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FOREST MAPPING IN MONGOLIA USING OPTICAL AND SAR IMAGES

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ABSTRACT: The main objective of this research is to apply a refined Mahalanobis distance classifier for the extraction of forest class information from the combined optical and microwave images. The refined classification method uses spatial thresholds defined from contextual knowledge and different features obtained through a feature extraction process. The result of the refined method is compared with the results of a standard classification method and it demonstrates a higher accuracy. Overall, the research indicates that multisource data can improve the classification of forest types and the elaborated refined classification method is a powerful tool to increase the classification accuracy.

1. INTRODUCTION

Recently, a combined use of optical and microwave images has been increasingly used for forest mapping (Amarsaikhan *et al.* 2009, Amarsaikhan *et al.* 2012a, Sybrand *et al.* 2014). The combined application of optical and SAR data sets 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. It is clear that the integrated use of the optical and microwave data sets can significantly improve forest class interpretation and analysis, because a specific forest type which is not seen on the passive sensor image may be observable on the microwave image and vice versa because of the complementary information provided by the two sources (Amarsaikhan *et al.* 2012b).

Traditionally, optical remote sensing (RS) data sets have been extensively used for forest mapping and, for this purpose, diverse classification methods have been applied. The traditional methods mainly involved supervised and unsupervised methods and hence, a great number of techniques have been developed. Unlike single-source optical data, data sets from multiple sources have proved to offer better potential for discriminating between different forest cover types. Many authors have assessed the potential of multisource images for the classification of different forest classes (Cartus *et al.* 2011, Laurin *et al.* 2013). In RS applications, the most widely used multisource classification techniques are parametric methods, neural networks, decision tree classifier, Dempster–Shafer theory of evidence, and knowledge-based methods (Amarsaikhan *et al.* 2012a).

The aim of this study is to apply a refined classifier for the extraction of forest class information from the combined optical and SAR images. For the refined classification, spatial thresholds defined from the contextual knowledge were applied. For the test site, Bogdkhan Mountain situated in central part of Mongolia, near the Ulaanbaatar city has been selected. It is a strictly protected area and one of the world's oldest officially and continuously protected sites. Officially declared a sacred mountain reserve in 1778, evidence of its protected status dates back to the 13th century. Because of its universal natural or cultural significance, the mountain was added to the UNESCO World Heritage Tentative List on August 6, 1996.

2. STUDY AREA AND DATA SOURCES

As a test site, Bogdkhan Mountain has been selected. The mountain has a territory of 41651ha, of which 55% is covered by forest. The entire massif extends about 32 km from the East to the West and 16 km from the North to the South. It has 588 species of high plants, which are related to 256 genuses of 70 families. The 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. Cedar and larch dominate the forest cover but pine, birch, spruce and poplar also occur.

The data used consisted of Landsat TM data from 31 July 2010 and Envisat SAR image acquired on 25 March 2010. The Landsat TM data have seven multispectral bands (B1: 0.45–0.52µm, B2: 0.52–0.60µm, B3: 0.63–0.69µm, B4: 0.76–0.90µm, B5: 1.55–1.75µm, B6: 10.40–12.50µm and B7: 2.08–2.35µm). The spatial resolution is 30 m for the reflective bands, while it is 120 m for the thermal band. In the current study, channels 2,3,4,5 and 7 have been used. The Envisat is a European Earth-observing satellite carrying a cloud-piercing, all-weather free polarimetric radar, which is designed to monitor the Earth from a distance of about 790km. In the present study, a C-band (i.e. 5.36 GHz) HH polarization image has been selected. Figure 1 shows a forest taxonomy map of the study area.

