LAND COVER CHANGE DETECTION IN MONGOLIA IN LAST DECADE USING MODIS IMAGERY

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ABSTRACT: Land cover composition and its change are important factors that could be used to estimate environmental change and sustainable development. Satellite derived remotely sensed images make it possible to monitor landscape condition, its change and trend over a specified time intervals. The objective of this study was (i) to classify land cover types (ii) to investigate spatial and temporal change in last 10 years on different land cover types in Mongolia using remote sensing classification and change detection method. MODIS Vegetation index products (MOD13Q1.5) at 250 km resolution were used to characterize land cover types in 2000 and 2009. And supervised classification maximum likelihood (MLC) algorithm was carried out to land cover classification process. And post classification change detection method was used to investigate land cover distribution and their temporal change analysis. Results showed that the accuracy of MLC was 89.59 and 89.42 in 2000 and 2009 image classification, respectively. A considerable change in land cover classes has taken place as huge transition from barrenland to sandyland in southern part of Mongolia due to desertification process.

1. INTRODUCTION

Land cover is a fundamental variable that impacts on and links many parts of the human and physical environmental, so there is an increasing and urgent information demand of land cover at regional and global scale for scientific research, resource management, environmental monitoring and planning. (Wu et al., 2004). Remote sensing technologies provide a cost-effective high quality source of data to characterize changing LC conditions and to monitor changes at multiple scales. One of the primary applications of remote sensing data is to identify the land cover types on the ground using classification algorithms. Classification is producing meaningful material distribution maps via identification of individual pixels or groups of pixels with similar spectral responses (spectral signatures) to incoming radiation. These pixels or groups represent different materials or classes. LC change detection analysis is also an important and common image processing technique to examine change between classes. Its important consideration is the nominal temporal frequency of remote sensor data acquisitions required to adequately characterize change events (Lunetta et al., 2004). The radiometric and geometric properties of the MODIS onboard NASA's spacecraft, in combination with improved atmospheric correction and cloud screening, provide a substantially improved basis for consistent spatial and temporal comparisons of global vegetation conditions that can be used to monitor land cover activity (Justice et al., 1998; Running et al., 1994). The objective of this study was (i) to classify land cover types (ii) to investigate spatial and temporal change in last 10 years in different land cover types in Mongolia using remote sensing classification and change detection method.

2. MATERIAL AND METHOD

2.1. Material

2.1.1. Study area

Mongolia is situated in transition zone between great Siberian taiga and Central Asian desert, which belongs to the central part of Eurasian continent. The country consists of high mountain, hills and wide steppe topography, the elevation ranging from 914 and 1524 m (about 3000 and 5000 ft). The greater parts of the highlands with gentle to steep slopes are placed in western, northern and south-west parts of Mongolia. Eastern and southern parts of Mongolia are wide plain steppe and desert area. Climate of the Mongolia is characterized by short dry summer and long cold winter season. The temperature ranges between -15° and -30° C (-5° and -22° F) in winter and 10° and 26.7° C (50° and 80° F) in summer. Winters are dry, and summer rainfall seldom exceeds 380 mm (15 in) in the mountains and 125 mm (5 in) in the desert. The rainy season lasting from mid June to the end of August limits the potential productivity of Mongolian land resources.

2.1.2. Satellite imagery

MOD13Q1 products with 16 days temporal resolution and 250 m spatial resolution were used for the research. The images taken in August 2000 and 2009 have been chosen for change detection analysis because vegetation reaches its maximum growth in august in Mongolia and provides us an opportunity to accurately discriminate between land cover types.

2.1.3. Ancillary data

The ancillary data include a vegetation class map, a DEM, and phenological documents. These supplementary data aid in determining the spatial distribution of land cover according to their natural characteristics such as phenological properties.

2.2. Methodology

The image processing was performed three stages including pre-processing, land cover classification and change detection.

