KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF ENGINEERING DEPARTMENT OF GEOMATIC ENGINEERING

LAND USE/LAND COVER MAPPING: ACCURACY COMPARISON OF CLASSIFICATION OF VARIOUS BAND COMBINATIONS:

(Ejisu Juaben Municipality Area)

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTERS OF GEOMATIC ENGINEERING, UNIVERSITY: KNUST, KUMASI - GHANA

By

M'BALI SYLVERE

September, 2015.

Supervisor: Dr. E. M. Osei Jnr.

DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct. I have fully cited and referenced all materials and results that are not original to this work.

M'BALI Sylvere	-------------------------	------------------
(Student Name)	Signature	Date
Certified By		
Dr. E. M. Osei Jnr	------------------------	--------------------
(Supervisor's Name)	Signature	Date
Professor, Dr - Ing Collins Fosu	-------------------------	--------------------
(Head of Department)	Signature	Date

DISCLAIMER

This document describes work undertaken as part of a programme of study at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi; Department of Geomatic Engineering. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

ABSTRACT

This thesis investigates the issue of selection of the optimum band combinations of Landsat 7 ETM+ that yield better Ejisu Juaben Municipality LULC classification when satellite data and training area are available. The classes obtained could help in performing classification using Maximum Likelihood Classification (MLC). The Principal Composite Analysis (PCA) yielded better information about land use and land cover (LULC) classes. Tasselled Cap (TC) was used for image transformation and the Normalized Difference Vegetation Index (NDVI) image was used to characterize green vegetation. All were used alone and in combination with original bands for classification accuracy comparison. The result from PC1-3, B1-4 and B1-5, 7 were respectively found better (Accuracy 90%, kappa 0.86), (Accuracy 88%, kappa 0.84) and (87%, 0.82). The PCA band combination is the best that yield optimum LULC within Ejisu Juaben Municipality.

***Keywords**: land-cover mapping, transformation, classification, band combinations, accuracy assessment.*

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS & ABBREVIATIONS

ANN: Artificial Neural Network

B: Blue

DT: Decision Tree

EMS: Electromagnetic Spectrum

ETM: Enhanced Thematic Mapper

G: Green

GCPs: Ground Control Points

GIS: Geographic Information Systems

GPS: Global Positioning systems

IFOV: Instantaneous Field Of View

IR: Infra-Red

IRS: Indian Remote Sensing

LULC: Land Use Land Cover

MLC: Maximum Likelihood Classification

MSS: Multispectral Scanner System

NDVI: Normalized Difference Vegetation

NIR: Near Infra-Red

OIF: Optimum Index Factor

PCA: Principal Composite Analysis

R: Red

RF: Random Forest

RMS: Root Mean Square

RS: Remote Sensing

RVI: Ratio Vegetation Index
SWIR: Short Wave Infra-Red

SVM: Support Vector Machine

TC: Tasselled Cap

TM: Thematic Mapper

KNUST
NYANSAPƆ WƆSANE NO BADWENMA

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to all Department of Geomatic Engineering lecturers for specific knowledge acquired of my study at Kwame Nkrumah University of Science and technology, Kumasi-Ghana.

My special thanks go to Dr. E. M. Osei Jnr. who helped me to formulate the research topic and its precious supervision during the research period.

I am thankful to: Mrs. Adwoa Sarpong Amoah, Ms. Beatrice Acheampong, Mrs. Lily Lisa Yevugah and Mr. Seth Frimpong who helped in the critical reviews of my thesis.

I greatly appreciate my MSc. Colleagues for their lovely and warm friendships. May God richly bless you all.

To M'BALI Christophe Pepin; C.E.O of Lege Engineering Company Ltd, my lovely mother FATINA Martine, my sister M'BALI Alda, my siblings, nephews, nieces to be saved and waiting patiently for my return.

CHAPTER ONE

INTRODUCTION

1.1. Background

Land cover has been defined as the physical features observed on the land (Comber et al., 2005). It can be determined by satellite analysis and aerial imagery. Land use is characterized as land cover attribute and could not be determined from satellite imagery (Comber et al., 2005). Land cover maps; as a final product and information obtained after image classifications. It has a purpose of using the obtained information to make decision by users, practitioners ... etc. These information's' are; natural or man-made features made up the landscape.

Remote sensing Techniques are becoming more important for extracting data from aerial photo or satellite imageries (Foody, 2002; Lu and Weng, 2007 and Heinl et al., 2009). However, the map obtained by Remote Sensing (RS) application is now the fastest method that gives information, save time of study and not labour intensive work over large area (Donnay et al., 2001). Satellite imagery studies by Remote Sensing within a large geographic area with high temporal frequency, offers an issue for extracting information from Land use and Land cover, processing, image analysis, interpretation and classification.

Remote sensing image classification techniques are an alternative used to increase information from original and enhanced data for analysis. Most classification techniques employed the image based on pixel for analysis. These analysis were performed using unsupervised i.e. the study was done without having reconnaissance field and training data while the supervised involve surveying procedures. An example of classification technique based pixels are (Maximum Likelihood (MLC), Artificial Neural Network (ANN), Decision

Tree (DT), Support Vector Machine (SVM), Random Forests (RF)) and Hybrid classification (Cao and Gu., 2005). These techniques were established to identify features on the ground in conformity to the image. The MLC via Landsat 7 ETM+ satellite images dispose all proprieties for identifying heterogeneous forest under canopies when Global Positioning System (GPS) is unable to be used.

