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Extraction of Information from Multispectral and PAN of Landsat Image for Land Use Classification in the Case of Sodozuria Woreda, Wolaita Sodo, Ethiopia

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Abstract
High-resolution and multispectral remote sensing images are an important data source for acquiring geospatial information for a variety of applications. The satellite images at different spectral and spatial resolutions with the aid of image processing techniques can improve the quality of information. More specifically, image fusion is very helpful to extract the spatial information from two images of different spatial and spectral images of same area. The Image fusion techniques are also helpful in providing classification accurately. In order to improve the information contents of the remote sensing satellite images at a specific spatial resolution, the different resolution image fusion techniques like Wavelet, PC and IHS have been used to combine panchromatic and multispectral datasets of Landsat ETM+ for the purpose of information extraction. The image under study has been used to identify existing Land use types and perform supervised classification. It has then been identified that forest land, farm land, bare land and built-up area are the most dominant land uses in the study area. Based on the supervised classification, classification accuracy assessment has indicated that Original image (MS) produced 83.33% overall accuracy and 0.7500 Kappa coefficient, PC fused image produced 91.67% overall accuracy and 0.875 Kappa coefficient, IHS fused image produced 86.67% overall accuracy and 0.800 Kappa coefficient, Wavelet-PC based transformation produced 91.67% overall accuracy and 0.875 Kappa coefficient and Wavelet-HIS based transformation produced 98.33% overall accuracy and 0.975 Kappa coefficient. Moreover, Wavelet-HIS based transformation method has produced relatively higher accuracy. Generally, based on the overall accuracy and kappa coefficient, fused images in terms of classification accuracy at the expense of information content perform by far better than the original image.

1. Introduction

1.1. Background information/Justification

Remote sensing techniques have proven to be powerful tools for the monitoring of the Earth's surface and atmosphere on a global, regional, and even local scale, by providing important coverage, mapping and classification of land cover features such as vegetation, soil, water and forests. The volume of remote sensing images continues to grow at an enormous rate due to advances in sensor technology for both high spatial and temporal resolution systems. Consequently, an increasing quantity of image data from airborne/satellite sensors have been available, including multi-resolution images, multi-temporal images, multi-frequency/spectral bands images and multi-polarization image. Fusion of multi-sensor image data has become a widely acceptable process because of the complementary nature of various data sets. While High spatial resolution dataset's are necessary for an extraction and accurate description of shapes, features and structures, whereas high spectral resolution is better used for land cover classification. Hence merging of these two types of data, to get multi-spectral images with high spatial resolution, is beneficial for various applications like vegetation, land-use, precision farming and urban studies. Integration of satellite data of high resolution and of multiple spectral bands with appropriate processing techniques, make it possible to get optimal result in limited fiscal environment (Jyoti and Akinchan, 2011).

Remote sensing information is convenient and easy to be accessed over a large area at low cost, but due to the impact of cloud, aerosol, solar elevation angle and bio-directional reflection, the surface energy parameters retrieved from remote sensing data are often missing; meanwhile, the seasonal variation of surface parameter time-series plots will be also affected. To reduce such impacts, generally time composite method is adopted. The goal of multiple sensor data fusion is to integrate complementary and redundant information to provide a composite image which could be used to better understanding of the entire scene. As explained by (Shuang Li & Zhilin Li, 2006), image fusion algorithms are used to combine a high spatial resolution panchromatic image and a low spatial resolution multispectral image into a new multispectral image with high spatial & spectral resolutions.

Image fusion is the process that combines information from multiple images of the same scene. These images may be captured from different sensors, acquired at different times, or having different spatial and spectral characteristics. The objective of the image fusion is to retain the most desirable information and characteristics of each image. With the availability of multisensor data in many fields, image fusion has been receiving increasing attention in the researches for a wide spectrum of applications. The main application of image fusion is merging the gray-level high-resolution panchromatic image and the colored low-resolution multispectral image for efficient and effective information extraction and further image interpretation. There are many different methods in image fusion process. The Intensity Hue Saturation (IHS) and Principal Component Analysis (PCA) and Wavelet (Petrovic and Xydeas, 2004) provide the basis for many commonly used image fusion techniques. Intensity-hue-saturation method is the oldest method used in image fusion. It performs in RGB domain. The RGB input image is then transformed to IHS domain. Inverse IHS transform is used to convert the image to RGB domain (Goshtasby and Nikolov, 2007). Brovey transform is based on the chromacity transform. In the first step, the RGB input image is normalized and multiplied by the other image. The resultant image is then added to the intensity component of the RGB input image (Pajares and de la Cruz, 2004). Principal component analysis-based image fusion methods are similar to IHS methods, without any limitation in the number of fused bands. Some of these techniques improve the spatial resolution while distorting the original chromaticity of the input images, which is a major drawback.

