FUSION OF MULTISENSOR REMOTE SENSING DATA: ASSESSING THE QUALITY OF RESULTING IMAGES

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ABSTRACT:

The primary attention of this study was to examine what improvement can be obtained for classification accuracies by using different merging techniques done with multisensor dataset. In this study, the existing fusion techniques that preserve spectral characteristics, while increase spatial characteristic such as Principle Component Analysis, Intensity-Hue-Saturation, Brovey and Multiplicative algorithms were applied to multi sensor data set. IRS 1 D Pan, LISS III and ERS images were used. Using fusion techniques IRS 1 D imagery combined with LISS III data and ERS radar data combined with LISS III remotely sensed data. Maximum Likelihood classification algorithm was applied to classify fused imageries. Before classification procedure training sites were selected for all various land cover/use categories. Classification accuracy assessment was calculated using an error matrix for all images. Finally, the results of classification accuracy were compared and the best result was obtained by combining IRS 1 D image with LISS III data by means of IHS colour transformation technique.

1. INTRODUCTION

Wald (2002) describes fusion as 'a formal frame work in which are expressed means and tools for the alliance of data orginating from different sources. It aims at obtaining information of greater quality; the exact definition of greater quality will depend upon application'. The data fusion of multisensor data has received tremendous attention in the remote sensing literature (Yao and Gilbert, 1984; Welch and Ehlers, 1988; Chavez et al., 1991; Weydahl et al., 1995; Niemann et al., 1998; Pohl et al, 1998; Saraf, 1999; Zhang, 1999; Gamba and Houshmand, 1999). The integration of spectrally and spatially complementary remote multi sensor data can facilitate visual and automatic image interpretation (Zhou et al, 1998). Data fusion is the combination of multi source data which have different characteristics such as, temporal, spatial, spectral and radiometric to acquire high quality image. The fusion of different sensor images is crucial method for many remote sensing applications such as land cover/ land use mapping. There is a huge variety of techniques to combine images from different sensors. However, this paper focuses on image fusion techniques that preserve spectral characteristics whilst increasing spatial resolution to provide images of greater quality. IRS 1 D Pan, LISS III and ERS images were fused by using Brovey, Multiplicative, IHS and PCA algorithms. All merged images were classified by means of Maximum Likelihood supervised classification technique. The overall accuracy and Kappa analysis were used to perform a classification accuracy assessment based on error matrix analysis. The quality of the fused images was examined by comparing classification accuracy results.

2. STUDY AREA

In this study, the region which is located southwest of Istanbul between 41 6' 13"- 40 55' 36" latitude and 28 37' 3"- 28 54' 11" longitude was selected as study area (figure 1). It comprises approximately 400 km^2 area which contains the diversity of land cover types and surface materials such as urban-built up, vegetation, water, agricultural field, Transit European Motorway and Yeşilköy Atatürk Airport. Land use in study site is very cosmopolitan and irregular. Most buildings in the area are small, form closely and do not have roof. The streets in the city are narrow.

Figure 1. Study area

3. DATA AND METHODOLOGY

3.1 Data

IRS 1 D Pan and LISS III images acquired on June 5, 1996 and ERS image acquired on June 13, 1996 were used for the aim of the study. 1/5000 scaled topographic maps and aerial photographs were used for rectification process. Also, these data were used to select training sites and perform accuracy assessment during classification procedure.

3.2 Pre-processing

Digital image processing techniques were performed to extract land cover categories from fused images in different phases. Image pre-processing was carried out including image enhancement, and geometric correction. ERS radar image was filtered using (3*3) mean and (5*5) median filter in order to supress speckle effect and improve interpretation capabilities. Geometric correction of all three images were performed using first order polynomial equations. Image to map and image to image registrations were applied to images in order to prepare them for an accurate fusion application. IRS 1 D Pan image was transformed into UTM coordinate system by means of GCPs obtained by 1/5000 scaled standard topographic maps. LISS III and ERS data were transformed to the same coordinate system by using rectified IRS 1 D image. All images were resampled to the same pixel size using nearest neighbourhood algorithm.

3.3 Combining high- and low resolution image data

After having transformed the dataset into the same coordinate system, the images were fused to produce images which have better spatial and spectral characteristics. The information content of the resulting image may adversely changed by using fusion techniques.