2.2.1. Image pre-processing

MODIS products downloaded from NASA were in sinusoidal projection. This original images were reprojected from their native sinusiodal projection to a uniform Geographical (lat/long) projection and datum WGS84, using a nearest neighbor resampling way. The individual scenes were mosaicked and subsetted by the boundary of Mongolia. NDVI radiance value has been converted to reflectance value to extract reliable range of NDVI value (-1 to +1). Radiometric correction of MODIS vegetation index product to remove the effects of atmosphere has already been carried out. However, some noise due to minor cloud cover, water, snow or shadow can be observed in the datasets. Further, to eliminate the noise, the Maximum Value Composite was used in data processing.

2.2.2. Land cover classification approaches (single date analysis)

The classification scheme used for classification process followed hierarchical physiognomic criteria adapted to Mongolian condition and included 13 land cover classes (Figure 1). Description of the land cover classes are given in the Table 1. A generally supervised classification available classical Maximum Likelihood Classifier (MLC) was applied to images of August which consisted of Blue, Red, NIR, MIR, NDVI, and EVI bands. The ability to discriminate land cover types was to use time series NDVI as a measure of phonological variability throughout the year. Image based phenology spectra representative of the classes of interest were chosen from homogeneous pixels throughout the study area (identified from the ancillary data).

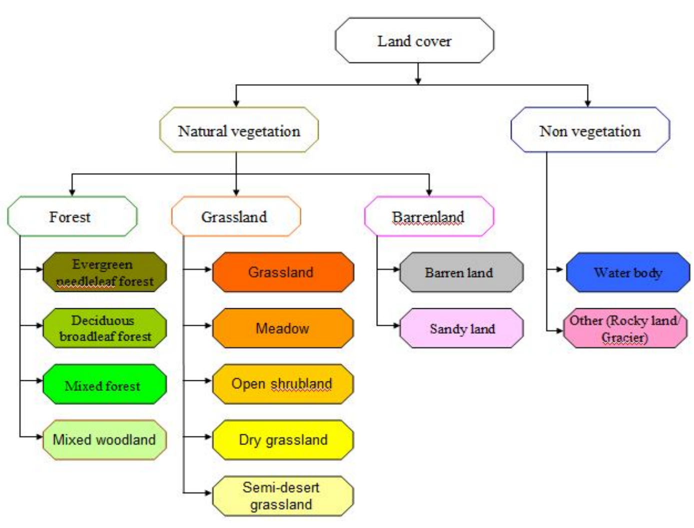

Figure 4. Classification scheme of land cover classes

According to statistical characteristics of classified images, the proportion of each land cover type in total area and change rate of each LC type was calculated. The change rate has been calculated by following formula:

$$\text{Change rate}\,(\%) = \frac{A_{pre} - A_{last}}{A_{pre}} \times 100 \qquad \text{Formula.1}$$

Where: A_{pre} is area of LC types in previous year (2000), A_{Last} is area of LC types in last year (2009).

2.2.3. Land cover change detection

Post-classification change detection technique was carried out, through cross-tabulation, for the classification results of 2000 and 2009 images in order to produce spatial and temporal distribution of changes.

Table 1. Description of land cover classes (IGBP classification scheme)

Level 2 class	Level 3 class	Description
Forest	Evergreen needleleaf forest (ENF)	Lands dominated by needleleaf woody vegetation with a percent cover >60% and height exceeding 2m. Almost all trees remain green all year. Canopy is never without green foliage.
	Deciduous broadleaf forest (DBF)	Lands dominated by woody vegetation with a percent cover >60% and height exceeding 2m. Consists of broadleaf tree communities with an intra-annualcycle of leaf-on and leaf-off periods.
	Mixed forest (MF)	Lands dominated by trees with a percent cover >60% and height exceeding 2m. Consists of tree communities with interspersed mixtures or mosaics of the other forest types. None of the forest types exceeds 60%.
	Mixed woodland (MW)	Land dominated by mixed woody vegetation with percent canopy cover less than 60%.
Grassland	Meadow (ME)	Land cover with meadow and meadow steppe herbaceous plants and less than 10% woody vegetation cover.
	Grassland (GL)	Land cover with typical steppe herbaceous plants and less than 10% woody vegetation cover.
	Open shrubland (OS)	A mosaic of herbaceous and woody vegetation less than 2m tall and with shrub canopy cover between 10% and 60%. The shrub foliage can be either evergreen or deciduous.
	Dry grassland (DG)	Land covered with steppe and desert steppe herbaceous plants and less than 10% woody vegetation cover.
	Semi desert grassland (SDG)	Land a mosaic of desert steppe herbaceous plants and exposed soil, sand and rocks: less than 10% woody vegetation.
Barrenland	Sandy land (SL)	Land of exposed sand that never have more than 10% vegetated cover during any time of the year.
	Barren land (BL)	Lands with exposed soil, sand and rocks never have more than 10% vegetated cover during any time of the year.
Non vegetation area	Water body (WB)	Land with permanent water
	Other (rocky and glaciers) (OT)	Lands rocky and under snow/ice cover throughout the year.

