AN EVALUATION OF GEOMETRIC DATA ACQUISITION USING LANDSAT IMAGERY

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The implementation of appropriate digital image processing method is crucial for deriving urban land cover maps of acceptable accuracy and cost. This study examines the effect of acquiring images in various spectral regions (bands), the impact of some image processing techniques on the combination of the different bands and the acceptable mode in which the features of the image could be classified using unsupervised classification (clustering) and supervised classification based on four different hard classifiers. Four different filter types were experimented on the colour composite images before classifying the images into different distinct land spectral classes. The Integrated Land and Water Information System (ILWIS) software was used to classify LandSAT 7 image of 2001, part 189r053, zone 32, bands 1 (Blue), 2 (Green), 3 (Red), 4 (Near infrared), 5 and 7 (Middle infrared) wavelength. From the study, it was observed that AVG 3x3 filter type is the most preferred. Colour composite of bands 5, 4, 3 in the RGB planes gave the best representation of the features of the image and that Box classifier, Minimum Distance to Mean Classifier and Maximum Likelihood classifier are excellent classifiers for image supervised classification.

Keywords: Image Processing, Landsat satellite imagery, Spectral regions, Colour composite, Geometric Data Acquisition.

INTRODUCTION

Image Processing is a technique that seeks to enhance raw images received from cameras/sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-today life for various applications (Rao, 1991). Since a digital image is an array of real numbers represented by a finite number of bits, the term digital image processing can be defined as the processing of a two-dimensional picture by a digital computer (Anil, 1989; Gonzaleze, 2002). There exist several image processing techniques, some of which include Image representation, Image pre-processing, Image enhancement, Image classification, Image restoration, Image analysis, Image reconstruction and Image data compression (Rao, 1991). Of these image processing techniques, Image enhancement and classification has been examined in the course of this research and as such our discourse shall be restricted to them.

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In image enhancement, the goal is to accentuate certain image features for subsequent analysis or for image display (Kenneth, 1996; Jensen, 2003). Examples of such techniques used for image enhancement include contrast stretching, density slicing, colour composite, edge enhancement, noise or spatial filtering, histogram equalization and band rationing. Spatial Filtering and Colour composite were the major image enhancement techniques considered and experimented in this research.

Images acquired through modern sensors may be contaminated by a variety of noise sources. Noise (referring to stochastic variations as opposed to deterministic distortions such as shading or lack of focus) can be said to be any unwanted disturbance in a digital image data due to limitations in the sensing system, signal digitization, data record process or a combination of some or all of these sources. The process of removing noise from an image is known as spatial filtering.

LandSAT 7 images are composed of seven different spectral bands, each representing a different portion of the electromagnetic spectrum. The characteristics of the various spectral bands of the LandSAT imagery has been lucidly examined and presented by (GIF, 2008). To visually interpret digital data such as satellite images, individual spectral bands must be displayed simultaneously in the form of a colour composite. For example, Landsat TM bands 1, 2 and 3 broadly represent the blue, green and red region of the electromagnetic spectrum (ES). When these bands are fed through the corresponding blue, green and red “colour bands” of a computer monitor, the resulting image strongly resembles what our eyes would see from the sensor’s vantage point. We thus have an intuitive understanding of the colours presented and can usually make an informed interpretation of the scene (e.g. dark blue probably represents deep water), such images are called true colour composites (TCC).

Image Classification is the primary method used to transform remotely sensed data into a thematic land cover map (Jensen, 2005). A variety of computer algorithms have been developed that essentially attempt to mimic an experienced human analyst to examine the image and recognize patterns, then assign portions of the image to pre-determined classes. Consequently, these methods can be characterized as computer-aided thematic information extraction systems. In general, methods of image classification can be grouped into two main categories: pixel-based and object-based. Conventional or traditional classification approaches operate on a per-pixel basis. These methods examine each pixel of the source image independently and assign class membership based on the spectral data available in that pixel. The most common categorization of per-pixel methods are supervised classification and unsupervised classification.

Due to the poor spatial resolution of LandSAT 7 images (30m for bands 1, 2, 3, 4, 5 and 7 and 60m for band 6), application of image enhancement and image classification (which groups image into distinctive land spectral classes or features) are very important for better visual perception, feature identification, image interpretation and acquisition of spatially referenced data from them. Therefore, this paper evaluates the significance of filtering on LandSAT images. To that effect, analysis of the performance level of four different filter types, colour composite (combination of three different image bands in RGB), as well as the performance level of clustering (unsupervised) with four other different (supervised) hard classifiers has been conducted. The considered filter types for this study are Laplace, Shadow, AVG

3x3 and Edge Enhancement filter types while the examined and experimented hard classifiers are Maximum likelihood Classifier, Minimum distance to mean classifier, Box classifier and Minimum Mehalanobis Distance classifier. All image processing operations and analysis were carried out using the ILWIS software.