Congalton et al., (1983) have specified that the accuracy of the band combinations involves the accuracy measured from the classification to be compared to identify the best LULC for analysis.

Different ways have been used by surveyor to select optimum band for LULC classification but the best is to choose the technique that seems familiar for performing LULC classification attained in combining different bands of Landsat 7 ETM+. Kauth and Thomas, (1976) have highlighted the linear algorithm bands combined with the 6 bands of Landsat 7 ETM+.

Most studies have confirmed the potentiality of selecting optimum bands through image enhancement bands or transformation techniques (Mausel, 1990) that are:

- The acquirement of the classification quality when PCA, TC or ratio bands are mixed.

- The effect of redundancy to be removed and the use of data correlated susceptible to give more information about the image e.g. ratio band or a PCA.

- The effect of haze, clouds, cloud shadow and plant canopy shadow, which affect the reflectance of the objects and confuse the analyst must be remove by the use of TC transformation when features on the ground are mixed with the above effects mentioned.

Some limitations are often signalized when enhance or transform data is to be applied. Sometimes, the use of enhanced or transformed data does not improve the quality of classifications, and make difficult the image interpretation. The reason why the use of these techniques needed procedures to be follows on a theoretical basis and also care must be taken for the expected results.

1.2. Problem Statement

Remote Sensing data users must always be consistence when images, graphs or statistics interpretation is to be done. With the advent of the new technology, RS through satellite images and aerial photos are efficient to extract information about LULC over large geographic areas and it is also a susceptible tool of saving time, cost and producing accuracy.

Ashanti region is composed of 30 administrative and political Districts in which Ejisu Juaben Municipality is a part. The municipality is totally attractive due to the kente weaving industry and tourism. The emphasis on study of land use land cover in the municipality is of more interest to be informed about the natural resources in the community, on environmental issues, resources and policy formulation (Ryan, 2013).

Many classification techniques; DT, SVM, ANN could also perform the band combinations for Landsat ETM 7 + but MLC is the most widely used classifier applied in different studies (Laba et al., 1997) because most of decision rules are based on statistics results (Jensen, 1996). The MLC uses the probability function in which each pixel is assigned the most likely class of membership. The class statistics are obtained from the training data.

The main goal of the study is to assess whether other band combination would give optimum land use land cover classification. Most researchers used the six band of Landsat to do their classification (Osei et al., 2011; Benefoh, 2008 and Asubonteng, 2007) using MLC which is not the optimum band combinations but I am trying to investigate through several band combinations which band shows the best land use and land cover within Ejisu Juaben Municipality.

1.2.1 Project Objectives

The research objective is to select the best band combinations that could yield optimum Land use Land cover classes of the area. The specific objectives include:

- Identifying the suitable band combination for land use land cover classification.
- The assessment of accuracy classification.

1.2.2. Research Questions

To achieve these objectives, questions would be answered:

- What is the optimum band combination for LULC classification within Ejisu Juaben Municipality?
- What is the accuracy assessment for the classifications?

1.2.3. Project Layout

The thesis is composed of five different chapters. The chapter one talks about the research background and highlight the problem statement (which investigates within these various band combinations the best shows better land use land cover), the research objectives and ended by the research questions. The chapter two reviews Image analysis parameters, Band combinations, Transformations and indices. The third Chapter shows the study area the materials followed by methods used in this study. The chapter four allows analyses and results discussions. The later, chapter five answers the research questions and make recommendations for the research.

