2007) as reported in the National Agricultural Statistics Service,[4] forest areas by forest management type are taken from the Forest Service FIA data bases for each state (e.g., Miles et al. 2001; Smith et al. 2009). Because farmers use a variety of crop rotation patterns (which we cannot identify *a priori*) and rarely employ monocultures, we treat cropland as a single use and

[4] Accessed at http://www.nass.usda.gov/ January 29, 2013.

assign the portfolio of six major crops produced within the sub-region based on cropland acreages. Forests are divided between intensively managed planted pine and all other, naturally regenerated forest types. We consider switching options for the former but not for the latter because currently planted forests have demonstrated economic feasibility for tree plantations. This logic limits our analysis to areas already identified as "operational" in terms of drainage and access and we revisit the implications of this assumption in the conclusions section by considering naturally regenerated pine.

Returns to land uses: Net returns to land uses are derived from annual return and cost estimates or from secondary sources and expressed in real terms using the implicit GDP price deflator with a base year of 2005. Forest land returns are developed for each county using sub-state timber (stumpage) prices linked to simulated outputs and costs associated with a specified management regime. For cropland returns we use reports of annual net returns to each major crop type for each subregion. For the historical time series of crop returns, years 1975-1995/6, we defined the net return as the gross value of production net of variable cash expenses. To most closely match the definition of crop returns between the historical and recent time series (years 1995/6-2011), we defined recent crop returns to be the value of production less operating costs and hired labor and excluded interest on operating capital. We construct an acreage weighted average return to cropland for each subregion using individual crop acreages for 1997, 2002, and 2007. We assume that the 1997 acreages apply to years prior to 1997 and then interpolate between data points to estimate acreages for 1997-2007. Acreages are held at 2007 levels for 2007-2011. Comparable data were not available for pasture and we have not included this land use in our analysis.

Net returns accruing to *Eucalyptus* plantations are inferred using cost and productivity data from recent published work related to Eucalypts grown in the southeastern United States (especially Gonzalez et al. 2011). These are linked to historical hardwood pulpwood prices to simulate the historical revenue series used to estimate the stochastic revenue functions. The same approach is used to construct a return series for planted pine forests. To produce return data comparable to annual crop returns, we calculate an equal annual return for both forestry uses based on a valuation using each year's stumpage prices for a given region. This approach is consistent with the landowner basing the decision to switch on anticipated returns for woody crops and that switching from the current woody crop would occur only following a harvest. That is, we do not directly address the issue of changing the harvest timing for existing woody crops in response to other options.

Estimates of land use switching are based on return processes (GBM or MR) estimated for the various land uses. We start with base scenarios that use the estimated models applied to starting conditions defined by 2011 prices. Alternative futures are constructed by adjusting the rates of return growth in the GBM models, adjusting the variability and correlations of returns in the MR or GBM models, or changing the starting conditions. We also construct sensitivity analysis of these models to examine the influence of *Eucalyptus* establishment costs and starting prices on eventual adoption of Eucalyptus across the southeastern U.S.

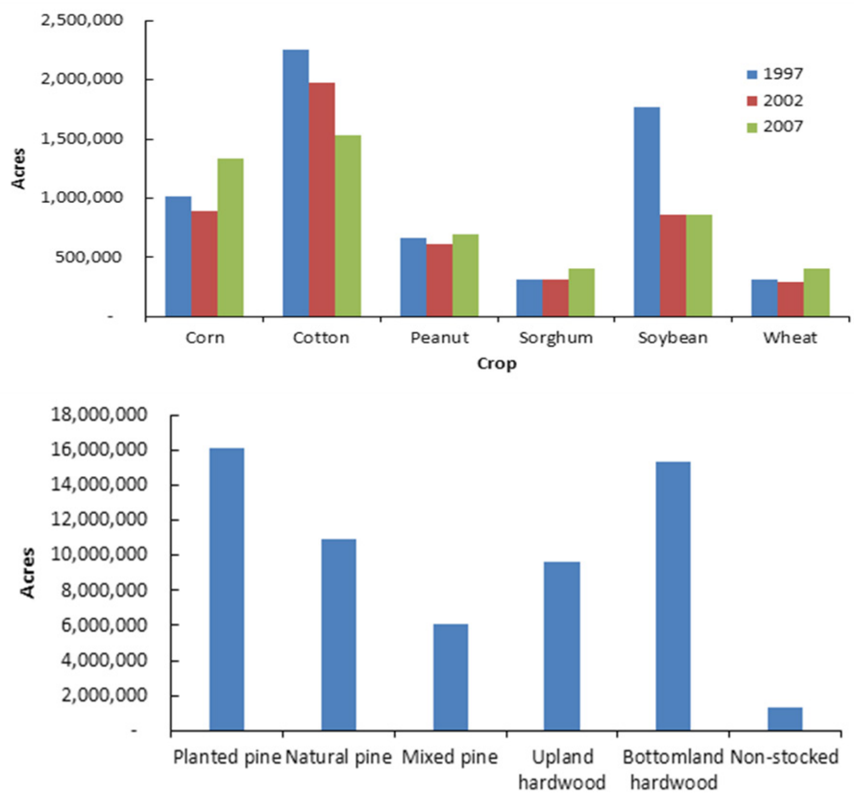


Figure 5. Distribution of rural land uses in the study area for (A) crop types in 1997, 2002, and 2007 and (B) for forest types in 2010 (Sources: USDA Census of Agriculture and FIA).

Results

Rural land in the region reflects a diversity of uses (Figure 5). The 2007 Census of Agriculture (USDA 2007) indicates that 7.7 million acres of land was dedicated to six major crop uses, down from 9.3 million acres in 1997.[5] Most of the decline between 1997 and 2007 is explained by declines in cotton acreage (-0.85 million acres) and soybean acreage (-0.98 million acres) coupled with a moderate expansion in corn acreage (+0.43 million acres). Peanut and wheat acreages are relatively small (0.5 million acres) but stable over this period. Forest uses dominate the rural landscape in the study area shown in Figure 2 at 59.3 million acres. Forest uses similarly show strong diversity in this region (Figure 2B). Pine forest types account for 27 million acres or 46 percent of total forest area, with 16 million acres (27 percent) in a planted forest condition. Hardwood forest types account for 25 million acres (42 percent) with a majority (15 million acres) in lowland hardwood forest types.

Table 1. Eucalyptus management regime for producing hardwood pulpwood.

Description	Timing	Value	Unit	Value	Unit
Mechanical site prep	Establishment	247	$/ha	99.96	$/ac
Chemical site prep	Establishment	116	$/ha	46.94	$/ac
Planting density	Establishment	1250	trees/ha	505.86	trees/ac
Planting cost	Establishment	133	$/ha	53.82	$/ac
Seedling cost	Establishment	0.25	$/seedling	0.25	$/seedling
Fertilizer	Mid-rotation (years 2 and 10)	247	$/ha	99.96	$/ac
Herbicide	Mid-rotation (years 1 and 9)	124	$/ha	50.18	$/ac
Management	Yearly	25	$/ha	9.98	$/ac
Growth rate	Yearly	30	ton/ha/year	12	tons/ac/year
Discount rate		0.08	-	0.08	-
Harvest age		8	years	8	years

[5] The percentage change (-17 percent) is roughly consistent with the 12 percent drop in cropland area reported for the entirety of these seven states by the NRI for 1997-2007 (NRI 2011).

Returns to Eucalyptus management

To estimate returns to *Eucalyptus* management we start by assuming removals will be sold in a hardwood pulpwood market and simulate management using a 16 year management regime (based on Gonzalez et al. 2011, Dougherty and Wright 2012). Conversion costs include mechanical and chemical site preparation, seedlings, and planting. An initial harvest occurs at age 8 followed by coppice regeneration and a final harvest at age 16. Management costs include fertilization applied at year 2 and at year 10, herbicide treatments at years 1 and 9, and annual management costs (generally consistent with management regimes described in Dougherty and Wright 2012). All cost estimates are shown in Table 1. Revenues depend on biophysical production and prices. FT-*Eucalyptus* productivity is uncertain, so we consider three different levels of productivity based on the published literature (see Table 2). We define a baseline level of expected productivity (mean annual increment) as 12 green tons/acre/yr and examine returns at 8 and 16 green tons/acre/year as lower and upper cases.

Table 2. Estimates of *Eucalyptus* productivity from various published studies.

Author	**Region**	**Productivity (Green tons $ac^{-1}yr^{-1}$)**	**Methods**
Dougherty And Wright (2012)	Southern United States	High: 15[1] Medium: 11 Low: 8	Assumption
Gonzalez et al. (2011)	Southern United States	Range for pulpwood management: 8-16 Range for energy crops: 10-18	Assumption
Kline and Coleman (2010)	Southeastern United States	Range: 8-11 Most likely: 9.8	Survey of forest industry experts
Stape et al. (2010)	Brazil	Average (current silviculture): 11[1] Irrigated: 14 Maximum: 19	Measured plots across 1000+km gradient
Langholtz et al.	Central Florida	Range: 15-28[1]	Model fit to field trial data

1- Converted from Mg ha^{-1} yr^{-1} assuming 1.1023 tons/Mg and 2.47 acres/ha.

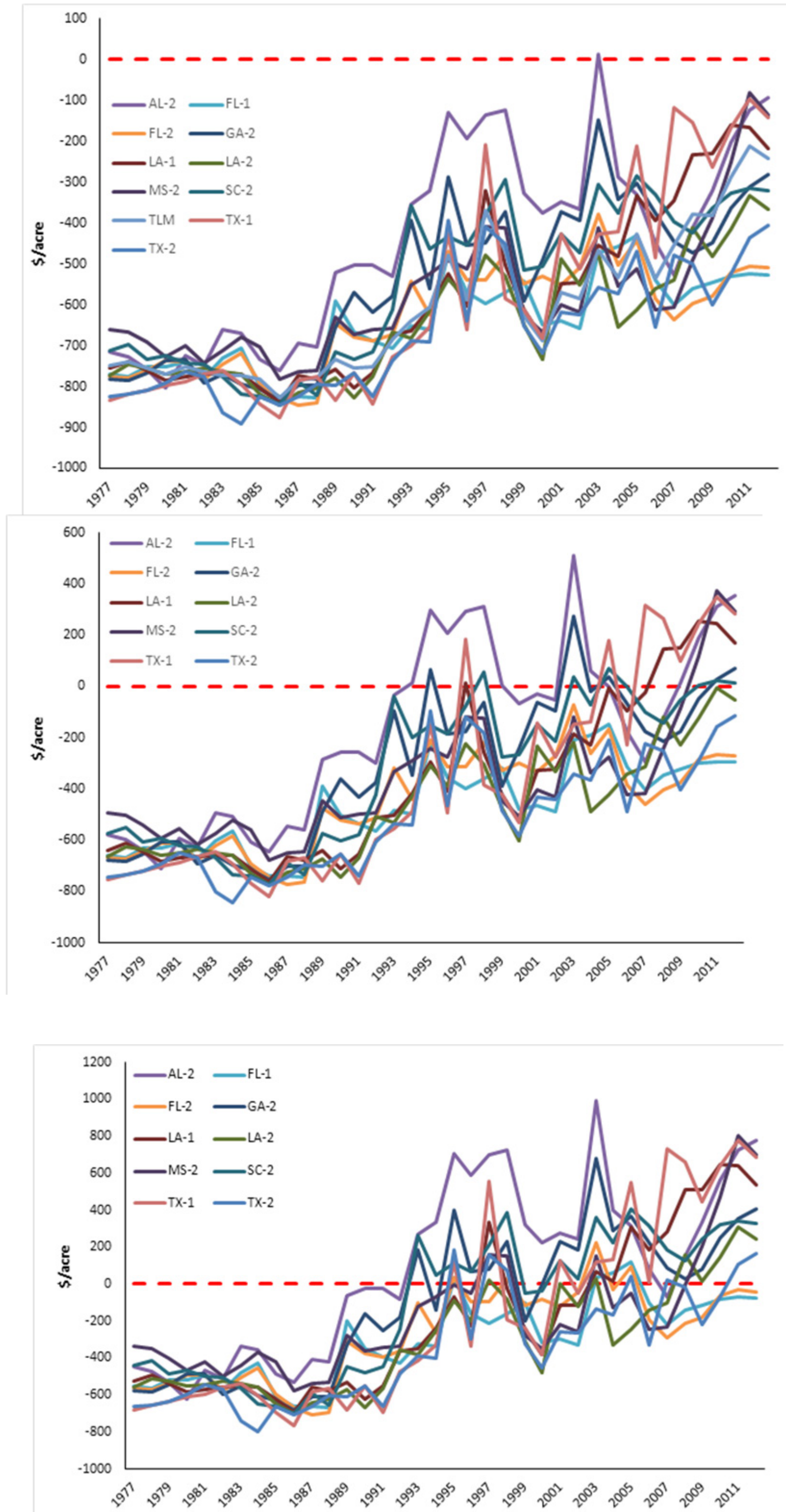


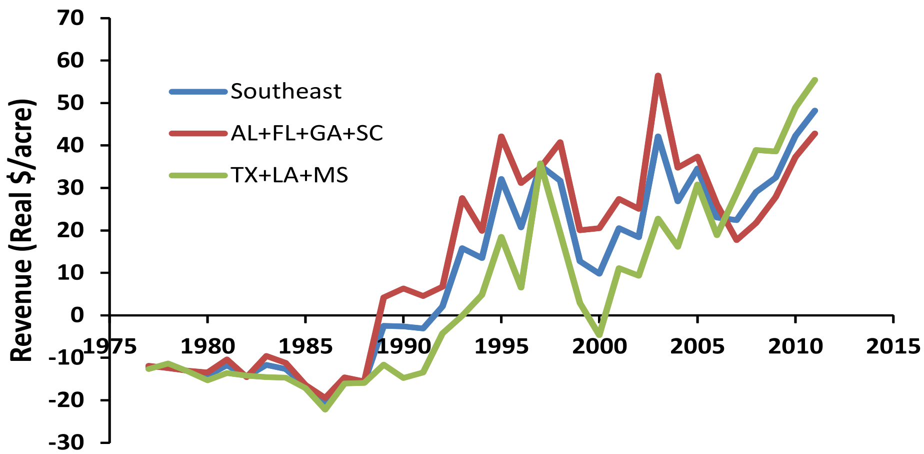
Figure 6. Implied bareland values for Eucalyptus management with a pulpwood management regime for (A) low, (B) baseline, and (C) high productivity scenarios, by Timber Mart-South zones within States, 1977-2012 (for example AL-2 refers to TMS zone 2 in the State of Alabama; see figure 3A for a map of zones).

Throughout this study we adopt a discount rate of 8 percent.

To simulate what the returns to the *Eucalyptus* management regime would have been over the historical period, we apply historical hardwood pulpwood prices to *Eucalyptus* output and calculate the net present value of perpetual management of *Eucalyptus* using the cost and revenue components described above.[6] This is the bareland value (BLV) for *Eucalyptus* management. Figure 6 shows the inferred *Eucalyptus* BLV for each subregion between 1977 and 2011. Reflecting a sustained growth in hardwood pulpwood prices over this period, *Eucalyptus* BLV increased from exclusively negative values between 1977 and the early 1990s to strongly positive values in the latter part of the series (2005-2011). Values are highly variable across the region ($173-$698/acre in 2011) with the highest values in 2011 found in the western part of the region (Texas, Mississippi, and Louisiana) and lowest values found in Florida. The ranking of values by State have not been constant over time.

We also constructed an annualized return series based on the discounted cash flow described above, excluding the conversion costs (initial site prep and planting), which are incorporated directly in the switching decision. The annualized return series is used to construct the stochastic returns. Consistent with the BLV estimates, annualized returns to *Eucalyptus* have trended upward since the late 1980s. In 2011, they ranged from between $16/acre and $66/acre across the subregions with an average return of about $48 for the entire region (Figure 7).

[6] An OLS regression between net annual revenues and hardwood pulpwood prices was developed using revenue estimates generated for a sequence of hardwood pulpwood prices between minimum and maximum historical values. These are forward looking NPV estimates and define return expectations for landowners.



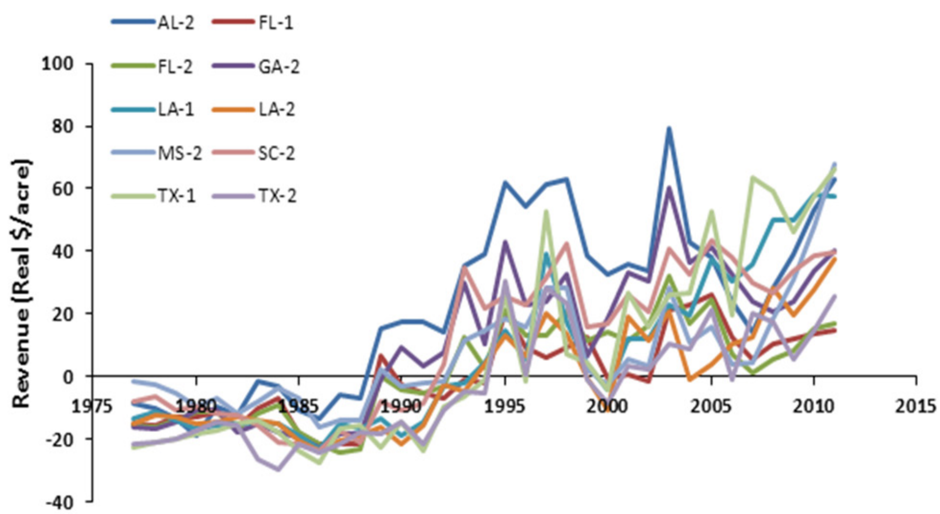


Figure 7. Returns estimates for Eucalyptus management, pulpwood management regime for baseline productivity (a) by by Timber Mart-South zones within States, 1977-2012 (for example AL-2 refers to TMS zone 2 in the State of Alabama; see figure 3A for a map of zones and (b) for regional averages (1977-2012).

Returns to pine management

Jones et al. 2010 conducted a financial analysis of intensive loblolly pine plantation management and our pine plantation management regime is based on their work. To obtain yield by product class, we reproduced a portion of their study using the simulation model LobDSS. Table 3A lists all of the management activities and costs. Regional averages of annual management costs and herbaceous weed control are from Barlow 2011. Table 3B lists the assumed yields by product class by harvest event.

Table 3. Planted pine management regime.

A) Costs and timings:

	Year	Value	Unit	Value	Unit
Mechanical site prep	0	370.65	$/ha	150.00	$/ac
Chemical site prep	0	286.31	$/ha	115.87	$/ac
Planting and seedlings	0	156.66	$/ha	63.40	$/ac
Weed control, banded	0	89.57	$/ha	36.25	$/ac
Weed control, broadcast	1	84.51	$/ha	34.20	$/ac
Fertilizer	1	74.13	$/ha	30.00	$/ac
Management costs	1 - 24	25	$/ha	9.98	$/ac
Discount rate	-	0.08	-	-	-

B) Harvest events and yields:

Event	Year	Pulpwood	CNS	Sawtimber	Unit
First thinning	11	35.5	-	-	Tons/acre
Second thinning	18	7.4	17	-	Tons/acre
Final harvest	24	18	9.4	61.3	Tons/acre

To examine the returns to planted pine over the historical period, we apply this management and cost regime and calculate implied bareland values in each year for the observed pine pulpwood and sawtimber prices. Bareland values (Figure 8) have been positive throughout the region except for five sub-regions in the western part of the region during a short period (1985-1988) and for Texas sub-regions in 1990 and 2009. Bareland values reached peak values in the late 1990s, but then fell substantially between 1998 and 2001 and have trended slightly downward since. The variability of bareland values across sub-regions fell along with the level of values during the latter period. The annualized return series (Figure 9) follows the same pattern. The average bareland values and returns to planted pine were at historically low values between 2009 and 2012.

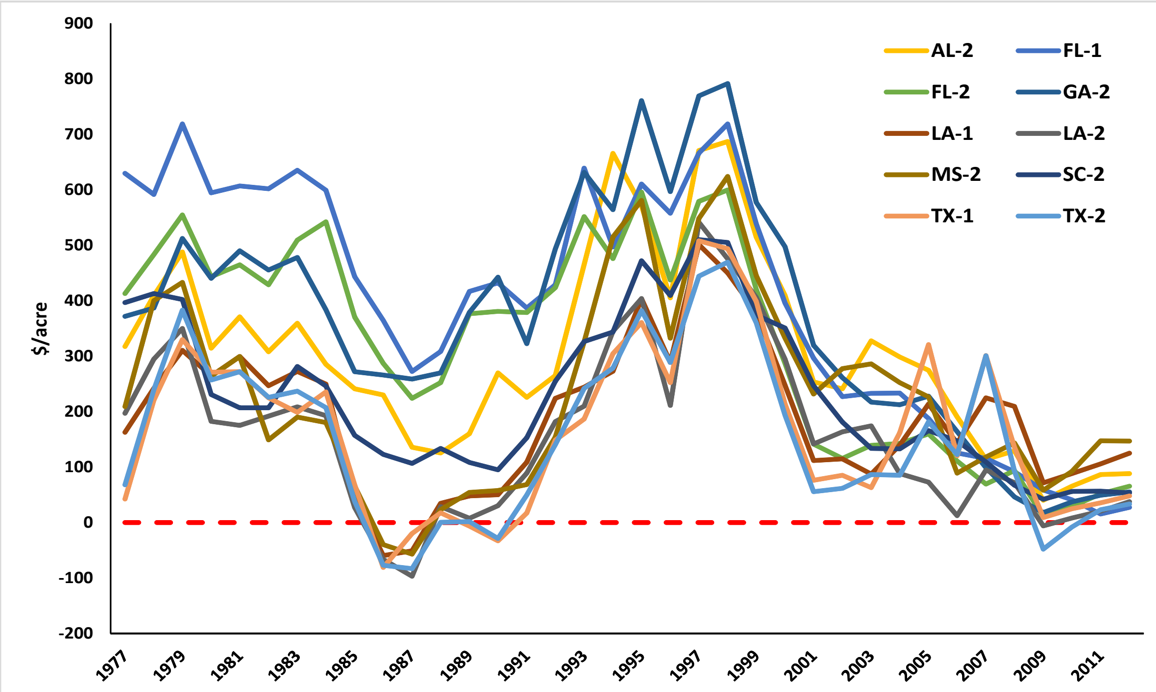
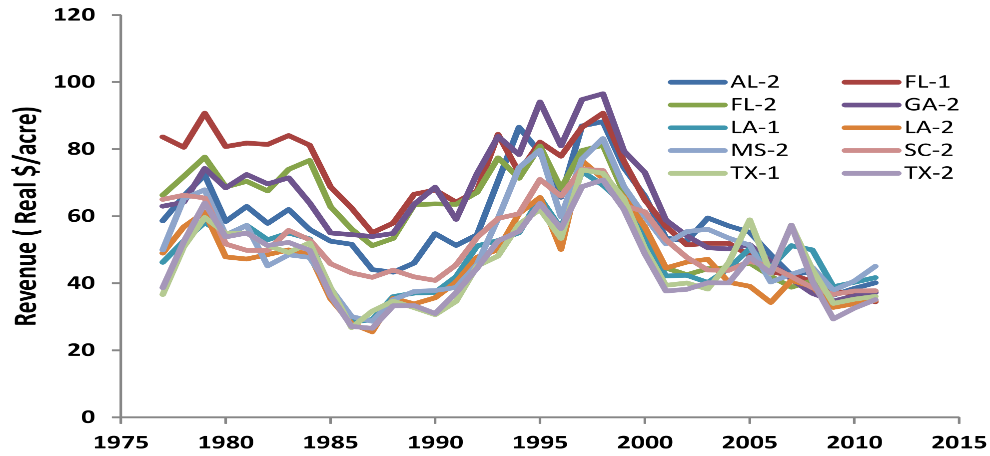


Figure 8. Implied bareland values for planted pine management, pulpwood management regime by Timber Mart-South zones within States, 1977-2012 (for example AL-2 refers to TMS zone 2 in the State of Alabama; see figure 3A for a map of zones).

Returns to cropland management

Returns to individual crops have been quite variable across the regions since the 1970s (see Figure 10 for an example from Alabama). The returns to peanuts for example trended downward between 1977 and 2005, but increased between 2005 and 2011. Returns to all crops have trended upward since 2005 and this is reflected in the returns to the composite crop index for each sub-region (Figure 11). For most regions, the real return to cropland nearly tripled between 2005 and 2011, reflecting increased returns to corn as well as shifts in crop acreages toward corn and other higher valued crops.



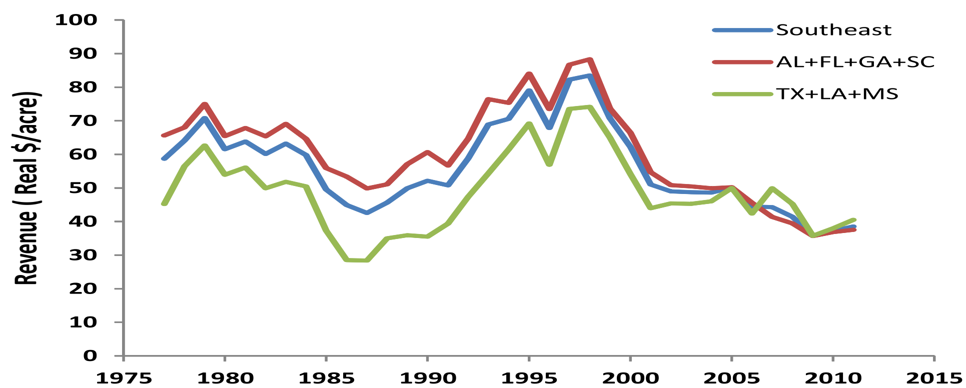


Figure 9. Returns estimates for planted pine management regime (a) by Timber Mart-South zones within States, 1977-2012 (for example AL-2 refers to TMS zone 2 in the State of Alabama; see figure 3A for a map of zones) and (b) for regional averages (1977-2012).

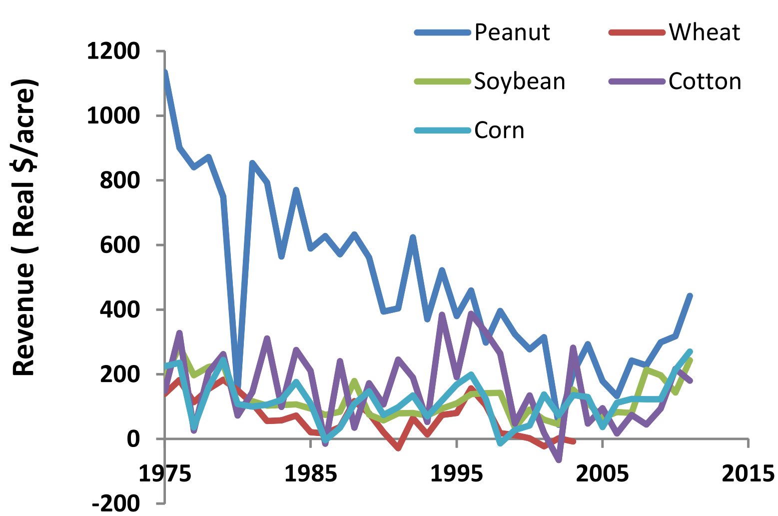
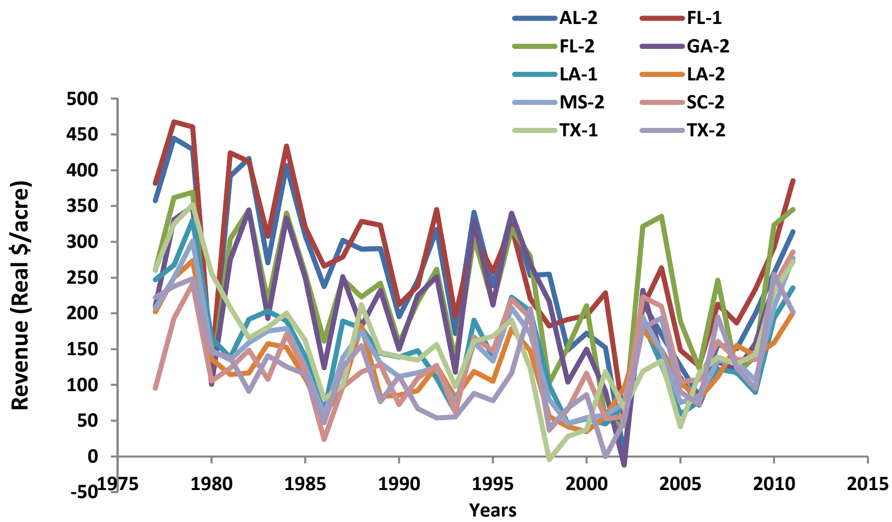


Figure 10. Returns estimates for individual crops (corn, peanuts, cotton, sorghum, wheat) in Alabama.



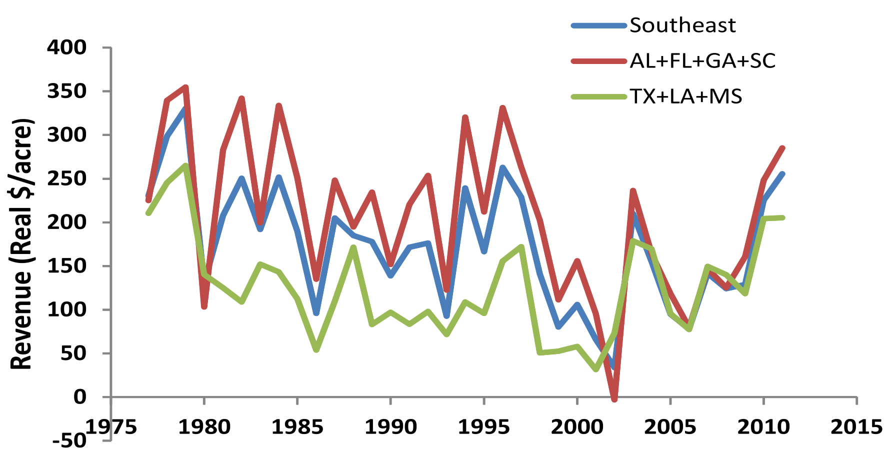


Figure 11. Returns estimates for composite of crops (a) by Timber Mart-South zones within States, 1977-2012 (for example AL-2 refers to TMS zone 2 in the State of Alabama; see figure 3A for a map of zones) and (b) for regional averages (1977-2011).

Return Comparisons

Figure 12 compares annual returns between *Eucalyptus*, planted pine, and crops for the years 1977-2011. Crop returns dominate the other two uses across the time series with the exception of 2003, where returns to crops were slightly less that the annualized returns to planted pine. Returns to pine peaked in the late 1990s and have declined to about $40/acre, while implied returns to *Eucalyptus* have increased over the period, becoming positive in the early 1990s and are now comparable to pine returns (slightly exceeding average returns to pine in the last year of the time series). Returns to pine are linked to the progression of real prices for pine pulpwood, sawtimber, and “chip-n-saw.” Pulpwood prices moved upward from the 1970s through the late 1990s and then dropped substantially, consistent with a strong expansion in pine pulpwood supplies (see Wear and others 2007). Sawtimber prices are generally cyclical and strongly affected by demands from the housing sector—recent declines in returns are strongly influenced by the post-2007 recession. Returns to Eucalyptus are driven by the dynamics of hardwood pulpwood prices and strong price increases are consistent with an overall tightening of hardwood pulpwood supplies (see Wear and others 2007). Because crop returns in 2010 and 2011 were about 5 times higher than both the *Eucalyptus* and pine returns, we assume that land use switching from crops to Eucalyptus would be highly unlikely. We focus exclusively on switching between planted pine and Eucalyptus.

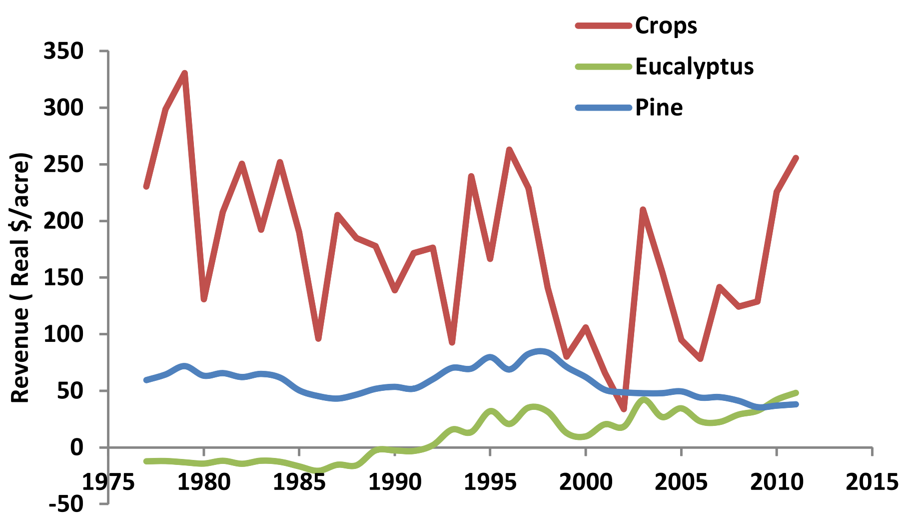


Figure 12. Southeast-wide regional average returns for Eucalyptus, planted pine, and crop composite (1977-2011).

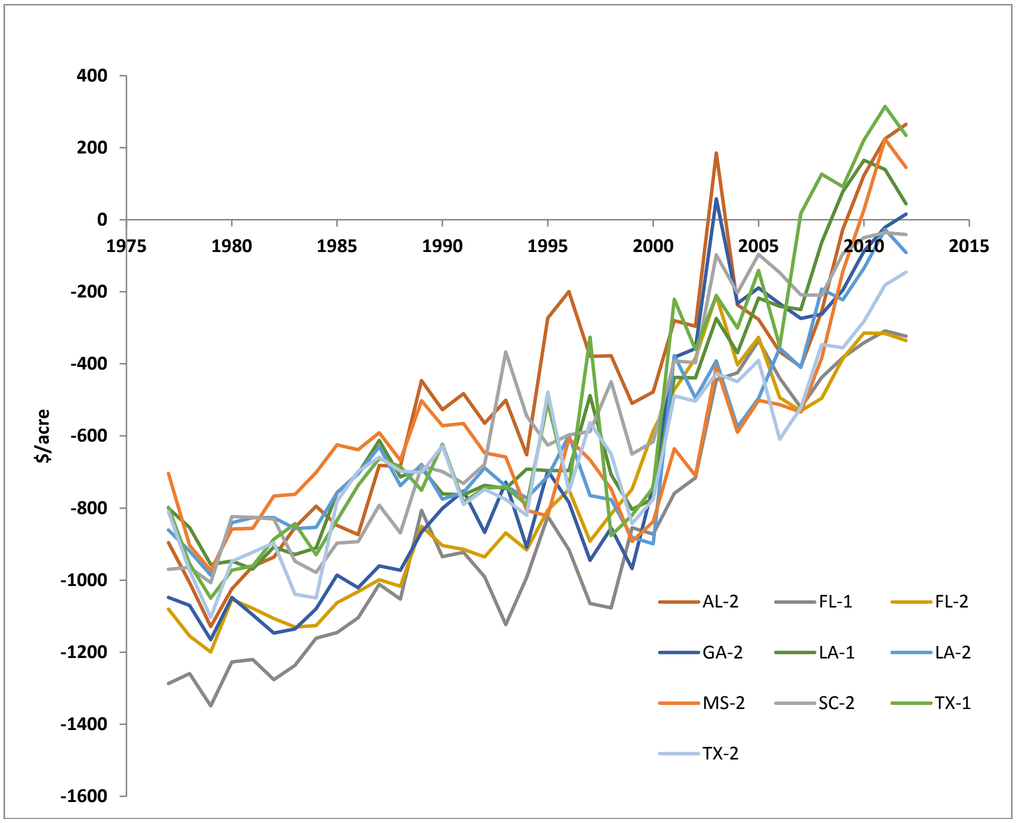


Figure 13. Difference between bareland values for Eucalyptus (base productivity) and planted pine management by Timber Mart-South zones within States, 1977-2012 (for example AL-2 refers to TMS zone 2 in the State of Alabama; see figure 3A for a map of zones).

To examine the possibility of land use switching between *Eucalyptus* and planted pine we first examine the difference between their respective bareland values (Figure 13). The differences have changed from a range of -$1300 to -$800 acre in the 1970s to a range of -$400 to +$200 /acre in 2012 (based on moderate Eucalyptus productivity) again reinforcing the observation that returns to the two technologies have become comparable in the recent past and supporting a careful analysis of potential switching. Note as well that the most positive differences are found for the western part of the study area (Texas, Louisiana, and Mississippi).

Stochastic Return Models

The geometric Brownian motion (GBM) model of returns as described by equation 4,

$$d\pi_i(t) = \alpha_i \pi_i dt + \sigma_i \pi_i dz_i$$

requires estimates of the drift parameter (α) and the variance parameter (σ) for each return series. After discretizing the series and rearranging terms, the parameters can be derived as functions of the first difference of the ln(π) series: $\alpha = m + 0.5s^2$ and $\sigma = s$ where m and s are the mean and standard deviation of the series $\ln(\pi_t) - \ln(\pi_{t-1})$ and ρ defines the simple correlation coefficient between the differenced return series for *Eucalyptus* and the alternative land use. Because the GBM estimates derive from the logarithm of the returns, the parameters are undefined when revenues are negative. In addition, in the context of the switching problem described in equation 7, explosive returns result when the drift parameter exceeds the discount rate (0.08 in this case).

As shown in Figure 7, returns to *Eucalyptus* are negative until the last 10-15 years of the time series (depending on the sub-region) leaving only a short time period over which to calculate the parameters of the GBM. During this period, *Eucalyptus* returns rose steadily to the point where they have converged with pine returns and this is reflected in high drift parameters (ranging from 0.07 to 0.592; Table 4), with a variance parameter ranging from 0.27 to 0.90. In nearly all cases, the growth in *Eucalyptus* returns would exceed the discount rate. In contrast, returns to planted pine exhibited relatively small drift rates ranging from negative (-0.02) to slightly positive (0.008) and fairly consistent variance parameters (from 0.09 to 0.16). The high drift parameters for *Eucalyptus* may indicate (1) a transition period where the scarcity of hardwood products increased substantially and then stabilizes or (2) that the short time series of positive *Eucalyptus* returns does not provide enough information to precisely discern drift from variance from the data.

A mean reverting model described by equation 6 provides a plausible alternative to the GBM for describing stochastic returns:

$$d\pi_i(t) = \eta_i(\bar{\pi}_i - \pi_i)\pi_i dt + \sigma_i \pi_i dz_i$$

where n is the speed of reversion back to the mean (and is expected to be positive), $\bar{\pi}$ is the mean return, and the variance parameter (σ) is directly comparable to the value from the GBM model. Following Dixit and Pindyck (1994), the mean reverting models were estimated in pairwise fashion using seemingly unrelated regression (SUR) model of differenced returns:

$$\pi_{i,t} - \pi_{i,t-1} = a_i + b_i\, \pi_{i,\, t-1} + \sigma_i \epsilon_i, \qquad i = pine,\ eucalyptus \tag{7}$$

Estimates for reversion speed are defined as $\eta_i = -\, b_i$, the long run revenue mean of revenue is defined as $\Pi_i = -\, a_i / b_i$, and σ_i is defined as the standard error of the regression. The model anticipates a positive reversion speed (otherwise the revenue series would be explosive). The correlation coefficients between return series is defined using the cross equation covariance from the SUR estimation. Inspection of product price and return values for forest products indicates a structural break at the end of the 1990s—prior to this time, softwood pulpwood prices grew steadily and afterward dropped substantially. After examining MR models for a variety of time frames, only the post-1999 series provided significant positive reversion speeds across all commodities (Table 5). Model estimates indicate that reversion speeds are higher for *Eucalyptus* than for other commodities—i.e., there is a stronger tendency to return to the mean for Eucalyptus—and the correlation between pine and *Eucalyptus* returns is estimated at 0.17.

Table 5. Estimates of mean-reverting stochastic return processes for *Eucalyptus* versus crop and *Eucalyptus* versus planted pine returns using data for 2000-2011.

	Eucalyptus versus crop composite				**Eucalyptus versus planted pine**			
		Eucalyptus		Crops		Eucalyptus		Pine
Long-run production profit	π_e	32.66	π_c	146.14	π_e	34.15	π_p	39.84
Reverting speed	η_e	0.0467*	η_c	0.021*	η_e	0.036*	η_p	0.0059*
Variance parameter	σ_e	0.40	σ_c	1.48	σ_e	0.404	σ_p	0.064
Correlation parameter	ρ	0.81			ρ	0.17		

* - significant at 5% level.

Table 4. Estimates of parameters of the geometric Brownian Motion (GBM) model of pine and *Eucalyptus* returns by Timber Mart-South zone. Estimates of pine returns are based on the full times series (1977-2012), while estimates for *Eucalyptus* returns are based on the series over the period where returns are positive (1993-2012).

Timber Mart-South zone	Pine Drift term	Pine Variance term	Eucalyptus Drift term	Eucalyptus Variance term	Correlation coefficient
AL2	-0.005	0.102	0.150	0.370	0.610
FL1	-0.020	0.090	0.007	0.432	-0.300
FL2	-0.011	0.095	0.332	0.784	0.480
GA2	-0.009	0.103	0.056	0.309	0.340
LA1	0.008	0.139	0.080	0.267	0.210
LA2	0.005	0.164	0.401	0.454	0.070
MS2	0.007	0.143	0.592	0.895	0.420
SC2	-0.012	0.088	0.024	0.281	0.140
TX1	0.006	0.104	0.074	0.326	0.84
TX2	0.003	0.098	na	na	na
Minimum	-0.020	0.088	0.007	0.267	-0.300
Maximum	0.008	0.164	0.592	0.895	0.840
Mean	-0.004	0.114	0.191	0.458	0.312
Median	-0.005	0.103	0.080	0.370	0.340
Southeast (SE)	-0.007	0.100	0.139	0.494	0.260
TX-LA-MS (TLM)	0.006	0.134	0.191	0.458	0.410
AL-FL-GA-SC (AFGS)	-0.013	0.088	0.049	0.334	0.380

Real options land use switching

To construct the real options model for land use switching using the GBM model, we start with the parameter estimates in Table 4 and modify them to reflect a set of scenarios. We adopt the average estimate of return variance parameter from the estimated models (0.11 for pine and 0.46 for *Eucalyptus*) showing substantially higher return variance for *Eucalyptus*. The drift parameter is set at zero for pine returns assuming that markets have adjusted to the point where plantation returns will no longer drift downward—recall that the estimated mean value for the drift parameter was slightly negative. We assume that *Eucalyptus* returns continue to drift upward but at a more moderate rate of

0.02. The correlation coefficient is set at the mean value for the TMS zones (0.31) reflecting a positive but relatively low correlation between the returns to these two forestry options.

