

Land Degradation Assessment in Gobi-Altai Province

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ABSTRACT

Remote Sensing and GIS analyses were embedded to monitor interactions and relationships between land use and land cover changes in the regional ecological space of Gobi-Altai province (Western part of Mongolia). In the last 76 years, Mongolia has experienced a combination of societal and governance system changes in transitioning from the feudal system to socialism and then from the socialist system with centrally planned economy to market. Each of these resulted in changes natural resources use throughout the country. Using GIS processing of data such as climate data (precipitation, air temperature) and vegetation, socio-economic data (livestock numbers, population density) were analyzed. We focused on developing a modeling approach for monitoring land degradation using GIS and Remote Sensing tools by merging climate and quantitative socio-economic data. The Modified Soil Adjusted Vegetation Index (MSAVI) from SPOT/VEGETATION was used to define vegetation cover change for the period from 2000 to 2013. GIS conditional functions were applied for mapping and analyzing climate and socio-economic driving factors, both of which affect land degradation. Conditional functions such as MAP-Algebra from ArcGIS were developed using ground truth data and data from National Administrative Department of Statistics. Remote sensing data were useful diagnostic tools for providing gross impressions on broad-scale spatial heterogeneity, to assist in land degradation monitoring. This paper defines that study area is affected by land degradation caused by climate and socio economic impacts.

Keywords: socio-economic change, climate impact, biodiversity, grassland degradation, MSAVI

INTRODUCTION

Mongolia is now experiencing many social and ecological issues such as population density, urban expansion and an increase of livestock will be affect the environment. The territory is susceptible to climate change due to its geographic location, vulnerable ecosystems and an economy that is highly dependent on seasonal climates. In the past

40 years, climate change and other anthropogenic activities have had a significant impact on the Mongolian ecosystem, resulting in desertification, increased occurrences of drought, water source depletion, and a decrease in biological diversity as well as affecting the well-being of local communities. Several quantitative studies using the methods outlined in the UN's Convention to Combat Desertification (UNCCD) has shown that approximately 90% of pastureland in Mongolia lies within vulnerable regions that are susceptible to desertification (Banzragch and Enkhbold, Chapter 3.3) Kappas and Propastin et al. (2008) estimated that drivers can determine both anthropogenic (e.g. demographic change) and natural forces. Human induced activities can be changed by socio-economic factors, which increase or diminish pressures on the environment. The Gobi region of Mongolia remains a place where nomadic pastoralism has been practiced for millennia and continues to provide livelihoods for 30% of the rural population (Sternberg et al., 2009; Ulambayar and Fernandez-Gimenez, 2013). A limited amount of research has been conducted on land degradation in Mongolia, and information on factors that influence land degradation in areas such as in the Mongolian Gobi-Altai region are lacking. The objective of this research is to assess current trends in degradation and identify the driving factors affecting the land degradation in the Gobi-Altai province of Mongolia. Furthermore an understanding of the factors and drivers that cause degradation will be useful for monitoring and mitigation of degraded lands and assist in developing policies for land use management local and regional levels.

STUDY SITE

Mongolia is a unitary state and divided administratively into 21 *aimags* (provinces) and the capital city of Ulan Baatar. The work in this study focused on determining the land degradation drivers in 18 *soums* (administrative units) in Gobi-Altai province. Gobi-Altai province is situated in the western part of Mongolia. It borders the Zavhan *aimag* to the north, Bayankhongor *aimag* to the east, Khovd *aimag* to the west and China to the south. The total area is 141,448 km². The Gobi bears, wild camels, ibex and snow leopards are protected species in several national parks located in the province. Vegetation is scarce in this zone of sand dunes, drifting sands, while shrubs are common for this region.

METHODS

We developed methodology to characterize and to monitor land degradation using remote sensing imagery, in addition to socio-economic and climate factors. We applied MSAVI indexes to monitor vegetation change between 2000 and 2013. In order to analyze socio-economic and climate factors, conditional function MAP-Algebra from ArcGIS was applied. We used the CON function inside ArcGIS to compute the influence of driver combinations. We acquired Spot 4 Vegetation data at 1km resolution data served as the data source for vegetation greenness and its spatial occurrence. Using the SPOT 4 data, we calculated the Modified Soil Adjusted Vegetation Index (MSAVI) for each of the images. Huete (1998) first described the soil adjusted vegetation index (SAVI) which was designed to minimize the effect of the soil background. A further development of the SAVI is an iterated version of this index, which is called MSAVI modified soil adjusted vegetation index (Qi et al. 1994a, 1994b):

$$SAVI = \frac{NIR - RED}{NIR + RED + L} * (1 + L) \quad MSAVI2 = \left[2NIR + 1 - \sqrt{(2NIR + 1)^2 - 8(NIR - RED)} \right] / 2$$

where RED is the red band reflectance from a sensor, NIR is the near infrared band reflectance, and L is the soil brightness correction factor. The difference between SAVI and MSAVI, comes in how L is calculated. In SAVI, L is estimated based on how much