This project aims to study the potentials of image fusion of multispectral and panchromatic satellite high ground resolution images and evaluating their significance in information extraction and more specifically existing land use classification while the usefulness of the fusion technique has been evaluated by estimating the percentage of correctly classified pixels for the original (non fused) and the fused images by applying supervised classification.

1.2. Objective

- Extract information and generate land use classification from Landsat image and assess classification accuracy result.

2. Literature Review

2.1. Remote sensing

As it is explained by (Dou et'al., 2007), remote sensing offers a wide variety of image data with different characteristics in terms of temporal, spatial, radiometric and Spectral resolutions. Although the information content of these images might be partially overlapping (Steinnocher, 1999) and imaging systems somehow offer a tradeoff between high spatial and high spectral resolution, whereas no single system offers both. Hence, in the remote sensing community, an image with 'greater quality' often means higher spatial or higher spectral resolution, which can only be obtained by more advanced sensors. For optical sensor systems, imaging systems somehow offer a tradeoff between high spatial and high spectral resolution, and no single system offers both. Hence, in the remote sensing community, an image with 'greater quality' often means higher spatial or higher spectral resolution, which can only be obtained by more advanced sensors. It is, therefore, necessary and very useful to be able to merge images with higher spectral information and higher spatial information (Zhang, 2004). Satellite-based remote sensing can provide continuous snapshots of Earth's surface over long periods. Among these, Landsat TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper Plus) imagery has a moderate spatial resolution (30 m), provides multispectral images (seven or eight bands), with a short revisit interval (16 days) and includes decades of records (~30 years). Recently, the Landsat archive has been made freely available (USGS); thus, comprehensively studying the earth surface is no longer cost-prohibitive (Goodwin et'al., 2013; Verpoorter et'al., 2012).

2.2. Image fusion

The term fusion means in general an approach to extraction of information acquired in several domains. The goal of image fusion is to integrate complementary multisensor, multitemporal and/or multiview information into one new image containing information the quality of which cannot be achieved otherwise. According to (Ibrahim and Wirth, 2009), image fusion is the process that combines information from multiple images of the same scene. These images may be captured from different sensors, acquired at different times, or having different spatial and spectral characteristics. The object of the image fusion is to retain the most desirable characteristics of each image. With the availability of multisensor data in many fields, image fusion has been receiving increasing attention in the researches for a wide spectrum of applications.

A common feature for remote sensing sensors is the fact that the highest spatial resolution is recorded in their panchromatic mode whereas the multispectral recording mode produces images of reduced spatial resolution. The difference in spatial resolution between the panchromatic and the multispectral mode can be measured by the ratio of their respective ground sampling distances (GSD) and may vary between 1:2 and 1:5. This ratio can get worse if data from different satellites are used. For example, the resolution ratio between Ikonos (pan mode) and SPOT 5 (multispectral mode) is 1:10. The objective of iconic image fusion is to combine the panchromatic and the multispectral information to form a fused multispectral image that retains the spatial information from the high resolution panchromatic image and the spectral characteristics of the lower resolution multispectral image. Applications for integrated image datasets include land cover classification, environmental/agriculture assessment, urban mapping, and change detection. (Sascha and Manfred, 2009).

Image fusion techniques can be classified into three categories depending on the stage at which fusion takes place; it is often divided into three levels, namely: pixel level, feature level and decision level of representation (Zhang, 2010; Ehlers et'al., 2010). The pixel image fusion techniques can be grouped into several techniques depending on the tools or the processing methods for image fusion procedure, and it is also grouped into three classes: Color related techniques, statistical, arithmetic/numerical, and combined approaches.