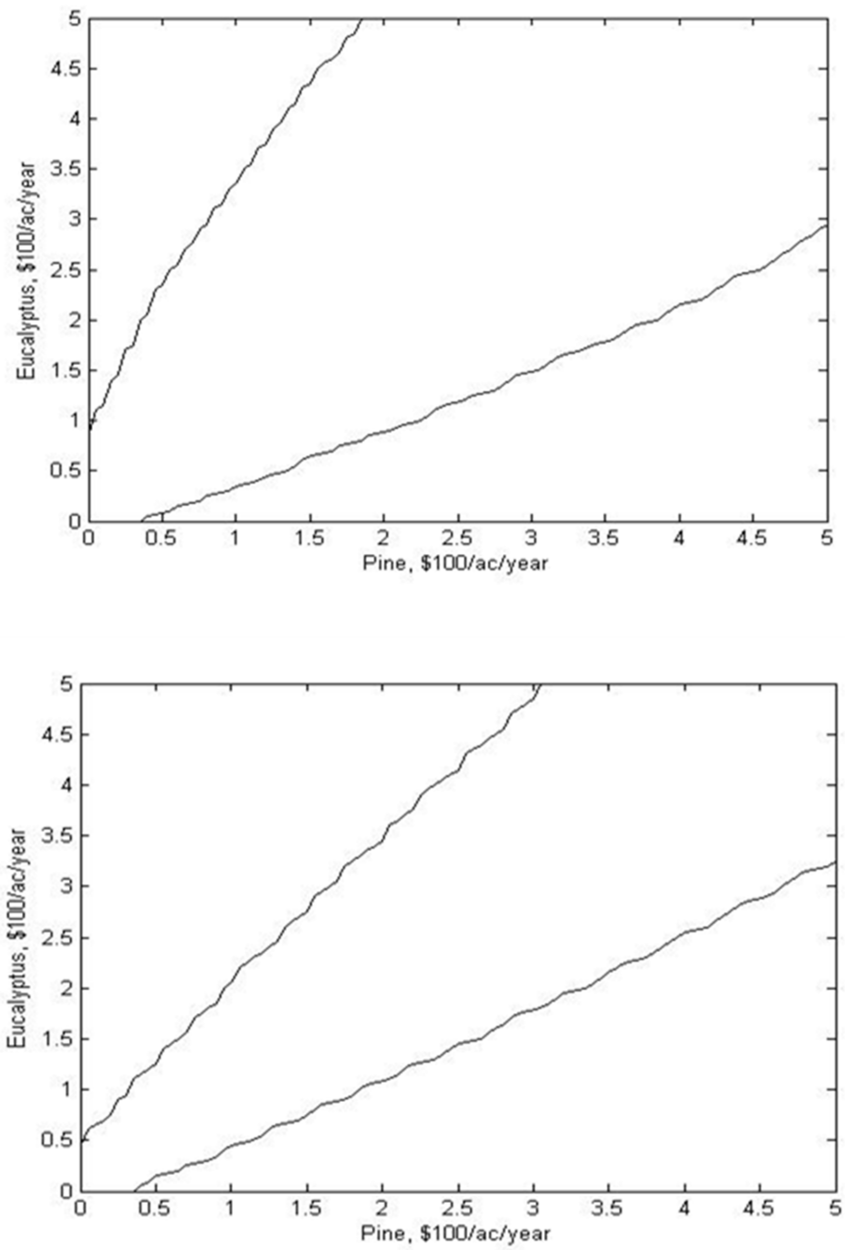


Figure 14. Switching boundaries for Eucalyptus and pine for A) the base model and B) with the variation in Eucalyptus returns reduced by 50%.

The base model, with drift parameters of 0.00 and 0.02 for pine and *Eucalyptus* respectively, yield the switching boundaries displayed in Figure 14A. Landowners are motivated to switch from pine to *Eucalyptus* only where the latter's returns are substantially higher than those for pine (the upper switching boundary in Figure 14A). For example, with pine returns at $50.00/acre, *Eucalyptus* returns would need to exceed about $200.00/acre to result in switching. Hysteresis is clearly indicated with these switching boundaries. For example, if land use switched to *Eucalyptus* at the *Eucalyptus*:Pine return pair of $210:$50, a subsequent reversal of land use would only result if *Eucalyptus* returns fell to nearly zero (Figure 14A). When the return variance term for Eucalyptus is decreased to 0.11 (the value of the pine return variance term), the switching boundaries are much closer as shown in Figure 14B, indicating that higher return certainty would lead to more frequent switching to Eucalyptus.

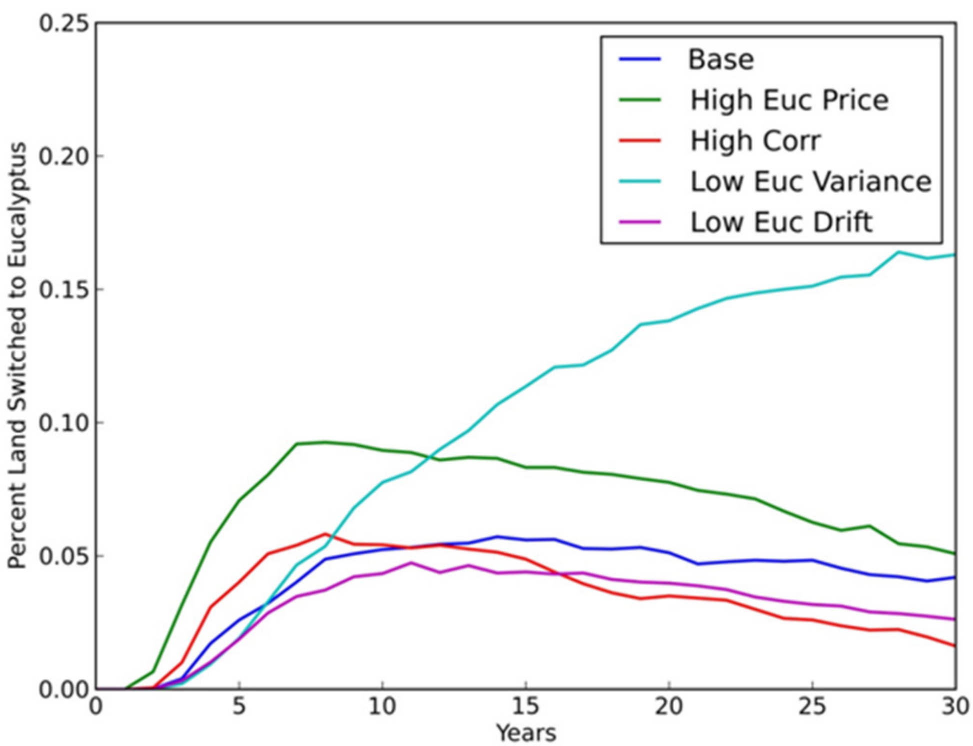


Figure 15. Projected proportion of planted pine land that switches to Eucalyptus from year 1 through year 30 for several scenarios of the GBM model.

Switching simulations based on 100,000 Monte Carlo simulations of the stochastic return series are played out against the switching boundaries in Figure 14A and land use switches are recorded for each realization. A summary of switching for all 100,000 realizations yields the proportion of land managed for *Eucalyptus* at each time step. We constructed simulations across several alternative GBM models: A) the base case described above, B) higher initial returns for *Eucalyptus consistent with the* high Eucalyptus productivity case shown in Figure 6, C) increased correlation between *Eucalyptus* and planted pine returns, D) reduced variance term for *Eucalyptus* returns (equal to the variance term for planted pine), and E) a 50 percent reduction in the drift term for *Eucalyptus* returns (0.01). Cases A and B can be simulated based on the switching boundaries from the base model while cases C, D, and E require estimating alternative models (i.e., parameters of the switching model are altered by these scenarios). *Eucalyptus* proportion of the planted pine area is shown in Figure 15, while total area

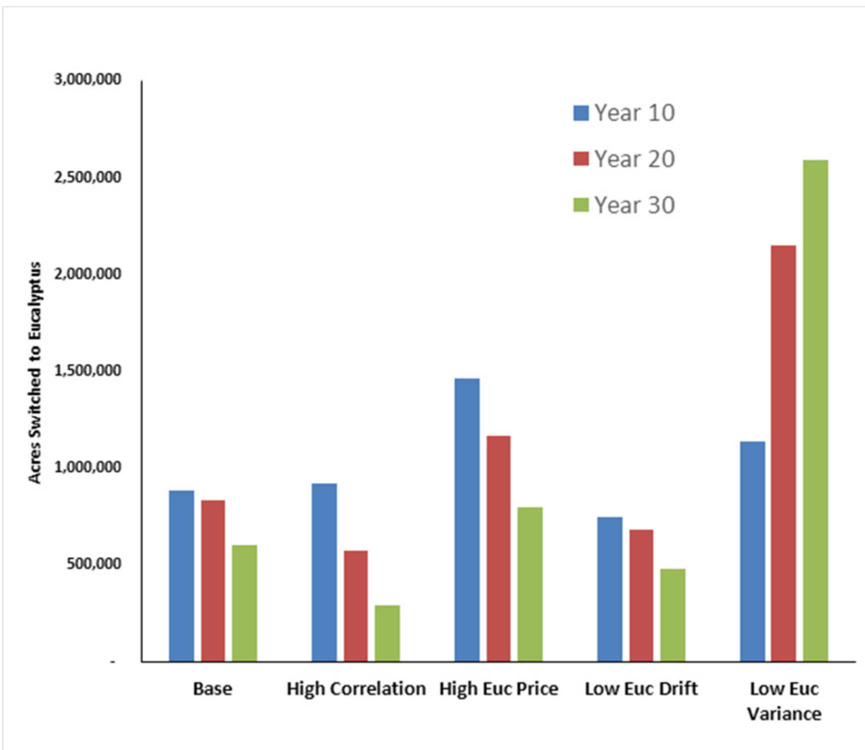


Figure 16. Projected area of Eucalyptus plantations by GBM scenario: a) base, b) higher initial returns for Eucalyptus, c) increased correlation between Eucalyptus and planted pine returns, d) reduced variance term for Eucalyptus returns (equal to variance term for planted pine), and e) 50 percent reduced drift term for Eucalyptus returns.

converted is shown in Figure 16 for these five scenarios.

Switching results, summarized in Figure 15, show that for the base case (Scenario A), the area of *Eucalyptus* grows steadily to about 5 percent of planted pine area in year 10 (2022) and remains between 4 and 5 percent through year 30 (2042). The percentage of *Eucalyptus* remains low in spite of the upward drift in returns. The low percentage reflects the high upper switching boundary in Figure 14A which reflects the high return variance associated with *Eucalyptus*. With a higher starting price for *Eucalyptus* (Scenario B), switching occurs earlier in the time series, peaks at about 10 percent at year 8 and then drifts back toward levels simulated under the base case. Higher early adoption reflects the higher likelihood of observing price pairs above the upper switching boundary but the higher return variance for *Eucalyptus* dominates over time. A higher correlation between the two return series (Scenario C) causes simulated price pairs to be closer to the 45 degree line in Figure 14A, thereby reducing the probability of price pairs being outside the switching boundaries. By year 30, only about 2 percent of pine land is planted in *Eucalyptus* under this scenario. Lowering the variance term for the *Eucalyptus* returns (Scenario D) results in a strong upward trend in the area of *Eucalyptus*, exceeding 15 percent by year 30. Recalling that *Eucalyptus* is modeled with a positive drift term (0.02) while the pine trend term is set to zero, lowering the variance term for *Eucalyptus* returns allows the trend—i.e., an increasing spread between *Eucalyptus* and pine returns—to be more dominant in the projected return series, resulting in an increasing rate of land use switching. Reducing the drift term by 50 percent lowers adoption of *Eucalyptus* by about 20 percent.

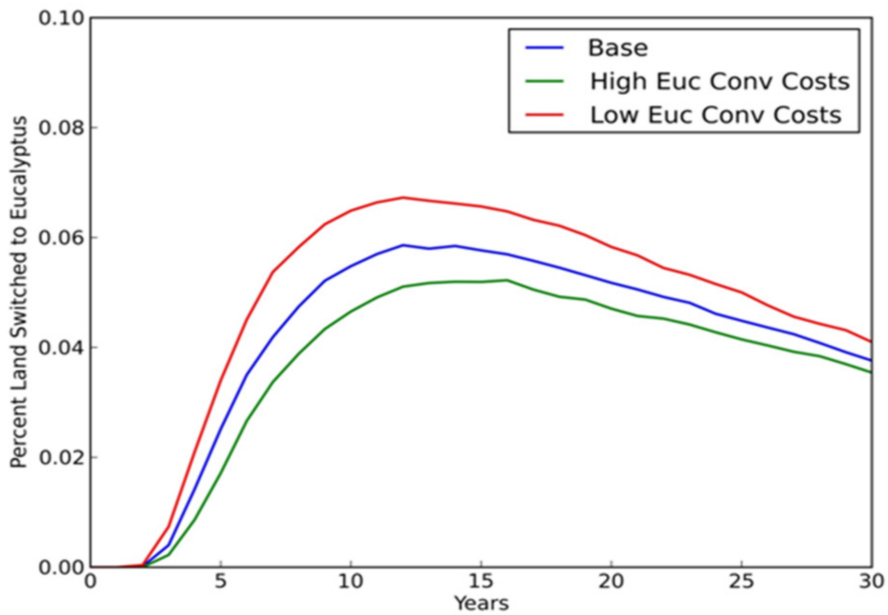


Figure 17. Projected proportion of planted pine land that switches to Eucalyptus from year 1 through year 30 using the GBM model for the Base scenario, a case with 25 percent higher conversion costs, and a case with 25 percent lower conversion costs.

To explore the sensitivity of the projections to conversion costs we rerun the base model for cases where Eucalyptus conversion costs are 25 percent higher or lower. The results indicate an inelastic response to conversion costs (see Figure 17) but do demonstrate that the costs of FT-Eucalyptus seedlings would influence the area of plantations. To examine differences across space we apply the regional models to prices observed in each of the ten Timber Mart-South zones. The resulting switching proportions (Figure 18) range from less than 2 percent in Florida zones and to a high of 7-10 percent for Alabama, Mississippi, Louisiana, and Texas zones.

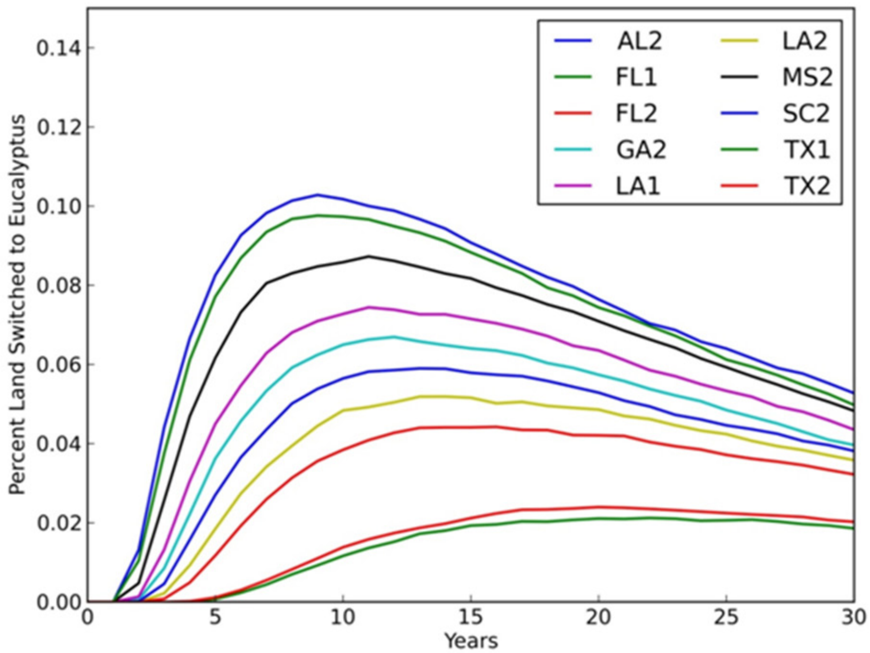


Figure 18. Projected proportion of planted pine land that switches to Eucalyptus from year 1 through year 30 by Timber Mart-South zones within States, 1977-2012 (for example AL-2 refers to TMS zone 2 in the State of Alabama; see figure 3A for a map of zones), using the GBM base model with TMS specific starting returns.

We also simulated switching with the mean reverting (MR) model, first using the base case defined by parameters in Table 5 and then for a set of model variants. Switching behavior is much less variable with the MR model (Figure 19). Using average return values (pine= $40 and Eucalyptus=$34) and parameters from Table 5, about 9 percent of planted pine area converts to Eucalyptus and this proportion is maintained throughout the simulation period. When the Eucalyptus average return is increased to $40 (the same as for pine), about 30 percent of the planted pine forest area switches to Eucalyptus. Model variants with higher return correlations do not lead to substantial departures from the Base MR model in terms of total area converted.

A mapping of potential adoption which is based on the conversion proportions from the GBM

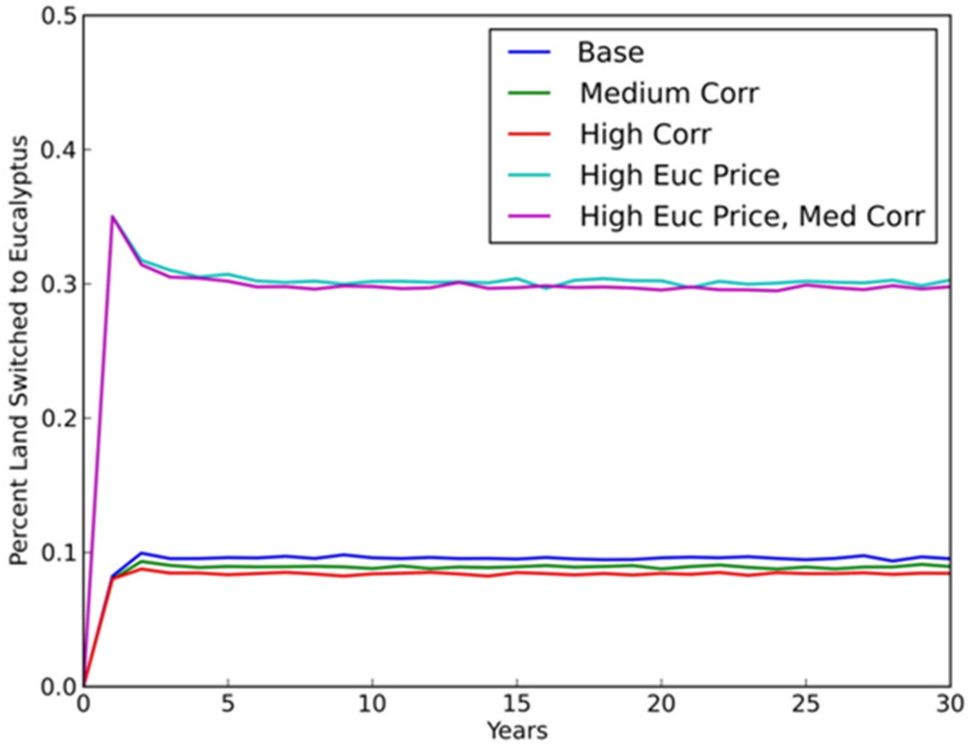


Figure 19. Projected proportion of planted pine land that switches to Eucalyptus from year 1 through year 30 for several scenarios of the mean reverting model.

switching model and the current distribution of prices and land uses (see Figure 18) indicates that conditions are most favorable for Eucalyptus in the western part of the study area Figure 20. The projected area of Eucalyptus exceeds 20 thousand acres for several counties stretching from coastal Alabama through Louisiana. Another area of high adoption is projected for the upper coastal plain in Georgia.

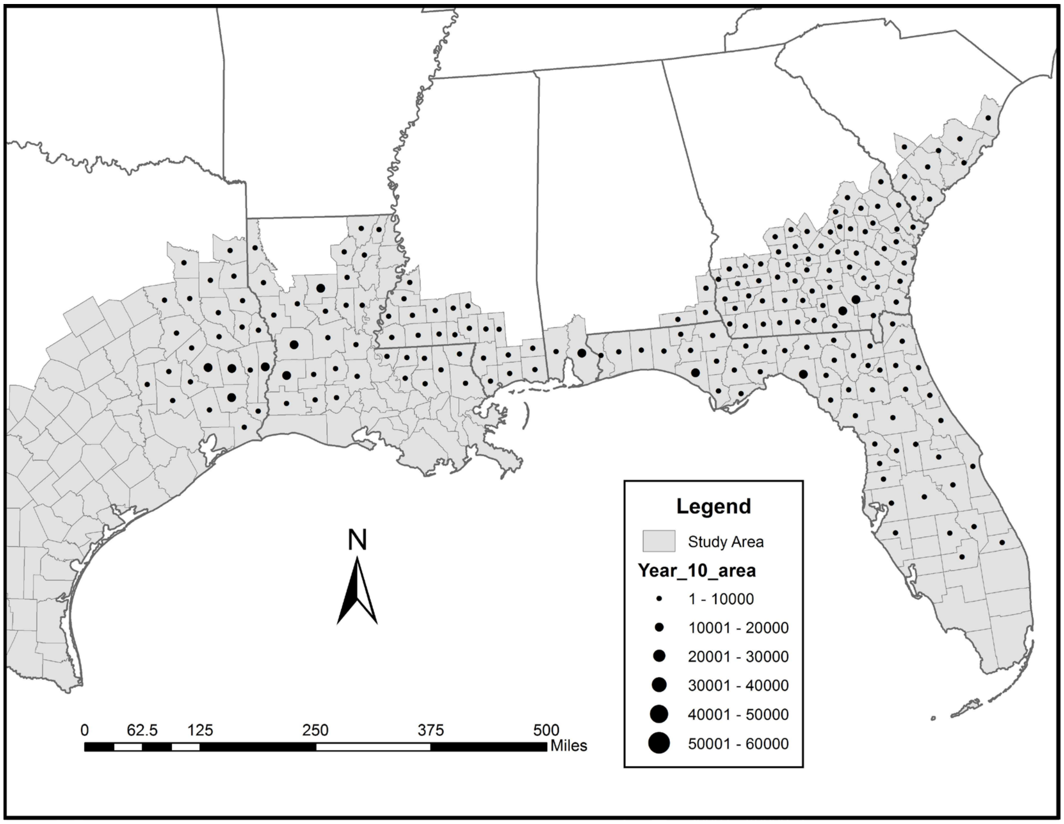


Figure 20. Forecasted area of Eucalyptus in the southeastern United States at year 10 using the Base GBM model and separate starting returns of each Timber Mart-South region.

Discussion and Conclusions

Our analysis of returns to *Eucalyptus* and other rural land uses indicates a potential for the commercial adoption of freeze-tolerant *Eucalyptus* in the southeastern United States. A comparison of bareland values indicates that FT-*Eucalyptus* could provide comparable returns to planted pine forests especially in the western part of the southeast (Texas, Louisiana, and Mississippi). This competitive position derives from strong growth in real hardwood pulpwood prices over the past two decades. In contrast, high returns to cropland would generally preclude transition to *Eucalyptus*—current crop returns currently exceed *Eucalyptus* returns by an order of 3-5 times.

While hardwood prices and returns to *Eucalyptus* plantations have grown, real softwood pulpwood prices and returns to pine plantations declined from peak levels in the late 1990s and have leveled off where returns to the two uses are comparable. A choice to convert from pine to *Eucalyptus* would depend on these return comparisons but also on the conversion costs and the return risk associated with the two land uses. The implied return variance for Eucalyptus has been higher than for pine and our real options analysis indicates that land use switching estimates are sensitive to the model used to describe these stochastic returns series.

Simulations based on the geometric Brownian motion (GBM) model, which allows for a continued upward drift in Eucalyptus returns, results in a conversion of about 5 percent of planted pine forest area (about 0.8 million acres) to Eucalyptus in year 30. Reflecting differences in its formulation, the mean reverting (MR) model generates different projections--for the base case, about 9 percent of planted pine area would switch to Eucalyptus (roughly 1.4 million acres). The MR model defines a higher degree of certainty regarding the range of future returns and this is reflected in the higher rates of land use switching over time. Variants of both models indicate that adoption of Eucalyptus is sensitive to return variance—lowering return variance parameters for Eucalyptus strongly increases adoption, especially with the GBM formulation—but is less sensitive to estimates of return correlations between pine and Eucalyptus.

How should these results be interpreted in terms of plausible future conditions? First, our analysis indicates that Eucalyptus is potentially competitive with planted pine management over a range of future conditions. Results further indicate that while Eucalyptus may be competitive in terms of expected returns, return variance and conversion costs will limit the degree to which land is actually converted. Our two empirical models which simulate future returns under base case conditions, project between 0.8 million acres (the GBM model) and 1.4 million acres (the MR model) of Eucalyptus in year 30. The GBM base model describes a case where returns to Eucalyptus drift upward while returns to planted pine follow a random walk, consistent with a future where the demand for hardwood material continued to grow relative to supply (i.e., hardwood scarcity increased). This could be consistent with a scenario where mild expansion in demands for bioenergy feedstocks steadily increased the demand for hardwoods. However, under such a scenario, we might also expect the return variance for hardwoods to decrease as demand strengthened. If this were the case, then a more substantial switching to Eucalyptus could result. This is clearly demonstrated in the variant of the GBM model where the return variance for Eucalyptus is reduced by 50 percent w doubling of the projected area of Eucalyptus. These and other variants of the models that adjust starting prices and variance indicate that conceivable shifts in key market parameters could lead to strong shifts in land use outcomes.

Our analysis assumes that forest areas likely to switch would be limited to the current area of planted pine because this is the portion of the region's forests that has demonstrated economic feasibility for tree plantations. This is likely to be a conservative estimate of available area. If we assumed instead that the eligible area also included the area of naturally regenerated pine—Wear and others (2013) find high probabilities of planting following harvests of this forest type—then the total eligible area would shift from about 16 million acres to about 27 million acres. Applying the proportion of switching from our two base models would shift the projected area of adoption from a range of 0.8-1.4 million acres to between 1.35 and 2.75 million acres.

The analysis is based on several assumptions about market futures and risk. One especially important assumption is that the freeze tolerance conferred by the FT-*Eucalyptus* will be successful in preventing substantial freeze damage to planted trees within the study area (plant hardiness zone 8b and higher). Mortality and productivity are however important stochastic elements of overall return estimates which would influence return risk. In general, higher return variance would reduce adoption of Eucalyptus as demonstrated by our sensitivity analyses. In addition, this study assumes that productivity is essentially uniform across the southeastern United States. This seems appropriate given the lack of data regarding these factors, but incorporating location specific productivity and damage functions could provide additional insights into the likely location of future Eucalyptus plantations. Another unknown is the actual cost of the FT-*Eucalyptus* seedlings. According to our analysis, the conversion costs between land uses could have an appreciable impact on the area that would ultimately switch. An additional source of risk and one that extends beyond the scope of this study, is the risk of some public backlash against the planting of genetically modified trees. This societal risk could affect investment choices in the same fashion as biophysical risk—i.e., increased risk would reduce the rate of adoption.

While our projections are not meant to be precise predictions of the area of Eucalyptus adoption, they do demonstrate that under current conditions, a risk-neutral and profit maximizing land owner could choose to adopt Eucalyptus as a preferred land use. The extent of that adoption will depend on the future of market prices for various timber products, including new bioenergy products, and on the demonstrated productivity and certainty of production from available Eucalyptus seedlings. It is important to note that this work is based on the assumption that the behavior of returns for each of the land uses will remain unchanged into the future and that we did not explicitly address the effects of shifting timber supply on future market equilibrium.

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Appendix. Key Assumptions and Uncertainties

This study represents a normative simulation analysis of potential land owner behavior and depends on a set of critical assumptions. Most fundamental is the set of behavioral assumptions behind the analysis. That is we assume that private landowners behave as maximizing entities. To quote from the theory section: "Our switching model anticipates that a risk-neutral decision maker chooses between retaining a current land use or (reversibly) adopting a new land use (Eucalyptus) based on a comparison of returns, conversion costs, and uncertainty regarding future returns." Intertemporal value comparisons depend on time preferences which we approximate with a discount rate set at 8 percent.

The analysis of land use data requires processing a large amount of data, often with incongruent boundaries. Nearly all land use and production data were organized by counties. We considered counties to be a part of plant hardiness zone 8B and higher if a majority of their land area was within the zonal boundary. What's more our restriction of the study area based on the environmental range of *Eucalyptus grandis* represents an important assumption and source of uncertainty. The relationship between environmental variables and productivity and commercial viability for the modified hybrid is not fully knowable prior to field experience.

Our analysis also assumes that the forest land base that would be plausible for transition to Eucalyptus is limited to planted pine. This is based on the assumption that these lands have already been selected or deemed suitable for intensive forest management. The managed condition of these forests also defines lower conversion costs compared to those associated with naturally regenerated forests. Analysis by Wear et al (2013) also indicates that rates of tree planting following harvest are very high for natural pine in this region but are low for upland and lowland hardwoods. Accordingly we explore the possibility that naturally regenerated pine could be a source in the future (see Conclusions) but do not consider hardwoods as a potential source based on current and anticipated economics. This set of assumptions deserves further study.

The analysis is also based on several assumptions about market futures and risk. One especially important assumption is that the freeze tolerance conferred by the FT-Eucalyptus will be successful in preventing substantial freeze damage to planted trees within the study area (plant hardiness zone 8b and higher). Mortality and productivity are however important stochastic elements of overall return estimates which would influence return risk. In general, higher return variance would reduce adoption of Eucalyptus as demonstrated by our sensitivity analyses. In addition, this study assumes that productivity is essentially uniform across the southeastern United States. This is a necessary assumption given the lack of data regarding these factors in the southeastern U.S., but incorporating location specific productivity and damage functions could provide additional insights into the likely location of future Eucalyptus plantations. Another unknown is the actual cost of the FT-Eucalyptus seedlings. According to our analysis, the conversion costs between land uses could have an appreciable impact on the area that would ultimately switch. An additional source of risk that extends beyond the scope of this study is the risk of some public backlash against the planting of genetically modified trees. This societal risk could affect investment choices in the same fashion as biophysical risk—i.e., increased risk would reduce the rate of adoption.

ArborGen, Inc. Petition (11-019-01p) for Determination of Non-regulated Status for Freeze Tolerant Eucalyptus Lines FTE 427 and FTE 435

Draft Environmental Impact Statement, April, 2017

Appendix C: USDA-FS Technical Report on the Potential Impacts to Hydrology from Freeze-Tolerant Eucalyptus

See Attached: Vose, J.M., Miniat, C., Sun, G., and Caldwell, P. Implications for Expansion of GE Freeze-Tolerant Eucalyptus Plantations on Water Resources in the Continental U.S.

Implications for Expansion of GE Freeze-Tolerant Eucalyptus Plantations on Water Resources in the Continental U.S.

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Abstract

The potential expansion of freeze-tolerant (FT) *Eucalyptus* plantations in the U.S. has raised questions about the implications for a variety of environmental and biological factors including fire risk, biodiversity, and water resources. Concerns about the effects of *Eucalyptus* plantations on water resources are based on numerous studies of evapotranspiration (ET = transpiration + interception evaporation) and stand level water balance (*Q* = precipitation – ET, where a positive *Q* results in streamflow and/or groundwater recharge) from across the world. We used a modeling approach to assess the potential implications of expanding the distribution of FT *Eucalyptus* plantations in plant hardiness zones 8b and greater on water balance (*Q*) and the resulting impacts on groundwater recharge. We focused our analyses at two scales: the local scale (or stand level) and the 12-digit Hydrologic Unit Code (HUC) watershed scale. Quantifying ET and *Q* required a modeling approach because to our knowledge, no data quantifying ET or streamflow changes from planting FT Eucalyptus are available. Our simulations indicated that the stand-level implications of planting FT *Eucalyptus* on *Q* could vary by location, the land cover type prior to *Eucalyptus* establishment, and the hydrological conditions of the planting site and surrounding area. Stand water budgets indicated that contributions to streamflow/recharge could be equal to or reduced by as much as to 180 mm yr^{-1} (relative to conifer forests) near the end of the rotation or on sites when leaf area index (LAI)LAI = 4 and reduced by as much as 300 mm yr^{-1} when LAI = 5. The implications for these reductions in streamflow or groundwater recharge depend on the hydrologic setting and the amount of land area planted in FT *Eucalyptus*. Conditions that could result in a substantial negative impact at the local scale would include: (1) planting in areas where precipitation (*P*) is limited or where dry years are likely, (2) planting in areas where the ratio of *P*/potential ET is low, and (3) planting in headwater areas or planting large acreages in close proximity to streams that have low annual baseflow. In contrast, at the scale of conversion indicated by an economic analysis (e.g., <20% conversion of conifer cover to FT *Eucalyptus*), our analysis suggests that the impacts on either *Q*, percent change in *Q*, or groundwater recharge at the scale of the 12-digit HUC will be negligible.

Introduction

Expansion of *Eucalyptus* plantations offers great potential for increasing wood-fiber production in the United States. The range of suitable environmental conditions, especially air temperature below freezing, has limited the extent of *Eucalyptus* primarily to central and southern Florida. The development of more freeze-tolerant (FT) *Eucalyptus* through genetic engineering (GE) has the potential to expand the range of GE FT *Eucalyptus* to climate zones 8b and greater (Hinchee *et al.* 2011) (Figure 1). The expansion of FT *Eucalyptus* plantations in the U.S. has raised questions about implications for a variety of environmental and biological factors including fire risk, biodiversity, and water resources (especially, water supply) (Stanturf *et al.* 2013). This analysis focuses on the potential impacts of FT *Eucalyptus* expansion on water resources.

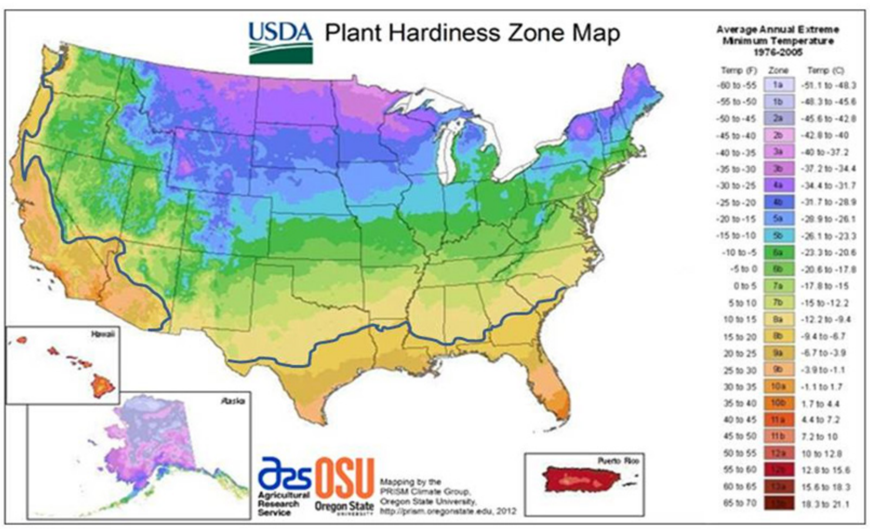


Figure 1. USDA Plant hardiness map. Dark solid line denotes approximate northern limit (zone 8b and greater) for GE FT *Eucalyptus* in the continental United States. Hawaii and Puerto Rico were not included in our analyses as climatic conditions would likely not require planting FT *Eucalyptus* for survival.

Concerns about the effects of *Eucalyptus* plantations on water resources are based on numerous studies of evapotranspiration (ET = transpiration + interception evaporation) and stand water balance from across the world (*e.g*., Farley *et al*. 2005, Ferraz *et al.* 2013, King *et al*. 2013); however, to our knowledge, no published studies have been conducted in the southern U.S. Based on these international studies, it is well accepted that *Eucalyptus* has among the highest ET rates of tree species (Whitehead and Beadle 2004, Farley *et al*. 2005), driven by high stomatal conductance, evergreen leaf habit, physiological characteristics that increase drought tolerance, and rooting characteristics that can exploit deep soil water reserves (Cavaleri and Sack 2008). *Eucalyptus* is also extremely fast growing and has a high water use efficiency (WUE = kg biomass produced/kg water transpired) (Stape *et al*. 2004) even in the fastest growing stands (Binkley 2012). High WUE could offset some of the potential negative impacts of high ET on water resources (King *et al*. 2013); however, this offset would only be realized if less land area was planted relative to species with a lower WUE. Regardless of higher WUE, substantial reductions or elimination of streamflow from greater absolute water use could have detrimental impacts on water resources and associated aquatic ecosystems, especially at local scales.

Assessing the potential impacts of FT *Eucalyptus* on water resources requires an analysis of all of the water budget components at multiple spatial levels. Evaluating water budgets requires quantification of the effects of changes in ET within the context of climate and other site characteristics that regulate soil water availability and storage. In its most basic form, the water budget of a forest watershed can be described as:

Surface Runoff + Groundwater Recharge = Precipitation – Evapotranspiration +/- Soil Water Storage.

At an annual time scale, water balance (Q) of *Eucalyptus* can be estimated as:

$$Q = P - \text{ET} \quad (1)$$

Here, *Q* is an estimate of excess water that goes into streamflow, groundwater recharge, or soil water storage. *Q* is also termed water yield in the hydrology literature and over long time periods (e.g., annual), the net soil water storage term is typically assumed to be zero. Depending on local topography, soils, and the geomorphic setting, a positive *Q* could contribute to streamflow or deep soil water storage and recharge, while a negative water balance implies a cessation of streamflow and groundwater recharge. Expansion of FT *Eucalyptus* plantations would not be expected to impact local *P* or net soil water storage at annual time scales; hence, our focus will be primarily on how changes in ET impact *Q*. As a result, analyses of the potential impacts of FT *Eucalyptus* culture will first require either direct measurements of changes in *Q* (*e.g.,* from gauged watersheds), scaled measurements of transpiration (*e.g.,* sapflow or canopy conductance) and predictions of impacts on *Q*, or modeled estimates of changes in ET and *Q*. For this analysis, we were constrained by a lack of available empirical data for *any* approach to estimating how changes in ET from planting FT *Eucalyptus* affect *Q*. Hence, our results should be considered a first approximation until empirical data are available for direct measurement or better model parameterization.

Three factors require consideration when evaluating the potential impacts of FT *Eucalyptus* on ET or water resources. First, because large-scale *Eucalyptus* plantations are not present over most of the U.S., the context for interpreting changes in ET and *Q* will vary based on what land cover serves as a reference. For example, among alternative forest covers, ET varies considerably, ranging from 480 mm yr^{-1} in hardwoods (Stoy *et al*. 2006) to ~1200 mm yr^{-1} in slash and loblolly pine plantations (Sun *et al*. 2010). Different interpretations of potential impacts are likely when comparing *Eucalyptus* ET to a "high ET" vs. a "low ET" land cover type reference. Second, the relative impact on *Q* depends in large part on the balance between precipitation and ET. Assuming that ET is comparable among areas of high and low precipitation, the *relative impacts* (*i.e.,* as a percentage of flow under reference conditions) of higher ET on *Q* are lower in areas where precipitation is higher (Table 1).

Table 1. Hypothetical example of the influence of annual precipitation levels on absolute *versus* relative impacts of *Eucalyptus* on *Q*.

	Initial Vegetation		*Eucalyptus*		Absolute	Relative
Rainfall (mm)	ET (mm)	*Q* (mm)	ET (mm)	*Q* (mm)	Δ*Q* (mm)	Δ*Q* (%)
1400	600	800	800	600	-200	-25%
1000	600	400	800	200	-200	-50%

Third, potential impacts are scale and location dependent. For example, small (*e.g.*, < 20 ha), infrequent, and well dispersed plantations over a large land area may limit impacts to the local scale, such as first order streams draining the *Eucalyptus* stand, while impacts at larger spatial scales would likely be minor and undetectable. Predicting the configuration of plantations to support end uses (*e.g.,* fiber or bioenergy) is beyond the scope of this analysis; however, factors such as minimizing transportation costs will likely influence the size and spatial distribution of plantations. For example, we would expect a greater concentration of plantations in areas where financial returns are likely to be highest (Wear *et al.* 2013 – APHIS report). Impacts on aquatic species and habitats at the local scale could still be significant, especially if plantations are established in or near areas where aquatic species and habitats are vulnerable to changes in *Q* (*e.g.*, Threatened and Endangered (T&E) species). In contrast, large plantations occupying large land area could have measurable, and perhaps undesirable, impacts at larger spatial scales. In short, the scale and location of *Eucalyptus* plantations is a critical consideration when evaluating potential impacts. Ultimately, business decisions on the size and location of *Eucalyptus* plantations will be driven by a combination of economic (are markets available to provide a return on investment?), technological (are site conditions suitable for using efficient establishment and harvesting technologies?), and environmental (can *Eucalyptus* survive and grow here?), considerations.

Questions Addressed in this Technical Document

1. **What are the potential impacts of FT *Eucalyptus* plantations on overall local stand water balance in areas where it is most likely to be grown?**

    a. How does this vary in space and time (*i.e.,* are some potential planting locations more sensitive than others and how does this change with stand age)?
    b. What are the environmental and biological factors that determine response patterns?
    c. How do reference conditions and climate regimes influence the interpretation of potential impacts?

