SAXAUL FOREST AREA DETERMINATION BY REMOTE SENSING IN MONGOLIA'S GOBI REGION

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ABSTRACT:

The main objective of the study was to monitor and map the saxaul forest in the Gobi region of Mongolia, using satellite remote sensing imagery. Saxaul forests usually grow in the arid and semi-arid regions of Asia and the desert of Mongolia, where they are the dominant endemic brush type plant. The importance of the saxaul forest to Mongolia is that they help to stabilize the active sand dunes and reduce the effects of sand storms. A decrease in the area of saxaul forests from logging and firewood gathering is one probably cause for why sand storms are becoming more harmful in Mongolia. Detailed monitoring of the saxaul forests over a large area of Mongolia, using satellite remote sensing has not previously been carried out. A Linear Mixing Model (LMM) was applied in this study to classify the saxaul forest. The accuracy assessment was compared between the fractions of pixels estimated from the LMM with ground data measured from on site fieldwork in the Gobi. The extents of the saxaul forest in the study area were delineated using Landsat TM data from 1994 along with topographic maps from 1969. The result of the study showed saxaul forest area as 19,480 hectares and 9,900 hectares in 1969 and 1994 respectively. Further research should test the robustness of the methods adopted here when applied to large areas by using multi-temporal data to detect saxaul forest changes resulting from desertification in the Gobi. Counter point mixtures of vegetation types to be present within a pixel, even with high-resolution data from Landsat TM and the SPOT High Resolution Visible Imaging System.

1. INTRODUCTION

Saxaul forests usually grow in the arid and semi-arid regions of Asia and the deserts of Mongolia, where they are the dominant endemic brush type plant (Figure1). In Mongolia, the saxaul forest grows in an area within the Gobi approximately 1650 km wide and 360 km in diameter from north to south. There are 7 provinces and 39 sub-provinces where Saxaul forests are thought to grow in Mongolia. Saxaul forests take the place of 25,3% of Mongolian forest area. A Saxaul forest is unique brushwood to obtain the environment of plants, animal kingdom, microclimate condition and soil. Saxaul forest vegetation is actually a dry land plant because they have many characteristics of biological and ecological adoption to the dry climate, which is different from distributed trees and shrubs in other desert areas.

Saxaul have a very large root system, enabling them to tap water from deep underground, allowing them to live a number of years. This root system also acts as a defense for soil from Aeolian erosion. Saxaul forests provide livelihood and daily necessities, such as the tending of livestock, for local people in Mongolia. Saxaul forest is not only used as stockyards of livestock animals and pigsty of some wildfire but also as their food source during the strong wind and dzud in winter and spring. Saxaul forests provide the people of the Gobi regions with their main source of farm firewood. The wood of the Saxaul forest is usually burned as firewood as well as the main raw material for charcoal (Svintsov 1981).

The caloric content of saxaul is 4500kkal on average (J.Gal 1968). Few scientists have ever studied the saxaul forest. The first scientific studies of the Saxaul forest were completed in the 1940's and only random notes were taken in previous years. Two censuses of the saxaul forest were completed during 1960 and 1990. Between 1961 to 1968, J. Gal (1968) completed several studies on the saxaul forest, describing the natural history of the saxaul forest, its coverage area, growth patterns, etc., as well as its use by the local inhabitants. J Gal (1968) also completed other research on the saxaul including human induced threats and diseases.

The importance of the saxaul forest to Mongolia is that they help to stabilize the active sand dunes and reduce the effects of sand storms. A decrease in the area of saxaul forests from logging and firewood gathering is one probable cause for why sand storms are becoming more harmful in Mongolia. The Saxaul forest is uniquely related to the overall area of Mongolian forests and therefore should be studied and be the subject of a regular census. However due to the extreme environmental conditions much time and money would be required to conduct such a regular census.

