Application of Multitemporal Optical and SAR Data for Different Forest Studies

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Abstract

The aim of this study is to demonstrate different applications of the passive and active sensor data for different forest studies in Mongolia. For this purpose, Landsat TM data of 1988, SPOT XS image of 1997, ERS-1/2 tandem pass SAR images of 1997, ERS-2 SAR and JERS-1 SAR intensity images of 1997, and other thematic information are used and different digital image processing techniques are applied. The results indicated that the integrated use of optical and microwave data can be successfully used for different forest studies as well as for differentiation between the fuzzy boundaries of different forest and vegetation classes.

Key words: Optical, SAR, Multitemporal, Forest change, Reflectance, Backscatter

1. Introduction

Optical remote sensing (RS) data sets taken from different Earth observation satellites such as Landsat and SPOT have been successfully used for forest monitoring and management since the operation of the first Landsat launched in 1972. SAR images taken from space platforms have been widely used for different forest applications since the launch of the ERS-1/2, JERS-1 and RADARSAT satellites. The combined application of data sets from both sources can provide unique information for different forest studies, because passive sensor images will represent spectral variations of the top layer of the forest classes, whereas microwave data with its penetrating capabilities can provide some additional information about forest canopy [3].

The aim of this research is to demonstrate different applications of the passive and active sens or data for different forest studies in Mongolia that is a) to conduct a forest change study usin g multitemporal optical RS images, b) to create a forest biomass map using SAR images and c) to analyze the boundary between fuzzy classes: grass-herb and young forest using both optic al and SAR images. As a test site, Bogdkhan Mountain situated in central part of Mongolia, n ear the city of Ulaanbaatar has been selected. To reach the final goals, different RS and GIS te chniques have been applied.

2. Study area and data sources

As a test site Bogdkhan Mountain situated in central part of Mongolia, near the city of Ulaanbaatar has been selected. 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. Cedar and larch dominate in the forest cover but pine, birch, spruce and poplar are also occur [1].

The data used consisted of Landsat TM data from summer of 1988, SPOT XS image of 19 June 1997, ERS-1/2 tandem pass SAR single look complex (SLC) images acquired on 10 and 11 October 1997, ERS-2 SAR intensity image of 25 September 1997 and JERS-1 SAR intensity image of April 1997. In addition, a topographic map of 1984, scale 1:50,000 and a forest taxonomy map, scale 1:100,000 were available.

