CHARACTERISTICS OF SPATIAL DISTRIBUTION OF ABOVEGROUND BIOMASS AND VEGETATION INDEX IN BAYAN SOUM, MONGOLIA

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ABSTRACT: The study was conducted on grasslands of Bayan soum, in which the primary land use is grazing. In recent years, unmanaged pastureland use is causing many issues in this area. In order to improve the land use management in grassland, it is important to understand the spatial distribution of aboveground biomass and vegetation index. We studied the characteristics of the spatial distribution of aboveground biomass in the Bayan soum using the vegetation biomass and vegetation percentage cover of the field sampling data, while a vegetation index (NDVI) was determined on satellite image of ALOS AVNIR-2. Land cover surveys for the vegetation percent cover were carried out at 200 sites in the ground survey area in the summer of 2010 and field work for vegetation biomass were conducted at 50 sited in the ground survey in the summer of 2011. Photos of ground cover of 1 square were taken to compute the percentages of ground surface components such as green grass, senescent grass, bare soil and shadows but vegetation biomass was sampled in 1 square m area basis for the biomass measurement. Geostatistical analysis was applied to examine the spatial correlation of the aboveground biomass and values of vegetation index. By comparing the characteristics of spatial distribution of both aboveground biomass on ground survey areas and vegetation index values on satellite images, appropriate spatial resolution of satellite images were determined. The results indicate that remote sensing at high resolutions, such as spatial resolutions of less than 130 m, are necessary for land use planning based on aboveground biomass, particularly green grass cover. According to this analysis, ALOS satellite data was appropriate for pastureland use planning in this area. The semivariograms also illustrate that spatial distributions of vegetation index in different sites on which have different rates of pasture overgrazing may have very varied characteristics.

1. INTRODUCTION

Characteristics of the spatial distribution of aboveground biomass and vegetation values are needed to determine suitable resolutions of satellite images which would be applied to mapping of pastureland for land use planning. Besides determination of appropriate resolutions of satellite image data, it maybe a way to efficiently evaluate pastureland conditions over large areas. The primarily land use is grazing land and the economic condition in Bayan soum strongly depends on livestock production. However, poorly managed pastureland is causing many issues in the area. A better understanding of the spatial distribution of aboveground biomass is necessary to improve land use planning. We used semivariogram to analyze and describe the characteristics of spatial distribution of aboveground biomass in our research. Semivariograms are commonly used in geostatistics to describe spatial autocorrelation as a function of the distance between the points (Isaaks and Srivastava,1989). The semivariogram is also useful to estimate the appropriate spatial resolution required for remotely sensed images and its ranges determines the distance above which ground resolution elements are not related (Curran, 1988). The purpose of the semivariogram in my study is to investigate spatial correlation of aboveground biomass in grassland. In our dataset, aboveground biomass means both vegetation percentage cover (%) and vegetation biomass (g/m^2). In addition, the evaluation of performance of the vegetation index for estimating vegetation cover and vegetation biomass in grassland is important for grassland studies using remote sensing. For this reason, NDVI (Normalized Different Vegetation Index) was applied for derivation of a vegetation index from the satellite image. The primary objective was to estimate potential applicability of remote sensing data for different spatial distributions of aboveground biomass in grassland. For more detailed objectives, we aimed to characterize not only the spatial variability of aboveground biomass, but also to define the spatial distribution of a vegetation index such as the Normalized Difference Vegetation Index (NDVI).

2. MATERIALS AND METHODS

2.1. Study area, ground survey areas and field samplings : Bayan soum in the central part of Mongolia (N46^{o}50^{I}- 47^{o}20^{I}, E107^{o}10^{I} - 108^{o}20^{I}) was chosen for study area. To determine applicability of remote sensing data for assessing land productivity, two different ground survey areas in grasslands in the Bayan soum were selected for the field investigation, and three different test sites in this area also were chosen from NDVI map of study area.

