LAND USE CHANGE ANALYSIS IN UVURKHANGAI PROVINCE

Tsolmon Renchin\textsuperscript{1}, Tungalag A.\textsuperscript{2}, Douglas A. Miller\textsuperscript{3}, James L. Sloan II\textsuperscript{4}

\textsuperscript{1,2} National University of Mongolia
NUM-ITC-UNESCO, Ulaanbaatar, Mongolia
\textsuperscript{3,4} The Pennsylvania State University, Earth and Environmental Systems Institute

\texttt{tzr112@psu.edu, miller@eesi.psu.edu, jimSloan@psu.edu}

ABSTRACT

Remote Sensing and GIS functions were used to monitor interactions and relationships between land use and land cover changes in the regional area. This study aims to determine the land degradation condition in the Ongi river basin of Uvurkhangai Province, Mongolia. Using GIS functions the climate factors: precipitation, air temperature, and vegetation condition and socio-economic factors: goat number, population number and mining activities were analyzed. Eighty percent of the study area is used as pasture land and for mining which means coupled human-environment systems are mainly causing poor land use and land degradation. We focused on developing a methodology for monitoring land degradation using both GIS and Remote Sensing tools. From 1998 to 2007 the vegetation indexes MSAVI2 and NDVI from SPOT/VEGETATION data were applied in order to determine vegetation cover change and the GIS conditional functions were used for mapping and analyzing climate and socio-economic factors, which both affect land degradation. When we combined vegetation indexes maps with the of climate and socioeconomic conditional maps from the GIS, we obtained a more complete understanding of the human impact on the Ongi River basin as well as the contribution of mining activity to the local economy.

KEY WORDS: socio-economic, mineral resources, degradation, biodiversity, MSAVI2, NDVI

INTRODUCTION

There are a limited number of research works occurring in Mongolia, particularly ones developing the necessary facilities and science for monitoring the socio-economic change and environmental impact derived from country's mining sector and climate change. During Mongolia’s transition to the free market, socio-economic factors such as poverty and profit-seeking have greatly increased small to large-scale mining, as well as illicit activity resulting in exploitation of the country’s mineral resources. Thus, the society and environment problems in Mongolia interact in such a way where poor environmental policy and regulation is linked to land degradation and environmental contamination, which therefore increases the society’s vulnerability. Lakes, rivers and ponds in Mongolia are drying up and have lost ecological balance, caused by wrong human activities and mineral extraction and climate change. Furthermore, environmental damage attributable to these factors has resulted in damage to the nomadic people’s lifestyle in Mongolia. This study is contributing to one of the case studies which use Land Change Science (LCS) in specific socio-economic regions with common and human and natural impacts.

Geist and Lambin (2004) found six common human and biophysical factors associated with the proximate causes of desertification. These factors included demographic factors, economic factors, technological factors, policy and institutional factors, climate factors and cultural factors. Each of these factors was associated with four common proximate causes of desertification which were: agricultural activities, infrastructure extension, wood extraction, and increased aridity. LCS assesses relationships between land use and land cover changes and assesses the ways in which people interact with terrestrial ecosystems and alter the global environment (Lambin et al. 2001). LCS methods employ satellite Earth Observation (EO) and geographic information system (GIS) technologies to monitor interactions between environment and society. The primary objective of sustainability science is to understand dynamic interactions between environment and society (Turner et al. 2007; Clark and Dickson, 2003). LCS has been a subject of study for many years and can be regarded as a “foundational element of sustainability science” (Rindfuss et al. 2004).

Several studies have dealt with climate controls on primary vegetation production in Mongolia. These studies focused on the water component as the major climate constraint as identified by Nemani et al. (2003). Ni (2003) and Li et al. (2007) showed that relationships existed between vegetation production and both precipitation and evapotranspiration in Mongolia. Miyazaki et al. (2004) and Munkhtetseg et al. (2007) demonstrated the influence of
climate on vegetation production in the growing-season. They both showed that precipitation in July had the greatest influence on vegetation production. Furthermore, other studies (Zhang et al. 2005; Munkhtetseg et al. 2007) concluded that air temperature had a negative influence on vegetation production, especially in dry regions.

