Application of Radarsat Imagery on Grassland heterogeneity Assessment

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Heterogeneity, the degree of dissimilarity, is one of the most important and widely applicable concepts in ecology. It is highly related to ecosystem condition and wildlife habitat. In this study, the feasibility of applying Radarsat-1 HH polarization Synthetic Aperture Radar (SAR) image on heterogeneity study is tested on the Grasslands National Park (GNP) and surrounding pastures. GNP is located in southern Saskatchewan along the international boundary of Canada and the United States, which represents northern mixed grasslands. Fieldwork was conducted at GNP and surrounding pastures from June to July, 2003. Biophysical variables including species composition, cover, biomass, and canopy height were collected from 10 sites. Height heterogeneity index, Shannon's index, and standard deviation were calculated based on field data. One standard mode Radarsat-1 HH image acquired on August 1, 2003 was used for this study. Parameters from texture analysis and standard deviation of the backscatters are correlated with biophysical parameters to measure grasslands heterogeneity. Results showed that different parameters had various abilities to detect field heterogeneity. Correlation showed the highest ability to explain variation of bareground cover (79%). Mean and contrast can also be utilized to explain the variation of grass biomass and standing dead cover (59% and 56% respectively).
Key words: Heterogeneity, Radarsat, synthetic aperture radar (SAR), Grasslands National Park, Texture analysis

1. Introduction

Heterogeneity, the degree of dissimilarity, is one of the most important and widely applicable concepts in ecology (Armesto et al., 1991). A higher degree of heterogeneity in ecological systems is supposed to associate with higher ecosystem stability (Tilman and Downing, 1994). Mixed grassland has been transformed to cultivated land or ranch for long time periods (Lauenroth et al. 1994). The original mixed grassland plant community disturbed by bison and fire has different secondary successions. Grassland has been described as inherently heterogeneous because composition and productivity are highly variable across multiple scales (Ludwig and Tongway, 1995). To preserve northern mixed grassland biodiversity (or heterogeneity), Grasslands National Park of Canada (GNP) was established to exclude cattle grazing. The enclosure of ungulate grazing might produce important impacts on the northern mixed grassland ecosystem and its heterogeneity. Therefore, it is necessary to investigate heterogeneity for the purpose of grazing management and wildlife habitat protection.

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Optical remote sensing have been applied to study heterogeneity (Briggs and Nellis, 1991; Lauver, 1997; Zhang et al., in press). However, the lack of its capability to detect vegetation structure (Guo et al., 2003) and the reduced availability during growing season because of clouds cover make optical remote sensing inappropriate for northern mixed grassland study. Synthetic Aperture Radar (SAR) image can be used as an alternative for optical remote sensing in northern mixed grassland for its sensitivity to soil moisture and topography (Goyal et al., 1999) and its ability to penetrate through cloud cover. Literature showed some studies in grassland using SAR products (Goyal et al., 1999; Hill et al., 1999; Buckley, 2004). In a study conducted in the mixed grassland ecossytem, Hill et al. (1999) noted that soil moisture is a significant confounding factor influencing radar backscatter from the grassland and changes in the water content of soils and vegetation can cause large variations in radar backscatter. However, none of the current studies attempted to investigate the heterogeneity of grassland with SAR data. Therefore, the objective of this study is to test the feasibility of using a HH polarization Radarsat-1 image to measure grassland heterogeneity.

2. Study Area

The study area included Grasslands National Park (GNP) (49° N, 107° W) and surrounding pastures, located in southern Saskatchewan along the Canada - United States border. This area falls within the mixed grassland ecosystem. The park is approximately 906.5 km^2 in area but in two discontinuous blocks, west and east. The first land was acquired for the park in 1984; as a result, some areas of the park have been under protection from livestock grazing for almost 20 years. The park area consists of upland grasslands and lowland grasslands. The dominant plant community in the uplands of the mixed grass prairie ecosystem is Needle-and-thread—Blue grama (*Stipa-Bouteloua*), which covers nearly two thirds of the park's ground area. The dominant species in this community include needle-and-thread grass (*Stipa comata Trin. & Rupr*), blue grama grass (*Bouteloua gracilis (HBK*) *Lang. ex Steud*.), and western wheatgrass (*Agropyron smithii Rydb. Selaginella Beauv.*) (Fargey et al., 2000). Apart from the Needle-and-thread—Blue grama (*Stipa-Bouteloua*) community, lowland grasslands contain higher densities of shrubs and occasional trees. The entire area consists of northern mixed grassland (Davidson, 2002). The GNP area has a mean annual temperature of 3.8 °C (Environment Canada, 2003) and a total annual precipitation of 325 mm; approximately half of the precipitation is received as rain during the growing season.