2.3. Information Extraction

Fusion of multi-sensor image data has become a widely acceptable process because of the complementary nature of various data sets. While High spatial resolution dataset's are necessary for an extraction and accurate description of shapes, features and structures, whereas high spectral resolution is better used for land cover classification. Hence merging of these two types of data, to get multi-spectral images with high spatial resolution, is beneficial for various applications like vegetation, land-use, precision farming and urban studies (Li et'al., 2002). Based on image classification (Jyoti and Akinchan, 2011) has demonstrated that an operation of image analysis such as image classification on fused images provides better results in comparison of original data.

Classification of land use and land cover is one of the key tasks of remote sensing applications. The classification accuracy of remote sensing images is improved when multiple source image data are introduced to the processing (Pohl And Van Genderen, 1998).

3. Methodology

3.1. Study area description

The study area lies between latitude and longitude of (6°54′N 37°45′E) with an elevation between 1600 and 2100 meters above sea level. The climate is stable, with temperature variation between 24°C and 30 °C during the day and 16 to 20 °C at night, all year round. The dry, temperate heat makes the climate simply "delicious" and the average rainfall for the entire region is 1350 millimeters per year.

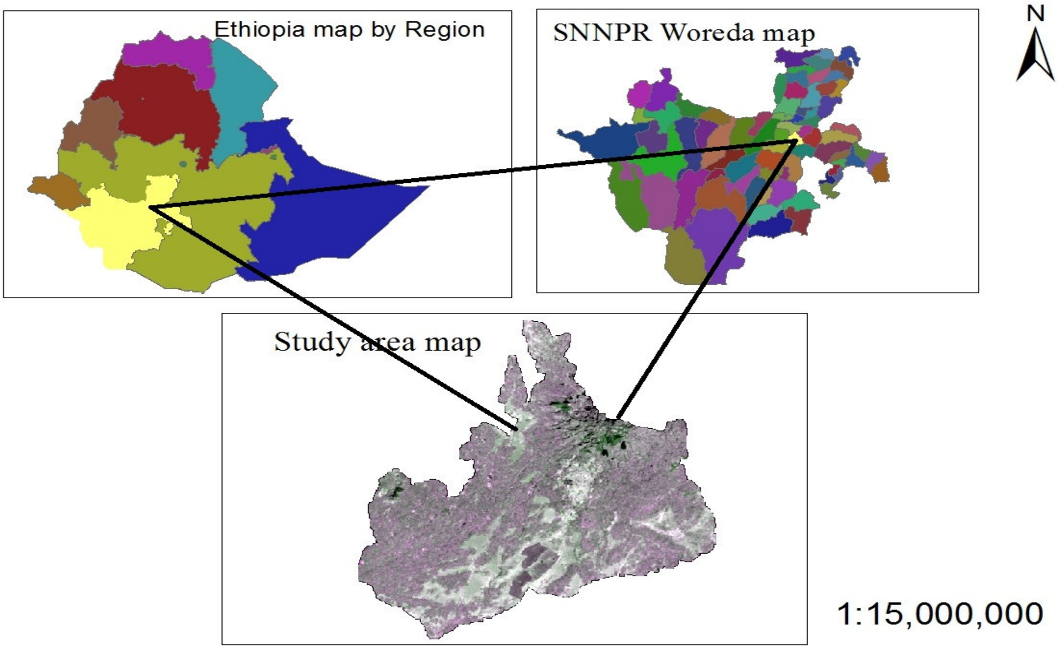


Figure 1: Map of the study area

3.2. Project Approach and Procedure

3.2.1. Dataset

Satellite-based remote sensing can provide continuous snapshots of Earth's surface over long periods. Landsat TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper Plus) imagery has a moderate spatial resolution (30 m) and 15 m for PAN images, provides multispectral images (seven or eight bands), with a short revisit interval (16 days) and includes decades of records (~30 years). Recently, the Landsat archive has been made freely available on USGS.

In optical remote sensing fields, the multispectral (MS) image which contains color information is produced by three sensors covering the red, green and blue spectral wavelengths. Because of the trade-off imposed by the physical constraint between spatial and spectral resolutions, the MS image has poor spatial resolution. On the contrast, the panchromatic (PAN) images has high spatial resolution but without color information. Image fusion can combine the geometric detail of the PAN image and the color information of the MS image to produce a high-resolution MS image.

