***Discussion Paper Series*, 13(7): 165-192**

Forest land use changes in Greece: An ordinal regression analysis at the regional level

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Abstract

Forest land use changes in Greece have been the outcome of combining forces with mostly economic and institutional origin. Interactions between the major land uses have diachronically resulted in spatial patterns of great economic and environmental interest. This paper aims at describing forest land use changes during the last decades in Greece as well as analyzing the major regional and economic development implications. Particular attention is given to the analysis of possible driving forces with economic and social origin. The estimations are curried out through the use of a statistical model that employs ordinal regression analysis. Ordinal regression is a variation of ordinary regression which is used when the dependent variable is categorical and the explanatory variables are continuous, or categorical. An advantage of this type of regression is that requires fewer assumptions as regards the relationship between the explanatory variables and the dependent variable. Assessing sustainability of development decisions on a regional scale through the evaluation of likely impacts on forest resources can provide great support in formulating better regional policies that incorporate the environmental protection objectives of the society.

Key words: *land use change, deforestation, ordinal regression, Greece*

September 2007

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Available online at: http://www.prd.uth.gr/research/DP/2007/uth-prd-dp-2007-07_en.pdf

1. Introduction

Access to sufficient empirical evidence on the causes of land use changes represents a critical step towards improving understanding of land system functioning and for addressing the perplexing interactions between people and their surroundings. Regardless of its purpose, a reliable and consistent pool of evidence on the evolution and state of regional land use systems within the broader context of a country can contribute considerably to the improvement of strategic policy design and implementation (Agarwal *et al.,* 2002). Nowadays, some of the most profound land alteration phenomena are forest fragmentation and forest land use conversion and modification (Geist and Lambin 2001; Lambin *et al.,* 2001). The processes that drive those types of changes are complex due to numerous dynamic interactions between natural ecosystems and human demand for utilising land for a diverse range of purposes.

Amongst others, forest land use changes occur for multiple reasons and from interacting processes and mechanisms. Human-driven changes at an array of scales are affecting forest ecosystems accelerating changes such as global warming that affect human well being. Research has demonstrated that in the long term there is not a single factor or set of factors that can explains the emerging patterns of land uses and the associated changes (Angelsen and Kaimowitz 1999; Aspinall 2004; Chomitz and Gray 1996; Geist and Lambin 2001; Lambin *et al.,* 2001). Deforestation processes have different characteristics across space and time (Verburg *et al.,* 2006a). A particular combination of factors that may explain deforestation pattern somewhere might not be applicable for justifying change in any other locations or time periods. Therefore, there is a need for conducting empirical investigations in order to analyse and understand the geographical and historical context of land use changes. In addition, forest fragmentation, conversion and modification have significant economic, social and environmental implications (Platt 2004; Verburg *et al.,* 2006b; Walker 2001) such as disruption in continuity of the natural landscape, forest and open-land squeeze between agricultural and urban land uses, deterioration of vital habitats that sustain valuable biodiversity as well as broader issues such as air pollution.

In this research, we concentrate on recent changes concerning forest land uses in Greece. Shortly, after the 1992 Earth Summit in Rio, there were numerous claims from non-governmental organisations, the scientific community as well as various land use planning stakeholders, of establishing more sustainable development patterns. There was concern for protecting the environment and for meeting the requirements for ecologically-friendly economic growth set by the EU structural funding programs. The consistent and systematic integration of environmental aspects into a broad range of state policies had been a major aim to achieve. Following Rio declaration of Agenda 21 a number of international initiatives and summits such as Kyoto Protocol moved further by setting certain commitments and concrete goals that will have be achieved in the near future. Some of these international initiatives stressed the importance of forest resources for the equilibrium of the whole planet and proposed tools such as the Clean Development Mechanism for achieving reductions to Greenhouse gas emissions. However, to-date it is not clear if the sustainable development goals that were set in the '90s have been achieved.

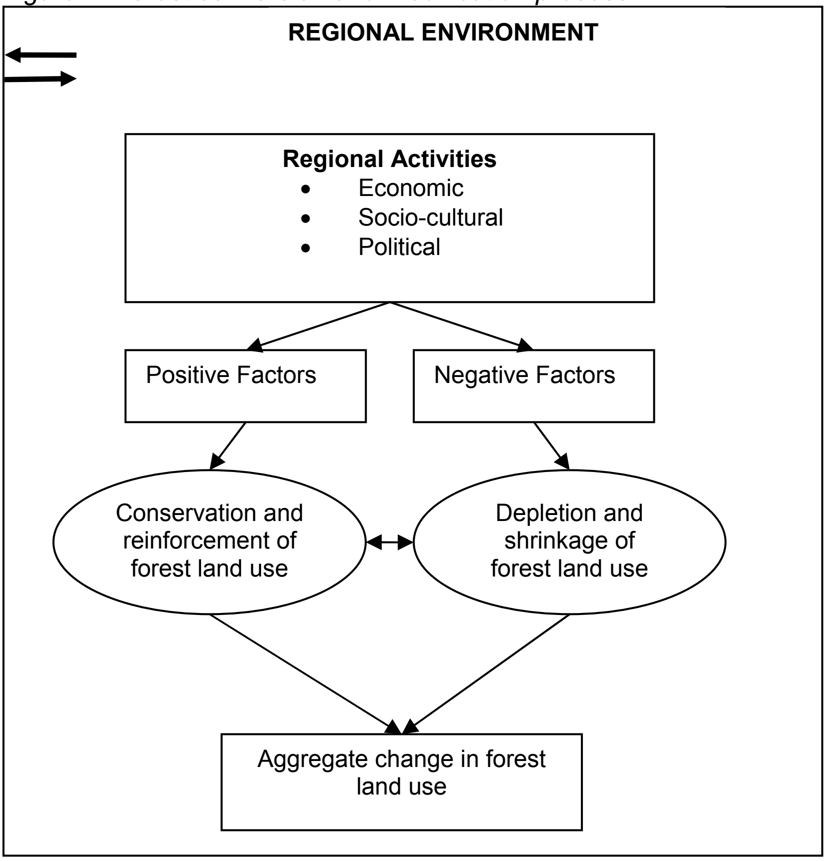
This study primarily aims at a) revealing the major underlying causes of forest land use change in Greece for a period the period from 1990 to 2000 by using as a spatial scale of analysis the prefectural administrative level (NUTS III) b) identifying the agents, structures and nature of change and c) assessing some of the implications of these changes. The above aims are pursued through the estimation of the kind and magnitude of relations between changes in forest land use and a wide range of socioeconomic factors. The methodology adopted is ordinal regression analysis. This type of regression is useful for land use decisions that show some hierarchy or grouping as well as when the data of land-use change are not fully reliable.

