INVESTIGATION OF GRASSLANDS BIOMASS IN MONGOLIA WITH MODIS AND ICESat/GLAS MEASUREMENTS

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Abstract

Degradation of Mongolian grasslands has led to the significant loss of livestock in the 2010 winter disasters (so-called *dzud* in Mongolia), with losses of around 8.5 million. Thus, spatial distribution of biomass is urgently required for productive and efficient nomadic herding. Since grasslands spread over an extensive area in Mongolia, remote sensing, backed up by ground survey, is a promising means for monitoring these lands. In this study, the amount of grassland biomass is estimated and demonstrated by using the shadow index (SI) from MODIS, in addition to that from ICESat/GLAS measurements representing 3D structure of grasslands. Firstly, land cover classification is carried out by applying SI and vegetation indices from MODIS to grasslands map across Mongolia from 2001 to 2012. Secondly, the height of grass is estimated by ICESat/GLAS measurement to draw out an empirical equation. This procedure is supported by in-situ measurement of grass heights and biomass, using geo-located match up database. Finally, the derived equations are applied to estimate the amount of biomass and the height of grass, by assuming and evaluating their seasonal and annual changes.

1. INTRODUCTION

1.1 Background and objective

In the recent years, winter disaster known as *dzud*, featuring heavy snow and low temperatures, has widely caused freeze and starvation damages to livestock in Mongolia. The livestock of approximately 8.5 million (20 percent of all livestock in the nation) was lost in the 2010 *dzud* disaster (IFRC, 2010). In addition, reports predict that livestock mortality is likely to increase when a harsh winter follows a drought in the previous growing season (Begzsuren et al., 2004) because livestock cannot survive winter without enough stock from the previous growing season. Real time spatial information on grassland condition is, therefore, essential to minimize damage from future *dzud.* Mapping biomass will be a crucial information to herders.

Field survey is the most accurate method for obtaining vegetation information, but is too time-consuming and costly to cover large expanses. Satellite remote sensing is useful for gathering information regarding surface conditions iteratively and also over a wide area. Many remote sensing studies deal with vegetated areas, such as the evaluation of vegetation phonological pattern using NDVI (Lee et al. , 2002), the prediction of plant diversity by vegetation condition from MODIS (Ranjeet et al., 2007), the detection of *Poaceae* grass abundance in Mongolian grasslands (Shimada et al., 2012) and the estimation of vegetation coverage (Muramatu et al., 2007). Many studies have made estimations on biomass using remote sensing, mainly focusing on correlation between NDVI and biomass using NOAA AVHRR data and Landsat TM (Calvao and Palmeirim, 2004; Kawamura et al., 2003; Kogan et al., 2004; Xie et al., 2009). However, in order to estimate the amount of biomass, evaluating 3D structure of grassland is necessary, in addition to spatial evaluation such as NDVI.

This study, based on a correlation of NDVI value from MODIS and biomass value by ground survey in Mongolian grasslands, has made estimations on the amount of biomass, reviewing the effects of the shadow index (Ono et.al.,2009) from MODIS, and also of ICESat/GLAS measurements that describe 3D structure of grasslands.

2. METHODOLOGY

2.1. Study site and biomass measurements

Investigation was conducted in the pasture and semi-desert areas in four prefectures around the city of Ulan Bator in Central Mongolia (Fig. 1.). Ground surveys were performed in August 2003, 2004, 2006, 2007 and 2012 (Table 1). Vegetation in Mongolia is mainly grassland. Annual precipitation is below 400 mm, around 80% of which occurs between June and August in Central Mongolia. Recent grassland degradation, due to overgrazing and expansion of cultivated land, has become a problem in the areas near Ulan Bator (Yoshihara et al., 2008; Hoshino et al., 2009). Lands for survey were chosen from different kinds of land use and miscellaneous kinds of vegetation.

