Discriminating Land cover Types Using SPOT 4 imagery in the Mixed Grassland Ecosystem

Y. He[1], X. Guo[1], Susan Crump[2], and David Hildebrand[2]

[1] Department of Geography, University of Saskatchewan, Saskatoon, SK S7N 5A5

[2]**Agriculture Financial Services Corporation, 5718-56 Avenue, Lacombe, AB T4L 1B1**

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Abstract

This study was conducted at a mixed grass prairie in southern Saskatchewan. The main objective of this study is to evaluate spectral differentiations of different land cover types and grassland communities, and thus find the way of improving the utility of the land cover data product with remote sensing techniques for the pasture insurance program. Data for this study were field measurements and two SPOT 4 images acquired in the summer of 2005. Using discriminant analysis, the study extracted and analyzed spectral signals from different land cover types. The results showed that a hierarchical classification method was necessary as different level of classification uses different spectral properties. Both June and July imagery can separate the seven major classes with high accuracy and July image is 1% more accuracy than June image. The images from different dates have different advantages for separating classes based on their discriminant functions. It is easier to differentiate land cover types, such as vegetation covered area and non-vegetation covered area, however, the accuracy will be lower when separating the classes of crop and shrub, and fallow and badland due to their similar spectral properties. Three common grassland management practices (cropland, grazed grassland, and ungrazed grassland) can be spectrally discriminated, but it is difficult to separate grasslands from different topography patterns because they have similar spectral features.

Introduction

Agriculture Financial Services Corporation (AFSC) has been operating a program in Alberta since 2001 to insure producers against production losses on pasture using Normalized Difference Vegetation Index (NDVI, Rouse et al., 1974) derived from Advanced Very High Resolution Radiometer (AVHRR) imagery. The program utilizes land cover data which was derived from satellite imagery in the mid-1990s. AFSC is anxious to update this information and redo the classification system to reflect more current land use. In addition, AFSC has been attempting to expand the area currently offering this insurance program by using higher resolution imagery. Furthermore, currently, the program is only offered in southeastern Alberta where large tracts of native pasture are the norm. Outside of this area, land use tends to be more diversified and smaller, and the current 1 km resolution of the AVHRR imagery does not provide enough data to establish a township estimate of growth conditions.

The mixed grassland ecosystem of Southern Saskatchewan is among the most biologically diverse grasslands in the world, and thus was an appropriate location to conduct a pilot study for AFSC. The goal of this pilot study was to find the best way of updating and improving the utility of the land cover data product with remote sensing techniques in the mixed grassland ecosystem. This paper, as a part of the pilot study, focused on discriminating spectral properties of grassland communities since extracting spectral properties of different land cover types and different grassland communities was the basis of classification.

In recent years, discriminant analysis, a multivariate approach to pattern recognition and interpretation, has been used extensively in land cover investigations. One objective of the discriminant analysis is to predict the group to which an observation belongs, based on its measurement values. Such a formulation is called predictive discriminant analysis, and the prediction equations are called discriminant functions. Alternatively, the objective may be to exhibit optimal 'separation' of groups, based on certain linear transforms of the measurement variables. This latter approach is called descriptive discriminant analysis, and the associated linear functions are known as canonical variates (Williams, 1983). For the purpose of extracting spectral properties, the second objective of discriminant analysis is to maximize the ratio of between-class variance to the within –class variance in any particular data set, thereby guaranteeing maximal separability. Extensive discussions of discriminant analysis may be found in Huberty (1994), Johnson and Wichern (1992), and Mclachlan (1992).

Regarding to above-mentioned background, we used discriminant analysis to examine the potential of multitemporal SPOT 4 imagery (acquired from June, 22 and July, 23 2005), and the combination of these data sources for discriminating among four commonly used grassland management practices, three mainly topographic patterns, and four dominant vegetation types in the mixed grassland prairie, southern Saskatchewan.