3. Materials and methods

Field work

Field work was conducted in June and July of 2003. Ten sites were randomly selected within the park and surrounding pastures. Three 100x100 m plots were set up in each site, and each plot was composed of two 100 m transects placed perpendicularly to each other with a north-west orientation. Twenty-one quadrats (20x50 cm) were placed in each plot at 10 m intervals. Percent cover of grass, forb, shrub, standing dead, litter, moss, lichen, and bare ground as well as species composition was collected at each quadrat. Biomass was collected at 20 m intervals using the harvesting method. Clipped fresh biomass was sorted into four groups: grass, forb, shrub, and dead materials. They were then dried in the oven for 48 hours at 60
_. LAI was measured using a LiCor-LAI-2000 Plant Canopy Analyzer. At each plot, LAI is the average of four automatically calculated LAI values; each was the result of one above

canopy reading compared with 10 below canopy readings. These measurements were completed within two minutes to avoid atmospheric variation. The 10 below canopy readings were set at five meter intervals. The sensor was shaded when observations were being taken to reduce the glare effect from direct sunshine.

Biophysical parameters were integrated into each site by averaging quadrat values. Standard deviation (SD) and coefficient of variation (CV) were used to measure the variation of biophysical parameters within sites. Shannon's index (Rosenzweig, 1995) and Heterogeneity index of height (HIH) (Wiens, 1974) were also calculated to stand for species diversity and the variation of canopy height inside sites respectively (Table 1).

Table 1. Grassland heterogeneity indices and their formulas used in the paper

Index	Equation	Notes
Shannon's index	$-\sum p_i \ln(p_i)$	p_i is the proportion of the total number of individuals occurring in species i
Heterogeneity index of height	$\frac{\sum (Max - Min)}{\sum \bar{x}}$	Max=maximum value of the canopy height within quadrats, Min=minimum value of the canopy height within quadrats, N=the total number of quadrats, $\bar{x}$ is the mean value of canopy height in a quadrat

Image analysis

One standard mode Radarsat -1 image with HH polarization was collected for this study. The image was taken on August 7, 2004 and has a spatial resolution of 12.5 m. DNs were converted to backscatter (db) and a Gamma filter was conducted to remove speckles before the conversion (PCI Geomatics software, 2004). The image was registered to a UTM projection. A nearest neighboring method was used in the correction and 35 GCPs were collected. The RMSE was 0.35 pixel.

GLCM Texture analysis is a commonly used method for describing localized variation of surface features in grey scale. During the process of texture analysis, a grey level co-occurrence matrix or grey level co-occurrence vector is computed to describe the stochastic properties of spatial distribution of grey level (Hall-Beyer, 2000; He and Wang, 1990). Results of textural analysis can be used to describe the heterogeneity within a landscape (Briggs and Nellis, 1991). Energy (angular second moment), contrast, entropy, have been used as indicators of heterogeneity or local variance(Anys and He, 1995; Briggs and Nellis, 1991; Woodcock and Strahler, 1987).

Texture analysis was applied to the HH polarization image with a window size of 3x3. Ten measures of texture analysis, i.e., contrast, homogeneity, dissimilarity, Angular Second Moment, entropy , GLDV entropy, GLDV Angular Second Moment, mean, standard deviation, correlation were calculated. These parameters can be applied to measure field heterogeneity (Baraldi and Parmiggiani, 1995; Briggs and Nellis, 1991). A 7x7 window was used to correlate textural parameters with field data**.** Mean values of textural parameters are used to measure imagery heterogeneity.

The relationships between standard deviation of biophysical parameters and corresponding textural parameters were first highlighted by Pearson correlation. Then linear regression was applied to decide the relationships between image heterogeneity and field heterogeneity.

4. Results and Discussion

Biophysical parameters and field heterogeneity

The field measured biophysical variables showed greater variation within sites for upland grasslands (Table 2), which was corresponded with our field design. The centre of each plot was placed on the top of hills and transects were placed in north-south and east-west directions along the slope. Therefore, there was a gradient with changing vegetation species, cover, biomass, and density along each transect. As a result, big variation existed within sites. Different parameters showed various levels of heterogeneity with forb showed the highest variation because of the small amount of forb biomass in total biomass and small amount is likely resulted in high variation. Among all sites, G1 (a site in grazed prairie) had the lowest degree of heterogeneity, which can be explained by the low fluctuations of elevation and homogeneous soil moisture in G1. In northern mixed grassland, flat areas with homogeneous soil moisture have low level of heterogeneity due to the critical role of soil moisture in vegetation growth.