2. **How does the size and distribution of FT *Eucalyptus* plantations influence impacts on water balance at varying spatial scales (e.g., local *vs*. 12-digit Hydrologic Unit Code (HUC)?**

II. Methods

Question 1 - *What are the potential impacts of FT Eucalyptus plantations on overall local stand water balance in areas where it is most likely to be grown?*

Plantation Scale Impacts on Water Balance

For estimating the plantation scale effects on the local water balance, we used a process-based transpiration model to estimate transpiration (*Ec*), then estimated canopy interception (Ic) to derive total evapotranspiration (ET) by a *Eucalyptus* stand at five locations (Figure 4) representing a range of potential land use changes, adoption rates, and climatic conditions (Table 2). Our expectation was that a detailed process model would provide the best estimate of actual ET. To our knowledge, no physiological data are available for FT *Eucalyptus* so we relied on physiological data and relationships from the published literature. Where possible, we used data for *Eucalyptus grandis* (*e.g.,* Mielke *et al.* 1999). The *Ec* model is based on the physiological processes of leaves in a tall canopy, and can be used to estimate hourly water use by the stand. Model components include:

$$E_c = \frac{1}{\lambda} \cdot \frac{sR_n + \rho c_p D g_a}{s + \gamma(1 + \frac{g_a}{g_c})} \cdot t, \qquad (2)$$

$$1/g_a = \{ln[(z-d)/z_0]\}^2/(k^2u), \qquad (3)$$

$$g_s = -0.024 + 0.00008PPFD - 0.156D + 0.129\Psi_{pd} + 0.016T_a, \qquad (4)$$

$$\Psi_{pd} = 0.33\ (\theta/\theta_{max})^{-0.57} \qquad (5)$$

where, E_c is canopy transpiration (mm hour^{-1}), s is the slope of the saturation vapor pressure curve (mbar °C^{-1}), at air temperature T_a (°C). R_n is average daylight canopy net radiation (W m^{-2}), ρ is air density (kg m^{-3}), γ is the psychometric constant (mbar °C^{-1}), c_p is the specific heat of the air (J kg^{-1} °C^{-1}), D is vapor pressure deficit of the air (mbar), g_a is canopy aerodynamic conductance (m s^{-1}), g_c is canopy conductance to water vapor (m s^{-1}), λ is the latent heat of vaporization of water (J kg^{-1}), and t is the number of seconds in an hour (s $hour^{-1}$). Canopy conductance, g_c, is given by $g_c = g_s$*LAI_{max}*fLAI, where g_s is the stomatal conductance (converted into m s^{-1} units), LAI_{max} is the maximum annual Leaf Area Index (m^2 m^{-2}) for each year of the rotation, and fLAI is the fraction of maximum annual LAI (range 0–1). This latter term changes on a monthly basis and simulates the seasonal dynamics of leaf phenology (described below). The equation for g_s (mol m^{-2} s^{-1}) was taken from Mielke *et al.* (1999), where *PPFD* is photosynthetically active photon flux density (μmol m^{-2} s^{-1}) and Ψ_{PD} is predawn water potential (MPa) estimated from the ratio of soil moisture content (θ, % v/v) and maximum annual soil moisture content (θ_{max}, % v/v). The soil moisture limitation on Ψ_{PD} does not incorporate changes in soil moisture resulting from soil water uptake by *Eucalyptus* tree roots. Instead, θ reflects the net effects of climate, soils, and vegetation in the location of the open-field climate station (described below). Boundary layer conductance (g_a) was fixed at 0.083 m s^{-1}, based on a study by Hatton *et al.* (1992) on *Eucalyptus maculata* trees. The hourly estimates of E_c are then summed for all 24 hours in a day to estimate daily transpiration, summed for all days in a month to estimated monthly transpiration, and summed for all months in a year to estimate annual transpiration.

We applied this model to a hypothetical *Eucalyptus* plantation from initial planting through a full rotation. Maximum leaf area for *Eucalyptus* hybrid plantations is a function of precipitation and tree age and typically ranges from 3–5 m^2 m^{-2} (Stape *et al.* 2004, le Maire *et al.* 2011), although values as high as 8 have been reported in irrigated and fertilized *E. grandis* plantations (Meyers et al. 1976) To model the dynamics associated with a developing stand, we began with an initial LAI = 2 at year one and then incrementally increased LAI by 0.5 m^2m^{-2} per year, until the end of the rotation at age seven when LAI = 5.0. Intra-annual variation in LAI was simulated based on maximum annual LAI and the monthly dynamics of two plantations in Brazil (Hubbard *et al.* 2010).

Climate data used in the *Ec* model were obtained from five open-field climate stations maintained by the Natural Resources Conservation Service (NRCS 2008–2012) as part of the Soil Climate Analysis Network (SCAN, http://www.wcc.nrcs.usda.gov/scan/). Climate data at each station were available for a variable number of years; we used data from five sites across five states that had at 18 months of data available to run the model. Sites were located across the southeastern gulf Coastal Plain in Texas, Alabama, Georgia, Florida, and Mississippi (NRCS SCAN stations 2016, 2180, 2027, 2009, and 2082, respectively) as shown in Figure 4. Data consisted of hourly measurements of standard climate variables (*e.g*., air temperature, relative humidity, solar radiation, wind speed) used to estimate plant water use, as well as soil moisture measured in a vertical array over five depths (depths 2–40 inches) at the climate station. To obtain an upper limit for ET, we also simulated ET without soil moisture constraints on g_s by setting θ to θ_{max} for all time periods; in other words, predawn water potential was always equal to 0.33 MPa (see equations 4–5). This would represent a well-watered soil such as what might occur in areas with high and well distributed rainfall, with irrigation, or where roots have access to groundwater.

To estimate I_C, we used an interception model ($I_C = 0.11*P$) developed for a *E. grandis* hybrid plantation (Soares and Almeida 2001), where *P* is annual precipitation in mm. Evapotranspiration was estimated for all years at each site and a mean for each year of stand development was calculated.

Question 2 - *How does the size and distribution of FT Eucalyptus plantations influence impacts on water balance at larger spatial scales?*

Simulating the Impacts on Water Balance at Larger Spatial Scales

While a process-based model is often a better approach for simulating complex hydrologic processes and estimating actual ET, the intensive data requirements of process-based models preclude this approach at larger spatial scales (such as USDA plant hardiness zone 8b and warmer). Hence, we used a parsimonious large-scale monthly water balance model (WaSSI; Sun *et al*. 2011; Caldwell *et al*., 2012) to evaluate the potential impacts of planting *Eucalyptus* at the larger watershed scale. This model was chosen because of its ease of use and performance in similar applications assessing the implications of changing land cover on water balance. Complete WaSSI model details are available in Sun *et al*. (2011) and Caldwell *et al*. (2012); so, only a brief explanation of the modifications required to use WaSSI to assess *Eucalyptus* ET is presented here.

WaSSI simulates actual ET, soil water storage, water yield, and streamflow at the watershed outlet at a monthly time step. WaSSI predicts ET of various land covers from empirical relationships between actual ET (AET) *vs*. climate variables, stand LAI, and potential ET (PET) (Figure 2). Accurate predictions of AET for the various land uses are a critical component of the overall model; however, no models are available for *Eucalyptus* growing in the southern U.S. Instead, for this evaluation, AET values for *Eucalyptus* were estimated by a revised WaSSI with a *Eucalyptus grandis* specific empirical AET model using data acquired from an eddy covariance study site in Brazil (Cabral *et al*., 2010).

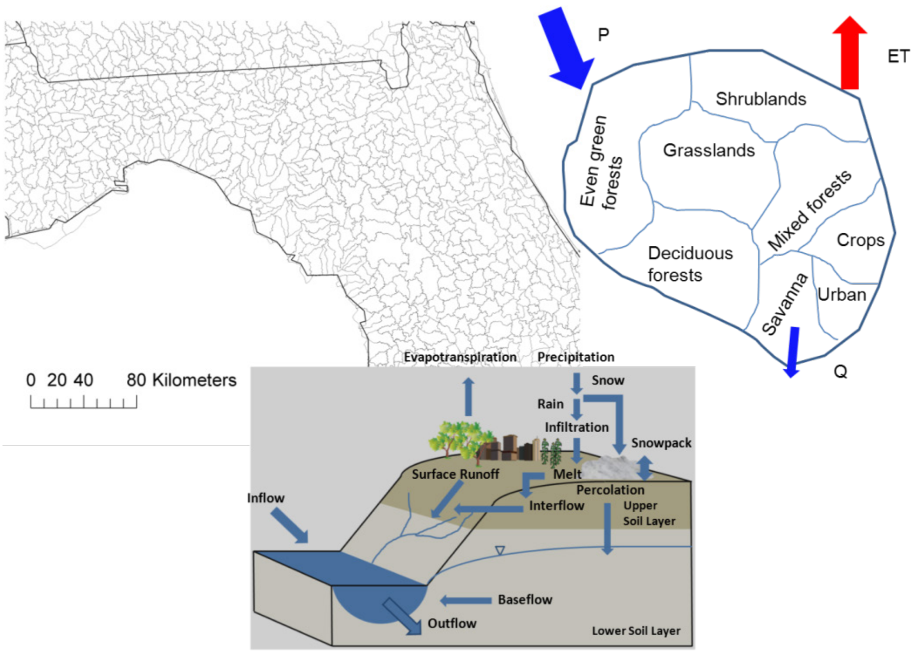


Figure 2. Structural diagram of the WaSSI water balance model (Sun *et al*., 2011, Caldwell *et al*. 2012).

The empirical AET model using the data from Cabral *et al.* (2010) has the following form:

$$AET = -270.3 + LAI^* (116.6 + 0.056\ PET - 0.455^* P_i) + 0.168^*\ P_{i-1} + 1.374\ ^* P_i \qquad (6)$$

Adj. $R^2 = 0.81$; $P < 0.001$; RMSE = 21 mm $month^{-1}$

Where, PET is estimated using a formulation published by Hamon (1963) based on mean air temperature (T) and sunshine hours; and P_i and P_{i-1} are current and previous month's total precipitation, respectively. All units are in mm per month. Within the the WaSSi model, AET modeled from this equation is further reduced if soil water stress occurs (Caldwell *et al*. 2012).

Based on the results from sensitivity analyses, the version of the empirical AET model described above was not particularly sensitive to variation in air temperature, most likely because (1) the range of air temperature data from the Brazil site used to develop the empirical relationship was narrow and generally warmer than observed across the SE region, and (2) the model only indirectly accounts for T through impacts on PET. As a result, AET estimates in the winter months were over-estimated, especially when T_a was $\leq$ 18 °C and *P* was large. To adjust for this, we applied a correction such that when predicted AET > PET and $T_a \leq$ 18°C, then AET = 1.6*PET, where a correction factor of 1.6 is within the range (*e.g.*, 1.4–2.0) of previous studies examining PET/AET relationships in the southern U.S. forests (Rao *et al.* 2011, Lu *et al.* 2009). We also compared monthly AET predictions generated with the stand level process-based model to the WaSSI large scale empirical model and found that they were well correlated with no obvious biases (Figure 3). This adds confidence to our AET estimates derived from the empirical model and subsequent evaluations of potential implications on large scale water balance.

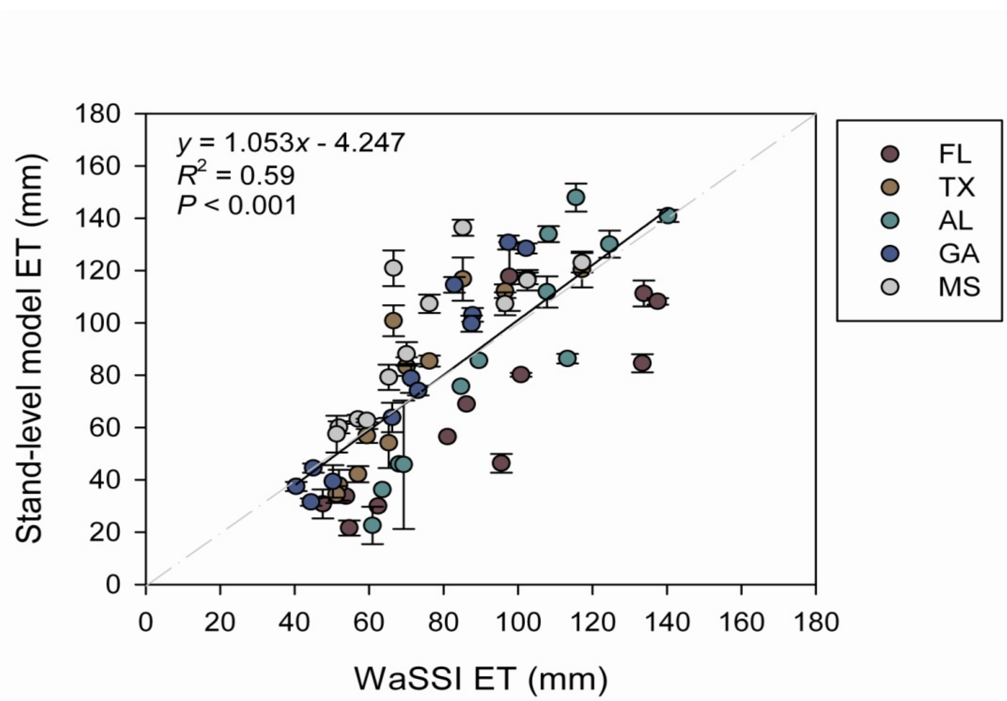


Figure 3. Comparison of ET based stand-level model and WaSSI large scale model.

To assess the watershed scale implications of planting *Eucalyptus* at the five study locations (Figure 4) where we conducted the process-modeling, we identified the associated 12-digit Hydrologic Unit Code (henceforth HUC 12) watersheds where they reside. HUC 12 is the watershed classification system that has the highest spatial resolution currently available for the continental U.S. There are about 17,000 HUC 12 watersheds in the 8b zone within the southeastern U.S. We applied WaSSI under current land cover conditions to calculate watershed-level *Q* (weighted by current land cover and driven by a climate for the time period from 1999–2010) and generated baseline monthly and annual water balances for the watershed. Next, we replaced varying proportions (ranging from 1% to 100%; Table 2) of current land cover (*i.e*., crop, conifer forest, deciduous forest, mixed forest) with *Eucalyptus* and re-calculated water yield. Scenarios 2, 14, 15, and 16 (Table 2) bracket the range of potential land use changes identified in the economic analysis (Wear *et al.* 2013 - APHIS report). The other scenarios examine the implications of wider, but far less likely, ranges of possible land use switching to Eucalyptus. Potential impacts were evaluated by quantifying the absolute (mm yr^{-1}) and percentage change in *Q* from baseline. In all cases, we used an LAI value for *Eucalyptus* of 4.0 to represent an older stand with moderate productivity. Water balance calculations for other land cover types are reported in Sun *et al.* (2011) and Caldwell *et al*. (2012). Additional data sets required for the model include land cover, climate (monthly mean precipitation and air temperature), and soil properties. Those data sets were obtained from various national sources and applied following the standard methods described in Sun *et al*. (2011) and Caldwell *et al*. (2012).

Table 2. Land Cover Change Scenarios

Scenario Number	Simulated Land Cover Change
1	Replace all vegetation with *Eucalyptus*
2	Replace 10% of the conifer forest cover with *Eucalyptus*
3	Replace 50% of the conifer forest cover with *Eucalyptus*
4	Replace 10% of the deciduous forest cover with *Eucalyptus*
5	Replace 50% of the deciduous forest cover with *Eucalyptus*
6	Replace 10% of the crop cover with *Eucalyptus*
7	Replace 50% of the crop cover with *Eucalyptus*
8	Replace 10% of the grass and shrub cover with *Eucalyptus*
9	Replace 50% of the grass and shrub cover with *Eucalyptus*
10	Replace 10% of mixed forest with *Eucalyptus*
11	Replace 50% of mixed forest with *Eucalyptus*
12	Replace 1% of all vegetation with *Eucalyptus*
13	Replace 10% of all vegetation with *Eucalyptus*
14	Replace 1% of the conifer forest cover with *Eucalyptus*
15	Replace 3% of the conifer forest cover with *Eucalyptus*
16	Replace 20% of the conifer forest cover with *Eucalyptus*

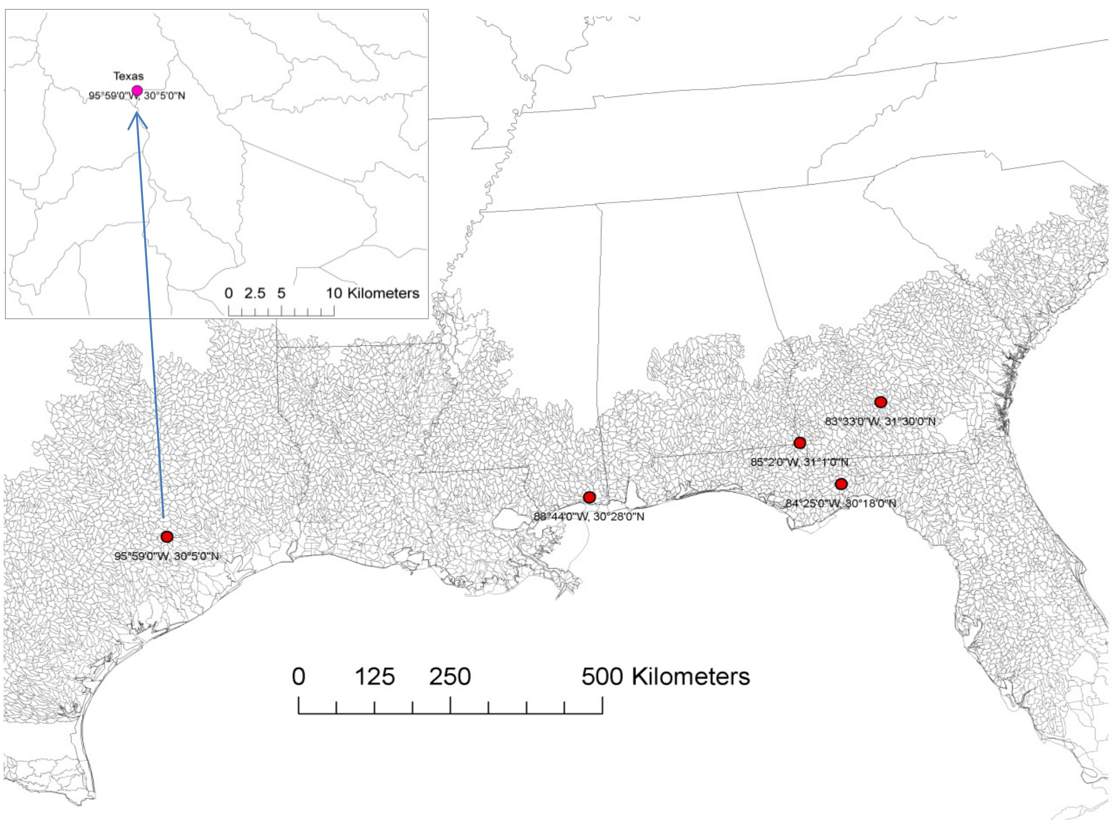


Figure 4. Locations of stand-level studies overlain on the 12-digit HUC watersheds. The expanded view provides a visual context for the scale of a 12-digit HUC.

Using the same approach, we expanded the analysis to include all areas in Plant Hardiness zone 8b and greater, excluding areas identified as highly unlikely to support *Eucalyptus* as a result of biophysical or socioeconomic constraints (Figure 5). In this case, we replaced 1%, 3%, 10%, and 20% of conifer land cover with *Eucalyptus*, as these span the most likely scenarios identified in the economic analysis (Wear *et al.* 2013 – APHIS report). Potential impacts were evaluated by quantifying the absolute (mm yr^{-1}) and relative (%) change in *Q* from baseline.

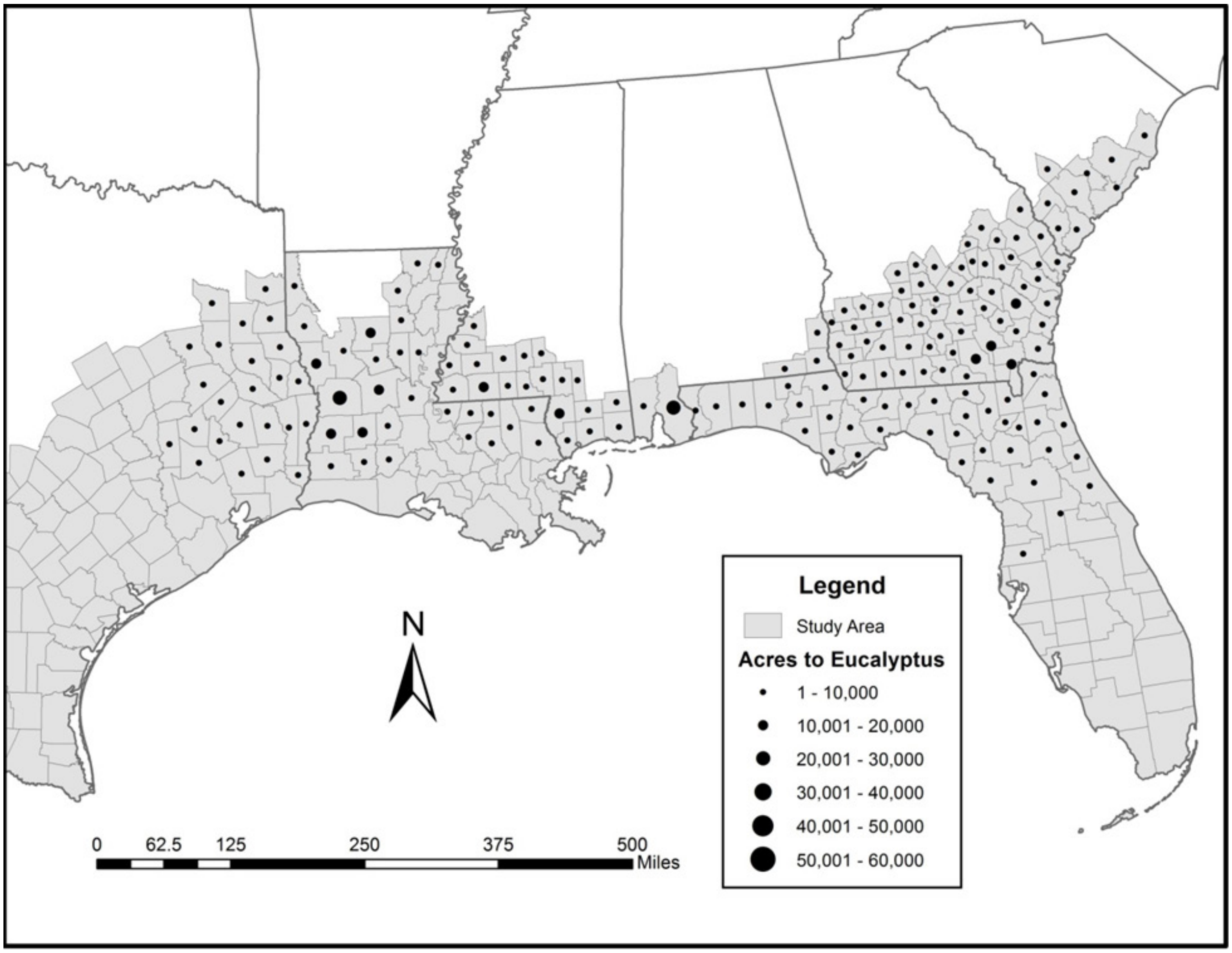


Figure 5. Forecasted area of *Eucalyptus* in the southeastern United States at year 10. For a detailed description of methods and assumptions, see Wear *et al*. 2013 APHIS report entitled "Projecting potential adoption of genetically engineered freeze-tolerant *Eucalyptus* plantations".

Impacts on Groundwater Recharge

When *P* exceeds ET, *Q* is distributed as streamflow soil water storage or groundwater recharge. Groundwater recharge is a critical part of the overall water budget and is one of the most difficult components to quantify, particularly at large spatial scales. We used Wolock's (2003a, 2003b) approach (below) to estimate long term potential impact of vegetation change on groundwater recharge (GWr) at a broad scale. GWr is a qualitative indicator of groundwater available to supply water in low flow seasons.

GWr = Base flow index * *Q* (7)

Watershed *Q* was modeled using the WaSSI model as described above under reference and altered landuse conditions. The baseflow index, the percentage of natural ground-water discharge in streamflow, is derived from historic streamflow records using a flow separation technique (Wolock, 2003b, 2003c).

Results

Question 1: What are the potential impacts of FT Eucalyptus plantations on overall local site water balance in areas where it is most likely to be grown?

Variation Among Locations

Climate - The five locations used to simulate the potential impacts of FT *Eucalyptus* on stand scale water balance represented a wide range of climatic conditions (Table 3). For example, mean annual precipitation (averaged over the years used for simulation) ranged from about 780 mm yr^{-1} for the site in Texas to about 1550 mm yr^{-1} for the site in Mississippi. Indeed, the low precipitation value for the Texas location is slightly below the precipitation limit (*i.e.,* 800 mm yr^{-1}) where FT *Eucalyptus* plantations would be expected to be viable (Figure 5) and clearly reflects the driest potential site for a FT *Eucalyptus* plantation. The nearly two-fold variation in precipitation influences soil θ and available water for transpiration; however, θ is also affected by soil textural characteristics that influence water holding capacity. As result, measured soil moisture ranged from 5.1% (by volume) to 25.3% and was lowest at the Florida location and greatest at the Mississippi location. Mean annual air temperature ranged from 18.1 to 20.6 ^{o}C and net solar radiation ranged from 155 to 201 W m^{-2}.

Table 3. Environmental conditions at the five study sites. Data are annual daily means (soil moisture, temperature, and net radiation) and annual total (precipitation) obtained from the NRCS field sites described in the methods.

Location	Soil Moisture (%)	Precipitation (mm)	Air T (^{o}C)	Net Radiation (w m^{-2})
Alabama	15.6	1479	20.6	201
Florida	5.1	1375	20.5	155
Georgia	13.1	1063	19.7	190
Mississippi	25.3	1553	18.1	183
Texas	21.2	779	19.9	196

ET Estimates - Because assumptions about leaf area and stand development patterns (*i.e*., an increase in LAI from 2.0 to 5.0 by 0.5 increments from age 1 to age 7) were consistent across the five study locations, variation in ET only reflects differences in climatic conditions and soil moisture (Figure 6A). Ranking locations, the highest ET was predicted for the Mississippi and Alabama locations, the lowest ET was predicted for the Florida location, and Texas and Georgia locations were intermediate. As would be expected, stand-level ET increased with stand age and assumed patterns of leaf area development. By the end of the rotation (age 7; LAI = 5), our predictions of annual ET rates (ranging from about 900 in Florida to over 1200 in Mississippi and Alabama). Because a large number of stand scale ET estimates already existed for alternative land covers in the SE U.S. (Table 4), we did not develop land cover specific physically based ET models. In addition, developing a full suite of species-specific physically based models would be especially challenging for stands with mixed species composition; an effort beyond the scope of this analysis. When comparing our predictions for FT *Eucalyptus* to published values for other land covers and species, our estimated ET values were 1.5 to 2-fold greater than estimates for old fields (460–650 mm, Stoy *et al*. 2006), mature deciduous hardwoods forests (480–640 mm, Stoy *et al*. 2006), loblolly pine plantations in the piedmont (560-740, Stoy *et al*. 2006) and crops, such as cotton (386–397 for no irrigation, 739–775 for irrigated; data not shown in Table 4) (Howell *et al*. 2004); but comparable to some slash and loblolly pine plantations in the coastal plain (676 to-1226 mm, Gholz and Clark 2002, Powell *et al*. 2005, Stoy *et al*. 2006, Sun *et al*. 2010). We are aware of only one study where *Eucalyptus* ET has been quantified in the U.S. Here, Abichou *et al*. (2012) estimated an average annual ET of 1086 mm (81% of precipitation) for *Eucalyptus amplifolia* in the Florida panhandle using weighing lysimeters and a constructed soil system. If site conditions (*e.g*., soil nutrients, disturbances, precipitation; Stape *et al*., 2006) preclude attainment of LAI = 5, and lower maximum LAI values (*e.g*., 3 to 4) result, ET estimates range from about 600 (Florida) to 850 (Alabama and Mississippi), well within the range of what has been observed for late-rotation pine plantations in the SE U.S (Sun *et al*. 2010). When soil moisture controls on stomatal conductance were removed by assuming an unlimited supply of soil water, ET values were on average about 20% higher overall, with the highest ET exceeding 1400 mm yr^{-1} in year 7 at the Alabama location (Figure 7). These wet soil conditions would likely be comparable to areas where high ET (*e.g*., > 1000 mm yr^{-1}) has been observed for loblolly and slash pine plantations (Gholz and Clark 2002, Sun *et al*. 2010). In these cases, the energy available to drive transpiration is the primary limiting factor.

Stand Water Balance - Estimates of stand water balance ($Q = P - \text{ET}$), declined as ET increased over time (Figure 6B). For three of the locations, *Q* remained positive over the full rotation. However, at the Texas site, estimates of *Q* reached zero by age 3 (LAI = 3) and *Q* reached zero at the Georgia site at age 7 (LAI = 5.0). In reality, if ET exceeds precipitation, trees would experience considerable water stress and physiological adjustments would occur that would reduce ET such that *Q* would not be less than zero (as shown in Figure 6B). For example, trees would either need to access water not supplied through precipitation (i.e., access deep water sources) to maintain ET, reduce ET through shedding leaves, or adjust stomatal and hydraulic properties (Whitehead and Beadle 2004). Leaf area reduction could occur through tree mortality or fewer leaves per tree, a likely result during drought conditions or when planted in low rainfall areas. These drought avoidance adjustments to limitations were too complex (and unknown for FT *Eucalyptus*) to be included in our modeling; however, the ability of *Eucalyptus* to survive sudden or prolonged drought is well recognized (Whitehead and Beadle 2004) and provides a mechanism for persistence in the driers regions of hardiness zone 8b and higher. If our model and assumptions are correct, these results indicate the potential for the complete elimination of groundwater recharge or surface water flows in areas with low annual precipitation or possibly during drought years in areas with higher average annual rainfall. It should be noted that predicting *Q* with a simple water balance approach (*i.e*., *P*-ET) would also suggest complete elimination of flow for many of the forest types listed in Table 4 under low rainfall conditions (e.g., ~800 mm yr^{-1}). However, this assumes that those species could tolerate or avoid drought and continue to transpire under low soil moisture conditions. In contrast, temporal patterns in areas with higher rainfall suggest that while *Q* declines as stand develop (Figure 6B), site water balance remained positive and complete elimination of *Q* would not be expected, although *Q* may decrease significantly.

Table 4. Annual evapotranspiration for *Eucalyptus* in Brazil and for major forest ecosystems in southeastern United States (U.S. values are adapted from Sun et al., 2010). Values in parentheses = range.

Ecosystems	Evapotranspiration (mm)	Precipitation (*P*, mm)	ET/*P*	References
Eucalyptus Plantation (clonal *Eucalyptus grandis* x *Eucalyptus Urophylla*), 2-4 years old, São Paulo State, Brazil	1179 (1124–1235)	1329 (1280–1377)	0.88 (0.82–0.96)	Cabral et al. 2010
Eucalyptus Plantation (hybrid of *E. urophylla* and *E. grandis*), 2-6 years old, spacing of 3.00 × 2.75m, São Paulo State, Brazil	1101 (943–1364)	1308 (1150–1601)	0.84 (0.81–0.89)	Lima et al. 2012
Eucalyptus Plantation (hybrid of *E. urophylla* and *E. grandis,* different clone), 0-2 years old, spacing of 6.00 × 1.40 m. São Paulo State, Brazil	1099 (949–1240)	1601 (1537–1716)	0.69 (0.55–0.80)	Lima et al. 2012
Loblolly pine plantation (LP) 16 year old, North Carolina	1087 (1011-1226)	1238	0.88	Sun et al. 2010
Loblolly pine plantation (CC), 4 year old, coastal North Carolina	838 (755-885)	1274	0.66	Sun et al. 2010
Loblolly pine plantation, 4 year old, Parker Track, North Carolina	895 (702–1078)	1152	0.78 (0.73–0.94)	Diggs 2004

Loblolly pine plantation, 15 year old, Parker Track, North Carolina	988 938 (after thinning 1/3 of basal area)	1098	0.9	Grace et al. 2006a, 2006b
Loblolly pine plantation, 14-30 year old, Parker Track, North Carolina	997 (763–1792)	1538 (947–1346)	0.65	Amayta et al. 2006
Loblolly pine plantation (PP), 25 year old, Piedmont North Carolina	658 (560–740)	1092 (930–1350)	0.60	Stoy et al. 2006
Mature deciduous hardwoods (HW), Duke Forest, Piedmont North Carolina	573 (460–640)	1092 (930–1350)	0.52	Stoy et al. 2006
Grass-cover old field (OL), Duke Forest, Piedmont North Carolina	508 (360–650)	1092 (930–1350)	0.46	Stoy et al. 2006
Slash pine (*Pinus taeda* L.) plantation, clearcut, Florida	958 (869–1048)	959 (869–1048)	0.85 (0.84–0.86)	Gholz and Clark 2002
Slash pine (*Pinus taeda* L.) plantation, 10-year old, Florida	1058 (994–1122)	1062 (877–1247)	1.0 (0.9–1.1)	Gholz and Clark 2002
Slash pine (*Pinus taeda* L.) plantation, full-rotation, Florida	1193 (1102–1284)	1289 (887–1014)	0.93 (0.92–0.93)	Gholz and Clark 2002
Slash pine (*Pinus taeda* L.) plantation, full-rotation, Florida (extreme drought years)	754 (676–832)	883 (811–956)	0.85	Powell et al. 2005
Pine flatwoods, Bradford Forest, Florida	1077	1261	0.87	Sun et al. 2002

Deciduous hardwoods, Coweeta, North Carolina	779	1730	0.47	Sun et al. 2002
Mixed Pine and hardwoods, Santee Exp. Forest, South Carolina	1133	1382	0.82	Lu et al. 2003
White pine (*Pinus strobus* L.), Coweeta, North Carolina	1291	2241	0.58	Ford et al. 2007
Deciduous hardwoods, Oak Ridge, Tennessee	567 (537–611)	1372 (1245–1682)	0.41	Wilson and Baldocchi 2000
Deciduous hardwoods, Oak Ridge, Walker Branch watershed, Tennessee	575	1244	0.45	Updated data from Lu et al. 2003; Hanson et al. 2004

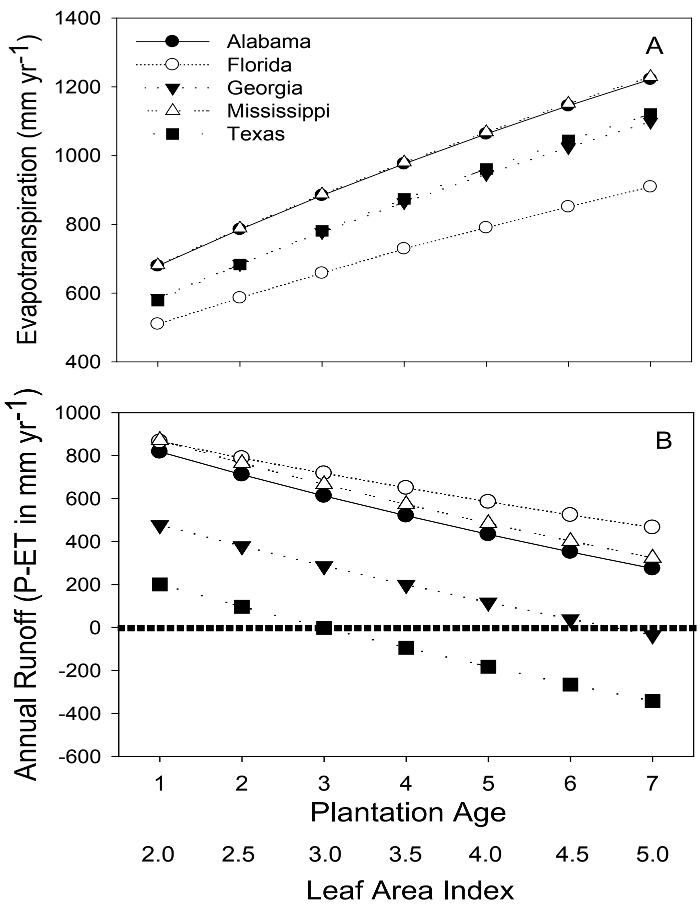


Figure 6A&B. Annual ET (A) and Runoff (B) predicted from process based model for the five intensive study locations. The model does not incorporate physiological or structural adjustments that occur when annual ET exceeds P (*i.e.*, leaf area reduction, access to deep soil water, etc.) so predicted runoff is negative for the Texas site when LAI > 3.0. Because "negative runoff" is not possible, these data should be interpreted as runoff = 0.

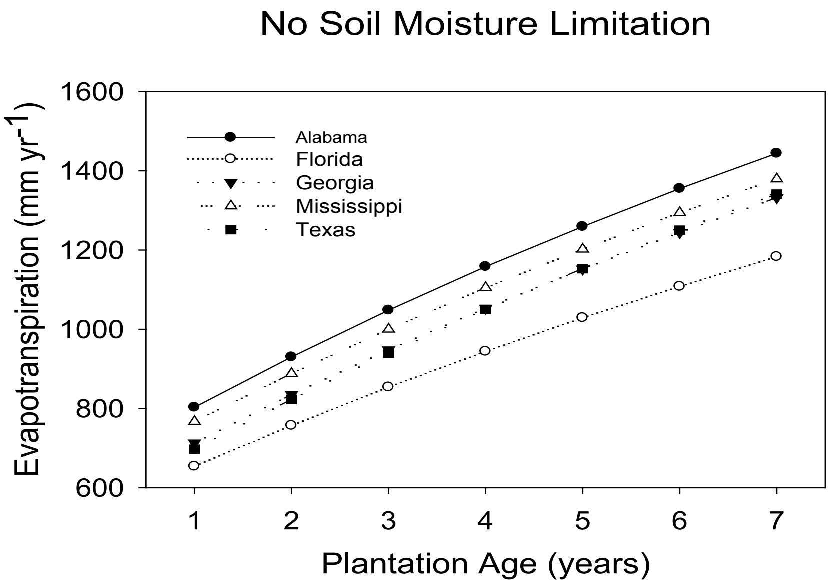


Figure 7. Estimates of FT *Eucalyptus* evapotranspiration without soil moisture limitations on stomatal conductance.

Intra-annual Patterns - At the monthly scale, ET estimates showed a distinct seasonal pattern. Across all sites, peak ET occurred in either June or July (Figure 8A-E). This is to be expected as this pattern coincides with the timing of maximum stand LAI and when climatic driving variables are most favorable to drive ET. These peak values are well within the range of what has been observed for other *Eucalyptus* species across the globe (Whitehead and Beadle 2004). Estimating Q by P-ET is not applicable at sub-annual time scales so we are unable to quantify seasonal variation in streamflow using this approach. However, these seasonal patterns in predicted ET suggest that depending on seasonal precipitation patterns, Q likely would be most impacted during the summer months.

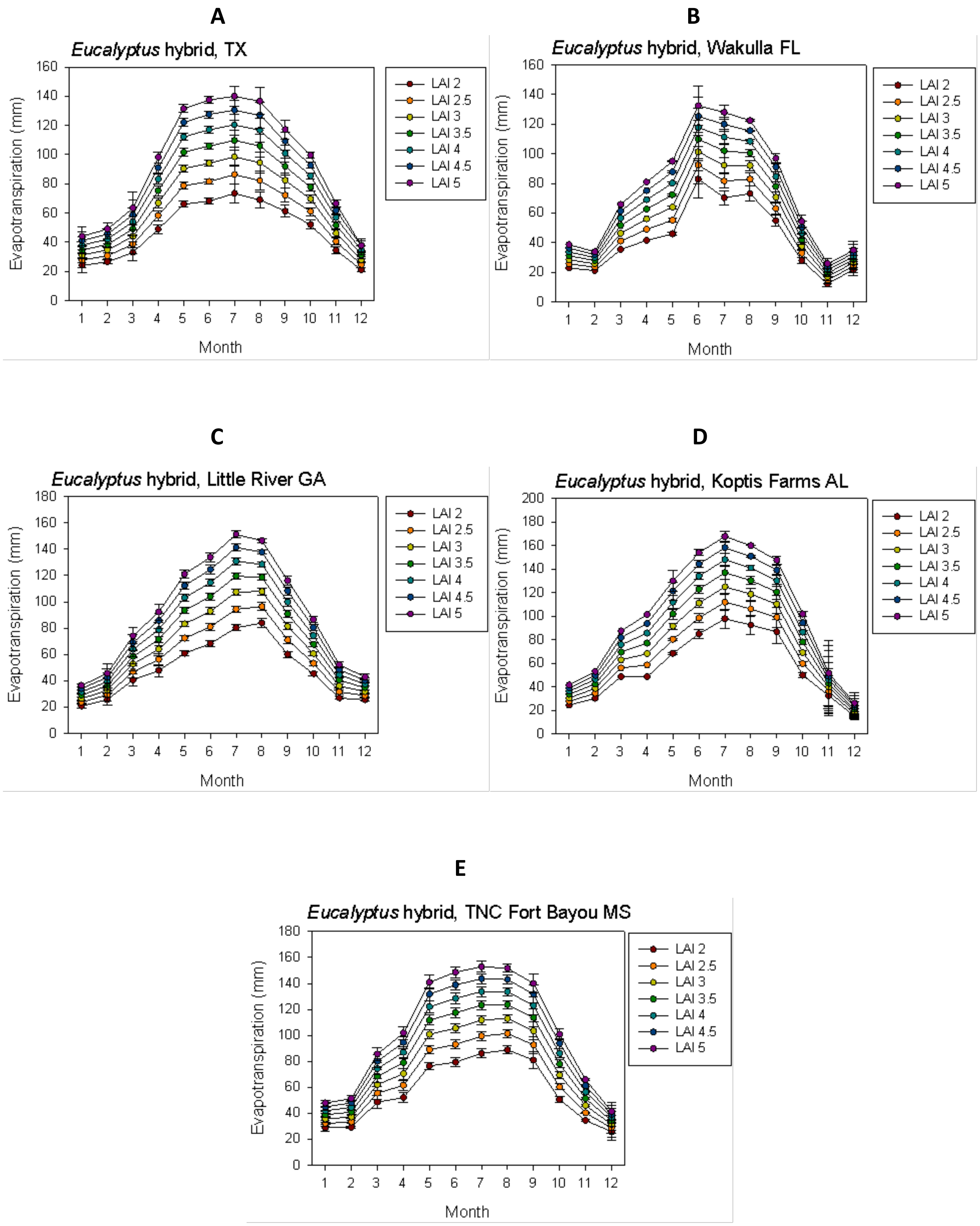


Figure 8A-E: Monthly total evapotranspiration (error bars denote standard error of the mean) simulated across all years of climate and over seven years of stand development for five sites. Stand development is represented as increases in leaf area index (LAI) from 2–5 m^2 m^{-2}.

