SPATIOTEMPORAL CHARACTERIZATION OF MONGOLIAN GRASSLANDS BASED ON VEGETATION TREND ANALYSIS — REVISITED

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KEY WORDS: grasslands, agriculture, Mongolia, vegetation trends

ABSTRACT: Spatial distribution of vegetation trends identified by the time-series analysis of normalized difference vegetation index (NDVI) for the Mongolian grasslands was cross-referenced with the recent land use/cover data and some socio-economic information in geographic domain. Global Inventory Modeling and Mapping Studies (GIMMS) datasets with an 8 km resolution provided by the Global Land Cover Facility (GLCF) of the United States were used for the vegetation trends computation. We used land use/cover information as of year 2005 extracted from the European Space Agency's (ESA) GlobCover Land Cover dataset and the statistics of Mongolian livestock for cross-reference. Results indicated that majority of vegetation or pasture degradation occurred in croplands (44.1%) in the north-central part of the country - which is likely be linked to soil degradation due to abandoning of large scale state-operated farmland after 1990 when Mongolia’s transition to a market economy. Degradation of vegetation vigor was also commonly observed in the provinces where livestock density experienced spikes in number - which is likely be linked to over-exploitation of pasture resources. Contrary, a greening belt was observed around the mountain areas along 45°N. The number or livestock stayed relatively constant and no major land use/cover change was observed in these areas, suggesting the improvement of vegetation vigor was caused by the recent global climate change.

1. INTRODUCTION

Mongolia is the second largest landlocked country in the world located in between Russia and China. The country has a total area of over 1.56 million km^2 and is located on a high Mongolian plateau ranging from 900 to 1500 m in elevation. The Mongolian territory is characterized by rocky desert and grassy semi-arid temperate steppe. Forests, limited to the mountainous areas, cover only about 7% of the entire country. Grasslands are an land use/cover of great importance in Mongolia. It is particularly unique that more than 99 % of its agricultural area is grasslands: permanent meadows and pastures. Changes in this vast agricultural area, totaling 1.15 million km^2 in extent, can have an impact on the country's economic future prospect and on regional environmental changes.

Despite there are reports suggesting large-scale desertification by the recent climate change and other anthropogenic causes, Suttie (2005) reported that Mongolian grasslands, although hard grazed, are still in good order. In an attempt to examine the magnitude and spatial extent of vegetation changes, Hirano *et al*. (2006) used the Global Inventory Modeling and Mapping Studies (GIMMS) normalized difference vegetation index (NDVI) dataset to compute the long-term vegetation trends and extracted only statistically significant vegetation trends throughout the Mongolian territory. After the statistical filtering, Hirano *et al*. (2006) concluded that meaningful degradation of vegetation during a decade after 1990 was limited only to 6.4% of the entire country.

The objective of this study is to spatially examine the vegetation changes during the 1990’s in connection with the recent land use/cover to characterize the Mongolian grasslands.

2. DATA AND METHOD

2.1 GIMMS NDVI Dataset

We obtained the GIMMS NDVI dataset, with an 8-km resolution from the Global Land Cover Facility (GLCF) of the United States to compute the vegetation trends in Mongolia between 1991 and 2000. The GIMMS dataset were originally constructed from NOAA AVHRR measurements and were corrected for calibration, view geometry, volcanic aerosols, and other effects not related to actual vegetation change (Tucker *et al*., 2005). Previous efforts suggested NDVI proved best or at least comparable among other proposed types of vegetation indices such as soil-adjusted vegetation index (SAVI), modified- and transformed soil-adjusted vegetation index (MSAVI and

TSAVI) for estimating the actual vegetation condition when no location-specific soil characteristics and vegetation densities are available (Purevdorj *et al.*, 1998) .

2.2 GlobCover Land Cover Dataset

The GlobCover initiative of European Space Agency (ESA) resulted in generation of the 300-meter global land cover map based on Envisat MERIS Fine Resolution products acquired during 2005 and 2006. The land use/cover classification system adopted in the GlobCover land cover product is that of the United Nations Land Cover Classification System (LCCS) which guarantees compatibility with other global land cover datasets. The GlobCover dataset had been officially and globally tested for classification accuracy (67.1% agreement with classification and validation) (Bicheron *et al*.,2008). We used this dataset because no other authoritative land use/cover information was readily available for the entire Mongolian territory for the same time period of our vegetation trend analysis with a validated accuracy.

2.3 Vegetation Trend Analysis

Vegetation trend for each pixel location was calculated using a series of maximum GIMMS NDVI value for each year based on the simple time series regression model. The process of selecting annual maximum NDVI for each pixel disregards the seasonal timing of the NDVI values (Rowland *et al*., 1996). The calculation resulted in a collection of slopes at each pixel location. Pixels with only statistically significant increase or decrease ($P < 0.05$) were used for the assessment of spatiotemporal pattern (Hirano *et al*., 2006) and the same approach was taken in this study.