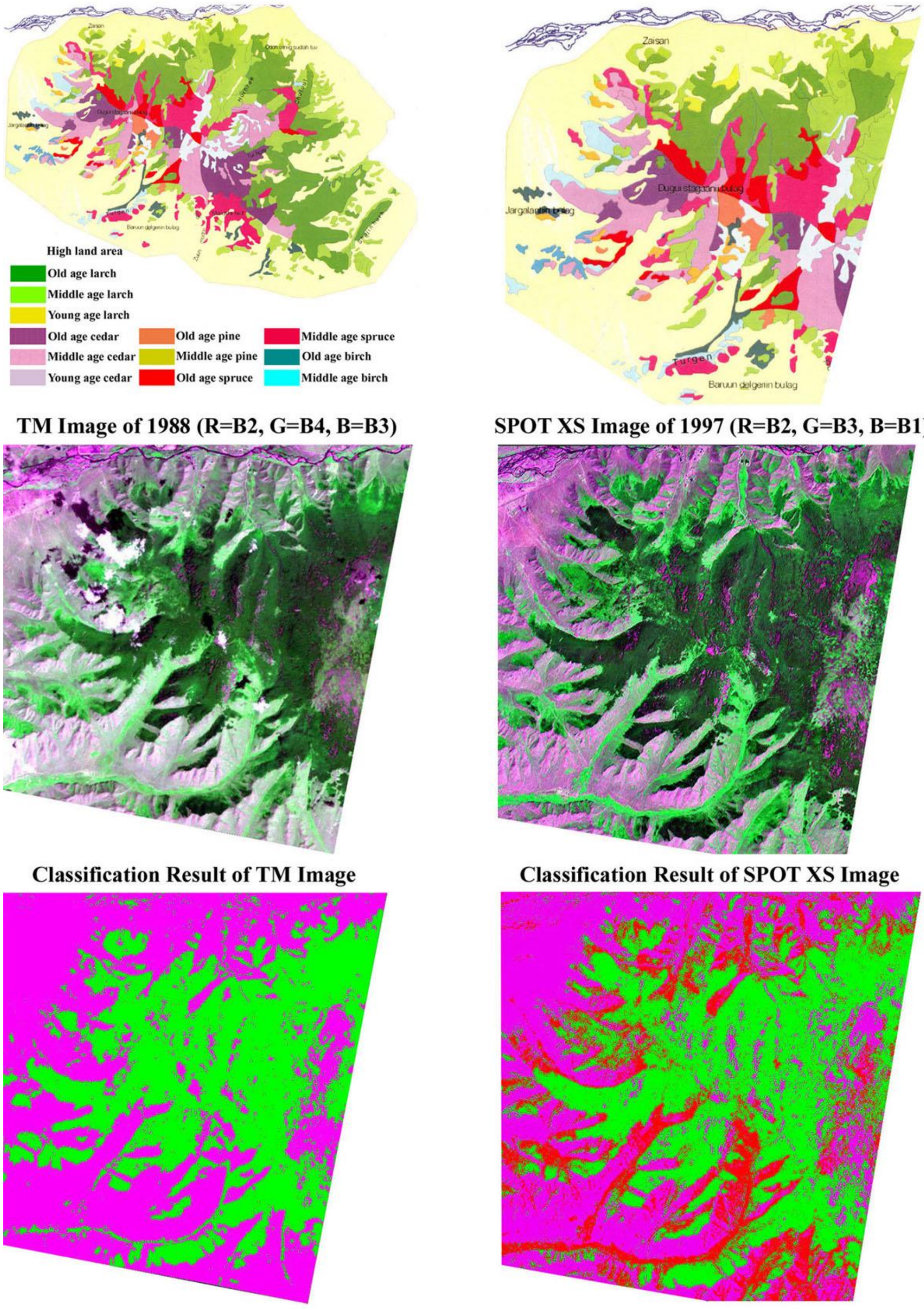

Figure 1. a) Forest taxonomy map of Bogdkhan Mountain, b) The selected part of the study area, c) Landsat TM image of 1988, d) SPOT XS image of 1997, e) Classified image of Landsat TM, f) Classified image of SPOT XS.

3. Forest change study using multitemporal optical RS images

In the test area, most of the mixed forests that represent fuzzy boundaries among different forest classes were situated in the central and western parts of the mountain. Therefore, for the analysis, the areas situated in these parts have been considered (figure 1a,b). Initially, the optical images (i.e. Landsat TM data of 1988 and SPOT XS image of 1997) were thoroughly analyzed in terms of brightness and geometric distortion and the images were of a good quality. Then, the SPOT XS and Landsat TM images were successively georeferenced to a UTM map projection using a topographic map of the study area, scale 1:50,000. The ground control points (GCP) 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 [6] have been applied and the related root mean square (RMS) errors were 0.68 pixel, and 0.76 pixel, respectively.

In order to demonstrate the forest changes, the selected multitemporal optical images were classified using the traditional statistical maximum likelihood classification (MLC) [7,9]. For the actual classification green, red and near infrared bands of the images were used and the images were classified into just two classes: forest and non-forest. The original SPOT XS and Landsat TM images and the results of the MLC are shown in figure 1c-f. As seen from the figure 1, different local changes had occurred in the mountain within a 9 year period.

4. Creation of a forest biomass map using SAR images

In the present study, for the creation of a forest biomass map of Bogdkhan Mountain, ERS-1/2 tandem pass SAR images and JERS-1 SAR intensity image have been used. Initially, we had to extract coherence and amplitude images from the ERS-1/2 data sets and for this purpose, the techniques used in Amarsaikhan and Sato (2004) have been applied.

