Pixel-based Classification of Forest Area using Multi-source Satellite Images in Central Mongolia

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Abstract

The aim of this research is to conduct a forest resources study in central Mongolia using the integrated optical and SAR data sets. As data sources, microwave Sentinel-1B C-band dual-polarization data and optical Sentinel-2B images are available. After creation of a pseudo color image using a principal component analysis (PCA), a supervised classification is conducted. For the classification of forest types, a support vector machine (SVM) classification method is used. The result has been evaluated using an accuracy assessment technique. Overall, the research demonstrated that the combined optical and SAR features can be successfully used for forest resources study in Mongolia.

Keywords: Remote sensing (RS), PCA, SVM classification, forest

Introduction

Forest is one of the most important natural resources in our planet and plays a fundamental role in the economic, social, cultural and sustainable development of the nations (Wang *et al.* 2012). Actual management of forest resources requires consistent and updated information about the status and trends of forest resources. Generally, all levels of the government, private entities and research institutions have conducted a wide range of forest inventory and monitoring efforts. In order to successfully manage the forest resources, the forest and land managers should require a much greater volume of information with different spectral characteristics and larger spatial and temporal scale (Peterson *et al.* 2000).
As the present RS techniques and methods are so advanced, it is possible to produce a reliable forest map and use it for planning and management (Amarsaikhan *et al.* 2011, Enkhjargal *et al.* 2015).

The study site is a forest located between the Siberian taiga and the Mongolian plateau of grassland, a region that plays a vital role in preventing soil erosion, regulating the water regime, and providing suitable conditions for wildlife and Biodiversity conservation (Tsogtbaatar, 2000). However, forests in Mongolia grow in harsh climatic conditions here low precipitation and high radiation rates prevail throughout the year (FAO 2011); hence, they have a low capability to restore naturally and a heightened sensitive to forest wildfires, plagues, and degradation by human influence (Mühlenberg *et al.* 2012). For these reasons, a detailed description of the Mongolian forests is relevant for sustainable management purposes.

The purpose of this study is to conduct a forest resources study in central Mongolia using the integrated optical and SAR data sets. Overall, the research demonstrated that the combined optical and SAR features can be successfully used for forest resources study in Mongolia.

Study area and data sources

As a test site, Bulgan soum located in Arkhangai aimag (province) has been selected. Arkhangai aimag is situated in the central part of the Khangai mountain range and its territory comprises mountains, steppe and plains. Over 70 percent of the territory of the aimag is pasture land, almost 2 percent with hay fields, about 1 percent with sown area, and 15 percent of the territory is covered with deciduous and coniferous forest.

The study area has an area of 3220 km^2 with a forested area of 410 km^2, approximately 12.7% of the total area. The topography is relatively mountainous area. The elevation range is between 1620 and 3464 m above sea level.

In the current study, the satellite data used consisted of geocoded Sentinel-2B multispectral images acquired on 18 August of 2018 and Sentinel-1B C-band dual polarization radar image acquired on 3 August of 2017 and topographic maps of the area. The ground truth information was acquired through a forest inventory, which by law has to be conducted for specific forest areas in Mongolia. In the study area, the forest inventory started in 2012 and ended in 2013. The data analysis and processing was completed by the Forest Division in the Ministry of Nature and Environment (MNE).

Methodology

The main goal of this study was to map the change of forest area using satellite image data and the ground truth data. According to the field surveying, the study area has four main tree species: larch (Larix Sibirica), cedar (Pinus Sibirica), poplar (Populus) and willow (Salix sp.). The larch is a dominating forest and it covers approximately 93.3% of the forested area in the study site. However, 11.8% of the larch forest was burned by wildfire. All datasets acquired for this study are shown in Figure 2.

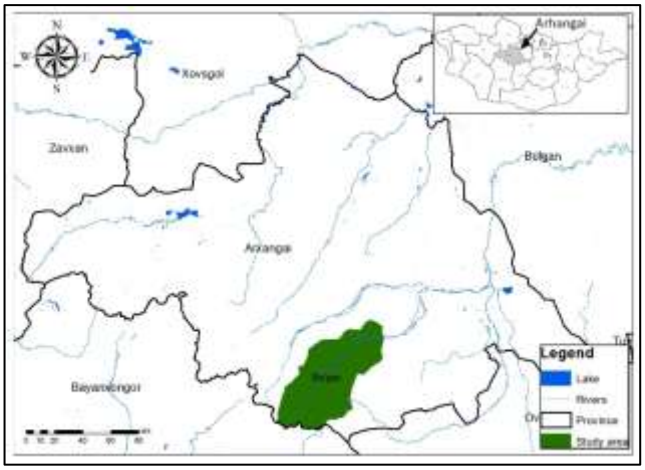

Figure 1. Location of the study area

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 images because they have different structures that can cause different backscatter return. These two fuzzy classes have the following backscattering properties (Amarsaikhan, 2004). 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 C-band SAR data sets only volume scattering from the top layer of the forest (Amarsaikhan, 2013).