In the next section (Section 2), a brief overview of spatial filtering and classification of digital imagery is presented. The methodology for the study is discussed in Section 3; the results from the study are given in Section 4. While Section 5 discusses the results, in Section 6, the paper was concluded.

Brief Background on Image Processing and Classifications

Different algorithms have been developed for spatial filtering of digital images some of which have been lucidly examined in Chandel and Gupta (2003), Le Meur (2011) etc. In the last few years, there has been an effort to develop methods of restoration and filtering of images while using atmospheric optical transfer functions (MTF and phase transfer function) in order to compensate for image blur and distortions (Arbel *et al.*, 2004). Digital restoration results for Landsat TM imagery using the atmospheric Wiener filter which corrects for turbulence blur, aerosol blur, and path radiance simultaneously were investigated and presented in Sadot *et al.* (1995), Arbel *et al.* (1998), Arbel *et al.* (1999), Arbel and Kopeika (2000). Arbel *et al.* (2004) also implemented a Kalman filter as an atmospheric filter, which corrects for turbulence blur, aerosol blur, and path radiance simultaneously.

Research efforts in colour composite generation include works by Carmelita (2002) who carried out comparison of false colour composites in mapping and discriminating between salt-affected soils in Kings County, California. Patra *et al.* (2002) presented a technique for generating natural colour images from false colour composite images using spectral transformation method to establish a relationship between false colour and true colour image pairs provided by a sensor with all the four bands, which has a broader spectral coverage. Vladimir *et al.* (2013) also proposed a method for generating natural colour from false colour images based on Normalized Difference Vegetative Index (NDVI) clustering. Rao (1991) followed a systematic visual interpretation approach using the False Colour Composite of TM bands 2, 3 and 4 for mapping two categories, moderately and strongly sodic soils.

Supervised and Unsupervised classification; the two major classification techniques were explored by Krishna (2009) in the Classification of Land uses of a mountainous watershed named Galaudu / Pokhare Khola, situated in Dhading district of Nepal, so as to scientifically evaluate the impact of modification of the original bands and integration of ancillary data in digital image classification in the improvement of the accuracy of land use/Land cover classification result. Using 12 feature sets containing Landsat MSS, TM and IRS etc. The Supervised Classification approach produced a result with better accuracy than the unsupervised approach. The colour composite and band rationing result also reported that the bands ration R4/3, R5/4 and R4/7 ranked the highest in terms of accuracy (82.86%) while the combination of bands 2, 3 and 4 ranked the lowest with 45.29%.

In a supervised classification procedure the analyst first identifies representative example (training sites) for each class of interest, and then the software processes the image to match pixels to the defined training examples. Several classification algorithms are available to determine to which class a pixel should belong. These algorithms (or classifiers) include Maximum Likelihood, Parallelepiped, Nearest

Neighbour, Minimum Distance to Means, Neural Network and others. The Maximum Likelihood Classifier (MLC) is a parametric statistical algorithm that works best with training class data that is normally distributed. Other classifiers are non-parametric and do not assume normal distributions of class populations (Jensen, 2005). A problem commonly observed with the output of supervised per-pixel classification is that of isolated pixels, also called speckling or the “salt & pepper effect”. Because each pixel is analysed independently, the spectral data of a given pixel may vary enough from its immediate neighbours that it gets assigned to a different class and thus stands alone. For many purposes it may be desirable to reduce this effect and produce a map with greater homogeneity. Post-classification processing, using smoothing filters or other techniques, has been done with some success to reduce speckling and increase overall classification accuracy (Aplin, 1999; Barr and Barnsley, 2000).

Aloke et al. (2014) proposed and tested the strength of unsupervised band elimination method in reducing the dimensionality of hyperspectral image analysis. This method iteratively eliminates one band from the pair of most correlated neighbourhood bands depending on the discriminating capability of the bands. The experiment showed promising results compared to three other experimented state-of-the-art approaches.

METHODOLOGY

Data Used

The data used for this study is a geo-referenced LandSat image of 2001, part 189r053, zone 32, bands 1 (Blue), 2 (Green), 3 (Red), 4 (Near infrared), 5 and 7 (Middle infrared) wavelength obtained from Regional Centre for Training in Aerospace Survey (RECTAS) Ile-Ife. The image covers major States of the North Central Geo-political zone of Nigeria. Other data acquired include the x and y co-ordinates of four corner boundaries of Minna, Niger State used in selection of training site and validation of results obtained.