Table 2 Descriptive statistics of biophysical variables

		Grass	Forb	Dead materials	Total biomass
SD	Average	52.9	22.9	66.7	110.1
	G1	28.8	15.1	30.2	54.0
CV	Average	62.1	109.9	65.3	52.0
(%)	G1	37.2	152.2	47.2	35.7
Shannon's index				2.13	
HIH				1.32	

SAR image heterogeneity

Heterogeneity variables derived from the SAR image with the texture analysis indicated a high level of heterogeneity for the study area except one site (G1), which is the same site showed the lowest variation based on field measurements (Figure 1). G1 had much lower contrast, dissimilarity, and entropy values and higher homogeneity value. The gap between G1 and other sites is bigger than measured field heterogeneity (Table 2), which could be explained by the low fluctuations of elevation and soil moisture too. Soil moisture influences Radarsat backscatter by changing the soil dielectric rate and homogeneous soil moisture resulted in homogeneous backscatters.

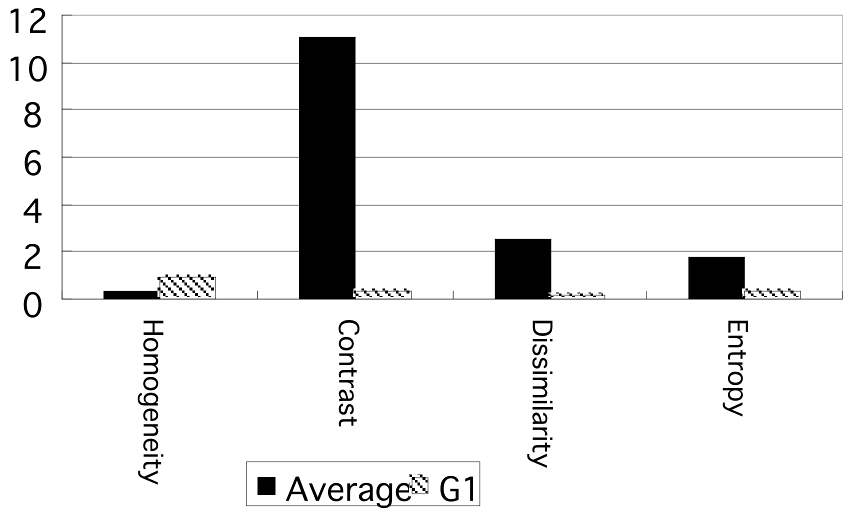


Figure 1 Imagery heterogeneity by textural parameters

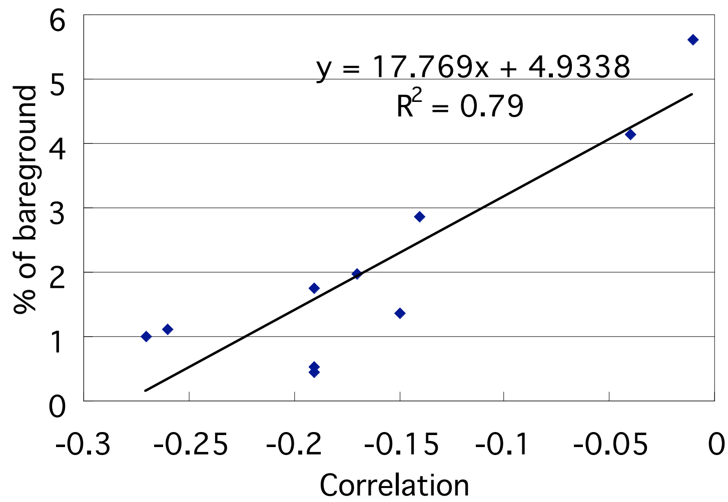
Modeling field level heterogeneity with RADARSAT imagery heterogeneity

The relationships between the field level heterogeneity (variation) and the image level heterogeneity (texture analysis) are significant for several variables (Table 3). About 79% variation of bareground cover can be explained by the correlation parameter derived from SAR texture analysis. The mean and contrast derived from SAR texture analysis were highly correlated with the variation of the standing dead cover negatively (r=-0.64 and -0.75 respectively). The variation of biomass was highly correlated with all image heterogeneity variables either positively or negatively (Table 3). However, there were no significant correlations between the image heterogeneity variables and Shannon's index or HIH. Consequently, these relationships can be simulated with linear regression (Figure 2). Correlation can explain 79% of variation of percent bareground. The proportion decreased to 76% when validation was applied.