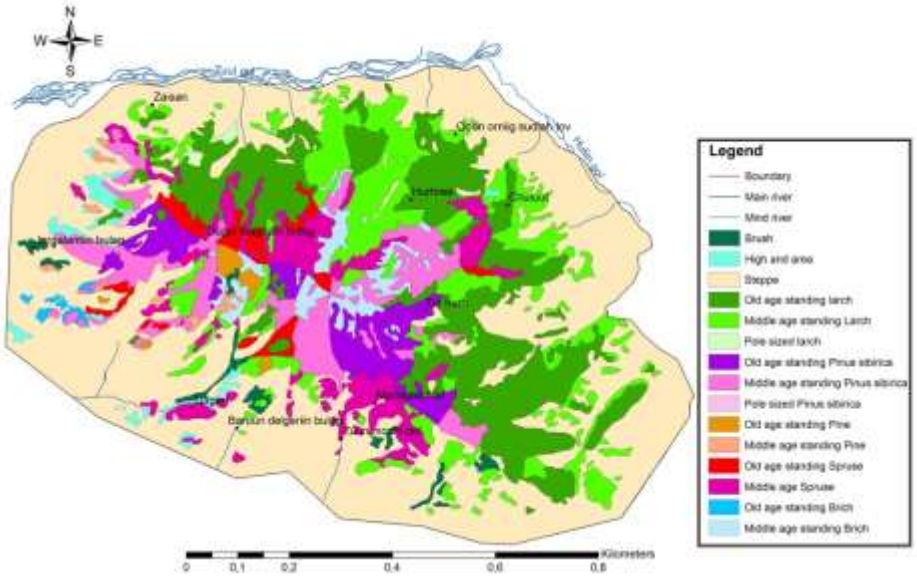

Figure 1. Forest taxonomy map of the Bogdkhan Mountain.

3. STANDARD CLASSIFICATION

After the co-registration of the optical and microwave images, they have been brought into the same coordinate system. In order to define the sites for the training signature selection, from the multisensor images, several areas of interest (AOI)s representing the selected forest classes (i.e. larch, cedar, pine, birch and spruce) have been selected through thorough analysis. The separability of the training signatures was firstly checked in feature space and then they were evaluated using Jeffries–Matusita distance. The values of Jeffries–Matusita distance 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 (ERDAS, 2010). After the investigation, the samples that demonstrated the greatest separability were chosen to form the final signatures. For the actual classification, the following feature combinations were used:

1. The original five spectral bands of the Landsat TM data.
2. The green, red, near infrared and middle infrared (2-5) bands of the Landsat TM data.
3. The HH polarization component of Envisat SAR and original five spectral bands of the Landsat TM data.
4. The PC1, PC2 and PC3 of the PCA.

For the actual classification, a Mahalanobis distance classification has been used and as the accuracy assessment method, 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 (Mather and Koch, 2010). For ground truth information, different regions containing purest pixels have been selected. The regions were selected on a principle that there were more available pixels to be selected for the evaluation of the larger classes, such as larch and cedar forests, than the smaller classes such as pine and birch forests.

The Mahalanobis distance classification of the Bogdkhan Mountain has been performed using the original five spectral bands of the Landsat TM data. The decision-rule used the signatures defined from the signature evaluation process and the final classified image is shown in Figure 3a. The confusion matrix indicated overall classification accuracy of 76.28% for the selected classes and there were high mixtures among birch, larch, cedar and spruce forests.

Then, the classification of the test area has been made using the green, red, near infrared and first middle infrared bands of the Landsat TM data. The decision-rule used the same signatures defined from the signature evaluation process and the final classified image is shown in Figure 3b. As seen from the classified image, the result is very similar to the result obtained by the use of the original five spectral bands. It has been evaluated using the same set of regions containing the purest pixels as in the previous classification, and it demonstrated an overall accuracy of 76.54%.

After that the test site has been classified using the HH polarization component of Envisat SAR and original five spectral bands of the Landsat TM data. The result of the classification is shown in Figure 3c. As seen from the classified image, the result looks similar to the result obtained by the use of original Landsat TM bands. However, the confusion matrix indicated an overall accuracy of 77.74%. This means that the combined use of optical and microwave data sets produced a better result than the single source image, but the result is still insufficient.

As it was seen from the PCA, PC1, PC2 and PC3 included 94.32% of the overall variance. In many PC-based image analysis, the selection of the first three PCs may be sufficient, if their overall variance exceeds 95%. In the case of the present study, as the overall variance almost reached that level, the PC1, PC2 and PC3 were classified using the decision rule. Figure 3d shows the result of the classification and the overall accuracy was 61.23%. As seen, the first three PCs give the worst result, because there are different mixtures among all classes. Specifically, there are high mixtures among the birch, larch and spruce forests. Also, many pixels belonging to the pine forest have been misclassified. This indicates that it is not necessary for the first three PCs to produce an improved classification result.

