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Kennesaw Mountain National Battlefield Park

A Case Study of the Potential Impacts of Neighboring Land Use Patterns on Local Ecosystems within Protected Federal Lands

Natural Resource Report NPS/SECN/NRR—2011/473

ON THE COVER
View from northwest side of Kennesaw Mountain
Photograph by Brent Blankley

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Abstract

In recent years, the negative ecological effects of land use change surrounding protected areas have become a subject of growing concern to conservationists, ecologists and natural resource monitoring organizations such as the National Park Service. The result of this concern has been a concerted research focus on protected areas that are threatened by land use change and to quantify the effects of these changes. Because of its proximity to a rapidly expanding metropolitan area and the historical and ongoing land use changes that have occurred there, Kennesaw Mountain National Battlefield Park (KEMO) provides a great opportunity to examine how land use change might affect ecological processes. Both the size and connectivity of the ecosystem outside of the Park have been greatly altered in recent years and will likely adversely affect the local ecosystem within KEMO's boundaries.

This study examines, documents and quantifies the land use changes that have occurred in the areas surrounding KEMO as well as the impacts that these changes might have had on the local ecosystem within the Park during a 20-year span between 1986 and 2006. Satellite imagery classification and land use change detection analysis were used to quantify the types and amount of land use change that has occurred at KEMO. Additionally, buffer distance ranges, hypothetical ecosystem boundaries, ecosystem fragmentation areas and transit corridors were used to demonstrate how changes in land use might have affected the ecosystem beyond and within the Park. The results of this study show that there were large conversions of undeveloped or "natural" areas (e.g., forest, agricultural) to urban land use areas across the entire time period of the study in the areas surrounding the Park and at a number of varying distances from the Park. The results of this study also illustrate that hypothetical ecosystem boundaries and transit corridors have been greatly reduced in size and number and that a great deal of ecosystem fragmentation has occurred.

Introduction

The United States has a long history of protecting lands that are considered to be of significant cultural, historic, or ecological importance. Evidence of this protective legacy can be seen in the form of the National Parks managed by the National Park Service (NPS). These areas provide numerous recreational and educational opportunities that would not be possible otherwise. Many Americans have taken advantage of these opportunities and have recognized the importance of protected areas such as National Parks; but, due to the sometimes narrow focus of the original intentions of these areas, few realize the ecological protection that the parks also provide. Unfortunately, even for those that recognize the protective ecological roles of the parks, the importance of the areas beyond the boundaries of the parks that make up the ecosystem as a whole are frequently ignored. Thus, when considering the health and potential threats to the local ecosystems in National Parks, the activities that occur beyond the protective boundaries should also be accounted for. One of the most important examples of an external activity that might lead to potentially harmful ecological consequences for the parks is land use change.

Importance of Monitoring Land Use Change

In 1999, the National Park Service (NPS) initiated a long-term ecological monitoring program, known as "Vital Signs Monitoring," to provide the minimum infrastructure to allow more than 270 national park system units to identify and implement long-term monitoring of their highest-priority measurements of resource condition (Fancy et al. 2009). The overarching purpose of natural resource monitoring in parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and determine how well current management practices are sustaining those ecosystems.

The NPS Vital Signs Monitoring Program addresses five goals for all parks with significant natural resources:

- Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
- Provide data to better understand the dynamic nature and condition of park ecosystems and provide reference points for comparisons with other, altered environments.
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards performance goals.

The NPS Vital Signs Monitoring Program consists of 32 regional networks that are responsible for monitoring key indicators of ecosystem condition, or Vital Signs in order to accomplish the goals described above. The Southeast Coast Network (SECN) is responsible for monitoring 20 parks within the states of Alabama, Florida, Georgia, North Carolina, and South Carolina.

The potentially harmful ecological consequences of land use change demonstrate the need for monitoring land use change in the areas surrounding protected areas such as National Parks. Within the SECN, parks are particularly susceptible to negative effects of land use change because many parks are situated near rapidly expanding urban centers or heavily used coastal recreation areas. Identifying and understanding how these patterns may affect the ecological and recreational (as well as aesthetic) integrity of NPS lands is crucial if effective mitigation strategies are to be implemented. As a result, *Land Use Change* was selected as one of 26 Vital Signs to be monitored by the SECN (DeVivo et al. 2008). This is not uncommon: twenty-nine of the remaining 31 networks have also selected land use change as a vital sign.

Ecological Consequences of Land Use Change

There are four primary ways in which land use changes that take place within a larger ecosystem may affect the connected local ecosystem within a protected area (Hansen & DeFries 2007). The first is by eliminating or fragmenting habitats and reducing the size of the larger ecosystem. It has been theorized that the size of an area is directly related to the number and types of species that the area may sustain (MacArthur and Wilson 1967). Thus, when the size of an ecosystem is reduced or fragmented, there is a much better chance that the ecosystem will suffer severe losses of many species, especially those that require larger areas. When these types of changes occur in the larger ecosystem outside of protected areas, they will likely have a similar effect on the local ecosystem.

The second way that land use change may negatively affect a local ecosystem is by disrupting the established ecological flow of materials and organisms that move between the local and larger ecosystems. Some land use changes may directly block access to previously connected areas of the ecosystem or indirectly influence existing pathways. This also applies to disturbance initiation and run-out zones such as those seen with fire effects (Hansen & DeFries 2007). When the initiation and run-out zones for a particular disturbance are separated or fragmented, it leads to the need for human intervention to maintain the necessary disturbance (e.g., reliance on prescribed burns). When ecological flow pathways or disturbance zones are blocked, the results lead to detrimental effects to the local ecosystem at many levels due to disruption of established naturally occurring cycles.

The third way that land use change may negatively affect a local ecosystem is by eliminating important seasonal habitats or blocking corridors between the ecosystem and habitats in the larger ecosystem. In many cases, the organisms that live in the local ecosystem rely on areas outside of the ecosystem for population source habitats that when blocked or eliminated will lead to decreases in local populations (Hansen & DeFries 2007). This situation often occurs because many protected areas are located in somewhat inhospitable locations which require certain species to rely on areas outside of the protected area for population viability. Unfortunately, the more hospitable source habitat areas are often located in very desirable areas for human habitation which results in conflicts between human and animal land use requirements.

Lastly, increased interaction between humans and organisms in the ecosystem is often a negative consequence of land use change. These interactions and their consequences, often called edge effects, can take many forms. Some of the more harmful effects include the introduction of invasive plant and animal species that interfere with the normal functioning of the ecosystem, the introduction of airborne or vector-borne diseases from organisms that are brought in by humans, their pets, and human adapted species (Hansen & DeFries 2007), and direct contact between humans, pets, and ecosystem members.