Data Processing

The Methodology of the data processing has been given in Figure 1. The acquired image was processed using ILWIS 3.1 Academic software. The geo-referenced Landsat image was imported into the ILWIS environment Via Geo Gateway. Sub map was created and used to identify the area from which ground truth information was obtained for effective classification. The impact of Filtering and the efficiency of different filter types were examined before performing colour composite operation. The composite image was classified using supervised classification techniques and four different hard classifiers while some of the geometric features of the area used for ground truthing were digitized from the classified image.

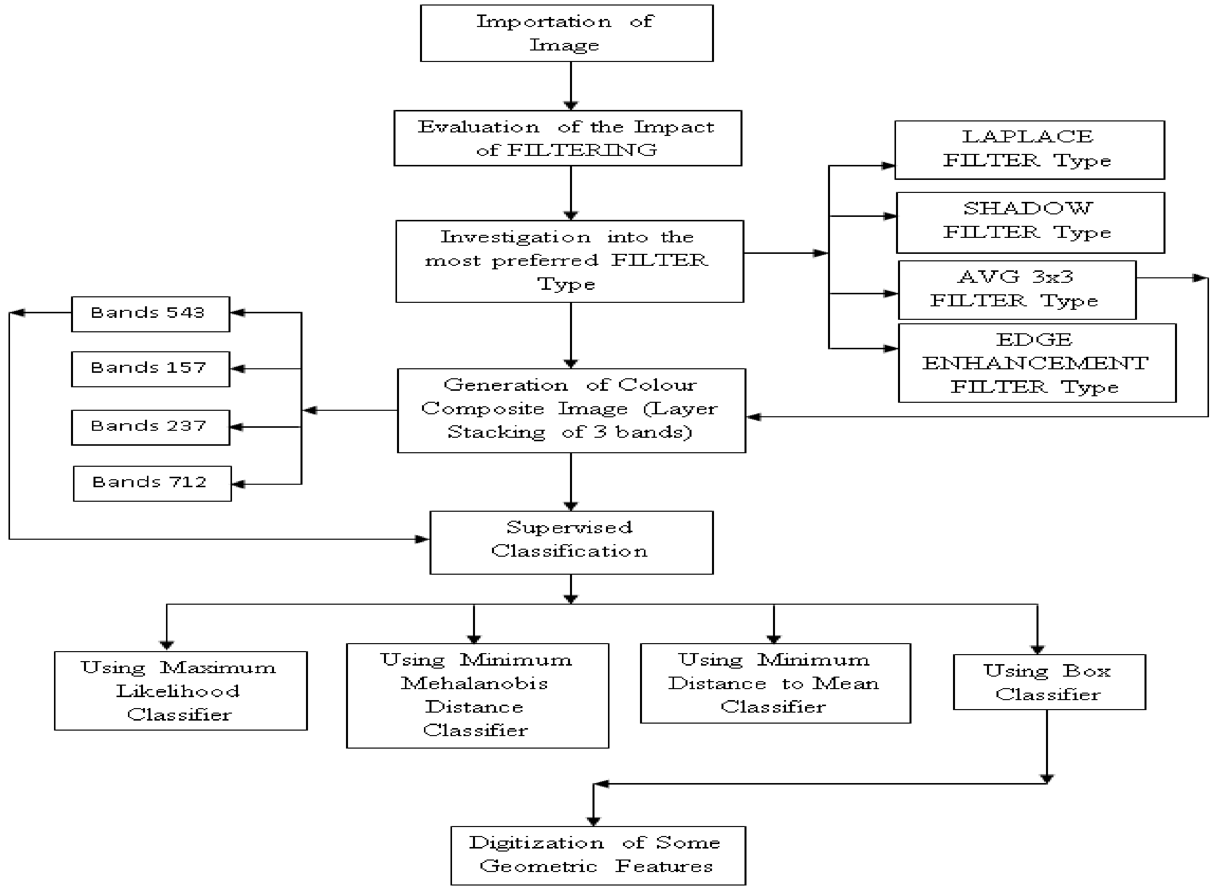


Fig.1: Data processing methodology.

Evaluation Process

In order to verify the impact of filtering on the spatial resolution of the image, bands 2, 3 and 4 were Layer Stacked and consequently filtered using AVG 3x3 Filter type, the evaluation was performed by comparing the filtered and unfiltered composite image.

However, for colour composite, three bands were combined together in one colour composite map for visual assessment of the reality on ground. Therefore, colour composite was created by combining three (3) different bands of the raster image. One band is displayed in shades of red, one in shades of green and the third in shades of blue respectively.

On the other hand, in supervised classification, the analyst provides a statistical description of the manner in which the expected land cover classes should appear in the imagery and a tool known as classifier is used to evaluate the likelihood that each pixel belong to one of these classes. The classification was carried out using four different classifiers. The image was classified into six (6) land cover types or spectral classes. The classes are built up areas, dams, rivers, rock outcrops, uncovered areas (bare surface), and vegetation.

