

DETECTING VEGETATION CHANGE USING MULTI-TEMPORAL AERIAL PHOTOGRAPHS AT CADILLAC MOUNTAIN IN ACADIA NATIONAL PARK, MAINE

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Abstract.—Cadillac Mountain, the highest peak on the Eastern Seaboard, is a major destination for Acadia National Park visitors. Managing vegetation impacts on Cadillac is extremely challenging given the high use and fragile environmental conditions. A number of direct and indirect management strategies have been employed to help to reduce the amount of vegetation impact. The primary purpose of this study was to detect vegetation change on Cadillac Mountain using multi-temporal remote sensing technology. Through image processing steps under ERDAS imagine 8.7, and ESRI ArcGIS 9, major changes between dates were analyzed. Vegetation density analysis was performed to identify distribution of vegetation regrowth and reduction. Study results show detailed measurable vegetation changes in terms of vegetation regrowth and reduction. Vegetation change detection is therefore a feasible approach for assessing vegetation impacts in Acadia National Park. Remote sensing imagery analysis could provide valuable baseline data for monitoring visitor impacts.

1.0 INTRODUCTION

Acadia National Park spans 47,000 acres, and as part of the National Park System (NPS), it has a dual mission to conserve biological and cultural resources as well as to provide for enjoyment by people. The park was established 85 years ago, and has become one of the ten most visited U.S. national parks. Acadia National Park visitation is not unlike many other national parks in that it has been relatively stable over the past decade. Acadia National Park received an estimated 2.4 million visitors

in 2003. Cadillac Mountain, the study site, is one of 26 peaks in Acadia National Park. At 1,530 feet, Cadillac's summit is the highest point on the Eastern Seaboard of the United States. The only mountain in Acadia with an auto road, Cadillac Mountain is a major destination for Acadia National Park visitors. The summit receives an estimated 500,000 - 800,000 visitors each year, mostly via the auto road (NPS 2002). According to the 1998 Visitor Services Project by NPS, 76 percent of total visitors to Acadia National Park visited the summit of Cadillac Mountain. There are three trails to the summit of Cadillac in addition to the auto trail, and the 0.3-mile long summit loop hiking trail.

Acadia's granite summits such as Cadillac serve as habitat for several state-listed rare plant species. The short growing season coupled with severe weather conditions make Cadillac a tough place for plants to grow. Many of the plants on the Mountain are slow to recover from damage because of the weather and soil conditions. With very high visitor use in a very small and sensitive area, it is no surprise that loss of soil and plant cover is obvious and extensive on Cadillac (NPS 1998). Both direct and indirect management actions have been implemented since 1996, including physical barriers placed around sensitive areas, and minimal impact messages to encourage visitors to remain on designated trails (Figure 1). This study sought to collect some data regarding vegetation impact over time on Cadillac Mountain. Specifically, this study set out to explore whether remote sensing could be used as a method of testing the effect of various direct and indirect management techniques. Therefore, considering the sensitivity of the area and the ecological pressure caused by high levels of visitation, this study had as its first objective to test a new way of monitoring visitor impact at high-use destination areas where management actions have been implemented. With the availability of improved technology in recent years, the second objective was to test the applicability and feasibility of remote sensing for baseline data for analysis with future data.

2.0. LITERATURE REVIEW

Vegetation is profoundly impacted by anthropogenic activities, particularly trampling. The ultimate effect of trampling is a reduction in amount of vegetation, often resulting in complete loss of vegetation cover. A variety of recreation management strategies have been implemented in U.S. national parks, including planning more active maintenance programs and more durable vegetation covers (Hammitt & Cole 1998). Managers are increasingly using aerial photographs to aid in these planning processes. For example, Price (1983) showed how air photos can be used to monitor visitor impact on meadows around Sunshine Ski Area in Banff National Park, Alberta. By taking repeat photos, he was able to identify where new trails were developing and where pre-existing trails were widening or becoming braided. Hammitt and Cole (1998) discussed the usefulness of overlaying aerial photographs to identify changes over time in Grand Canyon National Park, Arizona.