Implications

The stand-level implications of planting FT *Eucalyptus* on *Q* will vary by location, the land cover type prior to *Eucalyptus* establishment, and the hydrological conditions of the planting site and surrounding area. To illustrate, we can compare ET values of *Eucalyptus* to alternative options for wood fiber production such as pine plantations. As noted above, estimates of planted pine ET range from about 650 to 1200 mm yr^{-1}; with the latter being observed in areas where soil water is plentiful (Gholz and Clark 2002, Powell *et al*. 2005, Stoy *et al*. 2006, Sun *et al*. 2010). At LAI = 4, predicted *Eucalyptus* ET ranges from 790 mm yr^{-1} at the Florida site, to 980 mm yr^{-1} at the Mississippi site, within the range for pine stands. This suggests that contributions to streamflow/recharge could be equal to or reduced by as much as to 180 mm yr^{-1} relative to pine near the end of the rotation or on sites where LAI is below the maximum. Aat *Eucalyptus* LAI = 5, ET ranges from 909 mm yr^{-1} (Florida) to 1229 mm yr^{-1} (Mississippi) as compared to pine plantations with annual ET of about 900 mm yr^{-1} (the average of the low and high estimates from Sun *et al*. 2010). Under these conditions, reductions in contributions to streamflow or groundwater recharge of about 0 to 300 mm yr^{-1} are possible. The implications for these reductions in streamflow or groundwater recharge depend on the hydrologic setting and the amount of land area planted in FT *Eucalyptus*. For example, conditions that might result in a negative impact would include:

1. Planting in areas where precipitation is limited or where dry years are likely,
2. Planting in areas where the ratio of *P*/potential evapotranspiration is low, and
3. Planting in headwater areas or planting large acreages in close proximity to streams that have low annual baseflow.

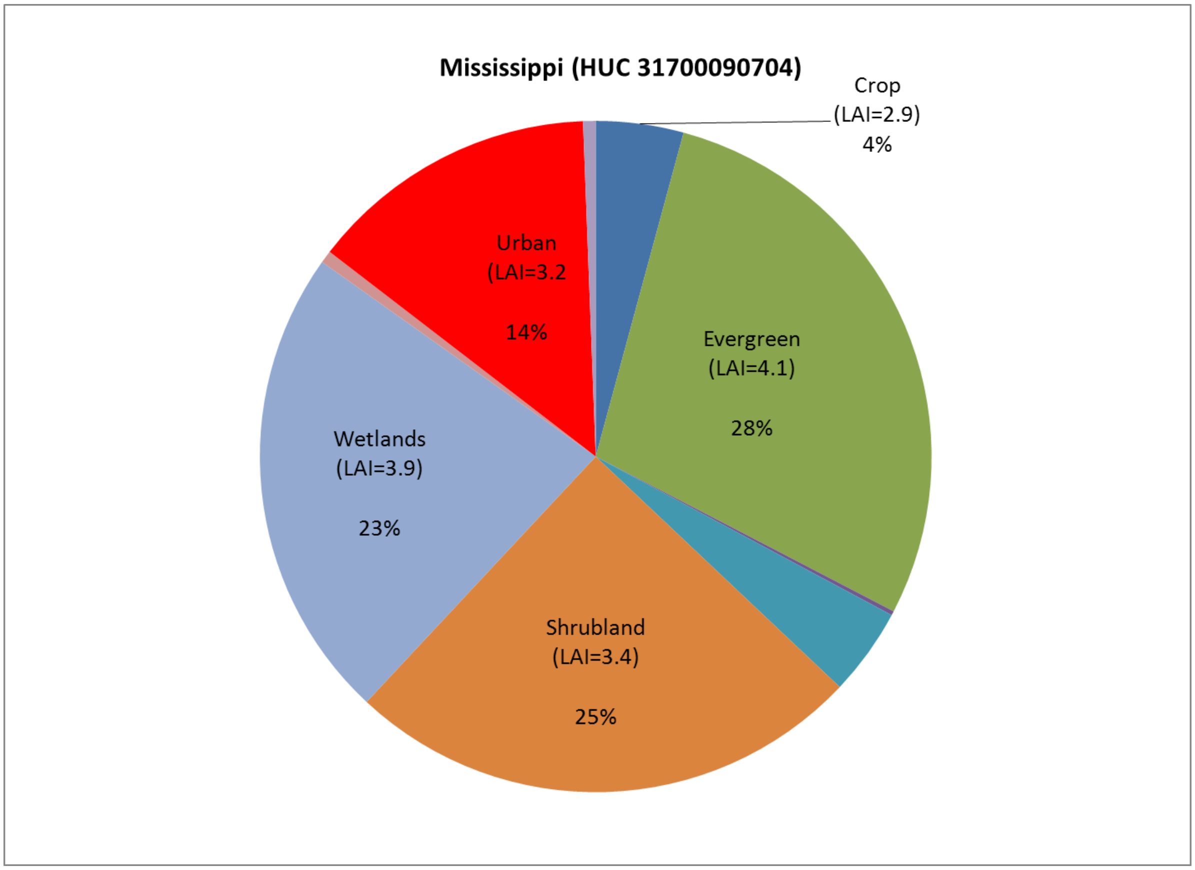
These implications must be viewed in the context of an incomplete understanding of the rooting characteristics, leaf phenology, and ecophysiology of FT *Eucalyptus* that could potentially affect the model-base estimates of ET. For example, we don't know aspects such as how g_s in FT *Eucalyptus* will recover after a freeze event and the implications for growing season length. Also, deep rooting could allow tree to maintain high leaf water potentials and g_s under dry conditions relative to pine or native species.

Question 2. *How does the size and distribution of FT Eucalyptus plantations impact water balance at larger spatial scales?*

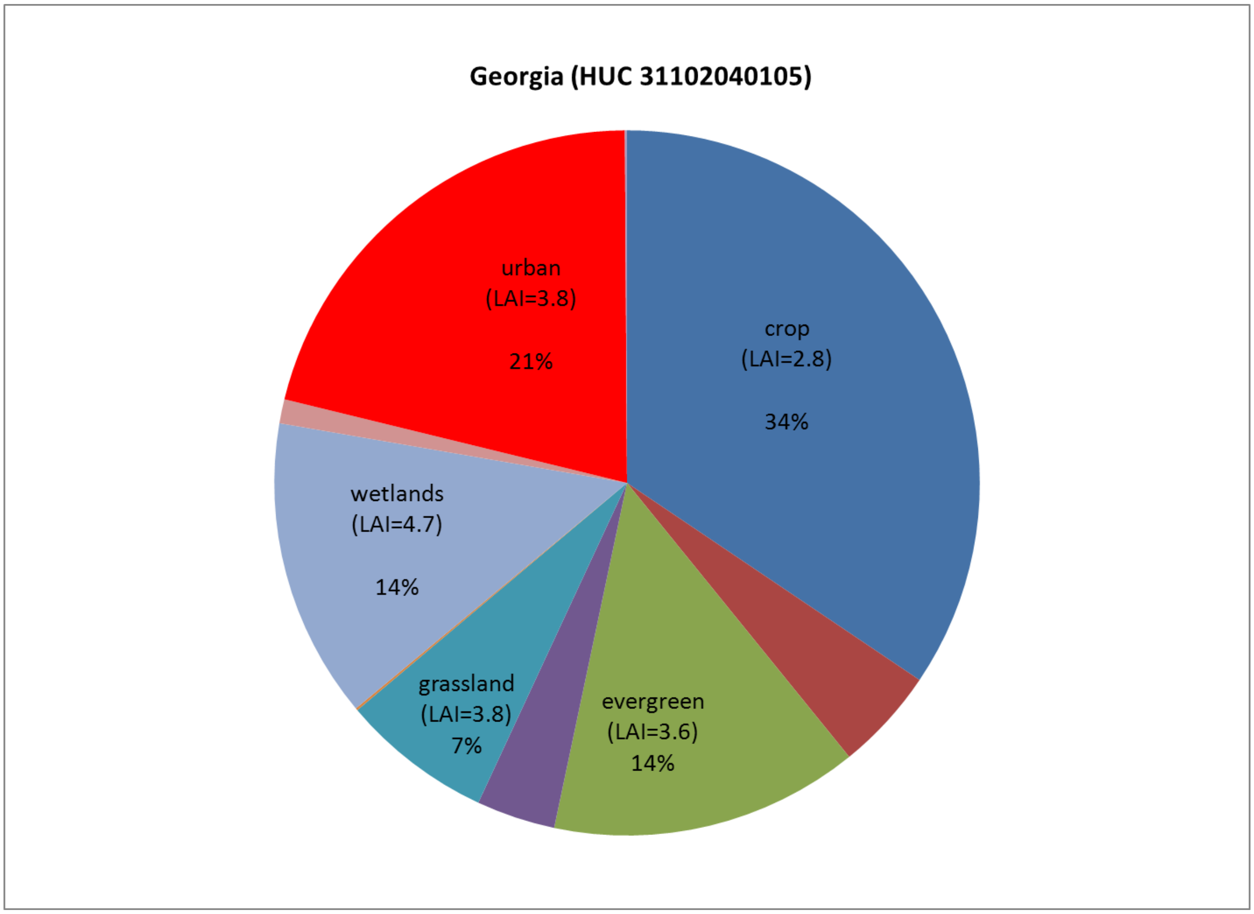
Scaling from the Stand to the Watershed

The impact of planting FT *Eucalyptus* at larger spatial scales will vary depending upon the hydrologic setting (e.g., high rainfall *vs*. low rainfall) and the type and amount land cover being replaced. To include the influence of land cover, one of our tasks was to quantify current land cover types across the region. As an example, at the five locations used for process based modeling, current land cover within the associated 12-digit HUC varied greatly (Figure 9 A-E). To characterize how different land covers influence water balance at the 12-digit HUC, land cover specific LAI data were derived from Moderate Resolution Imaging Spectroradiometer (MODIS) remote sensing products (1000 m spatial resolution) and water use was driven by land cover based variation in LAI (Sun *et al*. 2011). Although the WaSSI model does not use land cover specific ET models to estimate ET for each land cover in a watershed, the ET model does consider the effects of LAI (magnitude and seasonal dynamics) on water use.

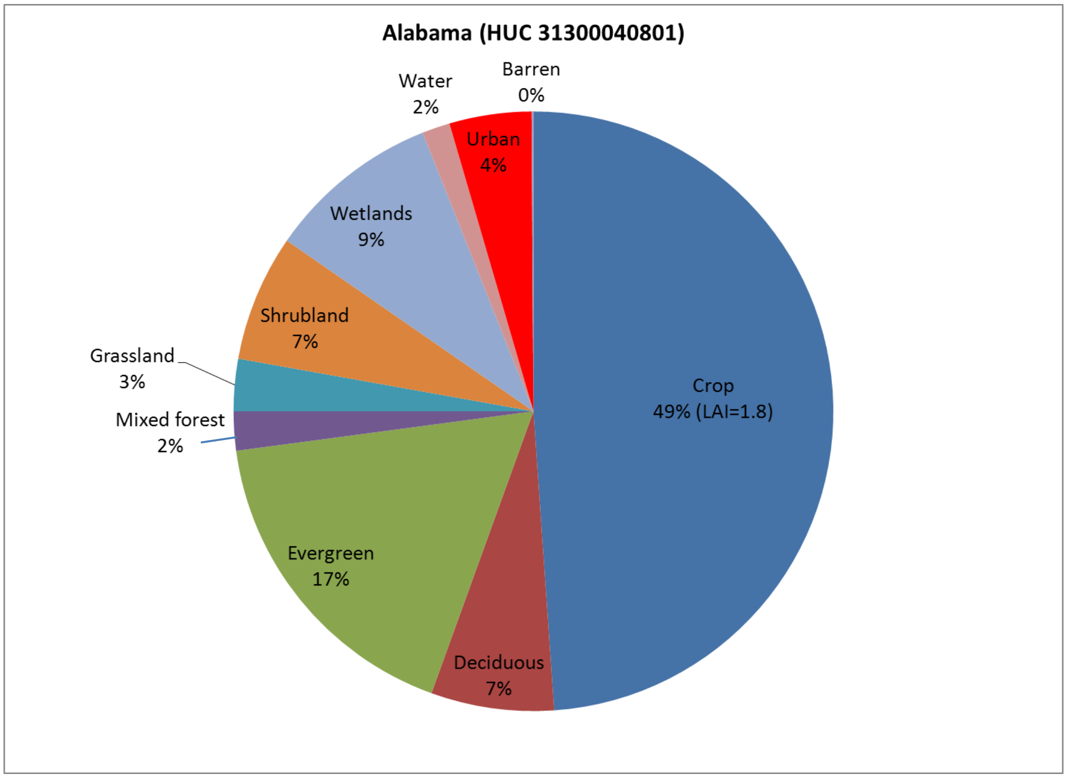
A



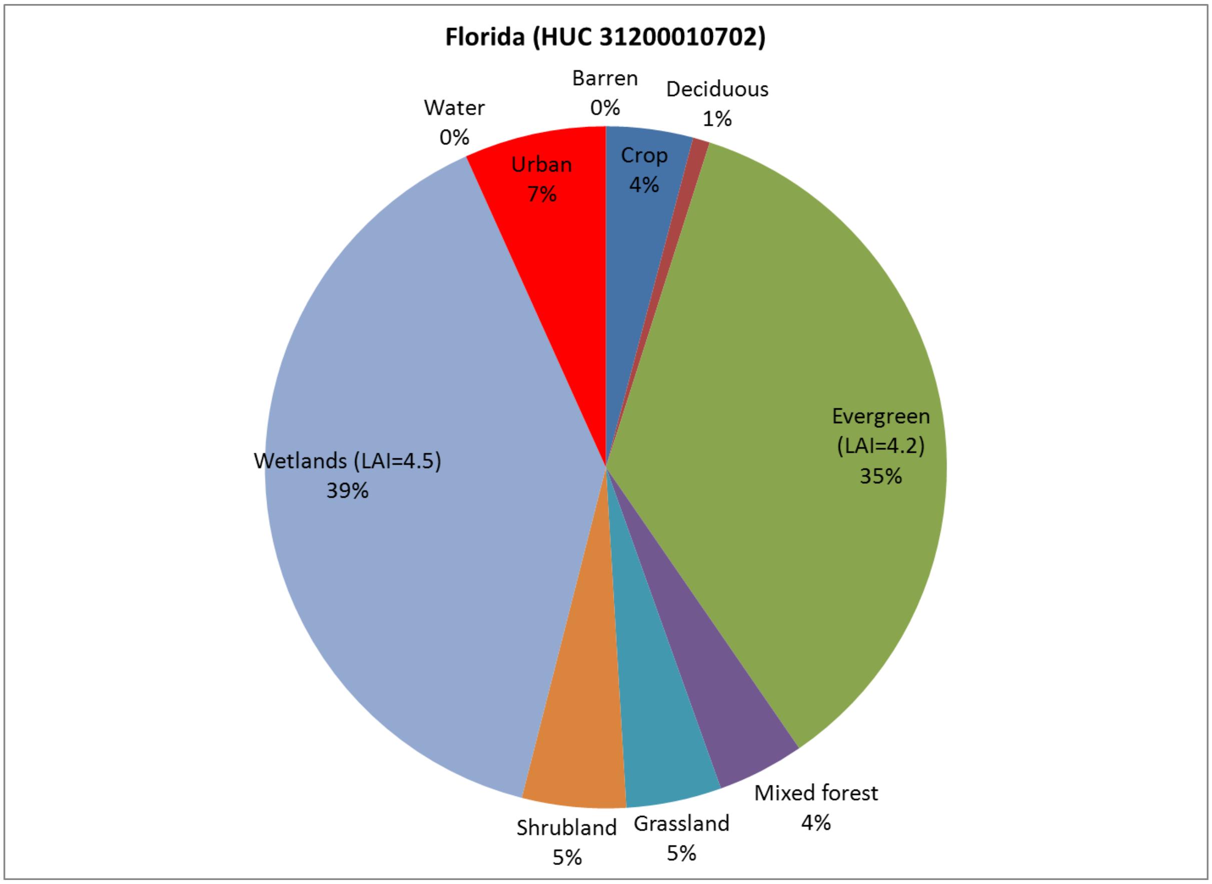
B


Georgia (HUC 31102040105)
urban
(LAI=3.8)
21%
crop
(LAI=2.8)
34%
wetlands
(LAI=4.7)
14%
grassland
(LAI=3.8)
7%
evergreen
(LAI=3.6)
14%

C


Alabama (HUC 31300040801)
Barren
0%
Water
2%
Urban
4%
Wetlands
9%
Shrubland
7%
Grassland
3%
Mixed forest
2%
Crop
49% (LAI=1.8)
Evergreen
17%
Deciduous
7%

D


Florida (HUC 31200010702)
Barren
0%
Deciduous
1%
Water
0%
Urban
7%
Crop
4%
Evergreen
(LAI=4.2)
35%
Wetlands (LAI=4.5)
39%
Mixed forest
4%
Shrubland
5%
Grassland
5%

E

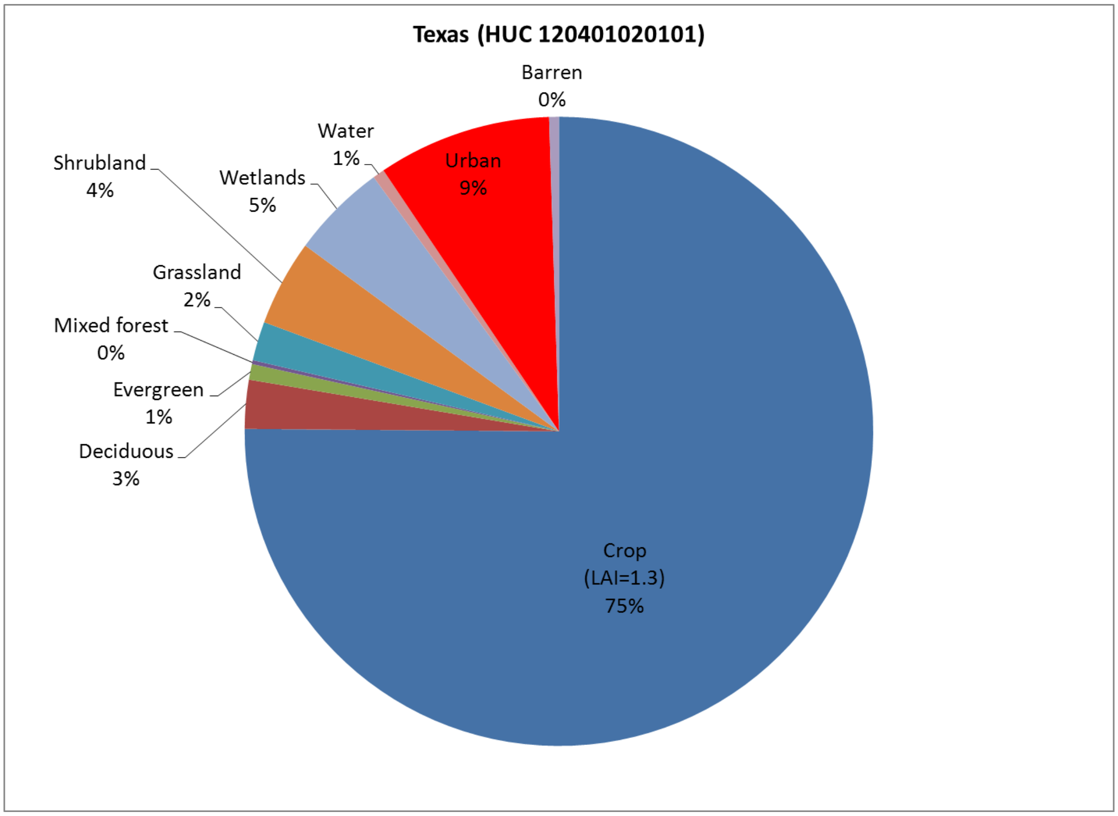


Figure 9A-E. Current land cover (2006) for the 12–digit HUC associated with the five study locations. Landcover sources: 2006 National Land Cover Database for the Conterminous U.S. (Fry et al., 2011).

The interactions among hydrologic setting, current land cover, and the amount of land cover changed were examined by predicting changes in absolute and relative water yield described in the case study scenarios (Table 2). Not surprisingly, the largest changes in *Q* (amount and %) were predicted when all of the vegetation within the watershed was converted to FT *Eucalyptus* (Scenario 1 - Figure 10 A&B). However, there were substantial differences in the magnitude of response among locations. For absolute changes in flow, responses varied from about -250 mm yr^{-1} (-48%) at the Alabama location, to about -100 mm yr^{-1} (-18%) at the Florida location (Figures 10 A&B). These changes are comparable to changes predicted at the stand scale. Based on the economic analysis (Wear *et al*. 2013 APHIS report), it is highly unlikely that FT *Eucalyptus* would be planted at this scale and much smaller changes are more realistic. For example, if only 1% of the vegetative cover in the watersheds were converted to FT *Eucalyptus* (Scenario 12 – Figure 10 A&B), changes in *Q* (amount or %) would be very small (e.g., < 5 mm and <1%) across all study areas. In short, responses of this magnitude would likely not be measurable with streamflow gauges at a large scale, are unlikely to negatively impact streamflow or groundwater recharge, and are well within the errors associated with this type of model-based approach. However, as noted in the previous section, measurable local scale impacts may still occur immediately downstream of FT

Eucalyptus plantations*.* At intermediate levels of change (e.g., 10% *vs*. 50%), impacts varied depending upon the land cover being replaced. For example, on average, the next largest change occurs when 50% of crop land cover (Scenario 7) is converted to FT *Eucalyptus* (S7; Figure 10A-B).

Based on the results of the socioeconomic analyses, projections suggest that FT *Eucalyptus* plantations could replace 3 to 20% of conifer land cover depending on economic assumptions, with the most likely scenario being an overall 10% conversion (Wear et al. 2013 APHIS report). The potential implications of 10%, 20%, or 50% conversion from conifer to FT *Eucalyptus* and a 100% conversion of all vegetation across climate zone 8b and higher is shown in Figure 11 A-H. At these larger scales, major changes in *Q* (absolute or %) were projected only when all of the vegetation was replaced with FT *Eucalyptus*. Simulations assuming either a 10% (scenario 2 – Figure 11 C&D) or 20% (scenario 3 – Figure 11 E&F) replacement of conifer land cover with FT *Eucalyptus* suggested that the impacts on Q would be minimal (*i.e*., > 24 mm of absolute *Q*; < 10% change in percent *Q*). At a 50% replacement of conifer cover with FT *Eucalyptus* (scenario 16 – Figure 11 G&H), simulations suggested reduction in *Q* of ~100 mm were possible, especially in the Florida panhandle region and parts of Louisiana, Alabama, and Texas.

We emphasize that these results are based on LAI = 4.0, which is representative of an older stand nearing the end of the rotation (assumed to be 7 years). As a result, our analyses and interpretations reflect what might occur under a near "maximum impact" scenario. At lower LAI's (reflective of factors such as younger stands, lower density, or poor quality sites), the projected effects would even less.

Impacts on Groundwater Recharge

Groundwater recharge rate in a watershed is controlled mainly by the water balance (precipitation and ET) and geological properties of the watershed as illustrated by Equation 4. Impacts of vegetation changes will affect water yield and thus the amount of groundwater recharge. Similar to water yield impact results, converting all vegetation to FT *Eucalyptus* is projected to have a large impact on regional groundwater recharge (*e.g*., decrease as high as 200 mm/yr in some watersheds); however, a 10% conversion (the most likely scenario) of conifer forests to FT *Eucalyptus* may have negligible effects on groundwater recharge rate on average, especially in the wet regions in the coastal plains (Figure 12A-B).

Implications

Assessing the impacts at larger spatial scales is an extremely challenging task because it is a function of the hydrologic setting, current land cover and its water use, and how much of the land cover is converted. Our modeling approach attempts to account for all of these variables and represents a "best approximation" based on the available data. At the scale of conversion indicated by the economic analysis (*e.g*., <20% conversion of conifer cover to FT *Eucalyptus*; Wear *et al*. 2013 – APHIS report), our analysis (using LAI = 4) suggests that the regional impacts on either *Q*, percent change in *Q*, or groundwater recharge at the scale of the 12-digit HUC will be negligible. At lower LAI's, impacts would be even lower. Again, local scale impacts may occur immediately downstream of FT *Eucalyptus* plantations even at low land cover conversion rates. In contrast, if economic conditions promoted large scale conversion of existing land cover (e.g., 50% of current conifer cover) to FT *Eucalyptus*, then regional impacts on *Q* could be observable in many areas of zone 8b and higher. Areas where changes are anticipated to be the greatest include the Florida panhandle, south Alabama, southwest Georgia, Louisiana, and southern Mississippi (Figure 11).

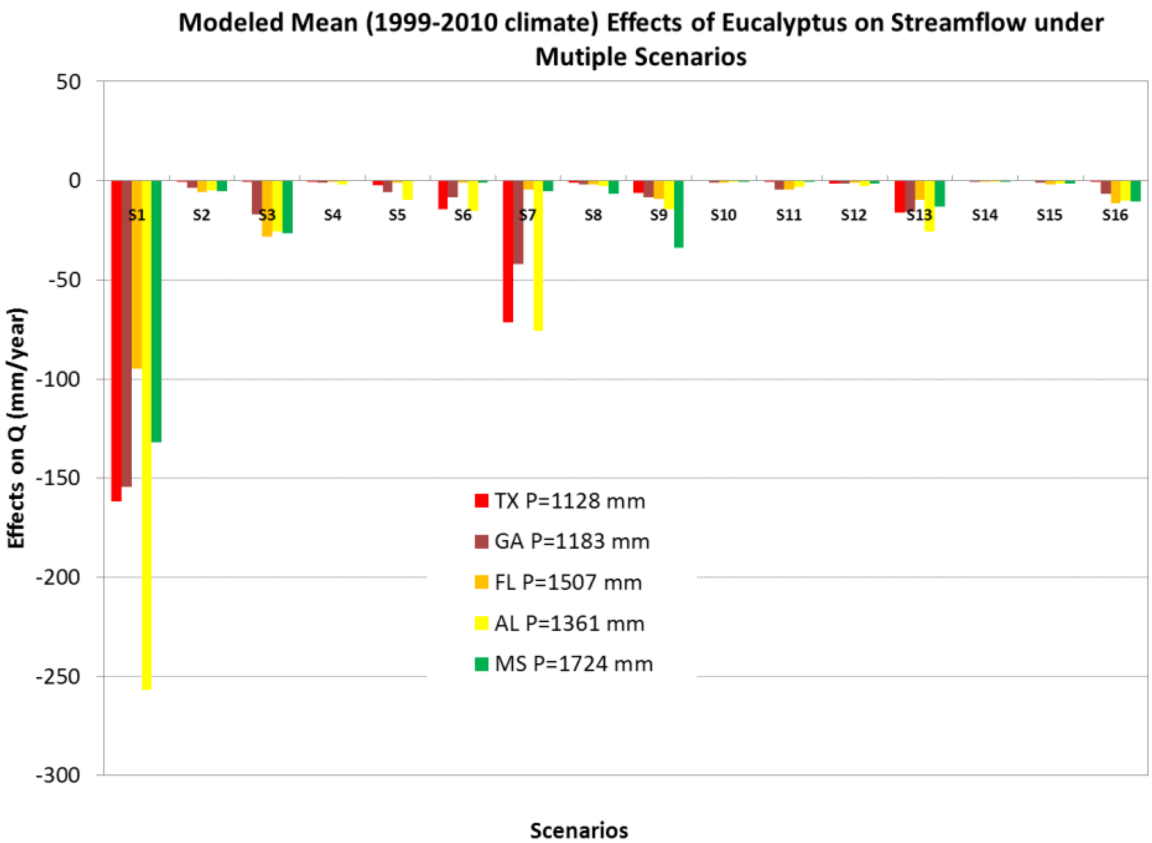
Assumptions and Uncertainties

Our model-based analysis of the potential impacts of the expansion of FT *Eucalyptus* represents our best approximation based on currently available data. Because physiological and structural data for FT *Eucalyptus* do not exist, we assumed that:

1. Physiological (*e.g*., stomatal conductance) and stand structure data (*e.g*., leaf area index amount, season dynamics, and development over time) from *Eucalyptus grandis* (and other *Eucalyptus* species) growing in other regions of the world are applicable to FT *Eucalyptus* growing in USDA plant hardiness zone 8b and higher.
2. The stand level model was a sufficient representation of how FT *Eucalyptus* would respond to climatic and soil driving variables at the five study locations.
3. The empirical AET model (equation 7) developed from an eddy covariance tower in Brazil was applicable to FT *Eucalyptus* growing in USDA plant hardiness zone 8b and higher.
4. A stand LAI = 4 is a reasonable value for commercial stands of FT *Eucalyptus* growing in USDA plant hardiness zone 8b and higher.

In addition to these assumptions, biophysical models at all scales are limited by imperfect knowledge and simplifications of processes, parameters, and driving variables; and by limits to the accuracy and precision of climate driving variables such as precipitation and air temperature. Furthermore, these results must be viewed in the context of the hydrologic setting of the area of the plantation. Key physical features such as soil texture, topography, existing drainage networks and road systems, and groundwater depth can either mitigate or exacerbate responses. Future climate variability, especially an increased frequency and severity of drought may make some areas much more sensitive to the effects of higher ET in the future. Our models were not appropriate for simulating the potential impacts of extreme drought due to a lack of model sophistication and data on physiological and structural responses from FT *Eucalyptus*. These assumptions and uncertainties reinforce the need to obtain empirical measurements to validate (or reject) model projections.

A


Modeled Mean (1999-2010 climate) Effects of Eucalyptus on Streamflow under Mutiple Scenarios
50
0
-50
-100
-150
-200
-250
-300
Effects on Q (mm/year)
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
TX P=1128 mm
GA P=1183 mm
FL P=1507 mm
AL P=1361 mm
MS P=1724 mm
Scenarios

B

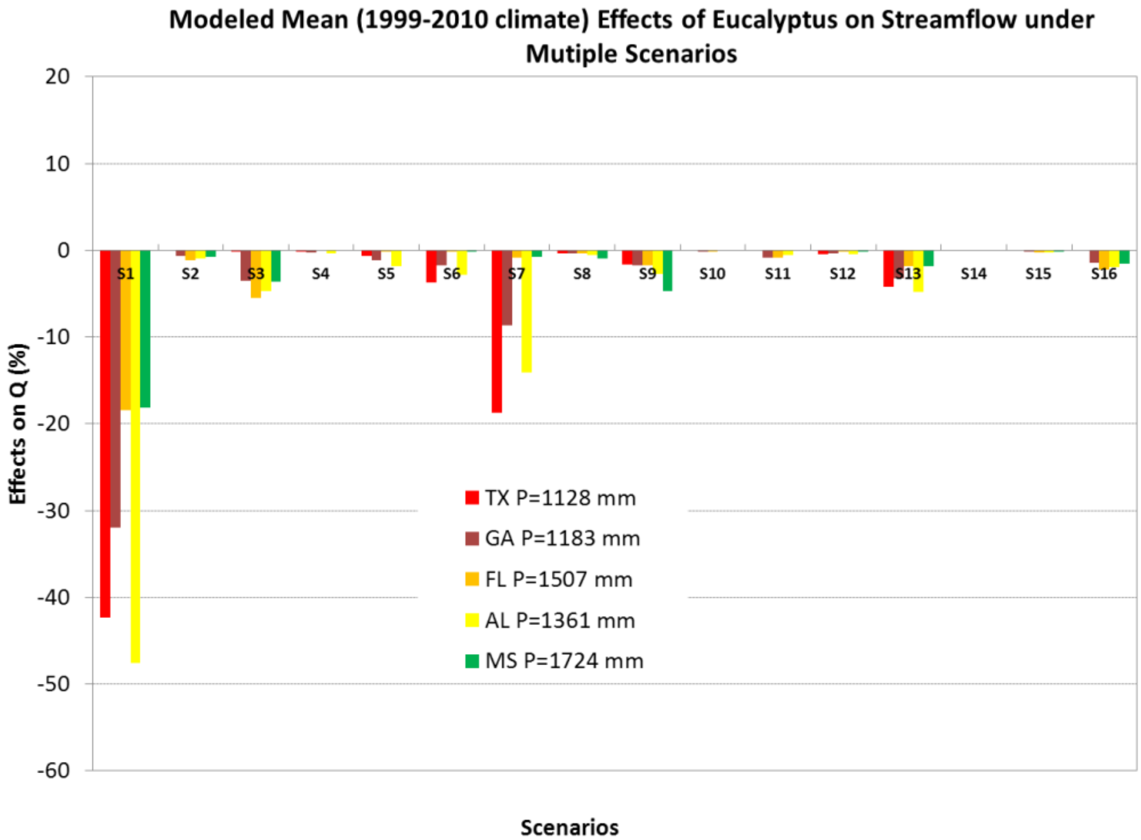
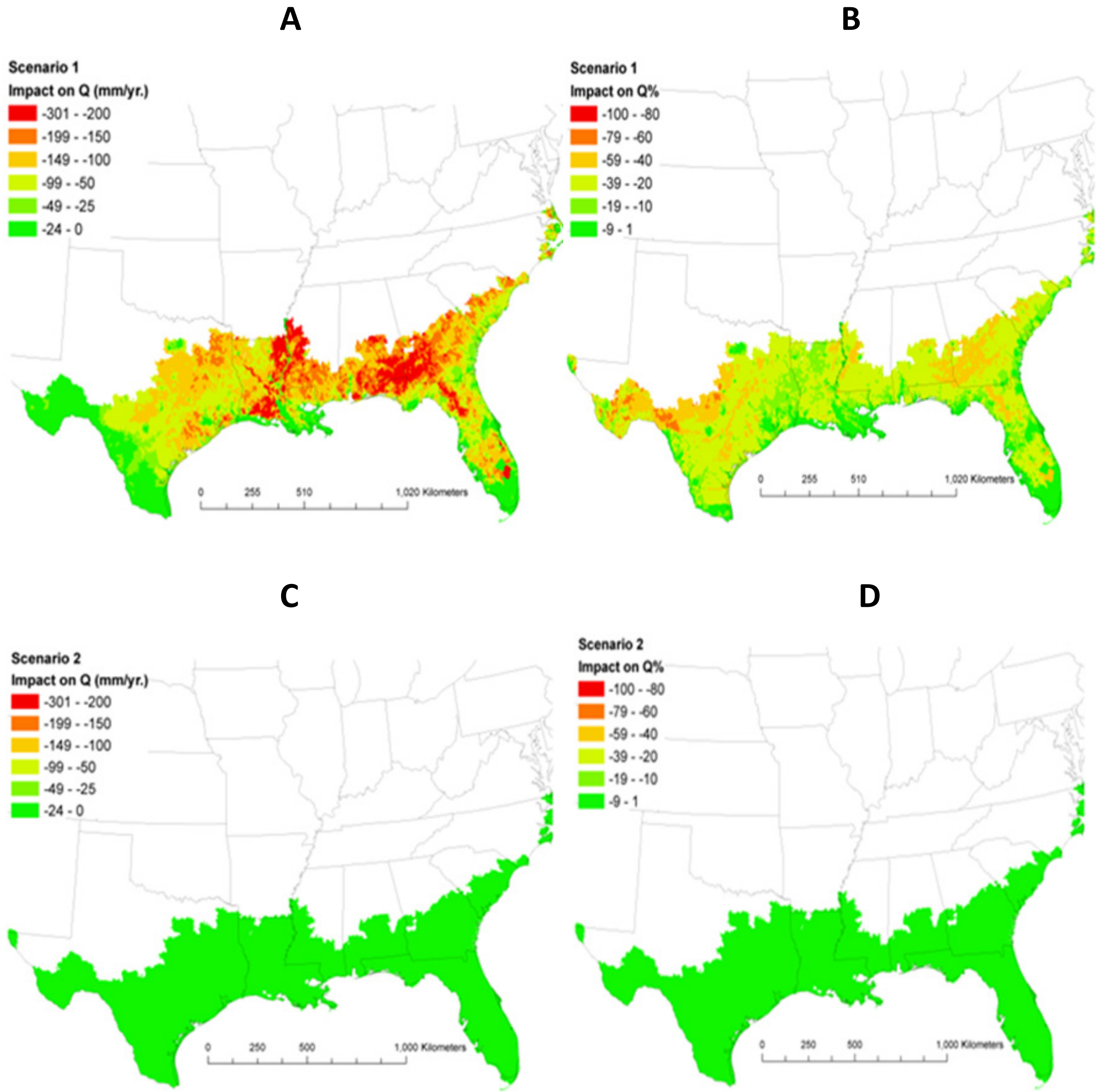


Figure 10A-B. Effect of planting *Eucalyptus* water yield where (A) is absolute change, and (B) is relative change in water yield. Scenario runs (labeled S1 through S16) by WaSSI for the 5 watersheds where the stand-level modeling sites are located (see Table 2 for scenario label definitions).


A
Scenario 1
Impact on Q (mm/yr.)
-301 - -200
-199 - -150
-149 - -100
-99 - -50
-49 - -25
-24 - 0
0 255 510 1,020 Kilometers
B
Scenario 1
Impact on Q%
-100 - -80
-79 - -60
-59 - -40
-39 - -20
-19 - -10
-9 - 1
0 255 510 1,020 Kilometers
C
Scenario 2
Impact on Q (mm/yr.)
-301 - -200
-199 - -150
-149 - -100
-99 - -50
-49 - -25
-24 - 0
0 250 500 1,000 Kilometers
D
Scenario 2
Impact on Q%
-100 - -80
-79 - -60
-59 - -40
-39 - -20
-19 - -10
-9 - 1
0 250 500 1,000 Kilometers

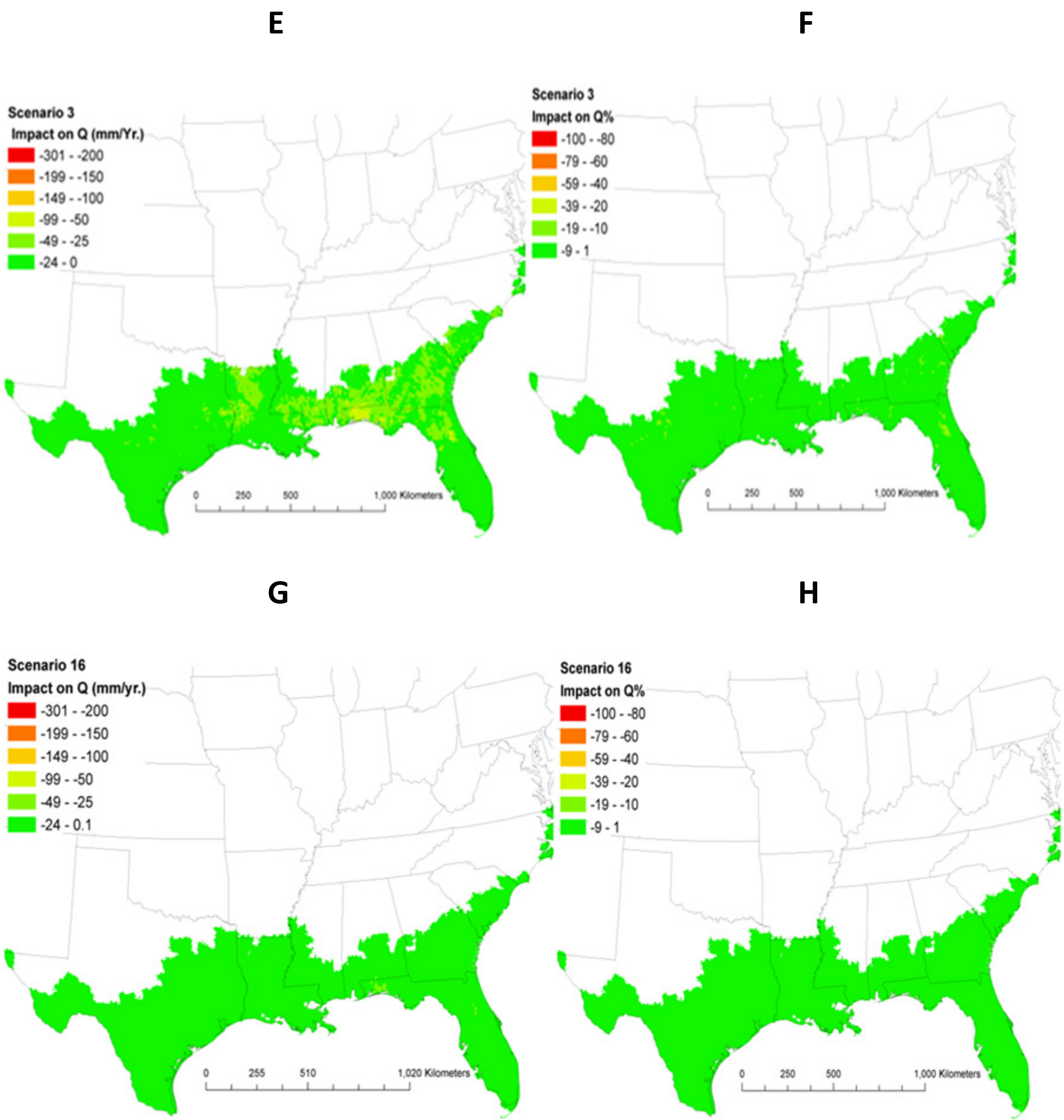
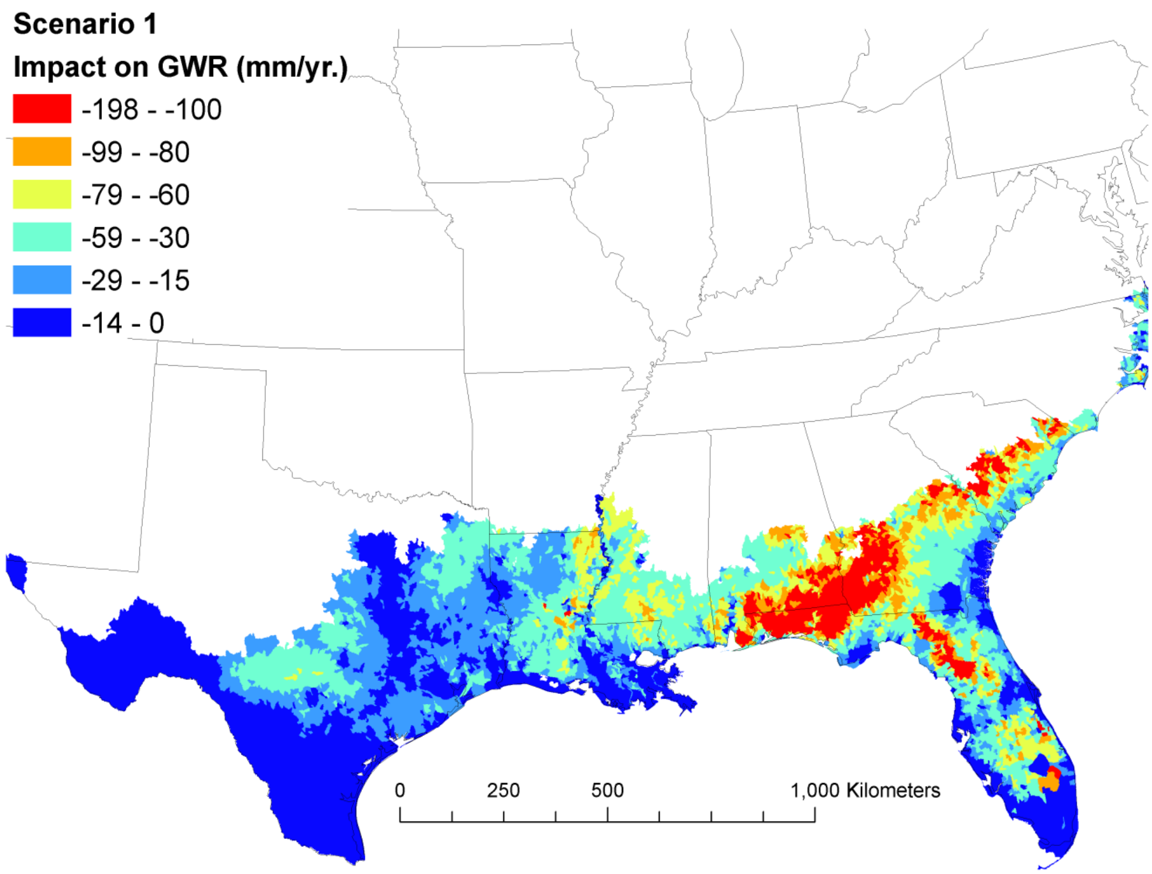


Figure 11A-H Regional analysis simulating the impact on Q (absolute change in mm yr^{-1} and percent change in) of replacing 100% of all vegetation (Scenario 1), 10% of the conifer cover (Scenario 2), 50% of the conifer cover (Scenario 3), and 20% of the conifer cover (Scenario 16) with FT *Eucalyptus* for all of the 12-digit HUCS in the southern region of hardiness zones 8b and greater.