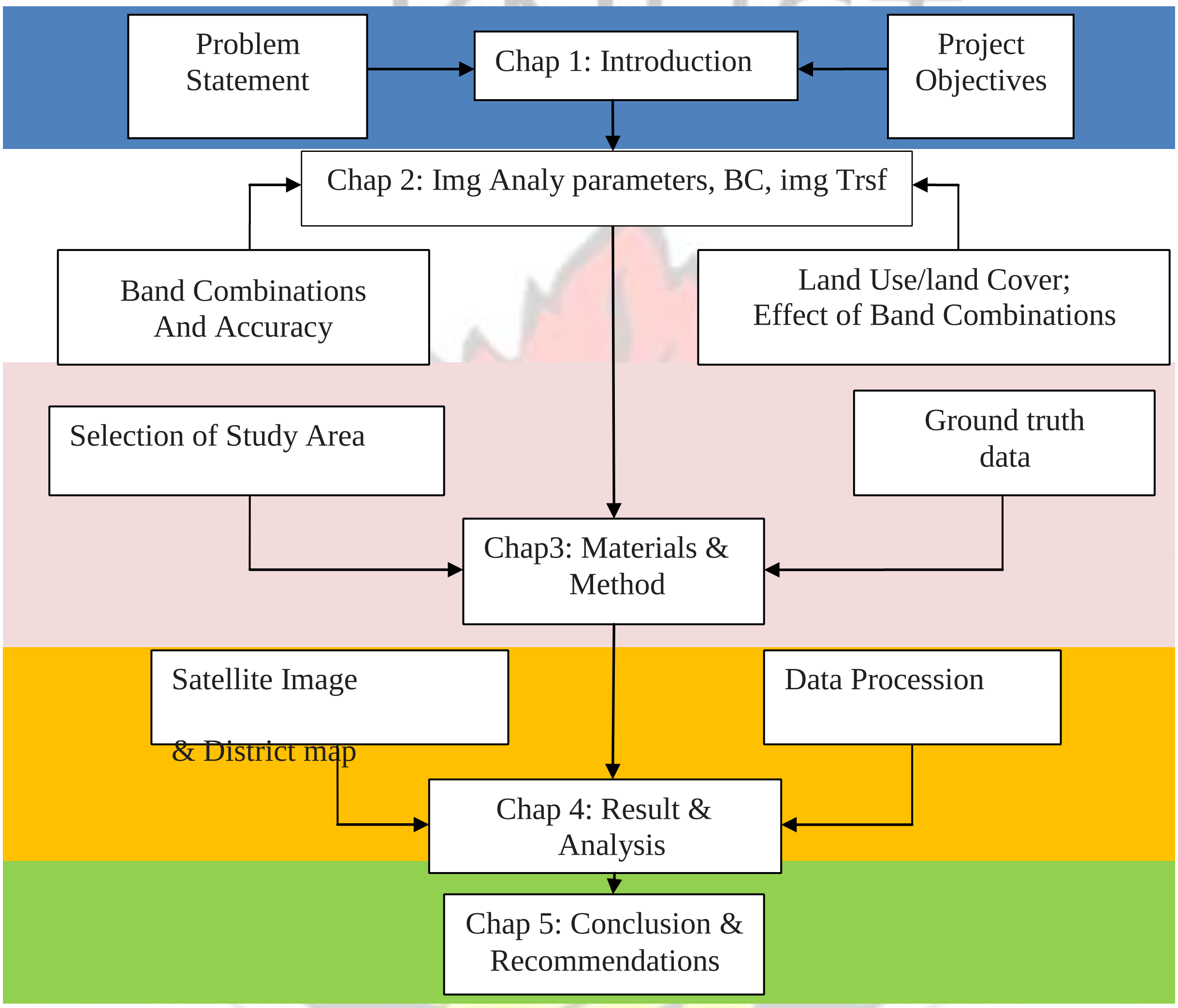


Figure 1.1: Layout of the Project

CHAPTER TWO IMAGE ANALYSIS PARAMETERS, BANDS COMBINATIONS AND TRANSFORMATION INDICES

2.1. Image Analysis Parameters

Imagery acquired aboard of satellite sensors and other remote platforms are effective information's source about the natural and manmade features located on the land. Remote sensing using Landsat 7 ETM+ system is a source for generating multispectral bands according to their wavelength and broadcast microwaves which measures the signal portion that has reflected to the sensor from the surface of the Earth. Such imagery could save time in acquiring effective environmental and mineral resources information (Pecora, 1972).

Landsat data are tremendously used to classify land use land cover and make analysis. Results have showed that Landsat had been widely used for many studies and it has been considered as a core for spatial temporal analysis of environment in large areas (Heinl et al., 2009; Perera and Tsuchiya, 2009).

Currently, many applications are based on various technology supports such as new Technology information and communications, image processing, global positioning systems (GPS) and geographic information systems (GIS) utilize Landsat data.

More scientists' used Landsat data to display images by processing and analysis techniques that combine satellite data and other data for measurement, mapping, monitoring and modelling. Such applications have the purpose to extract information that could help managers and decision-makers processes at a variety of levels.

Several studies were done in Ejisu Juaben Municipality using the six band of Landsat and MLC classification (Osei et al., 2011; Benefoh, 2008 and Asubonteng, 2007, etc) to identify LULC.

Results have showed that remote sensing studies using Landsat TM/ETM+ emphasis inventories on land use and land cover. Most of inventories were based on crops monitoring and the growing aspect of urban areas, water resources analysis, forestry management, agricultural activities and the management emergency. Further, many Ghana companies employed Landsat product in their research. E.g. Academic institutions are main users of Landsat data as well as Universities and lecturers within Ghana are also using Landsat data in their researches.

Nowadays, the best means of information provided by RS on LULC is the imagery captured by satellite. Knowing that, single date image is not consistent for monthly/seasonal LULC studies in some regions (Harding et al., 1994; Stoney, 1996 and Asner, 2001). But it can be used only and in combination with the transformation or enhanced image.

Asubonteng, (2007), study changes within Ejisu Juaben Municipality using Landsat TM 1986 and ETM 2004. Benefoh, (2008) also did the same but rather used Landsat TM 1986 and ETM 2004 to detect changes and map Ejisu Juaben Municipality. Osei et al., (2011) used single date image of Landsat 7 ETM+ (2007) to select the best classifications. All of cited references proved that, Universities of Ghana are Landsat data users. These student researches will serves as the first training and they would later utilize in government or private industries research.

Band Combinations seemed efficient with the advent of new development technology. Landsat imagery is made up of multispectral bands which allow RS users to know which bands produce the image.

