FUSION OF SAR IMAGES (PALSAR AND RADARSAT-1) WITH MULTISPECTRAL SPOT IMAGE: A COMPARATIVE ANALYSIS OF RESULTING IMAGES

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ABSTRACT:

Land use information is one of the most useful input element in forming policies concerning to economic, environmental issues at national and also at global levels. With the view of these different spectral, temporal and spatial qualified sensors are developed. On the other hand for some applications single sensor imagery might not be enough to gather information from earth surface. Fusion of satellite images with different spatial and spectral resolutions plays an important role for extracting information. Image fusion is an application for making use of two or more complementary images/spectral bands of the same or different sensors for the same area to get more information and to enhance the quality of image interpretation. This research investigates the quality assessment of SAR data fusion with optical imagery. Two different SAR data from different sensors namely RADARSAT-1 and PALSAR were fused with SPOT-2 data. Although the PALSAR and the RADARSAT-1 images have the same resolutions and polarisations, images were gathered in different frequencies (L band and C band respectively). Particularly in this case the operating frequency is a key factor in the penetration depth to see the affects on extracting information from fused images. This application describes a comparative study of multisensor image fusion techniques in preserving spectral quality of the fused images. IHS (Intensity-Hue-Saturation), HPF (High Pass Frequency), two dimensional DWT (Discrete Wavelet Transformation), and PCA (Principal Component Analysis) techniques are implemented for image fusion. For the statistical analysis bias, correlation coefficient (CC), Difference in Variance (DIV), Standard Deviation Difference (SDD), Universal Image Quality Index (UIQI) methods were applied on fused images. Statistically results depict that DCW fusion technique gives better result for both Radarsat-SPOT and PALSAR-SPOT fused images.

1. INTRODUCTION

Remote Sensing multisensor data fusion is used when the quality increase of quantitative analysis is needed. Due to complementary information of different characterized spectral or spatial multi sensor data, image fusion can facilitate image interpretation (Zhou et al,1998). Image fusion technique can be done with several algorithms and integration of multi source data is of the essence for many applications.

In recent years, the launches of new SAR satellites such as ENVISAT, ALOS, TERRASAR and RADRSAT-2 have opened a new era for remote sensing. Previous studies proved that the combination of optical and microwave data provide more accurate identification when compared to the results obtained with the individual sensors (Aschbacher and Lichtenegger,1990). Since the response of radar is more a function of geometry and structure than a surface reflection occurs in optical images (Pohl and van Genderen,1998), using these multiple types of sensors for image fusion increases the quality of images. IHS (Li and Wang, 2001, Tsai,2004), Brovey Transformation (Binh et al.,2006), PCA (Amarsaikhan and Douglas,2004), HPF (Bethune et al., 1998, Aiazzi et al., 2006a), DWT (Zhang and Hong,2005, Jin et al,2006), Gram Schmidt Transformation (GST) (Aiazzi et al,2006b), Smoothing Filter Based Intensity Modulation (SFIM) (Liu,2000), Synthetic Variable Ratio (SVR) (Zhang,1999) are some of the image fusion techniques generally used.

There are several studies comparing these techniques such as; IHS, PCA and Brovey transform methods compared with wavelet method to achieve the best spectral and spatial quality (Zhou et al,1998), IHS and wavelet combination of fusion method used on IKONOS and Quickbird images to decrease the colour distortions (Zhang and Hong,2005), Influence of image fusion on land cover mapping is analyzed by Colditz et al,(2006) using Brovey transformation, hue-saturation-value (HSV), principal component analysis (PCA), multi resolution image fusion technique (MMT), adaptive image fusion (AIF) and wavelet transformation methods. A multi resolution decomposition method based on "a tròus" algorithm used to improve the image classification (Teggi et al,2003). Shi et al,(2005), studied multi-band wavelet based image fusion and corresponding quality assessment. Mean value used to represent average intensity of an image, standard deviation, information entropy and profile intensity curve are used for assessing details of fused images. Bias and correlation coefficient analyses determined for measuring distortion between the original image and fused image in terms of spectral information. The other best known measurements of fused image quality are the estimation of Universal Image Quality Index (UIQI) (Wang,2002), and

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relative adimensional global error in synthesis (ERGAS-Erreur Relative Globale Adimensionnelle de Synthèse) (Wald, 2002).

