Detecting Change in Disturbed Areas in Grasslands National Park Using Remote Sensing Techniques

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Abstract

Grasslands National Park was established in 1984, when it began to acquire land from local land owners as it became available for sale. One of the purposes of this park was to create an area where native prairie can be restored and conserved. Because the park is concerned with creating a natural prairie ecosystem, the extent and spread of introduced species (disturbed areas), is of interest. In response to this interest, the first objective of this project is to analyze the spatial distribution of change between 1984 and 2001 in disturbed areas within the West Block of Grasslands National Park using remote sensing techniques. The second objective is to evaluate which vegetation indices were best suited to map vegetation change between 1984 and 2001. Normalized Difference Vegetation

Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Simple Ratio (SR) were calculated for both the 1984 and 2001 satellite data, and then each of the vegetation index images were subtracted from one another to reveal the change that had occurred between the two dates. Results showed that the species Summer-cypress was often associated with negative change; while Smooth Brome was possibly associated with areas of positive change, particularly in the north-east corner of the park where the Frenchman River crosses the park boundaries. It was found that NDVI was the best vegetation index to map change in disturbed areas of Grasslands National Park in valleys and high moisture areas, while the SAVI was best suited for dry, upland areas.

Introduction

Human activities, particularly those related to ranching have heavily modified the prairie landscape during the twentieth century (Kepner et al. 2000). A major challenge for land managers and ecologists is how to effectively manage non-native plants to preserve natural biodiversity (Underwood et al., 2003). Grasslands National Park (GNP) exists within a similar highly modified landscape, and as a result, a high level of active management is required to restore and maintain the missing ecological processes (Penny, 2004). GNP was established in 1984, when it began to acquire land from local land owners as it became available for sale. Currently, the park region consists of a patchwork of lands owned by Parks Canada and private landowners. As a result, two of the dominant issues in the management strategy of GNP are: 1) the restoration of native prairie disturbed by cultivation and 2) controlling the spread of exotic agronomic plant species (Penny, 2004). Unfortunately, monitoring the patches of non-native species is a challenge for park managers given the vast area of the park, and the frequent location of these patches in isolated areas.

An attractive method of mapping species coverage is through remotely sensed images. The images are advantageous as they are a non-invasive method to collect spectral data for large geographic areas instantaneously and repeatedly over time (Inoue, 2003). Remotely sensed images have also proven to be useful because of their link between various vegetation indices, which are derived from the spectral reflectance data collected by satellites, and various surface biophysical characteristics (Jensen, 2005). This method is regularly employed to differentiate different types of ground cover. Numerous studies have been completed where one particular weed species is discriminated from a homogenous cropland area (e.g. Medlin et al., 2000; Smith and Blackshaw, 2003; Koger et al., 2004). However, a much more challenging discrimination is to separate an invasive species from a heterogeneous area of grassland native species. Yet, with varying success, similar studies have also been completed within a grassland environment (Dewey et al. 1991; Everitt et al., 1995; Everitt et al. 1996,).

Remote sensing techniques can also be employed to detect change that has occurred in an area across a period of time (Kepner et al., 2000; Lu et al., 2004). Although many change detection techniques have been developed, the most common methods are image differencing, principal component analysis and post-classification comparison (Lu et al. 2004). In recent years, the integration of geographical information systems and remote sensing data has become an important technique for change detection (Lu et al. 2004).

The goal of this project is to analyze the spatial distribution of change in vegetation quantity and quality that has occurred in areas of non-native species (disturbed areas) within Grasslands National Park since its creation in 1984. This goal is accomplished by utilizing both remotely sensed images and a Geographic Information System (GIS) database supplied from the park. Specifically, the two main research objectives are to 1) evaluate how the park management strategy affected the distribution of introduced species, and 2) establish which vegetation indices are best for mapping vegetation change that has occurred in GNP between 1984 and 2001.