2.2. Remote Sensing with Band Combinations for land use/cover mapping

2.2.1. Remote Sensing

Remote Sensing is the study for extracting information from an object, area or phenomenon without having contact with the object under study. Information collected from the imagery is termed data and came in different format (Lillesand et al., 2008).

Remotely sensed imagery has been considered through its spectral bands, spectral resolution and the knowledge on different bands, features on the ground as well as the temporal characteristics. Spectral coverage is considered as the core of study when band combinations are used. This knowledge allows user to describe the part of the Electromagnetic Sensor (EMS) make up the image. The spectral resolution is an indication given by the sensor onto the bandwidths to show how the information is collected by the sensor. The number of spectral bands at a precise location of the EMS is termed spectral density.

2.2.2. Band Combinations

A band combination is the combination of visible colours represented by R, G, and B in a three dimensional space. Band combination is a technique used to display the standard colour composites. Trotter, (1998) showed that the images displayed through band combinations have roles in observation. E.g. the true colour composite images use bands 1, 2, and 3 for visual interpretation. The false colour composite called pseudo colour images has a purpose for increasing data interpretability. Band combinations were to obtain images with colour.

Some are very important in many applications. Band 4 for example is dedicated for mapping shorelines and biomass content; best band for vegetation detecting and analysis. The band 5 and 7 within were used to reflect more plant. Whatever the research objectives, the true or false colour composite may be used (Naga et al., 2013).

The band combinations 5-4-3 or 4-5-3 have already been allocated to land use by R, G, and B meanwhile land covers involve the band combinations 4-3-2 for LULC identification within the near infrared. The Shortwave Infra-Red (SWIR) involves bands 7, 4, and 2 to detect changes; soil disturbances type, soil and vegetation stress (Naga et al., 2013).

The shortwave infrared band composite; 7-4-2 identifies forest in red, agriculture in shed of red and settlement in pink, roads are shown as straight lines and coloured lines and rivers are coloured in dark blue nearly to black. In combining bands 4, 5 and 3, the forest appears green, the cultivated areas in shade of green and built-up areas in various shade of pink. In addition to these, roads are visible as straight lines and the rivers are dark blue colour; almost black.

The study based on selecting band combinations using Landsat is subject to the research purposes. Miller et al., (1998), in their study used a supervised classification to identified changes from 1973–1991 in New England USA. They also extracted PCA and NDVI bands in using multispectral scanner system (MSS) bands of Landsat.

The image classification based on optimum band combinations is like using all bands (Bruzzone and Serpico, 2000; Murakami, 2004). In addition image classification applied using optimum band combinations based on accuracy assessment comparison still (Stenback and Congalton, 1990). Priyakant et al., 2012, in their studies made emphasis on band combinations and other image processing to identify the best season that yielded optimum land cover classes. Results have showed the B1–4 classification as the best and could be used for mapping LULC. The B 1-4 has been chosen after analysis of seasonal images for January and September; period under which environmental conditions were normal. The output also showed that the accuracy given in classifying land-cover in January is best compared to September.

Wenbo et al., (2008) based on the statistical combination formula and obtained twenty (20) band combinations of three bands in ascending order. They used the Optimum Index Factor (OIF) to selection the best band combinations. As results, the B 3- 5 of TM and ETM+ gave the best OIF index value. Within the 20 band combinations, 10 three-band combinations have been maintained. Eight have band 4 in their combinations and gave significant OIF values.

Throughout the results, we can infer that 80% of 10 band combinations have band **4** in their combination (Jamshid et al., 2013).

TC and PCA bands were used for image enhancement. Their roles were to facilitate interpretation and make easy analysis (Klonus and Ehlers, 2007; Lu and Weng, 2007). NDVI added to PCA, TC has a purpose for developing and integrating bands information (Pohl and Van., 1998; Klonus and Ehlers, 2007; dong et al., 2009; Ceamanos et al., 2010; Ehlers et al., 2010 and Zhuang, 2010).

Landsat deals with multispectral bands and Spot panchromatic band. Many applications came out in band ratioing to identify land covers. Nelson (1983), in his research used band ratio (NDVI) to extract gypsy moth defoliation in Pennsylvania. Satterwhite, (1984) discriminated vegetation and soils using band ratios of Landsat MSS and Thematic Mapper. His results show the particularity of band ratios in characterizing vegetation.

The maximum likelihood was selected in many studies using multispectral image of Landsat 7ETM+ (Laba et al., 1997) due to its performance in analyzing spectral information. However an available image together with original band data is susceptible for generating new images and improving classification using image transformation techniques.

Two linear combinations have been developed (Tasselled Cap transformation and Principal Components Analysis) for image transformation and enhancement (Kauth et al., 1976). Some researchers showed that NDVI was used to define a vegetation band to classify land cover.

2.3. Concept and Definitions

2.3.1. Land use Land cover

The words LULC have been read and heard by people but each term has its own meaning. The knowledge of both LULC allows practitioners to help in their investigation in the areas under study. Data from LULC are the basic component for planners and decision-makers for helping communities' development. It also helps better understanding where and how to plan or preserve the natural resources. Ryan, (2013) have confirmed the efficiency of LULC knowledge in the connectivity or fragmentation of various features. Confusion and ambiguity would appear when data from LULC were to be matched, compared and/or combined.

