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FUSION OF OPTICAL AND SAR IMAGES FOR ENHANCEMENT OF FOREST CLASSES

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ABSTRACT: The aim of this study is to evaluate the performances of different image fusion techniques for the enhancement of spectral and textural variations of different forest types using optical and microwave data sets. For the data fusion, modified intensity-hue-saturation (IHS) transformation, principal components analysis (PCA) method, Gram-Schmidt fusion, and wavelet-based method are used and the results are compared. Of these methods, the better results are obtained through the use of the modified IHS transformation and wavelet-based fusion. Overall, the research indicates that multisource data fusion can significantly improve the interpretation and analysis of variety of forest types.

1. INTRODUCTION

Over the years, forest study extensively used both optical and microwave remote sensing (RS). Optical techniques are the most established remote sensing methods in forestry. Multispectral images rely on the radiometric information, where the intensity of the light reflected or emitted from the forest cover is measured in a number of discrete bands. By comparing the reflectivity in different wavelengths it is possible to relate these data to properties of the forest canopies. The areas of greatest potential are the assessment of stocking levels and the estimation forest parameters such as height, area and volume. Sensors with high spectral resolution can be used for mapping forest health in the form of nutrient and moisture deficiencies as well as damage caused by pests and diseases. On the other hand, radar sensors emit their own source of energy as a radio signal and determine the characteristics of the echo. They operate in different microwave regions and each region interacts differently with forest canopies allowing a better definition of their component parts. The longer wavelengths can penetrate the forest canopy to some extent and retrieve information of the underlying soil characteristics. As the microwaves are sensitive to forest structure and the moisture content of the canopy they can generate fully third dimensional information about the forest canopy (Suárez *et al.* 2005).

In the past years, integrated approaches of optical and microwave images have been increasingly used for different forest applications (Amarsaikhan *et al.* 2005, Morel *et al.* 2012, 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.* 2012).

One of the noticeable methods to combine RS data from multiple sources is image fusion which usually attempts to combine images with different spectral and spatial resolutions and increase detailed information in the combined product produced by the fusion process (Sritarapipa *et al.* 2014). Over the years, different fusion methods have been developed for improving spectral and spatial resolutions of RS data sets. The widely known techniques are the modified IHS transform, the Brovey transform, the PCA method, the Gram-Schmidt method, the local mean matching method, the local mean and variance matching method, the least square fusion method, the color normalization spectral sharpening, the wavelet-based fusion, the multiplicative method and the Ehlers fusion (Fang *et al.* 2013). Many image fusion applications use modified approaches or combinations of these methods.

The aim of this research is to investigate and evaluate different image fusion techniques for the enhancement of spectral and textural variations of different forest types. The selected fusion techniques are the modified IHS transformation, the PCA method, the Gram-Schmidt fusion, and the wavelet-based method. For the analysis, optical and microwave images with different spatial resolutions as well as some GIS data of the forest area in Mongolia have been used.

2. STUDY AREA AND DATA SOURCES

At present, forests account for 75% of the gross primary productivity of the Earth's biosphere, and contain about 80% of the Earth's plant biomass. Forest ecosystems may be found in all regions capable of sustaining tree growth, at altitudes up to the tree line, except where natural fire frequency or other disturbance is too high, or where the environment has been altered by different anthropogenic activities (Yude *et al.* 2013). In the current study, Bogdkhan Mountain situated in central part of Mongolia 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 (UNESCO, 1996).

The data used consisted of Landsat TM data from July 2010 and Envisat SAR image acquired on March 2010. The Landsat TM data have seven multispectral bands and the spatial resolution is 30 m for the reflective bands, while it is 120 m for the thermal band. In the present study, channels 2,3,4,5 and 7 have been used. The Envisat is a European satellite carrying a cloud-piercing, all-weather free polarimetric radar. In the present study, a C-band HH polarization image has been selected. In addition, a topographic map from 1984, scale 1:50,000 and a forest taxonomy map of 1988, scale 1:100,000 were available, accordingly. Figure 1 shows the study area in a Landsat TM image of 2010.