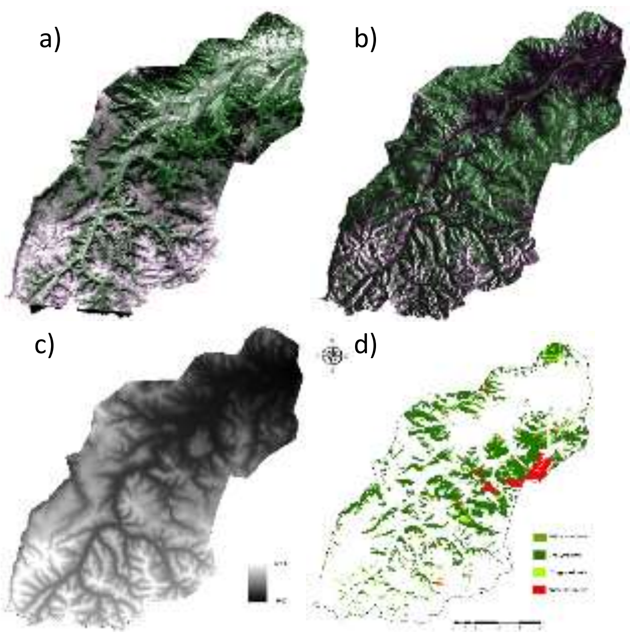

Figure 2. a) Sentinel 2B image, natural color b) Sentinel 1B, VH, VV polarization c) SRTM digital elevation model d) Forest reference map

In this study, PCA has been performed for the image fusion of the multisource datasets. The image fusion a technique used to combine image of different spatial and spectral resolutions. In other words the image fusion is the integration of different digital images in order to create a new image and obtain more information that can be separately derived from any of them (Amarsaikhan *et al*. 2012).

The PCA is a statistical technique that transforms a multivariate data set of intercorrelated variables into a set of new uncorrelated linear combinations of the original variables, thus generating a new set of orthogonal axes. It is also a data compression technique used to reduce the dimensionality of the multidimensional datasets and helpful for image encoding, enhancement and multitemporal dimensionality (Richards and Xia, 1999).

For the actual classification a SVM method has been used. In RS applications, SVM was primarily used for the hyperspectral image classification and object detection, although researchers have recently expanding its application for multispectral remote sensing data provided a detailed introduction of SVM to the RS community (Melgani and Bruzzone, 2004).

Results and discussion

In order to carry out forest analysis, the Sentinel images were thoroughly analyzed in terms of brightness and geometric distortion. The images were of a good quality and did not include distortions or noise. Then, the Sentinel images were successively geometrically corrected to a UTM projection using a topographic map of the study area, scale 1:100.000. The ground control points were selected on clearly delineated sites and in total 16 regularly distributed points were chosen. For the actual transformation, a second order transformation and nearest neighbor resampling approach (Mather and Koh, 2011) have been applied and the related root mean square errors were 0.57 pixel and 0.63 pixel. Then, image fusion has been applied to the optical and SAR images. The image fusion a technique used to combine image of different spatial and spectral resolutions. In other words the image fusion is the integration of different digital images in order to create a new image and obtain more information that can be separately derived from any of them (Amarsaikhan *et al.* 2012).

PCA has been performed using all available bands and the result showed that the first three PCs (principal components) contained 93.4% of the overall variance. The visual inspection of PC4 and others indicated that they contained noise. A color image created by the use of the first three PCs is shown in Figure 3.

After the image fusion, the image has been classified using SVM supervised classification technique. Initially, to define the sites for the training signature selection, area of interest representing the available four classes (old, middle, young aged larch and non-forest).