2.3.2. Land use

The term Land use, considered as an attribute of land cover, implemented by human activities with the purpose of obtaining the outcome and/or profits after exploiting land features. The results of human being actions on some land cover types produce changes. Adubofour, (2011) and Ryan, (2013), in their studies also got a link between land use and Land cover type.

2.3.3 Land cover

Land cover means any physical objects observed on the land however natural or done by human anthropogenic activities. Ryan, (2013) established that Buildings, Roads, Recreations Water, Bare rock, Sand are also considered as land covers but they do not go further about the use of land. E.g. Forest may be used for timber production, wildlife protection. It might also been allocated to a private company through a concession, this ambiguity may be at the origin of observations made from different sources (the human eye, aerial photographs and satellite sensors) at different distances between the source and the earth's surface (Adubofour, 2011; Ryan, 2013). Field survey and image analysis are methods used by sensors to extract LULC information.

Based on the purpose of the project, surveyor would come out with its LULC classes to defined features on the land. Many researches defined forests depending on the objectives set in the project. E.g. the forest inventory of Timber Companies is always based on the size and height of the trees. Areas made up with many trees may not be termed as forest when the tree heights' are smaller (Wooten et al., 1957).

2.4. Imagery analysis parameters using Landsat 7 ETM+

2.4.1. Spectral Resolution

Sensors carried on board of satellite measure the spectral reflectance on the target along all part of spectrum. This measurement as a purpose of identifying the target through the number of spectral bands called spectral resolution.

The spectral resolution shows the efficacy of sensor to difference remote sensing set from fine wavelength intervals. During the reflectance, the sensor records the area targeted in different wavelength ranges called spectral bands at different spectral resolutions.

2.4.2. Spatial Resolution.

Pixels are the basic of Remote Sensing images. The pixel sizes vary according to the way the sensors were designed. Landsat 4 and Landsat 5 (TM and ETM+) image has 30 m^2 resolution in bands 1-2-3-4-5 and 7 as an instantaneous field of view (IFOV) and Band 6 has 120 m^2 as an IFOV on earth. The spatial resolution image must always suit the project requirements.

Due to inaccessible areas, the new development of remote sensing has been implemented and deals with higher spatial resolution data from 1 to 2 m^2 pixel size. The new size of remote sensing data can extract information from small objects on the ground for observation. Due to the cost of the higher resolution, Landsat is the best satellites for studying areas up to several km.

2.4.3. Radiometric Resolution

Radiometric resolution emphasis on dynamic range; about 7 and 8 bits and the various record of radiant energy (about 128 and 256 levels) for a measurement for Landsat TM/ETM+. The results show that the more radiometric resolution, the more accurate remote sensing data living on the target surface.

2.4.4. Temporal Resolution

Added to spatial and spectral resolution, the temporal resolution is the period in which satellite used to sweep the area to obtain a data and also the time it makes for ground observations of a same target. The revisit period of satellite is of some days or months.

2.4.5. Image Transformations

In Remote Sensing, data are redundant over the bands due to the correlation among the visible, the near infrared and the red bands. To avoid redundancy over the band, image from satellite must spectrally be transformed to generate new bands without redundancy.

Image transformations are new representation of original bands with more information due to the combination of correlated bands and data over all bands of satellite image. The information extracted by image transformation is subject to image processing techniques. The information about green vegetation, environment and planning concerns vegetation differentiation indices and some other linear algorithms. There are two famous linear algorithms applied: Principal Composite Analysis (PCA) and Tasselled Cap transformation (TC). The Normalized Vegetation Index (NDVI) is used to characterize green vegetations.

2.4.5.1. Normalized Difference Vegetation Index (NDVI)

NDVI is always obtained in between red and near infrared portion of EMS. Rouse et al., (1973) applied NDVI to find vegetative study and estimated crops outcome. The crops production is due to greenness, water, the biomass quantity ... etc.

Generally the domain of near infrared shows more greenness (healthy vegetation) related to visible light absorbed. Unhealthy vegetation shows more the domain of visible than near infrared. The domain of red and infrared reflects Bareland (Holme et al., 1987).

The EM spectrum describes all behaviour of plants. The information about NDVI is focussed on vegetation from near infrared and red. The NDVI is the ratio of the difference between the near-infrared and the red to their sum (see Formula **1.**).

$$\mathbf{NDVI} = \frac{\mathbf{IR - R}}{\mathbf{IR + R}} \longrightarrow \mathbf{1}$$

Where, **IR** = Infrared band and **R** = Red band

This formulation has demonstrated that $-1 \leq NDVI \leq 1$.

- If $-1 \leq NDVI < 0$ the areas are water, Bareland, ice, snow, or clouds.
- If $0 < NDVI \leq 1$ the areas are vegetated.

Fernandes', (2003) showed the potentiality of NDVI to identify separability from a bare soil reflectance to canopy in between $0 < NDVI \leq 1$ and highlighted that the used ratioing band is to show the strength of chlorophyll absorption in red and the reflection of healthy vegetation in the near infrared. NDVI is function of parameters related to vegetation.