3. RESULT AND DISCUSSION

3.1. Land cover classification

Figure 2 and 3 illustrated that northern part of Mongolia is forested area on mountain ridges. Mixed woodland, meadow, grassland, open shrubland, dry grassland and semi desert grassland are distributed next to forest. Sandyland and barrenland are located in the southern part of Mongolia. Those spatial patterns of land cover classes allow us to see the gradual decrease of vegetation density north to south direction.

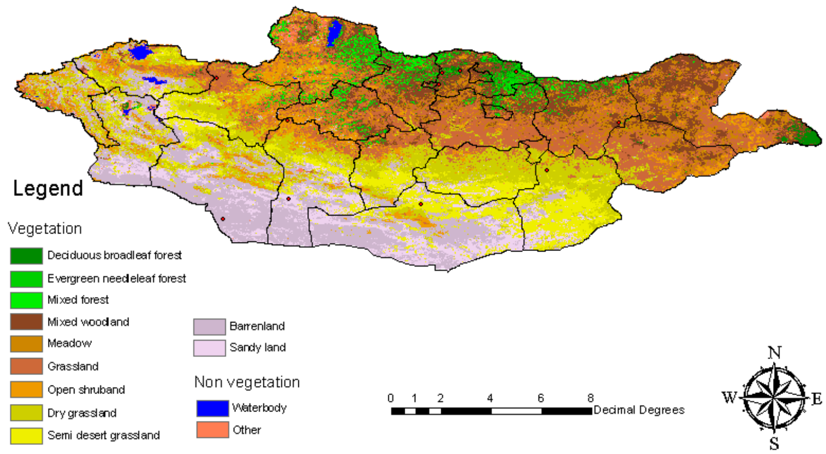

Figure 2. Land cover map of Mongolia in 2000.

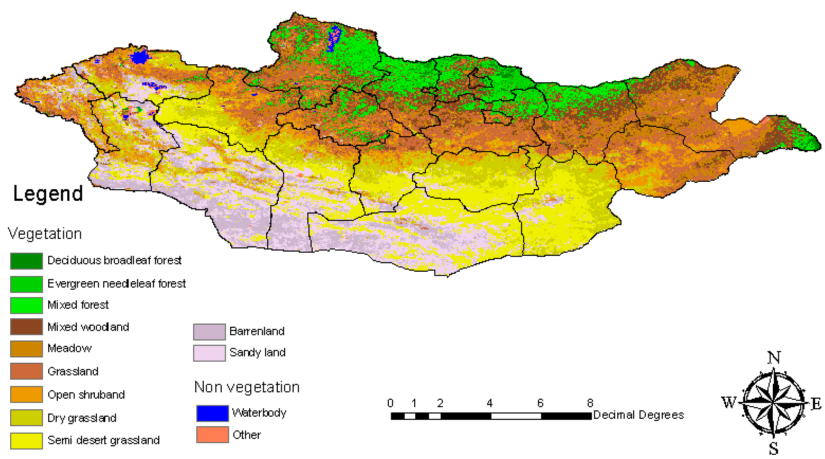

Figure 3. Land cover map of Mongolia in 2009.