Detailed monitoring of the saxaul forests over a large area of Mongolia, using satellite remote sensing has not previously been carried out. The main objective of the study is to monitor and map the saxaul forest in the Gobi region of Mongolia, using satellite remote sensing imagery. Through the use of modern spatial analysis techniques and remotely sensed satellite imagery data we believe that a detailed assessment of the current state of saxaul forest can be more quickly and accurately ascertained, in addition to costing less and requiring less field work.

Remote sensing is defined as the science and art of obtaining information about an object or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand 1994). Land cover classifications are among the most important applications of remote sensing; however, classifying vegetation cover is problematic because there is no standardized methods for classifying and mapping different land cover types. This is related to many factors, such as the spatial heterogeneity of different vegetation structures, vegetation classification and plant species identification, plant geometry and biomass. The linear mixing model (LMM) approach is one of the most often used methods for handling the mixed pixel problem.

Figure 1 Saxaul forest in the Gobi

2. STUDY AREA

The study area is situated near human activity in Bayanlig sub province, of Bayankhongor province, which is in the southwestern part of Mongolia (Figure2). It lies between $43°49^{/}51^{//}$-$44°55^{/}41^{//}$ north latitude and $100°61^{/}20^{//}$-$101°45^{/}42^{//}$ east longitude. The size of the study area is 1191766 hectares and has a population of approximately 4000 inhabitants and 77000 livestock. The basic economy is livestock ranching. In this area the saxaul forest lies between the ranges of the Bogd Mountains in the north, and the Altai Mountains in the south, and forms part of a large valley. The climate of study area is semi arid dry and hot; the hottest months are June and July (mean annual temperature at Bayanlig 28.5^0C) and the coldest month is January (mean annual temperature at Bayanlig -18^0C). The driest season is also June and July (mean annual rainfall 30-50mm).

The soil types show obvious vertical distribution by elevation: white-loamy and sandy soil (low 1300m), gray-stony soil (1300-2000m), dark brown soil (above 2000m). The plant diversity varies between *populus diversifolia*, saxaul， and tamarisk willows are between the humid areas the larch, *curgana pygmaya* and bramble. Native fauna consist of wild sheep, ibex, deer, lynx, snow leopard, wolf, fox, ermine and marmot. There are also wild camel and Gobi-bear in the semi-desert