Fusion methods are used for gathering information from SAR and Optical data. A comparative analysis described using L band Jers1 SAR and Landsat TM data. IHS, Wavelet, PCA and High pass filtering (HPF) techniques are applied and mean, standard deviation, coefficient correlation and entropy factors are computed to qualify the fused images (Rokhmatuloh et al,2003, Shi,2005). Pal et al. 2007 fused four bands IRS-1C to ERS-2 using PCA technique for enhancement of gathering geological information.

In our study the quality assessment analyses were evaluated for multi sensor data. An HH polarized L band PALSAR, an HH polarized C band RADARSAT-1 image and a three band SPOT-2 XS were used for image fusion. IHS, PCA, HPF, DCW techniques were used for the fusion of each of RADARSAT-SPOT and PALSAR-SPOT images. All fused images compared visually and statistically to SPOT XS. Bias, CC, DIV, SDD and UIQI statistical analysis derived from fused images.

2. STUDY AREA

In this research, Menemen (Izmir) Plain on the west of Gediz Basin in the Aegean Region of Turkey was selected as a study area that covers about 400 square km. The Aegean Sea lies on the west of the study area, and Manisa Province lies on the North (Figure 1). The study area covers both residential and agricultural areas. The area has a micro relief however the slope in general is 1 %. Texture and slope are important soil characteristics for SAR backscattering.

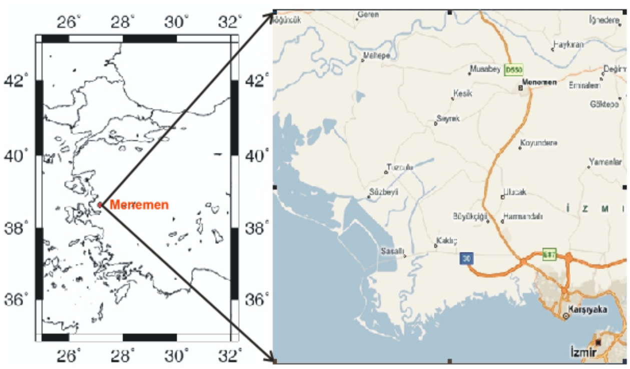

Figure 1. Memenen plain

3. MATERIALS AND METHODOLOGY

3.1 Data

Two different SAR data from different sensors namely RADARSAT-1 and PALSAR were both fused with SPOT-2 data (Table 1). Although the PALSAR and the RADARSAT-1 images have the same resolutions and polarisations, images were gathered in different frequencies (L band and C band respectively). Particularly in this case the operating frequency is a key factor in the penetration depth to see the affects on extracting information from fused images. An HH polarized L band PALSAR and an HH polarized C band RADARSAT-1 image were used as SAR data. A SPOT HRV-2 XS multispectral imagery having three spectral bands with a 20 m resolution were used as optical data. PALSAR (Phased Array type L-band Synthetic Aperture Radar) data of ALOS satellite (Advanced Land Observing Satellite) is a new SAR mission which has observation capability of high spatial resolution. In this study a fine single polarized (FBS) mode PALSAR imagery with pixel size 6.25 m x 6.25 m and a Fine Beam 1 mode of RADARSAT-1 image with pixel size 6.25 m x 6.25 m were used.

	RADARSAT1	**PALSAR**	**SPOT-2**
Date	28/05/2006	10/06/2006	14 /05/2006
Sensor	SAR Fine 1	PALSAR/FBS	HRV/HRG
Pixel Spacing	6.25 m.	6.25 m.	20m
Orbit	55139	2010	
Flight direction	Ascending	Ascending	
Processing	SGF	L1.5	
Polarization	H/H	H/H	
Swath	50 km	80 km	60 km
Incidence angle	37-40	41.5	L29.6

Table 1.Data information

3.2 Pre-processing

Before the image fusion process SAR images were pre-processed by the commonly used speckle reducing filter techniques. For the filtering of SAR images different sized kernel windows were used with Gamma filtering and 3x3 one was chosen.

In this study image fusion was conducted at the pixel level. In order to avoid the combination of unrelated data spatial registration accuracies should be at the sub pixel. Therefore in fusion applications geometric correction is very important for registration of the images. After reducing the speckle effects of SAR images, SAR images were registered to SPOT image by using image to image rectification method with a root mean square error of less than 1 pixel. Cadastral maps in 1/5000 scale and topographic maps in 1/25000 scale were used for the rectification of SPOT images.

