

IMAGE FUSION OF LANDSAT AND KOREAN SATELLITE KOMPSAT

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ABSTRACT :

Korea is providing images with the resolution of 6.6m level as launching multi-purpose satellite, Arirang satellite, in Dec. 1999. This study analyzed advantages and disadvantages of image fusion methods as applying fusion techniques to panchromatic images of high resolution of Arirang satellite and multi-spectral images of LANDSAT as test images. Analysis showed that the wavelet image fusion technique is good for a variety of test fields.

1. BACKGROUND AND GOALS

This study aims to create components for fusion techniques for spatial information of high resolution images and spectral information of multi-spectral images. General purpose of image fusion is to produce images that can be more easily analyzed as enhancing spatial resolutions of low resolution images with spectral data. This study carried out creation of components as applying the method to fuse spectral resolution of multi-spectral images from multiple wavelength ranges with inferior spatial resolution and spatial resolution of the latest panchromatic images of high resolution such as IKONOS. Among fusion methods for fusing multi-spectral images of low resolution and high resolution, the most common methods are IHS(Intensity Hue Saturation), HPF(High Pass Filter), PCA(Principal Component Analysis) and Wavelet Fusion that has been recently researched a lot(Kim, 2000).

The goal of this study is to develop a system through development of modules using Visual Basic and Visual C++ and to define algorithm for IHS and Wavelet fusion methods. Moreover, this study analyzes compatibility of satellite fusion methods as applying a developed system to Arirang (KOMPSAT; KOREAN Multi-Purpose SATELLITE) and identifying problems.

2. RESEARCH

2.1 Preparation of Test Images

This study prepared star images(500*500) by R.G.B band of Landsat and black and white images(1923*2124) of KOMPSAT(EOS) along the Hangang riverside. Land covers varies on images so that test images were selected as Landsat 319*319 and KOMPSAT 1335*1335. Raw images were normalized for easy processing. Figure 1 shows the images. Window parts of images indicated test areas. To enhance readability of images, histograms were analyzed and normalized by band. Test areas were defined on the basis of KOMPSAT images with high resolutions.

2.2 Geometric Correction of Images

For absolute comparison between IHS and Wavelet Fusion method, both images were sized enough to satisfy all test conditions. Landsat images were generated through fusion of R,G,B bend. Then, the geometric correction was applied to Landsat images as referring to KOMPSAT as reference images.

Geometric correction of images used ERDAS Imagine 8.4. To this end, the reference points were set to 6 points with good luminance on images and the check points were set to 5 points.



Figure 1 Testing area. (KOMPSAT B&W)

The table below explains the process for geometric correction. If overall errors on the reference point and the check point were within 1 pixel, they were accepted as allowable errors. In preparing test images in this study, the errors was

Table 1 Residual and RMSE of check points when Geometric correction

Check point	X residual	Y residual	RMSE (pixel)	Contrib.
7	-0.071	0.036	0.080	0.630
8	-0.001	0.195	0.195	1.538
9	0.031	-0.038	0.049	0.386
10	0.009	-0.134	0.134	1.059
11	0.004	0.175	0.175	1.385
12	-0.009	0.027	0.029	0.225
Avg.(ABS)	0.020	0.101	0.110	0.870

about 0.13 pixel for geometric correction. Table 1 describes the results of correction processing. It was required to satisfy limit requirements to apply each fusion method. In particular, for wavelet method, image sizes had to be limited to 2^n so that images were sized to 512*512 by adjustment. This study identified and applied the method to most effectively extract images with the sized of 2^n .

2.3 Component Development for Fusion

Main components to be developed in this study were data input component, filtering component for image improvement, image analysis component for such as geometric correction of images, image fusion component and output component. For image fusion component, modules for IHS and Wavelet method were developed.