2.3 Vegetation Trends Broken Down by the Land Use/Cover Classes

We examined the spatial distribution of selected per-pixel vegetation trends by land use/cover classes by overlaying the trends on GlobCover land cover product. Areas of 3 vegetation trend classes, namely 1) degraded, 2) improved, 3) no changes, were summarized by different land cover classes, respectively.

2.4 Vegetation Trends against the Provincial Statistics for the Number of Livestock

Statistics from the Mongolian government regarding the number of livestock showed constant increase during the 1990's until a major winter disaster (locally called "Dzud") hit the country in the winter 1999 resulting major loss of livestock. Since the increased grazing pressure is considered one of the major anthropogenic causes for the vegetation degradation, we computed the ratio (the number of livestock in 1999 over the number of livestock in 1991) in percentage to illustrate the livestock dynamics by provinces. The vegetation trends were then spatially cross-referenced with these statistics.

3. RESULTS AND DISCUSSION

Decadal vegetation trends of statistical significance is shown in Figure 1. As reported in Hirano, *et al*. (2006), only 6.4% of the entire national territory presented statistically significant vegetation trends of any kind. However, obvious concentration of negative trends were observed in the north-central part of the nation. It is only these north-central region where enough precipitation is received for irrigated cultivation and thus large-scale farming was practiced in the planned economy under then-Soviet influence before 1990. After the transition to a market economy, those large-scale farmlands experienced a sharp decline and majority were abandoned.

Cross-referencing these vegetation trends with the recent land cover revealed about 44% of vegetation degradation fell in the croplands classes followed by grasslands (25%) and bare land (22%) (Figure 2). These figures supported the hypothesis that much of the vegetation degradation correspond to areas of current and former cropland areas. The most likely cause of such degradation can be linked to soil degradation commonly observed in the abandoned croplands during our field survey. Other spatial concentrations of negative trends could be spotted in the north-western part of the country where majority of such areas corresponded to grasslands class. It is not very clear why degradation prevailed in these areas only be this spatial analysis.

Figure 4 illustrated the spatial pattern of livestock dynamics by provinces during the 1990's. Negative vegetation trends were commonly found in provinces whose number of livestock increased by 50% or more. Although same tendency could not be validated in the dry southern part of the nation – dominated by desert, where not many animals were kept to begin with. The increase in number of goats was commonly attributed to high market price of cashmere, but such increase did not necessarily resulted in negative vegetation trends.

Examining the spatial distribution of positive vegetation trends led us to identify greening belt around the mountain areas along 45°N. Since no particular land cover other than bare areas (in the mountains) corresponds to these positive vegetation trends and number of livestock stayed relatively constant (within 30% changes over the 10 years), other causes should be sought for. The most likely driver for such trends would come from the recent global climate changes but not enough data to back up this hypothesis is readily available at this point. One of the potential evidences for this hypothesis is the reappearance of some surface water (rivers and lakes) which once had dried up in these areas.

4. SUMMARY AND CONCLUSIONS

We attempted to the spatiotemporal characterization of the Mongolian grassland in a decade after its transition to a market economy in 1990. We analyzed the GIMMS NDVI time-series to compute the vegetation trend and filtered the per-pixel trends based on statistical significance. Although only 6.4% of the entire nation presented vegetation changes of any significance, negative trends dominated among the changes that happened in the 1990's. Cross -reference between these vegetation trends and recent land cover map (2005/2006) revealed about half (44%) of the negative trends fell in the croplands class. Majority of this concentration were observed in the north-central part of the nation. These degradation is likely be linked to soil degradation due to abandoning of large scale farmlands under the planned economy. Some areas with sharp increase in numbers of livestock (50% or more) also presented negative trends. Satellite-based data provided us tools to retrospectively examine the Mongolian nation-wide vegetation dynamics and cross reference these trends with land cover information.