3.3 Image Fusion Methods

In this study 4 fusion methods have been examined namely Intensity, Hue and Saturation (IHS), Principle Component Analysis (PCA), Discrete Wavelet Transformation (DWT) and High Pass Filter (HPF).

IHS method separates the Intensity, Hue and Saturation components of a RGB image. Three bands of an MS image are converted from RGB colour to IHS colour. Spatial frequency related I component is replacing the high resolution image and back transformation IHS to RGB is required (Pohl and Van Genderen,1998).

PCA converts a multivariate data set of inter-correlated variables into new uncorrelated linear combinations of the original values (Pohl and Van Genderen,1998, Teggi et al,2003). The difference between IHS and PCA is that while IHS is used for 3 bands, PCA method can be used for more than three bands.

DWT concept based transformation of high resolution image using wavelet to four portions that three of them have high frequency and the one has low frequency. Multispectral image is resampled to a size that low frequency portion of the high-resolution image has. Low frequency of high resolution images are replaced by resampled multispectral images. An inverse wavelet transformation is done for the three newly replaced images. These three images combined to one fused image. The fused image keeps in the high spatial resolution with the spectral information of the original multi-spectral image (Shi et al,2005).

The HPF fuses both spectral and spatial information with the band-addition approach. Edge information is extracted from high resolution image and added pixel by pixel basis to the low resolution one. High frequency component of the high resolution image is concerned to spatial information. High pass filter of the high resolution image corresponds to high frequency component. In conclusion adding filter to the low resolution band, spatial information content of the high resolution image replace and will be seen in the fused image (Bethune et al.,1998).

In this study pre-processed images were fused. 3 bands of SPOT images were merged with each RADARSAT and PALSAR images. Resulting fused images were resampled to the higher resolution of SAR images as 8m x 8m.

3.4 Quality Assessment

In order to evaluate the advanced spectral quality of the fused images, SPOT XS image is compared with the produced fused images. Assessment analyses for each of PALSAR-SPOT fused images and RADARSAT-SPOT fused image determined. Performing the increased interpretation capabilities, spectral relationship between the original SPOT image and each of fused images were compared to see the advances in spectral quality. Bias, Correlation Coefficient (CC), Difference in Variance (DIV), Standard Deviation Difference (SDD) and Universal Image Quality Index (UIQI) factors were computed and compared.

3.4.1 Visual Comparisons: Visual interpretation was done to compare the fused images with SPOT XS. Figure 2 shows the different fusion performances of RADARSAT-SPOT and PALSAR-SPOT images. Quality of the spatial resolution was analysed comparing the features like field borders, roads and buildings. In urban areas HPF shows features more detailed. The comparison of colour information between the fused images and the SPOT XS shows that HPF and DWT give similar result. IHS has the worst visual quality in both PALSAR and RADARSAT fused images. Urban objects and field borders are recognised better in all of the PALSAR fused images then RADARSAT fused images.