3. EXPERIMENT BY FUSION METHOD

3.1 IHS Fusion Method

The image fusion method using color models of IHS(Intensity-Hue-Saturation) had been firstly used by Hydan in 1982. Since then, it has been the most common method. IHS fusion method applies IHS transformation to three low resolution images existing on RGB color models and creates intensity images, hue images and saturation images(Jensen,1996).

$$\begin{aligned}
 I &= \frac{1}{3} (R + G + B) \\
 S &= 1 - \frac{3}{(R + G + B)} [\min(R, G, B)] \\
 H &= \cos^{-1} \left[\frac{\frac{1}{2} [(R - G) + (R - B)]}{\sqrt{(R - G)^2 + (R - B)(G - B)}} \right]
 \end{aligned}
 \quad (1)$$

Whereas, intensity images(grey image) include information related to spatial resolutions of low resolution images and hue images and saturation images contain data related to spectral resolutions. Thus, when intensity images are replaced by high resolution images with good spatial resolutions, spectral resolutions of low resolution images and spatial resolutions of high resolution images are combined. These images become fusion images of high resolutions containing plenty of spectral resolutions of low resolutions through RGB transformation. IHS transformation method is easy to apply, but allows only three bands to be applied.

3.2 Wavelet Fusion Method

Multiple resolution Wavelet transformation has been recently studied. It has been applied to signal processing and image processing in various ways. In particular, it has been widely used for image compression, boundary extraction, object recognition and image fusion in image processing (H.H.Kang et al., 2001; Garguet-Duport et al. 1996).

When applying Wavelet transformation to images, one rough image and three precise images are obtained. At this point, a rough image contains data related to spectral resolutions of images and three precise images contains spatial resolutions according to directivity. Therefore, Wavelet fusion method applies Wavelet transformation to high and low resolution images using properties of Wevelet transformation, replace a rough image of low resolution image by that of high resolution image and then, carries out Wavelet reverse transformation using a rough image of low resolution image and precise images of high resolution images. Wavelet transformation formula is defined as follows(Sunar et al. 1998).

$$W(a, b) = \int f(t) \frac{1}{\sqrt{|a|}} \varphi\left(\frac{t-b}{a}\right), a > 0, b \in R$$

a : scalar Factor
 b : translation Factor
 (t) : mother wavelet

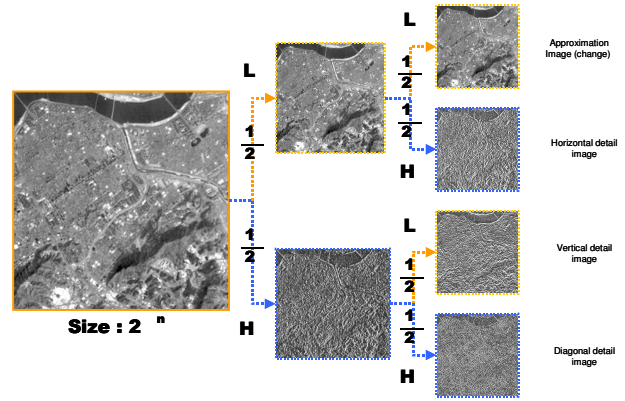


Figure 2 1 pass diagram of Wavelet method

Figure 2 describes image fusion processes using sample images applied in this study. Firstly, as applying two-step Wavelet transformation to KOMPSAT with high spatial resolution, approximate images and detailed images with the same size as LANDSAT images with low spatial resolutions are obtained. Next, approximate images on the second step are replaced by each multi-spectral image and then are reversely transformed. Accordingly, the images are fused as multi-spectral images with three spectral bands having high spatial resolutions.

4. DEVELOPMENT OF IMAGE FUSION COMPONENT

This study created component-based program using object-oriented concept to perform pre-processing function and image fusion function for image fusion. Figure 3 shows overall layout of image fusion system. Figure 4 explains links among classes

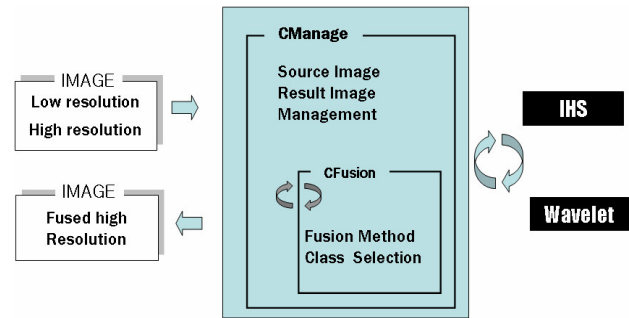


Figure3 Diagram of Fusion System.

and data flow for image fusion. System implementation largely consists of image input sector, fusion sector and output sector, in which fusion sector contains fusion modules and image filter modules of IHS and Wavelet.