In order to measure the above-ground biomass, the 50 m quadrat was established, from which three arbitrarily sub-quadrat (1 m square) were selected within each 50 m quadrat for each site. In 2012, one sub-quadrat was selected. First, the height above-ground grass was measured and then grass was cut within each sub-quadrat. Above-ground dry biomass (AGB) was calculated by “oven-drying”. The average value was used as ABG and grass height respectively for each site. In order to understand the land use of the survey sites, nomads who live in the neighborhood were interviewed each year, with the exception of 2012.

2.3. Satellite data

The terra/MODIS data from Institute of Industrial Science, University of Tokyo (IIS/UT) was applied in NDVI at each survey site in August 2003, 2004, 2006, 2007 and 2012. The MODIS data used in this study was 8 or 16 days composite; therefore the MODIS data that was the closest to the date of ground survey was selected each year. For the shadow index (SI) , MODIS surface reflectance (MOD09) from Boston University was used. SI was calculated, using band of visible to short wave infrared, obtained from the following equation;

$$SI = \frac{1}{\frac{1}{6}\sum_{i=1}^{6} Band_i} \qquad i = 1\text{-}4,\ 6,\ 7$$

where i is band number of MODIS data (band number i = 1 to 4, 6 and 7).

Regarding ICESat/GLAS data, analysis data to calculate the grass height based on elevation data was provided by ICESat/GLAS.

3. RESULTS AND DISCUSSIONS

Table 1 shows the result of ground survey. The above-ground dry biomass (AGB) has shown different values on the same site in 2004, 2006 and 2012, as shown in sites S and L. The influence of precipitation has been considered the cause because sparse summer precipitation and the resulting lack of soil moisture has depressed vegetation growth (Kondoh et al., 2005). It is suspected that ABG increased because the precipitation amount was particularly high in 2012.

The regression analysis was performed, using and the above-ground dry biomass (AGB) and NDVI. Although weak positive correlation was observed between AGB and NDVI (fig. 2.), no relationship between AGB and the shadow index (SI) was found. This study on the relationship between AGB and grass height has shown, a linear relationship (Fig. 3.). Therefore, it is predicted that AGB and 3D structure of grass has significant correlation.

In order to improve the estimating biomass, the ABG value of each site should be revised statistically after taking into account the ratio of vegetation and soil in the corresponding pixel of survey position. In the future, we will work on drawing grass height values from ICESat/GLAS data.

4. CONCLUSIONS

This study, based on a correlation of NDVI value from MODIS and biomass value by ground survey in the Mongolian grasslands, made research on the effect of shadow index from MODIS representing 3D structure of grasslands for the purpose of estimating biomass amount. Conclusions were as follows:

- Weak positive correlation was found between above-ground dry biomass (AGB) and NDVI, but no relationship was observed between AGB and the shadow index (SI).
- The significant relationship between AGB and height of grass suggests that the 3D structure of grass may provide valuable information in estimating AGB.

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Fig. 1. Locations of study site in Mongolian grassland