Methods

Study Area

The study area is located in the West Block of Grasslands National Park (GNP) and surrounding pastures, which is in southwest Saskatchewan, Canada (49º12', 107º24'). This area falls within the Great Plains, which are characterized by semiarid climate, flat landscape and large areas dominated by grass species (Coupland 1992). Grasslands National Park is further located within the mixed grass prairie, one type of biome found within the Great Plains. This biome is a transitional zone between tall grass and short grass prairie (Davidson 2000). The climate in the study area is semi-arid; winters are long, cold and dry while the summers are short, hot and comparatively wet (Environment Canada 2000). Average temperatures range from -12.4ºC in January to 18.3ºC in July, and the average precipitation is approximately 350 mm per year (Environment Canada 2000). The soils in the study area are brown Chernozemic clay loam (Saskatchewan Soil Survey 1992). The dominant native grass species found in the study site are June grass (*Koeleria gracilis*), needle-and-thread grass (*Stipa comata*), blue grama (*Bouteloua gracilis*), and western wheat grass (*Agropyron smithii*). A dominant introduced species included in this study is crested wheat grass (*Agropyron cristatum)*.

Field Data Collection

Two Landsat images, from July 20th, 1984 and August 23rd,1999, as well as one ASTER image from August 12th, 2001 were acquired. A GIS database created in 1994 which delineates the extent of the introduced species was obtained from Grasslands National Park. GPS points representing study sites located in native prairie were also utilized.

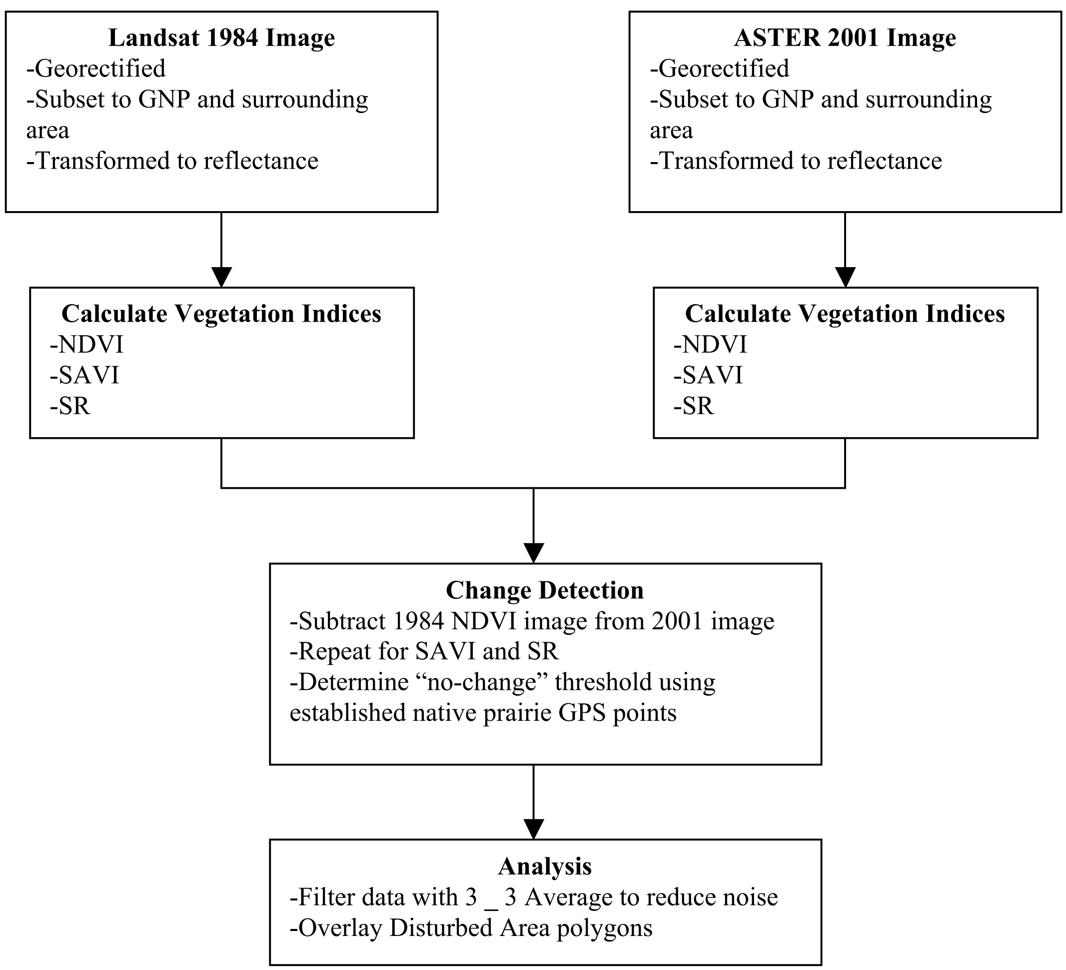

Figure 1. Methodology flow chart.