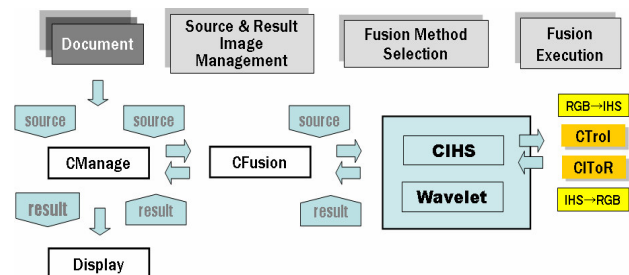


Figure 4 Work Flow of Class and Data

Raw materials are integrated and managed on CManage class and CFusion class is responsible for image fusion processing. Each algorithm for image fusion processing is configured to components.

4.1 Development of Relevant Components

Components developed related to this study were classified into total five categories according to component functions. Classified categories are data input, image filtering, image analysis, image fusion and output component. The details are explained below.

- ▣ Data Input Component
 - Image Loading Library(Tif, Jpg, Raw): CSateImage Class Allocation
- ▣ Filtering Component
 - Image Improvement Component : CFiltImage Class
- ▣ Image Analysis Component
 - Analysis of Fusion Images : Normalization, Equalization, Histogram Component
- ▣ Image Fusion Component
 - Integrated Fusion Component Management : CFusion Class
 - Analysis of Fusion Images: FusionImage Class
 - Optimization of Memory Use : CRetImage Class
- ▣ Output component
 - Output Component : CFusionImage

4.2 Developed Program Format

Program window in Figure 5 shows multi-band image input window. Overall program menus comprise of Enter and Save File, Image, Layer, Select, Fusion, Tools, Windows and Helps. Submenu on the left side consists of Fusion Method, Pass Step, Rough Images on Pass and Display Window of Image Size.

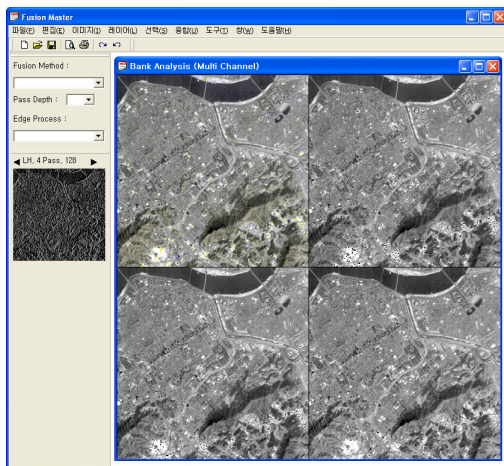


Figure5 Multi-band display of fusion program.

5. APPLICATION TEST AND ANALYSIS

5.1 Application Test

This study used multi-band images from LANDSAT taken around the Hangang river in Seoul on April 4, 1995 and images from KOMSAT-1 taken on the same area at 9 minutes to 2 on March 1, 2000. The same points on each image were manually selected and finally selected using Brightness Correlation. Geometric transformation formula between two images was defined using Affine Transformation and images were

rearranged by bilinear interpolation method. Next, two images were created for image fusion and IHS and Wavelet fusion methods were applied to those two images. HPF fusion images had relatively inferior resolutions so that they were excluded from analysis.

5.1.1 IHS Method

Low resolution images from LANDSAT were prepared by band and were transformed to Intensity(I), Hue(H) and Saturation(S). In Figure 6, 1, 2 and 3 means the upper limit of I, H and S, respectively. images on the upper limit 4 are fusion images. Dominant appearance of yellow was phenomenon caused by fusion because the angle of Hue was expressed only to 1 in an angle unit.

Intensity images were reversely transformed by RGB and the results were shown in Figure 8. R, G and B mean 1, 3 and 4 quadrant, respectively. These images were fused using intensifies of high resolution images. At this point, images were replaced by pixel values corresponding to each image size. Consequently, for images in 1:4 size, the intensify of one pixel of low resolution image was replaced by four pixel values. On the result image on the left side, slightly light colors were appeared on mountain areas and for areas with higher brightness, blue or sky blue color was shown. In terms of calculation, we could get values exceeding 0-255. These values were obtained because relevant values were lost during linear stretching for images to adjust these values. The final fusion images were presented on the left side of Figure 6.