Geographic Information System (GIS) technologies have also been employed, allowing more sophisticated analysis of change over time (Hammitt & Cole 1998). These change-detection technologies using aerial photographs and GIS have been implemented in several studies. For example, Yohay and Ronen (1998) introduced the illumination adjustment method and a modification of supervised classification by using 1 band panchromatic aerial photographs. Hurskainen and Pellikka (2004) used both ESRI ArcGIS and ERDAS together for their change detection analysis. In their study, ERDAS was used for image mosaics, masks, and classifications. The data were then transferred into ArcGIS for post-classification comparison change detection. Finally, the advantages of aerial photographs in terms of accuracy, costs saving, and scheduling compared to other satellite images were discussed in a study by Huang and Lin (2001).

3.0 METHODS

Three scanned and geo-referenced aerial photographs (1991, 1996, and 2004) were used in this study to detect

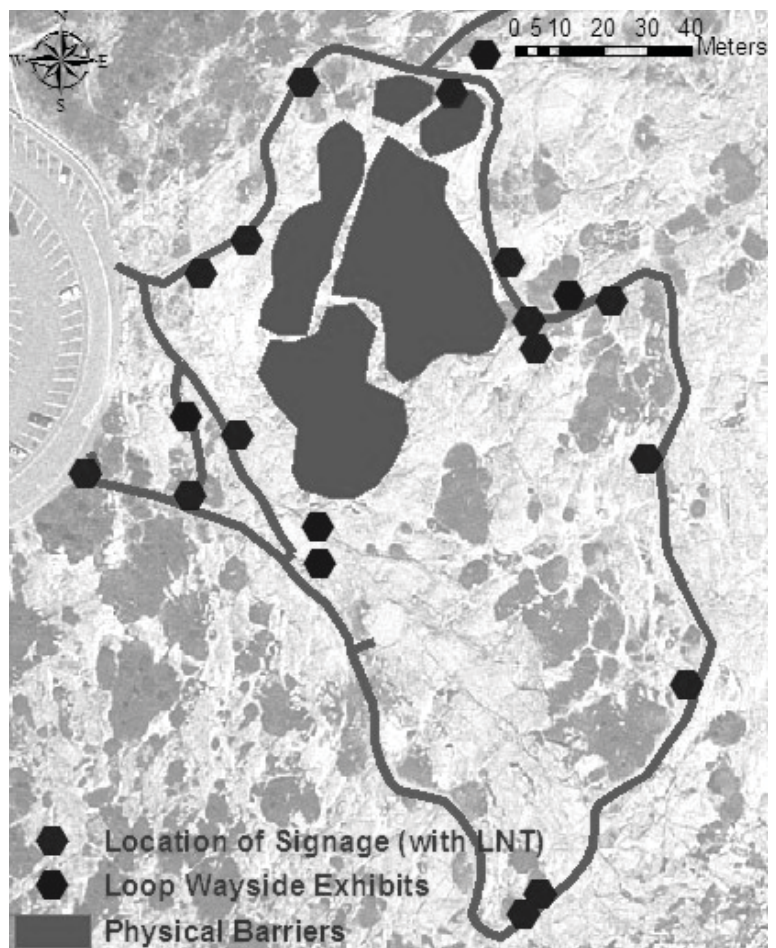


Figure 1.—Location information on Physical Barriers, Signages, and Wayside Exhibits: Signages and wayside exhibits datasets were captured by GPS unit and coded into ArcGIS. Also, edge information of physical barriers were captured by GPS unit and delineated in ArcGIS.

changes over time. Unsupervised classification and image comparison processes in ERDAS 8.7 were completed to identify vegetation change. Landsat TM imagery, which is more commonly used for detecting changes over time, was not used for this study because the pixel size of the imagery (30m * 30m) was too coarse for verifying small-scale changes. Using aerial photographs rather than Landsat TM imagery reduced the pixel size from 30m*30m to 1m*1m. The aerial photographs were black and white images (UTM Zone 19N, NAD 83) and were obtained from Acadia National Park. Several vector datasets were also obtained from Acadia National Park, including the location of the summit loop trail, several observation points, and the physical barriers. The location of signpost messages on the top of Cadillac Mountain was created using ESRI ArcGIS 9 with GPS