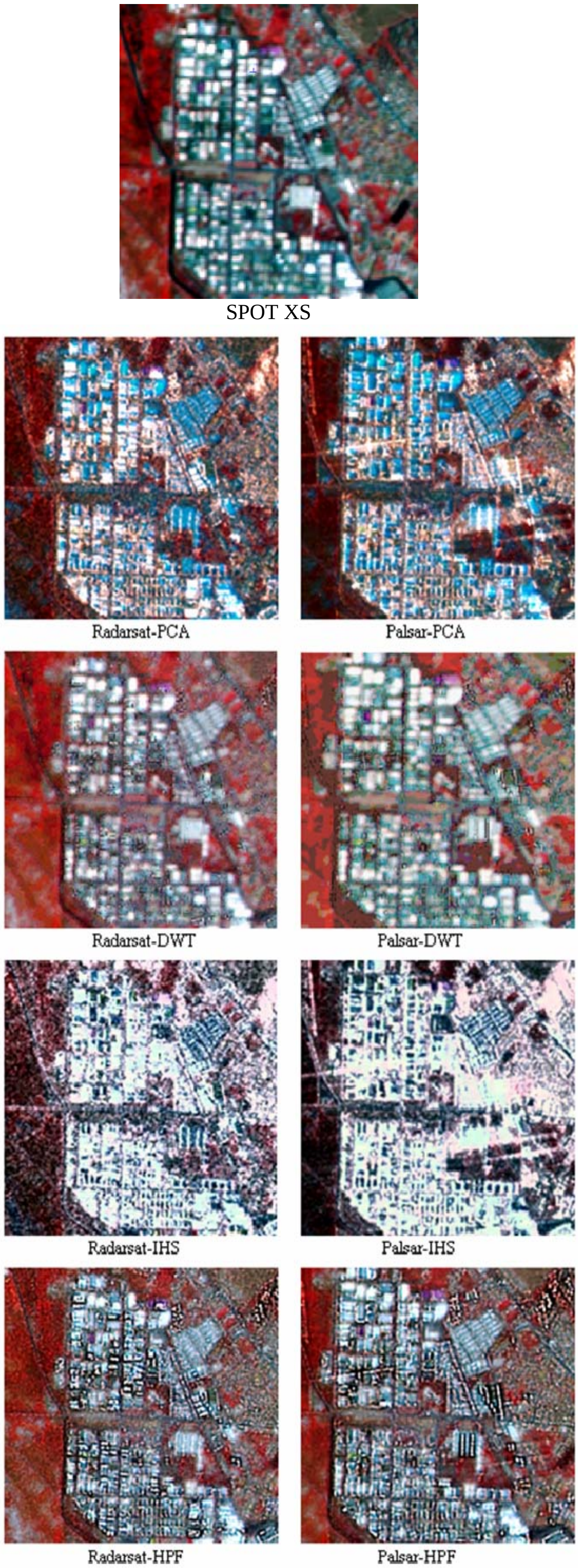

Figure 2. SPOT XS and Fused images

3.5 Statistical Inspections

In his study, an HH polarized L band PALSAR, an HH polarized C band RADARSAT-1 image and a three band SPOT-2 XS were used for image fusion. The quality assessment analyses were evaluated for multi sensor data. In order to evaluate the improved spectral quality of the image fusion techniques, the original SPOT XS image was compared with the 8 resulting fused images. IHS, PCA, HPF, DCW techniques were used for the fusion of each RADARSAT-SPOT and PALSAR-SPOT images. All fused images compared statistically to SPOT XS using Bias, CC, DIV, SDD, UIQI statistical analysis derived from fused images (Table 2 and Table 3).

Palsar		Bias %	DIV %	SDD %	CC	UIQI
HPF	B1	0.51	10.38	1.08	0.886	0,884
	B2	0.72	9.88	1.66	0.902	0,900
	B3	0.73	12.16	3.08	0.933	0,931
PCA	B1	0.04	19.39	2.07	0.735	0,730
	B2	0.12	28.81	4.76	0.611	0,603
	B3	0.82	48.12	13.71	0.449	0,425
IHS	B1	20.74	-524.63	-30.32	0.199	0,133
	B2	28.93	-457.72	-44.29	0.310	0,210
	B3	22.19	-155.63	-29.35	0.644	0,561
DWT	B1	0.11	19.17	2.04	0.777	0,772
	B2	-0.88	27.87	4.94	0.761	0,750
	B3	-9.13	59.92	17.98	0.616	0,554

Table 2.Statistical results for PALSAR fused images

Radarsat		Bias %	DIV %	SDD %	CC	UIQI
HPF	B1	0.50	7.60	0.79	0.868	0,867
	B2	0.70	6.94	1.16	0.884	0,883
	B3	0.66	9.32	2.34	0.915	0,913
PCA	B1	0.03	19.25	2.05	0.796	0,791
	B2	0.09	21.95	3.82	0.714	0,708
	B3	0.71	27.58	7.30	0.647	0,638
IHS	B1	6.84	-581.66	-32.57	0.308	0,205
	B2	8.39	-522.62	-49.02	0.458	0,315
	B3	1.84	-198.07	-35.61	0.774	0,671
DWT	B1	-0.07	4.02	0.41	0.897	0,896
	B2	0.12	2.31	0.38	0.915	0,914
	B3	0.60	-2.10	-0.51	0.938	0,937

Table 3.Statistical results for RADARSAT fused images

As seen from the tables HPF and DWT methods show better results in both PALSAR fused and RADARSAT-1 fused images. Statistical results show that the fusion results of PALSAR-SPOT using the HPF method gives the best performance. On the contrary DWT gives the better results for the RADARSAT-SPOT fused images.

Among the all fused images, statistical analyses show that IHS technique gives the worst results for both RADARSAT and PALSAR images (Figure 3).

