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Characteristics of Spatial Distribution of Vegetation Coverage in Grassland of the Bayan Soum, Mongolia

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Abstract: The semi-arid steppe of Bayan, in the central eastern part of Mongolia, was chosen for a field investigation in this study. In this area, the grassland occupies 96% of the whole area, and the economy strongly depends on livestock production. Therefore, the land is mainly used for grazing, as it constitutes around half of the population's livelihood. In recent years, unmanaged pastureland use is causing many issues in the area.

In order to improve the problematic land overuse of grassland, it is important to understand the spatial distribution of vegetation coverage. We studied the characteristics of the spatial distribution of the vegetation coverage in the Bayan soum area using the percentages of grass coverage in the field sampling data. Land cover surveys were carried out at 200 sites in the ground survey area in the summer of 2010. Photos of ground covering 1 m^2 were taken to compute the percentages of ground surface components such as green grass, dried grass, bare soil and shadows.

A geostatistical analysis was conducted to examine the spatial correlation of the vegetation coverage. The results indicated that remote sensing at high resolutions, such as spatial resolutions at less than 130 m, are necessary for pastureland use planning based on the vegetation coverage, particularly for green grass cover. The semivariograms also illustrate that the spatial distribution of vegetation coverage is related to differences in soil type and elevation.

Key Words: Geostatistics, Image classification, Semi-arid, Semivariogram analysis, Vegetation coverage

1. Introduction

Previous studies on the vegetation coverage in the grasslands of Mongolia have been focused on identifying the composition of plant species, the yields of plants, and monitoring the pastureland changes using remote sensing. In our research, geostatistics was applied to analyze and describe the characteristics of the spatial distribution of vegetation coverage. The geostatistics are a well-understood and frequently applied image processing technique (Jakomulska and Clarke, 2001). The variogram is the corner stone of geostatistics (Richard and Margaret, 2007).

Using semivariogram to determine what the minimum spatial resolution of remote sensing or ground data should be for a particular study is recommended (Curran, 1998). They are commonly used in geostatistics to describe the spatial autocorrelation as a function of the distance between the sample points (Isaaks and Srivastava, 1989). In remote sensing, the semivariogram is also useful for estimating the appropriate spatial resolution required for remotely sensed images. To choose a satellite image resolution, information is required on the spatial characteristics of the surface being investigated. Regarding the geostatistical measure of the semivariogram range is an appropriate method to select the optimal resolution of satellite imagery, instead of using inappropriate resolution of satellite imagery. After characterizing the spatial distribution of the vegetation coverage, we can readily find an appropriate resolution of satellite imagery, not only using high spatial resolution satellite data, but also moderate and low spatial resolution satellite data. Thus, examining the resolution of satellite data using semivariograms is helpful. After choosing the appropriate spatial resolution satellite data, land managers and herders can use the estimate from the spatial distribution of vegetation cover in areas of different productivity to plan pastureland utilization efficiently. As well, the pastureland use planning with locations of from these designs along with the seasonal campus and the moving distances of livestock are beneficial. Moreover, as many authors have reported, different land cover types usually have different variogram patterns, and also our hypothesis was that the spatial distribution of the vegetation coverage may have dependent on different environmental conditions.

The objectives of this study are 1) to characterize the spatial distribution of the vegetation coverage and 2) to determine the influences of environmental factors on the spatial distribution of vegetation coverage in grassland.

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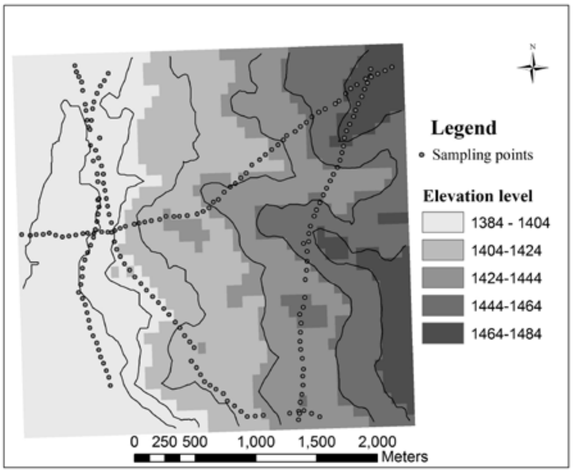

Fig. 1. Map of the ground survey area with sampling points.

2. Materials and Methods

2.1. Study area

Bayan soum (N 46°50'- 47°20', E107°10' - 108°20') is located in the Tuv province of Mongolia. The primary land use is grazing land. Poor management of pastureland is causing many issues in the area. Bayan soum has an annual precipitation of about 190 mm. Average annual temperature is -1.5-2°C and the temperature difference between summer and winter the year is 43°C. The average temperature has increased by 1.5°C during the last 40 years (Institute of Meteorology and Hydrology, 2009). For collecting field samples, a 3 km × 3 km ground survey area was selected in the central part of Bayan soum (**Fig. 1**). The altitude of the ground survey area ranged from 1380-1460 m above sea level. According to the soil map of the study area, the ground survey area has three different kinds of soil types: 1) sandy loam with gravel, 2) sandy clay loam with gravel and 3) sandy clay loam with saline. According to our field study, the dominant plant species are *Stipa krylovii* and *Artemesia adamsii*, followed by Cleistogenes songorica, Scorzonera divaricata and Elymus chinenses.