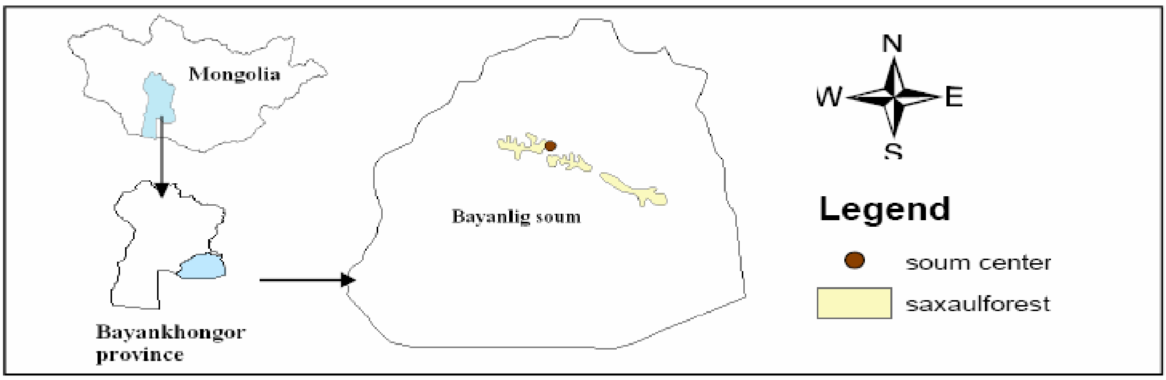


Figure2 The location of the study area

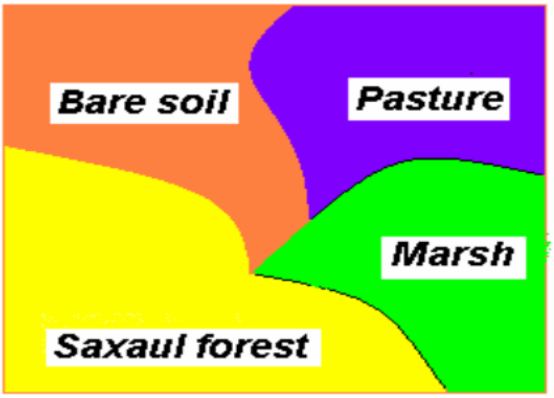
3. METHODOLOGY

Linear mixing models (LMM) can be applied to multi-spectral data in order to map proportions of gradually varying scene components, such as mineral composition (Settle and Drake, 1993). Studies by Cross et.al 1991 showed the model produced image outputs in which pixel intensities indicated the proportion of forest cover per square kilometer. Several techniques (Smith et al. 1985, Shimabukuro 1987, Adams et al. 1989) have been developed to solve the mixture problems in a number of fine spatial resolution data sets from Multispectral Scanner System (MSS); Thematic Mapper (TM) data (Adams1984, Shimabukuro 1987); and AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) data (Gillespie et al.1990). All of the above techniques produced similar results (Shimabukuro 1987) and their uses are usually dictated by the investigators personal preference.

Unmixing had already been applied to coarse resolution data in a number of studies, especially for vegetation monitoring. The first four AVHRR channels were used by Cross et al. (1991) for unmixing and was able to differentiate tropical forest from non-forest, with satisfactory results compared with TM images. More recent studies (Bastin 1997, DeFries et al. 1997) reflect the ongoing interest in sub-pixel analysis using coarse resolution satellite imagery. The linear mixing model based on the Optimization Method (Tsolmon 2003) was applied to saxaul forest monitoring using a Landsat TM scene [P134R029] with 30 m^2 resolution, from 25 August 1994 in this study. The saxaul percentage image was derived from four spectral bands with wavelength 0,45-0,52µm, 0,52-0,60µm, 0,63-0,69µm and 0,76-0,90µm of the Landsat image.

3.1 Linear Mixing Model

The linear mixing model is uses for defining the concentration of elements. Linear mixing models the reflectance of heterogeneous pixels as an area-weighted average of the reflectance of homogeneous pixels. The Linear Mixing Model approach assumes that the spectrum measured by a sensor is a linear combination of the spectra of all components within the pixel. For solving the LMM, Lagrange's method and optimization technique were used. This method was developed for assumed components in a pixel. The mathematic model of LMM can be expressed as shown in equations (1-6).



$$\begin{aligned} R_1 &= a_{11}x_1 + a_{12}x_2 + \Lambda + a_{1n}x_n + e_1 \\ R_2 &= a_{21}x_1 + a_{22}x_2 + \Lambda + a_{2n}x_n + e_2 \\ &\mathrm{K\ K\ K} \\ R_m &= a_{m1}x_1 + a_{m2}x_2 + \Lambda + a_{mn}x_n + e_m \end{aligned} \qquad (3.1)$$

$$f(x) = \sum_{i=1}^{m} e^2{}_i = \sum_{i=1}^{m} (R_i - \sum_{j=1}^{n} a_{ij}x_j)^2 \rightarrow \min, \qquad (3.2)$$

Subject to:

$$x_1 + x_2 + x_3 = 1,$$
$$x_1 \geq 0,\ x_2 \geq 0,\ x_3 \geq 0\mathrm{K}\ x_n \geq 0, \qquad (3.3)$$

$$L(x, \lambda) = f(x_1, x_2, \ldots, x_n) + \sum_{i=1}^{m} \lambda_i g_i(x), \quad x = (x_1, x_2, \ldots, x_n) \qquad (3.4)$$

$$\frac{\partial f(x)}{\partial x_j} + \sum_{i=1}^{m} \lambda_i \frac{\partial g_i(x)}{\partial x_j} = 0 \quad j = 1,2,\ldots,n \qquad (3.5)$$

$$\begin{cases} 2\sum_{i=1}^{m} (R_i - \sum_{j=1}^{n} a_{ij}x_j)a_{ij} - \lambda) = 0 \\ x_1 + x_2 + x_3 + \Lambda + x_n - 1 = 0 \\ x_1 \geq 0,\ x_2 \geq 0,\ x_3 \geq 0, \Lambda\ x_n \geq 0 \end{cases} \qquad (3.6)$$