Kennesaw Mountain National Battlefield Park – Land Use Change and Urban Sprawl

Within the SECN, Kennesaw Mountain National Battlefield Park (KEMO) is especially susceptible to threats from land use change such as those described in the previous section. Due to its proximity to the major metropolitan area of Atlanta, Georgia, this park has been in the path of a massive human migration as the urban sprawl that began in Atlanta has gradually moved further beyond the city limits over the past several decades. This influx of human activity has led to an increase in land use changes in much of the Atlanta metropolitan area and is evident in the areas immediately surrounding KEMO. Thus, this particular park can serve as example to investigate the potentially adverse effects of land use change on NPS park lands.

Studying KEMO Through the Use of Remote Sensing

By quantifying the spatial effects of land use change over time, temporal patterns can be accurately examined and trends in land use change can be investigated. Predictions can then be made about the vulnerability of the areas surrounding and within the local ecosystem and informed decisions can be applied by land managers that may mitigate losses of ecological integrity. One primary way that land use change can be quantified and monitored over time is through the use of satellite remote sensing. Satellite remote sensing allows land use change investigators to obtain a synoptic view of a particular area of interest across different time periods. Satellite remote sensing also provides a way of classifying land use areas in a more precise and efficient fashion compared to *in situ* methods since it can make use of highly sensitive optical and hyper-optical sensors that are capable of detecting subtle differences in land cover that may be missed otherwise. When using remote sensing data for these types of investigations, it is very important to remember that the type of imagery that is selected must be available for all future investigations. Using imagery that is not consistently available at present or will not be consistently available in the future will create standardization problems during the future iterations of the investigation since the type of imagery that is used will not be strictly controlled. It is also important to establish and use identical methods when processing the imagery acquired during different time periods so that additional errors that result from using differing methods in subsequent years will be eliminated (Jones et al. 2009).

With these advantages and considerations in mind, the main goal of this study was to investigate and quantify the changes in land use over a three decade time span between 1986, 1996, and 2006 in the areas around KEMO through the use of satellite imagery and remote sensing. Additionally, this study provides examples of how the land use changes that may affect the local ecosystems within protected areas have the same potential to cause problems for the local ecosystem in KEMO specifically by delineating areas surrounding the Park that exhibit any evidence of the four types of ecological disruption (ecosystem size reduction and/or fragmentation, disruption of ecological flows and cycles, eliminating seasonal habitats and/or transit corridors, and edge effects) that were discussed previously. This study provides the context for a better understanding of the effects of land use change in the areas surrounding KEMO and is likely similar to other NPS park lands experiencing similar issues due to increasing urbanization.

Methods

Study Area

The origin of Kennesaw Mountain National Battlefield Park can be traced back to the Battle of Kennesaw Mountain that took place in July of 1864 during the American Civil War. At that time, the Kennesaw Mountain area was the last substantial line of defense against any invasion of Atlanta from the Union Army. The notorious "March to the Sea" that Gen. W.T. Sherman and the Union Army made in the summer of 1864 ran directly through these defensive lines en route to Atlanta. The Confederate Army put up a strong fight but the overwhelming force of the Union Army eventually broke the defensive position which left Atlanta virtually defenseless. Because the battle was essentially the final seriously contested battle during the 1864 Georgia Campaign, the Battle of Kennesaw Mountain is often considered to be one of the more important battles that occurred during the latter stages of the war. The importance of the area as a historic site compelled the federal government, first through the War Department in 1917 and later the National Park Service in 1933, to protect the lands and preserve the battlefield sites found in the area that is encompassed by the Park today (NPS 2007). Thus, KEMO is a prime example of a park that was originally established for mainly historic reasons; the ecological importance of the Park was not realized until many years later.

The Park consists of 2,849 acres of mixed land cover types with a large amount of forest and a number of open fields that resulted from or were used during the 1864 battle. The topography within the Park is highlighted by three main peaks: Kennesaw Mountain (1,808 ft), Little Kennesaw Mountain (1,600 ft), and Pigeon Hill (1,240 ft). The lands found within the Park provide exceptional opportunities for a number of plants and animals to thrive. Fortunately, the lands within the boundary of the Park have changed very little over the years beyond adding acreage on occasion which has allowed the local ecosystem to remain intact; however, the areas outside of the Park have undergone a tremendous change. Evidence of this can be seen when viewing the visitation records of the Park.

The recreational visitation totals for the Park steadily increased over the years investigated during the study. In 1986, the number of patrons that visited the Park was 665,582. By 1996, that number had increased by 76% to 1,172,130. In 2006, the visitation numbers had increased by 12% to a total of 1,316,129. Thus, the total percent increase in visitors over the 20 year span of 1986 to 2006 was 98%. During these years, the Park ranked 91, 61, and 53 in visitation totals respectively out of the over 300 parks in the system (NPS 2009). The Park is projected to continue to increase its yearly visitation which is due in large part to the ever increasing population of the areas that surround the Park.

Population Trends

KEMO is located approximately 15 miles northwest of Atlanta, Georgia in Cobb County, one of the most populated counties in the state. The county has, like the Park, experienced a steady increase in population over the same time period of this study. In 1980, the population of the county was 297,718. By 1990, the population had increased by 50.4% to 447,745. By the year 2000, the population had increased by 35.7% to 607,751. Finally, in 2007, the population had increased by 13.8% to 691,905. Thus, between 1980 and 2007, the population of Cobb County increased by approximately 132%.

The largest cities within Cobb County also increased in population over the same time period but to differing degrees. The six largest cities in Cobb County are all within 8 miles of KEMO due to its central location in the county which has led to a great deal of urban pressure along its boundaries. The Park is immediately bordered on its eastern side by the city of Marietta. This city has grown from a population of 30,829 in 1980 to 44,129 (43.1% increase) in 1990 and 58,748 (33.1% increase) in 2000. To the immediate northwest of the Park lies the city of Kennesaw which has experienced meteoric growth over this same time period. The population of this city was 5,095 in 1980 which increased by 75.4% to 8,936 in 1990 and by 142.6% to 21,675 in 2000. The cities of Acworth, Austell, Powder Springs and Smyrna have also experienced a great deal of population growth during this time period but since they are located many miles from the Park, their influence may not be as strong as those of the cities of Marietta and Kennesaw which actually border the Park.