The accuracy assessment of classification was carried out based upon ground truth region of interest. Training site subset was used to define the spectral signatures of the land cover classes in classification process. Then the test subset was used as a ground truth in the accuracy assessment. Producer's and user's accuracy values were calculated for each classification scheme. The accuracy estimated is relatively high, the overall classification accuracy was found 89.59 % in 2000 and 89.42 % in 2009, respectively.

3.2. Land cover change detection

Figure 4 showed the quantitative result of the land cover change in 2000 and 2009. The quantitative structure change of land cover, caused by the various change extents of different land cover types, can be described by change amount of each land cover type. Barrenland covered the area of 25,861 thousand ha in 2000 and 12,908 thousand ha in 2009 decreased by 12,953 thousand ha area, of which 44, % area converted to sandyland, 4,4 % area converted to semi desert grassland, 4,6 % area converted to open shrubland, respectively. At the same time, sandyland and semi desert grassland were extended by 7,435 thousand ha and 8,803 thousand ha respectively. Sandyland were expanded into landscapes dominated by barrenland and semi desert grassland. This indicates that previously sparse vegetated areas might have been converted into sandyland by desertification processes. This change occupied in southern part of Mongolia which is the north edge of Central Asian desert. Dry grassland covered an area of 23,668 thousand ha (14.99 %) in 2000, 18,232 thousand ha (11.55 %) in 2009, meanwhile, grassland area reduced by 4,153 thousand ha. Generally, grassland area is main environment for animal husbandry. Increasing number of livestock impacts directly on the reduction of grassland. Mongolian livestock obtains over 90 per cent of its annual feed intake from the grassland. Shrubland, mostly occurs at forest edges, rocky mountain ridges and dry grassland sites and semi desert region in Mongolia, has been increased slightly by 1,862 thousand ha. Meadow area occurs along the river and mountain valleys. The Area of which was 10,754 thousand ha (6.81 %) in first year of study period and 11,083 thousand ha (7.02%) in last year.

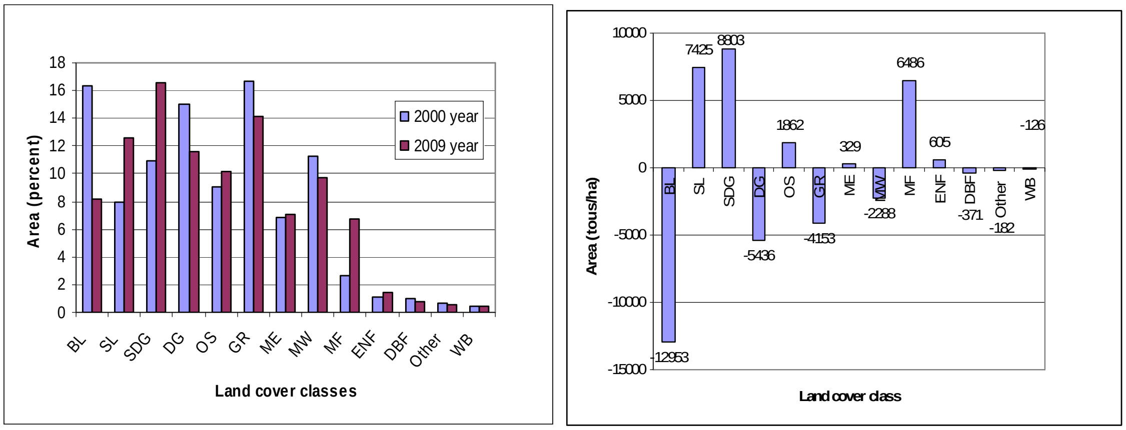

Figure 4. Quantitative result of land cover change in 2000 and 2009

Its increased area was probably owing to higher precipitation amount in 2009 than that in 2000. Mixed woodland area decreased from 17,711 thousand ha (11.22 %) to 15,442 thousand ha (9.77 %), most of which (31.1 %) has been transferred to mixed forest. Evergreen needleleaf forest possess 17,342 thousand ha (1.09 %) and 23,339 thousand ha (1.48 %), a little increasing trend has been observed. Deciduous broadleaf forest has decreased 3,715 thousand ha area. Water body and other classes decreased by 0.08 % and 0.12 % respectively. We found a decreasing trend in barrenland, dry grassland, grassland, and mixed woodland, but an increase in sandyland, semi desert grassland, open shrubland, meadow, mixed forest and evergreen broadleaf forest.