In order to find a relationship between land use and the environment, particular societies’ land use change models offer to test the sensitivity of land-use patterns to changes in selected variables. In particular, remote sensing data and analysis made important contributions in documenting the actual changes in land cover at regional and global spatial scales from the mid-1970s onwards. Modeling, especially if done in a spatially-explicit, integrated and multi-scale manner, is an important technique for the projection of alternative pathways into the future, for conducting experiments that test our understanding of key processes, and for describing the latter in quantitative terms. Today, only very few models of land-use change can generate long-term, realistic projections of future land-use/cover changes at regional to global scales. (Lambin et al. 2001)

This study contributes to modeling land use change on a regional level. Remote Sensing and GIS analyses helped assess relationships between land use and land cover changes in the regional area by monitoring how local people were affected and interacted. These analyses also helped assess ways in which people interact with the environment. The climate factors of precipitation, air temperature and vegetation conditions; and economic factors of population number and mining activities were analyzed. Each of these factors cause land degradation. A great concern for the environmental officers concerned with the health of the Ongi river basin is mining. Mining is done legally by companies that have large concessions, but also illegally by so called "Ninjas", individuals and families that literally dig for gold without a license. The mining companies use heavy equipment to remove the top layer and vegetation. Vegetation and pasture land are the most important for the nomadic people living in the river basin. It is one of the important rivers in the area supporting livestock breeding for the local people (“Ongi” movement). A main environmental concern is the river drying up and its flow starting to be intermittent since 1998. In order to determine land degradation in the specific area, models applying GIS and Remote Sensing in which all factors were analyzed need to be developed.

STUDY AREA

The study area is the Ongi River basin, Uvurkhangai province, is situated in the central part of Mongolia. It is located within an area bounded by E101°44'24"-E104°30'00" and N44°22'48"-N46°41'24" (Figure 1). The Ongi river basin is one of the world’s bigger freshwater watersheds. It begins in the Khangai Range then crosses 3 kinds of areas that are mountain and wooded area, steering plain area, gobi desert area. The length of the river is 437 km, site is 175 square km and 1000-3000m above the sea level. As mentioned above, the river flow has become intermittent. The drying up of the Ongi river is mainly attributable to the mining of gold placer deposit and to never making technical and biological reclamation (Mijiddorj.R, Bayasgalan.Sh, 2006).

The importance of the vegetation in the area is that it stabilizes active sand dunes maintains the river and stream channels. The main character of the vegetation in the study area is its root size and depth, which holds most of the soil moisture in arid and hyper-arid environments. Pasture overgrazing, and mining impact the economy of the area. The land degradation affects nomadic lifestyle, pasture land and the main source of drinking water, the Ongi river.

Figure 1. The Ongi river basin Uvurkhangai province (Ongi river interruption in south part: from imagery LANDSAT ETM+ data for 23 July, 1999 and 20 September, 2000).
DATA

VEGETATION SPOT 4 1km data from June to August 1998-2007, GIS data and LANDSAT ETM+ data for 23 July, 1999 and 20 September, 2000 were used in this research. Two kinds of vegetation indexes NDVI and MSAVI 2 were used for the monitoring vegetation change in the study area. Statistical data for socio-economic, climate data and ground truth data from “Ongi movement” NGO were used for GIS analysis.

METHODOLOGY

Both GIS and remote sensing techniques were applied in this research. With regard to monitoring land degradation with remote sensing, we applied NDVI and MSAVI 2 indexes. In order to analyze socioeconomic and climate factors, the conditional map algebra function from ArcGIS was applied. Output maps from remote sensing and conditional maps from GIS were compared with each other. For the GIS mapping analysis, we used only MSAVI 2 data. For validation, we used NDVI data.

REMOTE SENSING ANALYSIS

Spectral bands Near Infrared 0.78-0.89 μm, Short wave Infrared 1.58-1.75 μm and formulas 1-3 were selected for the vegetation mapping.

NDVI is normalized ratio of the NIR and RED bands (1).

\[ NDVI = \frac{NIR - RED}{NIR + RED} \] (1)

Huete (1998) suggested a new vegetation index, which was designed to minimize the effect of the soil background, which he called the soil-adjusted vegetation index (SAVI) (2) developed of an iterated version of this vegetation, which is called MSAVI2 (3)

\[ SAVI = \frac{NIR - RED}{NIR + RED + L} \] *(1 + L) (2)

\[ MSAVI2 = \frac{2NIR + 1 - \sqrt{(2NIR + 1)^2 - 8(NIR - RED)}}{2} \] (3)

MSAVI varies from 0.022675 to 0.633800 while NDVI values for vegetation is from 0.01 to 0.89. There is less greenness in south part area where is interruption river and mining activities (Figure 2 and 3). The condition of vegetation in NDVI and MSAVI2 maps green indicate best vegetation condition, while dark brown and dark pink indicate low vegetation respectively. The figures 4 and 5 describe that vegetation in Ongi river basin is decreasing.
Figure 2. Change of vegetation using MSAVI2 index between years 1998-2007.

