Ross Natural History Reservation: Six decades of changing land cover and management documented by aerial photography

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The Ross Natural History Reservation (RNHR) of Emporia State University includes grassland, aquatic sites, wooded tracts, and a central building compound. Changes in land cover are documented for the period 1945 to 2006 based on large-format and small-format aerial photography. These changes are related to regional landscape evolution and management practices at RNHR. From the 1940s until about 1990, woodland increased substantially at RNHR. However, the past 15 years have witnessed a decrease in woodland at RNHR, primarily because of systematic annual burning. Other land-cover changes include construction of ponds as well as several teaching, maintenance, and living buildings on the reservation. The combination of spatial and temporal scales inherent in large- and small-format aerial photography enhanced the interpretation of landscape change at RNHR.

Keywords: landscape change, aerial photography, prairie fire, woodland, Flint Hills, Kansas.

INTRODUCTION

The Ross Natural History Reservation (RNHR) of Emporia State University (ESU) consists of 200 acres (~80 ha) in the Flint Hills upland in western Lyon County, Kansas (Fig. 1). The major habitats include grassland, aquatic sites, and wooded tracts (Finck 1990). The grassland category can be subdivided into native-grass prairie and abandoned croplands. The major aquatic habitat is Gladfelter Pond, a 2½-acre (1-ha) farm pond that predates establishment of the natural area.

The goal of our investigation is to document through the use of aerial photography changes in land cover, particularly woody vegetation and human structures, and to relate these changes to RNHR management practices. Conventional, medium-resolution, large-format, archival airphotos are employed for the period 1945 to 2002, and we acquired high-resolution, small-format aerial photography of selected portions of RNHR beginning in 1997 to present. The aerial photographs are combined with historical accounts of land management practices to evaluate the impact of those practices on land-cover conditions.

ROSS NATURAL HISTORY RESERVATION

The F. B. and Rena G. Ross Natural History Reservation (RNHR), created on November 17, 1958, is a 200-acre tract of land located in west-central Lyon County, approximately four miles (6.4 km) west of Americus, or 14 miles (22.5 km) northwest of Emporia (Figs. 1, 2, and 3). Through a land donation, F. B. and Rena G. Ross made the area available to Emporia State University for use by faculty and students of the Department of Biological Sciences, with the understanding that the reservation would provide an area for research and field study, aid in the teaching of biological sciences, and enable a segment of the tallgrass prairie ecosystem to be preserved (Hartman 1960).

Early survey notes made in 1856 and 1857 described the surroundings of RNHR as rolling prairie with a considerable amount of good farming land (Breukelman, Eddy, and Hartman 1961). Some sections were said to be too uneven and stony for cultivation. In the late 19th century, the natural value of native grass cover was considered minimal. Streams

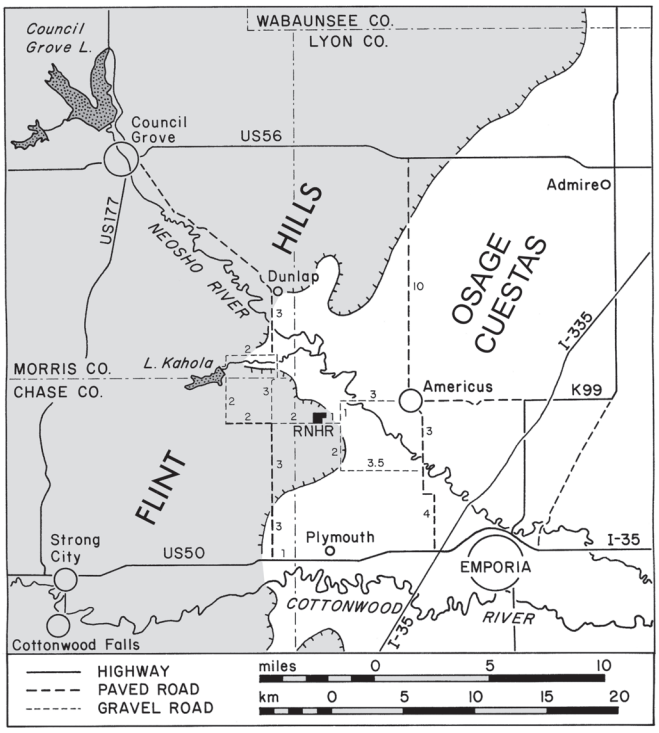

Figure 1. Map showing location of Ross Natural History Reservation (RNHR) in Lyon County and other features in east-central Kansas. Black box for RNHR represents the 200-acre tract owned by Emporia State University. RNHR is located at the easternmost edge of the Flints Hills (shaded gray). Road distances given in miles. Adapted from Aber and Finck (1990).