Where:

R_i is measured satellite sensor response for a pixel in spectral band i

a_{ij} is spectral response of mixture component, j, for spectral band i

x_j is proportion of mixture component, j, for a pixel

e_i is the error term for spectral band i

4. RESULT AND DISCUSSION

This research aimed to monitor the saxaul forest that is situated near areas of human activity population center in the Bayanlig sub province of Bayankhongor province. The saxaul forest areas were defined not only using Landsat TM satellite data from 1994 and also that were from digitized 1:100.000 scale topographic maps from 1969 (figure 4). There was 19480 hectares area of saxaul forest in the area in 1969 while 9900 hectares of saxaul from fraction image from the model using satellite data from 1994 (Figure3). A combination map of Landsat bands 5, 4 and 2 (RGB) is shown in Figure 5. The resulting fraction image also was compared with ground truth data collected in 2006. Validation of research was compared between the Landsat image and ground truth data that was 80 percent. .

5. CONCLUSION

The saxaul forest areas were determined by Linear Mixing Model using Landsat data covered a relatively small area. There was 50 percent decrease area of saxaul forest approximately after 25 years. From this study we conclude that increased case of saxaul forest has been influence on the desertification process in the Gobi. The overall decline in saxaul forest area may be attributed to effects of climate change such as drought, desertification and human rapid activity gathering for the firewood and fuel. In the future work we shall be calculating consider other related characters such as including the nearest boundary of non forest 300m area from forest ledge by forestry law.

The coverage of saxaul forest is less than 20 % percent coincides in anywhere we cannot define it by landsat data. We tested this method on the SPOT-VEGETATION sensor data with spatial resolution 1km in the entire Gobi region of Mongolia, however the results are incorrect because not only special resolution of sensor is not fine but also saxaul forest distribution of Mongolia is rambling. Therefore, monitoring of large areas for the saxaul forest should be use the fine spatial resolution data. Then, large areas study by satellite data is using the adopted method recommended using for further investigation

