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Detection of Grassland Degradation Using MODIS Data in Mongolia

Ayako SEKIYAMA*[1], Wataru TAKEUCHI [1] and Sawahiko SHIMADA [2]

Abstract: In this study, we attempted to map the degradation of Mongolian grasslands using MODIS imagery and statistical data which is number and composition of livestock from 2000 to 2006. Firstly we generated the distribution map by MODIS LAI using a biomass estimation equation which was derived from in-situ measurement of biomass with a geo-located match up database. Secondly the amount of biomass which is the quantity required for feeding the livestock in each county was calculated using data on numbers of livestock over the same time period. Thirdly, degradation intensity was determined in overgrazed areas in which the number of livestock exceeds grazing capacity and use of many goats creates high grazing intensity. As result,19 counties were identified as at high risk for degradation of the grasslands. These areas are located in southern region of Mongolia.

Key Words: Biomass, Grassland degradation, Livestock composition, Overgrazing

1. Introduction

1.1. Background and objective

Livestock husbandry is key industry for nomads in Mongolia. However, in recent decades, global climate change and overgrazing have caused degradation of the grasslands in this country (Kawamura *et al*., 2005). Livestock mortality has occurred as a consequence of forage shortages caused by grassland degradation (Begzsuren *et al*., 2004; IFRC, 2010).

In traditional Mongolian nomadic grazing, it is known that livestock herds should be balanced with goat comprising no more than 30% of the herds because goats have the habit of grazing grass down to the roots. However the total number of goats has surpassed that of sheep since 2003 owing to the establishment of cashmere as a major export product around urban areas (Yoshihara *et al*., 2008; Hoshino *et al*., 2009). Thus, appropriate management of livestock grazing is needed for sustainable use of grassland and to preserve the grasslands from degradation.

Previous studies of natural environments using remote sensing technology include: evaluating phenological patterns of vegetation 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). On the other hand, some studies have discussed the grassland degradation using statistical data and research reports on livestock in the social environment (Lise *et al*., 2006). However, few studies have reported that grassland degradation is comprehensively discussed regarding natural and social environment.

This study attempts to map the grassland degradation from MODIS imagery with the number and herd composition of livestock present from 2000 to 2006.

2. Methodology

2.1. Data used

The biomass distribution map is generated using MODIS LAI (MOD15: Leaf Area Index and Fractional Photosynthetically Active Radiation) of Institute of Industrial Science, the University of Tokyo (IIS/UT) during summer (from June to August) from 2000 to 2006. In order to eliminate cloud Covered images and error pixel, the quality flags of all images were checked, and only images taken during clear condition were selected in order to generate the resulting map.

Statistical data of livestock used was obtained from the Mongolian Statistical Yearbook (2000-2006) of the National Statistical Office of Mongolia (NSOM). These data provide the numbers of sheep, goats, cattle, horses and camels in each county within the administrative boundary called *soum* of Mongolia. There are 347 counties in Mongolia.

2.2. Correlation between biomass and livestock numbers

The biomass distribution map was generated using MODIS LAI, then a biomass estimation equation (Biomass = $48.70e^{0.82LAI}$ R= 0.62) is applied to these images. This biomass estimation equation was calculated from correlation between in-situ biomass and LAI value from MODIS (Sekiyama *et al*., 2012). Next, total biomass in each county was calculated using biomass distribution map from 2000 to