One additional geographic area that is of particular importance is the unincorporated corridor located between the city of Powder Springs to the southwest and the western side of the KEMO boundary as this corridor contains the remaining areas that immediately surround the Park. Upon examining the census tracts along this corridor, the population was found to have increased by 79.7% from 34,699 in 1990 to 62,362 in 2000 (1980 data were not available). In review, the areas that immediately surround the Park have grown by 79.7% (western boundary census tracts), 33.1% (Marietta), and 142.6% (Kennesaw) between 1990 and 2000 (see Figure 1 for geographic layout). These statistics overwhelmingly demonstrate the increase in human population that has taken place in the areas that surround the Park during the general time frames of the study.

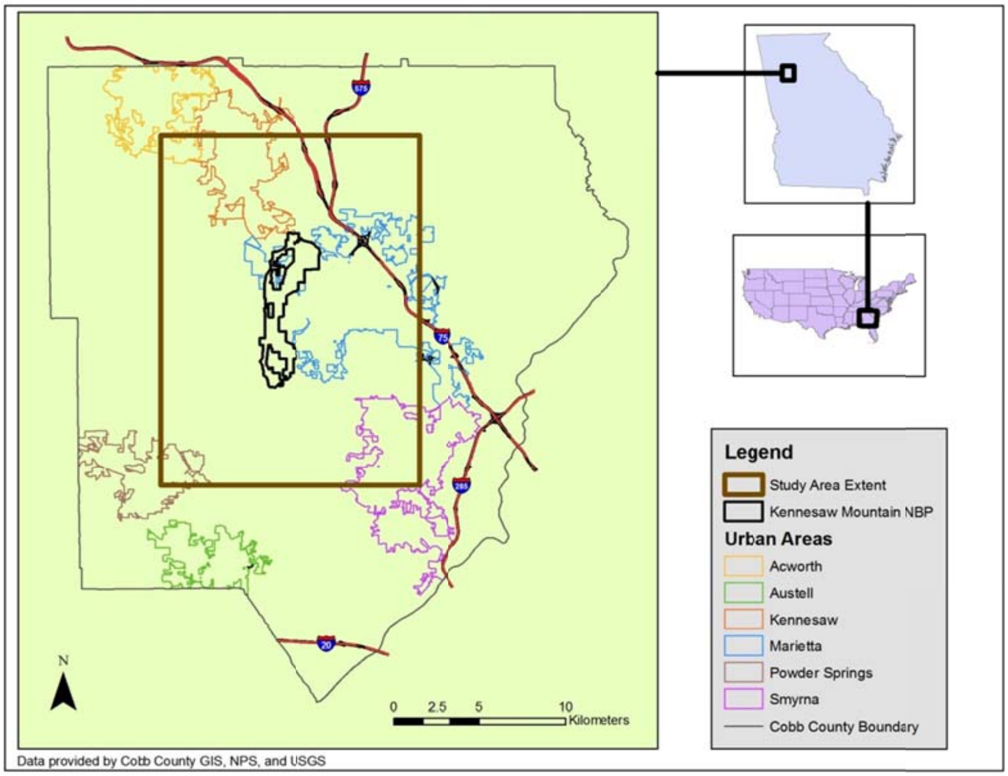

Figure 1. Map of Kennesaw Mountain National Battlefield Park and surrounding urban areas in northwestern Georgia.

Imagery Selection

The Landsat 5 platform was selected for this study because it has provided imagery for over 20 years and has proven its durability and reliability during that time. Additionally, imagery from this platform should be available for many years in the future. The Landsat 5 Thematic Mapper (TM) sensor array was selected as the sensing instrument for the imagery and was acquired from the USGS through the Global Visualization Viewer (http://glovis.usgs.gov). Since one of the main goals of this study was to perform accurate land classification of the imagery, the summer months were the seasonal time frame of choice since this is when there is the most foliage and the best view of all land cover classes should be available. After examining many blocks of the Landsat 5 scene that best depicted the KEMO area during the study division dates of 1986, 1996, and 2006, the month of September was selected as the final time frame primarily because it contained the highest quality images across all three years. The acquisition dates used in this analysis were September 14, 1986, September 25, 1996, and September 21, 2006. All scenes acquired were previously projected into the WGS 84, UTM 16N coordinate system and this projection was used for all additional imagery or vector files that were created during the study. The entire accompaniment of bands was acquired for each scene. All of the bands in each scene were then composited with the exception of Band 6 due to the fact that no thermal imaging was needed for the purposes of the study. Each scene contained 0% cloud cover and each band in the three scenes was rated at an acquisition quality level of 9 according to the imagery metadata provided by the USGS.

Imagery Processing and Correction

After the three scenes were selected, composited and verified to be free of excessive cloud cover or other potential features that may have impeded the analysis process, a bounding rectangle that extended approximately 5 km from the boundary of KEMO and contained an area of 304.489 km^2 was delineated and used as the method of subsetting the three selected scenes in order to reduce the size of the imagery to the extent of the actual land classification study area (Figure 1, Figure 2). The three subsetted images were then examined in order to verify that no geometric inconsistencies existed. Since all of the imagery was acquired from the same platform, sensor and location, and knowing that the USGS performs the same level 1T (precision/terrain corrected) processing on all of the images before they are made available for download (USGS 2006), no image to image registration was performed. To verify that the imagery had been processed, the metadata of each image was examined and each file noted that level 1T processing had been performed. The metadata also revealed that the same ground control points were used to correct each scene. The information from the metadata verified that the imagery had already been geometrically corrected by the original source organization and it was decided that any further correction may have actually been harmful to the analyses. However, the images were closely examined and indeed found to be aligned as a secondary verification.

After the imagery was determined to be correctly processed from a geometric standpoint, each image was then atmospherically corrected by using the models provided by Dr. Lawrence Kiage (Assistant Professor, Department of Geosciences, Georgia State University). The Landsat 5 version of the models consisted of two separate models that covered specific time frames of pre- and post 2003. Thus, the pre 2003 model was used for the 1986 and 1996 imagery and the post 2003 model was used for the 2006 image. The earth-sun distance was calculated for each image date and plugged into the model for the appropriate image. The models were executed and the resulting atmospherically corrected imagery was then used for the next phase of processing.