The field survey to measure vegetation percentage cover in the site 1 was conducted on 23 July, 2010, over a 3 km x 3km area (Fig 1, site 1) Vegetation photos for 200 ground points were been taken from 1 square m areas along four transects which have been established in different directions at the site. Field samples for determination of vegetation biomass were collected at the site 2 in the eastern part of the bayan soum. Samples were collected on 19th August, 2011, (Fig.1, site 2). Three transect lines have been established in different directions at the site. All together 54 points of biomass samples have been at the site 2 and vegetation biomass (g/m^2) were measured on a 1 square m area basis. In addition, three test sites were selected in a NDVI map of study area. Those representative example sites has potential to present different rates of grazing, namely non-degraded, moderately degraded, severely degraded, according to a vegetation map of Bayan soum with pastureland overgrazing rates which is estimated by researchers of the Institute of Geoecology, Mongolia.

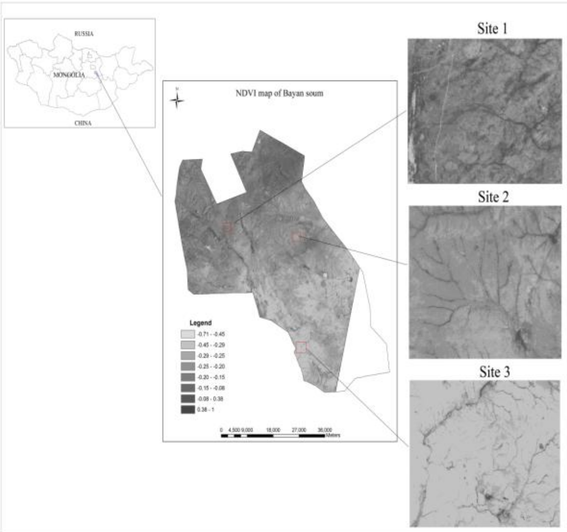

Figure 1. Location of the study and ground survey areas

2.2 Data pre-processing and image acquisition: All of the recorded measurements of vegetation biomass and percentage of vegetation cover in each 1 square and the calculated NDVI were applied in this semivariogram analysis. All of vegetation photos were analyzed with Paint Shop Pro 6 for image rectification and MultiSpec software was applied for unsupervised classification of digital photos to determine the percentage of four ground cover components; green grass, senescent grass, bare soil and shadows. Samples of vegetation biomass commonly referred to as 'dry matter yield were dried in oven. After this, final values of vegetation biomass on an area basis were recorded. ALOS AVNIR-2 satellite image with a pixel resolution of 10 m which is observed on August 29, 2010 was used to determine value of vegetation index (NDVI) using ERDAS imagine 9.1 in this data processing.

2.3. Statistical methods: The spatial correlation of aboveground biomass and NDVI data were studied using semivariograms defined as follows. The semivariance function $\gamma(h)$ is equal to the half of expected squared difference between values at locations separated by a given lag, h. It is used to express spatial variations (Journel and Huijbregts, 1978). The spatial analysis used the empirical the 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 aboveground biomass at locations separated by distance of vector h. Surfer 7.0 software was used to produce appropriate models of semivariograms which have sill and range parameters. Models of semivariogram have been fitted without nugget effect, so the nugget equals 0. The sill (c_0) is the value of semivariogram at the point at which it levels off. The range (a_0) is the separation distance where the semivariogram levels off, indicating the affected scope of the regional variable. The range also can be used as a measure of spatial dependency, or homogeneity, whereas sill reflects amount of variability (Warren B Cohen et al, 1990). Threfore, the range provides a measure of the distance around at point which spatial interpolation or processing is valid (Zawadzki.J et al, 2005). We obtained the exact values of actual lag distances after calculating distances between the lines of transects with points in ground survey areas using Arc GIS 9.3 software. For each of the aboveground biomass and vegetation index, results are shown using the actual lag distances. The actual lag distance equals to lag interval of 1000 m for percentage of vegetation cover and 550 m for vegetation biomass in the ground survey areas, whiles the actual lag distances was from 1100 m to 1600 m have been applied for determination of characteristics of the spatial distribution of vegetation index in the three different overgrazing rates for pastureland. In these semivariograms, Spherical, Gaussian and Exponential models were considered; only best-fitting models are shown in each case. The Gaussian model was generally the best fitting model, followed by the spherical and exponential model.