3.3.1 Brovey Transform

The Brovey Transform was developed to visually increase contrast in the low and high ends of an image's histogram. Consequently, the Brovey Transform should not be used if preserving the original scene radiometry is important. However, it is good for producing RGB images with a higher degree of contrast in the low and high ends of the image histogram and for producing visually appealing images (Erdas Field Guide 1999). The Brovey transform is a simple method to merge data from different sensors (Zhou, 1998). The formulae used are shown in equations (1), (2), and (3):

RED = band 5/(band 2+band 4+band 5) * Pan (1)
GREEN = band 4/(band 2+band 4+band 5) * Pan (2)
BLUE = band 2/(band 2+band 4+band 5)* Pan (3)

3.3.2 Multiplicative

The multiplicative algorithm is derived by using the four possible arithmetic methods to incorporate an intensity image into a chromatic image (addition, subtraction, division, and multiplication), only multiplication is unlikely to distort the color. Equation of the algorithm is as follow;

(DNMSn)*(DNPAN) = DNnew*MSn (4)

DN*MSn*= Digital number of pixel belongs to n-th multi spectral band
DN*PAN*= Digital number of corresponding pixel belongs to panchromatic band
DN*new MSn*= New digital number of corresponding pixel (Erdas, 1999).

3.3.3 Principal Component Analysis (PCA)

The purpose of PCA is to compress all of the information contained in an original n-band data set info fewer then n "new bands" or components. These components are computed by linear combinations of the original images. None of the component is linearly correlated with other because these n components are orthogonal. The total variance of original images is mapped onto new components. The first principal component (PC1) has the greatest percentage of the total variance and succeeding components (PC2, PC3,.., PCn) each contains a decreasing percentage of the total variance (Lillesand and Kiefer, 2000; Lucian Wald, 2002).

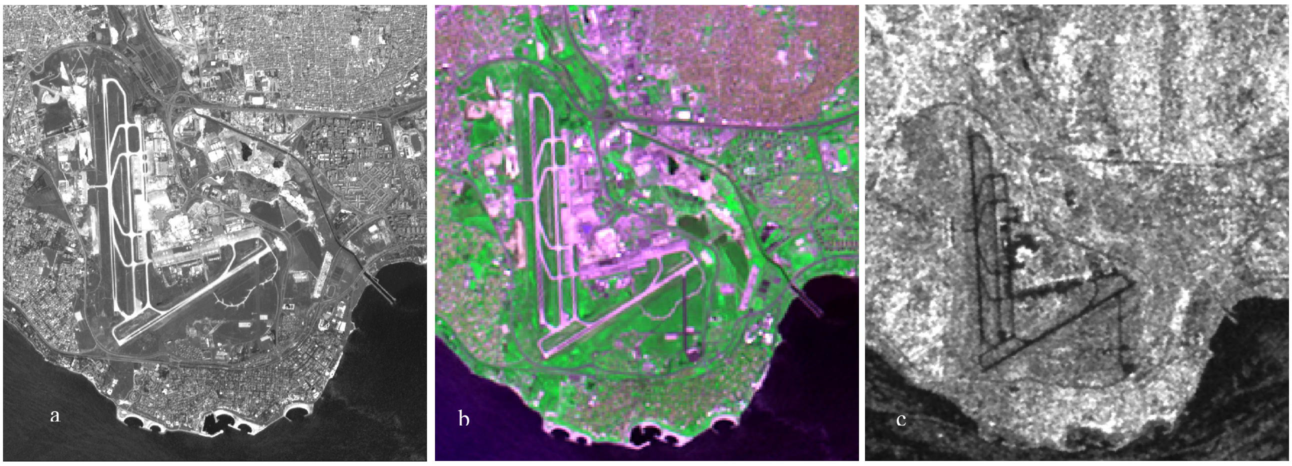
3.3.4 Intensity Hue Saturation Transformation

The general IHS procedure uses three bands of a lower spatial resolution dataset and transforms these data to IHS space. This numerical procedure was developed to convert a three-band RGB (red-green-blue) display into its fundamental physiological (IHS) elements of human color perception (Grasso 1993). The IHS color coordinate system is based on a hypothetical color sphere. The vertical axis represents intensity, which ranges from 0 (black) to 255 (white). The circumference of the sphere represents hue, which is the dominant wavelength of color. Hue ranges from 0 at the midpoint of red tones through green, blue and back to 255, adjacent to 0. Saturation represents the purity of the color and ranges from 0 at the center of the color sphere to 255 at the circumference (Jensen, 1996). The IHS values can be derived from the RGB values through transformation equations. In order to apply this technique for the enhancement of spatial resolution, a panchromatic higher resolution channel replaces the intensity component of a lower resolution multi spectral dataset.

