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Grassland Heterogeneity under Grazing and Protection Management Regimes in the Mixed Prairie Ecosystem

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Abstract

Grassland heterogeneity, in terms of spatial pattern, vertical structure, and species composition, is an important indicator of wildlife habitat. Aimed to restore ecological integrity of native prarie, the Grasslands National Park newly approved management plan consists of reintroducing large animals at moderate and intensive grazing densities into the park. Park managers are eager to have a fast and cost effective way to monitor the effects of the new management practices after the park has been under complete protection for over 15 years. This study was proposed to investigate the potential use of remotely sensed data for this purpose. As an ongoing project, a solid conclusion couldn't be made at this moment. With preliminary results, a new framework was discussed for further analysis.

Introduction

Native prairie, the most endangered habitat in North America, has experienced dramatic species declines as a result of conversion of native prairie to cropland and the introduction of exotic species. Even in the remnant prairies, species numbers and their population are decreasing significantly due to the decrease in grassland heterogeneity, such as the Swift Fox, Burrowing Owl, and Prairie Loggerhead Shrike that can only live in prairie grasslands. With the fact that many endangered prairie species have conflicting habitat requirements (Davis *et al*. 1999, Davis and Duncan 1999), grassland heterogeneity, a dynamic indicator of grassland conditions in terms of spatial pattern, vertical structure, and species composition, can be an indicator of wildlife habitat (Dennis *et al*. 1998). Researches have confirmed that disturbance such as grazing influence grassland heterogeneity dramatically (Collins and Steinauer 1998, Bai *et al*. 2001). The trend can be increased or decreased depending on interactions between spatial patterns of grazing and vegetation (Adler *et al*. 2001). The maximum species richness and diversity are in the good range condition (Pepper and Gauthier 1998). Therefore, land management should strive to create patchy vegetation structure to accommodate for as many species as possible. Wildlife conditions should be monitored regularly through measuring grassland heterogeneity.

It is difficult to measure and monitor grassland heterogeneity through field measurements. Remote sensing, through its repetitive acquisition of digital images using various types of electromagnetic energy at different spatial scales, provides an excellent tool for such a purpose. Hudak and Wessman (1998) successfully identified woody plant invasion in a grassland habitat in the South African Savanna using historical aerial photography. Synthetic Aperture Radar data were found useful to map woody vegetation structures and bird habitats (Imhoff *et al*. 1997). The grassland heterogeneity measurement is a challenge to remote sensing. Radar data wouldn't provide the same promising results as in forests because grassland has relatively homogeneous vertical structure compared to forests. Aerial photography is both expensive and irregularly available.

In this study, we aim to investigate the use of moderate resolution satellite image on grasslands heterogeneity measurement. The method developed from this study can not only applied to grasslands under conservation, but are also useful for rangeland condition monitoring. Overgrazing has raised international attention because it results in a severe degradation of grasslands. Overgrazing is caused by careless management of the grasslands and also is influenced highly by precipitation. Extremely dry conditions will extend the effects of overgrazing in a certain extent.

Study Area

This study was conducted in the Grasslands National Park (GNP) of Canada and surrounding rangeland. The park is located in southern Saskatchewan and its south edge is on the Canada/ United States border. The park consists of two parts, west block and east block, consisting of approximately 906.5 sq. km (Figure 1). The initial efforts to establish a grassland national park can be traced back to 1956 as a recommendation from the Saskatchewan Natural History Society. In 1981, a legal agreement assigned by Canada and Saskatchewan set the milestone, the formation of the park. With the first land acquisition in 1984, some areas of the park have been under protection for over 15 years. The current understanding of relationships among ecological integrity, wildlife habitat, and disturbance is that some level of grazing disturbance is necessary to assure the ecological integrity of the mixed-grass prairie ecosystem. Therefore, a park management plan was approved in 2002; its purpose is to help restore the ecological integrity of the park. One component of the management plan is the reintroduction of large animals at moderate and intensive grazing densities into the park (Parks Canada, 2002). It is critical to develop a cost effective and fast method to monitor the effects of the disturbance at the park.