vegetation there is (but it's generally left alone at a compromise of 0.5). The parameter L varies between 0 and 1 with lower values indicating denser vegetation conditions. The impact of socio-economic factors on land degradation was defined by looking at the number of livestock from statistical data (e.g. sheep's, horses, goats, and camels), the human population figures, and climate impact from Metrological data (precipitation and temperature variation). The MSAVI, livestock and human population and temperature variables were used in a GIS model to calculate an index of land degradation. Using ESRI ArcGIS software, we developed a tool to calculate the index using Algebra functions and conditional operators. The condition function (CON) in ArcGIS was employed for indexing the socio-economic factors. The (CON) function is basically a "true-false" statement that evaluates a true-false condition in each pixel cell of a raster and does different calculations based on whether the condition is true or false. The Con-function statements can be nested to examine multiple conditions. We employed this method for our degradation indexing. The nested conditional functions used in this study are shown in (Table 1). From the field experience we selected the most degraded areas. Four *soums* Tsogt, Altai, Delger, Bugat were selected as being the most degraded area in the province and average data from *soums* were used to construct a degradation function. In formula (i), if the number of livestock was greater than 130000, (in *soum* level 2013) then the output was assigned a value of 1. A value of 1 is defined as an indicator of land degradation. If these conditions were not met, the output was assigned a value of 0, and then land degradation was not significant. In formula (ii), if the MSAVI was less than 0.15 then the output was assigned a value of 1. A value of 1 signified land degradation. In formula (iii), if the temperature was higher than 18°C, during the vegetation season (August), the output was assigned a value of 1 which signified land degradation. In formula (iv), if the precipitation was less than 10 mm per vegetation period, then the output was assigned a value of 1. A value of 1 signified land degradation. If these conditions were not met, the output was assigned a value of 0, and then land degradation was not significant. In formula (v), if the population was greater than 2637, then the output was assigned a value of 1, which signified land degradation. If these conditions were not met, again the output was assigned a value of 0. Finally, possible output cell values ranged from 0 to 5, illustrating different intensities of land degradation conditions. If an output cell indicates a value of 5 that means all of the 5 factors have an influence on land degradation. If an output cell indicates 0 it means there is no land degradation detectable according to this simple valuation method.

RESULTS AND DISCUSSION

Figure 1 shows the MSAVI changes for the period 2000 to 2013. We observed that MSAVI values were decreased in 2006 from 0.95 to 0.74 and increasing in small values in the last years. The main climatic factors are precipitation development and temperature increase over the growing period. However, there is virtually little change over the 13 years for the study area. It describes that MSAVI variation is not sufficient to assess the land degradation process. The result indicates that the assessment of vegetation greenness alone is not a major indicator for land degradation evaluation in the study site.

Figure 2 presents results showing the GIS analysis were completed to describe which *soum* is affected most by driving factors. We considered here "Tsogt" *soum* had the largest number of degradation drivers of all study sites. During the 13 year period (2000-2013) there is influence from climate and increasing number of livestock as we defined 3-4 conditions are overlaying. We assumed that climate and socio-economic factors are the main affected factors for this site. GIS condition function analyses shows that the highest land degradation has been occurred in 2007 encompass Bayanuul, Tseel, Tsogt and Altai *soums*. The simple map algebra approach allows us to estimate which driving forces exist in the most degraded areas of the single *soums*. According to the National Report 2014 in Mongolia 77.8% of the Mongolian landscape has been

degraded at some level. This paper contributes to the studies which involves policy makers and stakeholders defining and negotiating relevant scenarios with participatory approaches in the local area as well as to the studies which link people to the environment. Our prospective scenarios will be more focused on how this interacts and merges with other data platforms that could be more reliable and sufficient for the land degradation process. In conclusion, we describe that the basic modeling approach can be used in other dry land regions in order to determine the precise driving factors of land degradation.

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Table 1. Conditional function key and related trends in study *soums*.

Indexes	Variables	Description
1	condition	([Livestock number] > 130000, 1, 0)
2	condition	([MSAVI] < 0.15, 1, 0)
3	condition	([Temperatura] > 18, 1,0)
4	condition	([Precipitation] <10,1, 0)
5	condition	([Population] > 2637, 1, 0)
1	True	
0	False	