In order to validate the integrity of the classification processes, ground truthing was conducted in Minna, Niger State. The features of the classified image were then compared with the data obtained from the ground truth operation.

RESULT AND ANALYSIS

Filtering

The result of the unfiltered composite image is presented in Figures 2a and 2c while Figures 2b and 2d presents the result of the filtered composite Image.

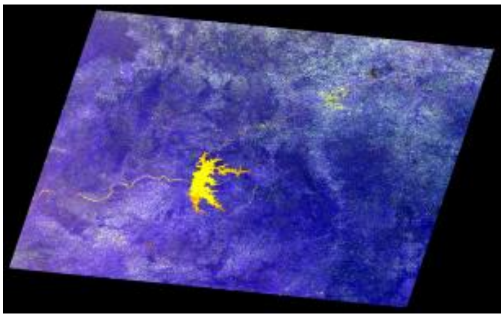


Figure. 2a: Unfiltered Colour composite (Band234)

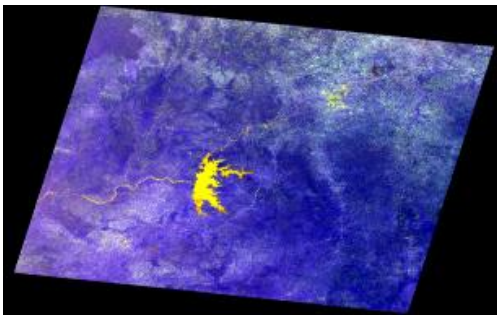


Figure 2b: Filtered Colour composite (Band234)

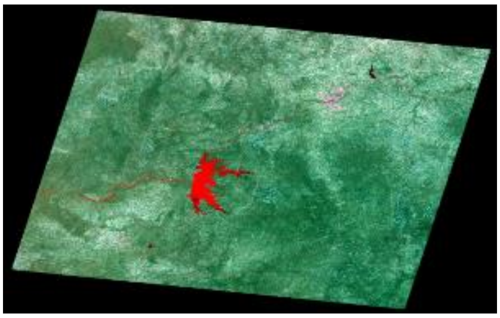


Figure 2c: Unfiltered Colour composite (Band357)

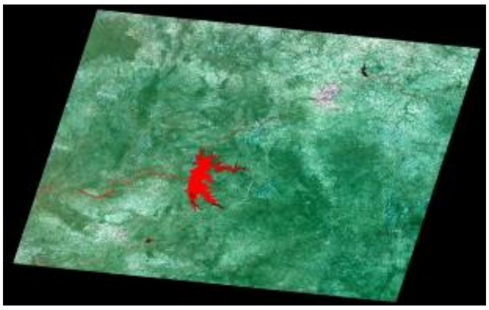


Figure. 2d: Filtered Colour composite (Band357)

Further attempt was made to investigate the reliability of the filter types used in the course of the study with the aim of suggesting the filter type that best filters the image without reducing the integrity of the image geometric and radiometric resolution. LAPLACE, Shadow, Edge Enhancement and Average 3x3 Filter types were considered and the results obtained are presented in Figures 3a, 3b, 3c and 3d respectively.