The paper is organised as follows. In section 2 we provide a framework for the empirical analysis by dealing with the forest land use change driving factors and the relevant empirical research that describe the process of deforestation. In section we present the study area, the ordinal regression model and the independent variables used in the analysis. The last part of this section is devoted to the regional analysis of forest land use changes. The overall performance of the model is commented upon and the results are presented and interpreted. We conclude in section 4 commending on the wider implications of the findings.

2. Review of theoretical aspects

A variety of economic and social forces might work competitively or additionally towards the configuration of land use patterns across the regions or the prefectures of a country (Verburg 2006; Verburg *et al.,* 2002). Thus, a theoretical land use change model is proposed and the possible effects of all explanatory variables are discussed hypothesizing that the effect of a particular variable may differ between geographical areas. The process of forest conversion and modification on a regional level can be presented schematically in figure 1.

Figure 1: Forest conversion and modification process



These economic, socio-cultural and political metamorphotic processes generate factors of change that are capable of impacting negatively or positively the extent and distribution of forests. The reality is even more complex because usually between these positive and negative factors there are linkages and interactions. The outcome of the combining action of the negative and positive factors is the aggregate change in forest land use.

The underlying causes of land use change vary from locality to locality and amongst countries (GLP 2005; Lambin *et al.,* 2001; Wood and Skole 1998). In most of the cases, quantification of these forces is a difficult task as it is also difficult finding the appropriate methodology that can give a reliable estimation of the magnitude of the relationships involved. A wide variety of approaches and techniques have emerged for this reason, namely to rationalise decision-making about land use matters. How and to what extent existing methodologies have reached satisfactorily this target is also a matter of research. Among the various methodologies statistical techniques concentrated mainly on land change dynamics and have widely been used. These models focus more on the causes of deforestation rather than its sources. Observed land use patterns are tightly connected to urban and regional development policies and to the enlargement of the regional economy. Their ceaseless transformation is fuelled by the need for serving the rapidly changing economic and social requirements as well as for fulfilling newly arising demands as a result of economic liberalization and privatization and transformation of lifestyle.

The morphology and evolution of land use patterns have been extensively studied and theorised by scientists of different disciplines (Irwin and Geoghegan 2001; Verburg *et al.,* 2004; Walker 2001; Wood and Skole 1998). Thus, a plethora of theoretical and modelling approaches have been developed so far in order to provide possible explanations of land allocation processes. Two general categories of land (cover /use) change are described in the literature: conversion and modification (Baulies and Szejwach 1998; Briassoulis and van der Straaten 2000; Lesschen *et al.,* 2005). Land cover conversion refers to a change from one cover type to another whereas land cover modification implies structural or functional transitions in cover without loss in initial determinative characteristics. Similarly, land use conversion refers to a complete change from one use type to another whereas land use modification implies structural or functional alterations in use without loss in initial attributive characteristics. Finally, the driving forces (causes) of LUC change can be divided into two categories: Proximate causes and underlying causes. Proximate causes of land use change are associated with coarse anthropogenic operations that directly influence spatial patterns, as are for instance urbanisation, agricultural expansion and forest exploitation (Geist and Lambin 2001; Lesschen *et al.,* 2005). Underlying causes of land use change are associated with generative agents that weave proximate causes, as are for instance economic, socio-demographic and technological factors (Geist and Lambin 2001; Lesschen *et al.,* 2005).

Table 1: Proximate and underlying causes of deforestation

Proximate causes	**Land use change forces at the Macroscopic level**	
	Functioning and expansion of urban land forms and activities	Transportation and other kinds of infrastructure
	Functioning and expansion or shrinkage of agricultural activities	Livestock breading systems and forest resources exploitation
Underlying causes	**Economic Factors**	
	Sector arrangement of the regional economy	Sectoral Employment
	Sectoral structure	Investments and business location decisions
	Size and synthesis of imports and exports	Consumption patterns
	Productivity	Diffusion of technology and adoption of innovations
	Competitiveness of the economy	Mean size of businesses
	Technological level of the economy	Scale and agglomeration economies
	Taxation	Investment incentives and development policies
	Income distribution	Added value
	Social factors	
	Population skills level	Housing policy
	Education level	Institutions
	Social infrastructure	Population quality in the public sector
	Social security	Life style
	Demographic factors	
	Population changes	Indirect population potential
	Urban and rural population	Direct population potential
	Age of the population	Population mobility
	Environmental factors	
	Soil fertility	Biodiversity
	Topography	Ecosystem productivity
	Climatic conditions	Water resources
	Stretch of the coastline	Insular or mainland area

There could also be done another useful distinction regarding land use change driving forces. They can be categorised into “endogenously changed or shifting or metamorphotic forces” that usually change very quickly over time (e.g employment patterns of the new economy, location and relocation decisions of certain types of firms, supply and demand of certain products and services) “slow-shifting forces” (e.g population size and other demographical characteristics) and “conditioning forces” which usually exhibit a temporal stability (e.g soil types, geomorphology). The last categorisation of driving forces, in a way, implies that a steady state of land use patterns should almost never be expected. This endogenous, ever-changing nature of certain forces has been pointed out by theoretical approaches such as game theory and has also certain modelling implication in land use change studies. As Arthur (2005) states, out-of-equilibrium situations or the emergence of equilibria and the general unfolding of patterns in the economy calls for an algorithmic approach. Land use patterns may represent temporarily fulfilled or unfulfilled complex expectations not necessarily rationally formed as in the case of El Farol Bar problem (Arthur 1994). Table 1 provides a summary of some of the deforestation driving forces.

3. Empirical Analysis

3.1 Study Area

Greece consists of 13 administrative regions, which are further subdivided into 51 prefectures (fig.3). The country covers a total area of some 131.957,4 km^2. The mainland part of the country marks the end of the Balkan Peninsula whereas the insular part borders with Asia and Africa continents. Coastline stretches for approximately 15.000km. The country's population is approximately 11 million people with 72.8% staying in urban areas and the remaining 27.2% being rural population. In mountainous areas lives 9.2% of the population, whereas in semi-mountainous and urban areas the figures are 21.8% and 69.0% respectively. Agriculture and pastoral uses cover 49.5% of country's surface, forests, shrub and bare land cover 47.2%, inland water 1.3% and urban and other artificial surfaces cover 2.0% (NSSG 2004b).

Geomorphologically speaking, most of the mainland territory consists of mountains. Just a few major agricultural plains exist the largest of which is placed in central Greece in the administrative boundaries of the Thessaly region. The country has a Mediterranean-type of climate with high temperatures and very little rainfalls in the summer. However, the area has relatively mild winters. The most common plant communities include forests of broadleaf evergreen trees, oak woodlands, sclerophyllic bushes of maquis and garrigue. On most of the insular areas maquis communities may be the climax. However, in the mainland parts of the country this type of vegetation has usually been the outcome of forest dislocation and overexploitation.