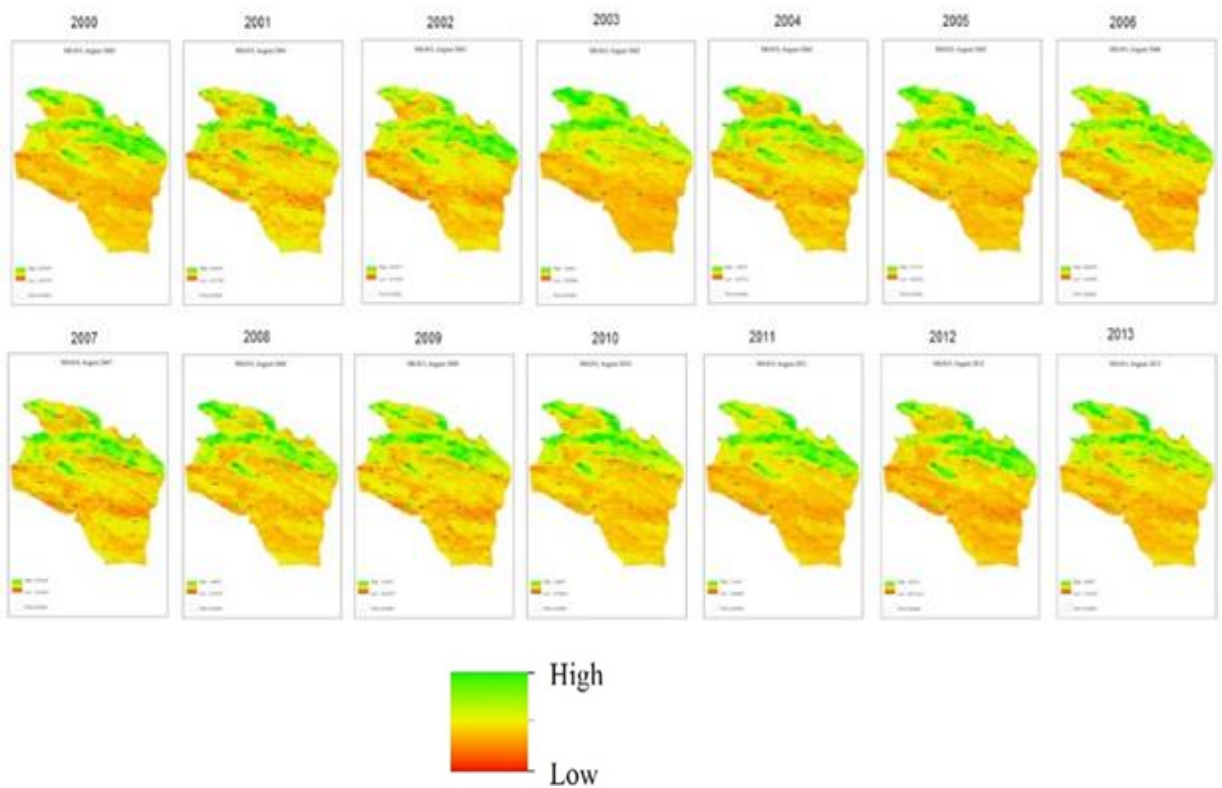


Figure 1. MSAVI change map from 2000 to 2013

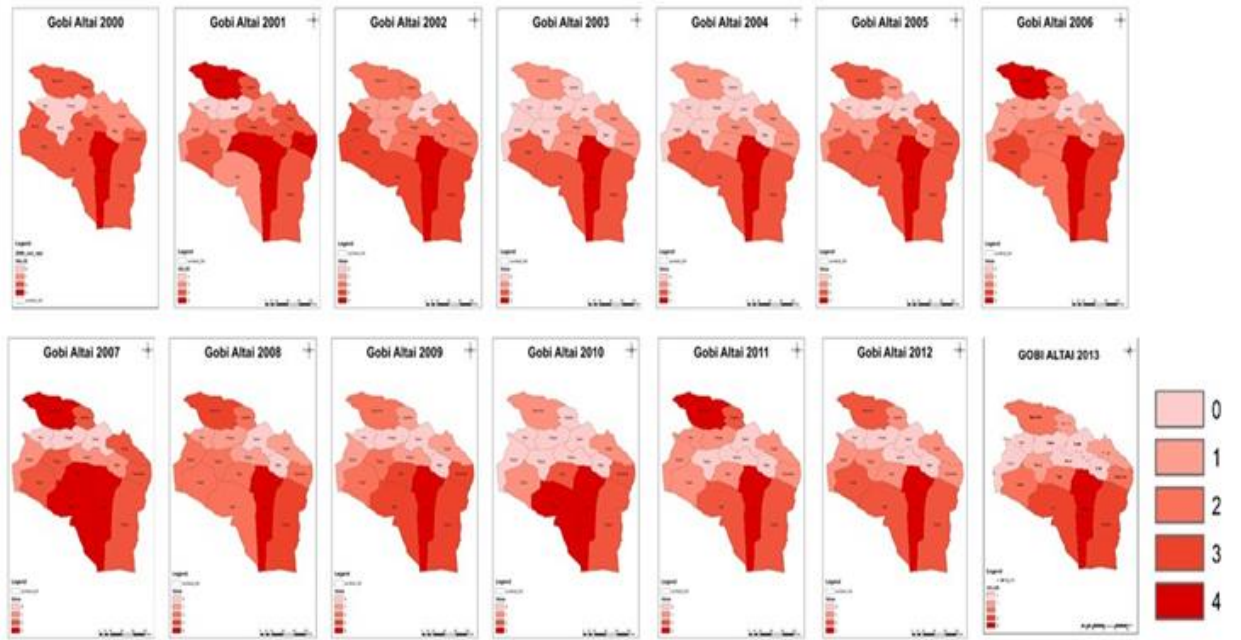


Figure 2. Land degradation change map from 2000 to 2013