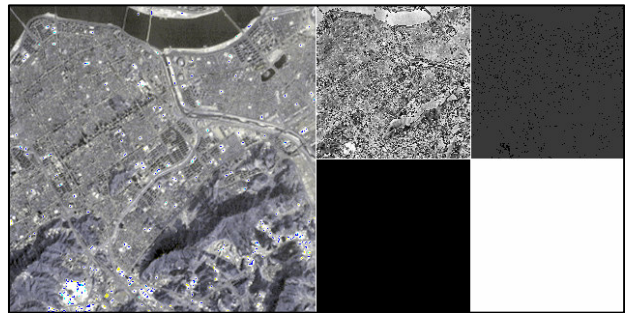


Figure6 RGB reverse transformed image and fused image.

5.1.2 Wavelet Method

Wavelet transformation was applied to low resolution images from LANDSAT as well as high resolution images from KOMSAT. As shown in Figure 2, these processes passed through low pass filter and high pass filter. The images in the size of 512*512 were reduced to 256*256→128*128→64*64→32*32. Therefore, we had limit that image sizes should be 2^n .

In general, as Wavelet transformation was processed in multiple steps, spectral resolution of low resolution images and spatial resolution of high resolution images could be fused much better. In accordance with analysis using a developed system, when image transformation exceeded appropriate image compression rate in Wavelet transformation, images were transformed and so influenced on image fusion. Images in Figure 7 described that image resolutions were increased as result passes of each band according to the number of each pass were repeated. It was found that four Wavelet transformation steps created the best image fusion in accordance with system analysis. From fifth step, images were transformed so that image fusion was not properly carried out.

This wavelet transformation was applied from step 1 to step 4 as passing through low resolution image and high resolution

image by step. When rough images and precise images were

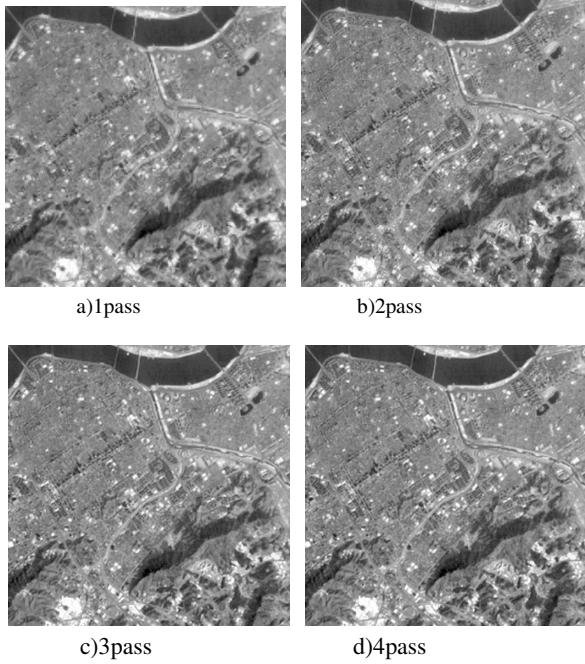


Figure 7 Reversed transformed image by wavelet transformation each step.



Figure 8 Result image by Wavelet method

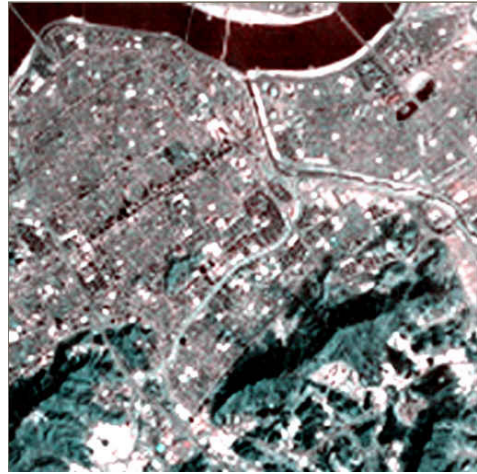


Figure 9 Result image by Mathlab.

obtained by step, rough images of high resolution images were replaced by those of low resolution images. Next, final images were obtained by reverse transformation to original sizes using rough images of low resolution images and precise images of high resolution images.