Table 1.—Post-classification with 45 classes

Vegetation Growth since 1991	Class 17
Vegetation Growth since 1996	Class 23 and 28
Vegetation Reduction since 1991	Class 15 and 16
No Change	Class from 1 to 14, from 18 to 22, from 24 to 27, from 29 to 45

data. The Maine Digital Elevation Model data for slope and contour analysis was obtained by the Maine Image Analysis Laboratory at the University of Maine. The years for vegetation change investigation were selected based on two main criteria: 1) to encompass a long enough time period to capture re-growth of slowly recovering plants, and 2) to investigate the effectiveness of management actions in the mid 1990s.

The following image processing steps were completed in ERDAS 8.7. First, as a pre-processing step an image subset was selected to focus on the summit loop trail area of Cadillac Mountain. In UTM Zone 19N, upper left X and Y coordinates were 561,818 and 4,911,660. Lower right X and Y coordinates were 562,270 and 4,911,032. Haze reduction and histogram equalization functions were performed to reduce the effect of atmospheric scattering on the dataset. Although all image datasets were taken in May, these functions are recommended procedures for reducing false interpretation when comparing datasets. Second, the layer stack function was used to prepare for multi-temporal change classification by combining the three original images as separate layers into one image. Next, a binary vegetation / non-vegetation mask was created to reduce the potential for classification confusion or false-change by essentially eliminating the areas represented by non-vegetation. To do this, unsupervised classification (with 45 classes) was completed on the 2004 image. Vegetation classes (0 to 27) were recoded to 1 and all non-vegetation classes (28 to 45) were recoded to 0. An attempt was made to classify species of vegetation in the study area, but even the aerial photograph imagery was too coarse to allow for species identification. This process created a new “mask” image, which was then applied to the layer-stacked dataset containing the three original images.

Fourth, another unsupervised classification on the masked layer-stacked image was completed for post-

classification. After developing this unsupervised classification image with 45 classes, the three aerial photographs along with the new classification image were carefully analyzed and compared pixel by pixel to assign informational labels about changes. In order to reduce classification error, the classification and interpretation procedures were executed several times until they were all verified as similar results. Class 17 was found to represent vegetation growth between 1991 and 2004 (Table 1), and classes 23 and 28 represented vegetation growth between 1996 and 2004. Classes 15 and 16 were vegetation reduction between 1991 and 2004, and all remaining classes depicted no change. No classes were discovered for vegetation reduction between 1996 and 2004. At this stage in vegetation change analysis, a spatial neighborhood majority filter is commonly used to eliminate scattered and isolated pixels. Because those details were important in this analysis, the filter was not applied.

Finally, the change data were brought into ESRI ArcGIS 9, where each representative color class signifying vegetation growth and reduction was extracted and converted to point data. In order to investigate vegetation change near the summit area caused by human activities, buffering layers (10m, 30m, and 50m) from the loop trail and observation points on the top of Cadillac Mountain were developed. The buffering layers were used to examine whether vegetation reduction lessened with increasing distance from the loop trail. The clip function was used to estimate the quantity of vegetation change within the buffering areas.

