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INTEGRATION OF RS AND GIS FOR FOREST MONITORING IN MONGOLIA

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ABSTRACT: The aim of this study is to demonstrate the case studies on the integrated approaches of RS and GIS techniques for forest monitoring. Within the framework of the study, it is assumed that there is an operational GIS that stores historical data about the forest and there are needs to produce updated forest maps and also to create a forest biomass map. As data sources, multitemporal optical and interferometric synthetic aperture radar (SAR) images as well as topographic and forest taxonomy maps are used. Overall, the study demonstrated that integrated RS and GIS techniques can be successfully used for different forest studies.

KEY WORDS: Integrated approach, Multitemporal images, RS, GIS, Forest studies

1. INTRODUCTION

Forests are an important natural resource that should be carefully managed, because on one hand they maintain an ecological balance and on the other hand they provide the raw material for a wide range of wood-based industries. In general, intensive and effective forest management requires reliable inventory data and maps indicating the current state of the forest. Over the years, remote sensing (RS) has been extensively used for forest monitoring and management, because it provides real-time information about the state and conditions of forests. However, most forest management practices mainly use optical RS data sets and applications of the combined use of optical and advanced microwave RS technologies are still limited.

The combined application of optical and microwave data sets can provide unique information because passive sensor images represent spectral variations only of the top surface of the forest canopy, while active sensors with canopy penetrating capability, can provide additional data and information about forest structure and biomass. When combined active and passive sensor data are integrated with historical data sets and stored in a GIS, the results can be used for thorough forest-related decision-making.

“The National Geoinformation Centre for Natural Resource Management (NGIC)” project jointly implemented by the Ministry of Nature, Environment and Tourism of Mongolia and the

Dutch Government started its activities from December 2006. In the project document, it was planned that different national trainings to be organized during the project implementation in order to strengthen the capacity of Mongolian specialists in applications of GIS/RS for natural resources assessment and other environmental studies. Within the framework of this part of the project, different case studies on applications of GIS/RS for forest studies have been developed and used during the national courses.

The aim of this study is to demonstrate the case studies on integrated approaches of RS and GIS techniques for different forest studies. For this purpose, different test sites of Mongolia have been selected. Within the framework of the study, it was assumed that there is an operational GIS that stores historical data about the forest and there is need to produce updated forest maps using multitemporal optical RS data sets as well as to produce a forest biomass map. For this purpose, multitemporal optical and microwave images as well as topographic and forest taxonomy maps have been used.

2. GENERATION OF THE MULTITEMPORAL FOREST COVER MAPS

The Bogdkhan Mountain is situated in central part of Mongolia, near the city of Ulaanbaatar. The mountain is a protected area and has a territory of 41651ha, of which 55% is covered by forest. The mountain has 588 species of high plants, which are related to 256 genuses of 70 families. 135 species such as carex, artemisa, oxytropis that relate to 11 main genuses comprise 22.9% of all species distributed on the mountain. Forest is distributed on the altitude range of 1400m (1450m)- 2100m (2150m) above sea level and consists of 3 sub zones such as mountain plateau, taiga and taiga type.

The data used consisted of SPOT XS images acquired on 11 May 1986 and 19 June 1997, Landsat ETM image of 2008, and JERS-1 SAR intensity image of April 1997 and ERS-1/2 SAR tandem pass single look complex (SLC) images acquired on 10 and 11 October 1997, respectively. In addition, a topographic map of 1969, scale 1:50.000 and a forest taxonomy map (made by the combined use of an aerial photograph of 1963 and ground survey of 1988), scale 1:100.000 were available, accordingly.

In the present study, it is assumed that there is an operational GIS that stores different thematic layers and there is a need to produce updated forest maps for different periods using multitemporal RS data sets. In order to carry out multitemporal forest analysis, initially, the optical images were thoroughly analyzed in terms of brightness and geometric distortion. The images were of a good quality but the SPOT XS image of 1986 had a haze effect and it was removed by subtracting the haze values from the actual data distribution thus shifting the data histogram to the origin. Then, the SPOT images of 1986, 1997 and Landsat ETM data of 2008 were successively geometrically corrected to a Gauss-Kruger map projection using a topographic map of the study area, scale 1:50.000. The ground control points were selected on clearly delineated sites and in total 9 regularly distributed points were chosen. For the actual transformation, a second order transformation and nearest neighbour resampling approach have been applied and the related root mean square (RMS) errors were 0.56 pixel, 0.64 pixel, and 0.85 pixel, respectively.