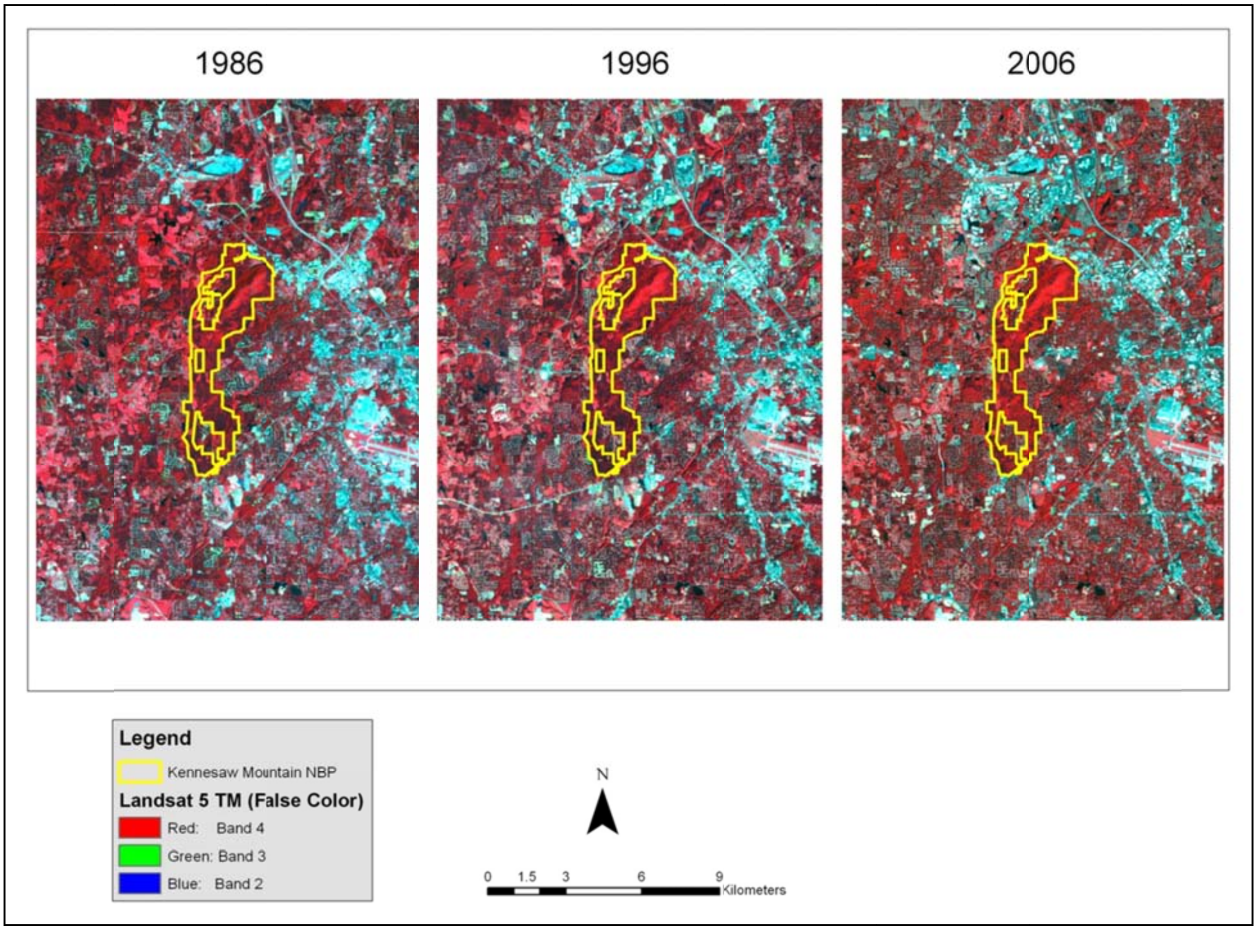

Figure 2. Overview of Kennesaw Mountain National Battlefield Park and surrounding landscape at three time periods selected for analysis using Landsat 5 TM false color composite imagery (red areas signify areas of vegetation while lighter colored areas signify areas of human development).

Imagery Classification and Accuracy Assessment

The next phase of imagery processing consisted of performing an ISODATA unsupervised classification of each corrected image (Figure 3). The number of classes selected for the procedure was 30 and the maximum iteration was set to 20. After the automated classification procedure was completed, each image was classified by visually examining each automatically generated class. To aid in this part of the procedure, both the original Landsat 5 image and a USGS topographic map that covered Cobb County were used to identify the feature type that each class represented. The 30 original classes in each image were then recoded into five classes based on five general land classification categories that were selected and given a numeric code value based on what was found in the classified imagery. The five general classes and their numeric codes were: (1) Urban, (2) Water, (3) Forest, (4) Agriculture, and (5) Barren Land; the same classes were used in every image. The agriculture class was defined as any apparently man-made open field, vegetated cleared land or naturally occurring open land. The barren land was defined as non-vegetated cleared land or naturally occurring open land that exhibited potential signs of ecological stress. The other classes were defined as their names would suggest. After the recoding procedure had been performed on all of the imagery, the pixel totals for each class were examined and class area calculations were performed by multiplying the pixel totals and the cell size to quantify how much change had occurred between the classes during the three time intervals of the study. The resulting class area calculations are reported as a percentage of the total study area.

