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THE INVESTIGATION OF LAND SURFACE FEATURES USING OPTICAL AND SAR IMAGES

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ABSTRACT: The aim of this study is a) to investigate land surface features and b) to conduct a land cover mapping in Mongolia using both optical and SAR images. As a test site, Tsagaantolgoi area, northern Mongolia having highly topographically changing landscapes is selected and for the analysis Landsat ETM(+) and ERS-2 C-band SAR images are used. The analysis was carried out using Erdas Imagine 8.6 installed in a PC environment.

1. INTRODUCTION

As it is known, RS images taken in the optical range of the electro-magnetic spectrum contain information on the reflective and emissive characteristics of the Earth surface features, while the synthetic aperture radar (SAR) images (intensity and coherence) contain information on the surface roughness, texture, dielectric properties and change of the state of natural and man-made objects. In years past, the integrated features of these multisource data sets have been efficiently used for an improved land cover mapping as well as land surface analysis. It is evident that a combined use of the optical and SAR images will have a number of advantages because a specific object or class which is not seen on the passive sensor image might be seen on the active sensor image and vice versa because of the nature of the used electro-magnetic radiation (Amarsaikhan and Douglas, 2004).

Optical RS data sets taken from different Earth observation satellites such as Landsat and SPOT have been successfully used for land cover mapping since the operation of the first Landsat launched in 1972, whereas SAR images taken from space platforms have been widely used for different thematic 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 thematic studies, because passive sensor images will represent spectral variations of various surface features, whereas microwave data with its penetrating capabilities can provide some additional information (Amarsaikhan *et al.* 2004).

In this study, we wanted to conduct a land cover mapping using both optical and SAR images. As a test site, Tsagaantolgoi area, northern Mongolia having highly topographically changing landscapes has been selected and for the final analysis Landsat ETM(+) image of 2001 and ERS-2 C-band SAR image of 1997 have been used.

2. STUDY AREA AND DATA SOURCES

Tsagaantolgoi area is situated in Orkhon-Selenge basin, northern Mongolia. The area represents a forest-steppe ecosystem and is characterized by fertile for agriculture chestnut soil. The vegetation in the region is dominated by hydrophyte and mezophyte. Based on the availability of the ground truth data and local knowledge from successive field surveys, such main classes as forest, shrub, grassland, soil, agricultiral field and water have been chosen.

The data used consisted of ERS-2 SAR intensity image of September 1997 with a spatial resolution of 25m and multispectral Landsat ETM+ image of 2001 with a spatial resolution of 28m. Also, as additional ground truth information a topographic map of 1984, scale 1:50,000 and soil and vegetation maps of scale 1:100,000 were available. Figure 1 shows the selected test site in the Landsat ETM+ image frame.