For the single-sensor/single-date fusion, a panchromatic **Landsat7 ETM+** image, recorded on 22 December 2015 is fused with its equivalent multispectral image of Sodo Zuria Woreda and Sodo town in Wolaita Zone, Ethiopia.

Figure 1: Study area map

3.2.2. Image Preprocessing

During image preprocessing Geometric correction has been completed from data vendor and hence the map projection used is UTM_zone37 with datum "WGS84" ellipsoid and the resampling option used was "cubic_convolution". In remote sensing ERDAS imagine 2014, provides an option where spatial resolution of panchromatic image is merged in to color image which tends to allow for Fusion of multispectral dataset with panchromatic images in order to get a color image which has the higher spatial resolution**.** Image enhancement has been made to get adequate information for visual image interpretation. A non linear statistical enhancement technique called Histogram equalization has been used for this particular project. Histogram of the original image is redistributed to produce a uniform population density and it was done by grouping certain adjacent grey values.

In addition, Image fusion procedure mainly Intensity-hue-saturation (IHS) transforms fusion; principal component analysis (PCA) fusion and wavelet-based fusion schemes are used. The fused image is requested to combine the high-resolution spatial information of the PAN and the color information of the MS image.

3.3. Information Extraction

Extraction of information and Image classification techniques can be applied to the moderate spatial resolution multispectral imagery of the Landsat7 Enhanced thematic mapper plus (ETM+) to produce thematic maps of land surface cover. Supervised classification method which requires extracting training pixels that represent the spectral signatures of the land cover types has been used. This process is facilitated by having field-collected information (from Google Earth imagery, 2014) about cover type. Interpretation has been improved by using a composite image created from MS and higher spatial resolution PAN data through pan sharpening of the lower resolution image.

3.4. Analysis

The commercial software used during image processing and analysis for this particular project was ERDAS IMAGINE 2014, ArcGIS (ArcMap 10.2) and Google Earth. Hence, different statistical analysis is presented to verify the result of the project and Classification Accuracy assessment in terms of Overall accuracy and Kapa coefficient

4. Result and interpretation

4.1. Panchromatic and multispectral image fusion

Several studies and publications have shown that merging high spatial resolution images with low spatial resolution and high spectral resolution images proves to be of great benefit in many applications.

The PAN and MS images are acquired from a Landsat ETM+ which is a commercial earth observation satellite. It offers Multispetral (MS) and Panchromatic (PAN) imagery characterized by 30-meter and 15-meter spatial resolution respectively. The PAN image is without color information while the MS image is color image with different spectral bands. Image fusion has been used to merge MS and PAN images, acquired from Landsat sensors, together to form a single image to enhance the information extraction (Shamshad et al., 2004). Based on the fusion principle, Intensity-Hue-Saturation (IHS), Principal component (PC) and Wavelet fusion methods are used for merging the two images where nearest neighborhood method was used as re-sampling technique for all fusion methods. Moreover, PC and IHS transformation based wavelet fusion method was also used during merging and information extraction.

As explained by (Gonzáles Audícana and Seco, 2003; Krista Amolins et'al., 2007.) the standard image fusion techniques, such as IHS based method, PCA based method and Brovey transform method operate under spatial domain. However, the spatial domain fusions may produce spectral degradation. This is particularly crucial in optical remote sensing if the images to fuse were not acquired at the same time. Therefore, compared with the ideal output of the fusion, these methods often produce poor result. Over the past decade, new approaches or improvements on the existing approaches are regularly being proposed to overcome the problems in the standard techniques. As multiresolution analysis has become one of the most promising methods in image processing, the wavelet transform has become a very useful tool for image fusion. It has been found that wavelet-based fusion techniques outperform the standard fusion techniques in spatial and spectral quality, especially in minimizing color distortion. Hence this project has used the HIS, PC, Wavelet PC based and

Wavelet IHS based image fusion from input Landsat ETM+ PAN and Landsat ETM+ Multispectral image to obtain high spatial resolution color image.

