APPLICATIONS OF MULTITEMPORAL OPTICAL IMAGES FOR FOREST RESOURCES STUDY IN MONGOLIA

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ABSTRACT: The aim of this research is to conduct the forest resources change study in Bogdkhan Mountain, Mongolia using multitemporal optical satellite images. For the analysis, Landsat images from different years and some other spatial information are used. To extract thematic information about forest class, a Mahalanobis distance classifier is applied to the multitemporal remote sensing (RS) images and land cover types are classified into forest and non-forest classes. For the improvement of the preliminary classification results, a fuzzy convolution with a 3x3 size window is applied and as the accuracy assessment, the overall performance is used. Overall, the results indicated that during recent years the forest resources of the Bogdkhan Mountain have been reduced and some measures should be taken.

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 (Haase and Camphausen, 2007). In general, intensive and effective forest management requires reliable inventory data and maps indicating the current state of the forest (Amarsaikhan *et al.* 2004). Generally, forests are managed for an evolving constellation of objectives: timber and other commodities production; environmental stability, ecological balance, maintenance of wildlife habitat; water quality protection; wilderness and open space preservation; and, in the coming years, as a buffer against climatic change, and effective management of these resources, requires reliable and timely information about their status and trends (Amarsaikhan *et al.* 2011).

Over the years, RS has been widely used for forest monitoring and management, because it provides real-time information about the state and conditions of forests (Amarsaikhan *et al.* 2012). The aim of this research is to analyze the forest resources in the Bogdkhan Mountain, which is a nature reserve with protected status situated in Central Mongolia. Within the framework of the study, it was assumed that there is an operational geographical information system (GIS) that stores different thematic layers and there is a need to check the reliability of the forest layer using RS data sets. For the analysis, multitemporal Landsat images as well as some other thematic maps have been used and different RS and GIS techniques were applied.

2. STUDY AREA AND DATA SOURCES

As a test site Bogdkhan Mountain situated in Central Mongolia, near the city of Ulaanbaatar has been selected. It 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. Cedar and larch dominate in the forest cover but pine, birch, spruce and poplar are also occur (Amarsaikhan *et al.* 2009).

The satellite data used in the current study consisted of a Landsat TM image acquired in August 1989, a Landsat ETM(+) image of September 2001, and a Landsat TM image of August 2011. In addition, a topographic map of 1984, scale 1:50.000 and a forest taxonomy map of 1997, scale 1:100.000 were available, accordingly. Figure 1 shows a forest map of the test area.

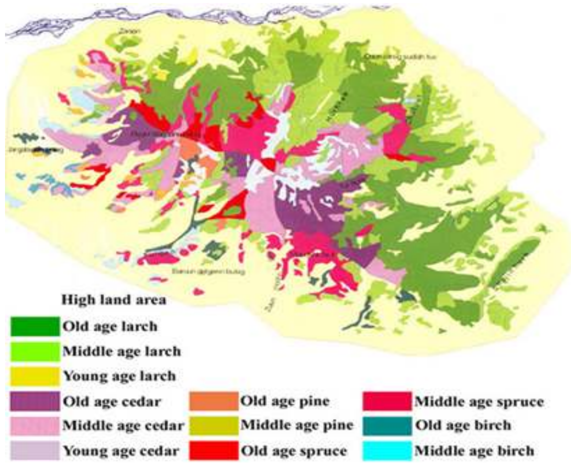

Figure 1.Forest taxonomy map of the test area.

3. ANALYSIS

In the present study, it is assumed that there is an operational GIS that stores different thematic layers and there is a need to check the reliability of the forest layer using multitemporal RS data sets. In order to carry out multitemporal forest analysis, initially, the Landsat images were thoroughly analyzed in terms of brightness and geometric distortion. The images were of a good quality. Then, the Landsat images were successively geometrically corrected to a UTM 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 15 regularly distributed points were chosen. For the actual transformation, a second order transformation and nearest neighbour resampling approach (Mather and Koh, 2011) have been applied and the related root mean square errors were 0.59 pixel, 0.65 pixel, and 0.56 pixel, respectively. Figure 2 shows false colour composite images of the multitemporal Landsat images.

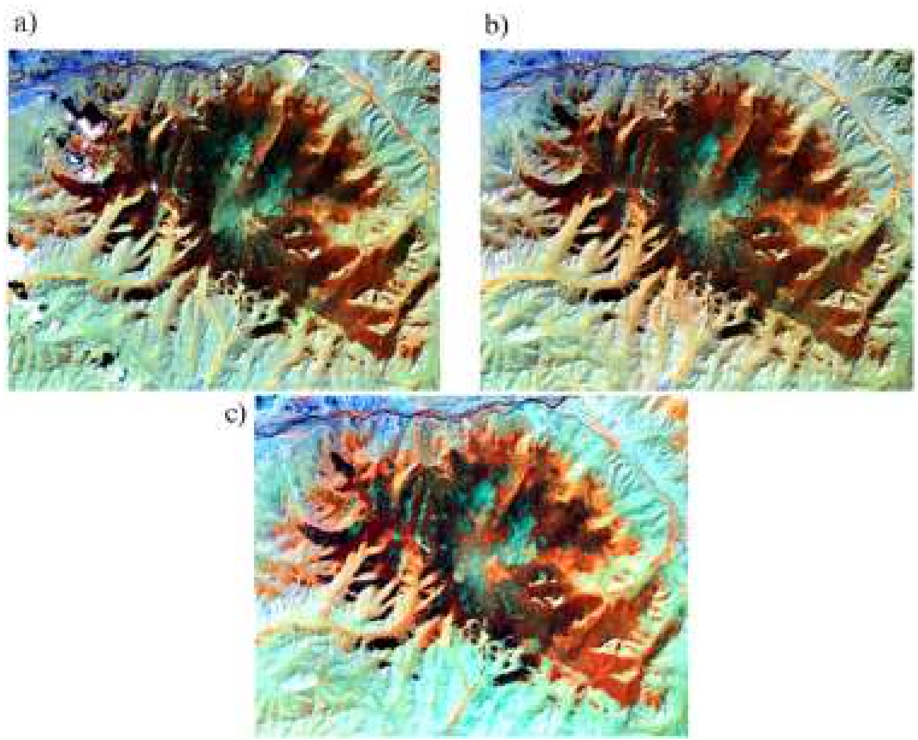

Figure 2. Comparison of multitemporal Landsat images:
a) TM image of 1989, b) ETM(+) image of 2001, c) TM image of 2011.