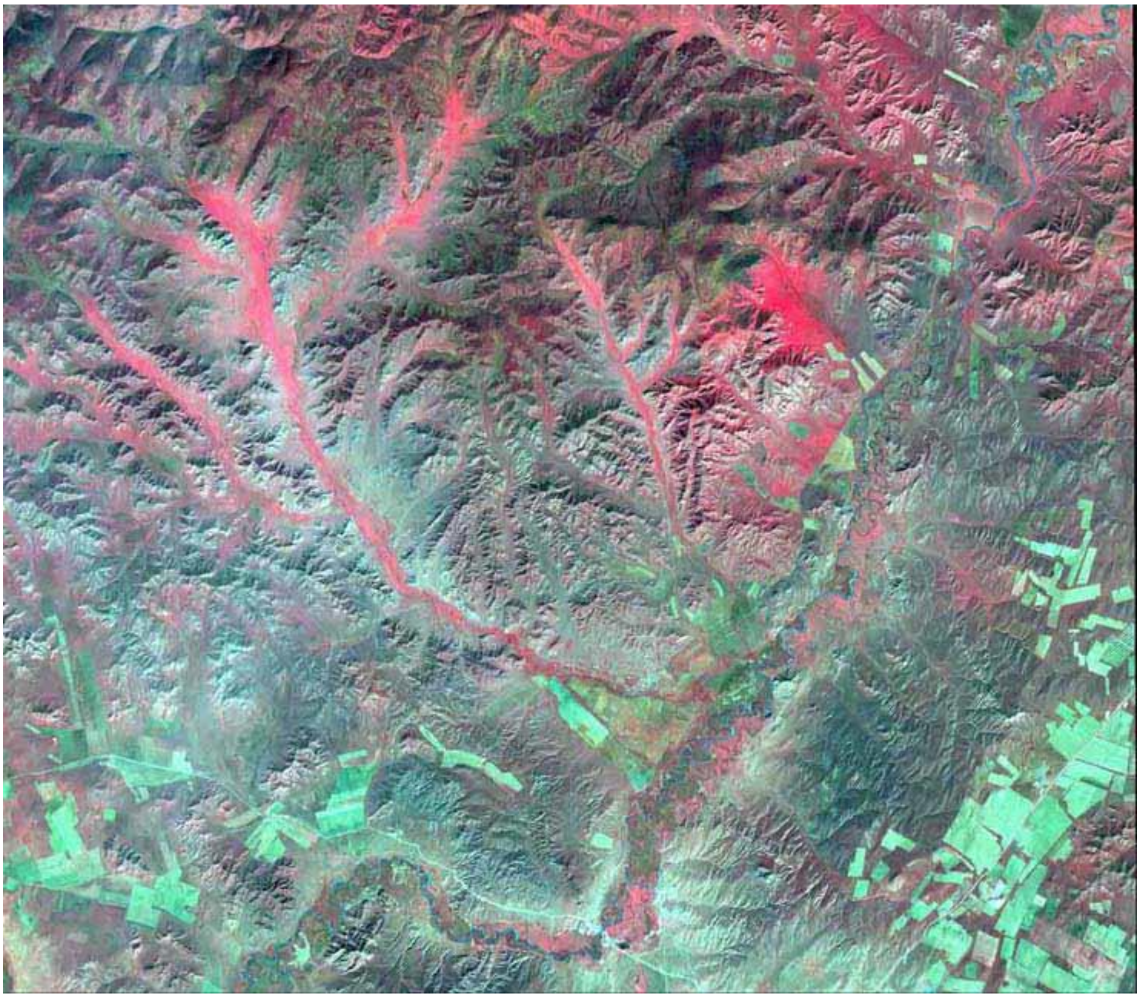

Figure 1. The Landsat ETM+ image of Tsagaantolgoi area.

3. GEOMETRIC CORRECTION OF THE MULTISENSOR IMAGES

Initially, the Landsat ETM+ image was geometrically corrected to a Gauss-Kruger map projection using a topographic map of the study area, scale 1:50,000. The GCPs have been selected on clearly delineated crossings of roads, rivers and other clear sites. In total 9 points were selected. For the transformation, a second order transformation and nearest neighbour resampling approach have been applied and the related root mean square (RMS) error was 0.98 pixel.

In order to correct the SAR image, 12 more regularly distributed GCPs were selected comparing the locations of the selected points with other information such as Landsat ETM+ image and the topographic map. Then, the image was geometrically corrected to a Gauss-Kruger map projection using the topographic map of the study area. For the actual transformation, a second order transformation and nearest neighbour resampling approach were applied and the related RMS error was 0.99 pixel. A subset of the fused image is shown in Figure 2.