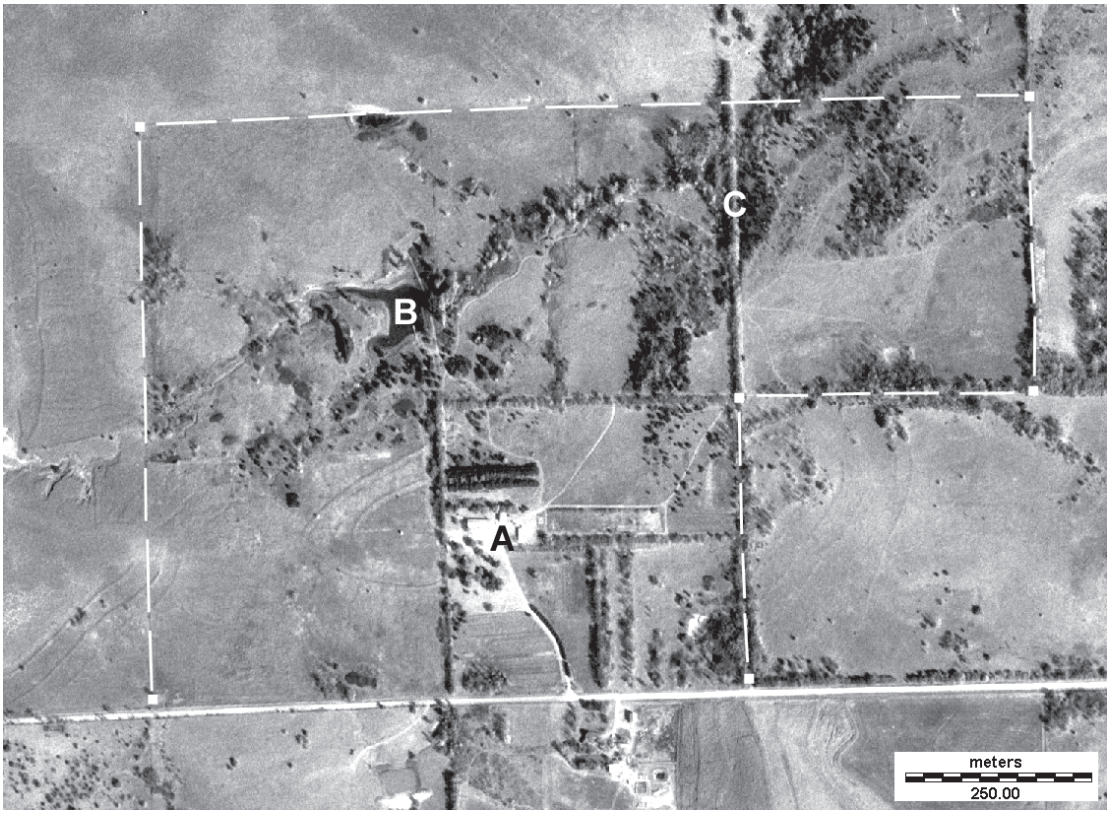

Figure 2. Digital orthophotograph of RNHR obtained from DASC at the Kansas Geological Survey. The original aerial photograph was taken on Oct. 14, 1991. White dashed lines indicate boundaries of the reservation. A = central building complex, B = Gladfelter Pond, C = abandoned county road.

Figure 3. Panoramic view toward the northeast over the northern portion of RNHR. Gladfelter Pond in lower left portion; boundaries of RNHR marked with small red dots. Kite aerial photograph, October 2006.

and springs were numerous and furnished adequate water supplies, and wells averaged from 15 to 40 feet deep, indicating a generally high level of ground water. Therefore, timber belts, consisting of cottonwood, hackberry, walnut, oak, hickory, mulberry, Kentucky coffee-tree, elm, locust, and sycamore, were planted along the water courses. Orchards reportedly were established and flourishing; these included peach, apple, pear, cherry, and other small fruits (Breukelman, Eddy, and Hartman 1961).

RNHR now comprises grassland, woodland, aquatic sites, an abandoned homestead, remains of a closed county road, and modern buildings erected for teaching, maintenance, living, and storage purposes. The area is underlain by lower Permian shale and limestone of the Council Grove Group, including the Neva and Cottonwood limestones that form stonelines on the hill sides (O'Conner 1953). A small perennial spring exists in the Neva Limestone. The grassland sites can be separated into native tracts and abandoned croplands (Spencer 1980; Finck 1990). Native grass tracts have been grazed but never plowed; these are dominated by big bluestem (*Andropogon gerardi*), Indian grass (*Sorghastrum nutans*), switch grass (*Panicum virgatum*), little bluestem (*A. scoparius*), and native forbs. The abandoned cropland has been reseeded to legumes and non-native, cool-season grasses, especially brome grass (*Bromus inermis*) and Korean lespedeza (*Lespedeza stipulacea*).