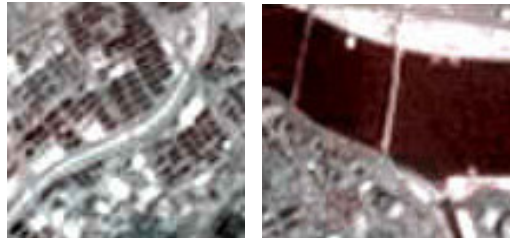
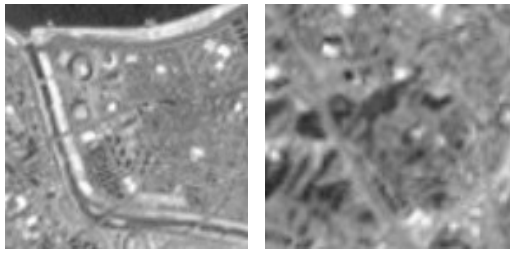
As shown in the figure, as transformation us processed by step, spatial resolution was increased. Figure 8 and 9 show fusion images from a developed fused program and images using Mathlab library. As comparing two images, images using Mathlab showed slight diffusion in terms of colors and two images had slight differences even in sharpness.

5.2 Image Analysis

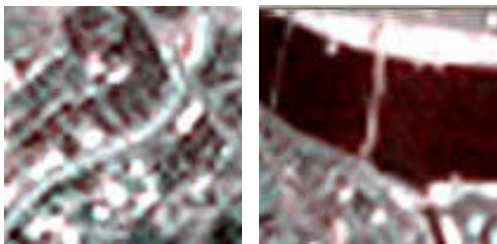
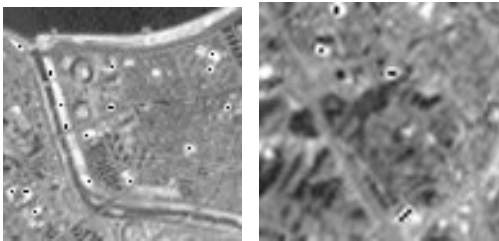
5.2.1 Resolution Analysis

Partial areas were enlarged to compare resolutions between Wavelet and IHS fusion method.

Mountain and river areas were enlarged for comparison. Linear structure was remarkably appeared in river areas. While



a) wavelet method



b) Matlab.method

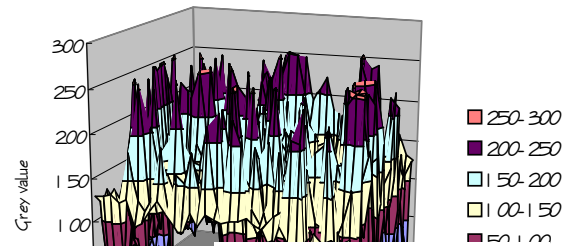
Figure 10 Part of image by each method.
(linear structure & Mt.)
(residential area & bridge)

IHS fusion images illustrated generally clearer sharpness, it was identified that wavelet fusion images were more excellent in smoothness or resolutions of overall gray scales. In particular, noise was observed on areas with extremely high brightness in HIS fusion images. On the contrary, two methods had similar resolutions in mountain areas, but also had noises. For comparing resolutions between images obtained from a developed program for Wavelet method and fusion images using Matlab library, bridge areas and residential areas were enlarged as shown in Figure 10. The definite differences of resolution differences were visually indicated. In particular, resolutions were significant for linear structures such as bridges. Gray scales in Wavelet fusion method had to be 0-255, but they were actually less than 0 and over 255. Therefore, a developed program applied stretching to gray scales to be within the range of 0-255. In Matlab, values below 0 and over 255 were ignored in calculation. Therefore, these adjustments could be the reason for differences in sharpness.

5.2.2 Visual Analysis

Roofs of primary colors, streams, roads, forests and grey roofs were mainly analyzed for each fusion method. IHS fusion method was useful for grey roofs, roads and streams and Wavelet fusion method demonstrated superior results on green color series, grey roofs, roads and streams. PCA method was excellent for streams, yellow roofs and red roofs. In general, Wavelet method was the most appropriate followed by IHS and HPF method according to applications.