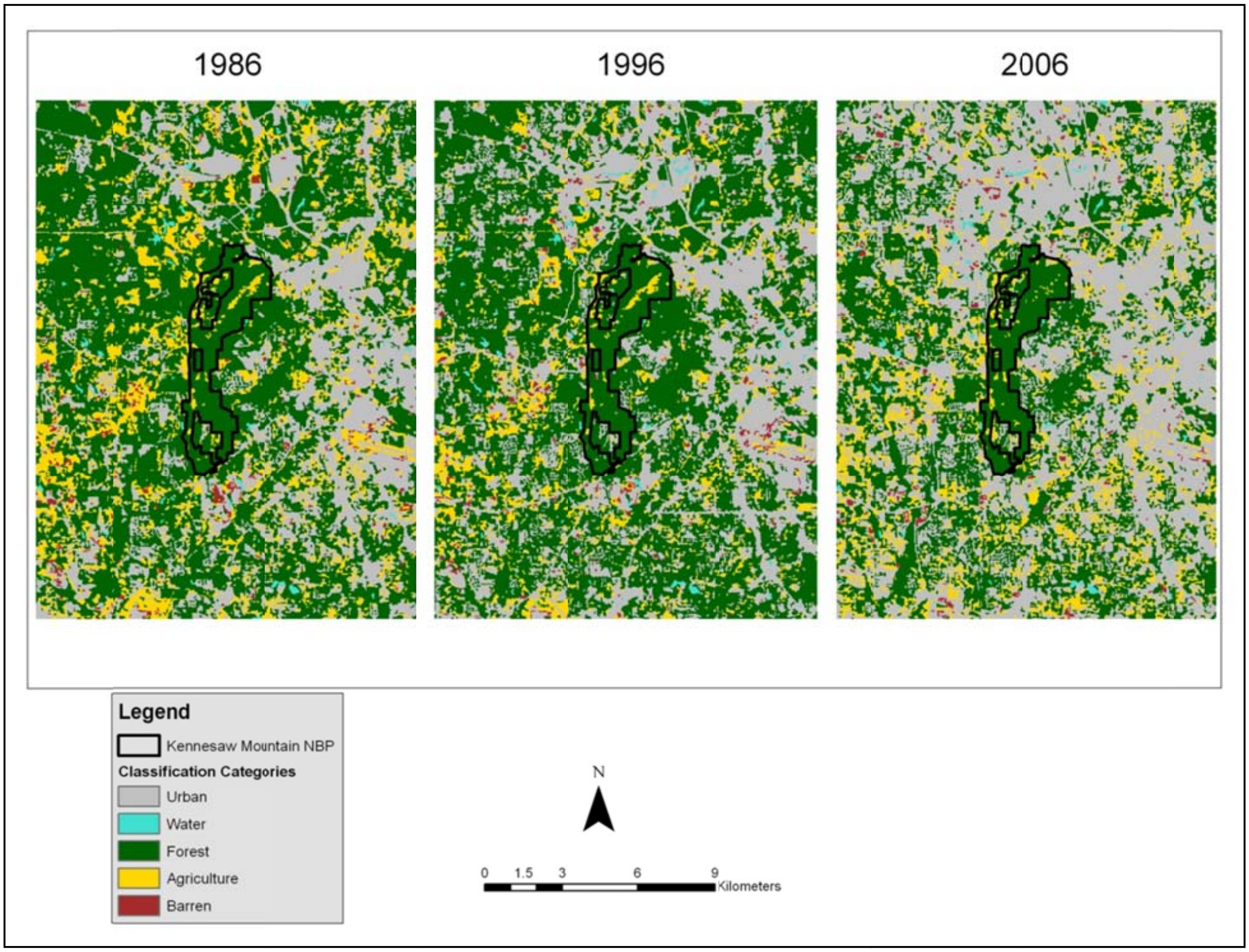

Figure 3. Land use classification of Kennesaw Mountain National Battlefield Park and surrounding landscape based on unsupervised imagery classification (refer to the legend for land use class descriptions).

Following the classification procedure, an accuracy assessment was performed on each classified image. The assessment was performed by generating 50 random points for each image that were automatically assigned the correct class designation. Each point location was then examined using the original imagery since there were no reliable reference sources for the earlier dated imagery. The observed class category of each point was recorded alongside the producer's original classification and the two values were compared. A formal accuracy report that stated the results of the comparisons was then generated.

Land Use Change Detection

The land use change detection analysis consisted of three procedures. First, a clumping procedure was performed in order to merge any individual pixels belonging to the same class that were within a four neighbor window. Second, the images that were produced during the clumping procedure were subjected to an elimination procedure that merged any clump of pixels that was less than five pixels in size into the majority class that surrounded the clump. Finally, the images that resulted from the elimination procedure were subjected to a change detection procedure that consisted of intersecting the imagery in the following sequence: 1986–1996, 1996–2006, and 1986–2006 with the 1986-2006 time period serving as a summary of the changes that had taken place during the entire time frame of the study. The outputs of these change detection procedures constituted the final processed imagery. The change detection images displayed all of the potential changes that took place between each class during each time period (e.g., urban changed to forest, forest changed to agriculture, etc.). These images and the classified imagery provided the numeric components that were needed to quantify the land cover changes that took place during the time period of the study.

At this point, it was necessary to determine whether the agriculture and barren land class should be classified as “natural” features or man-made features in order to better focus on the primary goal of the study which was to determine how much of the land had changed to a more human-focused usage type. These classes could have been merged with the urban or forest classes very easily depending upon how the agricultural and barren land classes were interpreted. The latter classes could be considered as belonging with the urban class since the features they represented may have been man-made in some cases; the classes could also be considered as belonging with the forest class if this class was interpreted as being more representative of the larger or local ecosystem or “natural” features since the agricultural and barren land could have provided a source of ecological habitat especially if they were found to be naturally occurring. For the purposes of this analysis, agricultural and barren land pixel counts were merged with the forest class pixel counts when performing the calculations on the change detection data only. This was done based on the assumption that these locations had at least some marginal ecological value and should therefore be included in the more “natural” oriented class. The merging of the classes also allowed a strictly urban vs. “natural” change area comparison (Figure 4).