A


Scenario 1
Impact on GWR (mm/yr.)
-198 - -100
-99 - -80
-79 - -60
-59 - -30
-29 - -15
-14 - 0
0
250
500
1,000 Kilometers

B

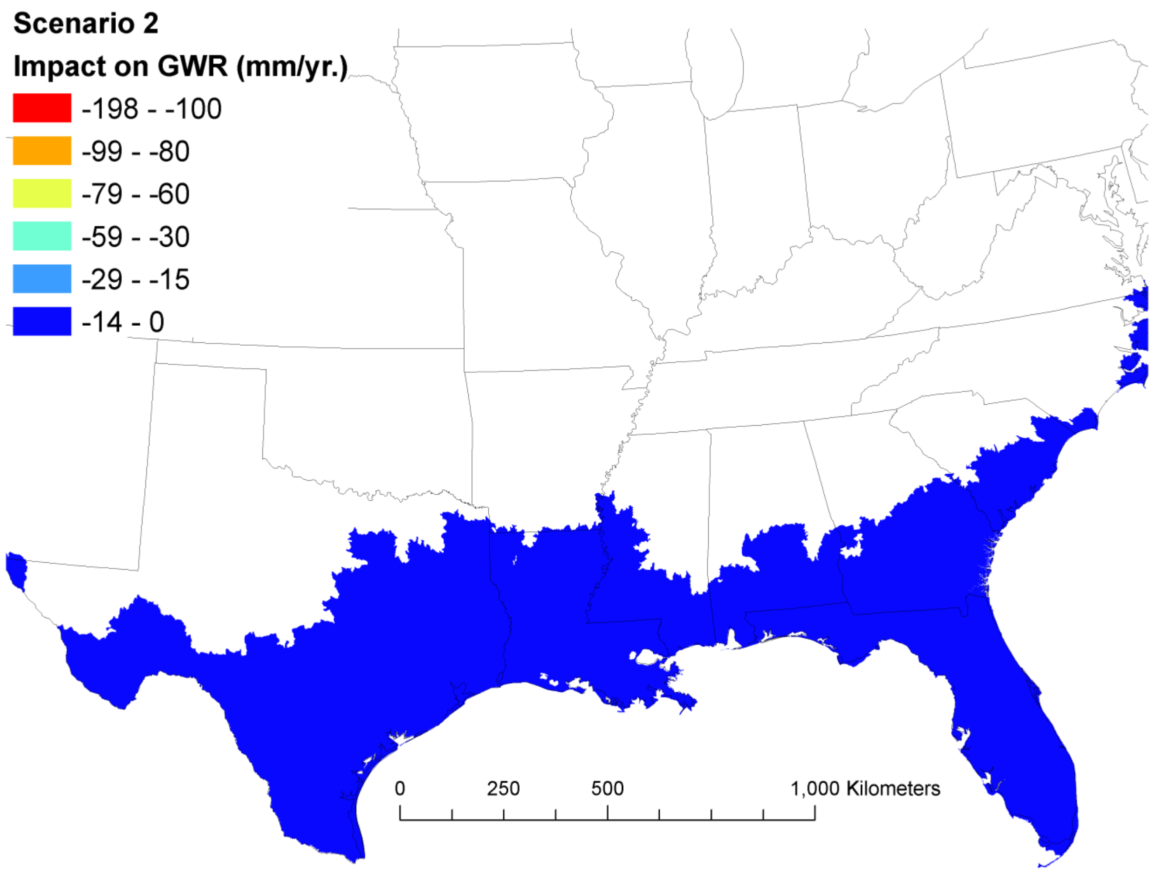


Figure 12A-B Spatial distribution of modeled impacts on groundwater recharge across 17,000 watersheds (A) Scenario 1 = Converting all vegetation to FT *Eucalyptus* (B) Scenario 2 = 10% of conversion of conifer forests to FT E*ucalyptus*.

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ArborGen, Inc. Petition (11-019-01p) for Determination of Non-regulated Status for Freeze Tolerant Eucalyptus Lines FTE 427 and FTE 435

Draft Environmental Impact Statement, April, 2017

Appendix D: USDA-FS Report on the Potential Fire Risk of Freeze-Tolerant Eucalyptus

See Attached: Andreu, A., Ottmar, R.D. and Prichard, S.J. Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States, September, 2013

Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant Eucalyptus (FTE) Plantations of the Southern United States

September 2013

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Executive Summary

Andreu, A., Ottmar, R.D. and Prichard, S.J. 2013. Evaluation of Potential Fire Behavior in Genetically Engineered Freeze-Tolerant (FTE) Plantations of the Southern United States.

The United States Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) is preparing an Environmental Impact Statement (EIS) to assess plantings of genetically-engineered freeze-tolerant *Eucalyptus* (FTE *Eucalyptus x urograndis*, FTE) in the United States. If approved for commercial production, some pine plantations mixed hardwood forests and agricultural lands in the Southern United States may be converted to FTE plantations. Since FTE plantations could pose an increase in risk of fire hazard relative to existing vegetation, a fire risk assessment is needed and will be addressed in the EIS. APHIS asked the Fire and Environmental Research Applications Team (FERA) of the Pacific Northwest Research Station to conduct the fire risk assessment using the Fuel Characteristic Classification System (FCCS).

The objective of this project was to model potential fire behavior in FTE plantations in the southern United States and assess fire risk compared to existing vegetation, including southern pine, mixed hardwoods, and post-harvest agricultural fields. To meet this objective, the FERA team of the Pacific Northwest Research Station developed detailed fuelbed pathways that represent current and potential fuelbeds of FTE and loblolly pine plantations. Each fuelbed in the pathways were constructed and used to generate FCCS outputs under a range of fuel moisture and weather scenarios. Potential fire behavior was compared between the FTE and loblolly pine plantation fuelbeds and compared with mixed hardwood forest and agricultural field fuelbeds already in existence.

Additional fuelbeds were constructed to evaluate potential fuel conditions that might contribute to fire hazard in FTE fuelbeds. These included:
1) Evaluating tree regeneration as a shrub stratum in FCCS calculations,
2) Replacing neutral shrub species in FTE and loblolly fuelbeds that do not influence predicted surface fire behavior with accelerant shrubs,
3) Examining potential fire behavior with cured herbaceous stratum to represent dormant season fuel conditions, and
4) Frost damage including canopy kill and leaf-off conditions.

Based on FCCS predictions, we conclude that in general, FTE fuelbeds do not pose a substantially higher fire risk than southern pine plantations, other forest types common to the southern United States, or agricultural lands. Potential fire behavior in the agricultural and mixed hardwood fuelbeds that we evaluated was actually higher in general than the FTE fuelbeds.

In their first year, plantations may pose a short-term fire risk, particularly under high wind scenarios and in the dormant season when the majority of herbaceous biomass is dead.

Treating first-year FTE plantations as a shrub layer provides the most conservative estimate of potential surface fire behavior. In addition, if FTE is planted in areas that typically have flammable shrubs in their understories (e.g., wax myrtle or gallberry), effective site preparation may be required to reduce the risk of shrub development and associated fire hazard. If such plantations do not receive effective site preparation, understory herbaceous vegetation may moderately increase the surface fire behavior potential. Frost damage would likely result in a short-term increase in surface fire potential associated with leaf-fall and resulting litter accumulations.

Due in part to low to moderate surface fire behavior potential, FTE plantations generally had low crown fire initiation potential. However, if a crown fire starts, there is a high risk of it spreading. Active management to reduce surface fuel loads, including flammable shrub layers and herbaceous fuels, would be important measures to reduce the risk of crown fire initiation.

Potential fire behavior generally increases over time in FTE biomass, pulpwood and coppice pathways as litter and woody fuels accumulate. We evaluated fuelbeds that represented over-mature or abandoned FTE and loblolly plantations that were 20-30 years old. Under these conditions, potential fire hazard is only moderate and does not markedly differ between FTE and loblolly pine plantations. However, if plantations were allowed to continue to grow, we would expect that ladder fuels could develop and lead to a high potential for crown fire initiation and spread.

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Introduction

The United States Department of Agriculture's Animal and Plant Health Inspect Service (USDA-APHIS) is preparing an Environmental Impact Statement (EIS) to assess plantings of genetically engineered freeze-tolerant *Eucalyptus x urograndis* (FTE) in the United States. If FTE is adopted for commercial production in the United States, pine plantations, mixed hardwood forests and agricultural lands in the southern United States may be converted to FTE (see other APHIS technical reports appended to this EIS for more information). Since FTE may pose an increased risk of fire hazard relative to existing vegetation, a fire risk assessment of these potential plantations is needed and will be addressed in the EIS and this technical report.

Because native *Eucalyptus* forests in Australia and other parts of the world have been associated with extreme surface and crown fire events (Cruz et al. 2012, McCaw et al. 2012) and firebrand spotting potential (Ellis 2011) a fire risk assessment for introduced FTE plantations is warranted. A preliminary analysis by Goodrick and Stanturf (2012) indicated little difference in potential fire behavior between young FTE plantations relative to existing southern pine plantations. However, the authors cautioned that flammable shrub layers could pose substantial surface fire risk and if crown fires were allowed to initiate, older FTE plantations had a high potential for crown fire spread.

This study was developed to further assess surface and crown fire hazard in FTE plantations by developing fuelbeds to represent different life stages and management scenarios for FTE plantations and predicting potential fire behavior under a range of wildfire scenarios. Predicted fire behavior was compared to common vegetation types that currently exist in the southern United States and could be replaced by FTE plantations. This assessment did not address firebrand spotting potential because FCCS does not evaluate spotting potential and FTE trees do not have stringy bark, a key fuelbed component needed for creating firebrands.

Fuel Characteristics Classification System

Assessments of fire risk, fire effects, fire emissions, and carbon have demonstrated the need for a system to quantify and classify wildland fuels and be able to adequately characterize the inherent variability of fuel characteristics across geographic regions, under various management scenarios, and over time. The Fire and Environmental Research Applications team (FERA) of the Pacific Northwest Research Station's Pacific Wildland Fire Sciences Laboratory (U.S Department of Agriculture, Forest Service) has developed the Fuel Characteristic Classification System (FCCS) (Ottmar et al. 2007, Riccardi et al. 2007, Sandberg et al. 2007a, Sandberg et al. 2007b, Schaaf et al. 2007, Prichard et al. *in press*) to meet this need. The system offers consistently organized fuels data and fire behavior models that can be used to assess fuelbeds for fire risk. Users can access fuelbeds from 500 reference FCCS fuelbeds contained in the database, modify or customize any of the 300 fuelbed input variables and calculate surface fire behavior, crown fire, and available fuel potentials (index between 0- 9) for each FCCS fuelbed. FCCS also predicts surface fire behavior, including reaction intensity (BTU ft^{-2} min^{-1}), flame length (ft), and rate of spread (ft min^{-1}), under specified environmental conditions.

The FCCS fuelbeds include characteristics for all strata, categories and sub-categories of a fuelbed that have a potential to burn including trees, snags, ladder fuels, shrubs, herbaceous fuels (herbs), sound and rotten woody fuels, stumps, piles, litter, and duff. The refinement of fuels into categories and subcategories allows specific attributes to be captured that contribute to fire behavior such as accelerant shrubs, stringy or fuzzy bark, or deep, fluffy litter composed of leaves and bark. Each strata, category, and subcategory may be modified to capture variability in fuels, and to create customized fuelbed(s) particular to a fuelbed type and applied at a management unit, forest, state, region, or any other scale of choice. This design can also be used to capture complexity and variability of fuels across time and space. For example, modification of height, percentage cover, and density of trees (overstory, midstory, or understory) can be used to represent the effects of a thinning operation on fuels. Changes to the values of the percentage live and live foliar moisture in either the shrubs or grass fuels can be used to represent a temporal change of season (i.e., growing vs. dormant). Many possibilities exist because every variable can be edited. Extensive data within, and produced by, FCCS can be used for fuel operation and management activities, fire behavior, emissions analysis, fire effects, and ecological analysis.

Project Objectives

The objective of this project was to model potential fire behavior in FTE plantations in the southern United States and assess fire risk compared to existing vegetation, including southern pine, mixed hardwoods, and post-harvest agricultural fields. To meet this objective, the FERA team of the Pacific Northwest Research Station developed detailed fuelbed pathways that represent current and potential fuelbeds of FTE and loblolly pine plantations. Pathway fuelbeds were constructed and used to generate FCCS outputs under a range of fuel moisture and weather scenarios. Potential fire behavior was compared between the FTE and loblolly pine plantation fuelbeds and compared with mixed hardwood forest, pine hardwood forest, and agricultural field fuelbeds already in existence.

Methods

Fuelbed pathways were constructed based on knowledge of local successional patterns and modeling and consultation with FTE experts. FERA performed a literature search and consulted with FTE experts (Pat Minogue, University of Florida, and José Stape, North Carolina State University) to develop FTE pathways and fuelbeds. Michael Andreu, University of Florida was consulted for loblolly pine pathway and fuelbed development.

Three main pathways were developed to represent typical management and harvest scenarios for commercial FTE plantations including

1) A biomass pathway that represents short FTE rotations for biomass and energy production
2) A pulpwood pathway that represents longer FTE rotations for pulpwood and chip harvests

3) A Coppice pathway that represents harvested plantations that have been allowed to sprout (*see FTE Pathway Handbook*).

Specific characteristics of the FTE plantations were incorporated, including standard stocking, height, height to live crown, and crown closure. A comparative pathway was developed for intensively-managed loblolly pine plantations. Loblolly pine fuelbed pathways were constructed in order to provide consistent comparisons between southern pine plantations and potential FTE plantations over similar management trajectories and successional stages.

The following paragraphs describe key assumptions made for each pathway.

FTE Biomass Pathway

The FTE biomass pathway represents fuelbeds across time, starting with dense (~1200 trees/acre) FTE plantations that established following: 1) intensive chemical and mechanical site preparation including bedding, fertilizer within tree rows and herbicide applications to increase tree growth and reduce competing vegetation and 2) incomplete or unsuccessful site preparation (Couto et al. 2011, Zalesny et al. 2011, Hinchee et al. 2009, Rockwood and Peter 1997). The incomplete site preparation is assumed to have resulted in lower stand vigor and delayed canopy closure, which would allow for competing vegetation (e.g., grasses, other herbaceous vegetation, shrubs and mixed hardwood trees) to become established (Couto, 2012, Rockwood and Peter 1997, José Stape, North Carolina State University, personal communication, 2013). Biomass harvests are generally conducted at 3-4 years and often are coppiced, so harvested fuelbeds from the FTE biomass pathway would be converted to early-stage coppice fuelbeds. FTE fuelbeds over 4 years old represent FTE biomass plantations that have been abandoned (José Stape, North Carolina State University, personal communication, 2013).

FTE Pulpwood Pathway

The FTE pulpwood pathway represents FTE pulpwood plantations over time, starting with a planting density of 625 trees/acre that established following: 1) intensive chemical and mechanical site preparation including bedding, fertilizer within tree rows and herbicide applications to increase tree growth and reduce competing vegetation and 2) incomplete or unsuccessful site preparation (Patrick Minogue, University of Florida, personal communication, 2013). Pulpwood plantations are considered harvestable at 7-8 years. Pulpwood FTE plantations are often coppiced; harvested pulpwood plantations would then be converted to early-stage coppice fuelbeds. Two older fuelbeds (16-30 years) are included to represent abandoned pulpwood plantations.

FTE Coppice Pathway

The coppice pathway represents biomass or coppice pathway fuelbeds that have been harvested and have been left to sprout following: 1) fertilizer and herbicide applications and 2) no application of herbicides or fertilizer. Effectively managed, coppiced fuelbeds are assumed to be thinned to one stem per stump within the first year, resulting in a density of 1200 stems per acre. Ineffectively managed coppiced fuelbeds are not thinned to one stem per stump and are assumed to have 3 sprouts per stem, resulting in a starting density of 3600 stems per acre. Fuelbeds past the typical age of harvest (3-4 years) are included to represent FTE coppice stands that have been abandoned. A coppice pathway that represents pulpwood densities was not included because fuelbeds would have been intermediate between pulpwood and biomass coppice and would not have added appreciably to the range of conditions modeled in this assessment.

<u>Loblolly Pathway</u>

The loblolly pathway represents loblolly pine plantations across time under intensive management for pulpwood and saw timber harvest following: 1) intensive chemical and mechanical site preparation including application of herbicide to increase tree growth and reduce competing vegetation, and 2) incomplete or unsuccessful site preparation. Frequent application of fertilizer is typical in intensively managed, commercial loblolly plantations, and saw timber stands are also thinned to improve stand vigor and tree growth. Pulpwood harvests are generally conducted at 12-15 years, and saw timber harvests are conducted at 20-30 years. Ineffectively managed fuelbeds and fuelbeds beyond the normal pulpwood harvesting age (e.g., fuelbeds 1347 and 1348) are also included to represent loblolly stands that have been abandoned (Moorhead et al. 1998, Zalesny et al. 2011, Michael Andreu, University of Florida, personal communication, 2013).

Fuelbed development

FCCS fuelbeds were developed using scientific literature, datasets, local plant guides, and expert opinion from local and foreign colleagues familiar with stand structures, species composition, and fuel characteristics. Due to a lack of actual field data for FTE plantations (e.g., surface fuels inventories to systematically quantify live and dead biomass across fuelbeds representative of pathway intervals), assumptions were made during this process. The fuelbeds are intended to be template fuelbeds that can be updated with more current and specific datasets as they become available. Key assumptions are listed by fuelbed stratum.

<u>Canopy</u>

Most FTE fuelbeds are assumed to reach canopy closure at 2 to 3 years (Campoe et al. 2013, Nutto et al. 2006). However, fuelbeds with incomplete site preparation (e.g., herbicide and/or fertilizer application) or lacking site preparation have partial canopy closure at 2-3 years with some grass and herbaceous cover (Rockwood and Peter 1997, Fox 2012). Height to live crown was estimated based on photos of very young stands and calculated for older stands based on crown ratios in the literature for various stand ages and interpolated for ages/heights that fell between those values (Campoe et al. 2013, Nutto et al. 2006). We assumed that snags would begin to occur in fuelbeds at 2-3 years. Snags were assumed to remain standing through time, moving through the three decay classes within FCCS (Prichard et al. *in press*), eventually falling and contributing to coarse woody debris in 9 to 15 years. Data on snag recruitment were lacking for *Eucalyptus* plantations, so we used loblolly plantation snag recruitment data (Samuelson et al. 2008, Zhao et al. 2011). Loblolly pine canopy data were taken from long-term studies in intensively managed pine stands (Samuelson et al. 2008, Zhao et al. 2011)

Shrubs

Shrub layers are expected to be sparse in most fuelbeds due to rapid canopy closure and herbicide applications. In ineffectively managed stands, shrubs are assumed to become established with a moderate increase in biomass and cover as the stand ages and canopy openings develop through tree mortality. Because few *Eucalyptus* plantations currently exist in the southern United States, an assumption was made that shrub vegetation would be similar in species composition, percentage cover, height and fuel loading to that of similarly managed pine plantations with comparable planting densities and cover (Miller et al. 1995, Martin and Jokela 2004, Jones et al. 2012). Shrub strata were assigned height values from 0.5 to 3.5 feet based on photos and typical heights of species included in the fuelbeds.

Shrub species typical of loblolly fuelbed understories (e.g., hollies, blueberries, blackberries, oaks, and woody vines such as greenbrier and muscadine) do not affect surface fire behavior or contribute to predicted reaction intensity. Because flammable shrub layers (e.g., wax myrtle and gallberry) have the potential to contribute to much higher reaction intensities than the neutral species assigned to the FTE and loblolly pathway fuelbeds, fuelbeds were also constructed with these species to evaluate differences in fire hazard between shrub understories common to loblolly pine plantations and scenarios in which flammable shrub understories were allowed to develop (see Additional Fuelbeds section below).

Herbs

Grasses and other herbaceous vegetation are the primary competing vegetation in young (less than 2 years old) loblolly plantations. Fuelbeds that lacked effective site preparation have substantial herbaceous cover. Species included in the *Eucalyptus* and loblolly fuelbeds were selected based on literature review of loblolly pine plantations managed at different intensities. As with the shrub stratum, an assumption was made that herbaceous vegetation would be similar in species composition, percentage cover, height and fuel loading to that of similarly managed pine plantations with comparable planting densities and percentage cover (Miller et al. 1995, Martin and Jokela 2004, Jones et al. 2012). Herbaceous vegetation was assigned a height of 8 inches, based on photos and typical heights of species included in the fuelbeds.

Downed Wood

There are no published estimates of woody fuel loads in FTE plantations. Fuel loads are expected to be negligible in new plantations. Coppice fuelbeds were assumed to inherit the same woody fuel loads as 3-4 year old biomass plantations with an estimated 10% recruitment of new woody fuels from harvest activities. Two- to three-year old plantations have an estimated 1 ton per acre of fine wood, and no coarse wood. However, pulpwood plantations with a lower stocking density were assumed to have 0.5 tons/acre of fine wood. Downed wood is assumed to increase by 20% to 4-6 year old and 7-8 year old plantations, 80% for 9-15 year old plantations and 200% in 16 to 30 year old plantations. However, fuelbeds with lower productivity associated with incomplete or ineffective site preparation, were assumed to have lower rates of woody fuel recruitment. Canopy depth, which is defined as tree height minus tree height to live crown of the overstory canopy layer, was used to inform differences in expected rates of woody fuel recruitment. For loblolly fuelbeds, we used loblolly photo plot data for downed wood estimates (Scholl and Waldrop 1999, Reeves 1988).

Litter

Estimates of litter depth and percentage cover are lacking for FTE fuelbeds. Litter is defined as the uppermost layer of the forest floor, composed of fallen leaves and decomposing organic matter. In the literature from other regions, litterfall estimates and current litter loads are available (Cunha et al. 2005, Turner and Lambert 2002, Bernhard-Reversat 2001, Lamb 1985, Ferreira 1984). However, we were not confident in their applicability to the southern United States because reported litter decomposition rates are highly variable, ranging from a few months to 2 years with differences due to climate, *Eucalyptus* species, plantation or forest age, soil type and origin (coppice vs. seedling) (Adair et al. 2008, Moorhead et al. 1999, Ferreira 1984). José Stape (personal communication) indicated that the half-life of *Eucalyptus* litter in the southern United States is approximately 3 to 4 months, but accurate information on *Eucalyptus* litterfall for the southern United States is not available. Due to the lack of reliable data, we did not focus on decomposition rates, but rather on the characteristics of the canopy and a range of litter loads. We used our expert opinion to assign initial litter inputs for young plantations and assigned a maximum of 3.5 inches for abandoned 20-30 year-old plantations based on measures taken from the *Eucalyptus globulus* East Bay Photo Series (Wright and Vihnanek *in press*). Midpoint values were interpolated based on assumed litter accumulation rates as well as differences in canopy depth (as described in downed wood).

Duff

Duff is defined as organic soil (Oe and Oa soil horizons) and is composed of decaying organic matter. It is generally found below a litter layer in forest floors. We set a range of duff loads (0-3.5 tons/acre) based on literature from southern United States hardwood forests and *Eucalyptus* stands in other regions and interpolated midpoint values based on relationships among values used for the litter layer (Ottmar and Vihnanek 2000, Ottmar et al. 2003, Ottmar and Andreu 2007, Scholl and Waldrop 1999, Reeves 1988). FTE and loblolly pine fuelbeds are both assumed to have shallow duff layers (less than three inches). We assumed there was no duff in mechanically site prepared fuelbeds and assumed young coppice stands retained duff from pre-harvest fuelbeds.

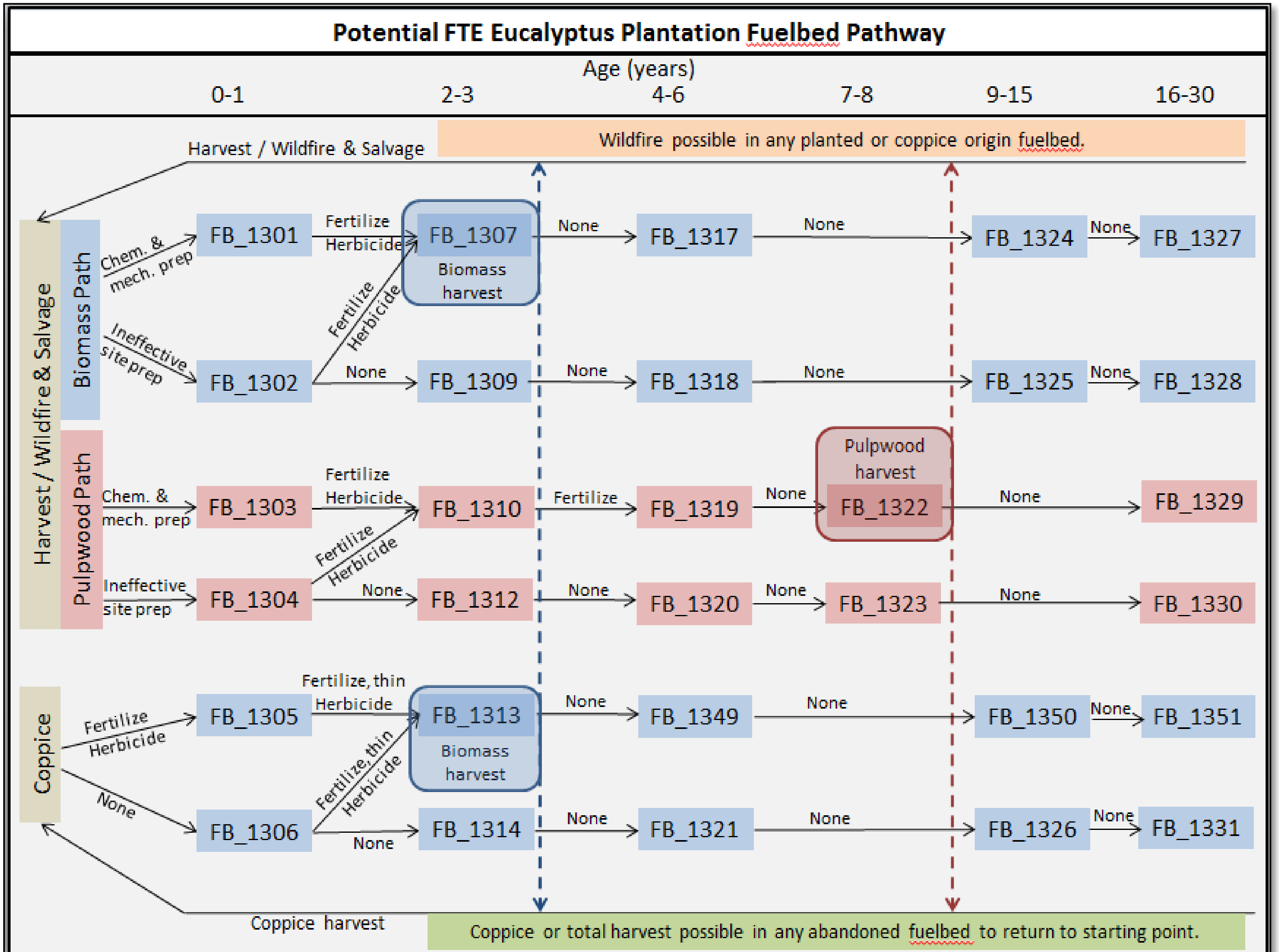

Figure 1: Genetically engineered freeze-tolerant *Eucalyptus x urograndis* (FTE) fuelbed pathways for the southern United States. Blue highlights represent high-density stands, and red highlights represent low-density stands. Vertical arrows indicate points at which biomass or pulpwood harvests may reset pathways to stand initiation. Wildfire or coppice harvests are possible at any stage of the fuelbed pathways.

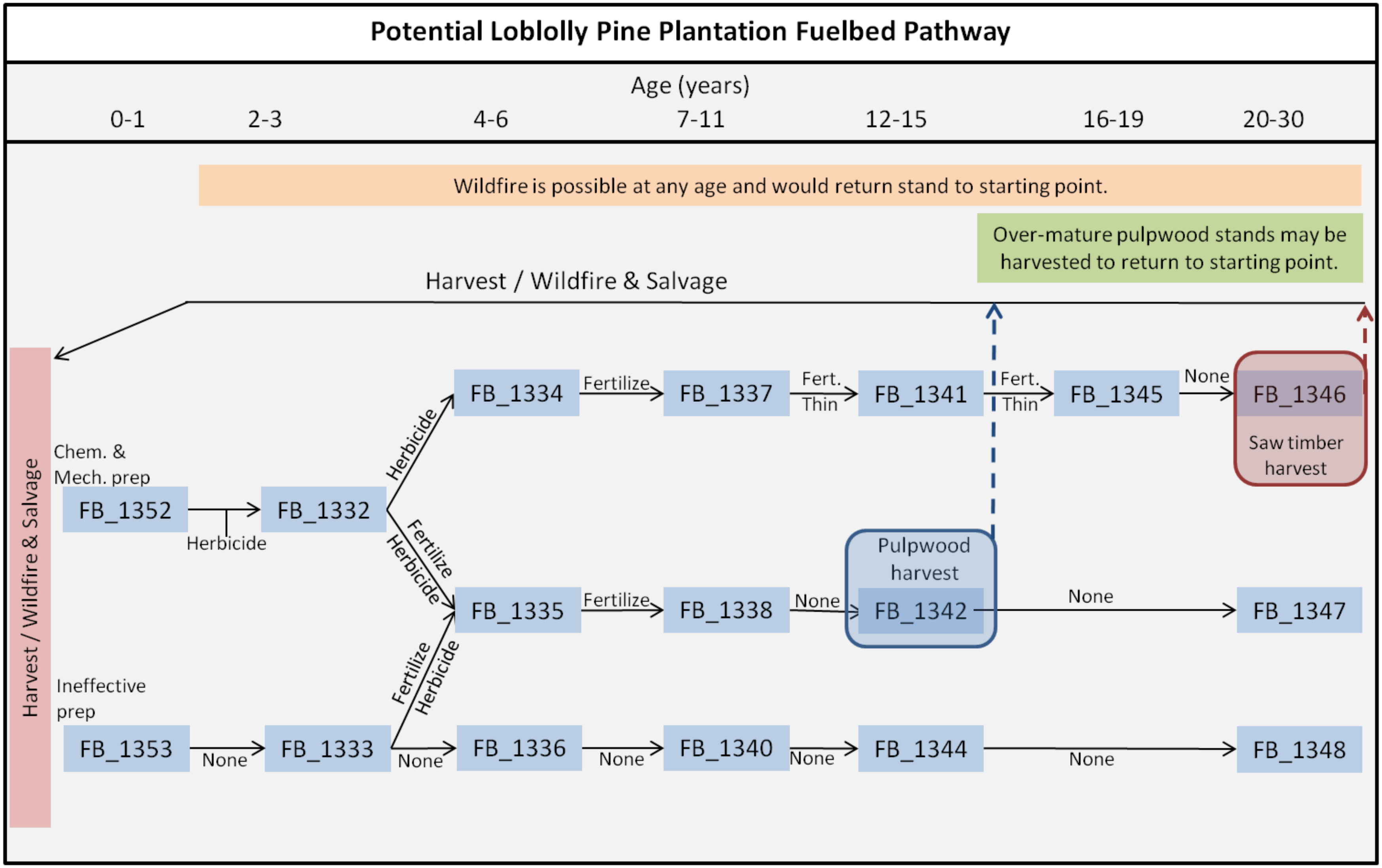

Figure 2: Loblolly pine fuelbed pathways. Vertical arrows indicate points at which pulpwood or saw timber harvests may reset pathways to stand initiation. Wildfires are possible at any stage of the fuelbed pathways.

FCCS model scenarios

Fuelbeds were calculated in FCCS version 3.0 using 18 combinations of three moisture scenarios, three mid-flame wind speeds and two slope gradients (Table 1). Environmental variables were selected to provide results at a wide range of fuel moisture and fire weather conditions that likely capture the actual variations in fuel moisture, wind speed, and slope gradients that could occur during wildfires. Further wind scenarios were tested to evaluate potential fire behavior under 10-mph, 15-mph and 20-mph winds under very dry, dry and moist fuel moisture scenarios.

Table 1: Environmental scenarios and descriptions. Midflame wind speeds include 0, 3 and 7 miles per hour (mph) and slope gradients include 0% and 15%. Moisture scenarios include very dry (1hr = 3%, 10hr = 4%, 100hr = 5%, Herb = 30%, Shrub = 60%), dry (1hr = 6%, 10hr = 7%, 100hr = 8%, Herb = 60%, Shrub = 90%), and moist (1hr = 12%, 10hr = 13%, 100hr = 14%, Herb = 60%, Shrub = 90%). Gray highlighted scenarios are most likely to occur in the Southern United States depending on season (moisture/wind) and terrain (slope) (Hollingsworth et al. 2007).

Scenario #	**Fuel moisture scenario**	**Midflame wind speed** (mph)	**Slope gradient** (%)
1	Very dry	0	0
2	Dry	0	0
3	Moist	0	0
4	Very dry	3	0
5	Dry	3	0
6	Moist	3	0
7	Very dry	7	0
8	Dry	7	0
9	Moist	7	0
10	Very dry	0	15
11	Dry	0	15
12	Moist	0	15
13	Very dry	3	15
14	Dry	3	15
15	Moist	3	15
16	Very dry	7	15
17	Dry	7	15
18	Moist	7	15

Additional fuelbeds

A set of existing fuelbeds in the potential FTE planting zone was compiled to provide a comparison to vegetation types other than pine plantations that might be converted to FTE plantations (see 1 below). We also constructed additional fuelbeds to evaluate potential fuel conditions that might contribute to fire hazard in FTE fuelbeds. These include 2-5 below:

1) Agricultural and mixed hardwood fuelbeds. Fuelbeds from the FCCS reference library were selected to represent agricultural crops and mixed hardwood forests common to the

southern United States. The mixed hardwood forests are generally 40- to 100-years old and are composed of mixed hardwoods, oak, and pine/oak/mixed hardwood.

2) Tree regeneration as a shrub stratum. Regardless of age, trees are typically included in the FCCS canopy stratum. However, young plantations of FTE and loblolly pine could be considered flammable shrublands. To evaluate the effect of modeling 0-1 year old plantations as shrublands, we created test fuelbeds that assigned all plantation trees to the shrub stratum. Due to rapid tree growth in the southern United States, resulting in distinct gaps between surface and canopy fuels, it would not be appropriate to assign young plantations to a shrub stratum in any other stage.

3) Accelerant shrubs. All FTE and loblolly pine pathway fuelbeds were constructed with flammable shrub species (*Ilex glabra*) in the shrub stratum to evaluate potential fire behavior on sites and management scenarios that support the growth of highly flammable shrub species. This evaluation is particularly applicable to pine flatwood sites that contain flammable palmetto/gallberry understories.

4) Cured (Senesced) herbaceous stratum. Dormant-season fuelbeds with dead grass in their understories were constructed to evaluate the difference in potential fire behavior between the growing season, when herbaceous biomass is mostly living, and the dormant season when herbaceous biomass is mostly dead.

5) Frost-damage. Fuelbeds were constructed to evaluate the effects of a hard freeze on FTE plantations and included leaf-on fuelbeds immediately following frost damage and leaf-off fuelbeds in which leaves had contributed to deeper litter layers.

Results and Discussion

Information from each fuelbed pathway is summarized in a table including a description, the age class, and any management actions or natural change agents associated with each fuelbed (*see TFE Pathway Handbook*). Outputs from FCCS fire behavior and potential calculations (Sandberg et al. 2007a, Sandberg et al. 2007b) were summarized in a data table for each pathway and include:

1) Surface fire behavior outputs: rate of spread (ft min^{-1}), flame length (ft) and reaction intensity (BTU $ft^{-2}min^{-1}$);
2) FCCS crown fire, surface fire and available fuel potentials (each is an index from 0-9); and
3) Fuel model crosswalks to the original Fire Behavior Prediction System (Rothermel 1972; Albini 1976) and standard fuel models (Scott and Burgan 2005).

In order to provide a comparison of a range of wildfire scenarios, outputs are provided for 18 different environmental scenarios (Table 1; see FTE Pathway Handbook for outputs). Graphical comparisons between fuelbeds were made under benchmark environmental conditions (dry fuel moisture scenario, 4 mph midflame wind speed, no slope) for consistency between predicted surface fire behavior and crown fire potentials. FCCS surface fire, crown fire and available fuel potentials for each pathway fuelbed are shown in Appendix A. Tabular outputs are provided in Appendix B. Outputs from the three additional wind scenarios (10, 15, and 20 mph) are listed in Appendix C. While these wind speeds aren't typical in the Southeast, they were included to model fire behavior in potential high wind conditions which can occur during fire season in the Southeast, most commonly during dry cold fronts.

The FCCS surface fire behavior predictions are based on a modified version of the Rothermel fire spread model (Sandberg et al. 2007a). They include:

1) Rate of spread (ft min^{-1}), defined as the predicted rate of spread of the flaming front of a surface fire under an input environmental scenario,
2) Flame length (ft), generally defined as the distance from the ground to flame tip,
3) Reaction intensity (BTU ft^{-2} min^{-1}), defined as the rate of heat release per area of the flaming front of a surface fire, expressed as heat energy per area per time.

The FCCS fire potentials are defined as indexed values (0-9) that rate the intrinsic physical capacity of a wildland fuelbed to release energy, spread, crown, consume, and smolder under benchmark dry fuel conditions, 4 mph wind speeds, and flat ground (Prichard et al. *in press*). The three fire potentials can be used to compare the potential fire behavior among fuelbeds. For example, an FCCS fire potential of 469 represents a fuelbed with a modest surface fire potential, above-average crown fire potential, and extreme potential for biomass consumption (Sandberg et al. 2007a). Comparing a FCCS potential of 469 to a FCCS potential of 222 would indicate that the second fuelbed is predicted to have lower surface fire potential, much lower potential for crown fire and also much lower potential for biomass consumption than the first fuelbed.

- **Surface fire behavior potential** is a relative index (0-9) based on the potential maximum flame length or rate of spread. Predicted surface fire behavior is influenced by the loading, flammability, fuel moisture, and arrangement of surface fuels, including shrubs, herbaceous vegetation, fine woody fuels (< 3 inches in diameter) and litter.

- **Crown fire potential** is a relative index based on a weighted average of three crown fire subpotentials, including:
    - Crown fire initiation potential – an index (0-9) of the likelihood a surface fire will reach individual tree crowns,
    - Crown-to-crown transmissivity potential – an index (0-9) of the likelihood that a crown fire will spread through forest canopies, and
    - Crown fire spreading potential - an index (0-9) of the rate of crown fire spread.