4.2. Extraction of information

4.2.1. Land use/Land cover identification

Information extraction and classification is an important problem in remote sensing, while the quality of data (image data set) remains very critical. Moreover, the qualities of data as well as associated result are to be considered equally important during the research/project work. Hence, fused image has been used to extract information regarding land use/land cover features in the study area. It is therefore found that four land use/land cover features like forest land which contains trees, bushes and shrubs, Built-up area which includes rural and urban settlement as well as road, farm land which contains agricultural field, grass land and bare land have been identified and mapped. Built-up area in this case includes areas which are locally characterized as rural settlement, urban area and other road infrastructures.

During extraction of information supervised classification has been used to identify target features from Landsat image and three pan sharpening images from different fusion techniques including HIS, PC and Wavelet fusion methods were used. In addition, original MS image has been also used for comparison on the ease and clarity of feature identification and accuracy of image classification. Actually information extraction using pixel based analysis was observed to be challenging as different features tend to have similar intensity value. This was practically observed when classifying built up area and some bare land areas.

4.2.2. Image classification

Image Classification is an efficient way extracting Information from satellite images in this case Lansat ETM+ image. According to the project, the classification of fused images was important and gave better result in feature clarity and extraction as compared to original image. As it was also explained by (Jyoti and Akinchan, 2011) the fused data have been classified using supervised classification with selection of sufficient training areas for each feature class. The Landsat7 ETM+ multispectral image has been used for land use classification, but it has certain limitation as its ground resolution is around 30 meter which cannot help to identify and extract relevant features. For this problem, fused images have been used to perform supervised classification and accuracy assessment was done. In the supervised classification the training data has been collected from the study area's subset and maximum likelihood parametric rule has been used to classify the study area into Forest land, Farm land and Built-up area. The classification results of original and fused image are presented here below.