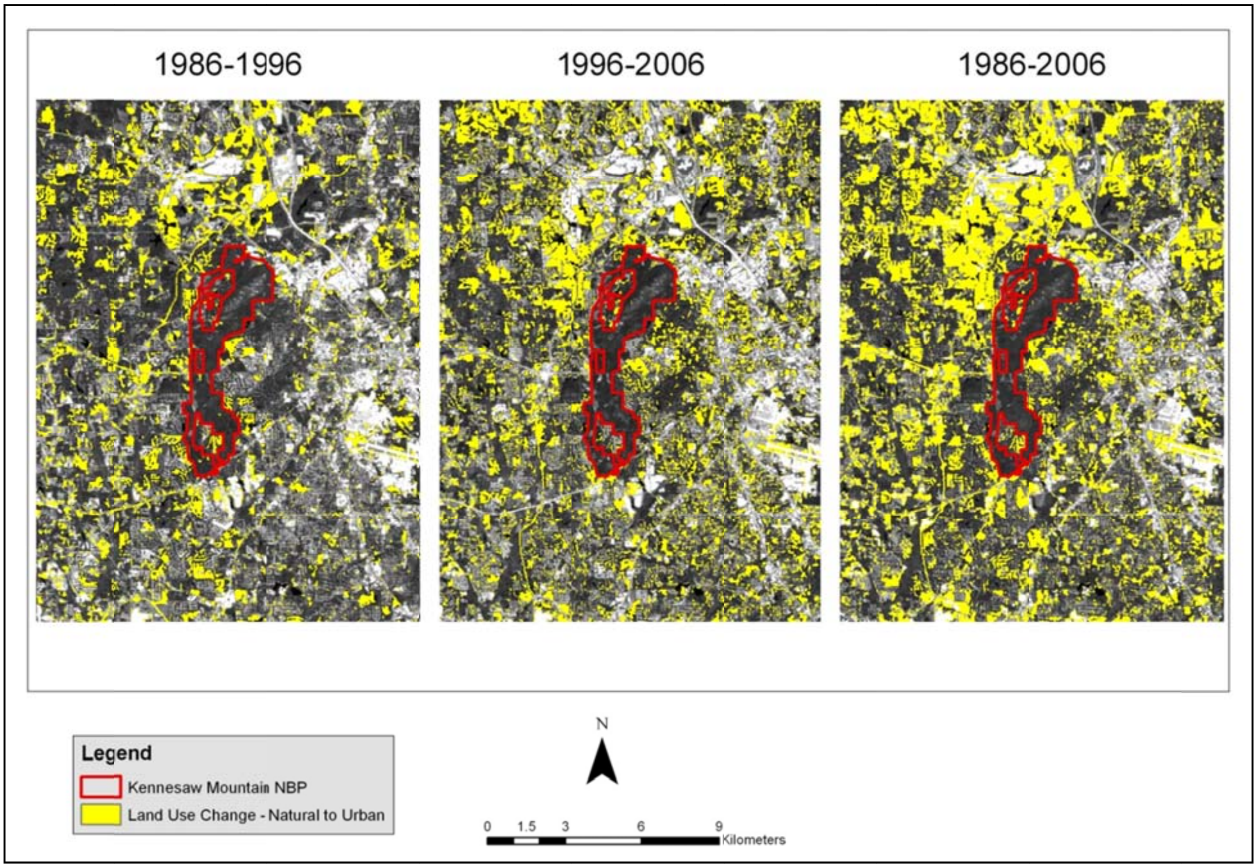

Figure 4. Change in land use from 1986–2006 at Kennesaw Mountain National Battlefield Park (yellow areas denote land that changed from barren, forest, and agriculture classes to the urban class).

Ecosystem Vector Analyses

The second set of procedures focused on performing visual inspections of the processed imagery that might reveal evidence of ecological disruption. These procedures consisted of creating a series of vector and clipped raster data sets that would provide a better means of visualizing and further quantifying the land use changes that had occurred. The vector data sets were created by generating a series of buffers that radiated outward from the KEMO boundary, delineating hypothetical ecosystem boundaries for each image, creating hypothetical fragmentation areas based on the changes to the ecosystem boundaries and creating hypothetical corridor indicators that would emphasize areas where potential corridors of transport for organisms between the local ecosystem in KEMO and the outlying sections of the larger ecosystem may have been. These data sets were designed to emphasize one or more of the ecological disruption types. It should be noted at this point that no hard data exists regarding the actual ecosystems and corridors that are located in and around KEMO. For this reason, the ecosystem boundaries and corridor indicators were created by visually examining the imagery and delineating the possible locations of these features. Thus, the ecosystem boundary and corridor data sets should be viewed as being hypothetical and as such they should be used as a means of general reference only. However, the features were digitized as accurately as possible based on the information that was available so they should not be completely discounted.

Buffers were created at distances of 1 km, 3 km, and 5 km from the KEMO boundary. These buffers were then used to clip the matching areas from each classified and change detection image so that only the pixel values that were found in a particular buffer distance range would be removed for analysis. The purpose of multiple buffer distances was to quantify how much urban land use change had occurred at varying distances from the Park so that the potential for edge effects could be examined. The class areas within the various buffers were calculated by multiplying the pixel counts by the cell size. The resulting calculations were reported as the total amount of urban land use that was present within a buffer distance range for each time period (from the classified imagery) and as the total amount of "natural" to urban land use change that had been detected within the same distance ranges (from the land use change detection imagery). Both of these sets of calculations are reported as km^2.

Ecosystem boundaries were delineated by examining the original Landsat imagery for each year selected for the study. Areas that appeared to be intact and connected vegetated areas (i.e., represented intact ecosystems) in each image upon a visual examination were enclosed by vector-based polygons that served as the hypothetical ecosystem boundaries for each time period. The areas of the polygonal boundaries were calculated in order to quantify how much the area within the boundaries changed across the three time periods. Areas that were separated from the ecosystem boundary of the previous year by new urban development and isolated from the ecosystem boundary of the year that was currently under examination were grouped into fragmentation area data sets by enclosing the remaining intact ecosystem areas that could still be visually identified within the previous year's ecosystem boundary in vector-based polygons. These data sets were created to provide a better indication of how much the size of the larger ecosystem had decreased over time and to what extent potential habitats in the larger ecosystem had been fragmented or lost due to a decrease in the ecosystem's size. These data sets may also show how the ecosystem within the park boundary has changed in size or become isolated from the larger ecosystem over time assuming that the land use change effects did adversely affect the Park. The corridor indicators consisted of a series of circles that highlighted areas where potential transport to sections of the larger ecosystem may have occurred directly along the boundary of the Park or beyond the boundary in cases where the Park ecosystem may have been linked to the larger ecosystem at an earlier time. The indicators were created based solely on a visual inspection of the same imagery that was used to create the hypothetical ecosystem boundaries and fragmentation areas. The purpose of the indicators was to mark where transit corridors may have been located initially so that their status could be assessed in subsequent years. Any decrease in the number of indicators would indicate where and when connectivity to the larger ecosystem was blocked.

Results

Land Use Classification

The land use classification results indicate that there was indeed a large shift in land area from forested and more "natural" land uses to urban land uses across the time periods used in the study (Figure 5). The other classes also decreased during each consecutive time period but the trends were not as extreme as what was seen with the "natural"/urban shift.

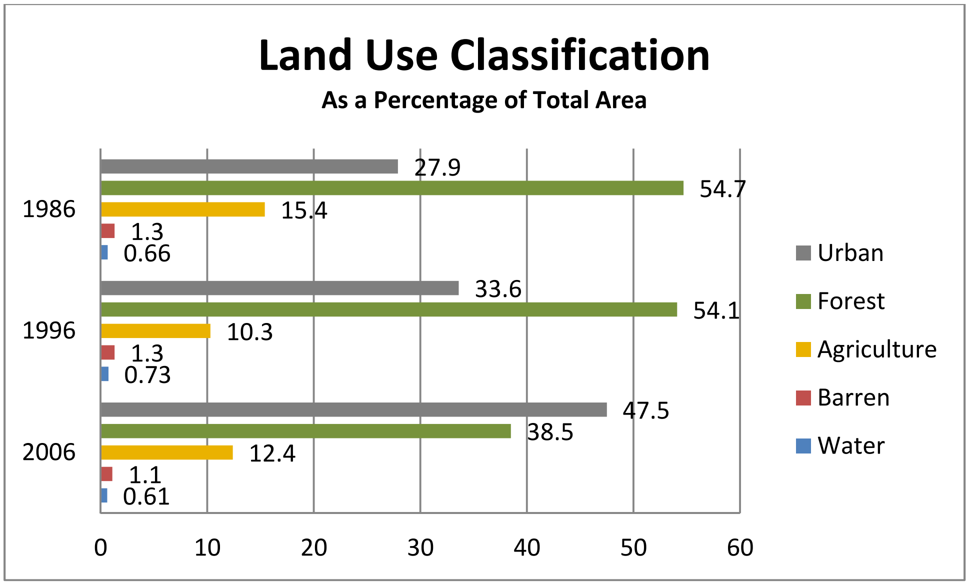

Figure 5. Percentage of land covered by the five land use classifications from 1986–2006.