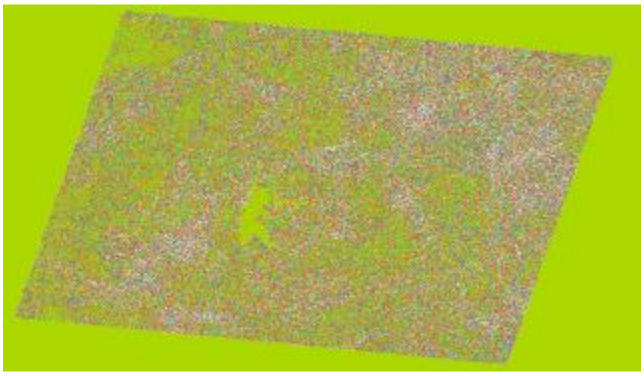


Figure 3a: Filtered image band 5 using LAPLACE

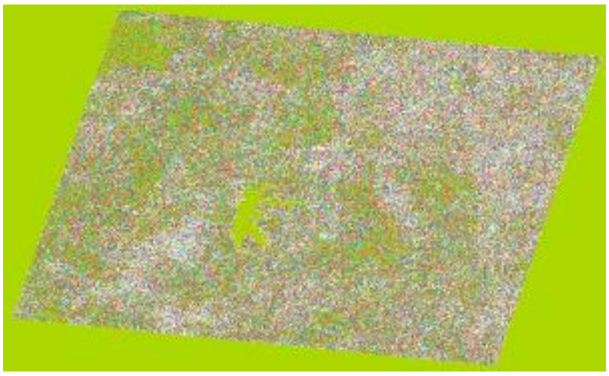
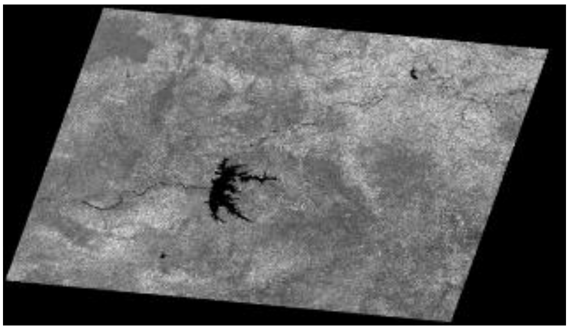


Figure 3b: Filtered image band 5 using SHADOW



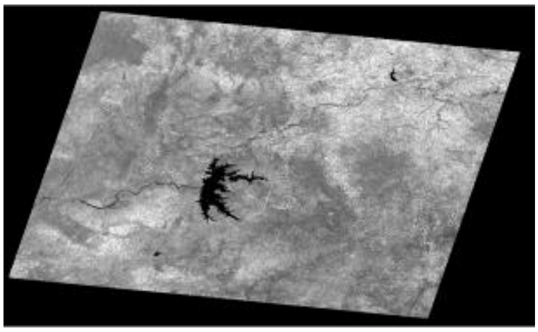


Figure 3c: Filtered image band5 using EDGESENH *Figure 3d: Filtered image band5*
using AVG 3x3

Colour Composite

Combining the three bands together in one colour composite map gives a better visual impression of the reality on the ground than by displaying one band at a time. The result obtained for the colour composite of bands 543, 157, 237 and 712 were as shown in Figures 4 a-d respectively.

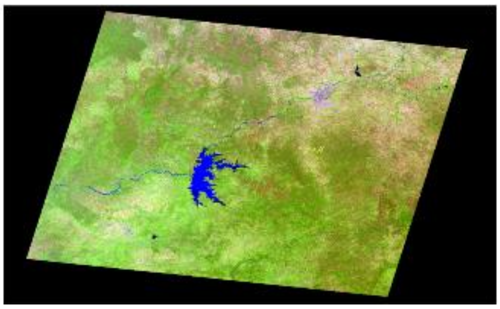


Figure 4a: Composite Image 543

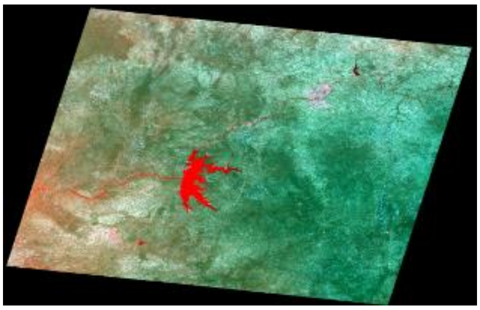


Figure 4b: Composite Image 157

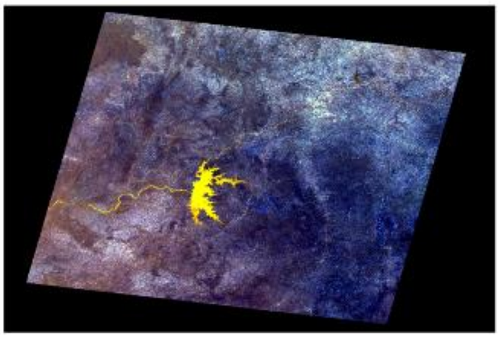


Figure 4c: Composite Image 237

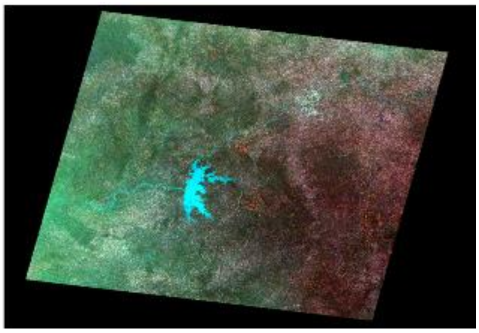


Figure 4d: Colour Composite image Band 712

Supervised Classification

The results of the supervised classification using Maximum Likelihood classifier, Box Classifier, Minimum Distance-to-Mean Classifier and the Minimum Mehalanobis Classifier are herein presented in Figures 5a, 6a, 7a and 8a respectively. The histogram representation showing the different classes in their number of pixels occupied of these classifiers are also shown in Figures 5b, 6b, 7b and 8b respectively.