- **Available fuel potential** represents the relative amount of combustible biomass available during the flaming, smoldering, and residual combustion stages. The available fuel potential tends to be highest in fuelbeds with high total biomass. However, a fuelbed with higher loading of finer fuels might have a higher available fuel potential than a fuelbed with higher loading of coarse fuels, because the fine fuels are more likely to be consumed. The three subpotentials (flaming, smoldering and residual smoldering) are scaled to 10 tons/acre (tpa).

The FTE, loblolly, mixed hardwood and agricultural fuelbed outputs are part of the project deliverables. Additional outputs can be calculated in FCCS using the fuelbed files provided in the final project deliverable and include fuel loading, total carbon, and summaries of fuel characteristics by stratum.

The following sections present results for each fuelbed within a pathway. Histogram comparisons are made to compare surface fire behavior (rate of spread, flame length, and reaction intensity by stratum) and crown fire potentials within and between FTE and loblolly pine pathways under benchmark environmental conditions (dry fuel moisture scenario, 4 mph midflame wind speed (wind), and no slope). FTE and loblolly pathways are presented with three-digit FCCS fire potential codes in Appendix C. Additional outputs including fuel model crosswalks are provided in the FTE Fuelbed Pathways Handbook.

<u>FTE Biomass pathway fuelbed outputs</u>

Predicted surface fire behavior is generally low for the FTE biomass pathway with rates of spread ranging from 2-5 ft min^{-1}, flame lengths ranging from 0.5 to 3 ft and reaction intensity below 3800 BTU ft^{-2} min^{-1} (Figure 3). Shrub reaction intensity is predicted to be zero in all FTE pathway fuelbeds because they contain neutral shrub species (as opposed to accelerant species) and do not contribute to predicted surface fire intensity (Prichard et al. *in press*).Under benchmark environmental conditions (4 mph wind, no slope, and dry fuel moistures), potential surface fire behavior does not substantially differ from the loblolly pine saw timber or pulpwood pathways.

Although crown fire initiation potential is low throughout the duration of the pathway, these dense FTE stands do have the maximum crown-to-crown transmissivity and spread potential, suggesting that if a crown fire initiation does start, it could spread quickly through plantation areas. There is little difference in crown fire potential between the effective versus ineffective site preparation pathways, likely because both pathways exhibit maximum crown-to-crown transmissivity and crown fire rate of spread potentials.

Compared to ineffective site preparation, the effective site preparation pathway prevents herbaceous undergrowth and results in lower predicted surface fire behavior in early stages. Due to lower tree density and cover, herbaceous vegetation remains a dominant fuel in the ineffective site preparation pathway, reflecting lower tree growth and more grassy openings in the forest floor.

FTE Pulpwood pathway fuelbed outputs

Potential surface fire behavior is low for the FTE pulpwood pathway with results similar to the FTE biomass pathway (Figure 4). Predicted rates of spread range from 2 to 7 ft min^{-1}, flame lengths range from 0.5 to 3 ft, and reaction less than 3400 BTU ft^2 min^{-1}. Ineffective site preparation has much higher predicted rate of spread and flame length than the effective site prep fuelbed at 0-1 yr. Herbaceous fuels remain a dominant fuel type throughout the ineffective site prep pathway.

The effective site preparation pathway for the FTE pulpwood plantations has similar crown fire potentials to the biomass pathway with low crown fire initiation potential but high spread potential if crown fires were to occur. The ineffective site preparation pathway has somewhat lower crown fire potentials, reflecting the lower tree density and cover in these plantations. However, crown fire initiation potential is higher due to the contribution of the herbaceous layer to surface reaction intensity.

FTE Coppice pathway fuelbed outputs

Although the coppice fuelbeds inherit litter from biomass and pulpwood plantations, litter is not a major contributor to predicted surface reaction intensity (Figure 5) compared to other strata. Predicted surface fire behavior is very similar to the biomass and pulpwood pathways with rates of spread ranging from 2.5 to 6 ft min^{-1}, flame lengths ranging from 1.2 to 3.6 ft, and reaction intensity values ranging from 700 to 3300 BTU ft^2 min^{-1}.

Coppice pathway fuelbeds have similar crown fire potential to the biomass and pulpwood pathway fuelbeds, reflecting similar canopy characteristics of high stocking but relatively low crown fire initiation potential.

Ineffective site preparation (i.e., herbicide application) of coppice plantations allows for herbaceous fuels to be a dominant fuel type and contributes to higher predicted reaction intensities. However, predicted rates of spread and flame lengths are actually higher in the effective site preparation pathway because woody fuel and litter depths are higher in effectively managed stands due to assumption of crown depth relationship to those strata. That is, more vigorous stands were assumed to have larger crowns that could contribute more branches and leaves to those fuelbed strata.

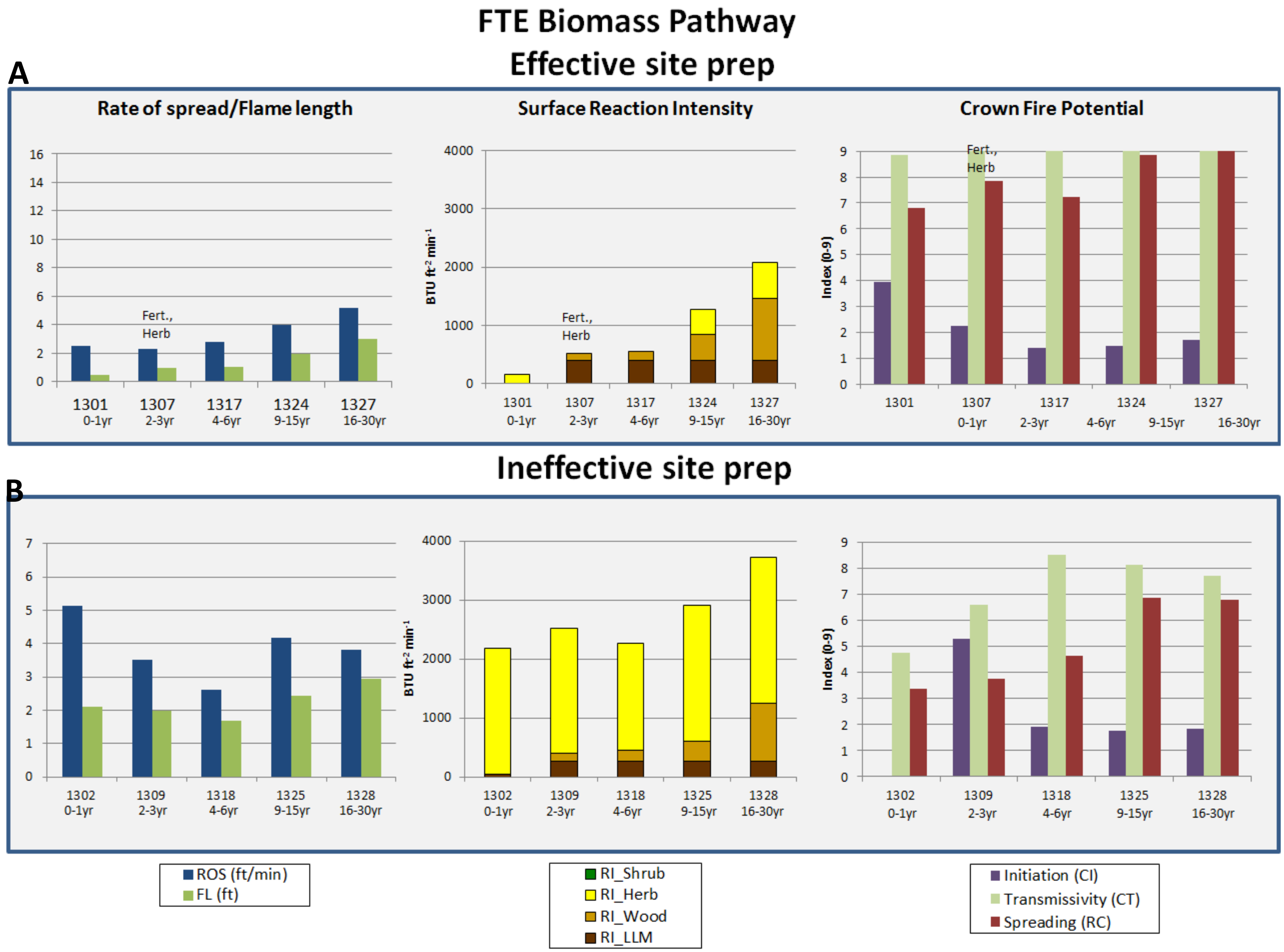

Figure 3: FTE biomass pathway including A) effective site preparation and B) ineffective site preparation. Fert. = fertilization, Herb. = herbicide treatment.

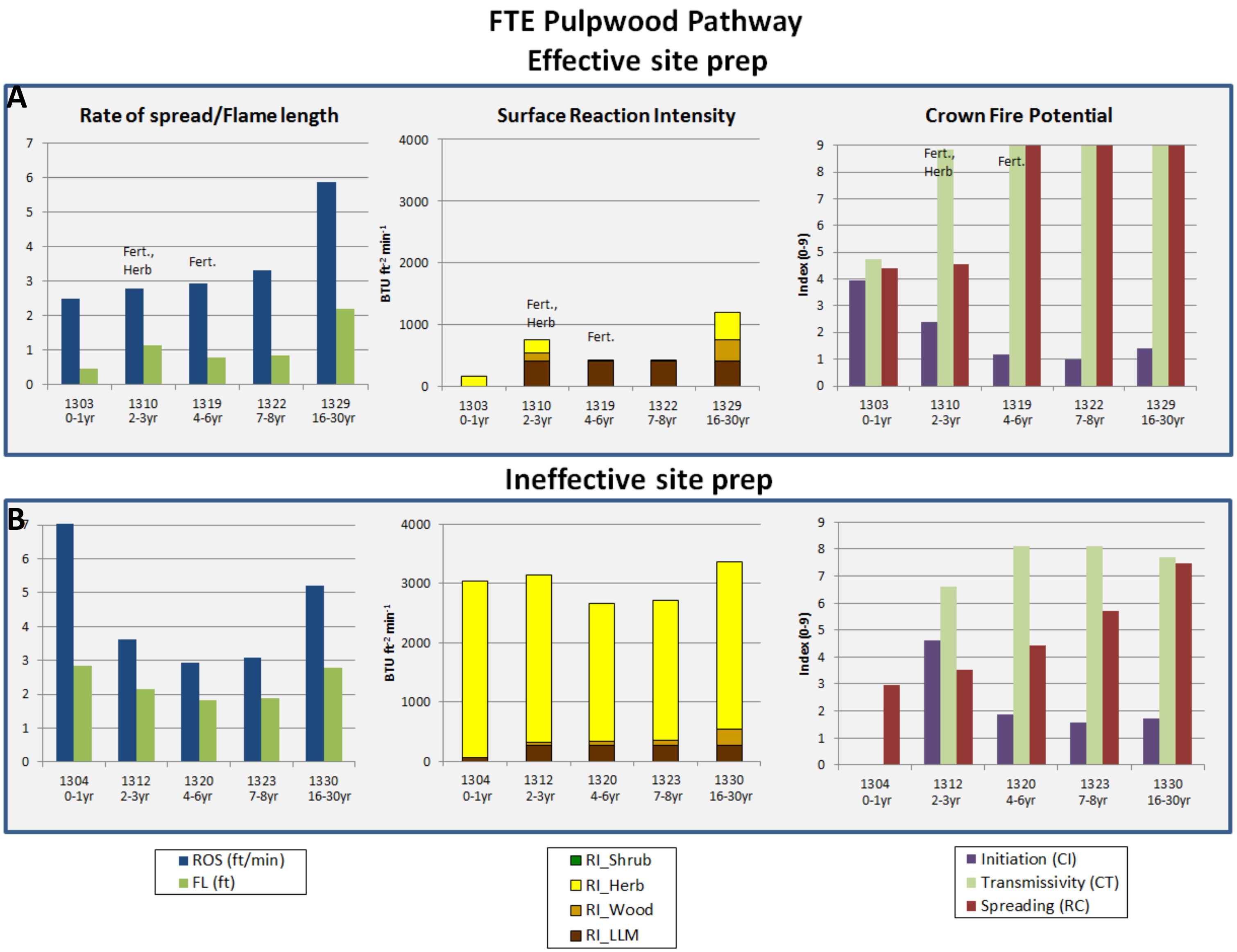

Figure 4: FTE pulpwood including A) effective site preparation and B) ineffective site preparation. Fert. = fertilization, Herb. = herbicide treatment.

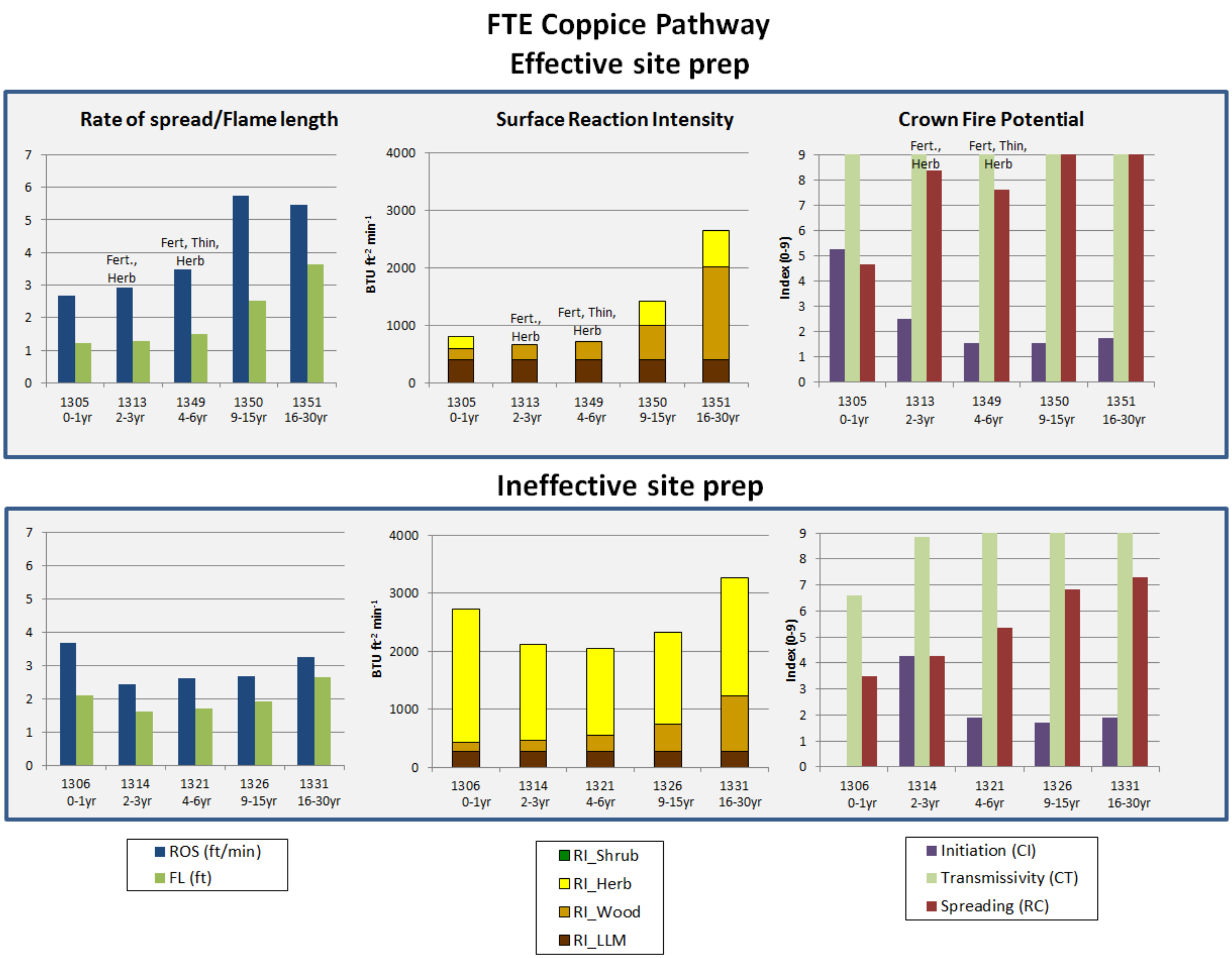

Figure 5: FTE coppice pathway A) effective site preparation and B) ineffective site preparation. Fert. = fertilization, Herb. = herbicide treatment, Thin = mechanical thinning.

Loblolly Saw timber pathway fuelbed outputs

The loblolly saw timber fuelbeds are dominated by litter and woody fuels with only a minor component of herbaceous fuels (Figure 6). Surface fire behavior predictions are only fractionally lower than FTE pathway fuelbeds with rates of spread between 0.5 to 5 ft min^{-1}, flame lengths less than 2.5 ft, and reaction intensity values less than 1700 BTU ft^2 min^{-1}. Surface fire behavior generally increases over the life of the stands but is not considerably different between harvest age (16-19 yr) and over-mature stands (20-30 yr).

Although the crown-to-crown transmissivity potential of loblolly saw timber plantations is high, they have a relatively low probability of crown fire initiation and only moderate potential for spread, reflecting relatively low surface fire behavior potential and that plantations are regularly thinned.

Loblolly Pulpwood pathway fuelbed outputs

The loblolly pulpwood pathway has somewhat higher predicted fire behavior than the loblolly saw timber pathway (Figure 7). Surface fire behavior is somewhat higher than FTE pathway fuelbeds with rates of spread between 0.5 and 5 ft min^{-1}, flame lengths between 0.3 and 4 ft, and reaction intensity values between 100 and 3500 BTU ft^2 min^{-1}. Ineffective site prep leaves a legacy of more herbaceous vegetation, which contributes to higher predicted reaction intensities but no corresponding increase in ROS and FL. Loblolly pulpwood plantations also have high crown-to-crown transmissivity potential but low crown fire initiation potentials and only moderate spreading potential.

Loblolly Sawtimber
Effective site prep

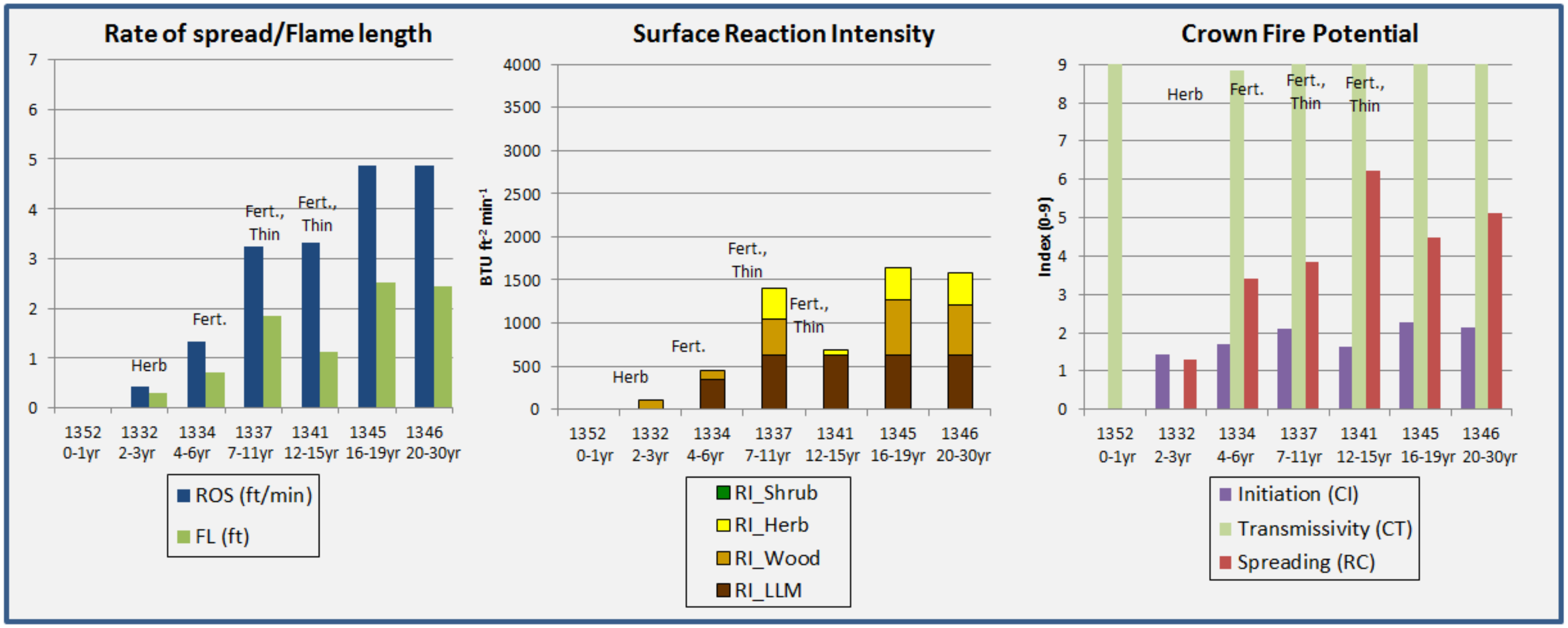

Figure 6: Loblolly saw timber pathway. Fert. = fertilization, Herb. = herbicide treatment, Thin = mechanical thinning.

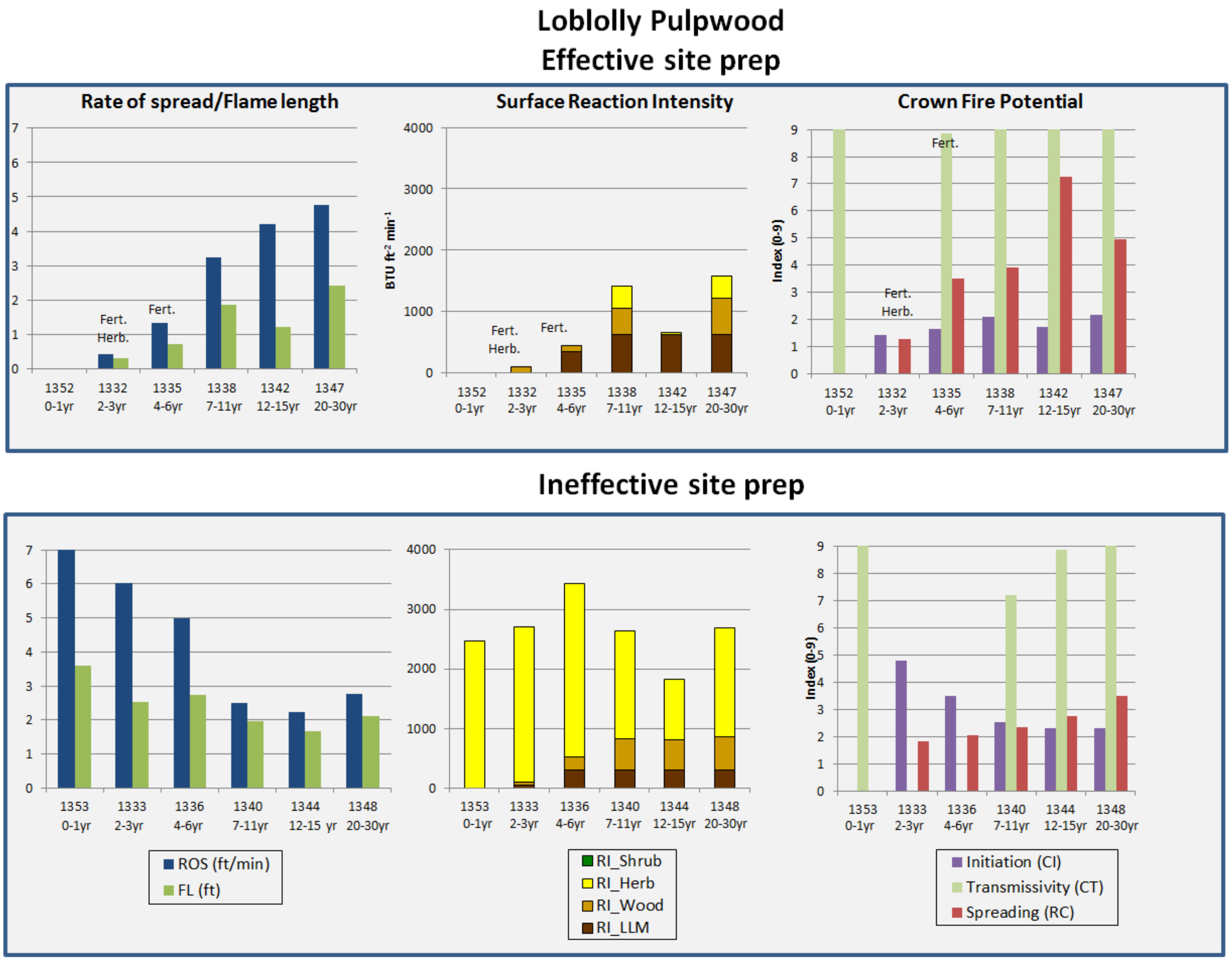

Figure 7: Loblolly pathway including A) effective site preparation and B) ineffective site preparation. Fert. = fertilization, Herb. = herbicide treatment.

Additional fuelbeds and environmental scenarios

Additional fuelbeds were created to evaluate conditions that could potentially lead to increased fire hazard and had mixed effects on potential surface and crown fire behavior.

1) Agricultural and mixed hardwood fuelbeds

Agricultural fuelbeds vary widely in their potential surface fire behavior under benchmark environmental inputs (Figure 8). All agricultural fuelbeds represent post-harvest crop residues. Growing season fuelbeds were not constructed because croplands are not considered flammable while they are green and regularly irrigated. The most flammable crop is the rice residue with extremely high rate of spread predictions (159 ft min^{-1}) and flame lengths (32 ft). Other major crops include corn, cotton and soybeans, with predicted rates of spread ranging from 20 to 55 ft min^{-1} and flame lengths ranging from 2.0 to 7.3 ft. Although these results suggest that replacement of crop residues with FTE plantations would not lead to higher surface fire behavior, the risk of fire spread through continuous forest canopies could be possible if FTE plantations replaced croplands adjacent to existing forestlands.

The mixed hardwood, oak and mixed hardwood/pine fuelbeds were selected from the FCCS library of reference fuelbeds. They generally range in age from 40-100 years old and have more developed woody fuel and litter layers than the younger FTE and loblolly pine pathway fuelbeds. Predicted rates of spread range from 1 to 12 ft min^{-1}, and flame lengths less than 5 ft (Figure 9). Crown fire potentials are low in all mixed hardwood fuelbeds because broadleaf deciduous canopies are mostly composed of neutral species that do not contribute to predicted crown fire potential (Appendix A). These results suggest that replacement of mixed hardwood forests with FTE fuelbeds would not lead to increased fire risk.

2) Tree regeneration as a shrub stratum

Comparison of FCCS predictions between treating young plantations as a canopy versus shrub layer produce markedly different surface fire behavior predictions. When FTE trees less than a year old are entered as a canopy layer, FCCS predicts only low surface fire behavior (e.g., with surface fire potential index of 2 or 3). Predicted ROS ranges between 2.5 and 7 ft min^{-1} and flame lengths range from 0.5 to 3 ft, depending on whether fuelbeds received effective site preparation or not (Figure 9).

In contrast, when FTE trees less than a year old are input into the shrub stratum, FCCS predicts much higher surface fire behavior. Predicted ROS and FL are at least five times higher when FTE is input as a shrub layer in FCCS. For the most conservative estimate of potential surface fire behavior (e.g., rates of spread, flame length and reaction intensity), young, 0-1 year old FTE should be considered as a shrub stratum for FCCS calculations.

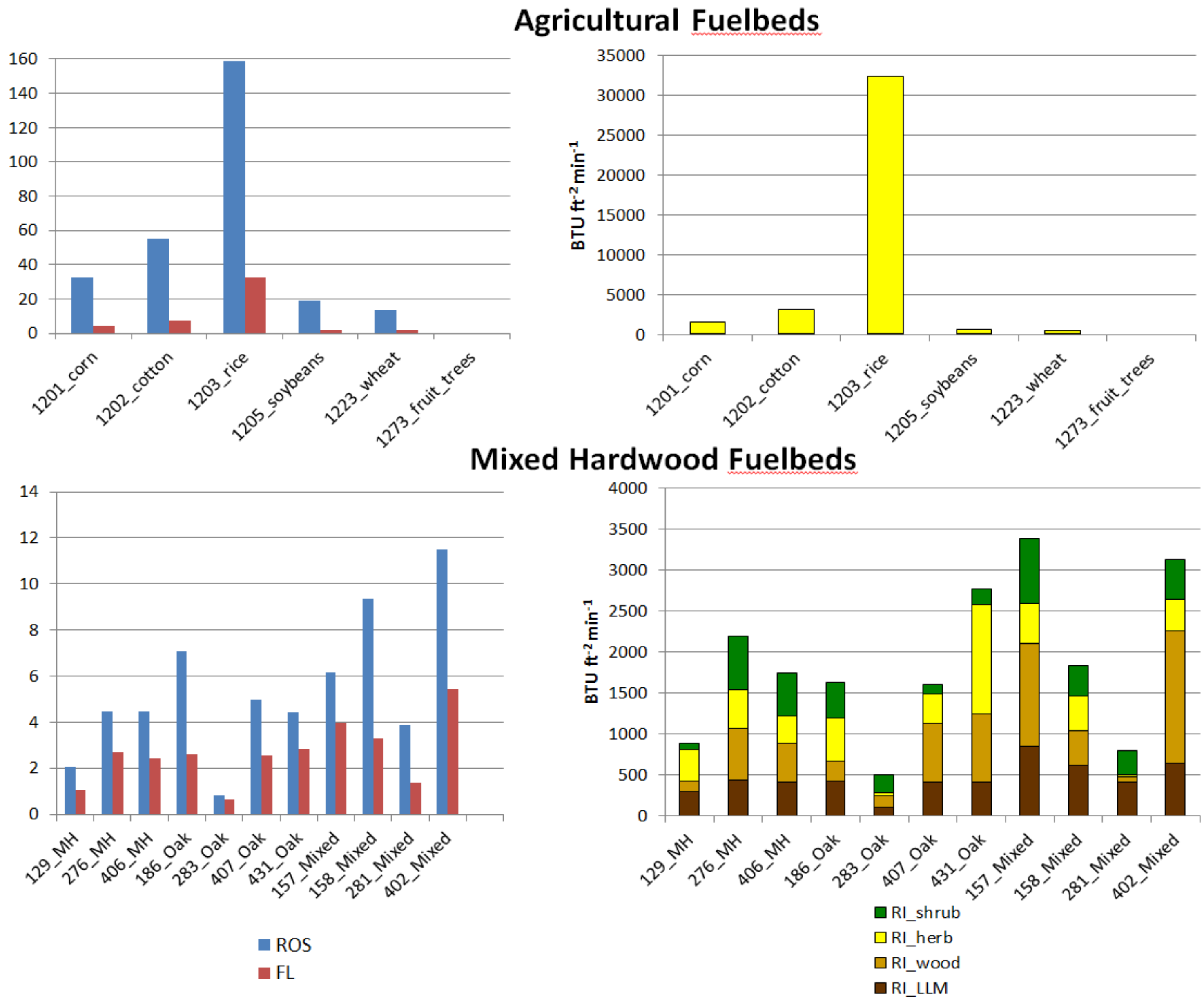

Figure 8: Predicted surface fire behavior for agricultural and mixed hardwood fuelbeds from the FCCS reference fuelbed library.

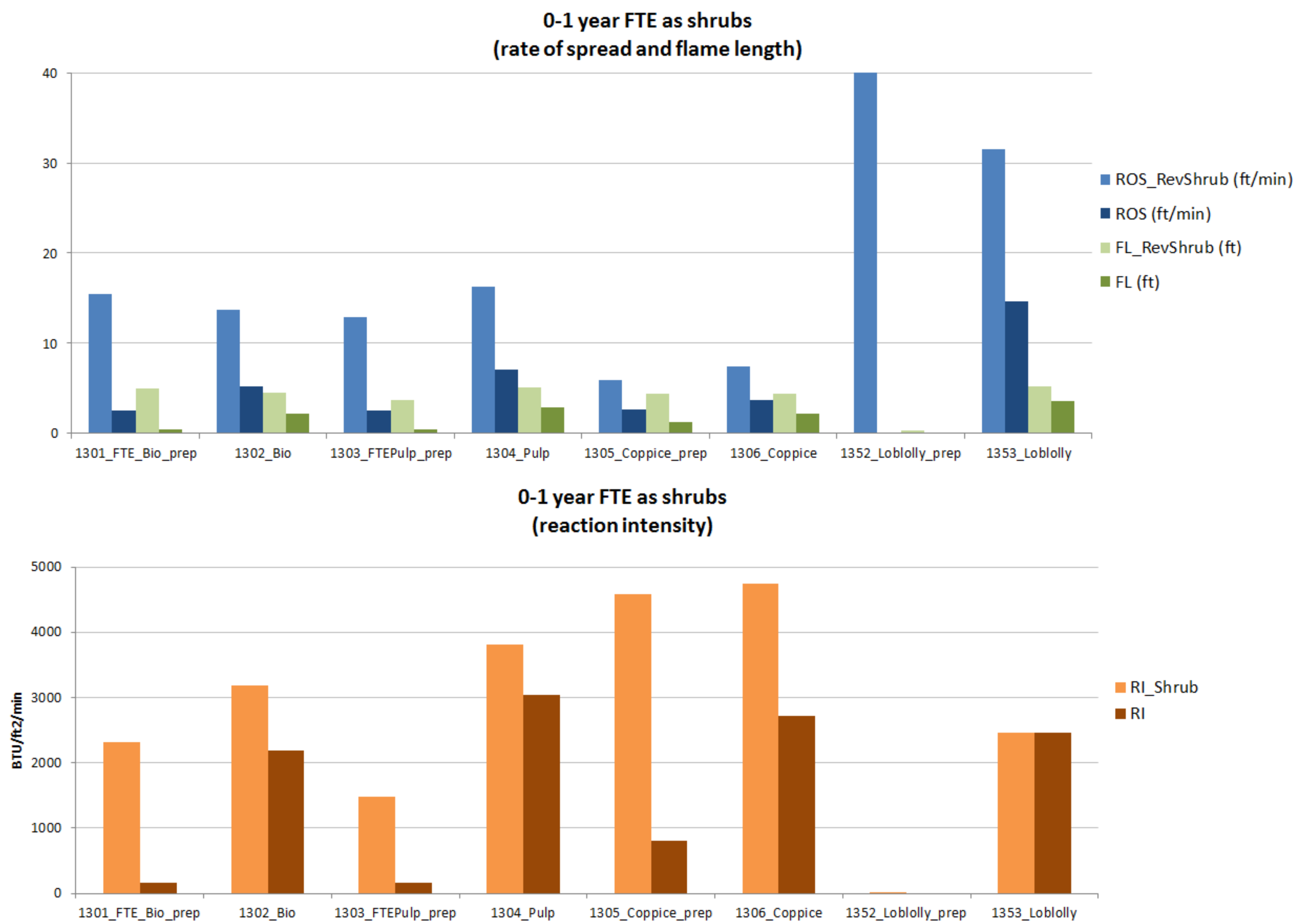

Figure 9: Predicted surface fire behavior for recent (0-1 year old) FTE and loblolly pulpwood plantations with FTE input as a shrub (ROS_shrub, FL_shrub, and RI_shrub) and as a typical canopy layer (ROS, FL, and RI). Initial fuelbeds from each of the six FTE pathways are represented, including biomass with effective site prep (BioPrep), biomass with ineffective site prep (Bio), pulpwood with effective site prep. (PulpPrep), pulpwood with ineffective site prep (Pulp), coppice with effective site prep (Coppice_Prep), and coppice with ineffective site prep (Coppice).

3) Accelerant shrubs

Because the shrub species in FTE and loblolly pathway fuelbeds are considered neutral species and do not contribute to predicted surface reaction intensity, we evaluated the potential effect of accelerant species on predicted fire behavior. Replacement of shrub species with accelerant species increased predicted surface fire behavior in young plantations, which are more open grown and support more shrub cover than older stages (Figure 10).

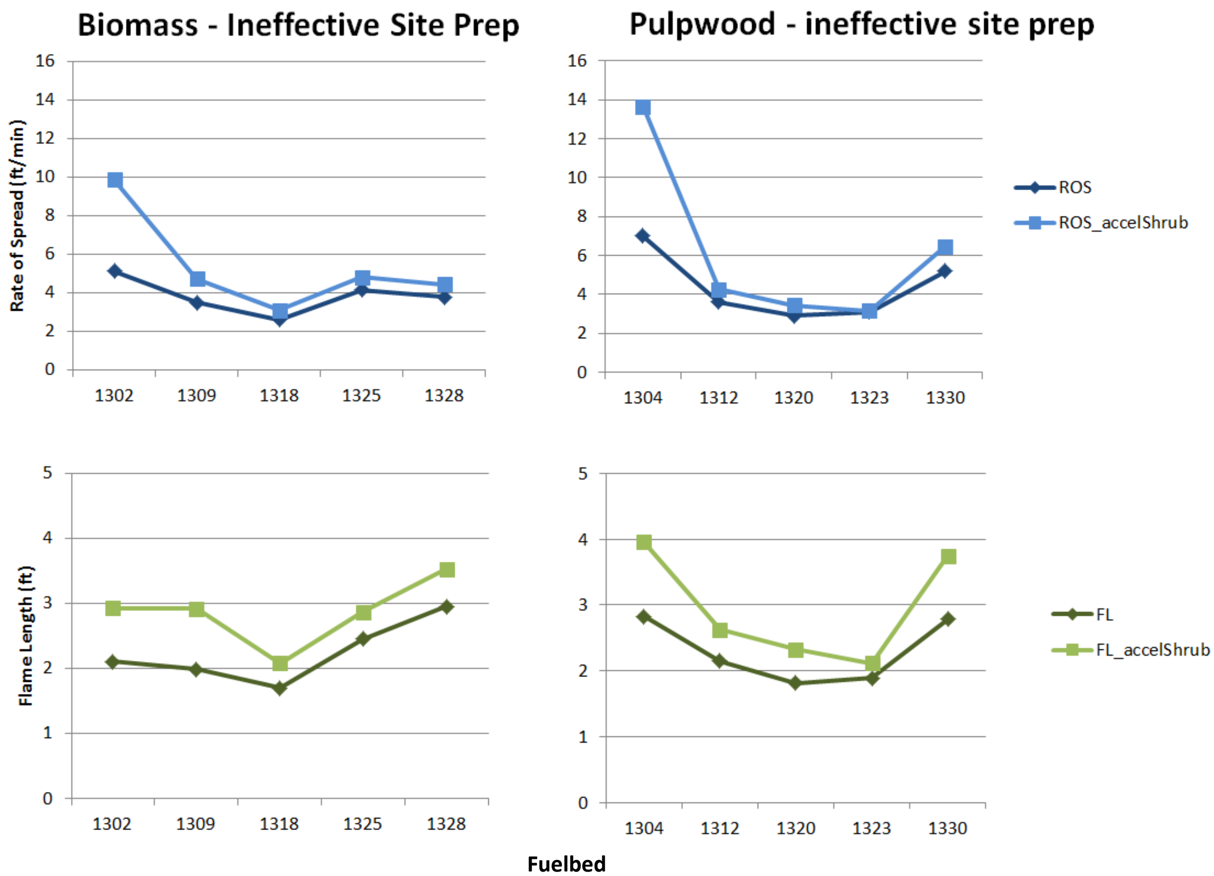

Figure 10: Comparison of predicted rates of spread (ROS) and flame lengths (FL) in FTE biomass and pulpwood pathway fuelbeds with regular shrub species (ROS/FL) and accelerant species (ROS_accelShrub and FL_accelShrub). Only ineffective site prep pathways are displayed because effective site prep pathways do not contain a developed shrub stratum.

4) Cured herbaceous stratum

We examined the potential influence of cured herbaceous fuels on predicted rates of spread and flame lengths. In some locations, grasses and other herbaceous fuels may be mostly composed of dead biomass during the dormant (winter) season. Because dead grasses have lower fuel moistures than living grasses, predicted surface fire behavior is indeed higher in fuelbeds with a 100% dead herbaceous stratum, suggesting that potential fire behavior may be greater during dormant season wildfires (Figure 11).