Data Pre-processing and Analysis

Using the previously georectified Landsat 1999 image, the ASTER image was registered using 15 ground control points (GCPs) with a resulting root mean square error (RMSE) of 0.37. Nearest neighbour re-sampling method was employed. The image was then subsetted to make the file size smaller and more manageable. The image was re-projected to Universal Transverse Mercator (UTM), zone 13. The Landsat 1984 image was then georectified to the ASTER 2001 image, again using 15 GCPs with a RMSE of 0.35. Nearest neighbour re-sampling method was used again. This image was subsetted to make the file size smaller and more manageable. The image was re-projected to Universal Transverse Mercator (UTM), zone 13. The digital numbers for the Landsat 1984 image were then transformed to radiance values, and then from radiance to reflectance using EASI modeling. The ASTER image was also converted into reflectance through USGS on demand request.

Normalized Difference Vegetation Index (NDVI) was calculated for both the 1984 and the 2001 image using Raster Calculator. Next, using the image differencing technique, one NDVI layer was subtracted from another using PCI Modeler. In order to see the areas of positive, negative and no change clearly on the “difference” image, it was necessary to set up thresholds. Establishing the thresholds was completed by using GPS points which represent study sites located within established native prairie within the park boundaries. The GPS locations were overlain onto the “NDVI difference” image. These sites represent the baseline of change for the Grasslands National Park and surrounding area, given any climatic or season difference which may have occurred during the study period. The highest and lowest values for change viewed at these points represent the upper and lower boundary for “no change” respectively. Anything above the highest level of “no change” was classified as positive change, which represents an increase in vegetation or vegetation health between 1984 and 2001. Anything below the lowest level of “no change” was classified as negative change, which represents less vegetation, or less healthy vegetation. These values were inserted into EASI Modeler to display the areas of positive, negative, and no change. The output map was smoothed using a 3 _ 3 average filter to help reduce noise. The same process was repeated for the Soil Adjust Vegetation Index (SAVI) and Simple Ratio (SR).

Finally, the GIS layers representing the park boundaries, the Frenchman River and the areas of invasive species, were overlain onto the output maps showing positive, negative and no change for each vegetation index.

Results

SAVI produced numerous polygons of positive and negative change (refer to Figure 1). As well, these polygons were located further away from the river valley, in the upland areas. SR displayed fewer polygons of positive and negative change in comparison to the SAVI (refer to Figure 2). NDVI however, displayed a quantity of positive and negative change polygons in-between the SAVI and the SR (refer to Figure 3). However, the NDVI polygons were observed to be concentrated in areas closer to the river valley, in lowland areas when compared to the SAVI image.