4.0 RESULTS

Within a 10m buffering layer from the loop trail and observation points (Figure 1), total vegetation growth between 1991 and 2004 was higher (43.5 m²) than reduction (5.9 m²). Within the 30m buffering layer (Figure 2), total vegetation growth (146.4 m²) was also

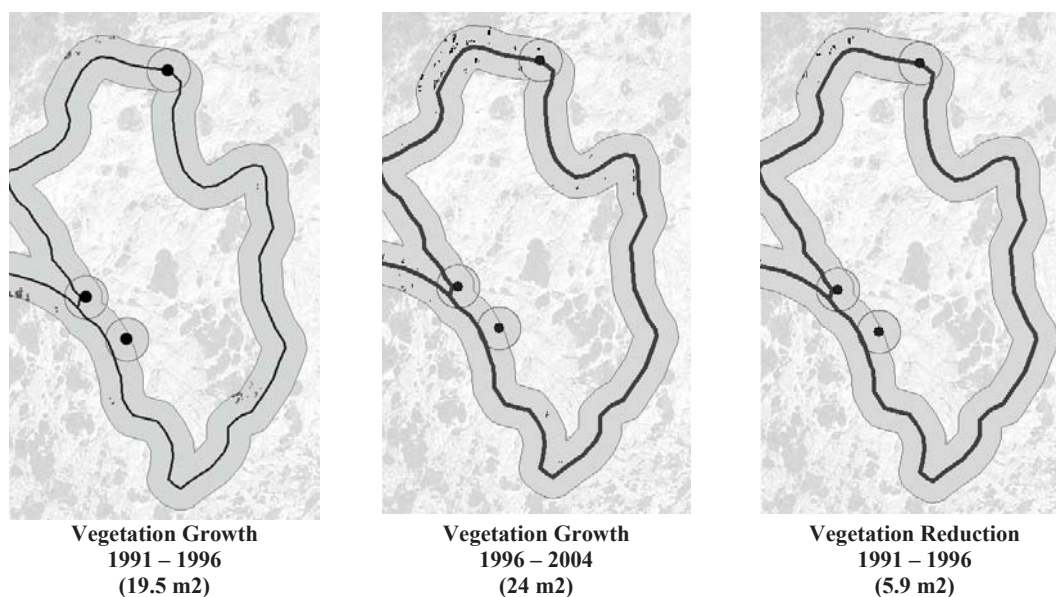


Figure 2.—2004 imagery with 10m buffering.

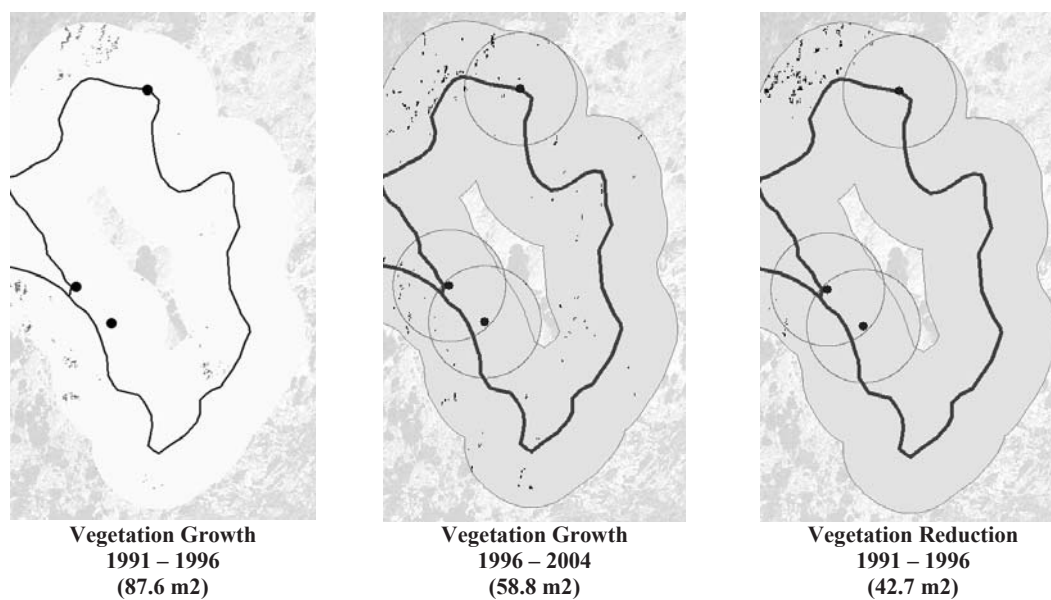


Figure 3.—2004 imagery with 30m buffering.

higher than reduction (42.7 m²). In the 50m buffering layer (Figure 3), total vegetation growth (294.4 m²) was higher than reduction (135.4 m²). The total vegetation change was calculated for each buffering layer for comparison (Table 2). Also, distribution difference between reduction and growth was noticed. Vegetation growth points were relatively well distributed across the map, but vegetation reduction points were concentrated in the northern section of the map between 1991 and 1996.