Adubofour, (2011) in his study used both January images of Landsat TM, (1986), ETM (2007) and Aster 2002 for mapping eight LULC classes with Fragstats software. Results have showed conformity to NDVI image classified and the image classified. The Overlapping of 1974, 1986, 2002 and 2007 images showed that the reserved forest has been tremendously depleted.

2.4.5.2. Principal Composite Analysis (PCA)

The original bands of remote sensing data are often correlated the reason why PCA has been used to eliminate redundancy in the bands. The new bands images implemented by PCA are represented in three axes by PC1, PC2, and PC3 and cannot be correlated with others (Chavez, 1992). The correlation always comes out with redundancy in the data. To avoid redundancy, the original band must perform transformation with PCA (Tso and Mather, 2001).

Ricotta et al., (1999) have also highlighted the role of PCA over the spatial structure based on Landsat image in Italy. The results showed that the PCA components displayed different spatial structure and the content of the original image. They put emphasis that, care must be taken when using PCA in remote sensing and its results interpreted.

2.4.5.3. Tasselled Cap Transformation (TC)

TC is a representation of the original image of Landsat MMS compressed in three dimensional coordinates, implemented by Kauth and Thomas (1976). They defined their new coordinate systems in term of Brightness, Yellowness and Nonesuch to well represent soils and vegetated areas. Later Crist and Cicone, (1984) also developed their research using six TM bands. After transformation they came out with six bands. To eliminate redundancy from the Landsat bands, they reduced them into three dimensional coordinates. Results have showed that TC provided more information's in the third axis of Landsat ETM, considered as wetness instead of yellowness in MMS. Hence the three new compressed coordinate axes are termed Brightness, Greenness and Wetness (Tso and Mather., 2001; Jensen, 1996).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study Area

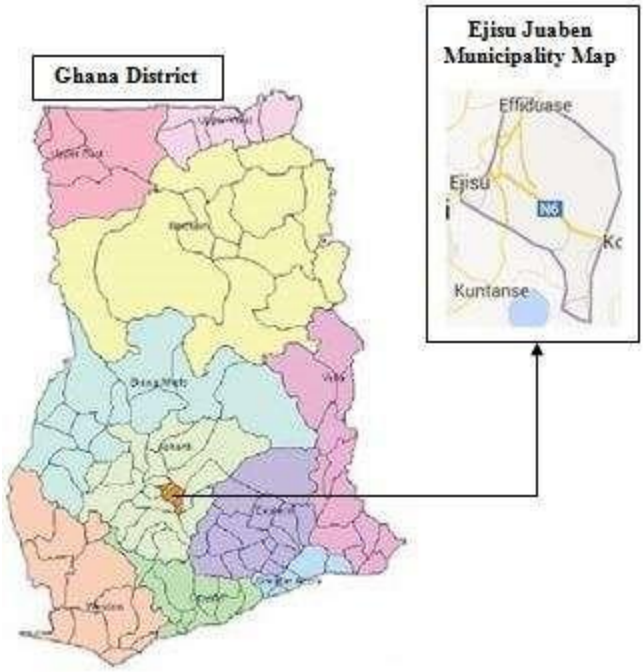


FIGURE 3.1: PHYSIOLOGICAL MAP OF GHANA AND ASHANTI REGION DEPICTING KUMASI AND EJISU JUABEN.

3.1.1. Location and Size of Ejisu Juaben Municipality

Ejisu Juaben Municipality is geographically located within longitude 1° 15’ W, 1 ° 45’ W and latitude 6° 15’N, 7° 00’N. Its capital is at 20 km from Kumasi to Accra called Ejisu in the Ashanti region and delimited by many districts (Asubonteng, 2007). The district covers an area of 637.4 km^2, representing 10% of all Ashanti region (Asubonteng, 2007).

3.1.2. Topography and Drainage

The Municipality is situated in the forest dissected physiographic region of Ghana, by preCambrian rocks of Birimian and Tarkwaian formations. The area is undulating and located above sea level, in between 240 – 300 metres. The area is well drained with a rivers and streams running through it. Occasional flooding is experienced in the inland valleys along river basins (Asubonteng, 2007).

3.1.3. Climate

The Municipality climate is a semi-equatorial and falls in the tropical forest in south Ghana. It is known by its double rainfall from March to July and the latter from September to end November. The annual rainfall stands at 1200 mm. The rainfall generates higher humidity in the Municipality during the raining season. Benefoh, 2008 inferred that the annual temperatures are of 20^{o}C in August and 32^{o}C in March

3.1.4. Vegetation and Soil

Ejisu Juaben Municipality vegetation was categorized by Hall and Swaine, (1976). Within the Municipality an area of 54.6 km^{2} is found as forest reserve termed Bobiri. It serves for Tourism, Research, and Conservation functions. Bobiri is tremendously rich with large amount of timber (Benefoh, 2008).

The surrounding reserve forest are crops, forest patches rivers and streams. More often the off forest is make object of illegal and legal logging. The dominant plants in the Municipality are Chromolena ordorata.

The Municipality is made up of granite (Asubonteng, 2007). Most of these soil classes can be used for some agricultural purposes but from yearly crops to cash crops (Benefoh, 2008; Asubonteng, 2007).