For the actual classification and generation of forest maps, a supervised statistical maximum likelihood classification (MLC) has been used assuming that the training samples have the Gaussian distribution (Richards and Xia 1999). In order to define the sites for the training signature selection, from the images, two to three areas of interest (AOI) representing the forest and non-forest classes have been selected through thorough analysis using a polygon-based approach. The separability of the training signatures was firstly checked in feature space and then evaluated using transformed-divergence (TD) separability measure. The values of TD separability measure range from 0 to 2.0 and indicate how well the selected pairs are statistically separate. The values greater than 1.9 indicate that the pairs have good separability (ENVI 1999). After the investigation, the samples that demonstrated the greatest separability were chosen to form the final signatures. The final signatures included about 568-784 pixels. Looking at the classified images, one can observe what kind of changes had occurred in those periods in the forest cover of the Bogdkhan Mountain. The available forest map, the satellite images and the results of the MLC are shown in figure 1.

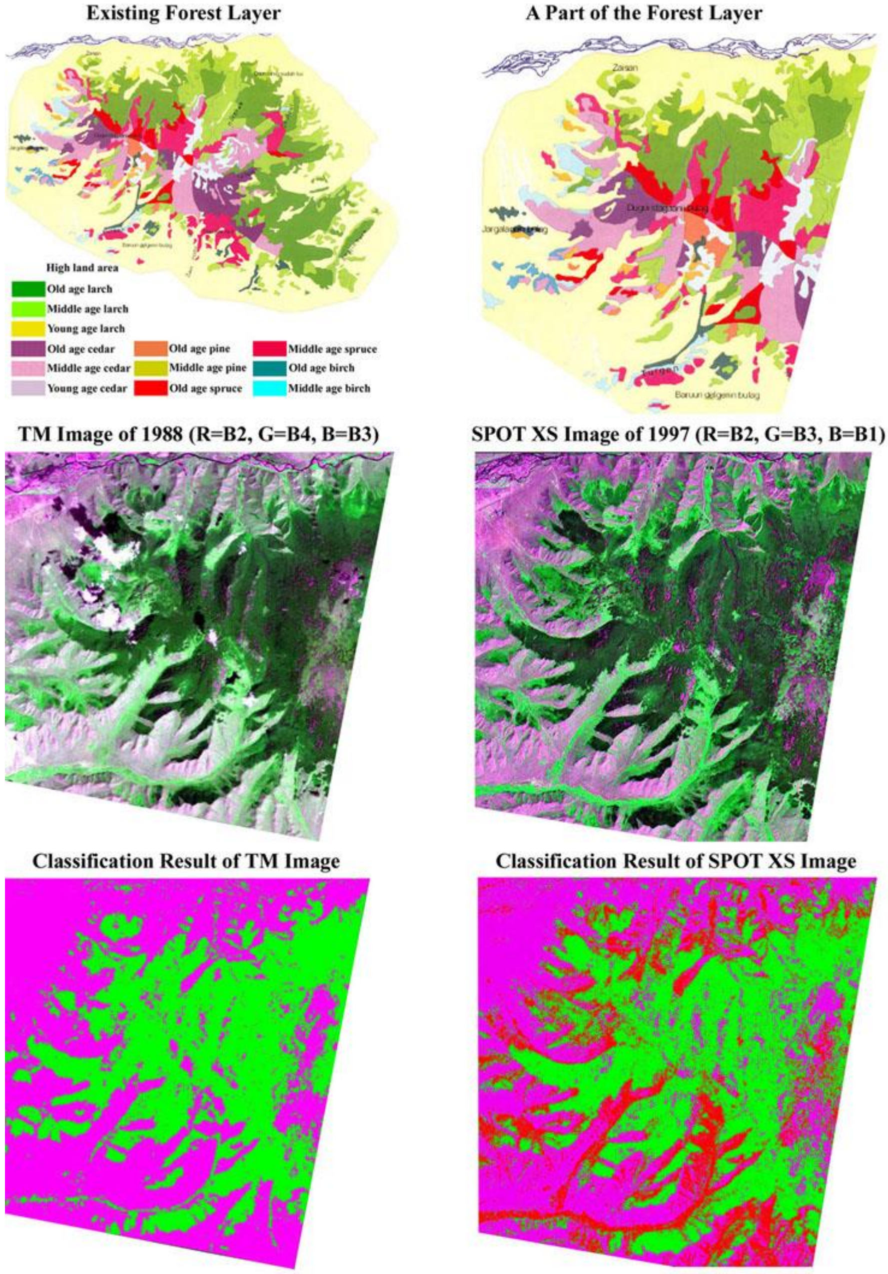

Figure 1. The available forest map, the satellite images and the results of the MLC.

3. CREATION OF THE FOREST BIOMASS MAP

As the initial ERS SAR data were represented in a SLC format, it was necessary to generate coherence and amplitude images. The coherence images are generated by using both the amplitude and phase information from a pair of SLC images. The coherence values range between 0 and 1. If some land surface changes had occurred in a target area between the two image acquisition periods, then coherence is low and if no changes had occurred, then the coherence is high. In general, the coherence over a dense forest and shrub will be the lowest, while for the bare soil, the coherence will be the highest. In this study, the coherence and amplitude images have been derived as follows:

1. Initially, 200 ground control points regularly distributed over the images were automatically defined using the satellite orbit parameters and the two SLC images were coregistered with 0. 1pixel accuracy. Then, a course registration followed by a fine registration was performed.
2. Coherence has been calculated using 10x2 size window and the coherence image was genera ted.
3. From the complex images, amplitude images were generated.
4. The preliminary SLC images were converted from the slant range onto a flat ellipsoid surfac e.
5. The true size (5800x5800) SAR images were generated using image undersampling applying 3x3 size low pass filter.

After deriving the coherence and amplitude images, they were integrated with the JERS-1 SAR data. Then, on the integrated image four classes indicating different biomass values have been defined. For the actual classification, Mahalanobis distance method was used and the result was reliable. The final forest biomass map is shown in Figure 2.

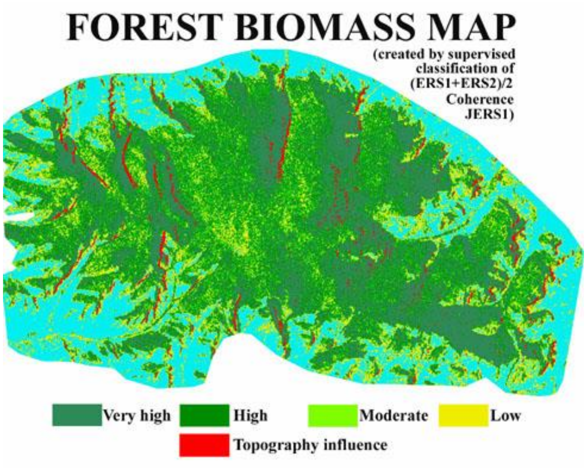

Figure 2. Forest biomass map created from the SAR images.

4. FOREST MONITORING IN BATSUMBER SUM

Batsumber sum of Tuv aimag is the test site of the NGIC project for forest monitoring and management. For selection of the test site, different human and natural influences such as forest fire, forest pest insects and desease, illegal logging, over use of non-timber forest products, air pollution effects, and high density human population as well as such criteria as further possibility to be affected by adverse effects, homogeneity of tree species, forest protection and sustainable use and implementation of forest conservation activities, had been considered. Based on the above mentioned conditions and criteria, forest area of Ulaanbaatar city, forest ecosystem of Bogdkhan Mountain protected area, Batsumber, Mungunmorit and Erdene sums of Tuv aimag, and Mandal sum of Selenge aimag had been considered for the pilot areas. After field visits to the prospective sites, Batsumber sum was selected.