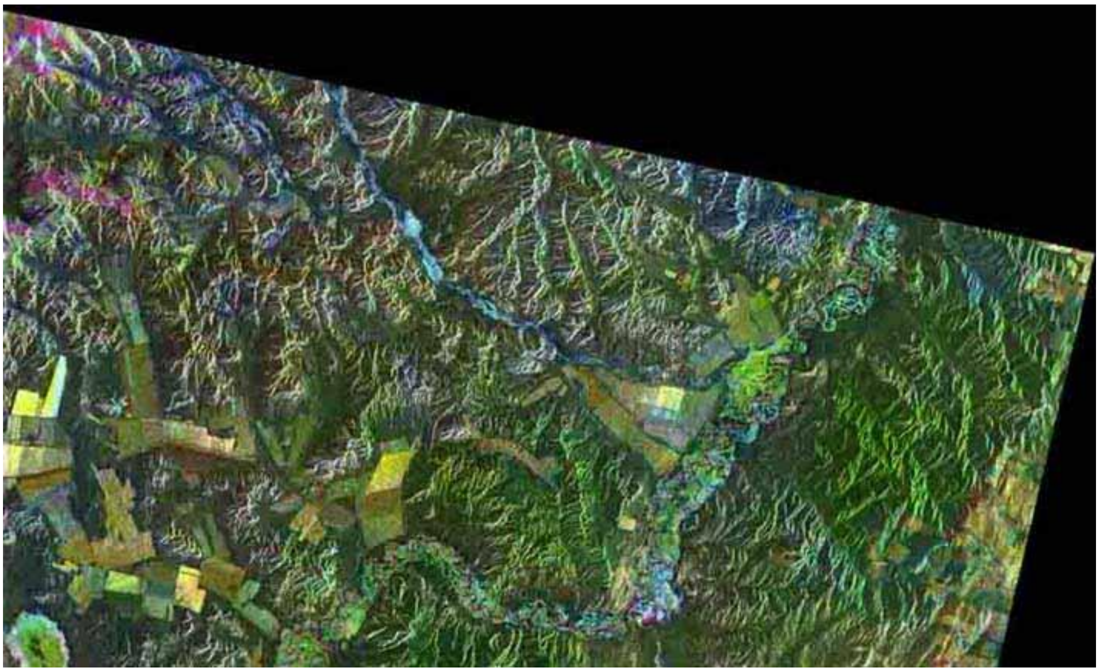

Figure 2. The subset of the fused image of ETM+ and SAR images of Tsagaantolgoi area.

4. THE INVESTIGATION OF LAND SURFACE FEATURES

Over the years, optical RS images have been extensively used for the study of different land surface features and there have been relatively few studies using microwave data sets. Therefore, in the present study we wanted to anlayse the selected land cover types based on their backscatter characteristics.

4.1. Backscatter analysis and signature evaluation

As the radar images have speckled appearances that influence the interpretation, it was necessary to choose the appropriate speckle suppression technique. For this aim, a 5x5 gammamap filter has been chosen. Also, as the interpretation of the objects on the radar images is site specific and the backscatter is dependent on the incidence angle, initially, on the ERS-2 SAR image, closely located from each other (2-4) polygons representing the selected land cover types have been selected. Then, the polygons were merged to form primary signatures of the representative classes. The statistics of the signatures representing different cover types are shown in table 1.

As can be seen from table 1, forest and shrub have higher average backscatter values than other classes and display higher variations. In the case of these classes, at different radar frequencies, trunk-ground double bounce scattering, branch-ground double bounce and branch-direct backscattering, crown volume backscattering and crown volume attenuation and ground backscattering can occur, i.e. backscatter will be volume scattering derived from multiple-path reflections from leaves, twigs, branches and trunks (Richards *et al.* 1987, Amarsaikhan and Ganzorig 1999). However, in 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 to forest canopy. Comparing the backscatter values in both classes, one can observe that shrub class caused much stronger volume scattering than forest. One of the reasons for this might have been a fact that because of the small size of foliage radar penetrated into the volume and interacted with internal parts causing multiple volume scattering that contributed to the overall backscatter return. Also, another reason could be differences in the moisture content.

Table 1. The mean backscatter values of the selected land cover classes and their variations in ERS-2 SAR image.