3.2. Materials

3.2.1. Data

Data from Landsat 7 ETM+ was acquired on Tuesday January 13, 2007 from the ITC database (KNUST). It was used for comparing image classification of various band combinations and mapping LULC of Ejisu Juaben Municipality.

A SYLVA, ATLAS PRO; Handheld GPS was used to perform ground survey.

3.2.2. Software

Software's involved for the research are:

- ERDAS Imagine 10.0; for performing image classification and assess the accuracy,
- MS Word 2007; tool for typing,
- Excel 2007 for building tables and graphs.

3.3. Methods

3.3.1. Structure of the Methodology

The issue of performing a various band combinations classification for LULC using Ejisu Juaben Municipality ETM data is research objectives. To meet this objective, three steps were implemented:

- Pre-processing image step,
- The extraction of NDVI, PCA, TC,
- Classification using different band combinations,

The method structured was detailed in **FIGURE 3.1.** by a chart.

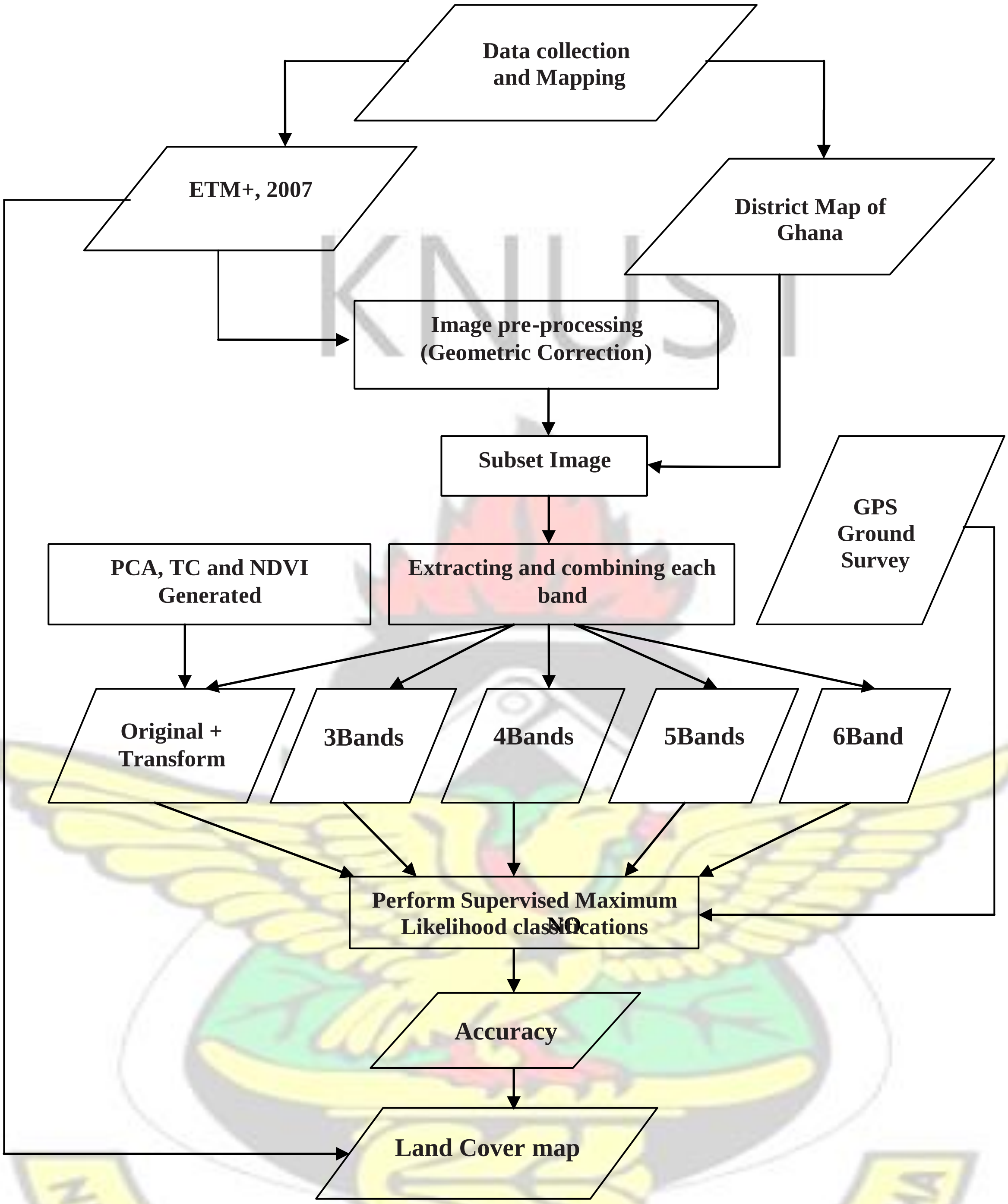


Figure3.1: Structure of the Methodology

3.3.2. Data Pre-processing

Data from remote sensing sensors always came with errors. Errors may not be used for mapping without correction. Due to the period the data was available, only geometric correction could be used. This correction used the ground control points (GCPs) to account sensor system (roll, pitch, and yaw) and/or atitude.