Materials

The study area is located in the West Block of Grasslands National Park (GNP) and surrounding lands, in southwest Saskatchewan, Canada (N 49º12', W 107º24'). This area falls within the Great Plains, which are characterized by semiarid climate, flat landscape and large areas dominated by grass species (Coupland, 1993). Grasslands National Park is 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 (Bragg, 1995). 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*). There also has been some invasion by exotic perennial grasses. Three exotic perennial grasses--smooth brome, crested wheat grass, and Russian wild rye--are of concern because they were used as hay/pasture species and continue to dominate the areas where they were seeded. Although the dominant type of land cover in the park is grassland, there are still large areas of ploughed soil.

Field data collection was conducted in the summer of 2005 on cropland and native prairies (upland, sloped land, and valley grassland) for both grazed and ungrazed management regimes. Two 100 meter transects were set in each plot perpendicularly at north-south and west-east directions. A 20 x 50 cm quadrat was placed at each 10 meter interval along each transect. Land cover and grassland community (grass, forbs, shrub, standing dead, litter, moss, lichen, and bare ground) identification were collected at each quadrat. Locational information was recorded by Garmin GPS.

Two SPOT 4 HRVIR images (one in June and one in July) with 20 m resolution were purchased for the study area. The SPOT 4 image includes four bands of green, red, near infrared (NIR), and short wave infrared (SWIR). SPOT images were processed for geometric and radiometric corrections in PCI Geomatica V. 9.1 software. First, the geometric correction was done with an accuracy of better than 0.3 RMS, representing approximately 6 meters for SPOT or less error on the earth's surface. Distortions caused by variations in topography were further corrected using a Digital Elevation Model (DEM), which was obtained from GNP's GIS database. Atmospheric and radiometric corrections were conducted, based on Chavez's improved dark object image subtraction (1988). After correction, the digital number (DN) values were converted to reflectance values.

In order to analyze the separability of seven major classes, the discriminant analysis (SPSS 12.0 software) was used to classify the typical spectra extracted from training sites in June and July SPOT 4 images (acquired from June 22 and July 23, 2005). The spectral data were extracted from images for different land cover types based on GPS readings. The two levels of classes (seven major land cover types and 11 sub-land cover types) were adopted in this research based on the knowledge of the ecology and characteristics of the study area and some knowledge gained in some earlier tests in the past studies. Thus, the two levels of classes may be detected by the satellite and meaningful for rangeland insurance in practice. The seven classes, including grassland, crop, fallow, shrub, forbs and dense grass, badland, and water, represent the dominate types of land cover in GNP and surroundings. The 11 sub-classes considered two commonly used grassland management practices (grazed and ungrazed), three mainly topographic patterns (upland, slope land and valley), and two dominant vegetation types (native grass and invade grass) in Northern prairie. In our study, vegetation is seasonally spectrally distinct and can therefore be discriminated by data from both June and July imagery. According to Congalton and Green (1998), at least 50 samples for each class should be used to evaluate classification accuracy. The accuracy of our discriminant function classification was tested using in-sample accuracy assessment and a Jack-Knife cross validation approach. The Jack Knife cross validation approach was implemented by withholding a spectral value and building the discriminant functions using the remaining data. The process of removing one value from the dataset was repeated until all data had been withheld.

Results and Discussion

Discriminating seven major classes based on June and July SPOT imagery

Both June and July imagery can separate those seven major classes as showed on the scatter plots (Figure 1). The “in-sample” accuracy and cross-validated accuracy demonstrated the ability of both image for separating seven major classes (figure 2). It is clear that both images could discriminate the seven classes with high accuracy, and July image is 1% more accuracy than June image. For comparison purposes, we also used a multi-temporal classification approach (combined June and July imagery) to perform the discriminant analysis and the result indicated that the multi-temporal classification slightly improved spectral discrimination among the seven major classes by 1%.