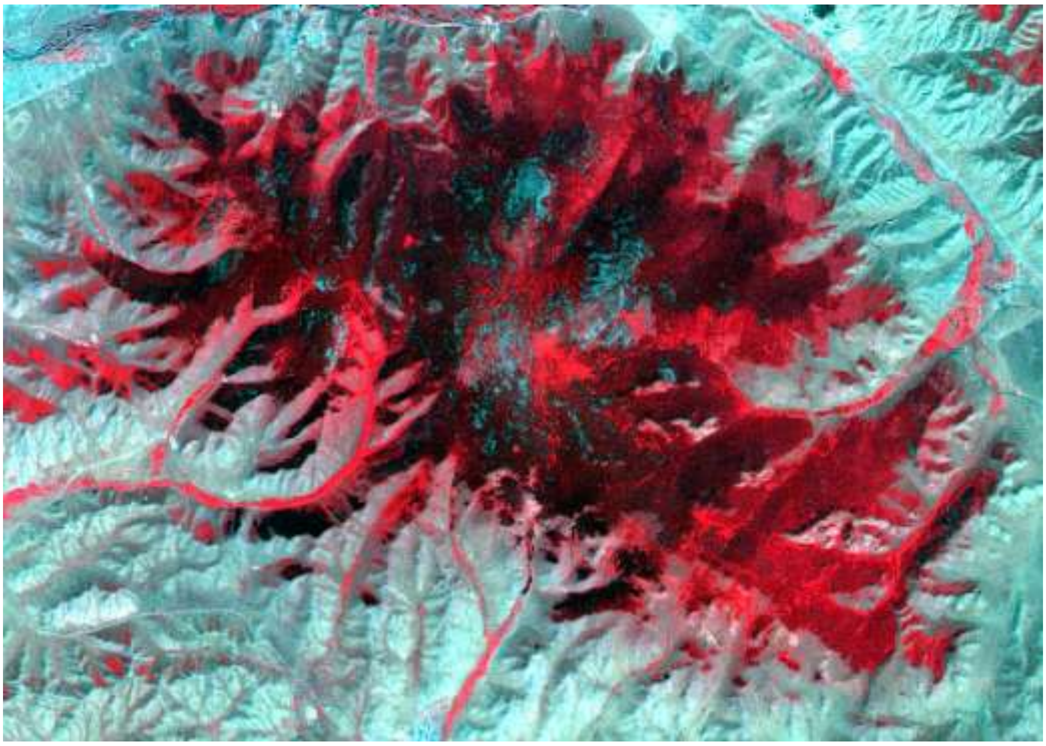

Figure 1. Landsat TM image of the Bogdkhan Mountain.

3. GEOREFERENCING OF OPTICAL AND SAR IMAGES

Initially, the Envisat image was rectified to the coordinates of the Landsat TM image using 11 more regularly distributed ground control points (GCP)s defined from topographic and forest taxonomy maps of the study area.

The GCPs have been selected on clearly delineated sites such as morphological structures, forest areas and roads. For the transformation, a second-order transformation and nearest-neighbour resampling approach were applied and the related root mean square (RMS) error was 0.52 pixel. After the first co-registration of the coordinates, the combined Envisat SAR and Landsat TM images have been georeferenced to a UTM map projection using the topographic map of the study area. The GCPs have been selected on clearly delineated sites and, in total, 9 randomly distributed points were chosen. For the actual transformation, a second-order transformation was used. As a resampling technique, the nearest-neighbour resampling method was applied and the related RMS error was 0.35 pixel.

4. SPECKLE SUPPRESSION AND DERIVATION OF THE SAR TEXTURE IMAGES

In the beginning, five different speckle suppression techniques such as lee, local region, frost, kuan and gammamap filters (ERDAS, 2010) of 3x3 and 5x5 sizes were compared in terms of delineation of forested areas and texture information. After visual inspection of each image, it was found that the 3x3 gammamap filter created the best image in terms of delineation of different features as well as preserving content of texture information. In the output image, speckle noise was reduced with very low degradation of the textural information.

In RS image analysis, texture is usually applicable to radar data. The ability to use radar data to detect texture and provide topographic information is a major advantage over other types of imagery. To derive texture images, co-occurrence measures (using 9x9 and 11x11 window sizes) were applied to the SAR image and they use a grey-tone spatial dependence matrix to calculate texture values (ENVI, 2004). By applying co-occurrence measures, initially 12 features have been obtained, but after thorough checking of each individual feature, only 3 features including the results of 11x11 skewness, 9x9 contrast and 9x9 correlation filters were selected.