In the selected test area, it is planned to implement such activities as determination of forest types and detection of the reasons for the changes, counting human and natural influences, elaboration of a modelling technique applied for counting of illegal logging effects, forest fire, forest insects and desease using GIS/RS technologies, and application of GIS/RS techniques for community based forest management.

The forest land cover changes have been determined using Landsat images of 1989, 2000, 2007 (figure 3).

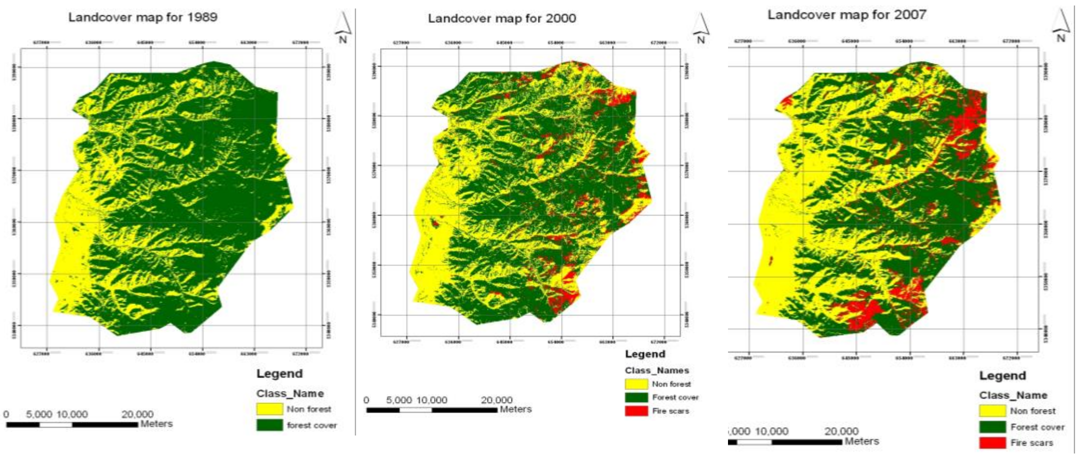

Figure 3. Forest land cover changes using multitemporal Landsat images.

Moreover, within the framework of the study, forest risk model has been developed and tested in the project test area. The general diagram of the model is shown in Figure 4.

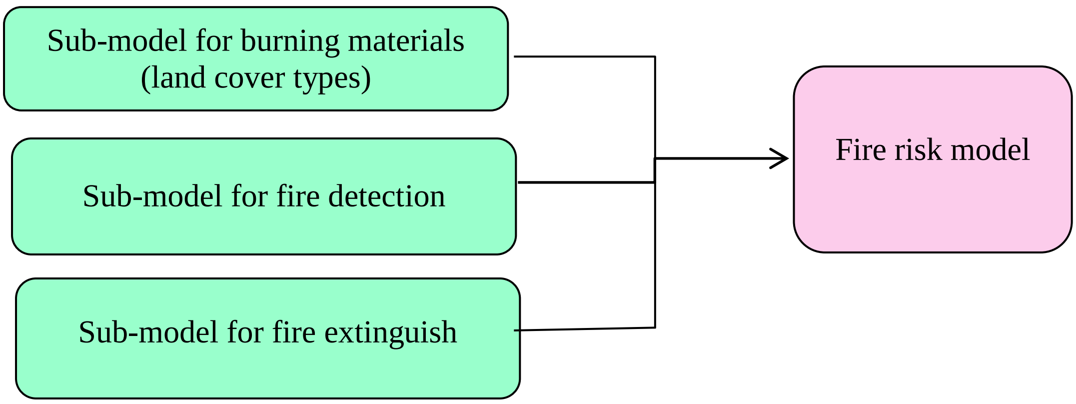

Figure 4. The general diagram of the fire risk model.

5. CONCLUSIONS

The aim of this study was to demonstrate the case studies on the integrated approaches of RS and GIS techniques for different forest studies. Within the framework of the study, it was assumed that there is an operational GIS that stores historical data about the forest and there are needs to produce updated forest maps and also to create a forest biomass map. As data sources, different optical and SAR images as well as topographic and forest taxonomy maps were used. Overall, the study demonstrated that integrated RS and GIS techniques can be successfully used for different forest studies.

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