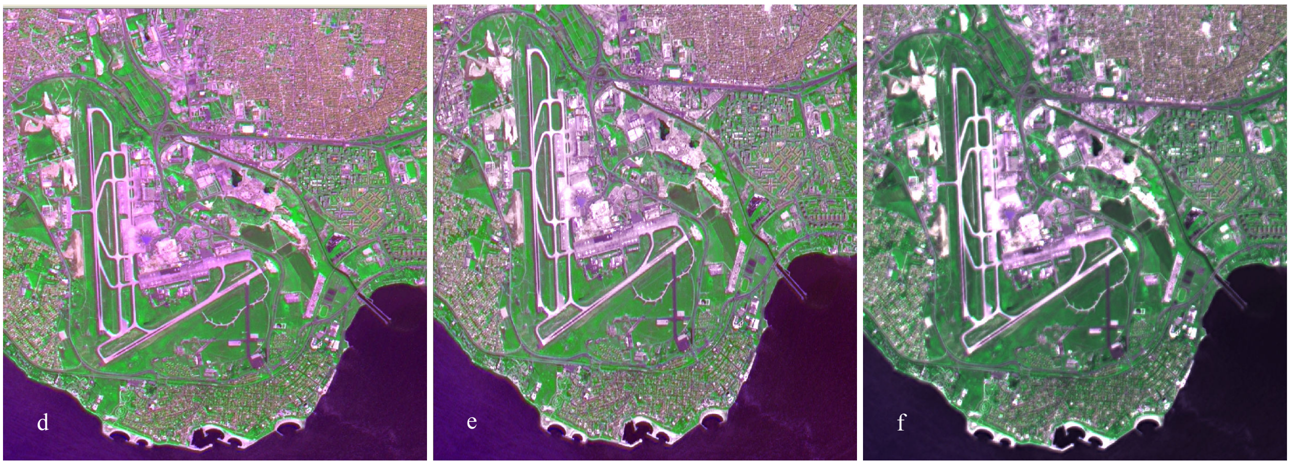
3.4 Comparison of the spectral and spatial effects of the merged IRS 1 D Pan- LISS III and ERS – LISS III images

3.4.1 Visual comparison

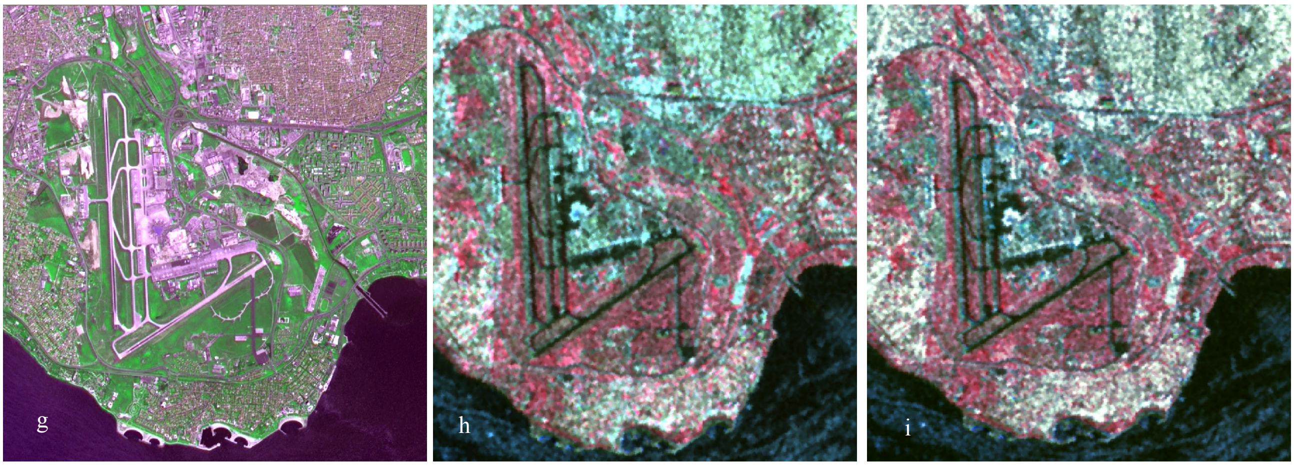
Visual image interpretation was performed for comparison of the merged images. Visual interpretation analysis showed that merged images of IRS 1 D pan and LISS III have better spatial and spectral details then original IRS 1 D Pan and LISS III images. Especially, buildings, roads and crossroads were identified easily from merged images compared to original LISS III image. Visual interpretation of ERS image was improved by merging ERS and LISS III images. Figure 3 shows all images which were merged by using different fusion techniques. Same section of the fused optic images were examined and interpratation results showed that Multiplicative method caused smoothing