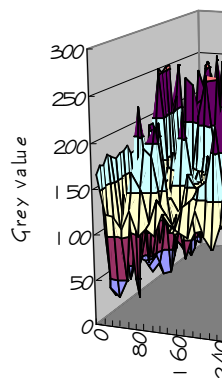
5.2.3 Brightness Range by Band



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Roofs of primary colors, streams, roads, forests and grey roofs were mainly analyzed for each fusion method. As shown in Table 2, IHS fusion method was useful for grey roofs, roads and streams and Wavelet fusion method demonstrated superior results on green color series, grey roofs, roads and streams. PCA method was excellent for streams, yellow roofs and red roofs. In general, Wavelet method was the most appropriate followed by IHS and HPF method according to applications.

a) Wav

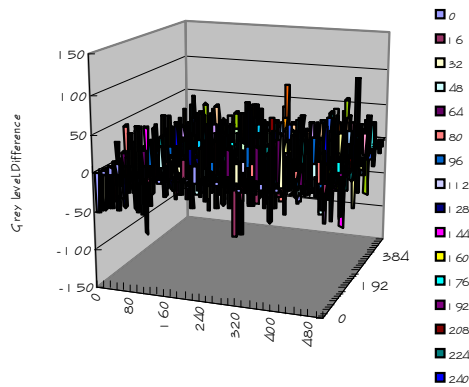


b) HIS method

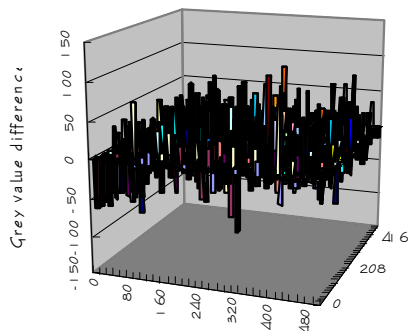
Figure 11 Red Level in Sampling of Wavelet Fusion Images

Brightness by band of images created by IHS and Wavelet fusion method was examined. Sampling was conducted every 16-pixel on an entire image and brightness was extracted. Among brightness, red level was presented.

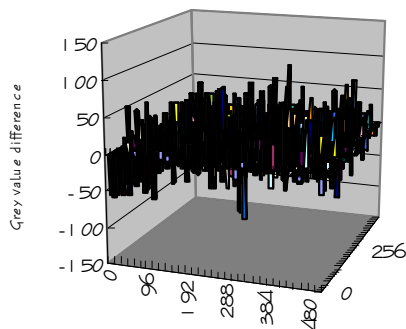
For red levels in two fusion methods, IHS fusion images demonstrated generally wider distribution ranges as compared to Wavelet method. Moreover, since Wavelet images had wider brightness range, smooth images were obtained. Average brightness of IHS and Wavelet method was 125 and 123, respectively. IHS images had generally broader green band distribution range. Green band range of Wavelet and IHS was 122 and 123, respectively. Blue band also showed similar patterns as Red and Green band. With respect of distribution ranges, blue band was distributed the most in 150-200 and next in 50-100.



a) Wavelet Red value-IHS Red value



b) Wavelet Green value-IHS Green value



c) Wavelet Blue value-IHS Blue value

Figure 12 Grey level difference after Wavelet method and HIS method.

5.2.4 Analysis of Brightness Differences by Method

Differences of gray scales by sample bands were calculated and presented to compare images obtained using Wavelet and IHS method. Two methods also demonstrated differences of red levels as shown in Figure 12.

Differences of grey values by bands of fusion images created by Wavelet and IHS method were presented. Pixels showing differences from 50 to -50 were the most frequently observed. While significant differences were occasionally observed, it was found that fusions were generally processed well. Consistent differences among Red, Green and Blue band proved the excellent function of a developed fusion program.

6. CONCLUSION

1. While IHS method is easy to apply, it has disadvantage because it allows only three bands to be applied. And it replaces intensities corresponding to image sizes, so its sharpness tends to be degraded.

2. Wavelet fusion method has different spatial and spectral resolutions according to steps applied when fusing images. In overall consideration, it showed the best results, but it is required to develop systems to deal with various image sizes without limits to 2^n .

3. In accordance with Wavelet fusion using a developed fusion program, the best result was obtained on Step 4. In this step, the final image size was 32×32 . Thus, if applying wavelet fusion processing for bigger images (1024×1024 , 2048×2048), it is considered that further steps over Step 4 can be carried out.

4. Existing HPF method demonstrated excellent results on non-coniferous, grey roofs. And PCA method showed remarkable results on roads and streams, yellow roofs and red roofs. IHS fusion method applied in this study presented generally good results on grey roofs, roads and streams. And Wavelet fusion method proved overall good results on green color series, grey roofs, roads and streams.

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