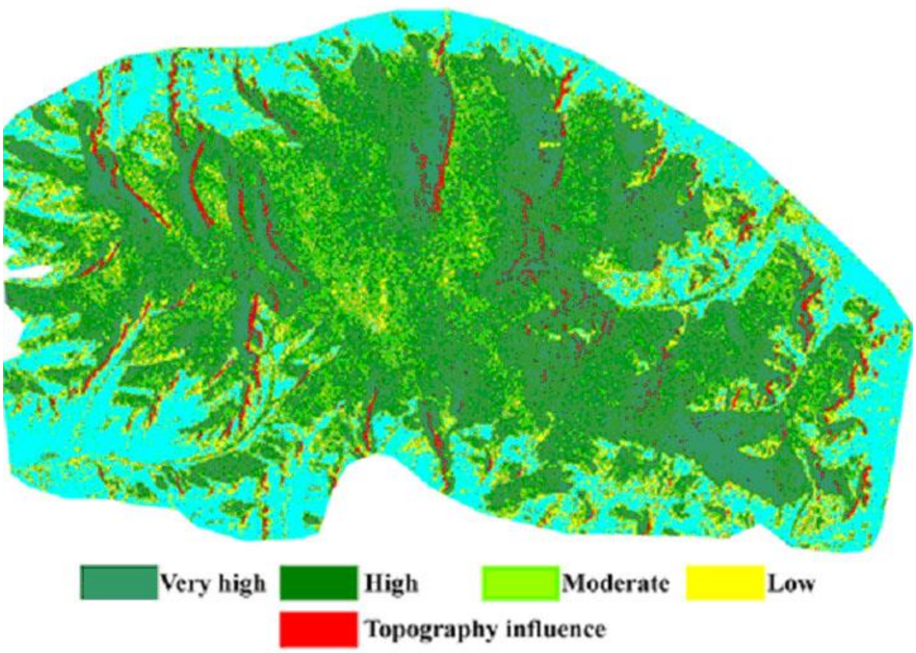

Figure 2. Forest biomass map of Bogdkhan Mountain

In general, the coherence is a measure of the variance of the phase difference of the imaged surface in the time between the two SAR data acquisitions. 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 [10]. 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. Based on this characteristics of coherence, it is possible to define different forest volumes which are directly related with forest biomass. To create a forest biomass map, initially the SAR images were successively georeferenced to a UTM map projection using a topographic map of the study area, scale 1:50,000. Then, the combined SAR bands were classified using the MLC defining such biomass classes as very high, high, moderate and low (figure 2). It was not possible to define the amount of biomass in the areas affected by radar layover.

5. Analysis of the boundary between fuzzy classes using ERS-2 SAR image

In some areas of the forest classes represented on the optical images, the boundary between fuzzy classes: grass-herb and young forest could not be distinguished due to their similar spectral characteristics. However, these two classes might be distinguished on the SAR image because they have different structure that can cause different backscatter return. These two fuzzy classes have the following backscattering properties [2,5,8].

From forest canopy, at different radar wavelengths, volume scattering derived from multiple-path reflections from leaves, twigs, branches and trunks can be expected. However, in case of the ERS-2 SAR data with its VV polarization only volume scattering from the top layer can be expected, because the wavelength is too short to penetrate the forest canopy. The backscatter will also be influenced by the local incidence angle as well as the underlying topography. In total, the forest area will behave as a diffuse reflector due to volume scattering although some other scattering might also be expected depending upon the height and geometry of the trees. As a result, the area will have brighter appearance on the radar image.

Grass-herb will behave as a mixture of grass and soil and the backscatter will depend upon the volume and characteristics of either of them. In C-band frequency, such a class will have components of both diffuse and specular reflection depending on the plant characteristics and incident angle. The backscattering of soil will also depend on different surface and system parameters. Specifically, the backscatter from a soil layer is very much dependent on the moisture content and the higher the water content the more reflection is expected. However, in this mountain area, the moisture content cannot be high enough to cause high reflection, and the reflection from the soil will most probably be dominated by specular reflection. As a result, the backscatter from this class will not be as high as in the case of volume scattering, thus resulting in lower to middle brightness.

Initial visual inspection of the speckle suppressed SAR image gave some distinctions between different features, but further interpretation highly required local knowledge about the sites and backscatter properties. To improve the image interpretation and increase the tonal discrimination between different forest and non-forest types, a synthetic false colour composite (SFCC) image has been created. To create such an image, at first the gammamap filtered SAR image was filtered by the use of different texture analysis and high pass filters of different sizes. Then, the results of three different filter operations were assigned to the red, green and blue (RGB) colours, respectively. The best colour image to represent the tonal variations was obtained by the combination of the results of 7x7 variance, 5x5 edge enhancement, and 5x5 mean euclidian distance filters. Figure 3 shows the comparison between the original speckle suppressed image and the created SFCC image. As seen from figure 3, despite the radar layover and foreshortening effect, the SFCC demonstrates more tonal variations between the two fuzzy classes: young forest and natural vegetation, which were not distinguishable on the optical images. The radar image in these areas shows brighter colour if there is a forest due to volume scattering. The tonal variations change to darker colour when there are classes that cause less volume scattering.