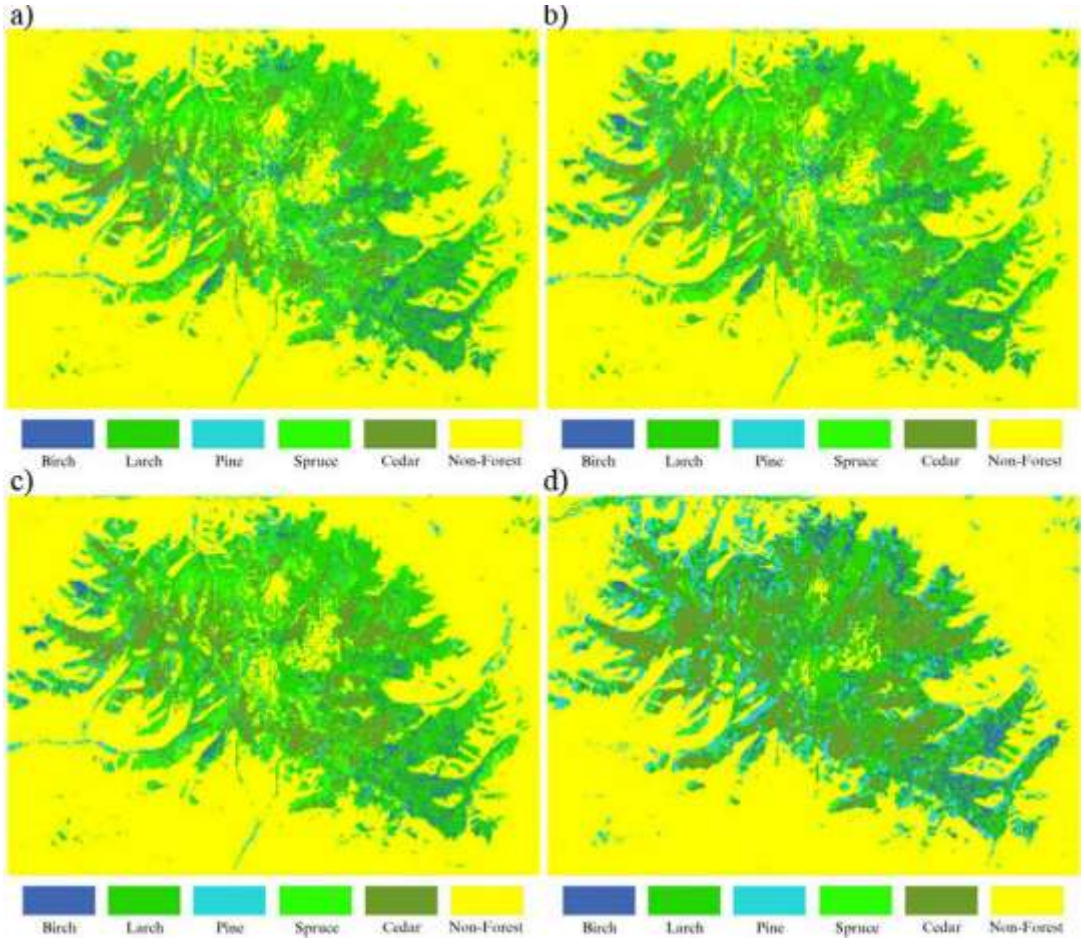

Figure 3. Classification results: a) the original five spectral bands, b) the green, red, near infrared and first middle infrared bands, c) the SAR and original five spectral bands,
d) the first three PCs.

4. THE REFINED CLASSIFICATION METHOD

Compared to the single-source data, multisource data sets have proved to offer better potential for discriminating between different forest classes. Generally, it is very important to design a suitable image processing procedure in order to successfully classify any digital data into a number of class labels. The effective use of different features derived from multiple sources and the selection of a reliable classification technique could be the important factors for the improvement of classification accuracy (Lu and Weng, 2007). In this study, for the classification of forest classes, a refined algorithm has been constructed. As the features, the HH polarization component of Envisat SAR and original five spectral bands of the Landsat TM data have been used.

The constructed classification algorithm uses spatial thresholds defined from the contextual knowledge. The contextual knowledge is based on the spectral and textural variations of the available forest classes in different parts of the images and the thresholds are applied to separate the statistically overlapping classes. The idea of the spatial threshold is that it uses a polygon boundary to separate the overlapping classes and only the pixels falling within the threshold boundary are used for the classification. In that case, the likelihood of the pixels to be correctly classified will significantly increase, because the pixels belonging to the class that overlaps with the class to be classified using the threshold boundary are temporarily excluded from the decision making process. In such a way, the image can be classified several times using different threshold boundaries and the results can be merged (Amarsaikhan *et al.* 2013). The result of the classification using the refined method is shown in Figure 4. For the accuracy assessment of the classification result, the overall performance has been used, taking the same number of sample points as in the multiple bands. The confusion matrix produced for the refined classification showed an overall accuracy of 93.12%. As could be seen from Figure 4, the result of the classification using the refined method is better than the results of the standard method.