However, images from different dates have different advantages for separating classes. The function 1(X-axis) from June image (figure 1 A) can be used to separate the classes into two groups---vegetation group and non-vegetation group. The function 2 (Y-axis) can be used to classify the vegetation density, which varied from low density to high density (grass, shrub, and crop) along the Y-axis with some overlaps between classes (e.g. three pairs----shrub and crop, badland and fallow, grass and forbs). The overlaps are due to their similar reflectance features especially in the near infrared channel. From July image (Figure 1 B), function 1 (also X axis) has less advantage to separate the classes to two groups, but there are less overlaps from July image than that from June image between classes. As a result, June image showed more difference between three pairs of classes, while July image showed more difference within three pairs of classes. This result indicated that June image could be better to separate major land cover types, while July image could be better to separate vegetation communities.

The overlaps in figure 1 indicated that it may be difficult to classify those overlapped land cover types, as expected by traditional classifiers when using reflectance information only. Considering their different texture, shape and slope, such as crops and fallow usually have well-organized pattern, regular shape, and located at the flat terrain, while shrub and badland are natural pattern with irregular shape, we could separate them using these characters.

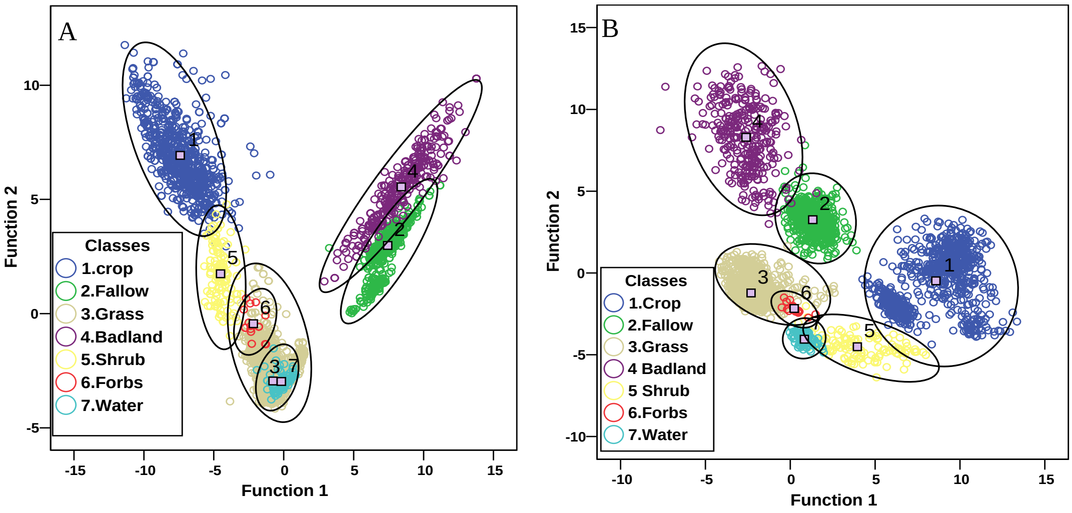

Figure 1. Discriminant functions of seven major land cover types in the mixed grassland prairie by using June (A) and July (B) SPOT 4 imagery.

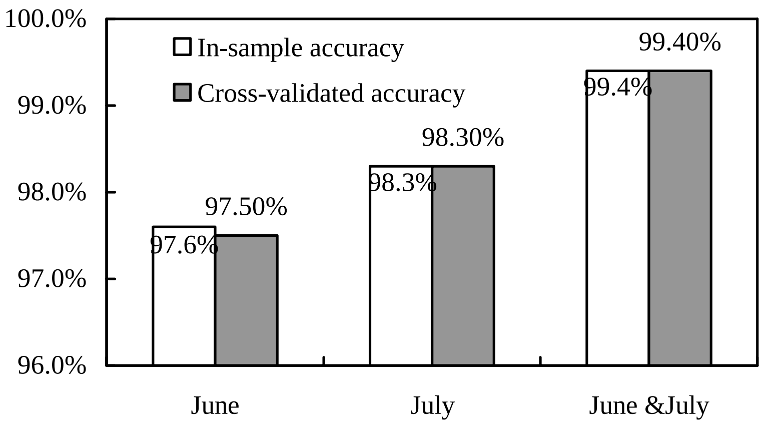

Figure 2. Discriminant classification accuracy for seven major land cover types.