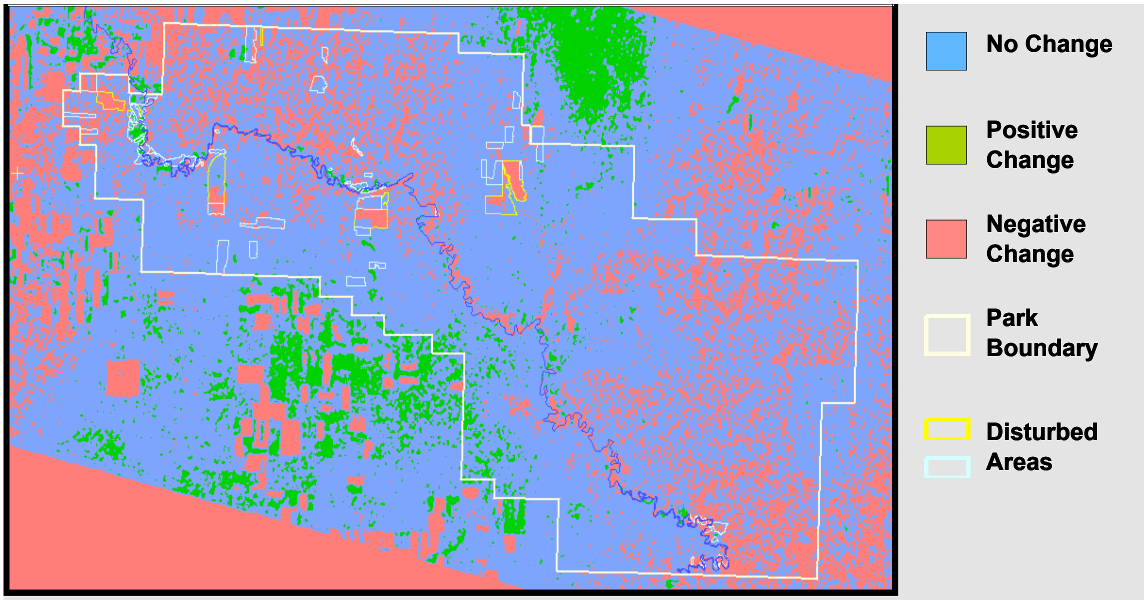

Figure 1. 1984-2001 difference in SAVI overlain with disturbed areas

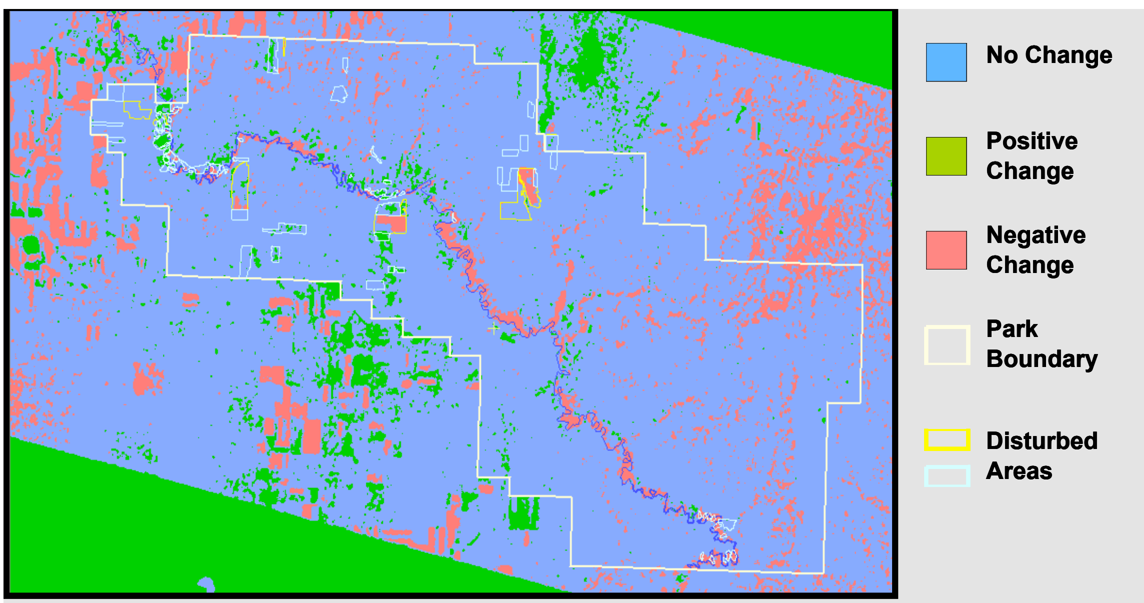

Figure 2. 1984-2001 difference in SR overlain with disturbed areas

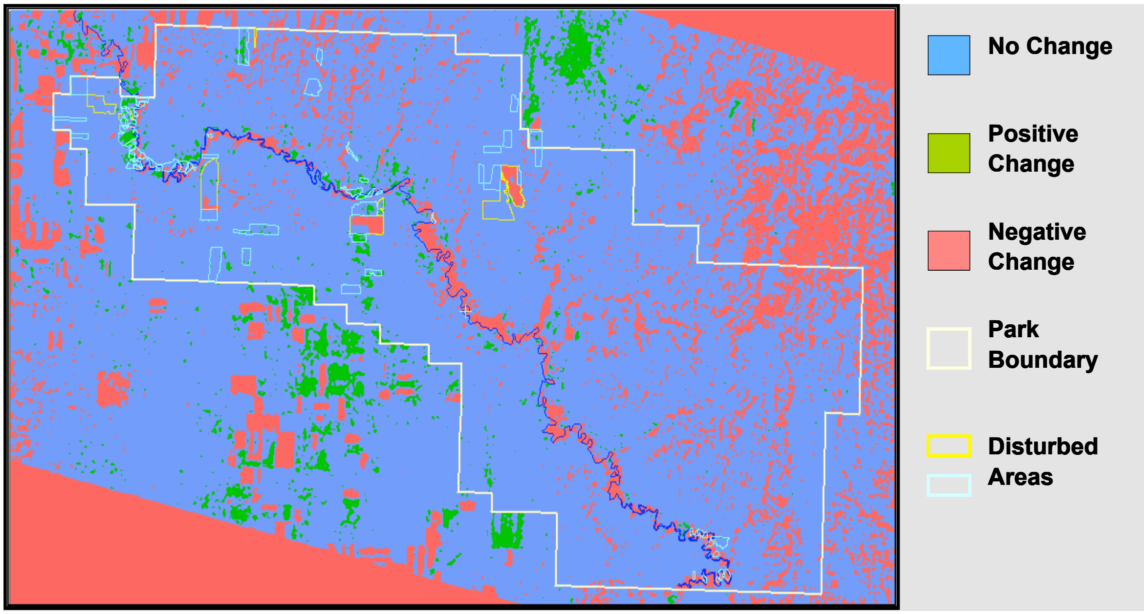

Figure 3. 1984-2001 difference in NDVI overlain with disturbed areas

Summary and Discussion

The finding that SR displayed much fewer polygons of positive and negative change in comparison to the SAVI and NDVI indicates that this vegetation index may be displaying less noise, but at the same time, may be missing information about change that actually did occur. This vegetation index is not recommended for this type of research in this semi-arid climate.

The finding that NDVI was the best vegetation index to map the disturbed areas of Grasslands National Park is based upon the observation that this index displayed the most amount of change while recording the least amount of noise. It can also be seen that the NDVI is more suited to identify change in the moister, lowland areas (near the river valley), where as the SAVI is more useful to identify change in the drier, upland areas (located away from the river valley). This finding has further support in another study conducted within the same biome (Zhang et al., In Press)

In all images, the polygons representing Summer-cypress and are often associated with negative change. This species is at full growth later in the season (July-Sept) (Jacques, 2002), so the negative change is not likely due to seasonal differences between the image dates (the 1984 image is from July, while the 2001 image is from August). The negative change is more likely a result of the park removing the weed entirely from either herbicide spray or from mowing, as this species is relatively easy to eradicate (Jacques, 2002).