5. COMPARISON OF THE FUSED IMAGES

In the present study, such fusion techniques as the modified IHS transformation, the PCA method, the Gram-Schmidt fusion, and the wavelet-based fusion have been applied to the combined Landsat TM, Envisat SAR and texture images. In all cases, the SAR image was considered as a high resolution band. In order to obtain good colour images that can illustrate spectral and spatial variations of the available forest classes on the selected multisource image, all the fused images have been visually inspected and compared.

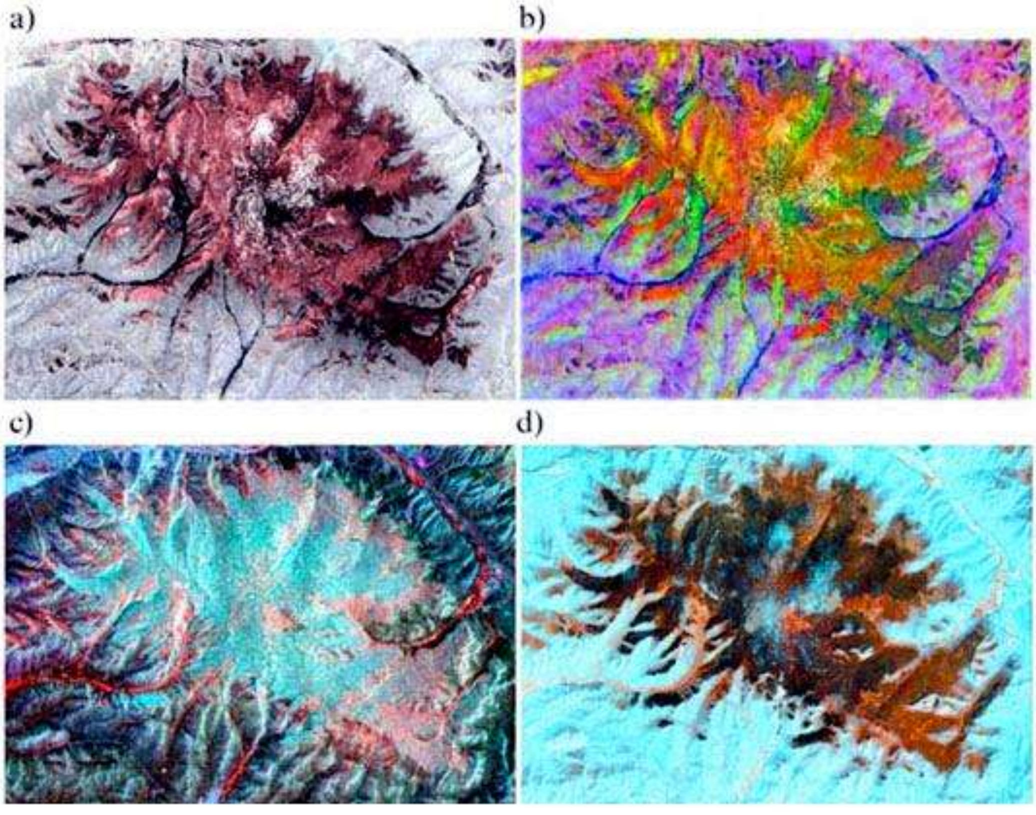

Figure 2. Comparison of the fused images: (a) the image obtained by modified IHS transformation; (b) the PC image; (c) the image obtained by Gram-Schmidt fusion; (d) the image obtained by wavelet-based method.

In the case of the modified IHS transformation method, the fused image (Figure 2a) demonstrated a better result compared to some other combinations, because beside the improved textural enhancement, the image has good spectral separations among some coniferous and deciduous forests. However, on the image it was not easy to perceive the separations between spruce and cedar forests.