Stream courses include willow and slough grass (*Spartina pectinata*), and the spring has spike rush (*Eleocharis obtusa*) and water cress (*Rorippa Nasturtium-aquaticum*). American lotus (*Nelumbo lutea*) thrives in parts of Gladfelter Pond. The pond was constructed in June 1958, and the dam and spillway bank were seeded with Bermuda grass. Several other smaller man-made ponds also are located on the reservation.

Management practices on RNHR reflect the history of wildlife management in North America (Finck 1990). During the early-to-mid-1960s, the area was fenced to prevent grazing, and prairie burning was not allowed (Spencer 1988). This policy led to an increase in woody vegetation (brush and trees). In the late 1960s, the strategy switched to management for wildlife with a major emphasis on game species. Growth of trees was controlled through burning and cutting, and limited grazing was allowed. Trees were planted to enhance wildlife habitat, but were not allowed to invade prairie sites. In spite of this approach, brush and trees continued to increase during the 1970s and early 1980s, especially in the eastern portion.

A change in management philosophy took place in the late 1980s toward a more holistic approach (Finck 1990). At this time, the expansion of woodland was recognized as a threat to the native tallgrass prairie of the Flint Hills. Of particular concern was proliferation of eastern red cedar (*Juniperus virginiana*), which is invading eastern Kansas and had become quite abundant at RNHR. Similar expansion of woodland is taking place in fields throughout eastern Kansas, wherever there is overgrazing or suppression of fire (Applegate, Flock, and Finck 2003; Peterson et al. 2004). In order to conserve the tallgrass prairie and reduce brush and trees, systematic controlled burning was instituted at RNHR in the late 1980s. Aside from the central building compound, one-third of the reservation is burned each year, usually in early April, on a three-year rotation schedule in order to maintain a diversity of habitats. Some portions are burned more frequently, and selected trees are cut to accelerate the reestablishment of prairie vegetation.

During the late 1990s and the early 21st century, renewed emphasis was given to infrastructure improvements at RNHR. New buildings were erected, an improved septic pond and rural water supply were installed, a new entry gate was constructed, some older structures were removed, and other renovations were made. All these efforts created an effective learning and research setting for ESU students and faculty as well as visiting students and researchers from other colleges and governmental agencies.

Use of fire as a management technique

Spring burning of the tallgrass prairie is a ritual in the Flint Hills of east-central Kansas. The practice begun by early cattle ranchers follows still-older Indian tradition, in which spring burning promoted the growth of new grass to sustain the buffalo. Long misunderstood or opposed by the public, prairie fire is now recognized as an important, natural management tool for maintaining the grassland environment (Hoy 1993). Controlled prairie burning has several important benefits.

- Old, dead grass is removed, which allows rapid growth of new grass for cattle grazing.
- Nutrients in the old grass are returned to the soil as ashes to fertilize new growth.
- Woody brush and trees are inhibited from spreading into prairie grassland.

In fact, the tallgrass prairie would not exist without occasional fire to prevent the spread of trees and woody brush in the relatively humid climate of eastern Kansas (Fitch, Von Achen, and Echelle 2001). Burning normally takes place in early spring, from about mid-March to early May. The optimum time is considered to be the first week of April, which is the target date for burning at RNHR. Earlier burning brings on green grass sooner, but has less effect on woody vegetation; later burning is an effective way to reduce woody vegetation. Some ranchers burn their grassland every year, but most skip a year of burning once in a while. The latter has proven to support greater diversity of grass and herbaceous plants.

However, a pasture must be burned at least once every three to seven years to prevent trees and brush from becoming established. A poorly managed prairie is evidenced by numerous small cedars and thickets of sumac or dogwood.

Burning techniques have become fairly sophisticated in recent years. A controlled burn usually involves a large number of people, often with neighboring landowners cooperating, to set and contain fires in desired tracts of prairie. Weather is a key factor. Favorable conditions include light-to-moderate wind, clear and dry air, and previous rain to wet the soil. When such conditions exist, fires may be seen in all parts of the Flint Hills, both day and night. However, the spring weather some years is too dry, or wet, or windy, so little burning takes place. Given these vagaries of weather, burning at RNHR may not take place every year. When burning is missed one year, an attempt is made the following year to "catch up" by burning two-thirds of the reservation. In this manner, the three-year burning scheme is maintained overall.

Aerial photography methodology

The primary documentary source consists of conventional, large-format aerial photographs of the type taken routinely by federal and state governmental agencies for various survey purposes. Such photographs are vertical views acquired with large cameras on 9-inch (23-cm) panchromatic (gray-tone) film. Such photographs typically have a ground resolution of 1-2 meters. On the National Imagery Interpretability Rating Scale, conventional airphotos usually have interpretability ratings of 4 or 5, depending on quality of the original image (Leachtenauer, Daniel, and Vogl 1997). The rating number depends on the most difficult interpretation task that can be performed, which indicates the level of interpretability that can be achieved. The following are examples of ratings in the 4-5 range: detect jeep trails through grassland, detect large animals (cattle) in grassland, and distinguish between stands of deciduous and coniferous forest during leaf-off season.