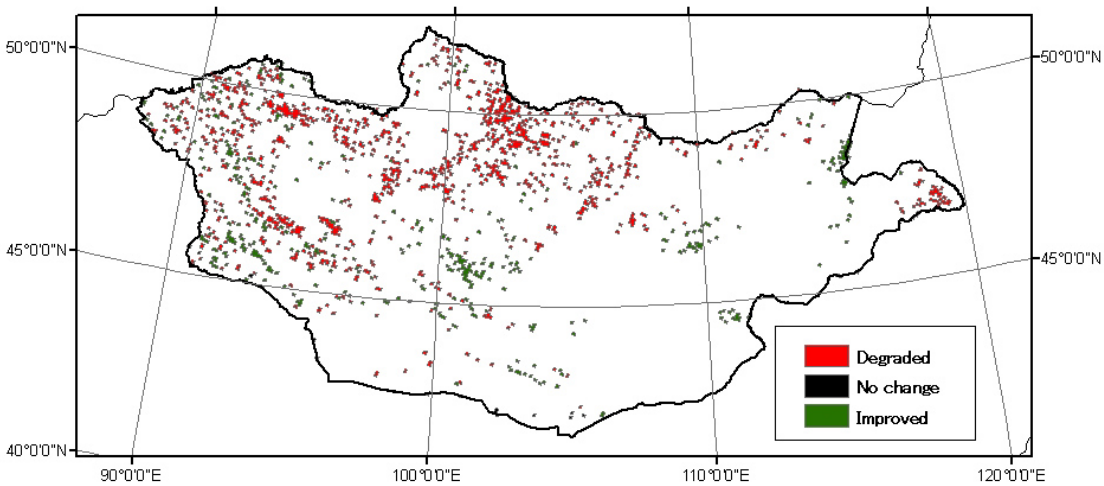

Figure 1. Spatial distribution of statistically significant vegetation trends in Mongolia (1991-2000)

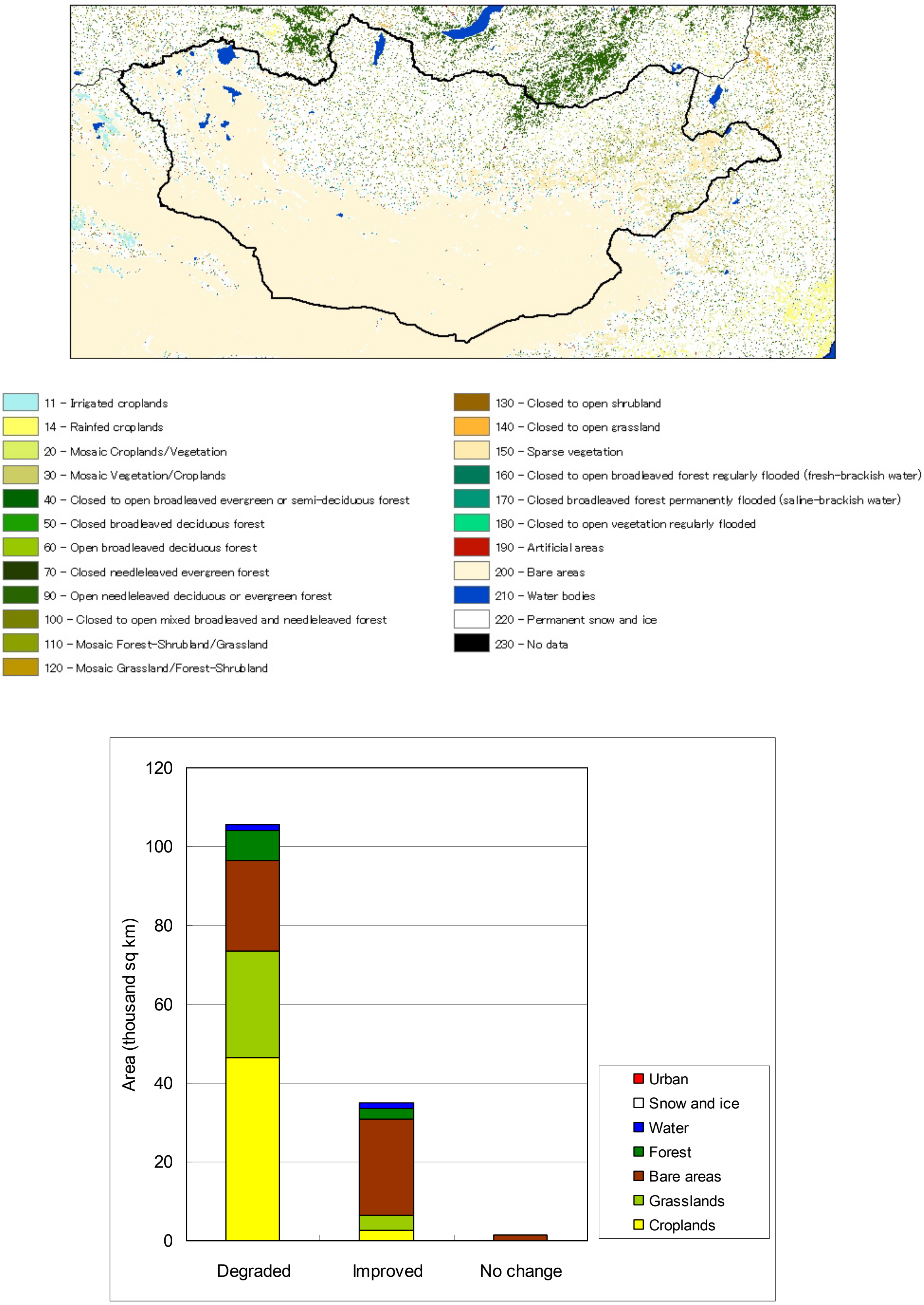

Figure 2. GlobCover land cover map of Mongolia and the break-down of statistically significant vegetation trends (1991-2000).