Figure 2. Supervised classification from Original MS image

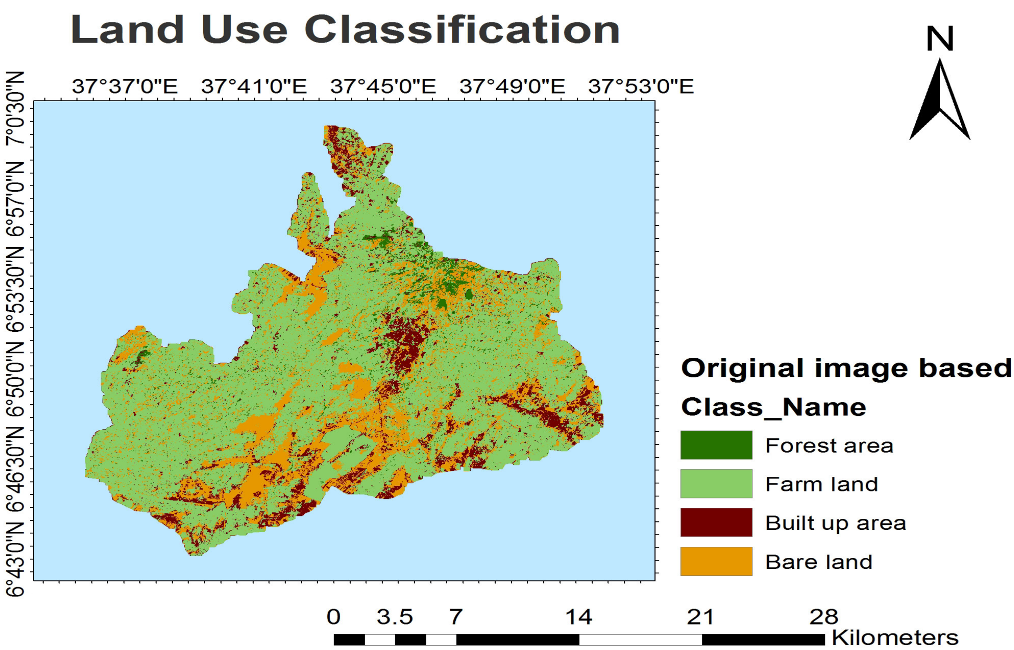


Figure 3. Supervised classification from IHS fused image

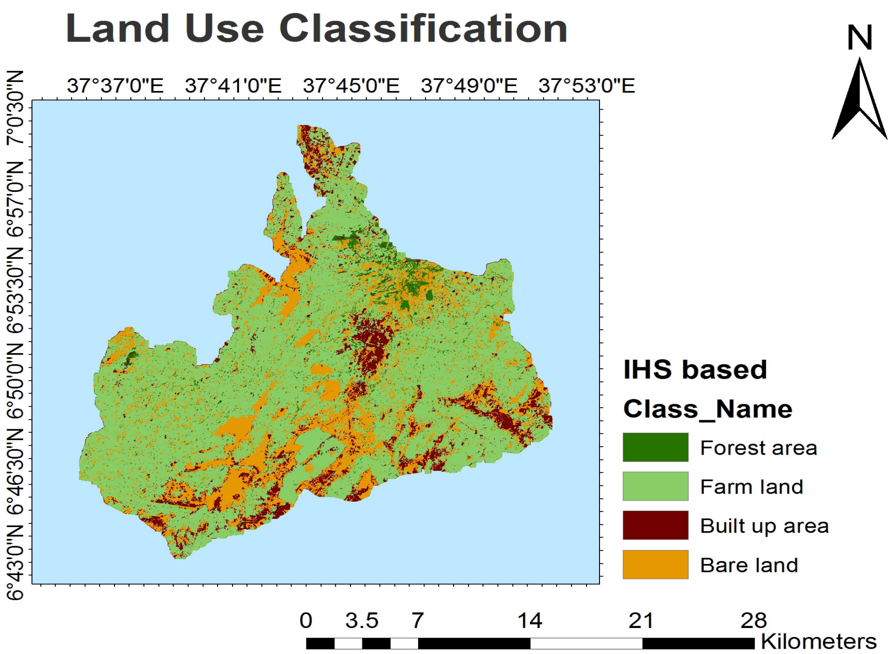


Figure 4. Supervised classification from PC fused image

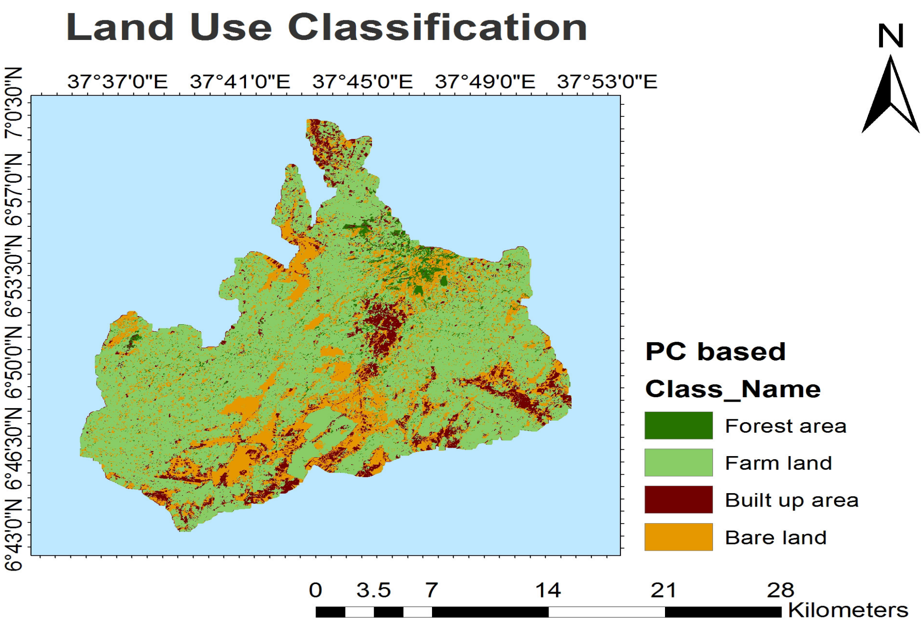


Figure 5. Supervised classification from **Wavelet-PC** based fused image

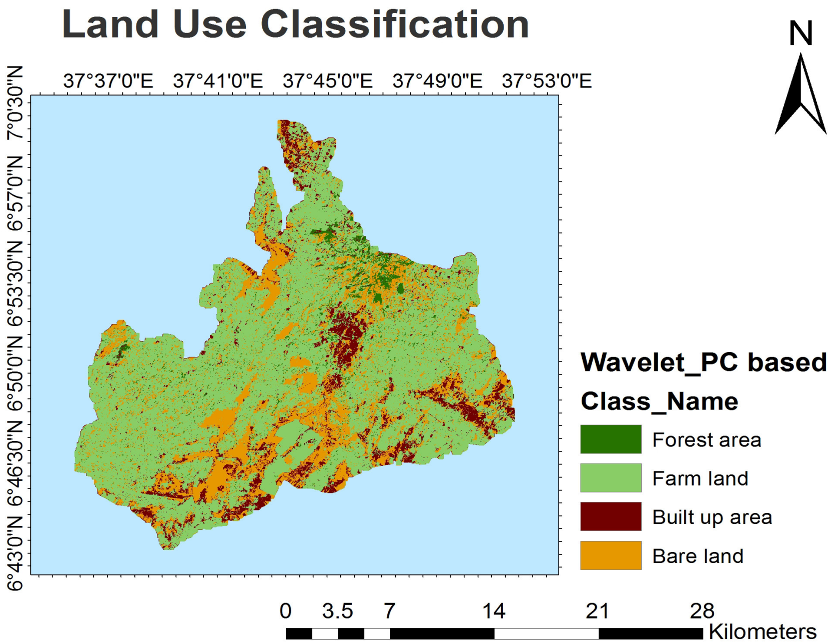
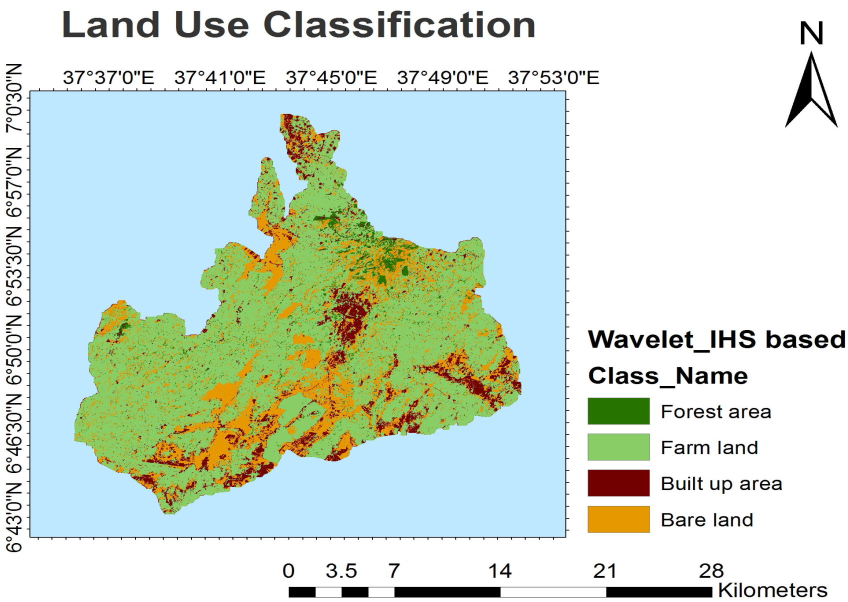


Figure 6. Supervised classification from **Wavelet-IHS** based fused image



4.3. Accuracy assessment of supervised image classification

Accuracy assessment is obviously an important step in the classification process. The goal is to quantitatively determine how effectively pixels were grouped into the correct feature classes in the area under investigation. The land use types derived from digital image interpretation and analysis requires validation with data obtained from ground verification. The confusion matrix, derived from image map and field data, as described by (Stehman, 1997) was generated for the accuracy assessment. Additionally, a coefficient of agreement between classified image data and ground reference data were calculated using Kappa. Accuracy assessment in the form of confusion matrix (or error matrix) is usually used as the quantitative method of characterizing image classification accuracy and shows correspondence between the classification result and a reference image by selecting sufficient ground truth data. Another accuracy indicator is the kappa coefficient which measures how the classification results compared to values assigned by chance. It can take values from 0 to 1. If kappa coefficient equals to 0, there is no agreement between the classified image and the reference image. If kappa coefficient equals to 1, then the classified image and the ground truth image are totally identical. So, the higher the kappa coefficient, the more accurate the classification is. In essence, therefore, classification accuracy is typically taken to mean the degree to which the derived image classification agrees with reality or conforms to the 'truth' as it was also supported by (Giles, 2001).