Methodology

There are seven pairs of grazed and ungrazed native prairie sites identified by park managers as biosites in the prairie upland within the park and the surrounding rangeland. Figure 2 shows the position of each site. Sites were matched primarily on the basis of soil texture and slope class, as well as soil pH, acidity and stoniness. Each site was defined by locating a baseline along 1 of the 600 m sides. Five 100 m transacts were located by dividing the site diagrammatically into a grid with 50 m intervals. The georeference coordinates for each base point and transact end were determined to within 3 m accuracy using differentially corrected global positioning system technology (McCanny et al. 1996). Their locations were permanently marked on sites and the coordinates were digitized into the park's geographic information system database.

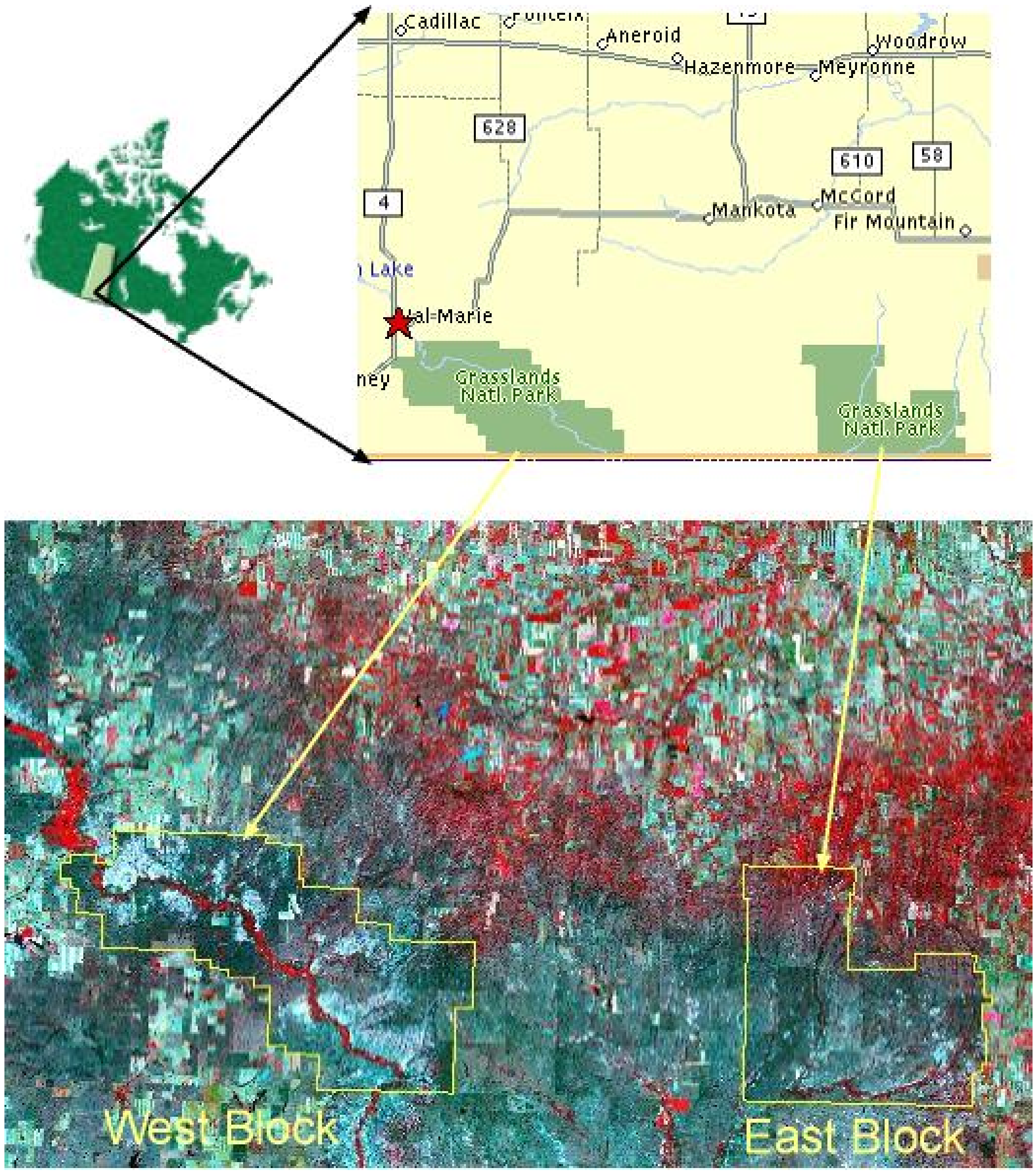

Figure 1. Study area: the Grassland National Park of Canada, which is located in southwestern Saskatchewan near the Saskatchewan-Montana border. The two separate blocks that comprise the park lie east of the village of Val Marie. The bottom graph is a portion of a Landsat image acquired on August 23, 1999 with a color composite of bands 4, 3 and 2.