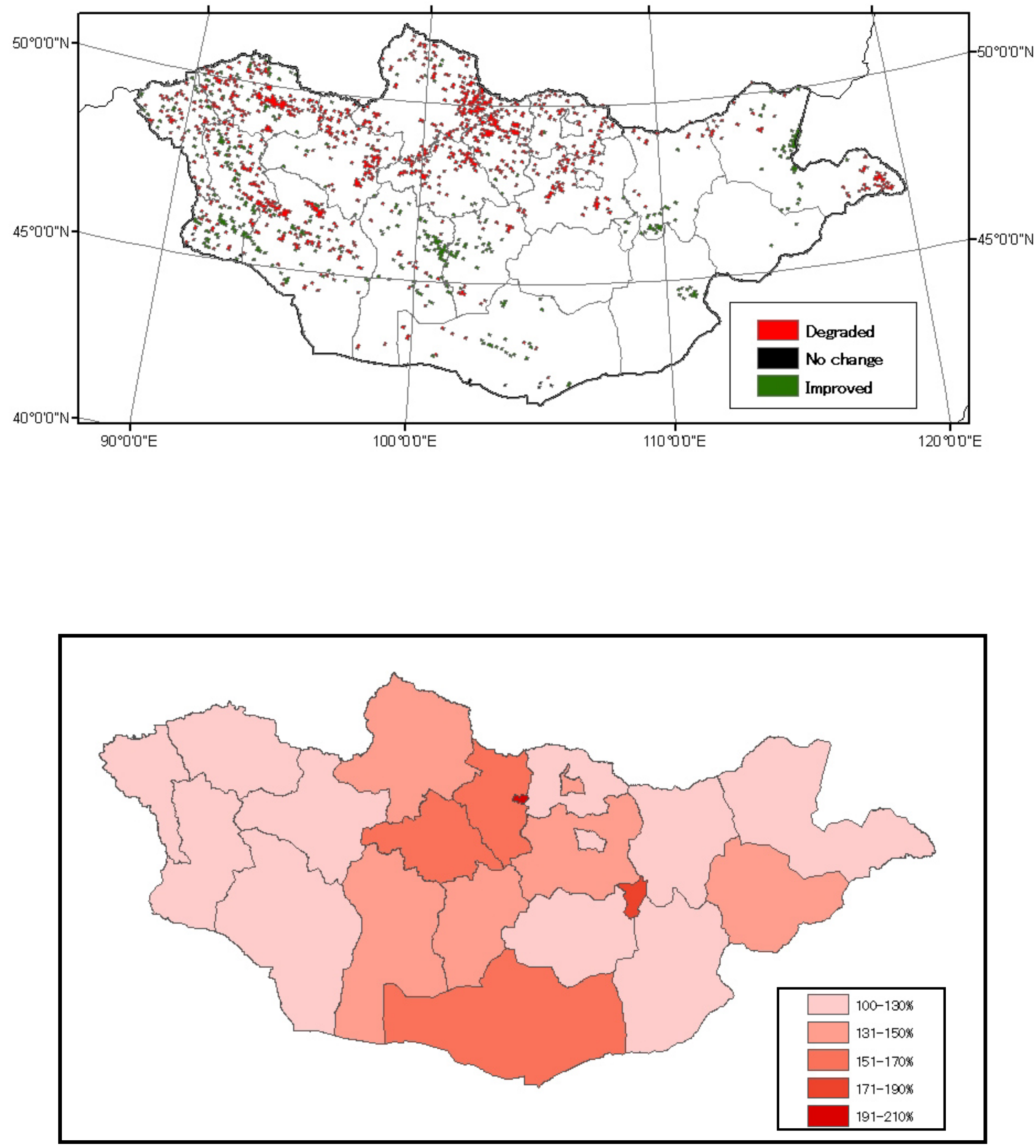

Figure 3. Spatial distribution of statistically significant vegetation trends in Mongolia (1991-2000) and the increase in number of livestock (from 1991 to 1999) by province.

ACKNOWLEDGEMENTS

This work is a part of the collaborative research activity between Japan International Research Center for Agricultural Sciences (JIRCAS) and Mongolian State University of Agriculture (MSUA) "Development of a sustainable agro-pastoral system in the dry areas of Northeast Asia" (2006-2010).

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