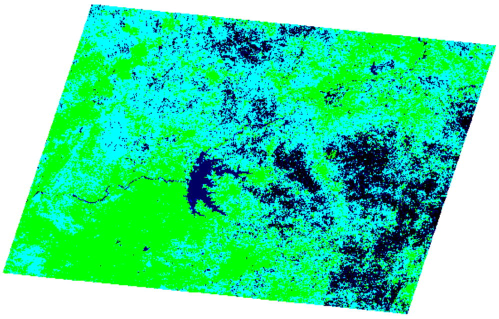


Figure 5a: Classification using MaxLike classifier

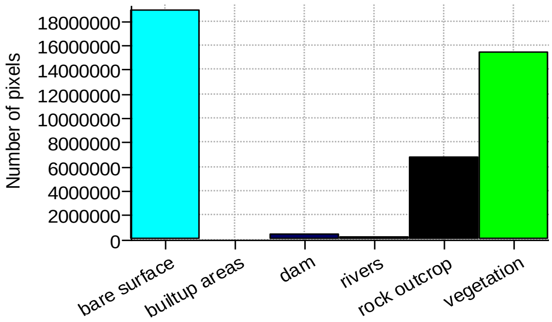


Figure 5b: Histogram of the classification

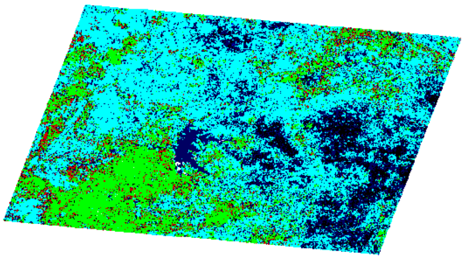


Figure 6a: Result of Box classifier

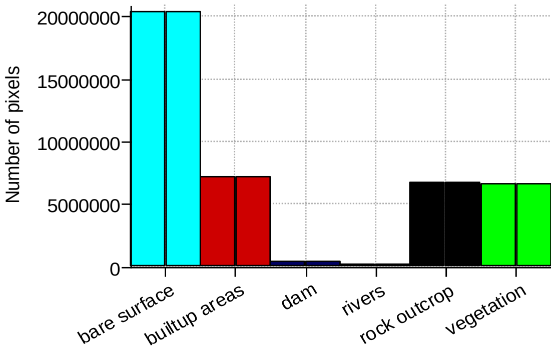


Figure 6b: Histogram of the classes

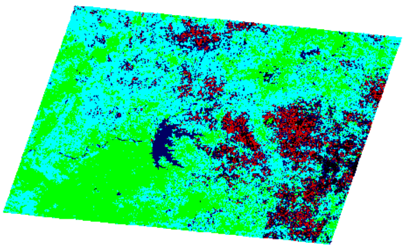


Figure 7a: Result of MINDIST classifier

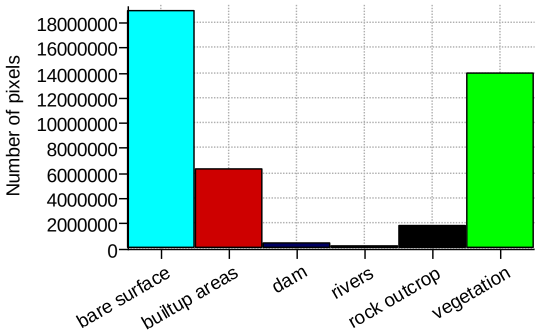


Figure 7b: Result of MINDIST Histogram

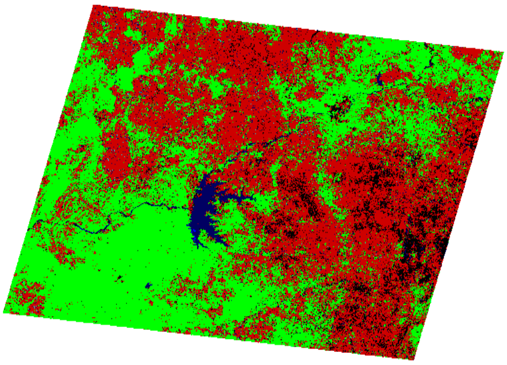


Figure 8a: Result of MINMEH DIST Classifier

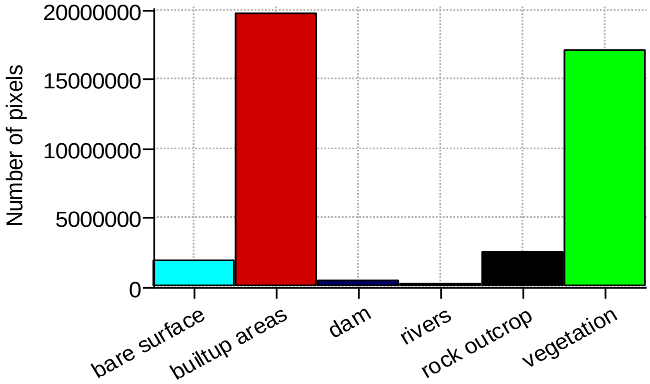


Figure 8b: Result of MINMEH DIST Histogram

Percentage of the Land Cover of the various Spectral Classes obtained from the supervised classification is summarized in Table 1. Table 2 presents the relationship between results obtained from each of the classifiers and their agreement with ground truth information.