3. RESULTS AND DISCUSSIONS

Each of the percentage of vegetation cover (green grass, senescent grass and total grass), vegetation biomass are shown in their spatial correlation in the all ground survey data and areas, as determined by their semivariances, while values of vegetation index (NDVI) is shown with its characteristics of the spatial distribution. In addition, comparison of the characteristics of spatial distribution of percentage of vegetation cover on the ground survey and values of vegetation index on satellite image have considered in this results and discussions section.

3.1 Spatial distribution of aboveground biomass in the ground survey areas: In this section, characteristics of spatial distribution of both the percentage of vegetation cover and vegetation biomass were considered and four empirical and fitted semivariograms for the aboveground biomass in the ground survey areas were plotted in Fig 2, 3, 5 and 6. Percentages of senescent grass (Fig.2) are spatially correlated up to a distance of 130 m, but the semivariogram model reveals that the range of green grass (Fig.3) was longer than the green grass, reaching 170m. Fig.4 indicates that the range of spatial correlation for the total grass was just 120 m (Fig 3), smaller than those of green grass and senescent grass. More clearly, these semivariograms (Fig 2, 3 and 4) indicate that points less than 130 m apart have more similar percentage of green grass cover, and the points less than 170m and 110m apart have more similar percentage of the senescent grass and total grass cover, respectively.

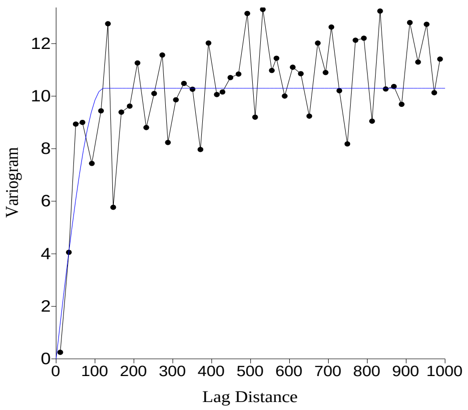

Figure 2. Semivariogram of green grass in the ground survey area 1.

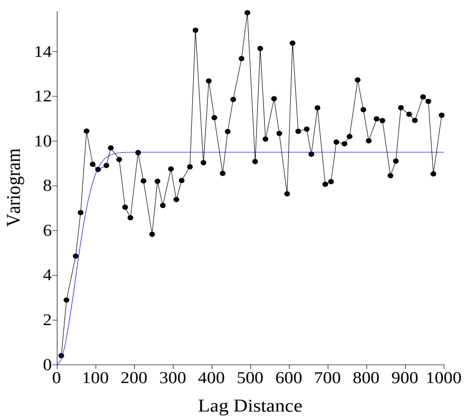

Figure 3. Semivariogram of senescent grass in the ground survey area 1.

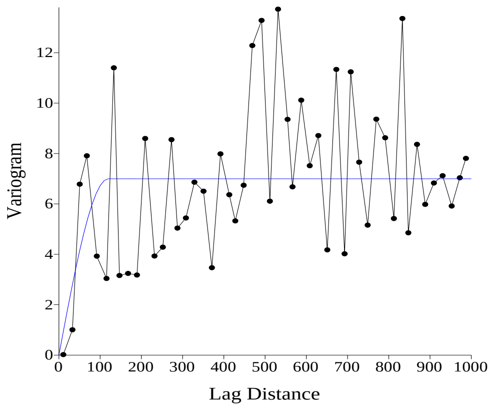

Figure 4. Semivariogram of total grass in the ground survey area 1.