* Corresponding Author: sekiyama@iis.u-tokyo.ac.jp
Ce-505, 4-6-1, Komaba, Meguro, Tokyo, 153-8505, Japan
(Present affiliation: Faculty of Regional Environment Science, Tokyo University of Agriculture, a3sekiya@nodai.ac.jp)
1) Institute of Industrial Science, the University of Tokyo 2) Faculty of Regional Environment Science, Tokyo University of Agriculture
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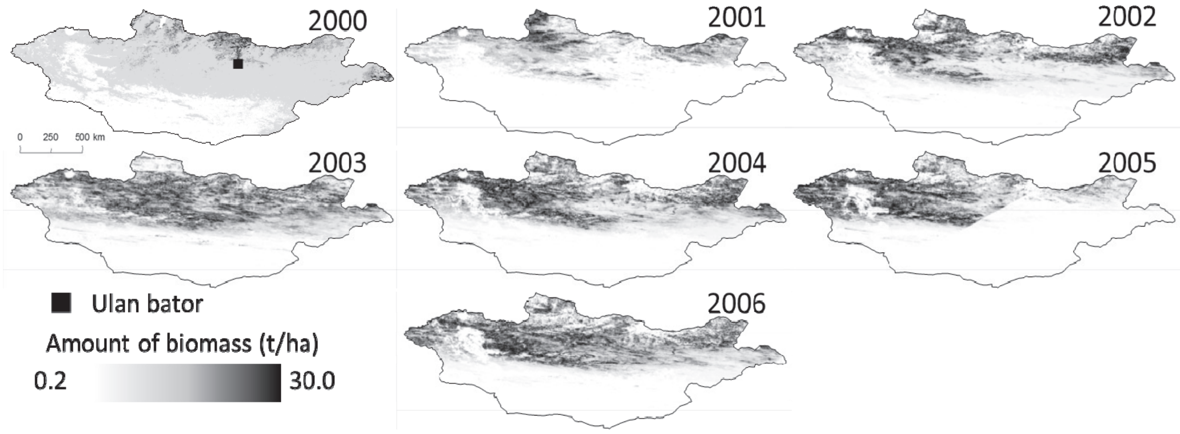

Fig. 1. Biomass distribution map using MODIS LAI of August from 2000 to 2006.

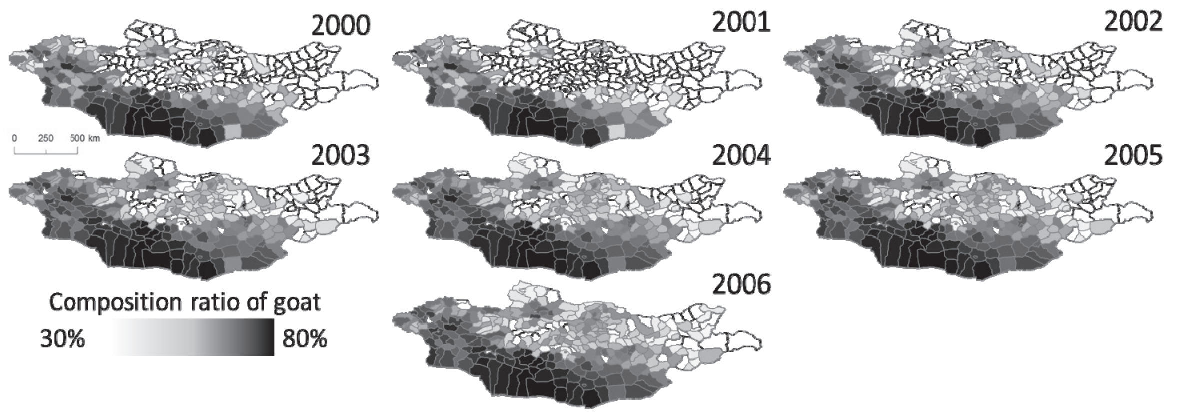

Fig. 2. High composition ratio area of goat from 2000 to 2006.

2006. Regarding the MODIS LAI product, land use data as parameter is used for generating LAI values, so pixels classified as bare soil and desert are assigned the value of 253 indicating as no leaf area. However, actually there is a small amount of vegetation in pixels classified as bare soil and desert. Therefore in this study, such pixels were given minimal biomass value for each year in the biomass distribution map from 2000 to 2006.

In order to extract areas of high risk as degraded grasslands, the grazing capacity was calculated in each county using biomass distribution map and ratio of goats in the herd compositions. First, grazing capacity is calculated by assessing the biomass of forage for livestock. As reported by JICA (Japan International Cooperation Agency), 560 kg of grass is needed for feeding sheep a year, and goat, cattle, horse and camel is 0.9 times, 6.0 times, 6.6 times and 5.7 times respectively for sheep case, so these criteria is used for required biomass amount for livestock feeding. Next, within counties grassland was defined as degraded if it was overgrazed by having inadequate forage for the number of livestock present and if the ratio of animals composing the herds was more than 30% goats, during 2000 to 2006. A map of grassland areas at high risk of degradation was generated.