To define the forest changes, multitemporal Landsat images have been classified into forest and non-forest classes. For this purpose, training signatures had to be formed and some areas of interest representing the available two classes (ie, forest and non-forest) have been selected. Separability of the training signatures was firstly checked in feature space and then evaluated using TD distance (ERDAS, 1999). The values of TD 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. After the investigation, the samples that demonstrated the greatest separability were chosen to form the final signatures. The final signatures included about 512-871 pixels. As the classification features, the combinations of Landsat bands 3, 4 and 5 were used.

For the actual classification, a Mahalanobis distance classification has been used. It is a parametric method, in which the criterion to determine the class membership of a pixel is the minimum Mahalanobis distance between the pixel and the class centre. The sample mean vectors and variance-covariance matrices for each class are estimated from the selected training signatures. Then, every pixel in the dataset is evaluated using the minimum Mahalanobis distance and the class label of the closest centroid is assigned to the pixel (Richards, 2013). To increase the reliability of the classification, to the initially classified images, a fuzzy convolution with a 3x3 size window was applied. The fuzzy convolution creates a thematic layer by calculating the total weighted inverse distance of all the classes in a determined window of pixels and assigning the centre pixel the class with the largest total inverse distance summed over the entire set of fuzzy classification layers, i.e. classes with a very small distance value will remain unchanged while the classes with higher distance values might change to a neighboring value if there are a sufficient number of neighboring pixels with class values and small corresponding distance values (ERDAS, 1999).

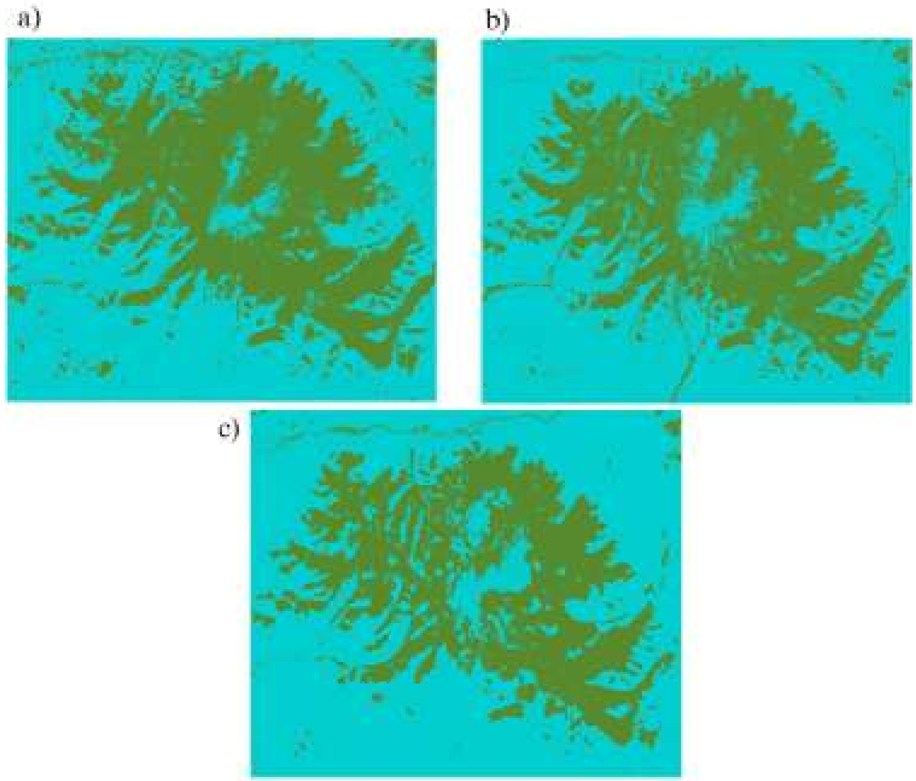

Figure 3. a) Classified image of 1989, b) Classified image of 2001, c) Classified image of 2011.

Initial visual inspection of the fuzzy convolved images indicated that there are some improvements on the borders of the neighboring classes that significantly influence the separation of the decision boundaries in multi-dimensional feature space. The final classified images are shown in figure 3(a–c). 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 (ERDAS, 1999). As ground truth information, different AOIs containing 1168 purest pixels have been selected. The overall classification accuracies for the selected classes were 86.34%, 87.98% and 86.76% for the 1989, 2001 and 2011 images, respectively.

4. CONCLUSIONS

The aim of the research was to conduct forest resources study in the Bogdkhan Mountain situated in Central Mongolia using multitemporal RS images. For this purpose, multispectral Landsat images of 1989, 2001 and 2011 as well as topographic and forest taxonomy maps were used. To discriminate between forest and non-forest classes, the Mahalanobis distance classification method was applied and it was followed by a fuzzy convolution with a 3x3 size window. For the accuracy assessment, the overall performance was used and the results of the classification indicated higher accuracies. Overall, the study demonstrated that RS is a good source that could be easily and successfully used for forest change studies.

5. REFERENCES

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