3.2 Variables Selection

Data for estimating the change in forest area between 1990 and 2000 in a prefectural level were derived from two surveys of NSSG (NSSG 1995, 2004b). The change is expressed by the ratio of the amount of forest land for the year 1990 to the amount of forest land for the year of 2000 in each prefecture. The original data were transformed in order to be compatible because the NSSG used different classification categories for recording forest land in the two surveys. However, because the data were still considered to be of questionable quality we treated the dependent variable as categorical and not as continues. The advantage of constructing broad categories of deforestation is that even relatively large errors during the recording procedure do not affect the results decisively. The drawback, however, is that the new categorical variable is much less informative than the original continues one. The categories of the dependent variable in which the prefectures where classified according to there rate of forest land use change were the following:

- Category 1: Extreme decrease in forest land (≤ 0.68)
- Category 2: High decrease in forest land (0.69 - 0.79)
- Category 3: Medium decrease in forest land (0.80 - 0.89)
- Category 4: Increase in forest area or limited decrease (90+)

A total of 12 variables describing economic, social and physical characteristics were employed for the empirical analysis. As a referencing unit for statistical analysis it was used the prefectural administrative level which corresponds to NUTS III level of Eurostat. The selection of the variables relied on the relative availability of data and a literature review on deforestation factors in developed as well as developing countries. Certain country-specific processes regarding mostly building activity (e.g. informal housing) were taken into consideration. The variables that were finally used as explanatory of the deforestation issue in Greece for the period 1990-2000 are presented in table 1 and described underneath.

Table 2: Description of the variable used in the ordinal regression model

	Variable	Description	Data Source
X_1	Urban Sprawl	Ratio of the number of building constructed outside the existing urban plans multiplied by 100 to the total number of buildings in that area	NSSG (1994; 2004a)
X_2	Change in Rural Population	Rural population in 2001 to rural population in 1991	NSSG (2004b)
X_3	Indirect Population Potential	The accessibility of each prefecture to the rest of the prefectures	(Ministry of Economy and Finance 1993; NSSG 2004b; Polyzos and Arambatzis 2006)
X_4	Total Population Potential	This variable is made up of the indirect and the direct population potential and shows the total accessibility of each prefecture.	Ministry of Economics and Finance (1993), NSSG (2004b), Polyzos and Arambatzis (2006)
X_5	Informal Housing Activity	Total number of legalised housing units per prefecture for the period 1997-2006 per 1000 residents	NSSG (2006)
X_6	Urban Plan Expansion	The total area incorporated within the boundaries of towns and cities for the period 1985-2003, per 100 residents	YPEHODE (2006)
X_7	Legal Housing Activity	The area in square meters per resident added to the existing building area stock for the period 1997-2000	NSSG (2006)
X_8	Prosperity Level	The contribution of each prefecture to the GNP of Greece and to GNP per capita in € as well as in Purchasing Power Standards (PPS)	Petrakos and Polyzos (2005)
X_9	Mean GDP in Agriculture	The share of the primary sectors of economy in the total production of each prefecture	NSSG (2005)
X_{10}	Change in GDP in Agriculture	Gross Domestic Product in agriculture to the Gross National Product (GNP) in agriculture for the period 1990-2000 in a prefectural level.	NSSG (2005)
X_{11}	Geographical Zone	3 Climatic Zones according to the Greek Presidential Decree 352/1979	Greek Presidential Decree 352/1979
X_{12}	Change in Hotel Beds	The ratio of the number of hotel beds for the year 1990 to the number of hotel beds for the year of 2000 in each prefecture	NSSG (1999; NSSG 2004b)

1. *Urban Sprawl:* The dominant development pattern of the old cities and towns in Greece used to be the compact one but over the past 50 years the density of resident per unit of area has declined considerably. Road expansion allowed people to commute greater distances between their residences and places of work. In addition, the improved transportation infrastructure as well as technological and communication advances have led to relocation decisions of an increasing number of businesses and industries. Moving outside of the borders of the formal urban plans poses great pressures on the natural environment resulting in habitat shrinking, forest and agricultural land uses conversion and modification. Numerous studies on land use change consider urban sprawl as a major driver of deforestation (Walker 2001). However, it is not clear whether the outwards sprawl of urban forms takes place mainly on agricultural land or on forest land in Greece. In a relevant study concerning agricultural land use change in Greece by Minetos and Polyzos (2007) the same variable appears to be a significant driving force of agricultural land use change in Greece for the same period and scale of analysis. Therefore, we set to examine whether urban sprawl impacted forest resources during the study period or only the agricultural was affected. The data for this variable come from NSSG (2005) and refer to the percentage of urban land laying outside the existing urban plans in each prefecture for the year 2000. The indicator is the ratio of the number of building constructed outside the existing urban plans in each prefecture multiplied with 100 to the total number of buildings in that prefecture.

2. *Change in Rural Population:* The rural population variable was used in the model in order to assess the influence on deforestation of contemporary demographic processes. Bearing in mind that the past phenomenon of rural-urban migration has long ceased in Greece, we wanted to investigate the influence of the opposite process of rural rebound. As reported in the relevant literature, population-driven land use changes can be the outcome of population migration towards the rural areas. When the country got into the developed stage, the post war massive rural-urban migration movements phased out and a reverse process of people seeking dwelling in exurban rural locations started. Most of the Greek regions, especially the insular and coastal ones increased there population. Data for this variable come from NSSG (2004b).

3. *Indirect Population Potential:* The variable of “indirect population potential” shows the accessibility of each prefecture to the rest of the prefectures. We use this indicator because very often changes in the use of land in a location are generated by people who live and work away from that location. Residents of large urban concentrations may sometime choose to build houses or undertake other forms of land use transformation in adjacent prefectures. As regards building activity, this tendency is known as secondary and/or vacation housing

and happens across the country in many instances (e.g. dwellers from Thessaloniki build houses in Pieria or Chalkidiki, dwellers from Athens in Evia, or Korinthia). The indirect population potential can be estimated by using the following equation (Clark *et al.,* 1969; Keeble *et al.,* 1982):

$$IPP_i=\sum_{j=1}^{50}\frac{P_j}{D_{ij}^{a}} \quad (1)$$

where:

IPP_i	=	The indirect population potential of region *i*.
Pj	=	The population of region j, where *j=1,…,50* (fifty is the number of Greek prefectures minus one).
D_{ij}	=	A measure of the distances between regions *i* and *j*.
α	=	The superscript α is a measure of distance "friction".