Another area of interest is the light blue polygons of positive change located in the north-east corner of the park. The light blue polygons represent the following species, Pasture Sage & Blue Grama, Crested Wheatgrass, and Russian Wild Rye. With the exception of Russian Wild Rye, all of these species are all drought tolerant (Jacques, 2002). Because the areas of positive change are located along the banks of the Frenchman River, it is likely that the rye seeds originate from farmland upstream and have been transported downstream by the Frenchman River and have since established themselves along the riverbanks within the boundaries of Grasslands National Park. This is reasonable as this species requires high moisture for establishment and for the continuation of its growth. However, since discussing this research with the park management, it was recommended that this area of positive change is more likely associated with another introduced species, smooth brome (*Bromus inermus*). Smooth brome is an invasive species that was not included in the disturbed area polygons of the GIS database because it was a minor threat to the park in 1994, when the database was created.

Limitations

Unfortunately, there are several limitations associated with this study. First, there is no ground data recording the change between 1984 and 2001, only GIS database from 1994. Because of this, we have no record of what vegetation was on the surface at either of these dates, we can only speculate. For example, the smooth brome was not included in the GIS database, and because there is no ground data representing the area, it was impossible to determine the presence of this invasive species. Second, the time period (1984-2001) for this change detection is too long, as there may have been changes that went unrecognized. For example, there may have been changes in the ecosystem during the 17 years that have passed, but the ecosystem has since recovered to its original state. A final limitation for this study is that the accuracy of GIS database is unknown, so the location of the disturbed area polygons may be inaccurate.

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