Table 2.—Total vegetation change for each buffer layer

	Re-growth (unit: m ²)	Reduction (unit: m ²)
0-10m	43.5	5.9
10-30m	102.9	36.8
30-50m	148	92.7

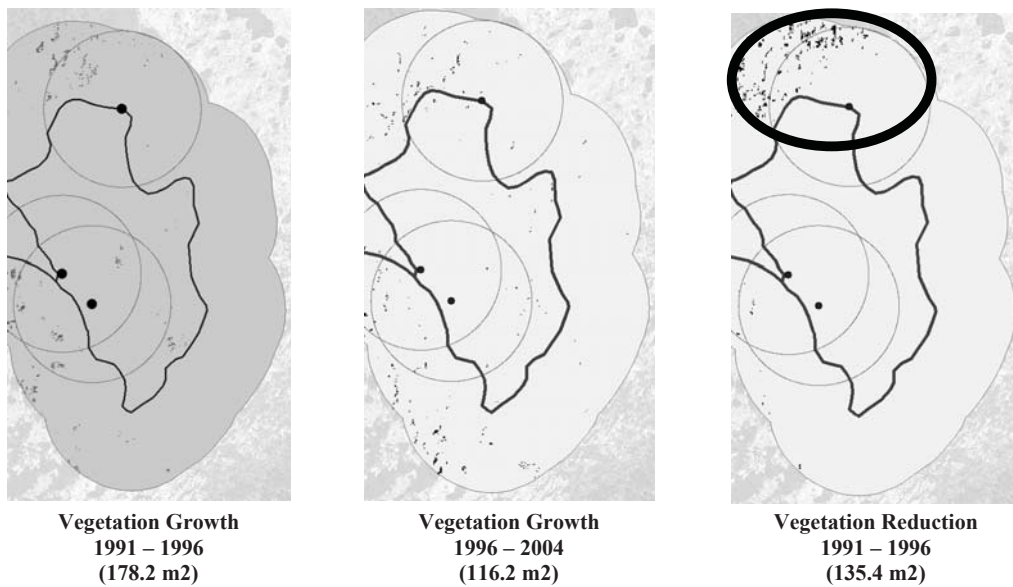


Figure 4.—2004 imagery with 50m buffering.

5.0 DISCUSSION

Vegetation regrowth was higher than reduction at all buffering levels. Management actions were considered in interpreting these results. For example, the physical barriers built in the late 1990s for directly preventing visitor impacts (Turner 2001) lie for the most part within the summit loop trail. However, the change maps suggest a relatively small amount of vegetation regrowth within these areas. Interestingly, large amounts of vegetation regrowth were discovered outside of the loop trail.

A question in this exploratory analysis was whether the minimal impact messages along the summit loop trail

could be detected as effective at reducing impact to the vegetation. Figure 5 shows an area where a signpost message was placed in the mid 1990s, and a large amount of vegetation reduction was discovered between 1991 and 1996, but no further reduction between 1996 and 2004. Although it cannot be certain that this vegetation increase between 1996 and 2004 is a result of the posted message, one suspicion is that the indirect management approach has effectively altered visitor behavior. This possibility is consistent with research that has suggested public values and attitudes have been shifting away from anthropocentrism toward the biocentric end of the spectrum (Cordell & Tarrant 2002).