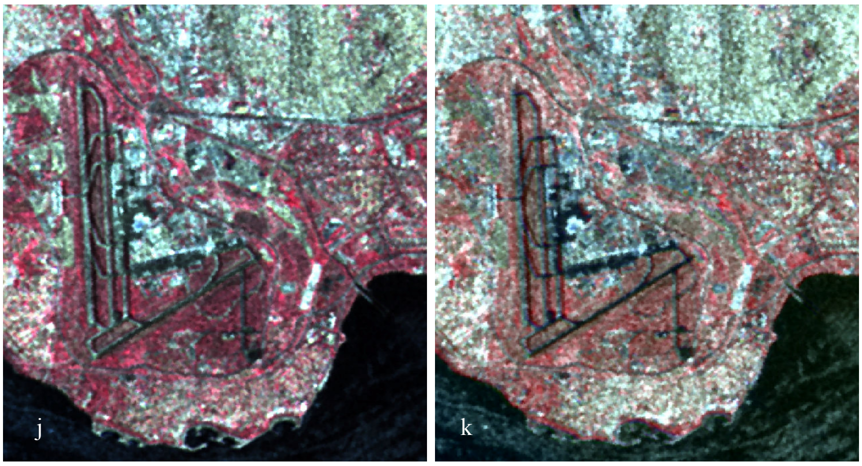
(a) Original IRS 1 D Pan image (b) Original LISS III image (c) Original ERS image



(d) Brovey transform of IRS 1 D Pan and LISS III (e) IHS transform of IRS 1 D Pan and LISS III (f) Multiplicative transform of IRS 1 D Pan and LISS III



(g) PCA transform of IRS 1 D Pan and LISS III (h) PCA transform of ERS and LISS III (i) IHS transform of ERS and LISS III



(j) Multiplicative transform of ERS and LISS III (k) Brovey transform of ERS and LISS III
Figure 2. The visual comparison of the merging methods from IRS 1 D Pan, LISS III and ERS images.

3.4.2 Classification

Maximum likelihood supervised classification and classification accuracy assessment were applied to all fused images. In order to select training sites for the classification 1/5000 scaled standart topographic maps and aerial photographs were used. Urban, grass land, barren land, water and highways were selected as classes to represent the surface of study area. After signature extraction, accuracy assessment of classification was calculated using an error matrix, which showed the accuracy of both the producer and the user (Lillesand and Kiefer 2000). The classification accuracy in remote sensing shows the correspondence between a class label allocated to pixel and true class. For accuracy assessment, 250 pixels were randomly selected for each image. Land use maps and aerial photographs were used as reference data to observe true classes. The overall accuracy and a Kappa analysis were used to perform a classification accuracy assessment based on error matrix analysis. Table 1 shows overall accuracy and kappa values for the classification of fused images.

Fusion technique	Overall %	Kappa %
Brovey (IRS Pan+LISS)	80	74,5
Multiplicative (IRS Pan+LISS)	77,6	70,1
HIS (IRS Pan+LISS)	83,2	78,9
PCA (IRS Pan+LISS)	82,8	77,6
Multiplicative (ERS +LISS)	70,4	58,3
Brovey (ERS +LISS)	1,2	61,5
HIS (ERS +LISS)	75,6	66,6
PCA (ERS +LISS)	72	63,1

Table 1. Classification accuracy results of fused images.

4. CONCLUSIONS

By using fusion techniques visual interpretability of images were improved. Furthermore, detailed land cover/use information was obtained by classification of fused data. As a result of containing very complex and irrregular features, land cover/use categories are highly spatially intermixed in the study site. Due to similar reflectance values of urban, road and bare land class, mixed pixel problems were occurred during the classification process. The reason of similar reflectance between these categories is the result of irregular and roofless buildings. According to classification results, the best result for the study site was obtained by using IHS colour transformation technique with overall accuracy of 83.2 % and kappa value of 77.6 %. In order to investigate appropriateness of fusion techniques a pilot area that has regular urban structure was selected and maximum likelihood classifications were applied to this data. The results showed that classification accuracy assessment values are better for the pilot area. The best result was obtained for the pilot site by means of IHS colour transformation with overall accuracy of 88.4 % and kappa value of 82.3 %. The classification accuracies of radar and LISS merged images were around 70 % because of the complex structure of the area. Merged radar and multi spectral data improved visual interpretability of radar image, these images can be used as ancillary data for classification procedure. For the aim of this study, the results of merged optic images were satisfactory for producing land cover map of the area.

5. REFERENCES

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