Table 1: Percentage Summary of the Land Use/Land Cover.

Features	Max. Like. (%)	Box (%)	Min. Dist. (%)	Min Meh Dist (%)
Bare surface	45.34	49.19	45.47	4.43
Built-up areas	0	17.4	15.22	47.27
Dam	0.99	0.91	1.04	0.99
Rivers	0.39	0.29	0.4	0.36
Rock outcrop	16.16	16.22	4.39	5.98
Vegetation	37.12	15.99	33.48	40.97

Note: Max Like = Maximum Likelihood Classifier.
Min Dist. = Minimum Distance to Mean Classifier.
Min. Meh. Dist. = Minimum Mehalanobis Distance Classifier.

Table 2: Summary of the relationship between the ground truth information and results obtained from each classifier

Classifier Type	Features	Percentage Cover (%)	Agreement with ground truth information	Remarks
Maximum Likelihood Classifier	Bare surface	45.34	Yes	Maximum likelihood classifier proved to be insensitive to Built-up area feature classes
	Built-up areas	0	No	
	Dam	0.99	Yes	
	Rivers	0.39	Yes	
	Rock outcrop	16.16	Yes	
	Vegetation	37.12	Yes	
Box Classifier	Bare surface	49.19	Near Yes	Box Classifier Proved to be sensitive to all the considered land spectral classes
	Built-up areas	17.4	Yes	
	Dam	0.91	Yes	
	Rivers	0.29	Yes	
	Rock outcrop	16.22	Yes	
	Vegetation	15.99	Near Yes	
Minimum Distance to Mean Classifier	Bare surface	45.47	Yes	Minimum Distance to Mean Classifier proved to be sensitive to nearly all the considered classes except for Rock outcrop feature class
	Built-up areas	15.22	Yes	
	Dam	1.04	Yes	
	Rivers	0.4	Yes	
	Rock outcrop	4.39	No	
	Vegetation	33.48	Yes	
Minimum Mehalanobis	Bare surface	4.43	No	The Minimum Mehalanobis
	Built-up areas	47.27	No	

Classifier	Dam	0.99	Yes	Classifier gave the least satisfactory results. It exaggerated its classification of Built-up areas and vegetation
	Rivers	0.36	Yes	
	Rock outcrop	5.98	No	
	Vegetation	40.97	Near Yes	

The area used for the acquisition of the ground truth information (Minna, Niger State) was sub-mapped from the image (Figure 4a). Some of the features of the area were digitized in the ILWIS Software environment. The result obtained is as shown in Figure 9.

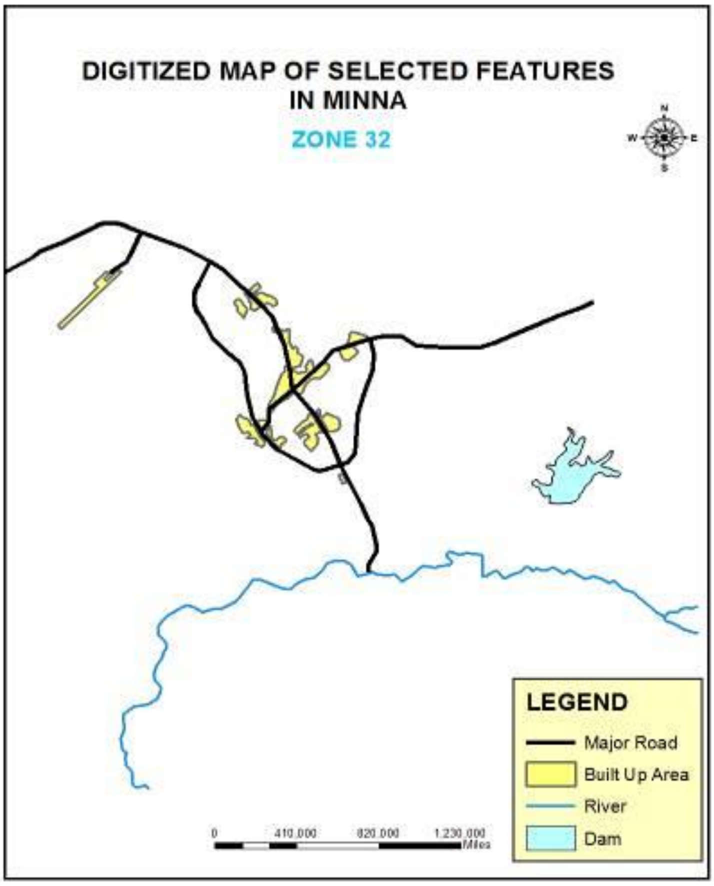


Figure 9: Some Digitized features of Minna, Niger state.