We obtained conventional airphotos in digital format for the years 1945, 1959, 1980, 1991, and 2002. Judging from tree foliage and shadows, all these were acquired during the growing season. The image datasets were imported into *ArcView* software for processing. Images from 1945, 1959, and 1980 were registered and rectified based on ground survey points. The images for 1991 and 2002 were supplied as digital orthophoto quadrangles (DOQs), which are already registered and rectified for release to the public (see Fig. 2). On the images, areas of forest (heavily wooded) and open water were interpreted visually, and polygon boundaries were digitized manually for each feature. This process was necessarily subjective, and results vary somewhat depending on quality of original images. The older airphotos (1945, 1959, 1980) suffer from reduced image quality compared with the newer DOQ images. For example, the 1980 airphoto has an interpretability rating of only 3, whereas DOQ images have ratings of 5. Surface areas were summed for woodland and water on each image, and area values were rounded to whole hectares, based on uncertainty derived from variations in image quality and visual interpretation.

Small-format aerial photography (SFAP) represents a secondary source for interpreting landscape details. Since 1997 we have acquired SFAP annually for selected portions of RNHR (Fig. 3). SFAP is based on 35- and 70-mm film cameras or compact digital cameras to acquire airphotos from manned or unmanned platforms (Warner, Graham, and Read 1996). SFAP has become widely employed in recent years for documenting all manner of natural and human resources (Bauer et al. 1997).

We have developed unmanned SFAP techniques based on kites (Aber et al. 1999) and a small helium blimp (Aber 2004) for lifting various types of film and digital cameras. Photographs are taken from 100-500 feet (30-150 m) above the ground using radio-controlled camera rigs (Fig. 4). The camera may be tilted (vertical to horizontal) and rotated (360°) in order to provide all possible viewing angles in relation to the ground target. Resolution of vertical SFAP is typically 5-10 cm, which yields interpretability ratings of 7 or 8. Examples of interpretation at this level include: detect stumps and rocks in forest clearings or meadows, identify a survey benchmark set in a paved surface, and recognize individual water lilies on a pond (Leachtenauer, Daniel and Vogl 1997).

Figure 4. Small-format aerial photography camera rig for use with a kite or blimp. Seven megapixel *Canon S70* digital camera is operated in a fast-shutter mode to minimize motion effects. Titanium frame holds servos for tilting (T) and panning (P), and a microservo on the aluminium craddle triggers the shutter button (S). Servos are controlled via radio signals from the ground.

Results

Processed conventional airphotos for the years 1945, 1959, 1980, 1991, and 2002 are presented in Figures 5-9, and statistical data for woodland cover are given in Table 1. These images demonstrate substantial changes in land cover, particularly woodland and water bodies, during more than half a century. In 1945, woodland within what would become RNHR amounted to only 5 hectares and was found primarily along field boundaries in the form of hedge rows and in the northeastern sector (Fig. 5). Small clumps of trees were located just south of the homestead and in other portions of the future reservation. No water bodies are visible. Row cropping is evident in the southwestern portion, where terraces can be seen in the field. The northwestern portion appears to be pasture grassland.

By 1959, substantial changes are depicted, including Gladfelter Pond and a second smaller pond along the northern

Table 1. Area of RNHR woodland coverage in hectares and percentage change (+/-) from prior condition. Based on visual interpretation of conventional, medium-scale aerial photographs. Note one hectare is ~2½ acres.

Year	Woodland	Change
1945	5	---
1959	8	+60%
1980	19	+138%
1991	21	+16%
2002	17	-19%

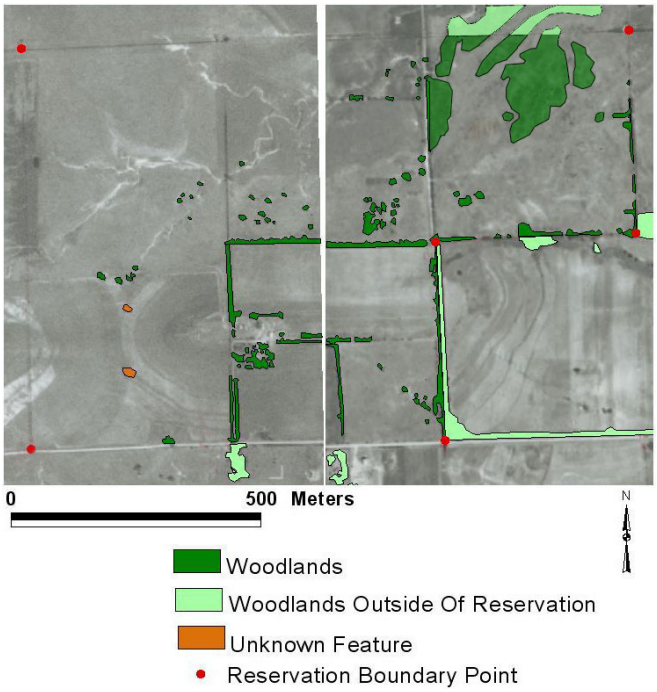

Figure 5. Interpreted conventional airphotos of RNHR showing woodland coverage within and outside the reservation for 1945.