The classification accuracy assessment report provided overall accuracy scores and Kappa statistics for each image. The overall accuracy score for the 1986 image was 76%, the score for 1996 was 74% and the score for 2006 was also 76%. The Kappa statistics for each year were 0.6016, 0.5217, and 0.5871 listed from 1986 – 2006. The decrease in accuracy seen in the 1996 values seemed to indicate that there may have been some classification errors in this image (see Conclusion).

Change in Land Use

In the 1986–1996 time period, 43.288 km^2 changed from forest, agriculture, and barren to urban land class. Between the years of 1996 and 2006, 58.491 km^2 of the landscape changed from forest, agricultural, and barren to urban. In the 1986–2006 time period, the area of the landscape that changed from forest, agricultural, and barren to urban was 79.819 km^2 (Figure 4). These numbers also indicate that there have been large changes in the land use patterns over the entire time period of the study.

Ecosystem Vector Analyses

The results of the land use buffer analysis showed steadily increasing urbanization across the years examined during the study. The results were divided into the categories of total urban land use area totals (Figure 6) and "natural" to urban land use class change detection area totals

(Figure 7). The values in both figures indicate that there was a substantial increase in urban land use and urban land use change in the immediate vicinities of the park boundary.

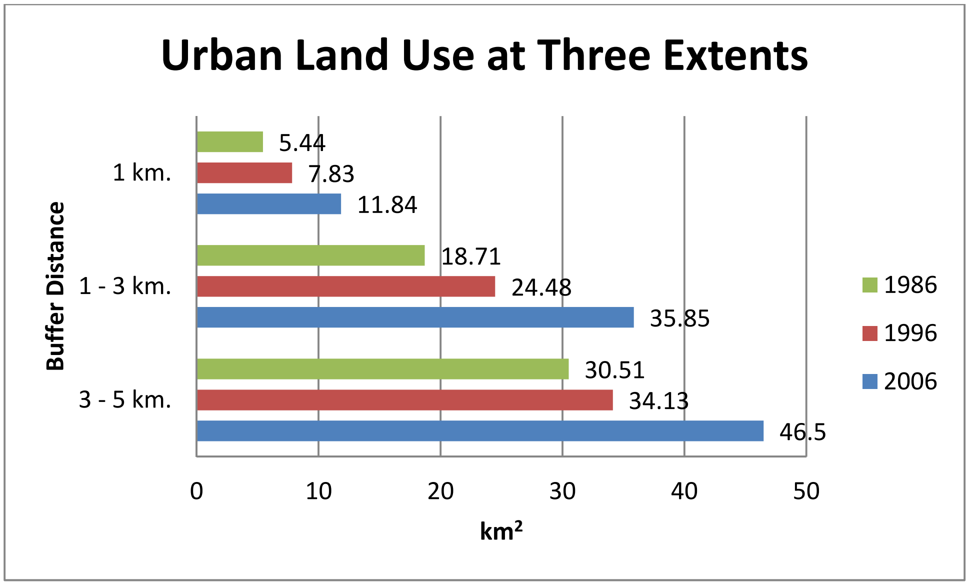

Figure 6. Amount of urban land use found within three distance ranges of the Kennesaw Mountain National Battlefield Park boundary across the three time periods of the study.

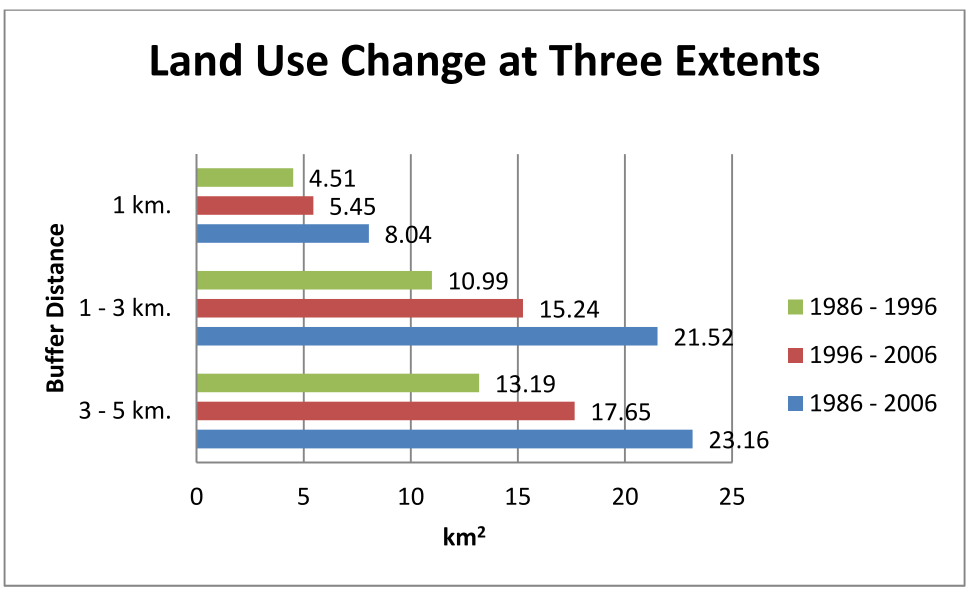

Figure 7. Amount of land use change from the "natural" classes to the urban class found within three distance ranges of the Kennesaw Mountain National Battlefield Park boundary across the three time periods of the study.

The results of the hypothetical ecosystem boundary and transit corridor investigations revealed that in 1986, the size of the hypothetical ecosystem was approximately 103.94 km^2. The number of hypothetical transit corridors during that year was 18. In 1996, the hypothetical ecosystem had decreased to 37.87 km^2. and the number of transit corridors had decreased to 5. In 2006, the hypothetical ecosystem had further decreased to 17.49 km^2. and the number of transit corridors had been reduced to 1 corridor that led to a small area just outside of the park boundary. Since the area of KEMO is approximately 11.73 km^2, the ecosystem had essentially receded to just beyond the park boundary which meant that the Park had become a virtual island in a sea of human land use (Figure 8).

There were also examples of fragmentation areas that had detached from the hypothetical ecosystems due to the introduction of new urban areas. In 1996, eight fairly large natural areas that had become detached from the contiguous ecosystem remained. In 2006, the hypothetical 1996 ecosystem was further fragmented into six separate areas. At the same time, the fragments that had been left over from the 1986–1996 land use changes had been further fragmented into 10 separate areas for a total of 16 fragmented areas (Figure 8).