One Landsat Enhanced Thematic Mapper Plus (ETM+) image of August 23, 1999 covering the study area was obtained through the GeoGratis website. The imagery has been radiometrically and geometrically corrected. All biosites showing each transact were overlaid on top of Landsat imagery. Digital numbers for each biosite were extracted using PCI Geomatics. Two methods were used to draw polygons on these biosites to extract the spectral data of each band; one is to trace the area covered by transacts (irregular polygons), and another way is to draw a rectangular polygon in the centre of each field (regular polygons). After exporting the spectral data of each site to a spreadsheet, descriptive statistics were conducted to calculate mean, standard deviation, and variance for each optical band (bands 1-5 and 7) using SPSS software (Table 1). A normality test was performed on all variables to ensure that all data are normally distributed before any other analysis was conducted. Comparison was made between grazed and ungrazed sites for raw digital numbers and standard deviation to test the variability. A Multivariate Analysis of Variance (MANOVA) was performed to test if the spectral differences between grazed and ungrazed sites are significant. Based on a concern of including little ponds in the polygon selection, the minimum digital numbers for each band and each sampling method were checked for each site.

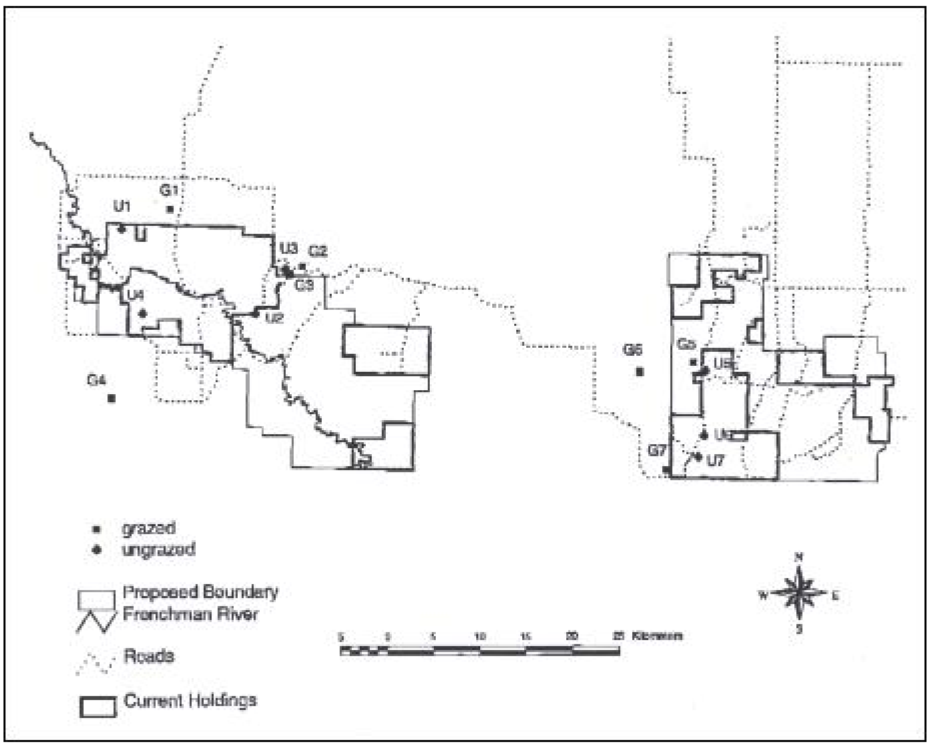

Figure 2. Locations of the biosites. Sites are labeled "G" for grazed prairies and "U" for ungrazed prairie (McCanny *et al*. 1996).