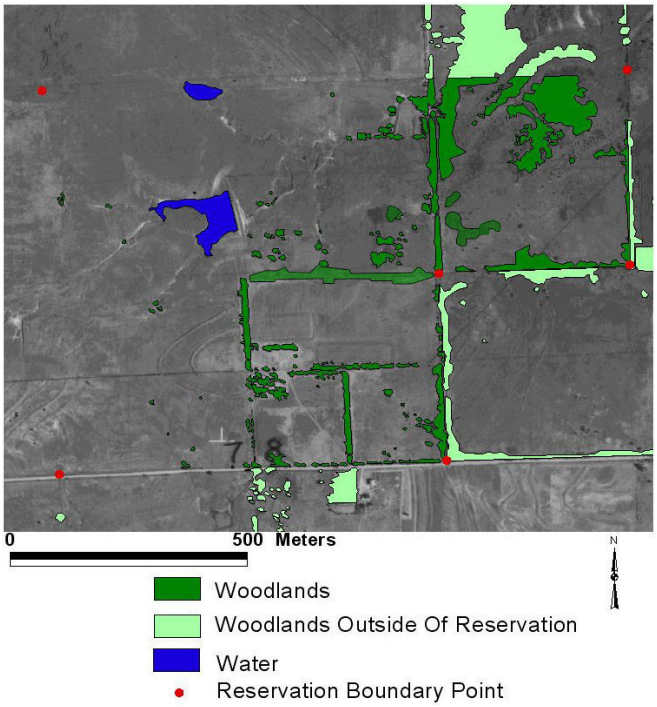

Figure 6. Interpreted conventional airphoto of RNHR showing woodland coverage within and outside the reservation and water bodies for 1959.

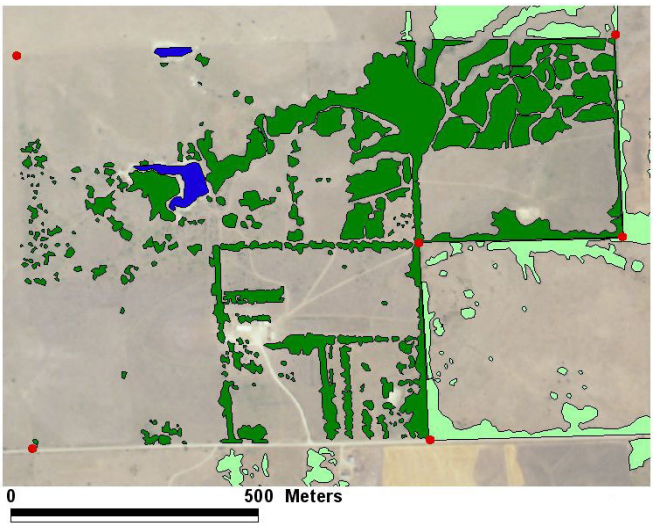

Figure 7. Interpreted conventional airphoto of RNHR showing woodland coverage within and outside the reservation and water bodies for 1980. For symbols see Fig. 6.

boundary of the newly created RNHR (Fig. 6). Woodland coverage had grown to 8 hectares, an increase of 60% from 1945. Row cropping had ended in the southwestern portion, although the terrace system is still quite visible. Little change is evident in the northwestern prairie portion. A couple of new trails led toward the central building complex from the southeast and northeast.

The decades of the 1960s and 1970s represent the greatest amount of change in land-cover conditions (Fig. 7). By 1980, woodland had expanded dramatically to cover 19 hectares, an increase of 138% since 1959 and a nearly four-fold increase since 1945. This growth took place in the northeastern and north-central portions, extended westward upstream from Gladfelter Pond, and also impacted the southeastern sector. A couple of new small pond basins are evident in the northeastern and southeastern portions, but they were apparently dry at the time of this image, so are not identified as water bodies. The southwestern and northwestern portions of the reservation show relatively homogeneous prairie characteristics. In spite of the poor quality of this image. New buildings are evident in the central compound as well as is a network of trails leading away from the buildings.