For the purpose of the present study, the *α* component is set to *1.5*, a value suitable for movements of general purpose (Martin and Witt 1989). Data for this variable come from the NSSG (2004b), Polyzos and Arambatzis (2006) and the Ministry of Economy and Finance (1993).

4. *Total Population Potential*: This variable is made up of the indirect and the direct population potential and shows the total accessibility of each prefecture. The total *(TPP)* and the indirect population potential *(IPP)* are indicators of population agglomerations in each prefecture and of the total accessibility of each prefecture in relation to the other prefectures. This measure is are estimated by using the following formulas:

$$TPP_i=DPP_i+IPP_i \quad \text{or} \quad TPP_i=\frac{P_i}{D_{ii}}+\sum_{j=1}^{50}\frac{P_j}{D_{ij}^{a}}, \quad (2)$$

where,

TPP_i	=	The total population potential of prefecture i.
DDP_i	=	The direct population potential of prefecture i.
P_i	=	The population of prefecture i.

D_{ij} = A measure of intra-regional distance (movements within each prefecture).

The data for this variable come from the Ministry of Economy and Finance (1993), NSSG (2004b) and a previous research by Polyzos and Arambatzis (2006). In addition *IPP*, we use this variable to distinguish whether the combination of the two population potentials has an effect on forest land uses.

5. *Informal Housing Activity:* Informal settlements in Greece form a complex issue. These groups of housing units are associated with a diverse population of a wide variety of social and economic backgrounds. Therefore, informal housing units do not have the same characteristics everywhere. In fact the individual cases have distinctive characteristics and can be classified into certain general categories. One such category concerns houses created by low-income households and they are scattered all over the country both close to urban centres and in ex-urban areas. A second category is made up by luxury vacation or secondary houses, placed close to the coastal zone or to remote rural locations. Finally, a third category encompasses the remaining cases such as illegal business building of the primary sector (e.g. farm buildings), the secondary sector (e.g. small family manufacturing companies) as well as the tertiary sector (tourism-related building all over the country). We use data on informal housing units that entered into the legalisation process in the period 1997 to 2006. We choose to cover this period assuming that most of these housing units were initiated in the '90 – therefore causing land use changes in that period - , but were legalised later on. We also assume that the legalised housing units which are only a fraction of the total informal housing activity in Greece are proportional to the ones that still remain illegal. Data for this variable come from the relevant annual building activity tables published by NSSG (2006).

6. *Urban Plans Expansion* per 100 residents 1995-2003: This variable represents the expansion of urban plans in each prefecture for the period 1995 to 2003. The area that was incorporated within the boundaries of towns and cities during that period was partly for meeting the demand of that time for urban developable land and partly for legalising build-up areas of informal housing units that were constructed during the early'90s. This variable was formed from unpublished data from the Ministry for the Environment, Physical Planning and Public Works (YPEHODE 2006).

7. *Legal Housing Activity* per Resident for the period 1997-2000: The *legal housing activity* in each prefecture depicts the area in square meters per resident added to the existing building area stock for the period 1997-2000. This area is added to the existing stock through the legal procedure of issuing a building licence.

The approved constructions can then be materialised either within the formal town and city urban plans or outside these plans in the countryside provided that all legal requirements (e.g. sufficient size of land-plots etc) are met. As long as forests and forest land areas have a strong degree of protection under the Hellenic Constitutional principal (articles 24 and 117, 1975/86/00) "forest use change only for the public interest and only in cases in which the public interest can not be accommodated for by alternative means that do not include forest land use change", the legal housing activity cannot directly affect forest resources negatively. Any observed negative association should be due to indirect detrimental effects of legal housing such as increased possibility for accidental forest fires etc. Environmentally speaking, however, this would mean, that despite the fact of being legal on institutional terms, the housing activity is not sustainable. The data for this variable come from the NSSG (2006).

8. *Prosperity Level:* The prosperity indicator has been estimated by using the official data for the Greek prefectures by Eurostat concerning the contribution of each prefecture to the GNP of Greece and to GNP per capita in € as well as in Purchasing Power Standards (PPS). Due to the fact that the per capita GNP cannot give a safe estimation of the prosperity in the NUT II & III levels, they have also been incorporated into the variable additional financial and development indicators concerning the levels of consumption and civil infrastructure in the prefectures. The data concerning this variable come from a previous study by Petrakos and Polyzos (2005). By using this variable we investigate whether the level of human prosperity in each prefecture is connected to forest land use change or the observed changes do not depend on the level of economic development of each prefecture. This is also an estimate of sustainability in relation the growth of the Greek economy during the '90s, a period in which two extensive European Structural Funding Programs.

9. *Mean GDP in Agriculture* for the period 1990-2000: The share of the primary sectors of economy in the total production of each prefecture is an indicator of the likely influence of the magnitude of agricultural sector on forest resources. We expect that prefectures with extensive agricultural sector would have their forests resources more severely affected due to agricultural expansion and livestock grazing. Data for this variable come from the NSSG (2005).

10. *Changes in GDP in Agriculture:* This variable represents the change in the Gross Domestic Product in agriculture to the Gross National Product (GNP) in agriculture for the period 1990-2000 in a prefectural level. The changes are estimated by using the following formula:

$$\frac{AgriGDP_{i-1990} \big/ AgriGNP_{1990}}{AgriGDP_{i-2000} \big/ AgriGNP_{2000}} \tag{3}$$

where,

$AgriGDP_{i\_1990}$	=	The mean GDP in agriculture in the years 1989, 1990, 1991 for prefecture *i*
$AgriGNP_{1990}$	=	The mean GDP in agriculture in the years 1999, 2000, 2001 for prefecture *i*
$AgriGDP_{i\_2000}$	=	The mean GNP in agriculture in the years 1989, 1990, 1991
$AgriGDP_{i\_2000}$	=	The mean GNP in agriculture in the years 1999, 2000, 2001

Data for this variable come from the NSSG (NSSG 2005).

11. *Geographical Zone:* By using this variable we investigate whether the geographical position of a prefecture has an effect on forest land use changes. The 51 administrative units have been allocated into 3 climatic zones according to the Greek Presidential Decree 352/1979. The first zone includes the prefectures in the north part of the country which are mainly dominated by mountainous terrains and the climatic conditions are relatively cold. The second zone includes the prefectures situated in the central parts of the country. Here, a great portion of the land is flat and fertile and the climatic conditions are mild. Finally, the third zone encompasses the prefectures of the north part of the country as well as most of the islands.