The PCA has been applied to all selected images. As could be seen from the PCA, the Envisat HH polarisation image had a high negative loading in PC1 and it contained 47% of the overall variance. This means that the PC1 was dominated by the characteristics of the SAR image. Although, PC2 contained 34.92% of the overall variance and had a very high negative loading of the result of the contrast filter, visual inspection revealed that it contained less information related to the available forest classes. In PC3 that contains 12.4% of the overall variance, the middle infrared band of TM and SAR image have moderately high loadings. Compared to the PC2, on this image, it was possible to see some tonal variations of different forest classes. It was seen that the PC4 dominated by the result of the skewness filter had no useful information. However, visual inspection of PC5 that contained only 1.38 % of the overall variance, revealed that this feature contained useful information related to the tonal variations as well as textural characteristics of different forest classes. The PC6 and PC7 dominated by the negative characteristics of the correlation filter and visible bands had some useful information. The inspection of the residual PCs indicated that they contained noise from the total data set. The PC image created by the combinations of PC1, PC3 and PC5 is shown in Figure 2b. As seen from the PC image, although the image could not show clear textural features, it could well illustrate the colour variations of different classes.

In the cases of the Gram-Schmidt fusion the result was worse than the images created by other fusion techniques. As seen from the results shown in Figure 2c, the image is dominated by the characteristics of the SAR image. It is possible to observe only some separations of the larch forest, and other forest types are almost not distinguishable on this image. In the case of the wavelet-based fusion, the integrated image (Figure 2d) demonstrated a better result compared to the results of the Gram-Schmidt fusion. On this image, larch, cedar, pine and spruce forest types could be distinguished by their spectral properties. Additionally, it could be seen that the image illustrates good textural differentiation between different forest types. Figure 2 shows the comparison of the images obtained by the designated fusion methods.

6. CONCLUSION

The aim of this research was to evaluate the performances of different image fusion techniques for the enhancement of spectral and textural variations of different forest types of the Bogdkhan Mountain situated in the central part of Mongolia. As the fusion techniques, modified IHS transformation, PCA technique, Gram-Schmidt method, and wavelet-based fusion were used. Of these methods, the modified IHS transformation, and wavelet-based fusion gave better results compared to the other fusion techniques in terms of the spatial and spectral separations among different forest types. Overall, the research indicated that multisource information could improve the interpretation and analysis of different forest classes and might be considered as a preliminary approach for the detailed forest studies.

REFERENCES

- 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, Vol. 4(3), pp. 27-33.
- Amarsaikhan, D., Saandar, M., Battsengel, V. and Amarjargal, Sh., 2012, Forest resources study in Mongolia using advanced spatial technologies. International Archives of the Photogrammetry, RS and Spatial Information Sciences, Vol.XXXIX-B7, XXII ISPRS Congress, Melbourne, Australia.
- ENVI, 2004, User's Guide, Research Systems Inc.
- ERDAS, 2010, New ERDAS Field Guide, ERDAS, Inc. Atlanta, Georgia, pp.776.
- Fang, F., Li, F., Zhang, G. and Shen, C., 2013, A variational method for multisource remote-sensing image fusion. International Journal of Remote Sensing, Vol. 34(7), pp.2470–2486.
- Morel, A. C., Fisher, J. B. and Malhi, Y., 2012, Evaluating the potential to monitor aboveground biomass in forest and oil palm in Sabah, Malaysia, for 2000-2008 with Landsat ETM+ and ALOS-PALSAR. Vol.33(11), pp. 3614-3639.
- Sritarapipat, T., Kasetkasem, T. and Rakwatin, P., 2014, Fusion and registration of THEOS multispectral and panchromatic images. International Journal of Remote Sensing, Vol.35(13), pp.5120-5147.
- Suárez, J.C., Smith, S., Bull, G., Malthus, T. and Knox, D., 2005, The use of remote sensing techniques in operational forestry, In: http://www.forestry.gov.uk/pdf/QJFarticle.pdf/FILE/QJFarticle.pdf.
- Sybrand V. B., Comber, A. and Lamb, A., 2014, Random forest classification of salt marsh vegetation habitats using quad-polarimetric airborne SAR, elevation and optical RS data. Remote Sensing of Environment, Vol.149, pp.118-129.

- UNESCO, 1996, Mongolia Sacred Mountains: BogdKhan, Burkhan Khaldun, Otgon Tenger, UNESCO World Heritage Center, available at http://whc.unesco.org/en/tentativelists/936.
- Yude, P., Richard, A. and Robert, B., 2013, The Structure, Distribution, and Biomass of the World’s Forests, Annu. Rev. Ecol. Evol. Syst. 44: 593–62. doi:10.1146/annurev-ecolsys-110512-135914.