The accuracy assessment comparison of supervised classification is done for the original and fused images and level of accuracy has been calculated and compared.

Table 1. Overall accuracy assessment and Kappa coefficient

Assessment	Original image(MS)	PC fused image	IHS fused image	Wavelet-PC transformation	Wavelet-IHS transformation
Overall accuracy	83.33%	91.67%	86.67%	91.67%	98.33%
Kappa coefficient	0.7500	0.875	0.800	0.875	0.975

Table 2: Statistical summary of fused and original images

Layer	IHS image		PC image		Wavelet_PC based transform		Wavelet_IHS based transform		Original image	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
1	67.4	7.2	36.9	3.8	38.3	33.7	67.1	8.2	44.7	4.2
2	41.8	9.0	31.8	3.8	23.5	21.1	41.2	8.1	38.8	4.9
3	38.6	5.7	34.3	5.8	21.8	19.3	38.1	5.0	41.8	8.0

Note: Sd…standard deviation; IHS…Intensity Hue Saturation; PC…Principal Component

Statistical comparison with in images has been used to compare information variability across the image. This has proved how information is spread and dispersed within a given dataset as the intension of this project was dedicated to extract information in terms of land use classification using original image and images from fusion techniques as indicated before. Based on result of the statistics, Wavelet_PC based transform fusion technique has produced variable dataset after the spectral and spatial images are being combined together as compared to others which are relatively similar and almost the information variability within the image is not different.

According to (Table 2), the comparison of total accuracy and kappa accuracy for the classifications shows that Wavelet-IHS Transformation is the most appropriate for fusion and is having higher level of accuracy in supervised classification as shown in Table 2 with detailed confusion matrix table for all fused images (see also Appendix). Based on the supervised classification, classification accuracy assessment has indicated that Original image (MS) produced 83.33% overall accuracy and 0.7500 Kappa coefficient, PC fused image produced 91.67% overall accuracy and 0.875 Kappa coefficient, IHS fused image produced 86.67% overall accuracy and 0.800 Kappa coefficient, Wavelet-PC based transformation produced 91.67% overall accuracy and 0.875 Kappa coefficient and Wavelet-HIS based transformation produced 98.33% overall accuracy and 0.975 Kappa coefficient. Higher kappa values have been obtained in wavelet IHS transformation based method. Overall accuracy can be arranged in following order Wavelet IHS > Wavelet PC > PC > IHS > Original while this result also explained by (Vijay et'al, 2016). From the comparison, the overall accuracy and Kappa index of the supervised classification of fused image are much higher than the original image which is also supported by results from (Xu Hanqiu, 2005.). In general, pan sharpening affords the option in order to combine different and complementary data sets (Asha et al, 2007) with the intention to enhance the task of extracting and identifying information apparent in the images as well as to increase the reliability of the interpretation.

5. Conclusion and Recommendation

5.1. Conclusion

Information extraction is important area of application in remote sensing while the information content of the image in Multispectral (MS) and Panchromatic (PAN) image is also considered. Three image fusion techniques has been used in this project for the purpose of information extraction with an ultimate out of land use classification. The comparison of total accuracy and kappa accuracy for the classifications shows that Wavelet-IHS Transformation is the most appropriate technique in pan sharpening and is having higher level of accuracy followed by Wavelet PC, PC and HIS respectively in supervised classification. Hence, four general land use class are identified. The land use classes include Farm land, Forest land, Bare land and Built up area (settlement, road and other features). Generally, the overall accuracy assessment and Kappa index of the supervised classification of fused image are much better than the original image and hence fusion analysis techniques followed by classification gives the quantitative evaluation of land use/cover class and can be applied successfully to extract other classes and features of interest.

5.2. Recommendation

Based on this particular project work, it can be recommended that image fusion provides better result and can be used in other information extraction and feature classification with the support of more finer spectral and spatial resolutions. Moreover, for easier and more accurate classification, some other classification methods like object based analysis instead of traditional pixel based technique has to be adopted .

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