12. *Changes in Hotel Beds* for the period 1994-2000: Likely linkages between tourism activity and change in forest resources are investigating by incorporating into the statistical analysis an indicator tourism infrastructure and demand. Assuming that the variable *"changes in hotel bed"* reflects both the magnitude of new tourism infrastructure for the period under investigation as well as the demand for vacations in Greece we look into the impact of tourism on forests on the prefectural scale of analysis. The change in hotel beds is expressed by the ratio of the number of hotel beds for the year 1990 to the number of hotel beds for the year of 2000 in each prefecture. Data for this variable come from NSSG (1999; 2004b). Modern tourism infrastructure results in profound changes to the landscape especially on the coastal and insular locations. We expect that large changes in tourism hotel infrastructure would have a detrimental effect on forests.

3.3 Data description

The normal probability Q-Q plot shows a relative medium fit to the normal distribution. We can see that the large observed values climb above the predicted normal line indicating that the tail towards large values is much longer than it would be if the distribution were normal. The detrended normal Q-Q plot depicts the differences between the observed and the predicted values. When the distribution of the values of the dependent variable is normal then the values of the difference between observed and predicted fall randomly about the zero line. This is not the case here. There are groups of values far above and below the zero line. Therefore, the distribution is not symmetric.

Figure 2: Normal Q-Q plot and Detrended Normal Q-Q plot of Forest Land Use Changes for the period from 1990 to 2000

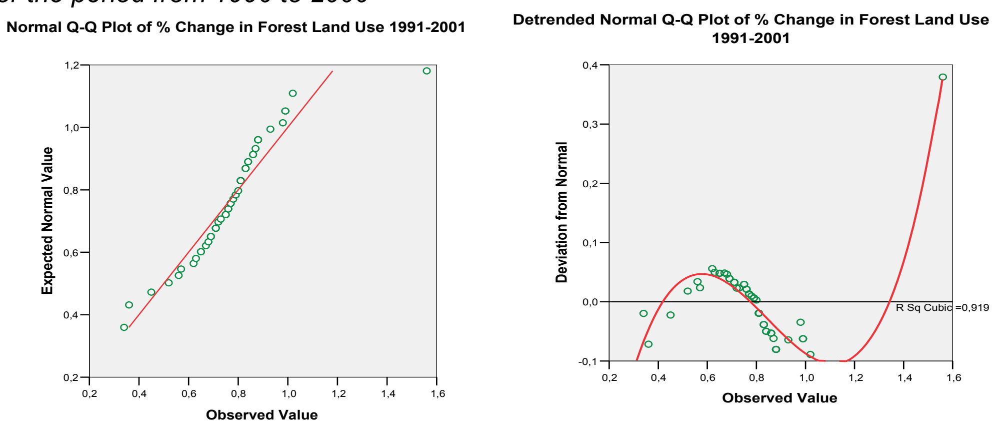


Figure 3: Stem-and-Leaf plot and Box-plot of the values of Forest Land Use Change