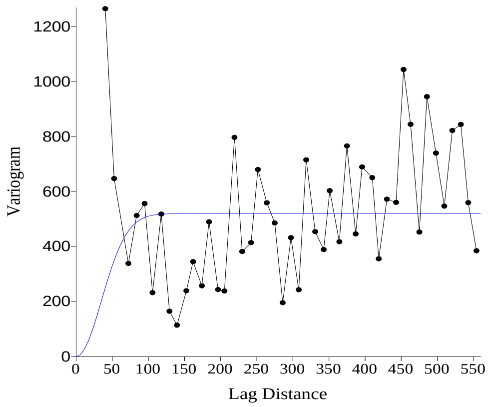

Figure 5. Semivariogram of vegetation biomass in the ground survey area 2

For all aboveground biomass types, the semivariograms (Fig 2, 3, 4 and 5) suggested the spatial distribution of percentage of vegetation cover with all of green grass, senescent grass and the total grass is higher than the spatial distribution of vegetation biomass. Specifically, the ranges of the semivariograms for vegetation biomass revealed no relationship and its range is no-well defined (Fig 5). For this reason, more precise resolution of satellite images would be useful for grassland studies which are related to vegetation biomass than the percentage of vegetation cover (Figure 5)and satellite data with large scales are less potentially useful for vegetation biomass monitoring.

3.2 Spatial distribution of values of vegetation index (NDVI) on satellite images in the three different overgrazing rates of pasture:

The spatial variation of NDVI which is derived from ALOS AVNIR-2 with 10 m resolution observed on 29 August 2010 was investigated by semivariogram. The semivariogram suggests that the spatial range of NDVI is 140 m using actual lag distance for the moderately overgrazed pasture. This is similar to the range of green grass coverage of field sampling on ground survey area 1. These semivariograms (Fig 6, 7 and 8) show that there are notable differences in the spatial distributions within the study area, for sites which have different rates of grazing pressure. Non degraded pasture had relatively larger spatial correlation than other degradation rates of pastures. The semivariogram for the moderately degraded area has 140 m range, whereas a very large range (570 m) was fitted for the non-grazed pasture. Those semivariograms (Fig 6 and 7) illustrated that the spatial correlation of vegetation index in non-grazed pasture area is higher than that of the moderately overgrazed pasture. The severely overgrazed pasture showed no relationship of spatial distribution between the sampling points. Livestock grazing pressure may strongly affect spatial distribution of vegetation biomass. It may also reflect rather densities of less vegetation. Or perhaps, ground elements are so different from the neighbors that it would be unsuitable for an appropriate satellite data selection for further analysis.