No	Classes	5x5Gammamap filtered image	
		Mean	SD
1	Forest	318.08	69.39
2	Shrub	349.27	51.98
3	Soil with sparse vegetation	160.09	20.23
4	Agricultural (abandoned) fields	201.59	32.55
5	Wet soil with sparse vegetation	404.86	90.78
6	Water	67.90	7.90

There are three soil-related (dominated) classes having different average backscatter values. As seen, they can be differentiated despite some overlaps on the edges of the signature distributions. Although, plant geometry, density and water content are the main factors influencing the backscatter coming from the vegetation cover, ground truth information revealed that the contribution of vegetation is not very significant. The backscatter of soil depends on the surface roughness, texture, existing surface patterns, moisture content, as well as wavelength and incident angle. The presence of water strongly affects the microwave emissivity and reflectivity of a soil layer. As it can be seen from table 1, soil with sparse vegetation, and agricultural (abandoned) fields have lower values in comparison with many other classes, but form more compact signatures. This indicates low backscatter intensities caused by specular reflection due to lack of some surface features, low roughness properties and low dielectric constant of the soil. Wet soil with sparse vegetation gives the highest backscatter return compared to other classes because of the soil moisture content and increase of dielectric constant (Manual of Remote Sensing, 1999).

Water has the lowest backscatter value creating the most compact signature. This is due to the specular reflection of water. As it can be seen, water can be differentiated from all other classes because it did not create a scattered signature.

4.2. Land cover mapping using optical and SAR images

In general, before applying a classification decision rule, the speckle noise of the SAR images should be reduced. The reduction of the speckle increases the spatial homogeneity of the classes which in turn improves the classification accuracy. In this study, to reduce the speckle of the selected features a 5x5 size frost filter has been applied (ERDAS 1999).

Initially, from the features, 2-4 areas of interest (AOI) representing the six selected classes have been selected using a polygon-based approach. Then, training samples were selected on the basis of these AOIs. The separability of the training signatures was firstly checked on the feature space images and then evaluated using JM distance (Richards, 1993). Then the samples which demonstrated the greatest separability were chosen to form the final signatures. For the final classification, bands 3,4 and 5 of ETM+ and SAR have been used.

For each of these feature combinations, supervised and unsupervised classifications have been applied. As a supervised classification the statistical maximum likelihood classification, whereas as an unsupervised classification the isodata clustering method have been used (Mather, 1999). For the accuracy assessment of the final classification results, the overall performance (ENVI 1999) has been used. As ground truth information, for each class 3-4 regions containing the purest pixels have been selected. When compared, the performance of the statistical maximum likelihood classification was better than the performance of the isodata method.

5. CONCLUSIONS

The aim of this research was to investigate land surface features as well as to conduct a land cover mapping in Mongolia using both optical and SAR images. For the investigation of land surface features, backscatter analysis was carried out, while for the land cover mapping supervised and unsupervised classifications were conducted.

Overall, the study demonstrated that the integrated features of the optical and SAR images can successfully be used for the analysis of land surface features as well as improve the classification of land cover types.

REFERENCES

1. D.Amarsaikhan, M.Ganzorig, 1999, Interpretation and comparision of AirSAR quad-polarised radar images, Proceedings of the 20th Asian Conference on RS, Hong Kong, pp695-700.

2. Amarsaikhan, D., Ganzorig, M., Batbayar, G., Narangerel, D., and Tumentsetseg, Sh., 2004, An integrated approach of optical and SAR images for forest change study, Asian Journal of Geoinformatics, No.3, 2004, pp.27-33.

3. D.Amarsaikhan, T.Douglas, 2004, Data fusion and multisource data classification, International Journal of Remote Sensing, No.17, Vol.25, pp.3529-3539.

4. ENVI, 1999, User’s Guide, Research Systems.

5. ERDAS, 1999, Field guide, Fifth Edition, ERDAS, Inc. Atlanta, Georgia.

6. Manual of Remote Sensing, 1999, 3^{d} edition, Volume 3, American Society of Photogrammetry.

7. Mather, P.M., 1999, Computer Processing of Remotely-Sensed Images: An Introduction, Second Edition, (Wiley, John & Sons).

8. Richards, J.A. 1993. Remote Sensing Digital Image Analysis-An Introduction, 2nd edition (Berlin: Springer-Verlag).

9. J.A.Richards, A.K.Milne, B.Forster, 1987, Radar Remote Sensing, UNSW, Sydney, Australia.