% Change in forest land use between 1990 – 2000: Stem-and-Leaf Plot

```
Frequency    Stem &  Leaf

    3.00 Extremes    (=<0.45)
    3.00         5 .  267
    8.00         6 .  23557899
   14.00         7 .  11123556677899
   17.00         8 .  01111113344667888
    4.00         9 .  3899
    1.00        10 .  2
    1.00 Extremes    (>=1.56)

 Stem width:       0.10
 Each leaf:        1 case(s)
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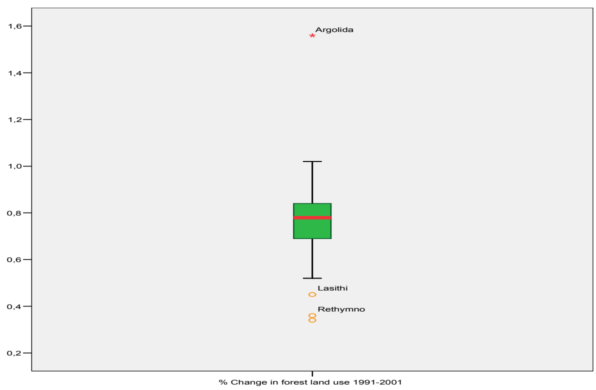
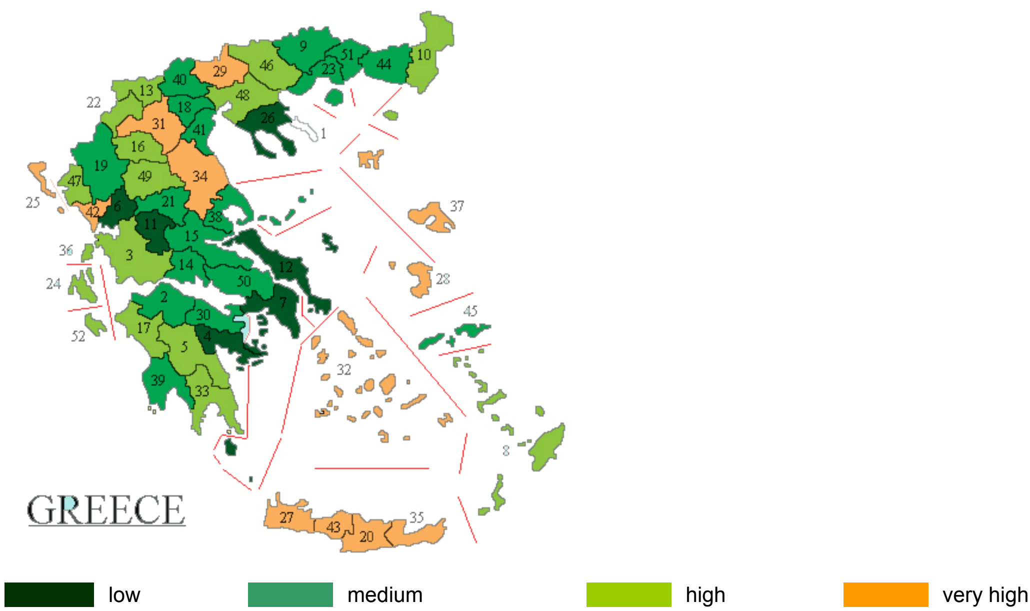


As the plots indicate the distribution is skewed to the right having a tail towards larger values. In addition, both the stem-and-leaf-plot and the box-plot indicate that there are also extreme cases to the left side of the distribution. In addition, some changes may have a positive sign. The prefecture of Argolida seems to be a positive extreme case. In the stem-and-leaf-plot we can seen that there are 3 outliers lying below 0.45. Bearing in mind all this information, we choose to construct 4 classes of prefectures according to the rate of “forest land use change”. The first class represents the prefectures with positive or slightly low rate of forest land use change. The second class encompasses the prefectures with medium rates of deforestation, the third the prefectures with relatively high rates and the last the remaining prefectures of very high deforestation rates. The cut points of the categories are presented in table 2.

Figure 3 presents the spatial distribution of the rate of forest-land change in Greece in NUT III administrative level. As we can see, the five prefectures that show the highest rate of depletion of their forest resources are all insular. The island of Crete seems to suffer most.

Figure 4: Spatial distribution of deforestation rates in Greece

% Change in forest land use 1990-2000



	Prefecture Name	Value
The 5 case with the lowest decrease or even with increase in their forest area	Argolida	1.56
	Evritania	1.02
	Attiki	0.99
	Chalkidiki	0.99
	Evia	0.98
The 5 cases with the higher diminution in their forest land	Irakleio	0.34
	Rethymno	0.36
	Lasithi	0.45
	Chios	0.52
	Lesvos	0.56

NUTS III ADMINISTRATIVE DIVISIONS (PREFECTURES)							
1	Agion Oros*	14	Fokida	27	Chania	40	Pella
2	Achaia	15	Fthiotida	28	Chios	41	Pieria
3	Aitoloakarnani	16	Grevena	29	Kilkis	42	Preveza
4	Argolida	17	Ilia	30	Korinthia	43	Rethimno
5	Arkadia	18	Imathia	31	Kozani	44	Rodopi
6	Arta	19	Ioannina	32	Kyklades	45	Samos
7	Attiki	20	Irakleio	33	Lakonia	46	Serres
8	Dodekanisos	21	Karditsa	34	Larisa	47	Thesprotia
9	Drama	22	Kastoria	35	Lasithi	48	Thessaloniki
10	Evros	23	Kavala	36	Lefkada	49	Trikala
11	Evrytania	24	Kefallinia	37	Lesvos	50	Viotia
12	Evia	25	Kerkyra	38	Magnisia	51	Xanthi
13	Florina	26	Chalkidiki	39	Messinia	52	Zakinthos
*This area was not included in the analysis							

3.4 Model Description

The relationships between deforestation and its driving factors are evaluated using ordinal regression. This methodology has not been used as often as polychotomous logistic regression or other types of multivariate statistical models in land use studies. However, there are some relevant applications in the international literature that have proven useful in understanding certain aspects of land use change processes. A relative application has been conducted by Fu et al. (2006) in order to evaluate changes in agricultural landscape pattern between 1980 and 2000 in the Loess hilly region of Ansai County, China . A second application was made by Rutherford et al. (2007). They applied multinomial and ordinal regression models in the investigation of patterns of successional change after agricultural land abandonment in Switzerland.

Ordinal regression can take into consideration and introduce into the calculations some of that extra information in the ordinal scale of the response variable (Norusis 2004). Therefore, the methodology can be used to analyse the degree of change of a particular land-use (low, medium or high change) when it is not possible to capture this by a continuous variable or proxy. There are five different link functions that can be used in the construction of an ordinal model depending on the distribution of values of the response variable cumulative probability (Norusis 2004; SPSS Inc 2006). We use the *negative log-log link* because the escalation the cumulative probability increases from 0 fairly rapidly and then slowly approaches 1 (see figure 2 and table 3). The *negative log-log* link takes the form $-\ln\left(-\ln\left(\gamma_{ij}\right)\right)$.The ordinal regression model instead of considering the probability of an individual event occurring, it estimates the probability of that event and all events that are ordered before it (cumulative probability). The general model for ordinal logistic regression is:

$$link\left(\gamma_{ij}\right) = \alpha_j - \sum_{n=1}^{k} \beta_k X_k \text{ where } \gamma_{ij} = \Pr ob\left(Y \leq j \mid x_i\right) = \sum_{l=1}^{j} \pi_{il} \quad (4)$$

where,

link (γ_{ij})	=	The abovementioned *negative log-log* link. The index *j* refers to the subcategory within the land-use type of investigation (e.g. *low* deforestation, *medium* deforestation, *high* deforestation, *very high* deforestation).
Y	=	The response variable, which takes integer values from 1 to *J*.
γ_{ij}	=	The cumulative response probability up to and including *Y=j* at subpopulation *i*.
X_k	=	The *k* predictor variables associated with the changes in the dependent variable.
α_j	=	The intercept of the regression equation or *threshold* for each cumulative probability. The index *j* refers to the subcategory within its land-use type.
β_k	=	The coefficients of the predictor variables or the *locations* of the model. The threshold α_j and the regression coefficient β_k are unknown parameters to be estimated by means of the maximum likelihood method.
Π_{ij}	=	The cell probability corresponding to *Y=j* at subpopulation *i*.

However, there is a strict assumption that has to be made when using ordinal regression model, the *parallel lines assumption*. That is to say, the regression coefficients are equal for all corresponding outcome categories. Therefore, it is extremely important to carry out the test of parallel lines and if the assumption fails, the multinomial logistic regression model can be used as an alternative model. The test of parallel line compares the estimated model with a single set of coefficients for all categories to a model with a separate set of coefficients for each category.

In the present study the event of deforestation has been defined as following:

$$\omega_1 = -\log\left[-\log\left[prob\left(deforestat\ ion \leq low\right)\right]\right] \quad (5)$$

$$\omega_2 = -\log\left[-\log\left[prob\left(deforestat\ ion \leq medium\right)\right]\right] \quad (6)$$

$$\omega_3 = -\log\left[-\log\left[prob\left(deforesttion \leq high\right)\right]\right] \quad (7)$$

Having chosen the negative log-log link the equation is written as following:

$$-\log\left(-\log\left(\gamma_{ij}\right)\right) = \alpha_j - \sum_{n=1}^{k} \beta_k X_k \quad (8)$$

3.5 Model fitting information

Some summary statistics of the model are presented in table 3. In particular, it can be seen the coding scheme and the selected cut-points, the number of prefectures that fall into each individual category of forest land use change and finally, the marginal and cumulative percentages.

Table 3: Summary statistics

	Codes	Intervals & Cut-points	N	Marginal Percentage	Cumulative Percent
Forest Land Use Change 1991-2001 (Banded)	1= Very High	≤ 0.68	12	23.5%	23.5%
	2=High	0.69 - 0.79	16	31.4%	54.9%
	3=Medium	0.80 - 0.89	17	33.3%	88.2%
	4= Low	0.90+	6	11.8%	100%
Valid			51	100.0%	---
Missing			0	---	---
Total			51	---	---

Table 4 present the test of parallelism namely the assumption that the regression coefficients are the same for all four categories of forest land use change. The assumption of parallelism cannot be rejected because the level of statistical significance for the general model is 0.808. Therefore, we sustain the null hypothesis that the location parameters are the same across the response categories.

Table 4: Test of Parallel Lines[(c)]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	103.471	---	---	---
General	85.566(a)	17.905(b)	24	0.808

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. The log-likelihood value cannot be further increased after maximum number of step-halving.