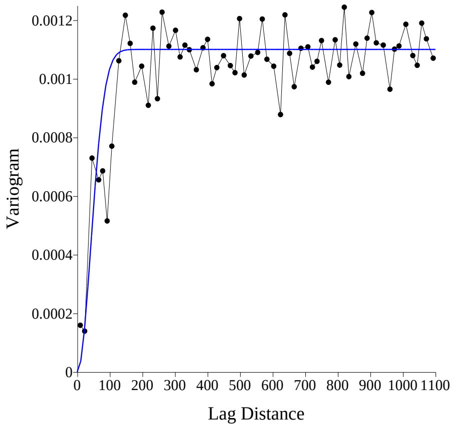

Figure 6. Semivariogram of NDVI at the moderately overgrazed pasture

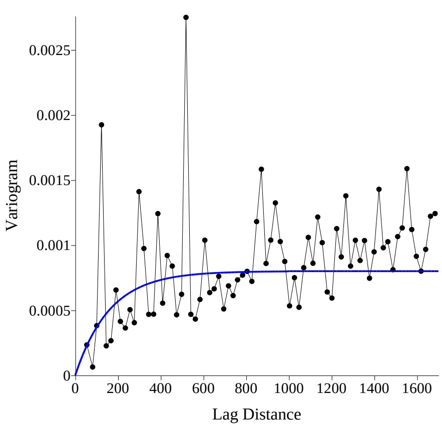

Figure 7. Semivariogram of NDVI at the non-overgrazed pasture

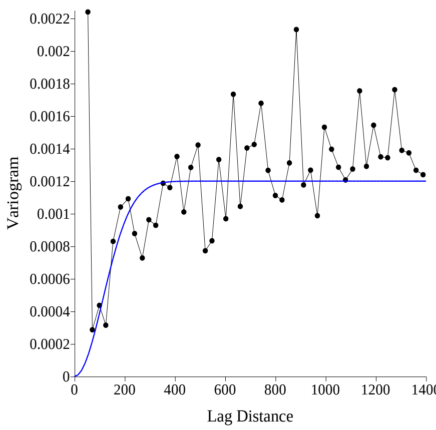

Figure 8. Semivariogram of NDVI at the severely overgrazed pasture

In moderately overgrazed pasture, ranges of the semivariogram were found to be 3-4 times lower than the non-overgrazed pasture. This suggested vegetation index in the non-grazed pasture has significantly highest spatial correlation, thus satellite images with wide frame of resolution are appropriate in this kind of area. Ranges of vegetation index in the severely degraded pasture showed in no-well defined range and in significantly less relationship. This suggests that satellite remote sensing data used in vegetation productivity mapping severely overgrazed pasture needs have a more precise resolution.

The ranges are reduced in the transition from non-overgrazed pasture to severely overgrazed pasture. Or perhaps, other factors are affecting the results, resulting in somewhat different density of vegetation in areas highly degraded by livestock grazing. Curran et al (1988) suggested that accurate ground data are required to calibrate remotely sensed imagery or to check accuracy of estimates made using remote sensed imagery. However, he suggests that due to the difficulties associated with sampling large areas in short time periods, the error in the ground data is usually high.

3.3 The comparisons between the spatial distribution of aboveground biomass and values of vegetation index: In this section, the comparisons between the spatial distribution of aboveground biomass of the field sampling and values of vegetation index on satellite image of remote sensing were discussed. The spatial correlation of green grass coverage (Fig 2) in ground data is lower than the spatial correlation of NDVI using ALOS AVNIR-2 at the moderately overgrazed pasture (Fig 6), whereas NDVI in non-overgrazed pasture has high spatial correlation (Fig 7). These semivariograms also show that the characteristics of spatial distribution of percentage vegetation cover is similar with to characteristics of values of vegetation index. In particular, their semivariograms showed the same ranges. The spatial distribution of pixel NDVI values from satellite image ALOS AVNIR-2 indicated that pixel size variations were similar to spatial distribution of percentage of green grass in the ground survey area which has been moderately degraded. The differences of these values are similar to about 10m.

4. CONCLUSIONS

Followings are concluded from this research.

1) This research suggests that satellite image on remote sensing data would be useful for vegetation monitoring study. Considering this study area, satellite data with less than 130 m resolutions would be needed for vegetation monitoring on grasslands, using both percentage of vegetation cover and vegetation index.
2) Remote sensing data with spatial resolutions that are less than 130 m (e.g. ALOS AVNIR-2, ASTER), would be useful for pastureland use planning based percentage of vegetation cover. However, the ranges of green grass in ground data and NDVI at the moderately overgrazed pasture were similar when ALOS AVNIR-2 satellite is applied.
3) The maximum spatial resolution would probably around 560 m, 140 m and less m, respectively, for the non-overgrazed, moderately overgrazed and severely overgrazed pasture. Thus, remote sensing data with a precise resolution is preferred for the vegetation biomass related study in this area.
4) Therefore, we conclude that the evidence of regions with different characteristics of spatial distribution of aboveground biomass and vegetation index makes difficulty to distinguish appropriate spatial resolutions for vegetation monitoring throughout this study area. More specific studies and field samplings are needed to clarify and assure these conclusions.

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