Discriminating 11 sub-classes based on June SPOT imagery

The 11 sub-classes with 5 grassland communities, which are grazed, ungrazed, slope, valley, and crested wheat grasslands were also discriminated. Within these communities, the classes can be separated into three groups: invade grass (crested wheat grass) and native grass (all others) as group 1, upland (grazed and ungrazed), slope land, and valley grass as group 2, and grazed and ungrazed as group 3. Discriminant analysis was again used to determine the separability of 11 classes. Figure 3 A indicated that it is possible to separate the major classes from satellite data, and both in-sample and cross-validated accuracy are 94%. Function 1 in this figure also separated classes into two groups (vegetation in the left side and non-vegetation in the right side with grass communities in the middle). However, the 5 sub-grass communities clustered together. Then the discriminant classification for five grass communities shown in figure 3 B indicated that function 2 can be used to separate invaded grasslands (blue dots) and native grasslands (other dots); function 1 is useful to separate grazed grasslands (green dots) and ungrazed grasslands (yellow dots). It is difficult to separate grasslands from three dominant topography patterns (upland, slope land and valley grasslands) because they have similar spectral features. The both in-sample and cross-validated accuracy are 91% for both classifications, which indicates that it is possible to separate them based on satellite data.

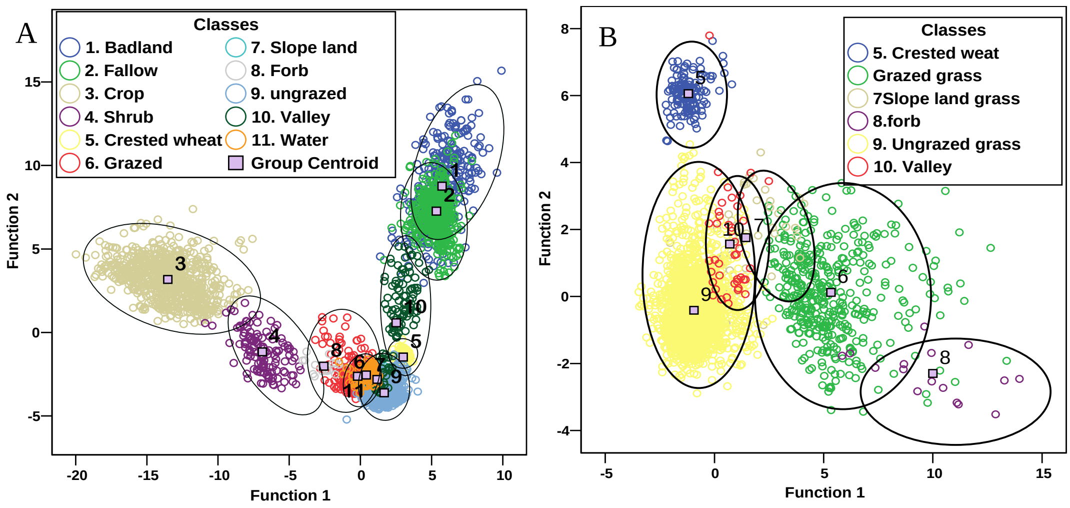

Figure 3 Discriminant classification accuracy for 11 classes (A) and five grass communities (B).

Conclusions

This study investigated spectral differentiations of different land cover types and grassland communities, and concluded that a hierarchical classification method is necessary as different level of classification uses different spectral properties. Both June and July imagery can separate the seven major classes with high accuracy and July image is 1% more accuracy than June image. A multi-temporal classification approach (combined June and July imagery) slightly improved spectral discrimination among the seven major classes. The different images have different advantages for separating classes based on their discriminant functions. June image could be better to separate major land cover types, while July image could be better to separate vegetation communities. It is easier to differentiate different land cover types, such as vegetation covered area and non-vegetation covered area, however, the accuracy will be lower when separating the classes of crop and shrub, and fallow and badland due to their similar spectral properties. Three common grassland management practices (cropland, grazed grassland, ungrazed grassland) can be spectrally discriminated, but it is difficult to separate grassland from three mainly topographic patterns (upland, slope land and valley grasslands) because they have similar spectral features.

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