Results and Discussion

Results showed that mean digital numbers for grazed sites were higher than ungrazed sites for all bands, and both sampling methods (Table 1). However, the digital numbers couldn't tell the variance. The hypothesis of this study is that grassland with higher heterogeneity will have higher standard deviation. Figure 3 showed standard devaition of grazed and ungrazed sites for two polygon selection methods. The assumption is that if grassland heterogeneity could be identified by standard deviation from spectral data, the comparison of standard derived from grazed and ungrazed sites will provide a mean for the effects of grazing activities on grassland heterogeneity. No matter what polygon selection method was used, the ungrazed sites showed significant higher standard deviation on bands 5 and 7. This is caused by the soil moisture conditions. Bands 5 and 7 are located in the middle infrared wavelength region, which are indicators of moisture content. Rangeland has lower soil moisture content because of trampling and explosion effects (Duffey and others 1974), while conservation can preserve grassland soil moisture at certain level. This will enhance the soil moisture variance. A reverse situation was observed for band 4; the standard deviation on grazed sites is higher than on ungrazed sites. Band 4 is the near infrared band which is strongly affected by vegetation cell structure and green vegetation component. Grazing activity increases the patchiness of vegetation cover, which in turn results in higher variance. In ungrazed sites, grassland tends to be more homogeneous in composition, spatial patchiness, and vertical structure.

Table 1. Dissipative Statistics Results of All Bands for Grazed and Ungrazed Sites under Two Different Sampling Methods.

Area Selection Method	**Grazed/ Ungrazed**	**Statistics Variables**	**Pixel #**	**Bands**					
				1	**2**	**3**	**4**	**5**	**6**
Irregular Polygons	Grazed	Mean	860	76.2	61.2	66.1	78.3	117.0	75.0
		Standard deviation		2.8	2.6	3.9	3.8	5.2	4.2
		Variance		7.6	6.6	14.9	14.6	26.6	18.0
		Min		65	54	55	69	98	55
	Ungrazed	Mean	795	74.1	58.6	62.4	74.4	110.9	70.2
		Standard deviation		2.8	2.6	4.0	3.6	6.8	5.5
		Variance		8.1	7.0	15.8	13.2	45.8	30.7
		Min		55	37	29	66	45	22
Regular Polygons	Grazed	Mean	2501	76.0	61.0	65.5	78.5	116.7	74.8
		Standard deviation		2.7	2.5	3.5	4.3	5.2	4.1
		Variance		7.2	6.2	12.1	18.3	26.6	17.0
		Min		64	52	51	68	87	47
	Ungrazed	Mean	2424	74.5	59.6	62.3	74.4	111.6	70.9
		Standard deviation		2.6	3.1	3.4	3.3	5.3	4.5
		Variance		6.7	9.7	11.2	10.6	28.6	20.7
		Min		55	37	29	65	45	22

Unfortunately, there is a conflicting result between different polygon selection methods in the visible wavelength region (bands 1 and 3). Ungrazed sites showed lower standard deviation compared to grazed sites with the regular polygon selection, while the standard deviation is higher in ungrazed sites than grazed sites when the data as extracted by tracing biosite transacts for these two visible bands. However, the difference in the visible bands is not as significant as that of near and middle infrared bands. It either means that the sampling methods are biased or the three visible bands are not suitable to test the difference between grazed and ungrazed grasslands.

By comparing minimum digital numbers for each site, the concern of including little ponds was eliminated because none of the digital numbers are lower than 60 in the near infrared band (Band 4) (Table 1). Pure water hardly reflects any near infrared energy and the digital numbers should be close to zero if a pond is included.

MANOVA test indicated that the spectral differences between grazed and ungrazed sites were significant. A further investigation showed that the spectral difference among sites for both grazed and ungrazed sites are significant too, even though the F values are lower than that of between grazed and ungrazed grasslands.