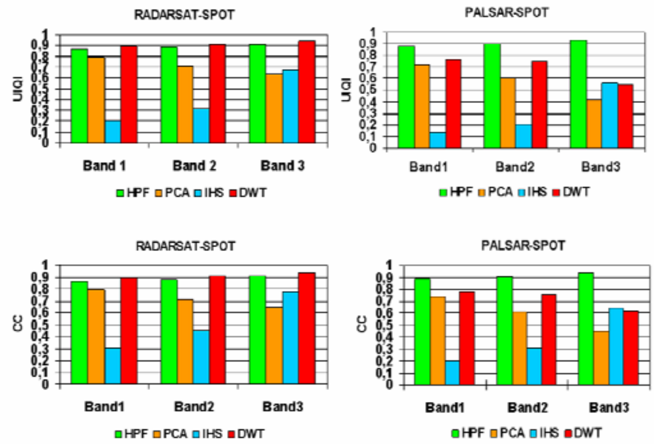

Figure 3. Graphics of statistical analysis

A spectral analysis was done for agricultural areas using a transect (Figure 4 and Figure 5). For the agricultural areas the best results have been gained using HPF for the fusion of PALSAR and SPOT XS (Figure 5 and Figure 6).

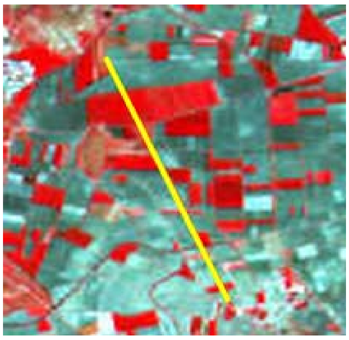

Figure 4. Transect on SPOT XS

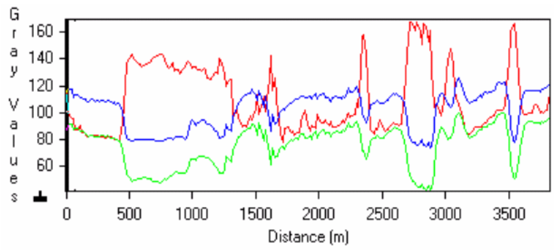

Figure 5. Spectral analysis of SPOT XS

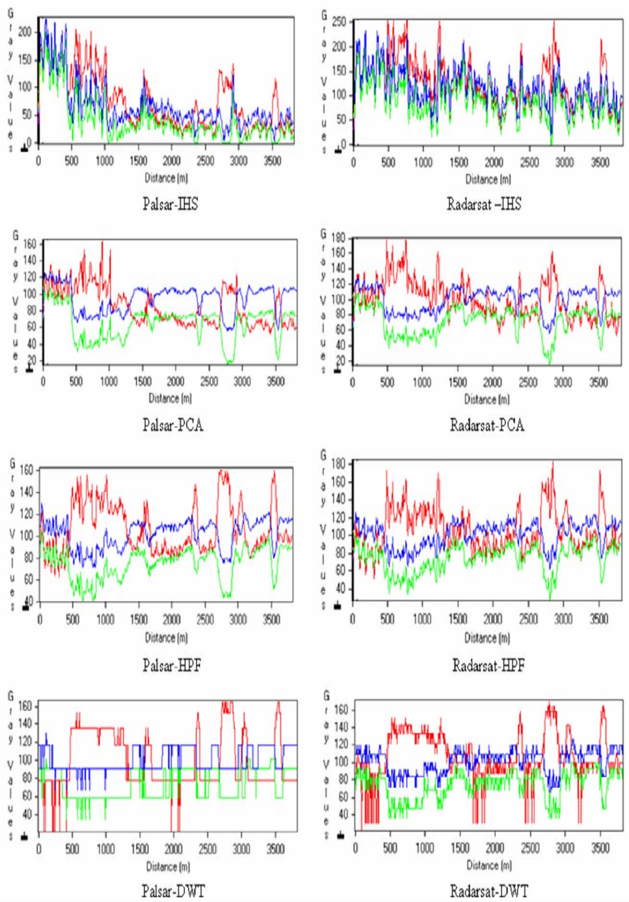

Figure 6. Spectral analysis of fused images

4. CONCLUSIONS

The aim of this study is to select the best fused images and making the comparisons between the SAR components of fusion process. To see the impacts of penetration only, SAR images (RADARSAT and PALSAR) were chosen with the same polarisation but with the different bands (C band and L band). The results show that HPF and DWT give the similar quality and quantity for both RADARSAT and PALSAR fused images. IHS gave the worst results. For the agricultural areas using HPF for PALSAR-SPOT fusion gave the best spectral results.

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