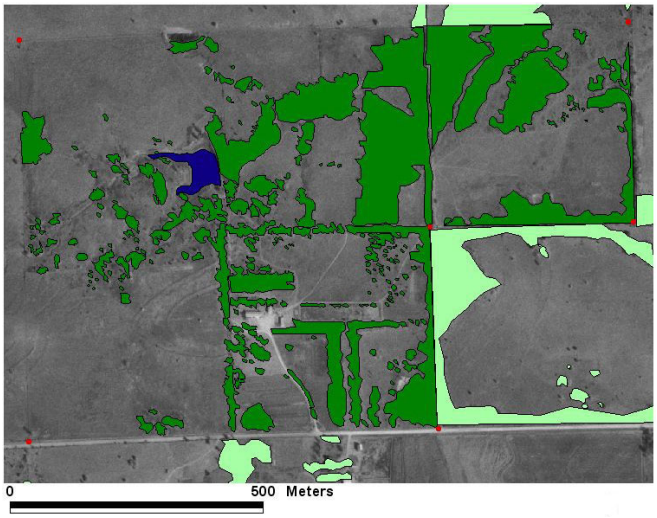

Figure 8. Interpreted conventional airphoto of RNHR showing woodland coverage within and outside the reservation and water bodies for 1991. For symbols see Fig. 6.

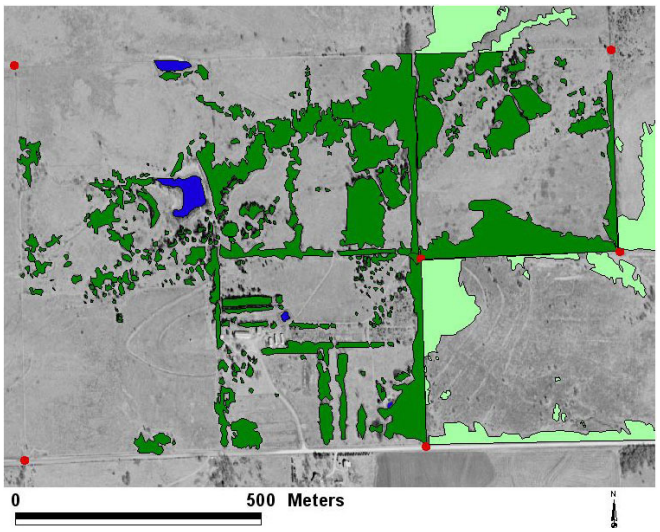

Figure 9. Interpreted conventional airphoto of RNHR showing woodland coverage within and outside the reservation and water bodies for 2002. For symbols see Fig. 6.

Figure 10. Oblique view toward northeast over the central building complex taken in November 1998 after deciduous trees had dropped leaves. A - main classroom and office building, B - maintenance barn, C - living quarters, and D - older buildings. Several other smaller sheds and structures are visible. Note cedar trees (dark green) in several portions of this view.

Figure 11. Oblique view toward southeast over the central building complex taken in October 2001 as deciduous trees were beginning to turn color. New structures: A - sewage pond, B - two living quarters and tornado shelter, and C - carport. A couple older structures had been removed. Kite flyers standing in lower right corner.

Most of the features noted in 1980 are still present in the 1991 image (Fig. 8). Woodland continued to expand, albeit at a slower pace, to 21 hectares, an increase of 16% since 1980. Other features remained relatively constant, and the old agricultural terraces are still evident within the restored prairie in the southwestern sector. In the most recent image from 2002, a noticeable decline in woodland is evident (Fig. 9). Woodland covered only 17 hectares, a decrease of 19% since 1991, and coverage was slightly less than in 1980. This retreat of woodland took place throughout most portions of RNHR; in most cases, woodland is replaced by grassland in a patchy mosaic. One of the small ponds in the southeastern corner of the reservation held water at the time of this image. Other significant changes are noted in the central building complex, including new structures and a sewage pond.

SFAP was employed for documenting the impact of fire at RNHR, the nature of water bodies, and structural changes in the central building compound during the period 1997 to 2006. Changes in the central building complex are among the most obvious (Figs. 10 and 11). Several new buildings were erected, a couple older ones were demolished, and a sewage pond was constructed at the northeastern corner of the building complex. Gladfelter Pond was photographed repeatedly, and images of smaller ponds were acquired occasionally (Figs. 12, 13, 14). Drought impact on water level is apparent, and seasonal and interannual changes in

Figure 12. Oblique view of Gladfelter Pond looking toward the north. Two intermittent streams feed into the arms of the pond from the west (left), and water level is full. A smaller pond is situated to the north on the boundary of RNHR. Image date October 2005.

Figure 13. Near-vertical view over Gladfelter Pond in a drought phase with low water. The bright green aquatic plant is American lotus (*Nelumbo lutea*), which stands in shallow water and wet soil around the diminished pond. Compare with previous figure. The dock is about 50 feet (15 m) long. Image date October 2006.

Figure 14. View toward the southeastern corner of RNHR with a small pond visible. The pond contained water when this image was acquired, although it is often dry. Private farm land is visible in the background and across the road to the south (right). Image date October 2003.

Figure 15. Fire was set along the southern boundary of the western portion of RNHR, along the road and around a patch of brush and trees. The initial fire was set to burn upwind, to the northwest in this case, so it progressed slowly across the pasture. Image date April 2000.