3. Results and Discussion

Figure 1 shows biomass distribution map in summer from 2000 to 2006. In 2000 and 2001, biomass was low throughout the Mongolia, with only a small area of high biomass occurring in the northern region. It was reported that livestock mortality occurred in winter of these years and was caused by lack of grass. Thus it was possible to predict the probable risk of livestock mortality by investigating biomass distribution in summer. The significant decrease of biomass was not shown from 2002 onwards.

Figure 2 shows the distribution of areas with herd composition ratios with more than 30% of goats from 2000 to 2006. The distribution of herds with a high proportion of goats increased yearly and was distributed throughout Mongolia in 2006, except in the eastern region. Grazing of livestock has not been conducted in eastern regions of Mongolia because there are few lakes and rivers. Overgrazing was most widespread in 2000 and 2001 (**Fig. 3**), then declined in 2002, but has gradually increased after this

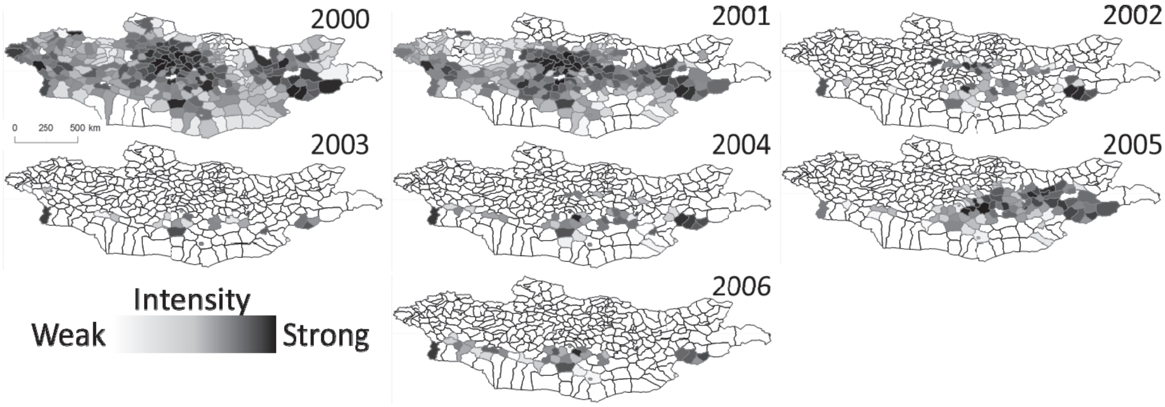

Fig. 3. Overgrazing area from 2000 to 2006.

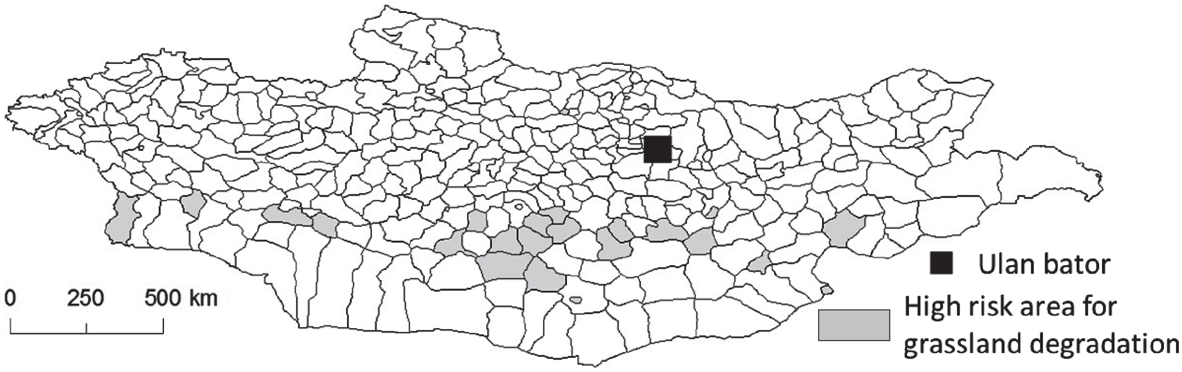

Fig. 4. High risk area for grassland degradation.

Calculated on the basis of goat composition ratio and overgrazing area from 2000 to 2006.

year. **Figure 4** indicates high risk areas of grassland degradation, with 19 counties being at high risk. All of extracted counties were located in the southern region.