Figure 3. Change of vegetation using NDVI index between years 1998-2007 in the study area.

Figure 4. Change of vegetation area between years 1998-2006 in the Onggi river basin /MSAVI/.
GIS ANALYSIS

Using ground truth measurement, statistical data, and expertise working in the study area, we developed degradation maps using GIS tools.

The ESRI ArcInfo software provides access to Map Algebra functions and operators. The Con, or conditional, function was employed in the analysis of the impact of a number of socioeconomic factors. Map Algebra functions operate on data that is in raster format.

The basic form of a Con function statement can be seen below.

I. Con(<condition>, <true_expression>, {false_expression})

In formula I, above, <condition> is a conditional expression that is evaluated for each cell in the participating raster datasets. If the condition is true, <true_expression> identifies the value to be used to compute the output cell value. If none of the results of the evaluations of the conditional statements is true, a value or expression can be applied to the cells through the {false_expression} optional argument. (ESRI, 2008)

The impact of socioeconomic factors was defined by looking at the number of goats, population, the amount of mining activities, climate impact, precipitation, and temperature. All of these were used as conditional statements (formulas II-IV).

Con function statements can be nested. Formulas II-IV each shows two nested Con function statements. The result of processing each formula was a new output raster dataset. In formula II, if the number of goats was greater than 20,000, and MSAVI was less than 0.35, 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 III, if the population was greater than 6,500, and the amount of mining activity was greater than 1, then the output was assigned a value of 2, which signified land degradation. If these conditions were not met, again the output was assigned a value of 0. In formula IV, if the temperature was higher than 16, and the amount of precipitation was less than 10 during the vegetation season, the output was assigned a 3. A value of 3 signified land degradation. If these conditions were not met, then the output was assigned a 0. Finally, the three output raster datasets are summarized into one raster output dataset by summing the values at each cell location. Possible output cell values ranged from 0 – 6, illustrating different intensities of land degradation conditions. Data for years 1998 – 2007 were processed (figure 6). In each case the output was compared to ground truth data and NDVI data derived from SPOT Vegetation.

II. con ( [goat] > 20000, con ([msavi] < 0.35, 1, 0),0)
III. con ( [population] > 6500, con ([mining activities] > 1, 2, 0),0)
IV. con ( [temperature > 16, con ([precipitation] < 10, 3, 0),0)

Figure 5. Change of vegetation area between years 1998-2006 in the Onggi river basin /NDVI/.
RESULTS AND DISCUSSION

Land Change Science (LCS) employing Remote Sensing and GIS was used to monitor interactions and relationships between land use and land cover changes in the regional area. Vegetation indexes MSAVI2 and NDVI from SPOT data were applied in this area in order to determine vegetation cover change in the time period of 1998 to 2007 (Figures 2,3,4,5). GIS tools produced raster condition map using these factors number of goats, population, the amount of mining activities, climate impact, precipitation, and temperature for the time period of 1998 to 2007 for land degradation (Figure 7). The conditions on each GIS maps were graded on their relative land degradation (0=no land degradation in green colors through 6=land degradation in dark blue color). Green indicates the best condition while dark blue indicates worst land degradation. According to the GIS analysis (figure 6) Uyanga soum is the most degraded part in the study area.

Both results from GIS and remote sensing maps show land degradation in this area. As seen in the Figure 8 mining, the number of goats and population are increasing. The most affected factors were goat numbers and mining activity numbers. In the most degraded local area, there is a larger number of goats and this causes overgrazing. Due to increasing mining activities, there is an increased population number caused by people migrating from the other parts of the country. The climate factors of precipitation and air temperature do not have a strong affect on the land degradation.

The results were compared with the results from the civil movement “NGO Ongiinhon” (www.onggiriver.com) research team which used ground truth data in 2000-2007. The civil movement was established in the Ongi river basin in order to protect against mining activities in 2000. This study contributes to the research which involves policy makers and stakeholders defining and negotiating relevant scenarios in participatory approaches in the local area.
Figure 7. Output raster data set of the condition map.

Figure 8. Factors in land degradation for Uynga soum.

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REFERENCES