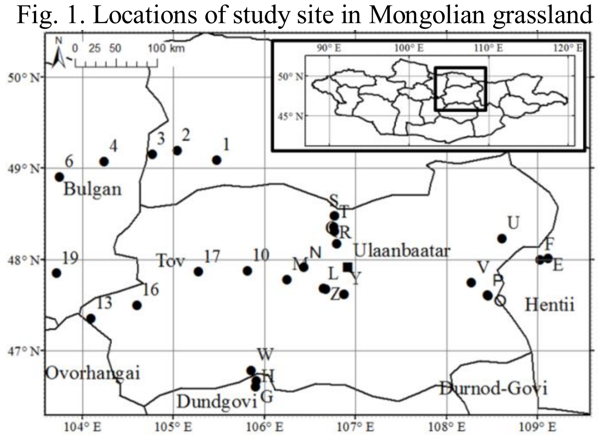

Table 1. Location information and Land use of Ground survey

Site	Longitude	Latitude	Date	Province	Land use	Above-ground biomass (g/m^2)	Grass height (cm)
M	106.24766	47.78298	20030809	Tov	Wintering	181.23	25.8
N	106.43601	47.91528	20030810	Tov	Grazing	30.21	11.27
O	108.45713	47.60261	20030813	Henti	Wintering	74.51	16.47
P	108.45061	47.61097	20030813	Henti	Wintering	94.64	24.48
Q	106.79481	48.17614	20040807	Tov	Grazing	181.23	29.81
R	106.77131	48.31146	20040807	Tov	Abandoned	201.37	24.83
S	106.76622	48.47848	20040808	Tov	Grazing	241.64	56.14
T	106.76330	48.35813	20040810	Tov	Grazing	191.3	13.47
U	108.61043	48.23344	20040814	Tov	Native grass	90.62	21.87
V	108.27030	47.74870	20040816	Tov	Native grass	30.21	10.8
L	106.64652	47.68292	20060809	Tov	Grazing	46.72	12.51
G	105.89939	46.60808	20060812	Dundgovi	Grazing	77.01	16.05
H	105.91423	46.67756	20060813	Dundgovi	Grazing	75.78	15.13
R	106.77131	48.31146	20060815	Tov	Abandoned	121.91	29.44
S	106.76622	48.47848	20060816	Tov	Grass collection	127.22	35.37
M	106.24766	47.78298	20070809	Tov	Wintering	63.03	10.89
W	105.85648	46.78864	20070813	Dundgovi	Grazing	45.73	22.65
N	106.43601	47.91528	20070813	Tov	Grazing	105.16	10.79
E	109.11491	48.01783	20070814	Henti	Native grass	93.87	17.76
F	109.02516	48.00251	20070814	Henti	Native grass	66.07	16.17
13	104.09452	47.36000	20120803	Tov	-	131.39	27.5
Y	106.87334	47.62414	20120803	Tov	Grazing	111.10	11.0
Z	106.67398	47.67663	20120803	Tov	Grazing	81.08	5.0
L	106.64652	47.68292	20120803	Tov	Grazing	115.33	6.5
10	105.81373	47.87972	20120806	Tov	-	62.34	10.0
16	104.59909	47.50193	20120806	Tov	-	218.91	25.5
17	105.27692	47.87061	20120806	Tov	-	101.09	7.5
3	104.76678	49.15970	20120808	Selenge	-	114.63	7.5
4	104.24095	49.07672	20120808	Bulgan	-	90.42	2.5
6	103.75209	48.90757	20120808	Bulgan	-	75.72	4.0
19	103.71428	47.85317	20120808	Bulgan	-	64.07	6.5
1	105.47408	49.09165	20120809	Selenge	-	59.38	5.5
2	105.03925	49.19693	20120809	Selenge	-	166.99	25.0
S	106.76622	48.47848	20120815	Tov	Grass collection	307.96	32.5

Fig. 2. Relationship between above-ground biomass by in situ measurement and NDVI from MODIS

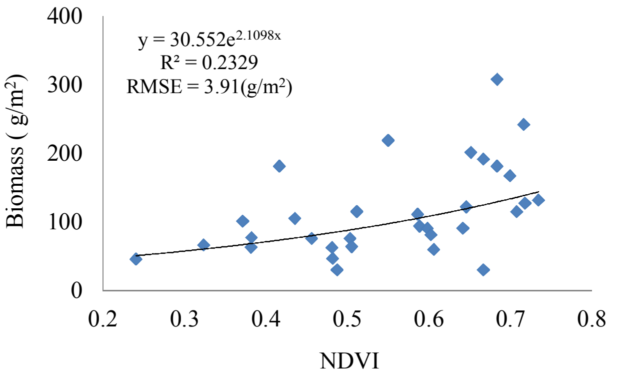

Fig. 3. Relationship between above-ground biomass and height of grass by in situ measurement