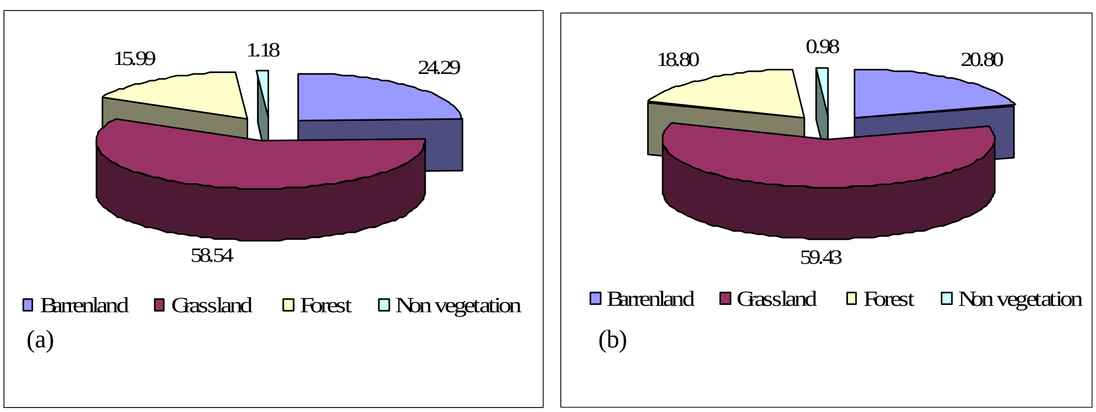

Figure 5. Level 2 classification result, proportion (%) of each LC type in total area in 2000 (a) and 2009 (b)

Figure 5 indicated that Level 2 classification result, proportion (%) of each LC type in total area in 2000 (a) and 2009 (b). Forest area covered 25,234 thousand ha in 2000 and 29,665 thousand ha in 2009, its proportion in a total area of Mongolia was 15.99% (15.99%) and 18,79%, respectively. The change rate of increasing was 17,56%. Grassland covered the area of 92,388 thousand ha (58.54 %) in 2000 and 93,793 thousand ha (59.42%) in 2009. Almost 60 % territory of Mongolia invaded by grassland with the increasing change rate 1,52% in last 10 years. Meanwhile area of barrenland decreased from 38,352 thousand ha (24.29 %) to 32,824 thousand ha (20.8 %) and non vegetated area also decreased from 1854 thousand ha (1.18%) to 1546 thousand (0.9%). The change rate of decreasing in barrenland and non vegetated area were 14.4% in 2000 and 16.6% in 2009, respectively. Total area of Mongolia is 157830291 ha, of which 74.8 % was unchanged, 8. 68 % was decreased and 16.5 % was increased during this study period.

As we concern cross tabulation matrix, most of the changed area transferred to higher vegetation area. It was likely the result of extreme drought which had been taken place in 2000 influenced on the previous image (2000) of this analysis. (Natsagdorj, 2002).

4. CONCLUSION

Compared to other land cover classes, a considerable change in land cover classes has taken place as huge transition from barrenland to sandyland in southern part of Mongolia due to global desertification process. Therefore, the effect of increasing sandyland is manifested in increasing desertification in southern part of Mongolia. Otherwise, this study did not confirm any overall degradation of the area as far as concern land cover. On the contrary, the analysis implies a little bit improvement of land cover change.

Land cover changes observed within area frame result of climatic factors and natural disasters (drought, desertification) might be more influenced on land cover changes rather than land management or pastoral practices in large area such as Mongolia. Two year temporal frequency information was not sufficient in order to reveal spatio-temporal changes of land cover types. Therefore, further analysis should be focused on: the relationship between land cover and weather condition as well as analysis of monthly precipitation and temperature data; high temporal frequency (time step) of remote sensing images were needed to give adequately characterize land cover change events for classifications.

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