2.2 Data collection and pre-processing

The field survey was conducted on July 23rd, 2010, and 200 ground data points were sampled and ground surface conditions were recorded with a digital camera along four transects. The ground cover data were derived from photos of a 1 m^2 grid area in the ground survey. These photos were analyzed using Paint Shop Pro 6 for image rectification and MultiSpec for an unsupervised classification of digital photos to determine the percentage of four ground cover components; green grass, dried grass, bare soil and shadows. A 1:100 000 soil map of Bayan soum from the Institute of Geoecology in Mongolia and a Digital Elevation Model were used to characterize the spatial distribution of the vegetation coverage depending on the different soil type and elevation.

The percentage of vegetation cover is one of the most important indicators in quantifying grassland productivity and it has also been linked to soil protection (Avaadorj and Baasandorj, 2007). We measured the green grass, dried grass, and the total grass cover which was the sum of green and dried grass cover. It should be noted that livestock eats both green grass and dried grass during different times of the year since the grass only grows during the short summer in Mongolia. Therefore, the condition of the pastureland vegetation depends on both natural factors and human activities (Erdenetuya and Bolortsetseg, 2004). From the agro-meteorological point of view, the main environmental factors for plant growth are heat, moisture, light and nutrients in soil (Erdenetsetseg, 2004). The nutrients themselves depend on water in the soil. For this reason, the characteristics of the spatial distribution of vegetation coverage have been considered in the three regions with different soil types or in the two ranges of altitudes (higher area or lower area) in the ground survey area in this study.

2.3. Statistical methods

The spatial correlation of the vegetation coverage data were studied using semivariograms defined as follows: The semivariance function $\gamma(h)$ is equal to half of the expected squared difference between the values at locations separated by a given lag, h. It is used to express the spatial variations (Journel and Huijbregts, 1978). The spatial analysis used the empirical with a semivariance estimated by Eq.1 :

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[Z(x_i) - Z(x_i + h)^2 \right] \qquad \text{(Eq.1)}$$

Where $\gamma(h)$ is the sample semivariance; $N(h)$ is the number of sample pairs at each distance interval h, and $Z(x_i)$ and $Z(x_i + h)$ are values of the vegetation coverage at locations separated by distances of vectors h.

Surfer 7.0 software was used to produce appropriate models of the semivariograms which have sill and range parameters. Models of semivariogram have been fitted without nugget effect, so the nugget equals 0. The range is the important parameter in this study and it is the separation distance where the semivariogram levels off, indicating the affected scope of the regional variable. The range provides a measure of the distance around at point in which the spatial interpolation or processing is valid (Zawadzki *et al*., 2005) and it defines the distance beyond which the ground resolution elements are independent of each other (no autocorrelation) (Curran, 1988). The sill is the value of semivariogram at the point at which it levels off. We obtained the exact value of actual lag distance after calculating distances between the four

Table 1. Ranges of the all fitted semivariograms.

Semiariograms	Ranges
Green grass	130
Dried grass	170
Total grass	110
Green grass in 1380-1420 m elevation	250
Dried grass in 1380-1420 m elevation	300
Total grass in 1380-1420 m elevation	90
Green grass in 1420-1480 m elevation	125
Dried grass in 1420-1480 m elevation	150
Total grass in 1420-1480 m elevation	80
Green grass in sandy loam gravelly soil	90
Green grass in sandy clay loam gravelly soil	No range defined
Green grass in sandy clay loam saline soil	50
Dried grass in sandy loam gravelly soils	160
Dried grass in sandy clay loam gravelly soil	No range defined
Dried grass in sandy clay loam saline soil	30
Total grass in sandy loam gravelly soil	80
Total grass in sandy clay loam gravelly soil	No range defined
Total grass in sandy clay loam saline soil	50

lines with points in the ground survey area using Arc GIS 9.3 software. We used both a maximum lag interval of 500 m, which is 2/3 of the actual lag distance and also a lag interval of 1000 m. In these semivariograms, the Gaussian model was generally the best fitting model, followed by the spherical and exponential model. In each case, in order to determine the range, only the best-fitting model of semivariogram was chosen.

3. Results

Each of the three biomass types (green grass, dried grass and total grass) showed differences in their spatial correlation in the all the ground survey data and area, as determined by their semivariances. They show clear differences when areas with different environmental factors were considered separately. Ranges of the all the fitted semivariograms were plotted in **Table 1**.