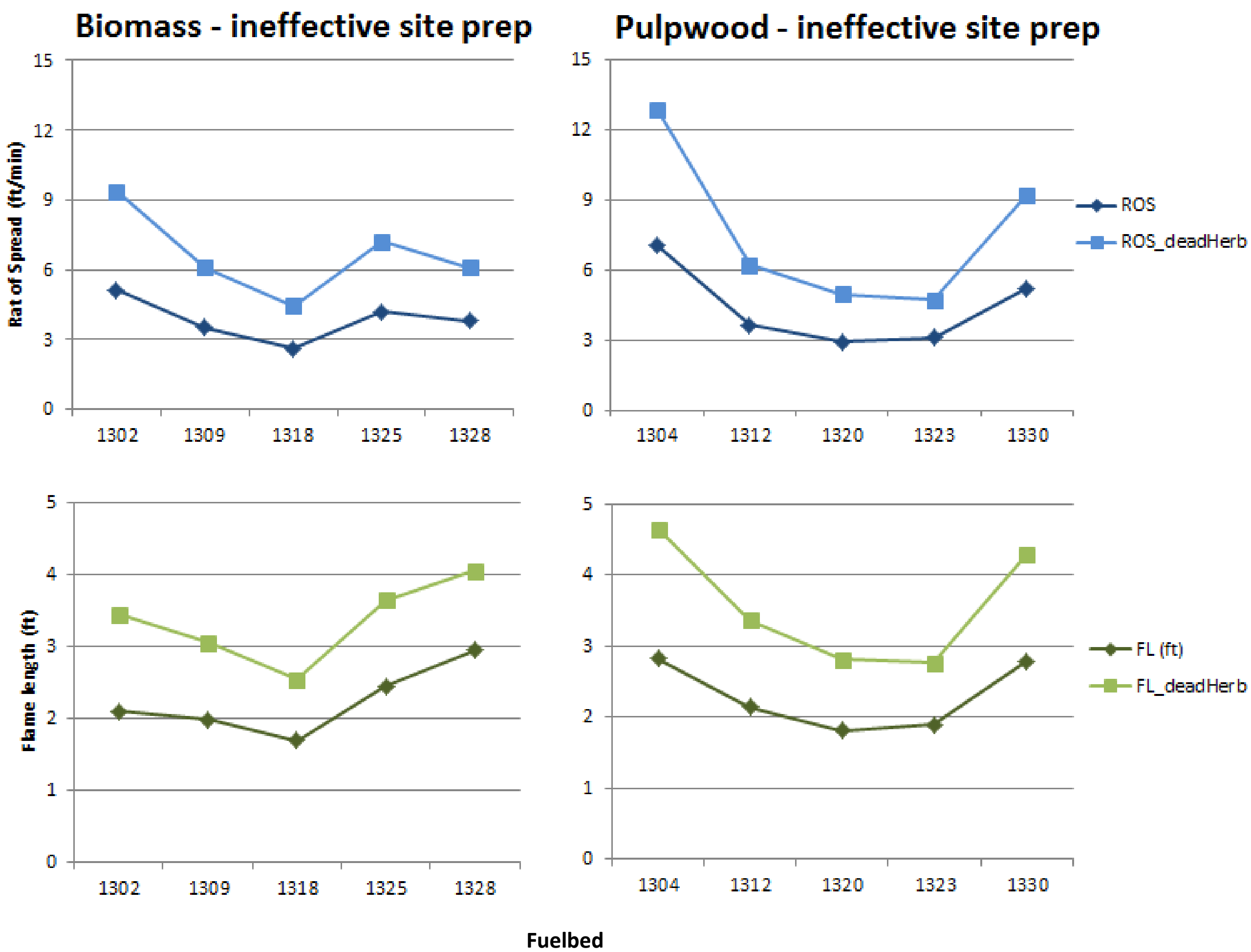

Figure 11: Comparison of predicted rates of spread (ROS) and flame lengths (FL) in FTE biomass and pulpwood pathway fuelbeds with regular herbaceous fuels (ROS/FL) and cured herbaceous fuels (ROS_deadHerb and FL_deadHerb). Only ineffective site prep pathways are displayed because effective site prep pathways do not contain a developed herbaceous stratum.

5) Freeze damage

We compared normal FTE pathway fuelbeds to fuelbeds at stand ages that had been damaged by a hard freeze. Recent, freeze-damaged with retained leaves have no difference in predicted surface fire behavior, which would be expected given that surface fuel characteristics remain unchanged (Figure 12). However, there is a sharp increase in predicted surface fire behavior in the leaf-off fuelbed, resulting from the large increase in litter fuels. The pronounced drop in crown fire potentials is likely an artifact of the FCCS crown fire model; trees with dead foliage were reassigned to snags and were not considered flammable.

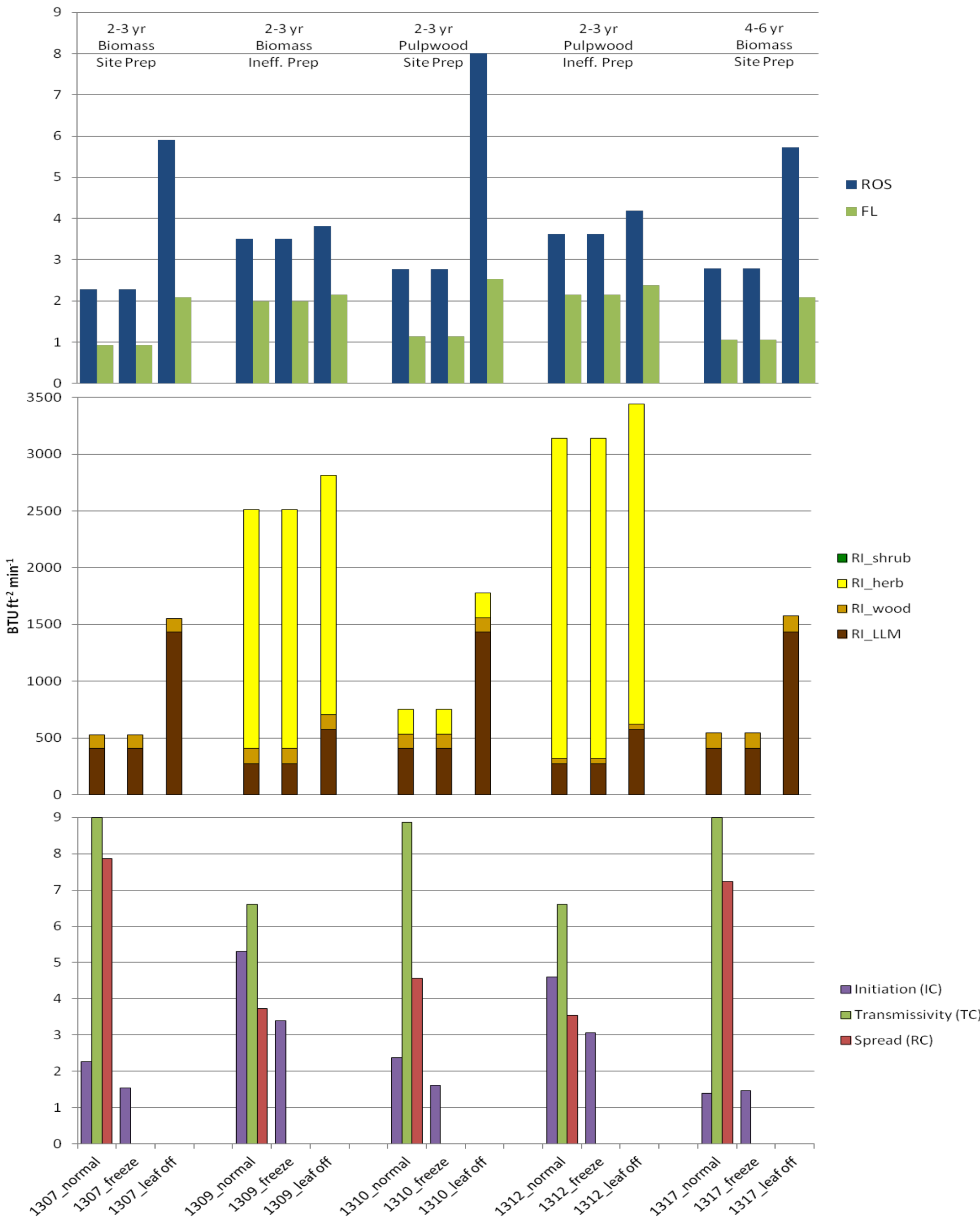

Figure 12: Comparison of FTE biomass and pulpwood fuelbeds under normal conditions (normal), immediately after frost damage in which the canopy has been killed (freeze), and following leaf-drop (leaf off).

6) Extreme wind scenarios.

Examination of predicted rates of spread and flame lengths under high winds (10, 15, and 20 mph) relative to the FCCS benchmark 4 mph wind speed demonstrates a close relationship between fire behavior and wind speed (Figure 13). There is a potential for high rates of spread, particularly in young plantations with high herbaceous cover following ineffective site preparation and also in abandoned plantations. Trends are markedly similar between FTE and loblolly plantations. Loblolly pulpwood plantations with ineffective site prep have the highest predicted rates of spread and flame lengths, suggested greater fire risk in loblolly pine plantations than the FTE plantations.

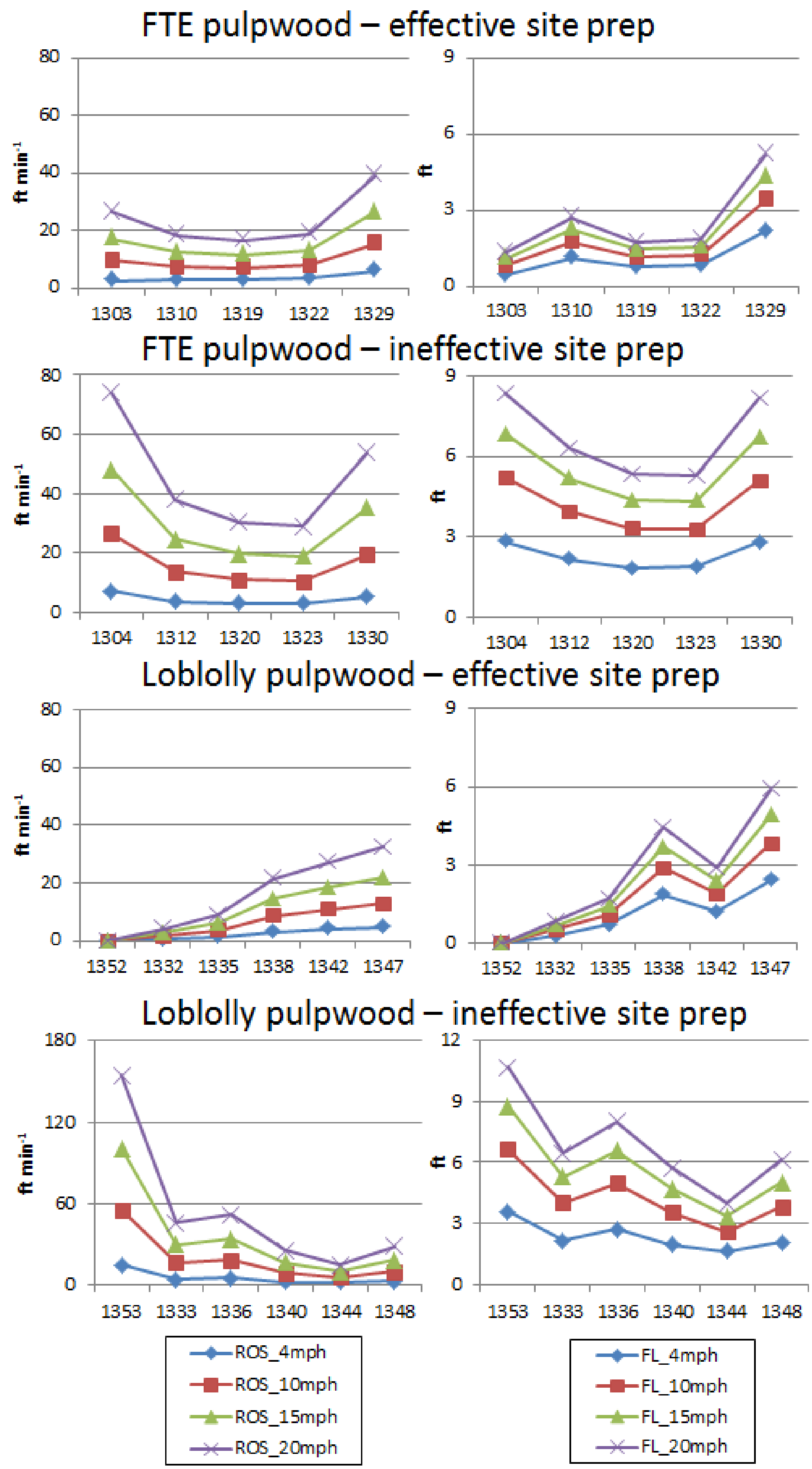

Figure 13: Influence of wind speed scenario on predicted rate of spread (ROS, left column) and flame lengths (FL, right column) for FTE and loblolly pulpwood fuelbeds.

Conclusions

We evaluated potential fire behavior for FTE fuelbeds and compared to fuelbeds that are common in the southern United States. Overall, we conclude that FTE fuelbeds do not pose a substantially higher fire risk than southern pine plantations. Predicted fire behavior in agricultural and mixed hardwood fuelbeds was generally higher than the FTE fuelbeds.

Young (0-1 year-old) FTE plantations may pose a short-term fire risk, particularly under high wind scenarios and if a fire occurs in the dormant season when the majority of herbaceous biomass is dead. If FTE plantations do not receive effective site preparation, understory herbaceous vegetation may contribute to moderate surface fire behavior potential. In addition, if FTE is planted on sites that typically have flammable shrubs in their understories (e.g., wax myrtle or gallberry), effective site preparation may be required to reduce the risk of shrub development and associated fire hazard (Goodrick and Stanturf 2012). Frost damage would likely result in a short-term increase in surface fire potential associated with leaf-fall and an increased litter layer.

Due in part to low to moderate surface fire behavior potential, FTE plantations generally had low crown fire initiation potential. However, in the event that crown fire initiation did occur, FTE plantations have a high risk of crown fire spread. Active management to reduce surface fuels, including flammable shrub layers and herbaceous fuels, would be important to reduce the risk of crown fire initiation.

Potential fire behavior generally increases over time in each FTE pathway as litter and woody fuels accumulate. We evaluated fuelbeds that represent abandoned FTE and loblolly plantations that were 20 to 30 years old. Under these conditions, potential fire hazard is only moderate and does not markedly differ between FTE and loblolly pine plantations. However, if plantations were allowed to continue to grow, we would expect that ladder fuels could develop and lead to a high potential for crown fire initiation and spread.

Assumptions and limitations

Because we lacked actual stand exam and surface fuel survey data for the FTE fuelbeds, our results and interpretations should be considered preliminary. The fuelbeds are intended to provide a logical and systematic exploration of potential fire risks in FTE plantations in the southern United States. The following are key assumptions made in fuelbed construction that could have substantial impacts on our fire hazard assessment for FTE plantations.

1) Understory species composition was assumed to be comparable to typical southern pine plantations. However, if individual sites have flammable understory shrubs such as gallberry or wax myrtle predicted surface fire behavior would be considerably higher (Figure 11).
2) To remain consistent with standard FCCS fuelbed development, 0-1 year old FTE and loblolly pine plantations are represented as short tree canopy layers in this report. However, if trees less than a year old are considered as shrubs, they are treated as flammable shrub layers by FCCS and the predicted surface fire behavior increases dramatically (Figure 9). For the most

conservative estimate of fire risk, we recommend using the fuelbeds constructed with 0-1 year FTE as a shrub layer.

3) Decomposition rates are assumed to be high in the southern United States, so accumulations of litter over time is considered to be low.

4) Although FTE bark does not slough off in large strips as in some species of *Eucalyptus*, we did notice substantial sloughing of bark flakes in photographs of FTE plantations. The contribution of FTE bark to litter reaction intensity has not been fully accounted for in our fuelbeds. Incorporation of a litter and/or bark layer would require some field sampling to accurately reflect the bulk density and decomposition rates of the fuels.

5) Fine woody fuel surveys would be required to more accurately represent this fuelbed component. Because we assumed that FTE plantations would have similar woody fuel loads as loblolly plantations, we didn't expect any difference in predicted surface fire behavior.

Data gaps

The following data would be needed to improve characterization of FTE fuels and provide more reliable predictions of fire hazard:

1) Forest inventory plots to provide important canopy inputs including tree height, height to live crown, tree density and forest cover across management scenarios and plantation ages.
2) Understory vegetation surveys including shrub and herbaceous species, relative cover, height, percent cover by ground projection, and fuel loading.
3) Downed woody fuel inventories by size class with particular emphasis on fine wood (1-hr, 10-hr, and 100-hr fuels for surface fire behavior prediction).
4) Forest floor inventories to measure litter depth, bark slough, percent cover and bulk density.

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Appendix A

Figure A1: Pathway diagram for genetically-engineered freeze-tolerant *Eucalyptus x urograndis* fuelbeds with 3-digit FCCS summary codes. The 3-digit code presents predicted surface fire behavior (red), crown fire behavior (blue) and available fuel potentials respectively (green) as a 0-9 index value.

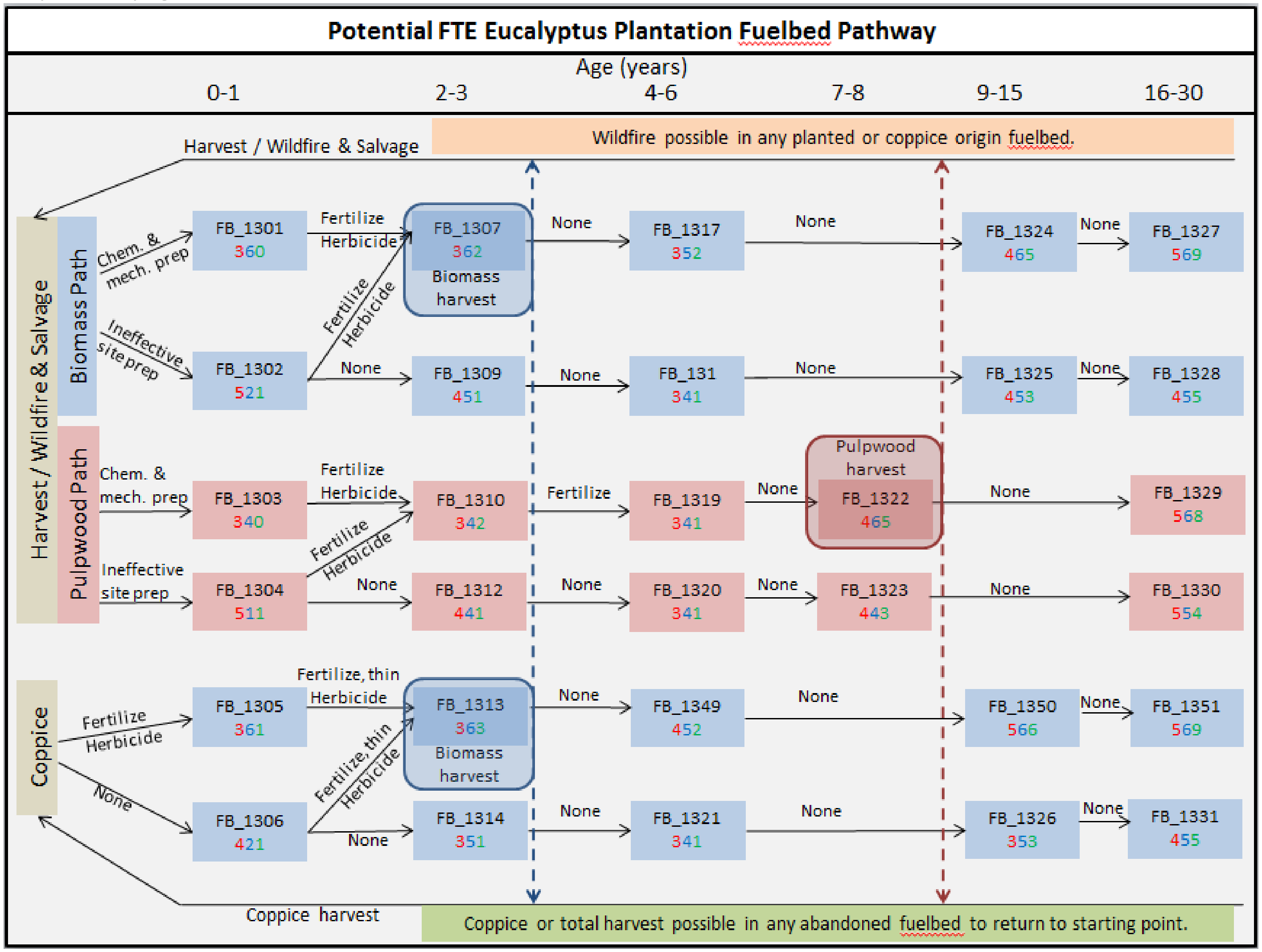
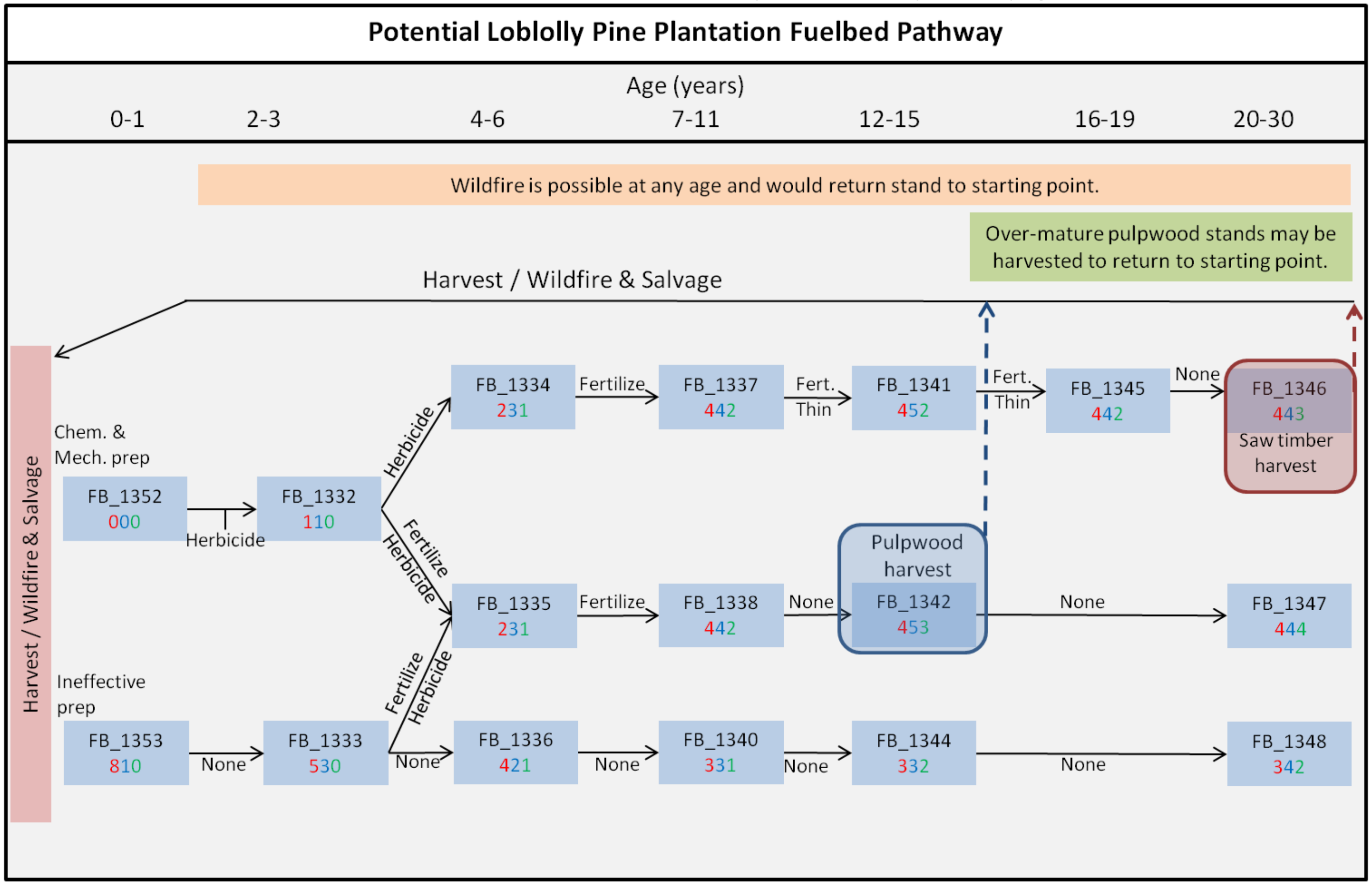


Figure A2: Pathway diagram for loblolly pine fuelbeds with 3-digit FCCS summary codes. The 3-digit code presents predicted surface fire behavior (red), crown fire behavior (blue) and available fuel potentials respectively (green) as a 0-9 index value.



Appendix B: FCCS outputs for FTE and loblolly pine pathways under benchmark environmental conditions

Table B1: FCCS fire behavior predictions at default environmental conditions for genetically engineered freeze-tolerant *Eucalyptus x urograndis* pathway fuelbeds. Default environmental conditions are 4 mph midflame wind speed, 0% slope gradient and dry fuel moisture scenario (Table 1). Surface fire behavior outputs include reaction intensity (BTU $ft^{-2}min^{-1}$), shrub, herbaceous vegetation, woody fuel, and litter reaction intensities (BTU $ft^{-2}min^{-1}$), flame length (m), and rate of spread (ft min^{-1}). Suggested crosswalks to the original 13 fire behavior fuel models (Rothermel 1972, Albini 1976) and standard 40 fire behavior fuel models (Scott and Burgan 2005) are also included, along with the percentage difference between the fuel model-defined and FCCS-predicted rates of spread and flame lengths.

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub RI	Herb RI	Woody RI	Litter RI	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard Fuel Models	Percent Difference ROS	Percent Difference FL
	yr	ft/min	ft	---------------- BTU/ft2/min ---------------						%	%		%	%
1301	0-1	2.5	0.5	161.8	0.0	161.8	0.0	0.0	8	151.2	45.7	183	191.9	50.7
1302	0-1	5.1	2.1	2180.5	0.0	2136.2	0.0	44.3	9	75.2	84.1	183	394.4	233.6
1303	0-1	2.5	0.5	161.8	0.0	161.8	0.0	0.0	8	151.2	45.7	183	191.9	50.7
1304	0-1	7.0	2.8	3032.6	0.0	2978.5	0.0	54.1	9	102.9	113.1	189	101.7	65.7
1305	0-1	2.7	1.2	796.6	0.0	201.6	187.1	407.9	8	161.1	121.1	185	78.2	63.7
1306	2-3	3.7	2.1	2719.9	0.0	2299.4	147.7	272.7	9	53.8	84.2	183	282.3	233.8
1307	2-3	2.3	0.9	524.5	0.0	0.0	116.5	407.9	8	138.6	92.4	183	175.9	102.6
1309	2-3	3.5	2.0	2514.9	0.0	2108.4	133.8	272.7	8	212.7	198.5	186	79.8	86.3
1310	2-3	2.8	1.1	752.9	0.0	222.6	122.4	407.9	8	167.6	113.7	185	81.3	59.8
1312	2-3	3.6	2.1	3141.5	0.0	2820.6	48.2	272.7	9	53.1	85.8	183	278.7	238.4
1313	2-3	2.9	1.3	665.8	0.0	0.0	257.9	407.9	8	177.7	128.8	185	86.2	67.8
1314	2-3	2.4	1.6	2109.5	0.0	1639.5	197.3	272.7	8	148.5	161.3	186	55.7	70.1
1315	4-6	2.8	1.1	546.7	0.0	0.0	138.7	407.9	8	168.4	105.4	184	146.3	87.8
1316	4-6	5.7	2.1	1574.0	0.0	0.0	138.7	1435.2	9	84.0	83.6	183	440.5	232.2
1317	4-6	2.8	1.1	546.7	0.0	0.0	138.7	407.9	8	168.4	105.4	184	146.3	87.8
1318	4-6	2.6	1.7	2266.4	0.0	1809.6	184.1	272.7	8	158.6	169.9	186	59.5	73.9
1319	4-6	2.9	0.8	417.9	0.0	0.0	10.0	407.9	8	177.7	78.2	183	225.5	86.9
1320	4-6	2.9	1.8	2665.5	0.0	2329.6	63.2	272.7	8	176.7	181.5	186	66.3	78.9
1349	4-6	3.5	1.5	724.3	0.0	0.0	316.4	407.9	8	210.0	148.7	185	101.9	78.3

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub RI	Herb RI	Woody RI	Litter RI	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard Fuel Models	Percent Difference ROS	Percent Difference FL
1321	4-6	2.6	1.7	2038.9	0.0	1495.6	270.6	272.7	8	158.6	169.6	186	59.5	73.7
1322	7-8	3.3	0.8	419.6	0.0	0.0	11.7	407.9	8	200.8	83.2	183	254.8	92.5
1323	7-8	3.1	1.9	2708.7	0.0	2358.7	77.2	272.7	8	187.5	188.9	186	70.3	82.1
1324	9-15	4.0	1.9	1269.9	0.0	422.4	439.6	407.9	8	241.7	194.8	186	90.7	84.7
1325	9-15	4.2	2.4	2904.6	0.0	2291.1	340.9	272.7	9	61.3	97.9	186	95.0	106.4
1350	9-15	5.7	2.5	1419.8	0.0	415.7	596.2	407.9	9	84.0	101.2	188	124.5	84.3
1326	9-15	2.7	1.9	2316.7	0.0	1568.2	475.8	272.7	8	162.7	193.3	186	61.0	84.1
1327	16-30	5.2	3.0	2086.1	0.0	627.2	1050.9	407.9	9	75.9	120.6	189	75.0	70.1
1328	16-30	3.8	3.0	3727.9	0.0	2480.5	974.7	272.7	9	55.9	118.1	189	55.2	68.6
1329	16-30	5.9	2.2	1188.5	0.0	431.4	349.2	407.9	9	86.1	87.3	183	451.5	242.6
1330	16-30	5.2	2.8	3355.3	0.0	2822.2	260.4	272.7	9	76.2	111.5	188	113.0	92.9
1351	16-30	5.5	3.6	2643.0	0.0	620.7	1614.4	407.9	9	80.2	145.2	189	79.3	84.4
1331	16-30	3.3	2.6	3270.4	0.0	2048.2	949.5	272.7	9	47.8	105.5	188	70.8	87.9

Table B2: FCCS fire behavior predictions at default environmental conditions for loblolly pine (*Pinus taeda*) pathway fuelbeds. Default environmental conditions are 4 mph midflame wind speed, 0% slope gradient and dry fuel moisture scenario (Table 1). Surface fire behavior outputs include reaction intensity (BTU $ft^{-2}min^{-1}$), shrub, herbaceous vegetation, woody fuel, and litter reaction intensities (BTU $ft^{-2}min^{-1}$), flame length (m), and rate of spread (ft min^{-1}). Suggested crosswalks to the original 13 fire behavior fuel models (Rothermel 1972, Albini 1976) and standard 40 fire behavior fuel models (Scott and Burgan 2005) are also included, along with the percentage difference between the fuel model-defined and FCCS-predicted rates of spread and flame lengths.

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub RI	Herb RI	Woody RI	Litter RI	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard Fuel Models	Percent Difference ROS	Percent Difference FL
	yr	ft/min	ft	--------------------------- BTU/ft2/min ---------------------						%	%		%	%
1352	0-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	121	0.0	0.0
1353	0-1	14.6	3.6	2466.3	0.0	2466.3	0.0	0.0	6	52.1	66.8	142	635.2	189.8
1332	2-3	0.4	0.3	99.0	0.0	0.0	99.0	0.0	8	26.0	28.9	181	61.4	57.7
1333	2-3	4.4	2.2	2695.7	0.0	2601.9	39.2	54.5	9	63.9	87.5	183	335.0	243.0
1334	4-6	1.3	0.7	447.0	0.0	0.0	97.6	349.4	8	80.1	70.2	183	101.6	78.0
1335	4-6	1.3	0.7	447.0	0.0	0.0	97.6	349.4	8	80.1	70.2	183	101.6	78.0
1336	4-6	5.0	2.7	3427.6	0.0	2905.4	214.5	307.7	9	73.0	109.0	188	108.3	90.9
1337	7-11	3.2	1.9	1408.3	0.0	363.6	419.9	624.8	8	195.8	185.0	186	73.4	80.4
1338	7-11	3.2	1.9	1408.3	0.0	363.6	419.9	624.8	8	195.8	185.0	186	73.4	80.4
1340	7-11	2.5	2.0	2636.9	0.0	1813.2	516.1	307.7	8	150.7	197.2	186	56.5	85.7
1341	12-15	3.3	1.1	681.5	0.0	54.8	2.0	624.8	8	201.4	111.4	184	174.9	92.8
1342	12-15	4.2	1.2	651.3	0.0	26.3	0.2	624.8	8	255.7	121.9	185	124.1	64.2
1344	12-15	2.2	1.7	1816.7	0.0	1012.8	496.2	307.7	8	135.5	167.2	186	50.8	72.7
1345	16-19	4.9	2.5	1637.5	0.0	372.6	640.2	624.8	9	71.3	100.7	188	105.7	84.0
1346	20-30	4.9	2.4	1581.7	0.0	372.9	584.1	624.8	9	71.3	98.0	186	110.4	106.5
1347	20-30	4.8	2.4	1581.7	0.0	372.9	584.1	624.8	9	70.0	97.2	186	108.4	105.6
1348	20-30	2.8	2.1	2682.7	0.0	1821.3	553.8	307.7	9	40.5	84.1	183	212.6	233.7

Table B3: FCCS predicted fire potentials (0-9 index) for genetically-engineered freeze tolerant *Eucalyptus x urograndis* pathway fuelbeds. The surface fire potential summary potential has three sub-potentials (reaction potential, spread potential, and flame length potential). The crown fire summary potential has three sub-potentials (crown initiation potential, crown to crown transmissivity potential, and crown fire spread potential). The available fuel summary potential three sub-potentials (flame available potential, smolder available potential, and residual smolder potential).

Fuelbed #	Age Class	Surface fire summary potential	Reaction potential	Spread potential	Flame length potential	Crown fire summary potential	Crown initiation potential	Crown-crown transmissivity potential	Crown fire spread potential	Available fuel summary potential	Flame available potential	Smolder available potential	Residual smolder potential
1301	0-1	3.16	1.02	3.16	1.35	5.87	3.94	8.85	6.81	0.48	0.48	0.00	0.00
1302	0-1	4.53	3.74	4.53	2.90	2.12	0.00	4.75	3.36	0.58	0.58	0.00	0.00
1303	0-1	3.16	1.02	3.16	1.35	4.25	3.94	4.75	4.41	0.32	0.32	0.00	0.00
1304	0-1	5.30	4.41	5.30	3.36	1.27	0.00	0.00	2.96	0.58	0.58	0.00	0.00
1305	0-1	3.26	2.26	3.26	2.20	5.54	5.28	9.00	4.65	1.19	1.04	0.15	0.00
1306	2-3	3.83	4.17	3.83	2.90	2.45	0.00	6.60	3.51	0.78	0.64	0.15	0.00
1307	2-3	3.02	1.83	3.02	1.92	5.63	2.26	9.00	7.87	2.24	2.09	0.15	0.00
1309	2-3	3.75	4.01	3.75	2.82	4.81	5.30	6.60	3.74	0.89	0.74	0.15	0.00
1310	2-3	3.33	2.20	3.33	2.13	4.24	2.38	8.85	4.56	2.05	1.91	0.15	0.00
1312	2-3	3.81	4.48	3.81	2.93	4.43	4.59	6.60	3.54	0.88	0.74	0.15	0.00
1313	2-3	3.42	2.06	3.42	2.27	5.94	2.50	9.00	8.36	2.57	2.42	0.15	0.00
1314	2-3	3.13	3.67	3.13	2.54	4.93	4.29	8.85	4.27	1.03	0.89	0.15	0.00
1317	4-6	3.33	1.87	3.33	2.05	4.98	1.40	9.00	7.23	1.74	1.58	0.15	0.02
1318	4-6	3.23	3.81	3.23	2.61	4.02	1.91	8.51	4.65	1.17	1.02	0.15	0.00
1319	4-6	3.42	1.64	3.42	1.77	5.64	1.16	9.00	9.00	1.98	1.82	0.15	0.02
1320	4-6	3.42	4.13	3.42	2.69	3.86	1.87	8.12	4.43	1.21	1.06	0.15	0.00
1349	4-6	3.72	2.15	3.72	2.44	5.21	1.55	9.00	7.61	1.99	1.84	0.15	0.00
1321	4-6	3.24	3.61	3.24	2.60	4.40	1.90	9.00	5.36	1.33	1.18	0.15	0.00
1322	7-8	3.64	1.64	3.64	1.82	5.57	1.00	9.00	9.00	4.71	4.34	0.20	0.17
1323	7-8	3.52	4.16	3.52	2.75	4.27	1.56	8.12	5.70	2.52	2.28	0.19	0.05
1324	9-15	3.99	2.85	3.99	2.79	5.71	1.46	9.00	8.86	4.88	4.33	0.24	0.31
1325	9-15	4.09	4.31	4.09	3.13	4.84	1.75	8.12	6.84	3.00	2.51	0.24	0.25
1350	9-15	4.79	3.01	4.79	3.18	5.81	1.56	9.00	9.00	5.63	5.06	0.25	0.32
1326	9-15	3.28	3.85	3.28	2.78	4.96	1.73	9.00	6.84	2.94	2.44	0.24	0.26

Fuelbed #	Age Class	Surface fire summary potential	Reaction potential	Spread potential	Flame length potential	Crown fire summary potential	Crown initiation potential	Crown-crown transmissivity potential	Crown fire spread potential	Available fuel summary potential	Flame available potential	Smolder available potential	Residual smolder potential
1327	16-30	4.55	3.65	4.55	3.47	5.88	1.71	9.00	9.00	9.00	5.82	0.35	4.27
1328	16-30	3.90	4.88	3.90	3.44	4.80	1.85	7.69	6.78	5.43	3.30	0.35	1.79
1329	16-30	4.85	2.76	4.85	2.96	5.75	1.40	9.00	9.00	7.68	6.29	0.34	1.06
1330	16-30	4.56	4.63	4.56	3.34	5.02	1.70	7.69	7.45	4.43	3.43	0.34	0.67
1351	16-30	4.68	4.11	4.68	3.81	5.90	1.77	9.00	9.00	9.00	7.02	0.37	6.52
1331	16-30	3.61	4.58	3.61	3.25	5.24	1.91	9.00	7.31	4.69	3.18	0.35	1.16

Table B4: FCCS predicted fire potentials (0-9 index) for loblolly pine (*Pinus taeda*) pathway fuelbeds. The surface fire summary potential has three sub-potentials (reaction potential, spread potential, and flame length potential). The crown fire summary potential has three sub-potentials (crown initiation potential, crown to crown transmissivity potential, and crown fire spread potential). The available fuel summary potential has three sub-potentials (flame available potential, smolder available potential, and residual smolder potential).

Fuelbed #	Age Class	Surface fire summary potential	Reaction potential	Spread potential	Flame length potential	Crown fire summary potential	Crown initiation potential	Crown-crown transmissivity potential	Crown fire spread potential	Available fuel summary potential	Flame available potential	Smolder available potential	Residual smolder potential
1352	0-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00
1353	0-1	7.64	3.97	7.64	3.80	0.86	0.00	0.00	2.00	0.44	0.44	0.00	0.00
1332	2-3	1.31	0.80	1.31	1.07	1.17	1.44	0.00	1.29	0.29	0.21	0.05	0.04
1333	2-3	4.17	4.15	4.17	2.96	2.32	3.79	0.00	1.61	0.37	0.28	0.05	0.04
1334	4-6	2.30	1.69	2.30	1.68	3.46	1.70	8.85	3.43	1.16	1.07	0.05	0.04
1335	4-6	2.30	1.69	2.30	1.68	3.48	1.67	8.85	3.50	1.19	1.10	0.05	0.04
1336	4-6	4.46	4.68	4.46	3.30	2.38	3.50	0.00	2.06	1.13	0.74	0.37	0.02
1337	7-11	3.59	3.00	3.59	2.72	3.84	2.12	9.00	3.84	1.52	1.37	0.11	0.05
1338	7-11	3.59	3.00	3.59	2.72	3.86	2.08	9.00	3.91	1.59	1.44	0.11	0.05
1340	7-11	3.15	4.11	3.15	2.81	3.12	2.53	7.19	2.35	1.07	0.86	0.18	0.03
1341	12-15	3.65	2.09	3.65	2.11	4.66	1.65	9.00	6.21	2.33	1.98	0.27	0.09
1342	12-15	4.11	2.04	4.11	2.21	5.14	1.73	9.00	7.27	2.75	2.14	0.14	0.46
1344	12-15	2.99	3.41	2.99	2.59	3.43	2.30	8.85	2.76	1.63	1.28	0.20	0.15
1345	16-19	4.41	3.24	4.41	3.17	4.18	2.27	9.00	4.48	2.33	1.96	0.32	0.06
1346	20-30	4.41	3.18	4.41	3.13	4.39	2.12	9.00	5.13	2.72	2.35	0.31	0.07

Appendix C: FCCS fire behavior predictions for high wind scenarios (10, 15 and 25 mph)

Table C1: FCCS fire behavior predictions at 10 mph midflame wind speed for genetically engineered freeze-tolerant *Eucalyptus x urograndis* pathway fuelbeds. FCCS predictions are calculated at 10 mph midflame wind speed, 0% slope gradient and dry fuel moisture scenario (Table 1). Surface fire behavior outputs include reaction intensity (BTU $ft^{-2}min^{-1}$), shrub, herbaceous vegetation, woody fuel, and litter reaction intensities (BTU $ft^{-2}min^{-1}$), flame length (ft), and rate of spread (ft min^{-1}). Suggested crosswalks to the original 13 fire behavior fuel models (Rothermel 1972, Albini 1976) and standard 40 fire behavior fuel models (Scott and Burgan 2005) are also included, along with the percentage difference between the fuel model-defined and FCCS-predicted rates of spread and flame lengths.