Mongolia has the Govi desert in south of this country, north of the desert is a transition zone between grassland and desert (ecotone). The counties identified as having a high risk of grassland degradation are located in this transition zone. It is considered necessary to take immediate action because the transition zone is easily influenced by environmental changes such precipitation and heavy grazing pressure.

4. Conclusion and Future Works

Areas at risk of degradation of the grasslands were successfully identified by creating a biomass distribution map using MODIS LAI and relating this to the numbers of livestock. In particular, heavily grazed areas were characterized by areas in which goats make up more than 30% of the livestock numbers. This method identified:

- Changes in biomass throughout Mongolia from 2002 to 2006.
- An annual increase in herds comprising over 30% goats.
- Overgrazing was associated with low biomass production in 2000 and 2001 but thereafter overgrazing was associated with the increased proportion of goats in the herds.
- Nineteen counties were extracted as being at high risk of grassland degradation. These counties were located in the transition zone between grassland and desert.

Future work to augment the quantitative evaluation of biomass with evaluation the quality of grass, and vegetation classification will be conducted using in-situ spectral data and ALOS/avnir-2 as high resolution imagery.

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References

Begzsuren S., Ellis J.E., Ojima D.S., Coughenour M.B., Chuluum T. (2004): Livestock responses to droughts and severe winter weather in the Gobi Three Beauty National Park, Mongolia. *Journal of Arid Environments*, **59**: 785-796.

Hoshino B., Tamura K., Fujimaki H., Asano M., Ose K., Higashi T. (2009): Effects of crop abandonment and grazing exclusion on available soil water and other soil properties in a semi-arid Mongolian grassland. *Soil & Tillage Research*, **105**: 228-235.

International Federation of Red Cross and Red Crescent Societies (2010): *Mongolia: Severe winter Emergency*. appeal n° MDRMN004 GLIDE n° CW-2010-000010-MNG.

Kawamura K., Akiyama T.,Watanabe O., Hasegawa H., Zhang F., Yokota H.,Wang S. (2003): Estimation of aboveground biomass in Xilingol steppe, Inner Mongolia using NOAA/NDVI. *Grassland Science*, **49**: 1-9.

Kawamura K., Akiyama T., Yokota H., Tsutsumi M., Yasuda T., Watanabe O., Wang S. (2005): Quantifying grazing intensities using geographic information systems and satellite remote sensing in the Xilingol steppe region, Inner Mongolia, China. *Agriculture, Ecosystem & Environment*, **107**: 83-93.

Lee R., Yu K., Price K.P., Ellis J., Shi P. (2002): Evaluating vegetation phenological patterns in Inner Mongolia using NDVI time-series analysis. *Journal of Remote Senssing*, **23** (12): 2505-2512.

Lise W., Hess S., Purev B. (2006): Pastureland degradation and poverty among herders in Mongolia: Data analysis and game estimation. *Ecological Economics*, **58**(2): 350-364.

Muramatsu K., Xiong Y., Nakayama S., Furumi S., Ochiai F., Daigo M., Hirata M., Oishi K., Bolortsetseg B., Oyunbaatar D., Kaihotsu I. (2007): A new vegetation index derived from the pattern decomposition method applied to Landsat-7/ ETM+ images in Mongolia. *Journal of Remote Sensing*, **28** (16): 3493-3511.

Ranjeet J., Chen J., Lu N., Guo K., Liang C., Wei Y., Noormets A., Ma K., Han, Xingguo (2008): Predicting plant diversity based on remote sensing products in the semi-arid region of Inner Mongolia. *Remote Sensing of Environment*, **112** (5): 2018-2032.

Sekiyama A., Takeuchi W. (2013): Characteristics of Biomass from MODIS imagery response to precipitation in Mongolian grasslands. *Proceedings of 34the International Symposium on Remote Sensing*. (DVD-R).

Shimada S., Matsumoto J., Sekiyama A., Aosier B., Yokohana M. (2012): New spectral index to detect *Poaceae* grass abundance in Mongolian grasslands. *Advances in Space Research*, **50**: 1266-1273.

Yoshihara Y., Chimeddorj B., Buuveibaatar B., Lhagvasuren B., Takatsuki S. (2008): Effects of livestock grazing on pollination on a steppe in eastern Mongolia. *Biological Conservation*, **141** (9): 2376-2386.