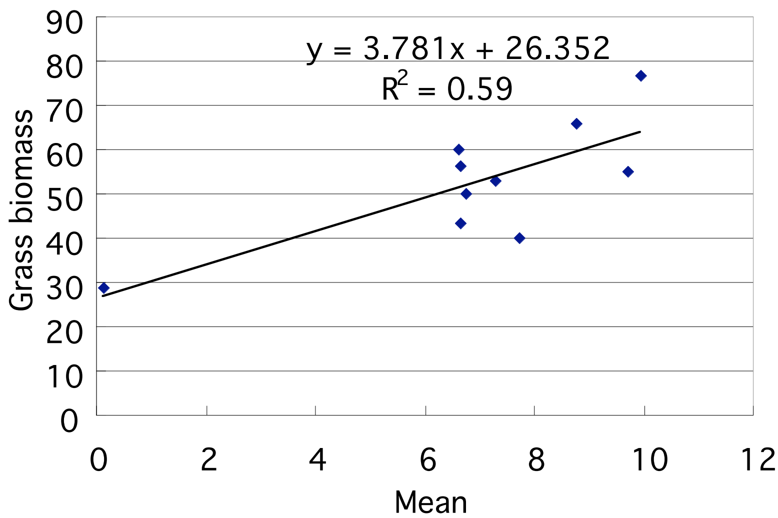
Table 3 Correlation coefficients between field level heterogeneity and image level heterogeneity

	Homogeneity	Contrast	Dissimilarity	Mean	Correlation
Grass biomass	-0.63*	0.63*	0.64*	0.76**	-0.69*
Standing dead cover	0.63*	-0.75**	-0.68*	-0.64*	0.19
% of bareground	0.46	-0.36	-0.43	-0.44	0.89**

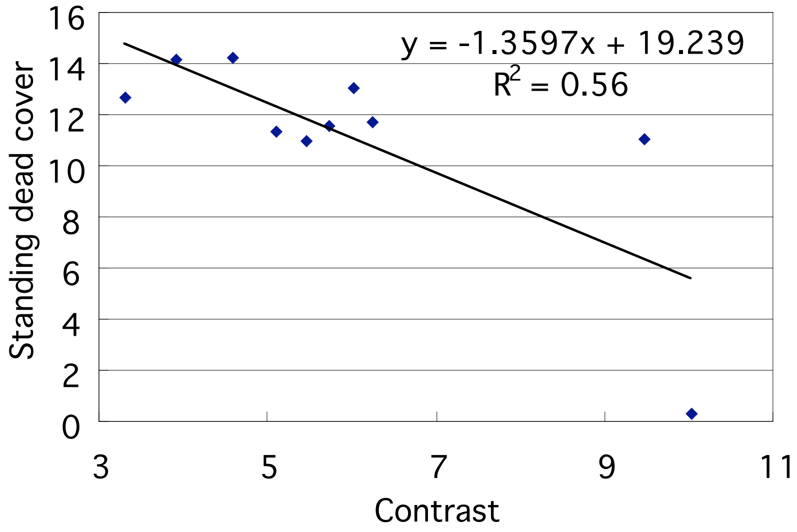
** significant at 0.01 level
* significant at 0.05 level


y = 17.769x + 4.9338
R^2 = 0.79
% of bareground
Correlation
6
5
4
3
2
1
0
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0

(a)


y = 3.781x + 26.352
R^2 = 0.59
Grass biomass
Mean
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12

(b)



(c)

Figure 2. Field geterogeneity prediction models based on imagery heterogeneity, (a) bareground cover, (b) grass biomass, (c) standing dead cover.

In northern mixed grasslands, soil moisture, the key factor of vegetation growth, is decided by topography (Zeleke and Si, 2004). Influences of topography on vegetation community is important that Rey-Benayas and Pope (1995) even used topographic index to stand for vegetation richness. Topography and soil moisture are the major sources of variation in SAR backscatter coefficients in high relief areas (Goyal et al., 1999). Therefore, measured landscape heterogeneity in the image indicated how vegetation communities vary across space. Accordingly, heterogeneity from Radarsat image indirectly showed vegetation variation.

5. Conclusions

In a HH polarization SAR image, the information from vegetation canopy is very weak (Bindlish and Barros, 2001). However, textural measurements, like contrast, mean, and correlation, can be applied to detect field heterogeneity through measuring the variation of soil moisture and topography. They could be used to predict heterogeneity of standing dead cover, grass biomass, and bareground cover. This study indicated that about 40% to 80% of field level grassland heterogeneity can be estimated through RADARSAT-1 SAR data through texture analysis. Other studies have concluded that cross-polarized (HV or VH) channel is better for vegetation study (Bindlish and Barros, 2001; Buckley, 2004; Goyal et al., 1999; Hill et al., 1999; Kasischke et al., 1997).Buckley (2004) simulated Radarsat-2 image to study prairie landscapes classification and found that VH and HV polarization are good at detecting vegetation canopy and structure. Therefore, VH and HV polarization Radarsat-2 image will be investigated for the same study area.

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