3.1. Spatial distribution of vegetation coverage in the whole ground survey area

The fitted semivariogram model reveals that the range of the green grass is 130 m, but the range of the dried grass was longer, reaching 170 m. The range of the spatial correlation for the total grass was just 110 m; smaller than those of green grass and dried grass. These semivariograms indicate that points less than 130 m apart have a more similar percentage of green grass cover, and the points less than 170 m and 110 m apart have a more similar percentage of the dried grass and total grass cover, respectively.

As was introduced in the methodology, the range of the semivariogram will be used to determine an optimal resolution with remote sensing imagery for vegetation monitoring study, with consideration of area having different environmental conditions such as different elevations and the different soil types.

3.2. Spatial distribution of vegetation coverage in 2 areas with different elevations

The results suggest that the spatial correlation of green grass cover at low altitudes is higher than that of the higher altitude. More specifically, at lower altitudes, green grass cover is spatially correlated up to a distance of 250 m compared with 125 m for higher altitudes. For example, green grass in low elevation area shows the largest range and the average vegetation percentage had more density that in the low elevation area.

Dried grass had relatively a larger spatial correlation than the other vegetation coverage, as compared with the previous semivariograms. Dried grass at different elevations also has different spatial correlations and again the lower elevations had larger range parameters. At both low and high elevations, the spatial distributions of total grasses are similar with ranges around 80 to 90 m.

3.3. Spatial distribution of vegetation coverage in three areas of different soil types

In this study, three soil types were considered. The fitted range for green grass was 90 m in sandy loam gravelly (SL gravelly), and 50 m sandy clay loam saline (SCL saline) soil. A very large range was found for dried grass coverage with SL gravelly soil. By contrast, its range was very small in SCL saline soils. Thus, it seems that dried grass cover is spatially correlated up to distances of around 160 m for SL gravelly soils, compared to that of only around 30 m for SCL saline soils. In addition, large variations from point to point of dried grass cover were observed in these semivariograms.

When the spatial distribution of total grass coverage was considered, the SCL saline soils once again had a lower range parameter than those of the SL gravel soils. Overall, the empirical semivariograms, estimated in terms of the soil types for vegetation percentage groups, were often rather variable, particularly for SCL gravelly soils.

4. Discussions

For all biomass types, the empirical semivariogram of the SCL gravel soils was showed a slight relationship. This may be due to an insufficient sample size when the area is divided into 3 groups according to soil types. It may also reflect the rather small size of the study area. Or, perhaps, other factors (such as the distribution of water in the landscape and its interaction with soil type) are affecting the results.

To determine the spatial resolution for each pixel in the remote sensing data, ground sampling points in that area were obtained from up to 130 m for green grass, 170 m for dried grass, and 110 m for the total grass on a per pixel basis. The optimal resolution satellite data would be at maximum 130 m, according to the semivariogram patterns of green grass coverage, because the range is reaches to 130 m of lag distance. For this reason, our results suggest that more than 130 m resolution data can provide only summary information on grassland through whole study area, whereas with high resolution data with less than 130 m resolution would make it possible to study the fundamental spatial distribution of vegetation coverage, namely the individual zones with different vegetation productivity. Spatial resolution remote sensing imagery with a pixel size of 130 or less, allows vegetation productivity mapping which would be useful for pastureland use planning in different utilization zones. Although clearly the optimal spatial resolution is dependent on the pixel size of vegetation area in the image, typically a pixel size of 130 m or smaller has been found necessary for individual-vegetation remote sensing in most study regions. If the correlation of the ground data is small, we need more precise resolution of satellite data. For instance, a vegetation monitoring study with a percentage of green grass in sandy clay loam saline soil requires a spatial resolution of remotely sensed data which should not be higher than the spatial characteristics of the vegetation percentage for this area. Thus, a similar percentage of data points recorded closely together at 90 and 50 m, the high spatial resolution satellite data with 90 and 50 m of pixel size are preferred in an area with green grass in sandy loam gravelly soil and green grass in sandy clay loam saline soil, respectively.

5. Conclusions

The followings are concluded from this research:

1) Remote sensing at a high resolution, such as spatial resolutions of less than 130 m (e.g. ALOS AVNIR-2, ASTER), is necessary for proper land use planning of pastureland based on a spatial distribution of the vegetation coverage, particularly green grass cover.
2) Remote sensing images with geostatistical analysis would allow pastureland managers to plan more efficiently, and then to help herders move to areas by means of efficient and sustainable grazing.
3) These semivariograms also show that vegetation coverage is strongly dependent on soil types and elevations. Spatial distributions of vegetation coverage in the study site are different depending on the different environmental conditions such as soil type, and elevation.
4) The water flow and water content in the landscape may interact with soil type and affect plant growth. Sample points in SCL saline soils generally had higher green grass cover than points in SCL gravelly soils. However, SL gravelly soils in the catchments benefit plant growth. Although there were only small numbers of samples, the area of SL gravelly soils showed an unexpectedly higher percentage of green grass cover. This could result from enough water flow due to landscape characteristics such as shallow valleys in this area.
5) The regions with different characteristics of spatial distribution of vegetation coverage make it difficult to distinguish an optimal resolution of satellite imagery for vegetation monitoring in this area.

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