Figure 16. The fire advanced in a nearly linear fashion across the west-central portion of RNHR. In this view, the fire had attained considerable momentum and a thick cloud of smoke approached the camera rig. Notice the shadow cast by the smoke plume. Image date April 2000.

Figure 17. Low-height view of fire effects on eastern red cedar (*Juniperus virginiana*). Healthy trees are dark green color. Those damaged recently by fire are reddish brown, and long-dead trees are merely skeletal trunks and branches. Image date August 1997.

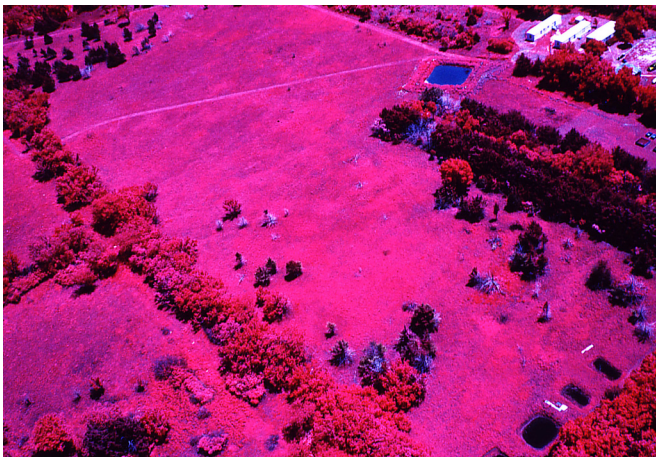

Figure 18. Color-infrared photograph of the tract immediately north of the central building complex; view toward southeast. In this type of image, photosynthetically active (green) vegetation appears in red and pink colors. Numerous dead trees are revealed by bluish gray color of bare limbs. Image acquired in late spring, June 2003.

Figure 19. View toward the south over the southwestern portion of RNHR. Two terraces loop around the hillside. These terraces date from agricultural land use in the 1940s and remain quite visible today. Kite flyers standing on left side of scene; the small hut near scene center was subsequently removed. Image date October 2001.

aquatic vegetation coverage, namely American lotus, are particularly noticeable in Gladfelter Pond.

Spring burning at RHNR was photographed in 2000 and 2001. In the normal procedure, fire is set along roads or field boundaries in order to burn slowly in the upwind direction (Fig. 15). This typically results in a wall of flames moving across the selected burn area (Fig. 16). SFAP depicts unmistakable effects of burning trees, particularly eastern red cedar (Figs. 17 and 18). Trees that are partly damaged by fire display the reddish-brown color of dead leaves, which may remain attached to limbs for some time. Dead trees eventually are reduced to a framework of bare trunks and branches. These dead trees are mostly left to weather and decay naturally and, so, persist for many years as "skeletons" in the landscape. We did not attempt to count the number of dead trees throughout RNHR; however, it is apparent that such dead trees are numerous in all wooded portions.

SFAP also highlighted long-lived man-made features that predate establishment of the reservation. Agricultural terraces remain quite distinct in the southwestern portion of RNHR (Fig. 19). Although row cropping was replaced by grass half a century ago, the structural alterations of topography and soil survive as permanent legacies in the landscape. Likewise,

Figure 20. View toward the northeast showing a mosaic of woodland and prairie vegetation. Note the grid pattern resulting from hedge rows along the abandoned county road and old field boundaries. Agricultural fields can be seen in the Neosho River valley in the far background. Image date October 2002.