For the accuracy assessment of the classification results, the overall performance has been used. This approach creates a confusion matrix in which reference pixels are compared with the classified pixels and as a result an accuracy report is generated indicating the percentages of the overall accuracy (Amarsaikhan *et al.* 2011). As ground truth information, different AOIs containing 2,585 purest pixels have been selected. AOIs were selected on a principle that more pixels to be selected. The overall classification accuracy for the selected classes were 80.29 % using PC bands. Figure 4 shows a forest map created by the SVM classification method. Table 1 shows the area size of the forest.

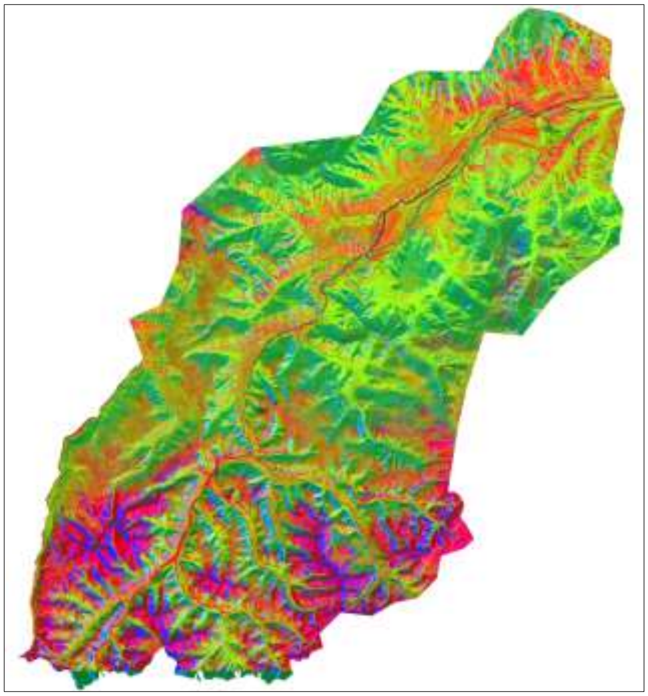

Figure 3. Image created by the PCA method (Red-PC1, Blue-PC2, Red-PC3)

Table 1. Area of larch forest

1	Forest types	2013 (км^2)	2018 (км^2)
	Old aged	330.664741	382.722264
	Middle aged	36.23877	29.1547
	Young aged	12.752183	68.06399
	Larch	379.655694	479.940954
3	*Burned larch*	44.797094	14.836667

To compare the final result with the existing information, a GIS layer was created using a ground truth of 2013 and ArcGIS system.

As seen from Table 1, in recent five years the middle aged larch forest has been decreased, but old aged and young aged larch forest have been increased, respectively. However, the burned larch area has been reduced due to recovery. It seen that the most significant increase occurred in young aged larch class. As could be seen from the final result, the class of burned trees was transformed into the class of young forests.

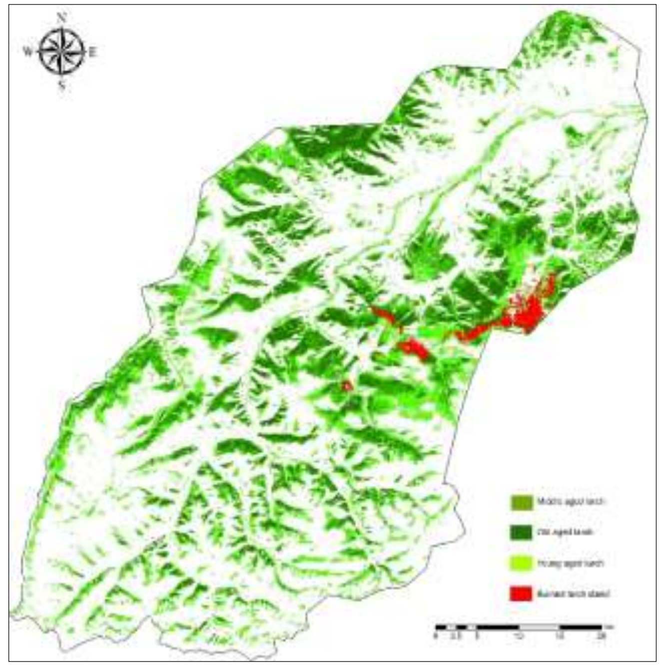

Figure 4. Classification result

Conclusion

The main goal of this study was to conduct a forest resources study in central Mongolia using multisource satellite datasets. As data sources, multispectral optical images, C-band dual polarization microwave images and ground truth data were used. Overall, the research indicated that in recent years, the forested area in the selected site have been significantly changed and multisource information could improve the interpretation and analysis of forest classes.

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