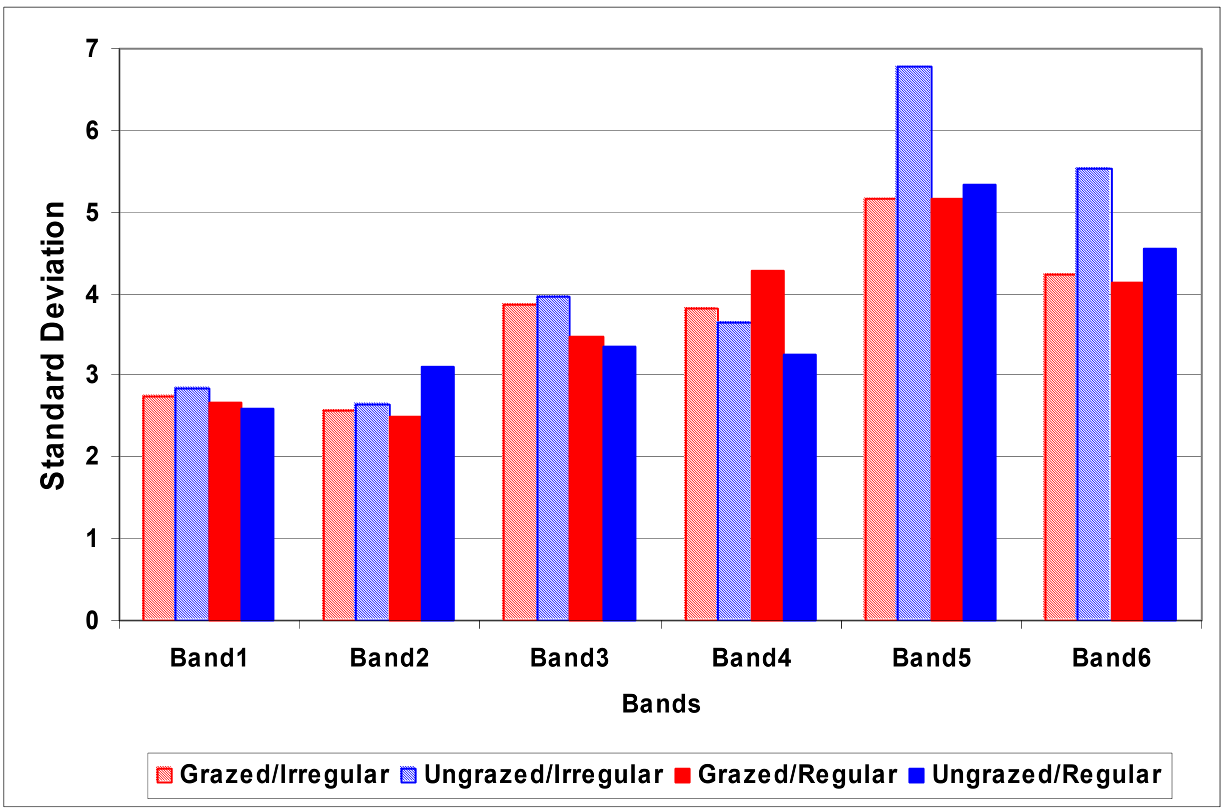

Figure 3. Comparison of standard deviation between grazed and ungrazed sites and between two different polygon selection methods.

Summary

As an ongoing project, it is hard to give a solid conclusion from current data analysis. Clearly, remotely sensed data could be used to detect difference between grazed and ungrazed grasslands.

However, many questions still remain unanswered, such as the quantitative measurement of grassland heterogeneity, the most suitable bands and spatial resolution, and the influence of topography on remotely sensed data. Therefore, a further investigation will focus on these following aspects.

1. Draw five 5 x 5 pixel polygons in each site. Polygons should be at least two pixels away from edge of the field and one pixel apart between polygons. Any significant ponds will be excluded for area selection. This sampling method will eliminate any sampling bias. A comparison should also be made between paired grazed and ungrazed sites.
2. An orthorectified image will be used to reduce the effects of topography. The image was downloaded from the GeoGratis website.
3. A texture analysis will be investigated in several window sizes such as 3 x 3, 5 x 5, and 7 x 7. Texture analysis has been broadly used for heterogeneity studies especially in forest areas.
4. Previous field collected digital pictures for two sites will be analyzed to validate the results derived from satellite imagery alone. In this dataset, eighteen digital pictures were taken at each transact of two sites showing the vertical structure of grasslands. Combining this dataset, not only will the scale be extended to centimeter level, but the grassland heterogeneity can be investigated in both horizontal and vertical levels. Semivariograms will also be developed to test the range of heterogeneity.
5. Field measurements (cover, height, species composition, and reflectance) are planning to be conducted in the coming growing season to develop a qualitative relationship model using spectral data.

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