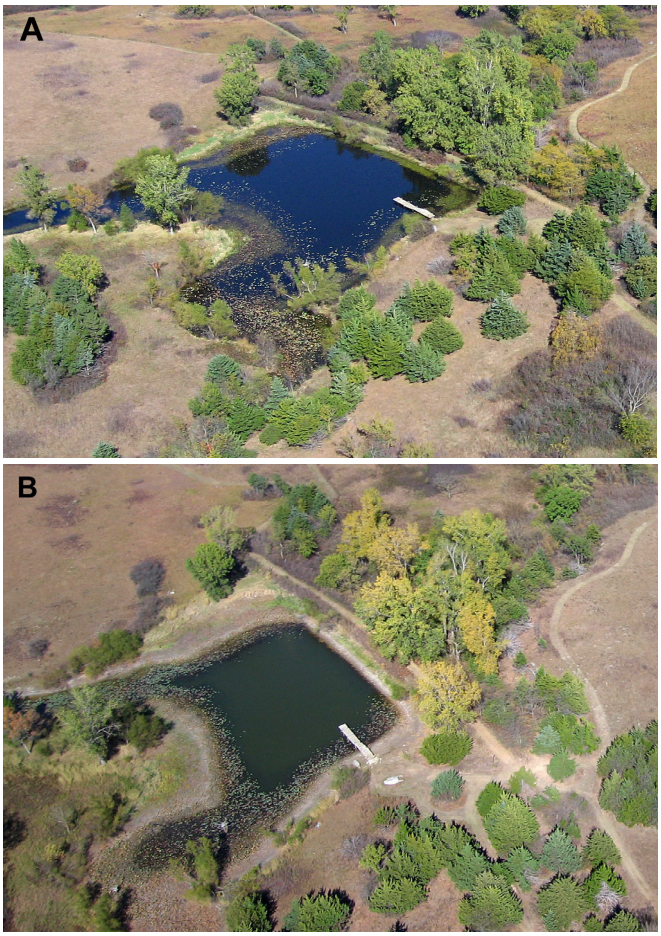

Figure 21. Comparison of autumn foliage color change. A - mid-October 2005 depicts little autumn color in trees, and pond is full of water. B - early October 2006 reveals substantial autumn color developed early in a drought year with low water in pond.

hedge rows along old field boundaries and the long-abandoned county road impose a grid pattern on RNHR overall (Fig. 20). Finally SFAP revealed interannual variations in the timing of autumn senescence of tree foliage, which normally takes place in mid-to-late October. In 2006 during a drought episode, however, autumn color appeared already in late September and was visible clearly in early October (Fig. 21).

Discussion

Throughout eastern Kansas, forest cover has increased during the past few decades because of abandonment of agriculture fields, overgrazing of pasture, and limitation of fire (Fitch, Von Achen, and Echelle 2001; Applegate, Flock, and Finck 2003). The acreage of RNHR followed a similar trend with expansion of woodland, particularly in the northeastern and north-central portions, as well as southeastern and west-central sectors. This increase in trees and brush began at least in the 1950s, while the land was still in private hands. Woodlands continued to expand rapidly during the first and second decades of RNHR, perhaps enabled by suppression of fire and planting of trees and brush for wildlife management purposes. The rate of woodland increase slowed during the decade of the 1980s, but woody vegetation still expanded at RNHR.

Beginning in the 1990s and early 21st century, woodland coverage experienced a substantial retreat at RNHR. This contrasts with the general trend across eastern Kansas, in which forest cover continues to gain (Peterson et al. 2004). Changes in woodland coverage revealed by analysis of conventional aerial photographs suggest that systematic burning begun in the late 1980s along with selected cutting of trees have been effective in reversing the expansion of woodland cover at RNHR. The character of fire damage and death, especially for eastern red cedar, is clearly displayed in large-scale images acquired with small-format aerial photography. This leads us to believe that fire is the primary cause for recent reduction of woodlands at RNHR. On this basis, it seems reasonable to forecast that continuation of the burning regime should result in additional shrinkage of woodland cover in future years.

During the 1970s two small ponds were constructed in the northeastern and southeastern portions of RNHR, both of which appeared as dry basins in the 1980 photograph. Only rarely, in fact, do aerial photographs reveal water in these pond basins. This confirms ground observations that these ponds are perennial failures both in terms of their water-holding capability as well as aquatic habitats. In contrast, Gladfelter Pond is a relatively stable water body that supports characteristic wetland vegetation.

The growth of infrastructure at RNHR took place episodically. An early phase of building construction was completed in

the 1970s, and then little change occurred until the late 1990s. A remarkable burst of improvements happened during the brief period, 1999 to 2001, as depicted in both conventional and small-format aerial photographs. Such developments reflect institutional priorities, available funding, and the individual people involved with management decisions.

The types of information provided by large- and small-format aerial photography differ significantly in spatial and temporal scales. In general, conventional airphotos provide medium-resolution imagery that covers large areas infrequently; whereas, SFAP is high-resolution, restricted in areal coverage, and frequent. The repeat interval for the former is normally several years to decadal; the latter may be seasonal or annual. For change detection, conventional aerial photography is most useful for documenting broad regional changes that occur relatively slowly, in this case gradual waxing and waning of woodland cover over the entire area of RNHR for several decades. In contrast, SFAP is best suited for revealing short-term details of landscape change, for example the impact of burning on individual trees, human construction, drought conditions, and vegetation phenology.

Conclusions

The primary long-term change in land cover at Ross Natural History Reservation was an increase in woodland from the 1940s until the early 1990s. Since then, woodland coverage has declined, mainly as a consequence of systematic annual burning. Small water bodies (man-made ponds) appeared in the 1950s, and additional small ponds were constructed in the 1970s. The former are perennial water bodies; the latter are ephemeral. Infrastructural improvements were made in two stages, an early phase in the 1960s and 1970s and a later phase, 1999-2001. The spatial and temporal resolutions offered by conventional and small-format aerial photography, in combination, lead to better understanding and interpretation of landscape changes than either format would by itself.

Acknowledgements

We wish to thank Elmer Finck and Greg Smith, former directors of RNHR, as well as Marshall Sundberg, former chair of Biological Sciences, for their assistance and encouragement of this investigation. Financial support for small-format aerial photography was provided by a Kansas NASA EPSCoR grant and institutional funding.

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