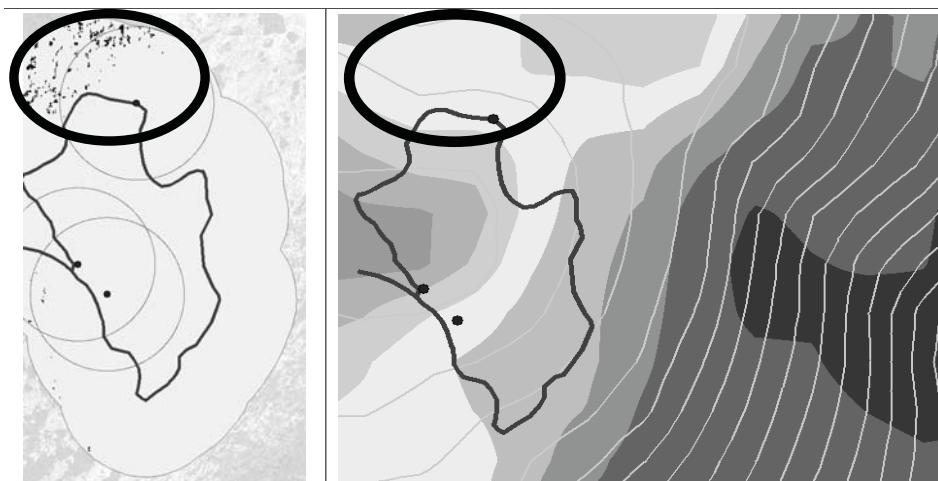


Figure 5.—Vegetation reduction between 1991 and 1996 (left) and Slope Analysis (right).

The slope of the summit area represents a possible explanation for the convergence of the vegetation reduction between 1991 and 1996 (left image in figure 5). As we see in the right image of figure 5, the slope is very steep in the east area of the loop trail compared to other areas. The slope could cause visitors who want to enjoy viewpoints from the summit of Cadillac Mountain to use the north area, which is relatively flat. Considering crowded conditions are common on the summit of Cadillac during the summer months, this Northern end of the summit loop trail is likely the preferred destination for people to stray off the loop trail for privacy.

Two main conclusions were drawn in relation to the study objectives and results. First, vegetation change detection is clearly a feasible approach for assessing vegetation impact in Acadia National Park. The change data will be useful for monitoring further changes over time on Cadillac Mountain; the ability to compare these data with future change images will add a valuable component to current monitoring initiatives in the park. The change data could also potentially be important for analyzing the effectiveness of management actions. However, it is difficult to develop confidence that vegetation change is a direct result of visitor impact. This is especially true in a sensitive area such as this sub-alpine zone, where natural events also have long-lasting effects.

6.0 LIMITATIONS AND RECOMMENDATIONS

This study set out to explore the applicability of a tool, thinking that with promising results the next step would be to address some important wrinkles. Two main limitations exist within the study approach. First, although the imagery used in the study was less coarse than the popular alternative, the use of even more accurate data would likely have allowed for the detection of greater, and more detailed, change. Also, this study used single band, or black and white imagery, which requires an extra subjective processing step that would not be required with multi-spectral, or colored imagery. Multi-spectral data provide the ability to use color theory equations instead of counting on the human eye to identify change. Second, the sensitivity of the study area limited confidence that detected change is a correlate of management intervention. Although the vegetation

change imagery will be helpful as baseline data, the slow rate of re-growth prevents the identification of causal relationships. This difficulty is particularly present with a location such as Cadillac Mountain, where vegetation reduction has been evident for decades because of high visitor use.

Two main recommendations for further research are suggested considering the implications of this study. First, this study method should be replicated in an area more susceptible to change. This could be a recreation area that is only beginning to receive higher levels of use, or a visitor area with a greater variety of plant species. Second, this study should be replicated using higher-resolution, and multi-spectral imagery. Imagery with greater accuracy would enable testing of the effectiveness of the physical barriers. If the physical barriers are found to protect vegetation, the enclosed areas could potentially be used as control sites to detect whether vegetation impact is actually decreasing as a result of the management actions. They could also serve to develop an understanding of the rate of sub-alpine species regeneration in heavily impacted areas as a result of indirect management implementations.

7.0 CITATIONS

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