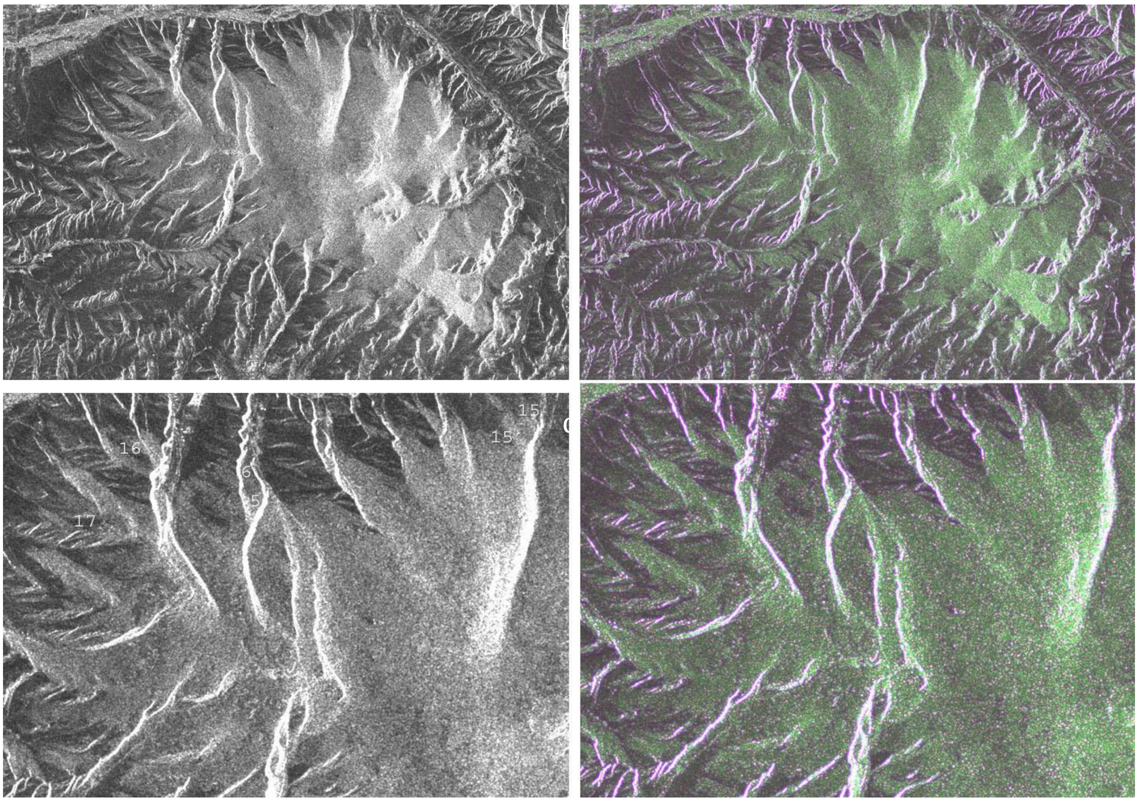

Figure 3. (a) The original speckle suppressed image. (b) SFCC image (7x7 variance=R, 5x5 edge enhancement=G, and 5x5 mean euclidian distance=B). (c) A subset from (a) indicating some of the selected sites. (d) A subset from (b).

6. Conclusions

The aim of this study was to demonstrate different applications of the optical and microwave data sets for different forest studies in Mongolia. Within the framework of the study a) a forest change study using multitemporal optical RS images, b) creation of a forest biomass map using SAR images and c) analysis of the boundary between fuzzy classes: grass-herb and young forest using both optical and SAR images, were carried out.

Overall, the study demonstrated that the integrated use of optical and microwave data can be successfully used for different forest studies as well as for differentiation between the fuzzy boundaries of different forest and vegetation classes.

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