b. The Chi-Square statistic is computed based on the log-likelihood value of the last iteration of the general model. Validity of the test is uncertain.
c. Link function: Negative Log-log.

Table 5 presents the Goodness-of-Fit Pearson and Devience measures. The observed significance levels are large meaning that the null hypothesis that the model fits cannot be rejected. However, we should not rely on these measures because the number of empty cells in the model is very large due to the use of several continues dependent variables (there was a warning that 153 or 75.0% cells with zero frequencies). As regards the overall-model test of the null hypothesis that the location coefficients for all of the predictor variables in the model are zero, it yields a significance level of 0.002. Therefore, that the intercept-only model does not perform better than the model with the predictors. This is an important test because the change in the likelihood function has a chi-square distribution even when there are cells with small observed and predicted counts (Norusis 2004). Finally, the pseudo-R^2 measures the success of the model in explaining the variations in the data which is an indication of the strength of association between the dependent and the independent variables. The pseudo R^2 for McFadden (0.233), Cox and Snell (0.460), and Nagelkerke (0.495) can be considered satisfactory as the values of the ordinal regression measures are almost always much smaller than the corresponding ones for a linear model (Norusis 2005). Therefore, the interpretation of pseudo R^2 needs to be careful.

Table 5: Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.	
Intercept Only	134.855	---	---	---	
Final	103.471	31.385	12	0.002	
	Pseudo R-Square	**Goodness-of-Fit**			
Cox and Snell	0.460		**Chi-Square**	**df**	**Sig.**
Nagelkerke	0.495	**Pearson**	132.265	138	0.622
McFadden	0.233	**Deviance**	103.471	138	0.988

Link function: Negative Log-log.

3.6 Estimation Results and Discussion

The estimates in table 6 indicate that population-related variables and indicators of economic activity had a strong influence on forest resources during the '90s in Greece thought the unfoldment of the particular relationships has created a highly complex pattern. The regression coefficient for "*Urban Sprawl" (X_1)* appears to have a negative sign; however, the level of statistical significance is not satisfactory indicating that, at least in the current model, urban sprawl does not appear to be strongly related to deforestation. The negative sign in the relationship seems logical as long as an increase in urban sprawl can result either directly to the decrease of forest land due to encroachment of such areas for building housing units or through the deterioration of natural environment due to wildfires or other detrimental acts. Urban sprawl, usually, increases land values and population density creating the necessary conditions for forest land use conversion and modification. Nevertheless, we cannot conclude safely about the actual influence of urban sprawl on the deforestation rate in the regional level of analysis.

On the other hand, the variable representing *"Change in Rural Population"(X_2)* appears to be positively related to the rate of change in forest land uses. The observed significance level is 0.013. These results lead to the conclusion that the growth in population of the numerous small and medium size settlements in Greece does not poses serious problems on the conservation of forest resources. It is worth mentioning that the non-urban population is defined by the NSSG as those people who live in settlement of less than 10.000 individuals. The density of buildings within these settlements is usually low, and also there is sufficient space for meet future demand for housing. Furthermore, the prices of developable land are relatively medium or even low. Therefore, any demand for housing due to population increase can be satisfied within the approved boundaries set by the town plan. In such cases, there are not intense pressures on forest land stock.

The coefficient of *IPP (X_3)* has a positive sign; however it is not significantly different from 0 indicating that this variable is not strongly related the observed changes in forest land uses during the study period. At least for the current model, the accessibility of each prefecture to the rest of the prefectures does not seem to be an important causal factor of deforestation. Therefore, the observed changes in forest land uses in each location are not generated by people who live and work away from that location. As regards *TPP (X_4)*, the relevant coefficient has a positive sign and the observed significance level is less than 0.05 indicating a statistically significant relationship. Therefore, during the study period the prefectures that increased there population potential did not have their forest resources negatively impacted. Contrarily, they had them reinforced. Hence, the demand for new urban space was met either by using undeveloped urban land or by converting agricultural land into urban. This conclusion coincides with the outcome of a multinomial logistic model by Minetos and Polyzos

(2007) on the influence of population potential on agricultural land use changes in Greece for the same studying period.

Table 6: Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold								
$\omega_1 \rightarrow$	Forest Land Use Change (n= 1)	3.409	2.915	1.368	1	0.242	-2.304	9.123
$\omega_2 \rightarrow$	Forest Land Use Change (n= 2)	4.733	2.955	2.566	1	0.109	-1.058	10.525
$\omega_3 \rightarrow$	Forest Land Use Change (n= 3)	6.711	3.031	4.903	1	0.027	0.771	12.652
Location								
X_1	Urban Sprawl	-0.059	0.100	0.346	1	0.557	-0.256	0.138
X_2	Change in Rural Population	6.808	2.729	6.224	1	0.013	1.460	12.157
X_3	Indirect Population Potential	0.013	0.013	0.923	1	0.337	-0.013	0.038
X_4	Total Population Potential	0.015	0.005	8.006	1	0.005	0.005	0.026
X_5	Informal Housing Activity	-0.059	0.068	0.770	1	0.380	-0.192	0.073
X_6	Urban Plan Expansion	-0.034	0.112	0.094	1	0.759	-0.253	0.185
X_7	Legal Housing Activity	-0.061	0.045	1.867	1	0.172	-0.148	0.026
X_8	Prosperity Level	-0.081	0.045	3.217	1	0.073	-0.170	0.008
X_9	Mean GDP in Agriculture	-0.037	0.021	3.089	1	0.079	-0.077	0.004
X_{10}	Change in GDP in Agriculture	-0.587	0.410	2.051	1	0.152	-1.390	0.216
X_{11}	Geographical Zone	-0.422	0.321	1.722	1	0.189	-1.051	0.208
X_{12}	Change in Hotel Beds	1.095	0.632	2.998	1	0.083	-0.144	2.335

Link function: Negative Log-log.

"Informal Housing Activity" (X_5) has a negative coefficient although the observed level of statistical significance is not satisfactory. Therefore, at least with respect to the current model we can not draw any firm conclusions about the actual strength of influence of this particular independent variable on deforestation rate at the regional level. The negative relationship between the two variables, however, is logical and means that illegal housing activity grows in the expense of forest land. We speculate that the underlying process might be through the encroachment of forest land for building housing units or thought the deterioration of environmental quality due to wildfires and other detrimental activities which usually accompany unplanned urban development. When urban structures are sprawling into frontier forest land then the likelihood that the neighbouring inner-forest areas will become negatively affected, increases considerably.

Next, the variable *"Urban Plan Expansion" (X_6)* for the period 1995-2003 has a negative sign but the *p* value is very large (0.759) indicating that the null hypothesis of no actual relationship between this independent variable and the observed changes in forest resources cannot be rejected.

As regards the variable *Legal Housing Activity per Resident"(X_7),* because the observed significance level is 0.172 we cannot reject the null hypothesis that this particular regression coefficient is 0. Although the sign of the regression coefficient is negative indicating a counteractive relationship, the 95% confidence interval includes also some positive values. Therefore, we do not have enough evidence to conclude neither for the existence of a relationship nor for the likely character and magnitude of it.