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub	Herb	Woody	Litter	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard FMs	Percent Difference ROS	Percent Difference FL
	yr	ft/min	ft	BTU/ft²/min						%	%		%	%
1301	0-1	9.5	0.8	161.8	0.0	161.8	0.0	0.0	2	30.9	14.8	121	84.6	30.1
1302	0-1	19.3	3.9	2180.5	0.0	2136.2	0.0	44.3	6	68.9	71.7	142	840.9	203.7
1303	0-1	9.5	0.8	161.8	0.0	161.8	0.0	0.0	2	30.9	14.8	121	84.6	30.1
1304	0-1	26.5	5.2	3032.6	0.0	2978.5	0.0	54.1	6	94.3	96.4	144	127.2	89.7
1305	0-1	6.9	1.9	796.6	0.0	201.6	187.1	407.9	8	417.1	187.6	186	156.4	81.6
1306	2-3	13.7	3.9	2719.9	0.0	2299.4	147.7	272.7	6	48.7	71.3	142	593.6	202.7
1307	2-3	5.4	1.4	524.5	0.0	0.0	116.5	407.9	8	328.0	137.3	185	159.2	72.3
1309	2-3	13.1	3.6	2514.9	0.0	2108.4	133.8	272.7	6	46.6	67.3	142	568.6	191.4
1310	2-3	7.3	1.8	752.9	0.0	222.6	122.4	407.9	8	442.8	177.7	186	166.0	77.3
1312	2-3	13.6	3.9	3141.5	0.0	2820.6	48.2	272.7	6	48.4	72.9	142	589.7	207.3
1313	2-3	6.9	1.9	665.8	0.0	0.0	257.9	407.9	8	420.6	191.4	186	157.7	83.2
1314	2-3	8.3	2.8	2109.5	0.0	1639.5	197.3	272.7	9	122.0	113.2	164	92.4	57.8
1317	4-6	6.6	1.6	546.7	0.0	0.0	138.7	407.9	8	398.7	156.6	186	149.5	68.1
1318	4-6	9.7	3.1	2266.4	0.0	1809.6	184.1	272.7	11	179.6	100.0	202	84.9	58.5
1319	4-6	6.9	1.2	417.9	0.0	0.0	10.0	407.9	8	420.6	116.2	185	204.1	61.2
1320	4-6	10.8	3.3	2665.5	0.0	2329.6	63.2	272.7	11	201.3	107.2	202	95.2	62.7
1349	4-6	8.2	2.2	724.3	0.0	0.0	316.4	407.9	11	152.2	71.3	201	170.9	81.9
1321	4-6	9.2	3.0	2038.9	0.0	1495.6	270.6	272.7	11	171.3	97.7	201	192.4	112.2
1322	7-8	7.8	1.2	419.6	0.0	0.0	11.7	407.9	2	25.6	21.7	121	70.0	44.2
1323	7-8	10.3	3.3	2708.7	0.0	2358.7	77.2	272.7	11	191.7	106.1	202	90.6	62.1

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub	Herb	Woody	Litter	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard FMs	Percent Difference ROS	Percent Difference FL
1324	9-15	10.5	3.0	1269.9	0.0	422.4	439.6	407.9	11	195.1	98.2	201	219.0	112.7
1325	9-15	15.4	4.5	2904.6	0.0	2291.1	340.9	272.7	6	55.0	82.7	142	671.0	234.9
1350	9-15	15.0	3.9	1419.8	0.0	415.7	596.2	407.9	6	53.4	72.9	142	651.1	207.2
1326	9-15	8.8	3.3	2316.7	0.0	1568.2	475.8	272.7	9	129.5	133.7	164	98.1	68.2
1327	16-30	13.4	4.7	2086.1	0.0	627.2	1050.9	407.9	10	179.0	99.3	164	148.8	95.2
1328	16-30	13.9	5.4	3727.9	0.0	2480.5	974.7	272.7	10	186.1	114.0	163	70.0	85.0
1329	16-30	15.5	3.4	1188.5	0.0	431.4	349.2	407.9	6	55.4	63.3	142	675.4	179.8
1330	16-30	19.3	5.1	3355.3	0.0	2822.2	260.4	272.7	6	68.9	94.5	144	92.9	87.9
1351	16-30	14.0	5.6	2643.0	0.0	620.7	1614.4	407.9	10	186.5	118.8	163	70.1	88.6
1331	16-30	11.8	4.8	3270.4	0.0	2048.2	949.5	272.7	10	158.2	101.5	163	59.5	75.8

Table C2: FCCS fire behavior predictions at 10 mph midflame wind speed for loblolly pine (*Pinus taeda*) pathway fuelbeds. FCCS predictions are calculated at 10 mph midflame wind speed, 0% slope gradient and dry fuel moisture scenario (Table 1). Surface fire behavior outputs include reaction intensity (BTU $ft^{-2}min^{-1}$), shrub, herbaceous vegetation, woody fuel, and litter reaction intensities (BTU $ft^{-2}min^{-1}$), flame length (ft), and rate of spread (ft min^{-1}). Suggested crosswalks to the original 13 fire behavior fuel models (Rothermel 1972, Albini 1976) and standard 40 fire behavior fuel models (Scott and Burgan 2005) are also included, along with the percentage difference between the fuel model-defined and FCCS-predicted rates of spread and flame lengths.

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub	Herb	Woody	Litter	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard FMs	Percent Difference ROS	Percent Difference FL
	yr	ft/min	ft	------------------------ BTU/ft²/min ------------------------						%	%		%	%
1352	0-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	121	0.0	0.0
1353	0-1	55.1	6.6	2466.3	0.0	2466.3	0.0	0.0	1	82.5	174.8	109	43.4	23.8
1332	2-3	1.6	0.5	99.0	0.0	0.0	99.0	0.0	8	94.5	52.2	183	120.0	58.0
1333	2-3	16.4	4.0	2695.7	0.0	2601.9	39.2	54.5	6	58.4	74.5	142	712.0	211.7
1334	4-6	3.5	1.1	447.0	0.0	0.0	97.6	349.4	8	213.7	110.3	184	185.6	91.9
1335	4-6	3.5	1.1	447.0	0.0	0.0	97.6	349.4	8	213.7	110.3	184	185.6	91.9
1336	4-6	18.5	5.0	3427.6	0.0	2905.4	214.5	307.7	6	66.0	92.3	144	88.9	85.9
1337	7-11	8.6	2.9	1408.3	0.0	363.6	419.9	624.8	9	125.8	116.0	164	95.3	59.2
1338	7-11	8.6	2.9	1408.3	0.0	363.6	419.9	624.8	9	125.8	116.0	164	95.3	59.2
1340	7-11	9.1	3.6	2636.9	0.0	1813.2	516.1	307.7	9	133.4	143.2	164	101.1	73.1
1341	12-15	8.6	1.7	681.5	0.0	54.8	2.0	624.8	8	520.6	172.4	186	195.2	74.9
1342	12-15	10.9	1.9	651.3	0.0	26.3	0.2	624.8	8	661.5	188.8	186	248.0	82.1
1344	12-15	5.9	2.6	1816.7	0.0	1012.8	496.2	307.7	9	87.2	104.9	188	129.3	87.4
1345	16-19	13.2	4.0	1637.5	0.0	372.6	640.2	624.8	6	47.2	73.9	142	575.1	210.0
1346	20-30	13.2	3.9	1581.7	0.0	372.9	584.1	624.8	6	47.1	71.9	142	574.3	204.2
1347	20-30	12.9	3.8	1581.7	0.0	372.9	584.1	624.8	6	45.8	71.0	142	559.1	201.7
1348	20-30	10.2	3.8	2682.7	0.0	1821.3	553.8	307.7	9	149.3	153.3	146	54.7	46.7

Table C3: FCCS fire behavior predictions at 15 mph midflame wind speed for genetically engineered freeze-tolerant *Eucalyptus x urograndis* pathway fuelbeds. FCCS predictions are calculated at 15 mph midflame wind speed, 0% slope gradient and dry fuel moisture scenario (Table 1). Surface fire behavior outputs include reaction intensity (BTU $ft^{-2}min^{-1}$), shrub, herbaceous vegetation, woody fuel, and litter reaction intensities (BTU $ft^{-2}min^{-1}$), flame length (ft), and rate of spread (ft min^{-1}). Suggested crosswalks to the original 13 fire behavior fuel models (Rothermel 1972, Albini 1976) and standard 40 fire behavior fuel models (Scott and Burgan 2005) are also included, along with the percentage difference between the fuel model-defined and FCCS-predicted rates of spread and flame lengths.

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub	Herb	Woody	Litter	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard FMs	Percent Difference ROS	Percent Difference FL
	yr	ft/min	ft	------------------------- BTU/ft²/min -------------------------						%	%		%	%
1301	0-1	17.3	1.1	161.8	0.0	161.8	0.0	0.0	2	56.4	19.5	121	154.4	39.8
1302	0-1	35.3	5.1	2180.5	0.0	2136.2	0.0	44.3	2	114.9	89.5	103	96.1	83.7
1303	0-1	17.3	1.1	161.8	0.0	161.8	0.0	0.0	2	56.4	19.5	121	154.4	39.8
1304	0-1	48.3	6.9	3032.6	0.0	2978.5	0.0	54.1	1	72.3	180.6	109	38.0	24.6
1305	0-1	11.6	2.4	796.6	0.0	201.6	187.1	407.9	11	215.5	77.0	201	242.0	88.4
1306	2-3	24.8	5.1	2719.9	0.0	2299.4	147.7	272.7	6	88.5	93.9	144	119.4	87.4
1307	2-3	8.9	1.7	524.5	0.0	0.0	116.5	407.9	8	540.3	172.7	186	202.6	75.1
1309	2-3	23.8	4.8	2514.9	0.0	2108.4	133.8	272.7	6	84.9	88.7	144	114.4	82.6
1310	2-3	12.4	2.3	752.9	0.0	222.6	122.4	407.9	6	44.2	42.0	142	538.9	119.3
1312	2-3	24.7	5.2	3141.5	0.0	2820.6	48.2	272.7	6	88.1	96.1	144	118.8	89.5
1313	2-3	11.4	2.4	665.8	0.0	0.0	257.9	407.9	11	212.1	77.7	201	238.1	89.2
1314	2-3	15.1	3.7	2109.5	0.0	1639.5	197.3	272.7	6	53.9	69.0	142	657.3	196.1
1317	4-6	10.8	2.0	546.7	0.0	0.0	138.7	407.9	8	656.7	197.0	186	246.3	85.7
1318	4-6	17.6	4.1	2266.4	0.0	1809.6	184.1	272.7	6	62.7	75.6	142	765.1	214.9
1319	4-6	11.4	1.5	417.9	0.0	0.0	10.0	407.9	2	37.2	25.7	121	102.1	52.2
1320	4-6	19.8	4.4	2665.5	0.0	2329.6	63.2	272.7	6	70.4	81.0	142	858.9	230.3
1349	4-6	13.5	2.8	724.3	0.0	0.0	316.4	407.9	6	48.2	51.5	142	587.4	146.3
1321	4-6	16.8	4.0	2038.9	0.0	1495.6	270.6	272.7	6	59.8	73.8	142	729.0	209.7
1322	7-8	12.9	1.6	419.6	0.0	0.0	11.7	407.9	2	42.1	27.3	121	115.3	55.6
1323	7-8	18.8	4.3	2708.7	0.0	2358.7	77.2	272.7	6	67.1	80.3	142	817.9	228.1
1324	9-15	17.8	3.9	1269.9	0.0	422.4	439.6	407.9	6	63.6	71.8	142	775.1	204.2
1325	9-15	28.0	5.9	2904.6	0.0	2291.1	340.9	272.7	6	100.0	108.8	144	134.8	101.3
1350	9-15	25.3	5.0	1419.8	0.0	415.7	596.2	407.9	6	90.3	92.8	144	121.8	86.4

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub	Herb	Woody	Litter	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard FMs	Percent Difference ROS	Percent Difference FL
1326	9-15	16.0	4.4	2316.7	0.0	1568.2	475.8	272.7	6	57.1	81.4	142	696.6	231.4
1327	16-30	22.6	5.9	2086.1	0.0	627.2	1050.9	407.9	6	80.6	109.9	144	108.6	102.4
1328	16-30	25.2	7.0	3727.9	0.0	2480.5	974.7	272.7	5	116.5	128.1	147	86.5	61.3
1329	16-30	26.4	4.4	1188.5	0.0	431.4	349.2	407.9	2	85.9	76.4	101	219.7	256.3
1330	16-30	35.2	6.7	3355.3	0.0	2822.2	260.4	272.7	5	162.3	122.1	145	79.2	55.5
1351	16-30	23.5	7.1	2643.0	0.0	620.7	1614.4	407.9	5	108.2	128.9	147	80.3	61.7
1331	16-30	21.4	6.3	3270.4	0.0	2048.2	949.5	272.7	5	99.0	114.1	147	73.4	54.6

Table C4: FCCS fire behavior predictions at 15 mph midflame wind speed for loblolly pine (*Pinus taeda*) pathway fuelbeds. FCCS predictions are calculated at 15 mph midflame wind speed, 0% slope gradient and dry fuel moisture scenario (Table 1). Surface fire behavior outputs include reaction intensity (BTU $ft^{-2}min^{-1}$), shrub, herbaceous vegetation, woody fuel, and litter reaction intensities (BTU $ft^{-2}min^{-1}$), flame length (ft), and rate of spread (ft min^{-1}). Suggested crosswalks to the original 13 fire behavior fuel models (Rothermel 1972, Albini 1976) and standard 40 fire behavior fuel models (Scott and Burgan 2005) are also included, along with the percentage difference between the fuel model-defined and FCCS-predicted rates of spread and flame lengths.

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub	Herb	Woody	Litter	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard FMs	Percent Difference ROS	Percent Difference FL
	yr	ft/min	ft	------------------------- BTU/ft²/min -------------------------						%	%		%	%
1352	0-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	121	0.0	0.0
1353	0-1	100.5	8.8	2466.3	0.0	2466.3	0.0	0.0	3	102.5	74.2	104	194.0	116.8
1332	2-3	2.8	0.7	99.0	0.0	0.0	99.0	0.0	8	171.3	68.7	183	217.4	76.3
1333	2-3	29.8	5.3	2695.7	0.0	2601.9	39.2	54.5	6	106.4	98.2	144	143.5	91.4
1334	4-6	6.1	1.4	447.0	0.0	0.0	97.6	349.4	8	367.3	141.6	185	178.3	74.5
1335	4-6	6.1	1.4	447.0	0.0	0.0	97.6	349.4	8	367.3	141.6	185	178.3	74.5
1336	4-6	33.7	6.6	3427.6	0.0	2905.4	214.5	307.7	5	155.3	119.3	145	75.8	54.2
1337	7-11	14.6	3.7	1408.3	0.0	363.6	419.9	624.8	6	52.0	68.5	142	633.8	194.8
1338	7-11	14.6	3.7	1408.3	0.0	363.6	419.9	624.8	6	52.0	68.5	142	633.8	194.8
1340	7-11	16.5	4.7	2636.9	0.0	1813.2	516.1	307.7	6	58.8	87.2	142	717.4	247.8
1341	12-15	14.5	2.2	681.5	0.0	54.8	2.0	624.8	2	47.2	38.5	121	129.4	78.3
1342	12-15	18.4	2.4	651.3	0.0	26.3	0.2	624.8	2	60.0	42.1	121	164.4	85.8
1344	12-15	10.1	3.3	1816.7	0.0	1012.8	496.2	307.7	11	187.5	107.9	202	88.6	63.1
1345	16-19	22.6	5.1	1637.5	0.0	372.6	640.2	624.8	6	80.6	94.5	144	108.6	88.0
1346	20-30	22.6	5.0	1581.7	0.0	372.9	584.1	624.8	6	80.4	91.9	144	108.5	85.6
1347	20-30	21.9	4.9	1581.7	0.0	372.9	584.1	624.8	6	78.2	90.7	144	105.4	84.5
1348	20-30	18.5	5.0	2682.7	0.0	1821.3	553.8	307.7	6	65.9	93.4	144	88.9	87.0

Table C5: FCCS fire behavior predictions at 20 mph midflame wind speed for genetically engineered freeze-tolerant *Eucalyptus x urograndis* pathway fuelbeds. FCCS predictions are calculated at 20 mph midflame wind speed, 0% slope gradient and dry fuel moisture scenario (Table 1). Surface fire behavior outputs include reaction intensity (BTU $ft^{-2}min^{-1}$), shrub, herbaceous vegetation, woody fuel, and litter reaction intensities (BTU $ft^{-2}min^{-1}$), flame length (ft), and rate of spread (ft min^{-1}). Suggested crosswalks to the original 13 fire behavior fuel models (Rothermel 1972, Albini 1976) and standard 40 fire behavior fuel models (Scott and Burgan 2005) are also included, along with the percentage difference between the fuel model-defined and FCCS-predicted rates of spread and flame lengths.

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub	Herb	Woody	Litter	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard FMs	Percent Difference ROS	Percent Difference FL
	yr	ft/min	ft	------------------------- BTU/ft²/min -------------------------						%	%		%	%
1301	0-1	26.6	1.4	161.8	0.0	161.8	0.0	0.0	2	86.5	23.8	121	237.1	48.4
1302	0-1	54.1	6.2	2180.5	0.0	2136.2	0.0	44.3	1	81.1	163.6	109	42.7	22.3
1303	0-1	26.6	1.4	161.8	0.0	161.8	0.0	0.0	2	86.5	23.8	121	237.1	48.4
1304	0-1	74.1	8.4	3032.6	0.0	2978.5	0.0	54.1	1	110.9	219.9	109	58.4	30.0
1305	0-1	17.2	2.9	796.6	0.0	201.6	187.1	407.9	2	56.1	50.2	101	143.5	168.3
1306	2-3	38.1	6.2	2719.9	0.0	2299.4	147.7	272.7	1	57.0	162.5	109	30.0	22.1
1307	2-3	13.1	2.1	524.5	0.0	0.0	116.5	407.9	2	42.6	36.1	121	116.6	73.5
1309	2-3	36.5	5.8	2514.9	0.0	2108.4	133.8	272.7	1	54.7	153.4	109	28.8	20.9
1310	2-3	18.4	2.7	752.9	0.0	222.6	122.4	407.9	2	60.0	47.7	121	164.5	97.1
1312	2-3	37.9	6.3	3141.5	0.0	2820.6	48.2	272.7	5	174.9	114.9	145	85.3	52.2
1313	2-3	16.7	2.9	665.8	0.0	0.0	257.9	407.9	6	59.7	53.2	142	728.2	151.1
1314	2-3	23.2	4.5	2109.5	0.0	1639.5	197.3	272.7	6	82.6	84.0	142	1007.4	238.6
1317	4-6	15.9	2.3	546.7	0.0	0.0	138.7	407.9	2	51.7	41.2	121	141.8	83.9
1318	4-6	27.0	5.0	2266.4	0.0	1809.6	184.1	272.7	6	96.2	92.0	144	129.7	85.7
1319	4-6	16.7	1.7	417.9	0.0	0.0	10.0	407.9	2	54.6	30.6	121	149.5	62.2
1320	4-6	30.3	5.3	2665.5	0.0	2329.6	63.2	272.7	6	108.0	98.7	144	145.7	91.9
1349	4-6	19.8	3.3	724.3	0.0	0.0	316.4	407.9	6	70.6	61.4	142	860.7	174.5
1321	4-6	25.7	4.8	2038.9	0.0	1495.6	270.6	272.7	6	91.6	89.8	144	123.5	83.6
1322	7-8	18.9	1.9	419.6	0.0	0.0	11.7	407.9	2	61.7	32.6	121	169.0	66.3
1323	7-8	28.9	5.3	2708.7	0.0	2358.7	77.2	272.7	6	102.9	97.7	144	138.7	91.0
1324	9-15	26.5	4.7	1269.9	0.0	422.4	439.6	407.9	6	94.4	86.2	142	1151.6	245.0
1325	9-15	43.0	7.1	2904.6	0.0	2291.1	340.9	272.7	1	64.4	188.1	109	33.9	25.6
1350	9-15	37.6	6.0	1419.8	0.0	415.7	596.2	407.9	1	56.3	158.2	109	29.6	21.6

1326	9-15	24.5	5.3	2316.7	0.0	1568.2	475.8	272.7	6	87.5	99.1	144	118.0	92.2
1327	16-30	33.5	7.1	2086.1	0.0	627.2	1050.9	407.9	5	154.6	129.4	145	75.4	58.8
1328	16-30	38.7	8.6	3727.9	0.0	2480.5	974.7	272.7	5	178.4	155.8	145	87.1	70.8
1329	16-30	39.2	5.2	1188.5	0.0	431.4	349.2	407.9	1	58.7	137.6	107	50.7	32.7
1330	16-30	53.9	8.2	3355.3	0.0	2822.2	260.4	272.7	1	80.7	215.2	109	42.5	29.3
1351	16-30	34.7	8.5	2643.0	0.0	620.7	1614.4	407.9	5	160.2	154.4	145	78.2	70.2
1331	16-30	32.8	7.6	3270.4	0.0	2048.2	949.5	272.7	5	151.5	138.7	145	73.9	63.1

Table C6: FCCS fire behavior predictions at 20 mph midflame wind speed for loblolly pine (*Pinus taeda*) pathway fuelbeds. FCCS predictions are calculated at 20 mph midflame wind speed, 0% slope gradient and dry fuel moisture scenario (Table 1). Surface fire behavior outputs include reaction intensity (BTU $ft^{-2}min^{-1}$), shrub, herbaceous vegetation, woody fuel, and litter reaction intensities (BTU $ft^{-2}min^{-1}$), flame length (ft), and rate of spread (ft min^{-1}). Suggested crosswalks to the original 13 fire behavior fuel models (Rothermel 1972, Albini 1976) and standard 40 fire behavior fuel models (Scott and Burgan 2005) are also included, along with the percentage difference between the fuel model-defined and FCCS-predicted rates of spread and flame lengths.

Fuelbed #	Age Class	Rate of Spread	Flame Length	Reaction Intensity	Shrub	Herb	Woody	Litter	Crosswalk FBPS FMs	Percent Difference ROS	Percent Difference FL	Crosswalk Standard FMs	Percent Difference ROS	Percent Difference FL
	yr	ft/min	ft	------------------------- BTU/ft²/min -------------------------						%	%		%	%
1352	0-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	121	0.0	0.0
1353	0-1	154.3	10.7	2466.3	0.0	2466.3	0.0	0.0	3	157.4	90.4	106	295.0	93.5
1332	2-3	4.3	0.8	99.0	0.0	0.0	99.0	0.0	8	262.1	83.5	183	332.7	92.8
1333	2-3	45.8	6.5	2695.7	0.0	2601.9	39.2	54.5	1	68.6	169.9	109	36.1	23.1
1334	4-6	9.1	1.7	447.0	0.0	0.0	97.6	349.4	8	549.3	170.3	186	206.0	74.1
1335	4-6	9.1	1.7	447.0	0.0	0.0	97.6	349.4	8	549.3	170.3	186	206.0	74.1
1336	4-6	51.6	8.0	3427.6	0.0	2905.4	214.5	307.7	1	77.3	210.2	109	40.7	28.6
1337	7-11	21.7	4.4	1408.3	0.0	363.6	419.9	624.8	6	77.3	82.3	142	942.6	233.8
1338	7-11	21.7	4.4	1408.3	0.0	363.6	419.9	624.8	6	77.3	82.3	142	942.6	233.8
1340	7-11	25.3	5.7	2636.9	0.0	1813.2	516.1	307.7	6	90.1	106.1	144	121.5	98.8
1341	12-15	21.5	2.6	681.5	0.0	54.8	2.0	624.8	2	70.0	46.1	121	191.8	93.8
1342	12-15	27.3	2.9	651.3	0.0	26.3	0.2	624.8	2	89.0	50.5	102	107.1	71.9
1344	12-15	15.0	4.0	1816.7	0.0	1012.8	496.2	307.7	6	53.6	74.4	142	653.5	211.4
1345	16-19	33.7	6.1	1637.5	0.0	372.6	640.2	624.8	5	155.5	111.5	145	75.9	50.7
1346	20-30	33.6	6.0	1581.7	0.0	372.9	584.1	624.8	6	119.9	110.5	146	180.9	72.7
1347	20-30	32.7	5.9	1581.7	0.0	372.9	584.1	624.8	6	116.4	109.0	146	175.6	71.8
1348	20-30	28.3	6.1	2682.7	0.0	1821.3	553.8	307.7	5	130.8	111.6	165	388.2	93.0

ArborGen, Inc. Petition (11-019-01p) for Determination of Non-regulated Status for Freeze Tolerant Eucalyptus Lines FTE 427 and FTE 435

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Appendix E: List of States and Counties Where Freeze-Tolerant Eucalyptus May Be Expected to Be Grown

Alabama
Baldwin County
Geneva County
Henry County
Houston County
Mobile County

Florida
Alachua County
Baker County
Bay County
Bradford County
Brevard County
Calhoun County
Citrus County
Clay County
Columbia County
Dixie County
Duval County
Escambia County
Flagler County
Franklin County
Gadsden County
Gilchrist County
Glades County
Gulf County
Hamilton County
Hernando County
Highlands County
Hillsborough County
Holmes County
Jackson County
Jefferson County
Lafayette County
Lake County
Leon County
Levy County
Liberty County
Madison County
Manatee County

(Florida cnt'd)
Marion County
Martin County
Nassau County
Okaloosa County
Okeechobee County
Orange County
Osceola County
Pasco County
Polk County
Putnam County
Santa Rosa County
St. Johns County
Sumter County
Suwannee County
Taylor County
Union County
Volusia County
Wakulla County
Walton County
Washington County

Georgia
Appling County
Atkinson County
Bacon County
Baker County
Ben Hill County
Berrien County
Brantley County
Brooks County
Bryan County
Bulloch County
Calhoun County
Camden County
Candler County
Charlton County
Chatham County
Clay County
Clinch County

(Georgia Cont'd)
Coffee County
Colquitt County
Cook County
Crisp County
Decatur County
Dodge County
Dooly County
Dougherty County
Early County
Echols County
Effingham County
Emanuel County
Evans County
Glynn County
Grady County
Irwin County
Jeff Davis County
Lanier County
Lee County
Liberty County
Long County
Lowndes County
McIntosh County
Miller County
Mitchell County
Montgomery County
Pierce County
Pulaski County
Randolph County
Screven County
Seminole County
Tattnall County
Telfair County
Terrell County
Thomas County
Tift County
Toombs County
Treutlen County
Turner County

(Georgia Cont'd)
Ware County
Wayne County
Wheeler County
Wilcox County
Worth County

Louisiana
Acadia Parish
Allen Parish
Avoyelles Parish Louisiana
Beauregard Parish Louisiana
Caddo Parish
Calcasieu Parish
Caldwell Parish
Catahoula Parish
De Soto Parish
East Baton Rouge Louisiana
East Feliciana Parish
Evangeline Parish Louisiana
Grant Parish
Jefferson Davis Parish
La Salle Parish Louisiana
Livingston Parish Louisiana
Morehouse Parish Louisiana
Natchitoches Parish Louisiana
Ouachita Parish
Rapides Parish
Richland Parish
Sabine Parish Louisiana
St. Helena Parish Louisiana
St. Landry Parish Louisiana
St. Tammany Parish Louisiana
Tangipahoa Parish Louisiana
Vernon Parish Louisiana
Washington Parish Louisiana
West Carroll Parish Louisiana
West Feliciana Parish Louisiana
Winn Parish Mississippi

Mississippi
Adams County Mississippi
Amite County Mississippi
Claiborne County Mississippi
Forrest County Mississippi
Franklin County Mississippi
George County Mississippi
Hancock County Mississippi
Harrison County Mississippi
Jackson County
Jefferson County
Jefferson Davis
Lamar County
Lawrence County Mississippi
Lincoln County Mississippi
Marion County Mississippi
Pearl River County Mississippi
Pike County Mississippi
Stone County Mississippi
Walthall County Mississippi
Wilkinson County

South Carolina
Bamberg County
Beaufort County
Berkeley County
Charleston County
Colleton County
Dorchester County
Georgetown County
Hampton County
Jasper County

Texas
Anderson County
Angelina County
Cherokee County
Grimes County
Hardin County
Harrison County

(Texas Cont'd)
Houston County
Jasper County
Jefferson County
Liberty County
Montgomery County
Nacogdoches County
Newton County
Orange County
Panola County
Polk County
Rusk County
Sabine County
San Augustine County
San Jacinto County
Shelby County
Smith County
Trinity County
Tyler County
Walker County

ArborGen, Inc. Petition (11-019-01p) for Determination of Non-regulated Status for Freeze Tolerant Eucalyptus Lines FTE 427 and FTE 435

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Appendix F: Threatened and Endangered Species Recorded in Counties within the FTE Action Area

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Amphibians	*Ambystoma cingulatum*	Frosted Flatwoods salamander	Threatened	Yes	FL, GA, SC
Amphibians	*Rana capito sevosa*	Dusky gopher frog	Endangered	Yes	MS
Amphibians	*Ambystoma bishopi*	Reticulated flatwoods salamander	Endangered	Yes	FL, GA
[redacted]					
Birds	*Polyborus plancus audubonii*	Audubon's crested caracara	Threatened	No	FL
Birds	*Vermivora bachmanii*	Bachman's warbler (=wood)	Endangered	No	FL, SC
Birds	*Rostrhamus sociabilis plumbeus*	Everglade snail kite	Endangered	Yes	FL
Birds	*Ammodramus savannarum floridanus*	Florida grasshopper sparrow	Endangered	No	FL
Birds	*Aphelocoma coerulescens*	Florida scrub-jay	Threatened	No	FL
Birds	*Dendroica kirtlandii*	Kirtland's Warbler	Endangered	No	FL, SC
Birds	*Sterna antillarum*	Least tern (interior pop.)	Endangered	No	LA, MS, TX
Birds	*Grus canadensis pulla*	Mississippi sandhill crane	Endangered	Yes	MS
Birds	*Charadrius melodus*	Piping Plover, except GL watershed	Threatened	Yes	AL, FL, LA, SC, TX
Birds	*Charadrius melodus*	Piping Plover, Great Lakes watershed	Endangered	Yes	MS
Birds	*Picoides borealis*	Red-cockaded woodpecker	Endangered	No	AL, FL, GA, LA, MS, SC, TX

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Birds	*Calidris canutus fufa*	Red Knot	Threatened	No	AL, GA, FL, MS, SC, TX
Birds	*Grus americana*	Whooping crane	Endangered, NE EXPN pop.	Yes	FL, TX
Birds	*Mycteria americana*	Wood stork	Endangered	No	AL, FL, GA, LA, MS, SC
[redacted]					
Clams	*Potamilus inflatus*	Alabama heelsplitter	Threatened	No	AL, LA, MS
Clams	*Elliptio spinosa*	Altamaha spinymussel	Endangered	Yes	GA
Clams	*Elliptio chipolaensis*	Chipola slabshell	Threatened	Yes	AL, FL
Clams	*Villosa choctawensis*	Choctaw bean	Endangered	Yes	AL, FL
Clams	*Potamilus capax*	Fat pocketbook	Endangered	No	LA, MS
Clams	*Amblema neislerii*	Fat three-ridge (mussel)	Endangered	Yes	FL, GA
Clams	*Pleurobema strodeanum*	Fuzzy pigtoe	Threatened	Yes	AL, FL
Clams	*Medionidus penicillatus*	Gulf moccasinshell	Endangered	Yes	AL, FL, GA
Clams	*Margaritifera hembeli*	Louisiana pearlshell	Threatened	No	LA
Clams	*Fusconaia escambia*	Narrow pigtoe	Threatened	Yes	AL, FL
Clams	*Medionidus simpsonianus*	Ochlockonee moccasinshell	Endangered	Yes	FL, GA
Clams	*Pleurobema pyriforme*	Oval pigtoe	Endangered	Yes	AL, FL, GA

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Clams	*Lampsilis abrupta*	Pink mucket (pearlymussel)	Endangered	No	LA
Clams	*Elliptoideus sloatianus*	Purple bankclimber (mussel)	Threatened	Yes	AL, FL, GA
Clams	*Quadrula cylindrica cylindrica*	Rabbitsfoot	Threatened	PCH	MS
Clams	*Fusconaia rotulata*	Round ebonyshell	Endangered	Yes	FL
Clams	*Lampsilis subangulata*	Shinyrayed pocketbook	Endangered	Yes	AL, FL, GA
Clams	*Pleurobema decisum*	Southern clubshell	Endangered	Yes	AL
Clams	*Ptychobranchus jonesi*	Southern kidneyshell	Endangered	Yes	AL, FL
Clams	*Hamiota (=Lampsilis) australis*	Southern sandshell	Threatened	Yes	AL, FL
Clams	*Medionidus walker*	Swannee moccasinshell	Threatened	No	FL, GA
Clams	*Fusconaia burkei*	Tapered pigtoe	Threatened	Yes	AL, FL
Conifers s	*Torreya taxifolia*	Florida torreya	Endangered	No	FL, GA
Crustaceans	*Palaemonetes cummingi*	Squirrel Chimney Cave shrimp	Threatened	No	FL
Ferns and Allies	*Isoetes louisianensis*	Louisiana quillwort	Endangered	No	AL, LA, MS
Ferns and Allies	*Trichomanes punctatum ssp. floridanum*	Florida bristle fern	Proposed Endangered	No	FL

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Fishes	*Scaphirhynchus suttkusi*	Alabama sturgeon	Endangered	Yes	AL
Fishes	*Etheostoma rubrum*	Bayou darter	Threatened	No	MS
Fishes	*Acipenser oxyrinchus desotoi*	Gulf sturgeon	Threatened	Yes	AL, FL, LA, MS
Fishes	*Etheostoma okaloosae*	Okaloosa darter	Threatened	No	FL
Fishes	*Scaphirhynchus albus*	Pallid sturgeon	Endangered	No	AR, LA, MS
Fishes	*Percina aurora*	Pearl darter	Proposed Threatened	No	MS
[redacted]					
Flowering Plants	*Schwalbea americana*	American chaffseed	Endangered	No	AL, FL, GA, LA, SC
Flowering Plants	*Conradina glabra*	Apalachicola rosemary	Endangered	No	FL
Flowering Plants	*Crotalaria avonensis*	Avon Park harebells	Endangered	No	FL
Flowering Plants	*Deeringothamnus pulchellus*	Beautiful pawpaw	Endangered	No	Fl
Flowering Plants	*Nolina brittoniana*	Britton's beargrass	Endangered	No	FL
Flowering Plants	*Campanula robinsiae*	Brooksville bellflower	Endangered	No	FL
Flowering Plants	*Oxypolis canbyi*	Canby's dropwort	Endangered	No	GA, SC
Flowering Plants	*Warea carteri*	Carter's mustard	Endangered	No	FL
Flowering Plants	*Rhododendron chapmanii*	Chapman rhododendron	Endangered	No	FL
Flowering Plants	*Thalictrum cooleyi*	Cooley's meadowrue	Endangered	No	FL, GA
Flowering Plants	*Justicia cooleyi*	Cooley's water-willow	Endangered	No	FL
Flowering Plants	*Conradina etonia*	Etonia rosemary	Endangered	No	FL

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Flowering Plants	*Bonamia grandiflora*	Florida bonamia	Threatened	No	FL
Flowering Plants	*Chrysopsis floridada*	Florida golden aster	Endangered	No	FL
Flowering Plants	*Cladonia perforata*	Florida perforate cladonia	Endangered	No	FL
Flowering Plants	*Scutellaria floridana*	Florida skullcap	Threatened	No	FL
Flowering Plants	*Ziziphus celata*	Florida ziziphus	Endangered	No	FL
Flowering Plants	*Asimina tetramera*	Four petal paw paw	Endangered	No	FL
Flowering Plants	*Silene polypetala*	Fringed campion	Endangered	No	FL, GA
Flowering Plants	*Dicerandra christmanii*	Garrett's mint	Endangered	No	FL
Flowering Plants	*Spigelia gentianoides*	Gentian pinkroot	Endangered	No	AL, FL
Flowering Plants	*Pinguicula ionantha*	Godfrey's butterwort	Threatened	No	FL
Flowering Plants	*Arabis georgiana*	Gerogia rockcress	Threatened	Yes	GA
Flowering Plants	*Baptisia arachnifera*	Hairy rattleweed	Endangered	No	GA
Flowering Plants	*Ptilimnium nodosum*	Harperella	Endangered	No	GA
Flowering Plants	*Harperocallis flava*	Harper's beauty	Endangered	No	FL
Flowering Plants	*Hypericum cumulicola*	Highlands scrub hypericum	Endangered	No	FL
Flowering Plants	*Dicerandra immaculata*	Lakela's mint	Endangered	No	FL
Flowering Plants	*Polygala lewtonii*	Lewton's polygala	Endangered	No	FL

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Flowering Plants	*Dicerandra cornutissima*	Longspurred mint	Endangered	No	FL
Flowering Plants	*Ribes echinellum*	Miccosukee gooseberry	Theatened	No	FL
Flowering Plants	*Spiranthes parksii*	Navasota ladies'-tresses	Endangered	No	TX
Flowering Plants	*Hibiscus dasycalyx*	Neches River rose-mallow	Threatened	Yes	TX
Flowering Plants	*Geocarpon minimum*	No Common name	Threatened	No	LA, TX
Flowering Plants	*Cucurbita okeechobeensis ssp. okeechobeensis*	Okeechobee gourd	Endangered	No	FL
Flowering Plants	*Paronychia chartacea*	Papery whitlow-wort	Threatened	No	FL
Flowering Plants	*Clitoria fragrans*	Pigeon wings	Threatened	No	FL
Flowering Plants	*Lindera melissifolia*	Pondberry	Endangered	No	AL, GA, MS, SC
Flowering Plants	*Chionanthus pygmaeus*	Pygmy fringe-tree	Endangered	No	FL
Flowering Plants	*Trillium reliquum*	Relict trillium	Endangered	No	AL, GA
Flowering Plants	*Deeringothamnus rugelii*	Rugel's pawpaw	Endangered	No	FL
Flowering Plants	*Polygonella myriophylla*	Sandlace	Endangered	No	FL
Flowering Plants	*Liatris ohlingerae*	Scrub blazingstar	Endangered	No	FL
Flowering Plants	*Eriogonum longifolium var. gnaphalifolium*	Scrub buckwheat	Threatened	No	FL
Flowering Plants	*Lupinus aridorum*	Scrub lupine	Endangered	No	FL

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Flowering Plants	*Dicerandra frutescens*	Scrub mint	Endangered	No	FL
Flowering Plants	*Prunus geniculata*	Scrub plum	Endangered	No	FL
Flowering Plants	*Amaranthus pumilus*	Seabeach amaranth	Threatened	No	SC
Flowering Plants	*Conradina brevifolia*	Short-leaved rosemary	Endangered	No	FL
Flowering Plants	*Eryngium cuneifolium*	Snakeroot	Endangered	No	FL
Flowering Plants	*Euphorbia telephioides*	Telephus spurge	Threatened	No	FL
Flowering Plants	*Leavenworthia texana*	Texas golden gladecress	Endangered	Yes	TX
Flowering Plants	*Hymenoxys texana*	Texas prairie dawn-flower	Endangered	No	TX
Flowering Plants	*Phlox nivalis ssp. texensis*	Texas trailing phlox	Endangered	No	TX
Flowering Plants	*Polygala smallii*	Tiny polygala	Endangered	No	FL
Flowering Plants	*Macbridea alba*	White birds-in-a-nest	Threatened	No	FL
Flowering Plants	*Lesquerella pallida*	White bladderpod	Endangered	No	TX
Flowering Plants	*Warea amplexifolia*	Wide-leaf warea	Endangered	No	FL
Flowering Plants	*Polygonella basiramia*	Wireweed	Endangered	No	FL
Lichens	*Cladonia perforata*	Florida perforate cladonia	Endangered	No	FL

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Mammals	*Peromyscus polionotus ammobates*	Alabama beach mouse	Endangered	Yes	AL
Mammals	*Peromyscus polionotus phasma*	Anastasia Island beach mouse	Endangered	No	FL
Mammals	*Peromyscus polionotus allophrys*	Choctawhatchee beach mouse	Endangered	Yes	FL
Mammals	*Eumops floridanus*	Florida bonneted bat	Proposed endangered	No	FL
Mammals	*Puma (=Felis) concolor coryi*	Florida panther	Endangered	No	FL
Mammals	*Microtus pennsylvanicus dukecampbelli*	Florida salt marsh vole	Endangered	No	FL
Mammals	*Myotis grisescens*	Gray bat	Endangered	No	AL, FL
Mammals	*Herpailurus (=Felis) yagouaroundi cacomitli)*	Gulf Coast jaguarundi	Endangered	No	TX
Mammals	*Myotis sodalis*	Indiana bat	Endangered	Yes	FL
Mammals	*Ursus americanus luteolus*	Louisiana black bear	Threatened	Yes	LA, MS, TX
Mammals	*Myotis septentrionalis*	Northern Big-Eared Bat	Proposed Endangered	No	AL, GA, LA, MS, SC
Mammals	*Peromyscus polionotus trissyllepsis*	Perdido Key beach mouse	Endangered	Yes	AL, FL
Mammals	*Puma (=Felis) concolor (all subsp. except coryi)*	Puma (=mountain lion)	Similarity of Appearance to a Threatened Taxon	No	FL

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Mammals	*Peromyscus polionotus niveiventris*	Southeastern beach mouse	Threatened	No	FL
Mammals	*Peromyscus polionotus peninsularis*	St. Andrew beach mouse	Endangered	Yes	FL
Mammals	*Trichechus manatus*	West Indian manatee	Endangered	Yes	AL, FL, GA, LA, MS, SC, TX
Reptiles	*Pseudemys alabamensis*	Alabama red-belly turtle	Endangered	No	AL, MS
Reptiles	*Nerodia clarkii taeniata*	Atlantic salt marsh snake	Threatened	No	FL
Reptiles	*Pituophis melanoleucus lodingi*	Black Pine Snake	Proposed Threatened	No	AL, MS
Reptiles	*Eumeces egregius lividus*	Bluetail mole skink	Threatened	No	FL
Reptiles	*Drymarchon corais couperi*	Eastern indigo snake	Threatened	No	Al, FL, GA
Reptiles	*Gopherus polyphemus*	Gopher tortoise (w of Mobile/Tombigbee Rs.) Candidate species east of this point in AL, FL, GA, and SC.	Threatened	No	AL, LA, MS
Reptiles	*Chelonia mydas*	Green sea turtle	Endangered	Yes	AL, FL, GA, LA, MS, SC, TX
Reptiles	*Eretmochelys imbricata*	Hawksbill sea turtle	Endangered	Yes	AL, FL, GA, LA, MS, SC, TX
Reptiles	*Lepidochelys kempii*	Kemp's ridley sea turtle	Endangered	No	AL, FL, GA, LA, MS, SC, TX
Reptiles	*Dermochelys coriacea*	Leatherback sea turtle	Endangered	Yes	AL, FL, GA, LA, MS, SC, TX

Group	Scientific Name	Common Name	Status	Critical Habitat	States Within Action Area
Reptiles	*Caretta caretta*	Loggerhead sea turtle	Threatened	No	AL, FL, GA, LA, MS, SC, TX
Reptiles	*Pituophis ruthveni*	Louisiana pinesnake	Proposed Threatened	No	LA, TX
Reptiles	*Graptemys oculifera*	Ringed map turtle	Threatened	No	LA, MS
Reptiles	*Neoseps reynoldsi*	Sand skink	Threatened	No	FL
Reptiles	*Graptemys flavimaculata*	Yellow-blotched map turtle	Threatened	No	MS