DISCUSSION OF RESULT

In the process of evaluating the filtering operation on an image, attempt was made to perform colour composite on both the filtered and the unfiltered Image, it was discovered that there were slight differences between the filtered colour composite results (Figures 2b&2d) and the unfiltered colour composite results (Figures 2a &2c). It could be inferred that the spectral reflectance of the satellite image before filtering was enhanced after the filtering process, the noise in the image has been reduced and that the image has been smoothened by the AVG filter that was used. Since it has been established that Filtering improves the resolution of the image, it is important to also investigate which of the filter type best filters the image while still ensuring the integrity of geometry of the resulting image.

Four different filter types were used to filter the band 5 of the LandSAT Image viz: LAPLACE, SHADOW, EDGE ENHANCEMENT and AVERAGE 3x3 filter types. The result of this operation was presented in Figures 3a-d. Close examination of the results revealed that there was distinctive difference in the output of the four filter types. LAPLACE and SHADOW filter types (Figure 3a and 3b respectively) were discarded because of their poor representation of image features and gross distortion of the image's geometric and radiometric integrity, EDGE ENHANCEMENT and AVG 3x3 Filter types (Figures 3c and 3d respectively) were further considered because of their excellent representation of features which contribute to the accurate classification of the image. AVG 3x3 filter type was selected as being more efficient.

After series of different band combinations as colour composite, it was discovered that the combination of bands 543 of RGB planes of the electromagnetic spectrum (Figure 4a) gives the best representation of the features on the image based on the ground truth information. Colour Composite images of bands 157, 237 and 712 (Figures 4b, 4c and 4d respectively) were discarded due to their inability to depict the ground features in their true colour. The Composite image of Figure 4a was then used for the supervised classification and the digitization of some features within the area used for ground truthing.

Based on the results obtained from the Supervised Classification process (See Table 1 and Table 2), it was discovered that Minimum Mehalanobis Distance classifier classified that "Built up areas" has the highest percentage of pixels (Figure 10b) which is not in agreement with our ground truth information and it is also against the submission of the three other classifiers which agreed that bare surface has the highest percentage of pixels. Also, Minimum Mehalanobis Distance classifier (Figures. 10a and 10b) and Minimum Distance-to-Mean classifier (Figures 9a and 9b) submitted that the percentage of pixels that belongs to "rock outcrop" in the image is 5.98% and 4.39% respectively. This is contrary to the findings of the analyst as the percentage of the pixels that belongs to "rock outcrop" should be more than that based on the ground truth information. Maximum Likelihood classifier (Figures 7a and 7b) and Box classifier (Figures. 8a and 8b) gave a more reliable result as they agreed that rock outcrop covers 16.16% and 16.22% respectively.

Furthermore, Maximum Likelihood Classifier submitted that there is no "built-up area" on the whole image by allocating 0% to the "Built-up area" spectral class. This was contrary to our groundtruth information and even the submission of the three other classifiers i.e. Minimum Distance-to-mean, Minimum Mehalanobis and Box classifiers which submitted that 15.22%, 47.27% and 17.4% respectively of the entire image was occupied by "built-up areas" even though the 47.27% voted by Minimum Mehalanobis classifier is outrageous.

Base on these, the analysts indicated that Box classifier, Minimum Distance to Mean Classifier and Maximum Likelihood classifier can be more effective and better suited for classification of multi-featured images than the other three classifiers for accurate and reliable image interpretation.

CONCLUSION

This research has evaluated the significance of spatial filtering, Colour composite and classifier types on LandSAT images. After the analysis, it was observed that proved to AVG 3x3 filter type was the best filter type for LANDSAT multi-featured images while colour composite of bands 3, 4, 5 gave the best representation of the features of the image. The Box classifier, Minimum Distance to Mean Classifier and Maximum Likelihood classifier also proved to be excellent classifiers and are more suitable for this type of image classification. Though we do not have enough scientific proof, it is opined that one of the perceived influential factors of the performance level of each of these algorithm is their sensitivity to different image features. The authors are currently carrying out a research to validate this claim.

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