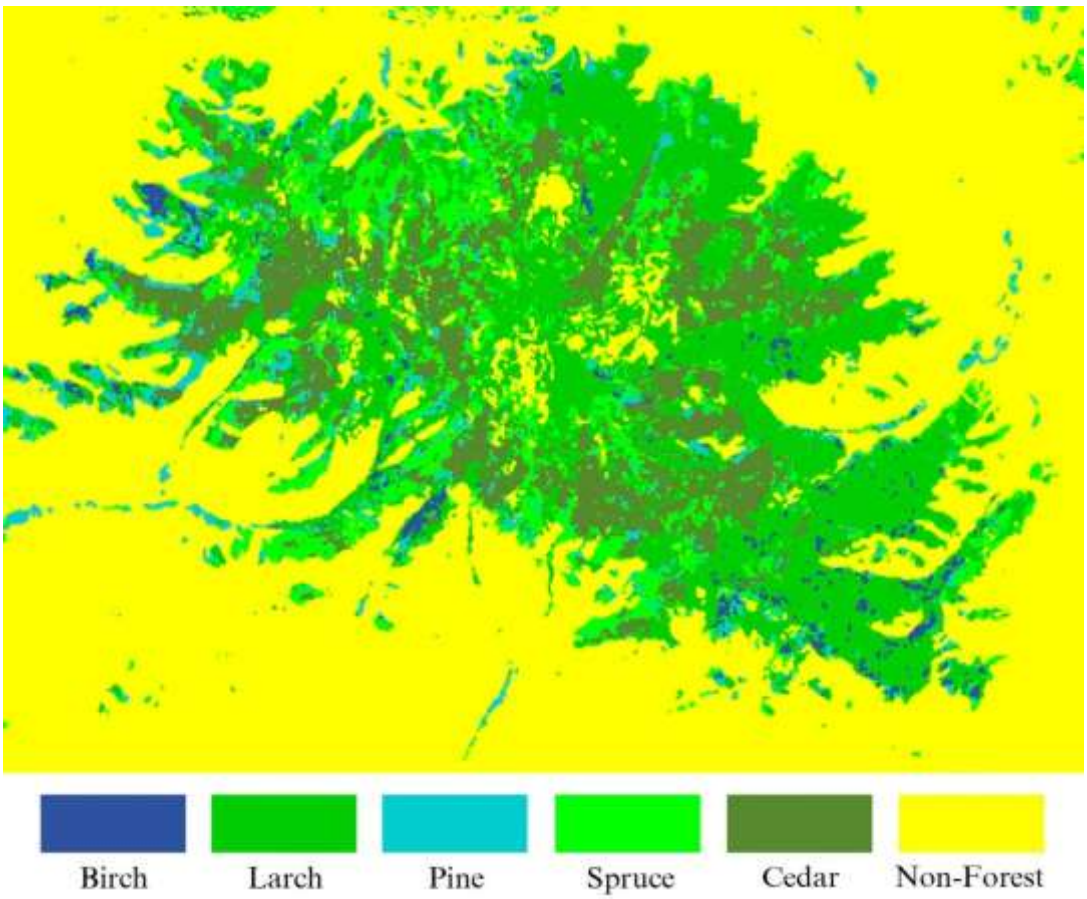

Figure 4. Classification result using the refined method.

5. CONCLUSION

The aim of this research was to construct a refined classification method for the extraction of forest class information from the multisource images. For the test area, Bogdkhan Mountain situated in the central part of Mongolia was selected and for the classification, the Mahalanobis distance classification method was applied. In

order to evaluate the classification accuracy of different features, the feature combinations were classified using the standard method. When the results were compared, the combined use of optical and SAR images gave an improved result. The refined classification technique used spatial thresholds defined from the contextual knowledge. As could be seen from the classification results, the performance of the refined classification was much better than the performances of the standard method and the elaborated refined classification method might be a powerful tool in the production of a reliable forest map.

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