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APPENDIX 1

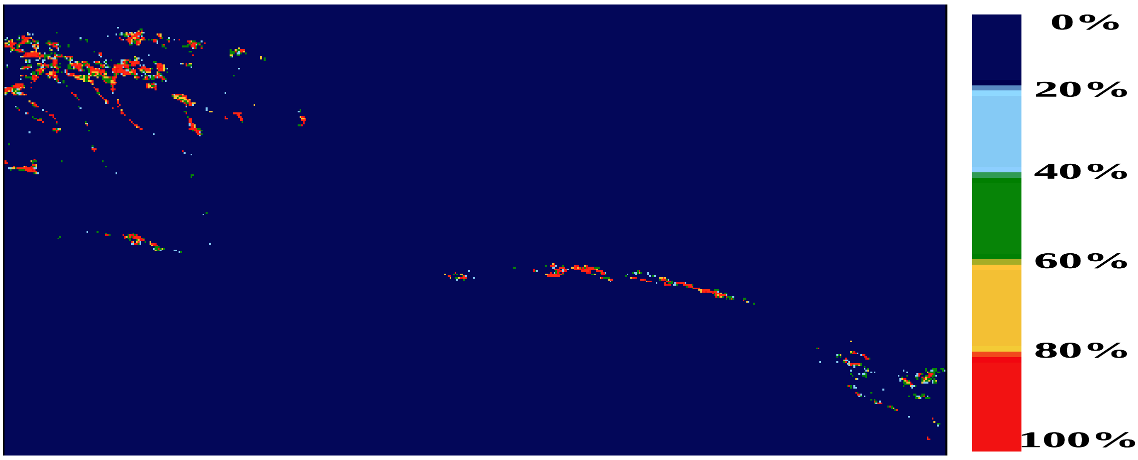

Figure 3 Saxaul forest fraction image derived from LMM in 1994

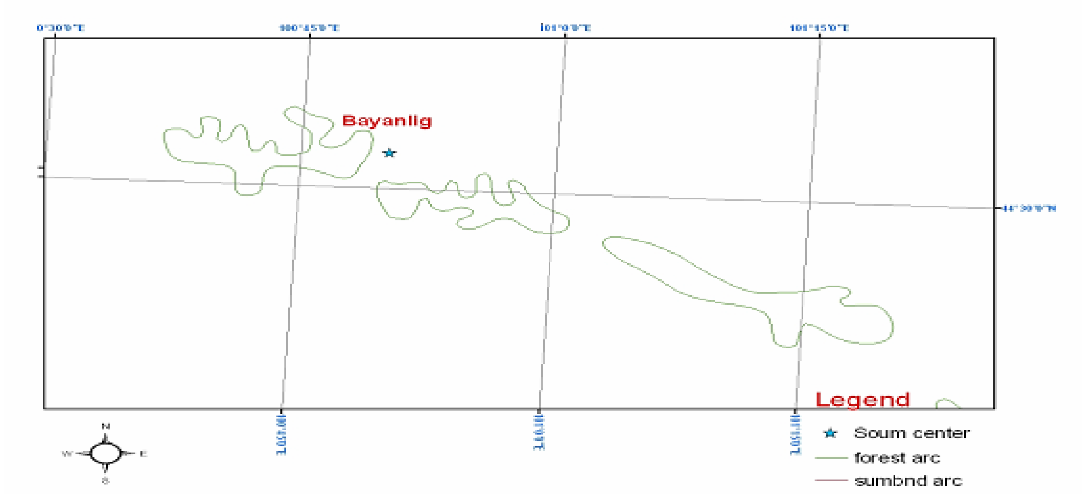

Figure4 Topographic map for saxaul forest in 1969

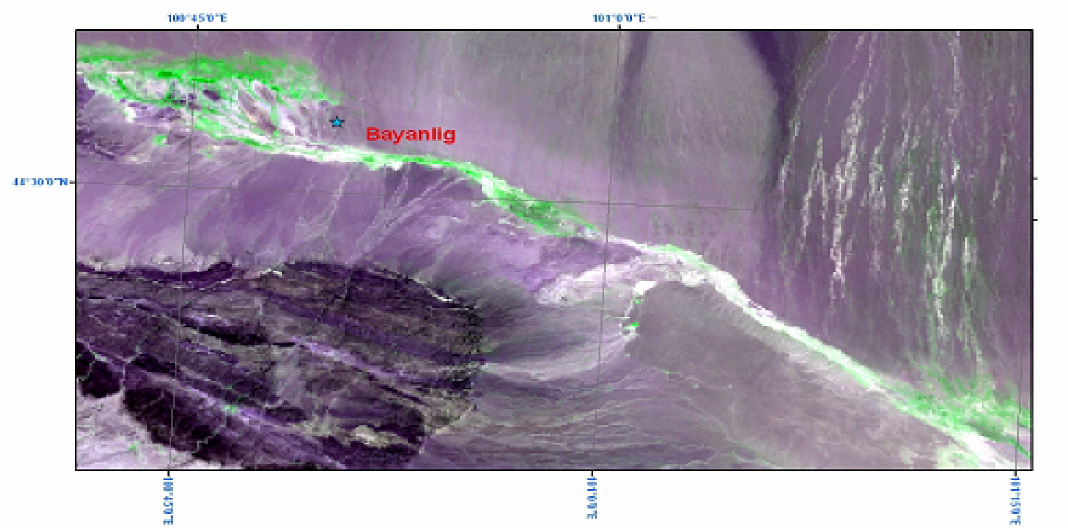

Figure5 Colour composite of Landsat TM [P134R029]， 1994 data (R:band5， G:band4， B: band2)