The "*Prosperity Level"(X_8)* indicator is significantly associated with forest areas shrinking during the period of investigation. These results indicate that the increase in the prosperity level that was achieved during the '90s across the prefectures of the country was not materialised through sustainable procedures at least, as long as forest resources were concerned. This suggests that the level of benefits and sustainability of economic growth are questionable and need to be thoroughly evaluated if environmental protection is to be achieved in the future. Placing stronger emphasis on environmental and social sustainability calls for more in-depth investigation of the complex multiple-scale economic decision processes.

In order to determine any likely linkages between agricultural activity and forest losses, two variables were introduced into the analysis: (a) the "*Mean Share of Agricultural Sector" (X_9)* to the prefectural economy in terms of GDP and (b) the "C*hange in the GDP in Agricultural Sector" (X_{10})* for the period 1991-2001. The relevant coefficients of the model reveal a negative association with the dependent variable which is statistically significant at 7% confidence level as regards the variable representing the contribution of agricultural sector to the regional economy but not statistically significant as regards the change in GDP in agriculture in the period 1990-2000. These results indicate that as the importance of the agricultural sector for the local economy increases, forest resources are getting depleted. Therefore, the magnitude of the agricultural sector impacted negatively forest resources during the studying period. Negative seem to be the impacts of the change in GDP in agriculture in the same period on forest resources but the observed significance level is 0.15. This means that there is not enough evidence to reject the null hypothesis that the coefficient of the independent variable is 0. As it can be seen in table 4, the value of 0 is included in the in the 95% confidence interval for changes in GDP in agriculture. Overall, the results indicate one or both of the two following processes may be true:

a) The cultivated area of some crops increases to the expense of forest areas. It is important, therefore, to scrutinise the analysis, locate the prefectures whose forest resources are been depleted due to agricultural expansion and find the particular crops that advance on forest land.

b) The growth of livestock sector during the period of investigation has had a negative effect on forest land.

The *"Geographical Zone" (X_{11})* in which each prefecture belongs to has a negative regression coefficient indicating that in mild and high temperature regions the rate of deforestation increases. A possible explanation for the south parts of the country suffering greater losses in their forest resources is that these areas due to environmental conditions are more susceptible to forest fires. In addition, if burned, the forest ecosystems of the north of the country can recover or been restored faster than those in the south, due to environmental conditions and vegetation structure. Ecologically speaking, some forests may need no management intervention to restore forest structure. However, the observed level of statistical significance is 0.189 which is not satisfactory for forming robust conclusions about the relationship. Nevertheless, the use of a more direct variable such as the mean number of forest fires or total area burned per prefecture during the study period could have possibly yielded more satisfactory results. This is important because the magnitude of environmental, social, and economic impacts from wildfires is related to the characteristics and the size of the location of the burn.

Finally, the variable representing *“Changes in Hotel Beds”* for the period 1990-2000 is positively associated with changes in forest land use and the observed level of significance is 0.08. Although, the 95% confidence interval for the location estimate includes zero as well as some negative values due to the level of statistical significance, it can be said that in most of the cases the expansion of hotel infrastructures during the studying period did not happened to the expense of forest land uses. However, it should be stressed that the new hotel beds refer to legal construction activity that is usually materialised with urban areas or in ex-urban non-forest land. The regression location estimate suggests that there was an indirect positive relationship between new hotel infrastructure and forest areas during the study period. This might mean that when there are effective rules and the new tourism infrastructure follows these rules, forest land is been protected. An alternative explanation which may be the case in a lot of instances in Greece is that the development of tourism sector in the ’90 was materialised through the restructuring of the agricultural sector resulting in the transfer of a considerable share of workforce to tourism-related activities. Therefore, some agricultural land was abandoned and through natural vegetation succession processes became forest land. In addition, some forest-land disturbing agricultural activities such as livestock grazing were contained.

4. Conclusions

This paper has dealt with the likely factors of forest land use changes in Greece for the period from 1990 to 2000. Making informed forest policy decisions is central to achieving sustainability at a regional level. Prior to formulating certain sustainable policy objectives and targets, the baseline information which is needed is the kind of driving forces that influence current forest land use patterns. Generally speaking, these driving forces are closely associated with the economic, social and environmental context within which the regions exist and function. The effects on forest land of the predictor variables that where employed by this study, while significant in most regions are still covered with many uncertainties. Some theoretically interesting explanatory variables have indicated that the effects of certain processes on land use changes may be important but not always straightforward.

Certain demographic indicators and economic processes seem to affect forest land uses through fuzzy pathways that while identified by this study need also to be looked at in more detail and possibly at a lower level of analysis. Downscaling of land use change investigation can scrutinise and examine more thoroughly with critical attention the patterns of associations among the variables. There is extensive literature on the importance of the effects of scale to spatial analysis. Some research have even suggested that it is not necessary the relationships that exist at an aggregated level to exist at a lower level of analysis (Robinson 1950).

The influence of each driving factor on the forest land use changes are evaluated by using ordinal regression, a methodology that has not been used as often as polychotomous logistic regression or other types of multivariate statistical models in land use studies. Effective methodologies for assessing sustainability of land use planning and investment allocation decisions on a regional scale are vital. This methodology has demonstrated that can cope with low quality land use change data and this is an advantage. The results of the statistical analysis suggest that forest land uses are negatively influenced by changes in legal building activity, agricultural economic sector, urban sprawl, illegal housing activity, regional prosperity level, urban plan expansion, and geographical zone. However, the negative relationship is statistically significant only with the regional prosperity level and the mean GDP in agriculture. On the other hand, forest land uses are positively influenced by rural population, population potential and regional tourism activity.

These results could guide further research for improving understanding on spatial processes such as forest land use changes and for rationalizing forest-related decision making. Strategic project monitoring and appraisal as well as evaluation of project impacts on land uses can help land planners and land use decision-makers to introduce specific environmental protection objectives into land development and planning processes.

Acknowledgements

Dionysios Minetos is a PhD Candidate at the University of Thessaly, Department of Planning and Regional Development, receiving a scholarship by the Greek State Scholarships Foundation.

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