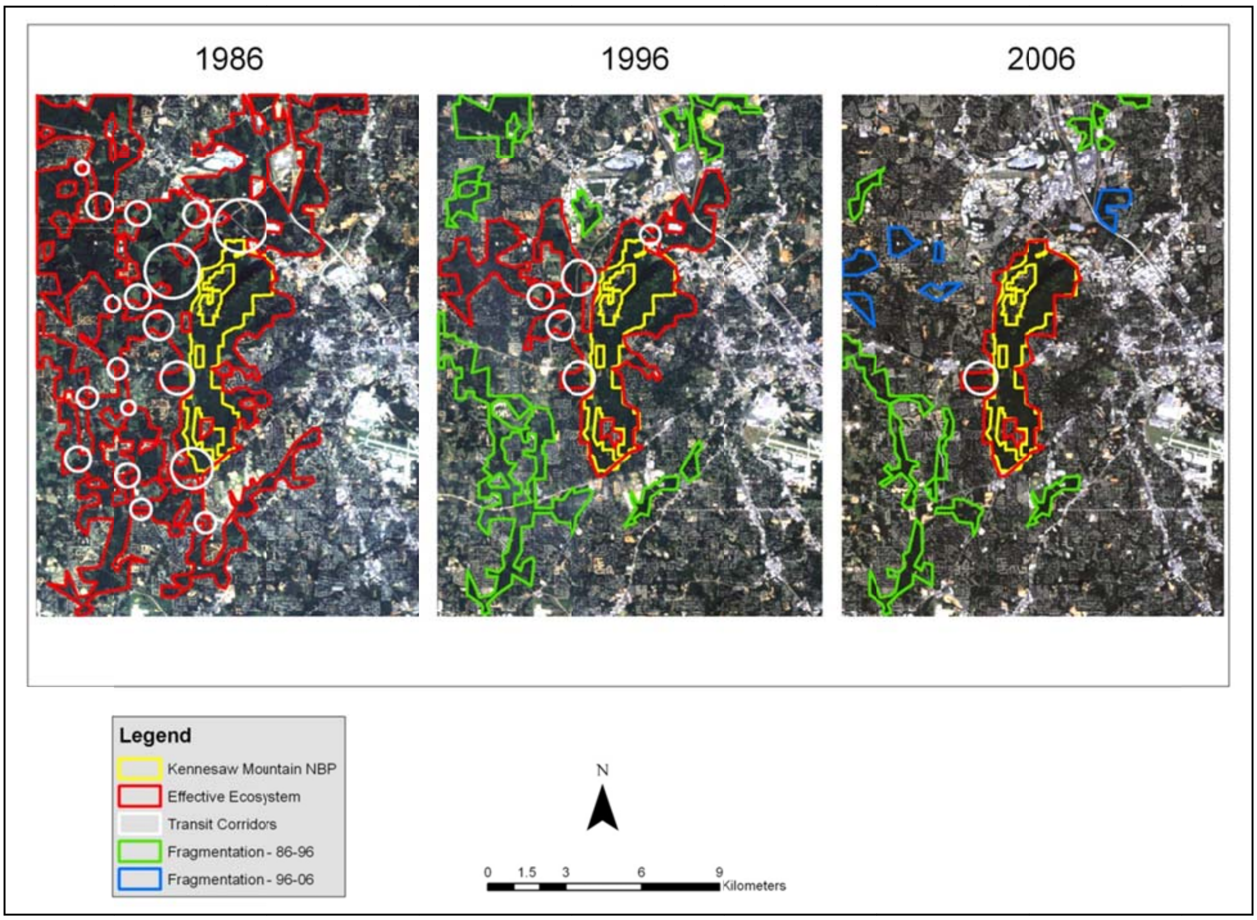

Figure 8. Hypothetical ecosystem boundary and transit corridor changes from 1986–2006 for Kennesaw Mountain National Battlefield Park.

Conclusion

The goals of this study were to examine and quantify how human-focused land use patterns have changed between the years of 1986, 1996, and 2006 and to provide examples of how the local ecosystem may have been disrupted due to the effects of land use change in the areas that surround Kennesaw Mountain National Battlefield Park. The methods used to examine these changes included performing an unsupervised classification of images that depicted the study area during those years, processing the classified imagery to better depict the classes, and running a change detection routine on each temporal combination of the imagery. As a secondary investigation, buffers of various distances from the park boundary, hypothetical ecosystem boundaries, fragmentation areas and transit corridor indicators were developed in order to aid in visualizing the potentially harmful effects of land use change on the local ecosystem within KEMO. The results showed that there has indeed been a large increase in land use change in the areas surrounding the Park between 1986 and 2006. Evidence of this was seen in both the amount of increase in urban land use class area at the expense of "natural" land use classes and in the "natural" to urban change detection area values. The land use buffer analysis results, hypothetical ecosystem boundaries, fragmentation areas, and transit corridors, also revealed that the land use patterns would have contributed to the ecological disruptions of edge effects, reduced ecosystem size and fragmentation, habitat isolation and elimination, and transit corridor removal if the hypothetical areas were indeed the actual features represented by the vector data sets.

One technical issue also needs to be addressed at this point. Upon closer examination of the imagery and the results of the study, the 1996 values exhibited some very interesting trends that may suggest that the classification was less accurate when compared to the 1986 and 2006 classifications; the water class actually increased between 1986 and 1996 and the forest class remained relatively unchanged from 1986 to 1996. This may indicate that there were some slight errors in the classification of the 1996 imagery perhaps due to previously unseen atmospheric obstructions even though the imagery was rated as having very high acquisition quality with 0% cloud cover. The use of a different image from 1996 may provide results that would be more akin to what was found in the 1986 and 2006 images. However, the main findings of the study do not appear to be adversely affected by this apparent lack of image quality and/or misclassification. In the future, different imagery may be used if the study is repeated in order to see if the imagery had any undue influence on the outcomes.

In conclusion, the areas surrounding KEMO demonstrate the effects of human-focused land use change very well. Due to the Park's proximity to a rapidly expanding metropolitan area, these results are not surprising. In fact, the areas of human-focused land use have – or will very soon– reach their maximum capacity at which point KEMO will be completely surrounded by areas of increased human activity. For this reason, the study of the land use changes surrounding the Park may be moot at this point beyond performing very detailed examinations of the land use changes that occur directly along the Park boundary. The real utility of this study relates to how the KEMO results may be applied to newly created parks or parks that may be in an earlier stage of the same pattern of development that KEMO experienced during the study time frame. The observations that have been made and the quantitative data regarding the magnitude and potential negative effects of land use change can be used to aid these parks in developing their own land use change statistics as well as contribute to the monitoring and land management plans that may be instituted at a particular park. The utility of this information does not end at the park level; with the information and data that was acquired during this and similar studies, better monitoring and management plans may be devised to mitigate the negative ecological effects of urbanization.

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