This correction aim at the registration of each pixel to real world coordinates and the image was also georeferenced to the local coordinate system (Traverse Mercator (TM)) projection using a line map of scale of 1: 50000. Forty points picked consisted of road intersections and river confluences which gave a root mean square error (RMSE) of 0.4. The acceptance of error was because it is within 0.5 as recommend by Osei and Zhou (2004). All these were done by ERDAS Imagine 10.0 versions software. A first order polynomial transformation was used for image data sets registration. The resampling image was to 30x30 pixels using the nearest neighbour method. This correction helped obtain the highest geometric integrity (Lillesand et al, 2004).

3.3.3 Image Subsets

It is the process in which the study area could be depicted from the whole map with the aid of the remote sensing software. This ensures that the area of interest and the whole shapefile coincide spatially. The subset images must not be smaller in order to identify significant features.

3.3.4. Various combinations of bands

The issue of selecting various band combinations of Landsat ETM depend on the objective requirements of the research. The study of LULC involves band three to show water in blue and the computation of NDVI (see **FORMULA 1**) for the purpose of characterizing vegetation. Band four and five were selected for Agricultural studies and also show healthy vegetation. The use of B 2-4 and B 3-5 were respectively to show the standard false colour (vegetation in shed of red) and the latter is the pseudo colour that shows the forest in green and different shade of green agricultural areas. The pseudo image shows also Settlement in pink colour, Roads as lines and Rivers are blue dark.

The number of band combinations is given by **FORMULA 2**.

$$\frac{\boldsymbol{n}!}{\boldsymbol{p}!\,(\boldsymbol{n}-\boldsymbol{p})!} \quad \rightarrow \quad \mathbf{2}$$

Where **n** the number of original bands and **p,** the number of selected bands

The number of bands obtained was Thirteen (13).

Three band combinations has given only four (4) combinations; B 2-4, B 3-5, PC 1-3 and TC.

Four Band combinations have given six combinations but only four were selected to perform LULC classification; B 1-4; B 1-3, 5; B 2-5 and B 3-5, 7.

Four mixed bands (original and transformed bands) combinations have given due to the first two PCA and TC components which acquire significant information of the image as well the band 4 and five. They are; B 4-5, 7, PC1; B 4-5, PC1, NDVI; B 3-5, TC1 and B4-5, PC1, TC2.

Only two band combinations obtained for five original bands; B 1-5 and B 1-4, 7.

The six band of Landsat ETM gave the image usually used; B 1-5, 7.

3.3.5. Feature Extractions

The NDVI has been generated to characterise vegetation and show boundary between greenness and soil due to its value computed in the red and infrared (Fernandes, 2003).

TC bands are the representation of the original bands obtained by linear combinations of Landsat ETM. This transformation helps giving significant information about agriculture and also shows the separation of bare soil from vegetated and wet soils. All TC bands were done by Erdas Imagine through processing. TC components involve are.

- TC1 given in red colour. Vegetation is non-significant and more reflected.
- TC2 given in green colour. Deals only with greenness.
- TC3 given in blue colour. Identifies water and moisture.

PCA bands are linear transformation of the original spectral bands and uncorrelated. The results obtained after processing had given six components from one to six but only three has been selected. The compression gave PC1, PC2, and PC3.

- PC1 could show well urban and water;
- PC2 is able to clearly identify vegetation;
- PC3 is the best component that can show ground soil.

These three components were sufficient to obtain LULC information good for image analysis.

3.3.6. Accurate combination of bands for LULC Classification

The probability combination equation was used to get the number of band combinations. The three band combinations needed band 3 and 4 to identify vegetation. The four band combinations depend on all visible bands and one NIR/IR or two visible and one IR/R. The five band combinations require all visible, one NIR and IR. The six bands of Landsat is the image obtained by combining the six bands.

About thirteen subset bands images included the original and transformed bands. About twenty (20) band combinations were obtained. Fifteen (15) band combinations were used to classify LULC. Original bands were combined alone and together with the enhanced bands.

The mixed band combinations were to obtain good information for classification analysis.

MLC classification was performed on the fifteen band combinations in order to know the image that yield best LULC classes within Ejisu Juaben Municipality (see **TABLE 3.1)**. **TABLE 3.1.: Optimum Band Combination for Classification**

Group	Band Combinations
Three original or derived bands	(a) B2-4 (b) B3-5 (c) TC1-3and (d) PC1-3
Four original bands	(a) B1-4 (b) B1-3,5 (c) B2-5and (d) B3-5,7
Four mixed original and derived bands	(a) B4-5,7,PC1 (b) B4-5,PC1, NDVI (c) B35,TC1 (d) B4-5,PC1, TC2
Five original bands	(a) B1-5 and (b) B1-4, 7
Six original bands	(a) B1-5,7

3.3.7. Image Classification and Accuracy assessment

The system of classification based on RS is a very important tool for extracting LULC information. Maximum likelihood classification has been considered as the best technique applicable when several band combinations (including the transformed band component) are to be combined. This technique has the potentiality to have the statistical report given by the software. Its reliable results report could serve for accuracy assessment comparison. The classification accuracy assessment is based on the samples collected from the site, the generating of enhanced images and the computation of the probability in which this pixel belong to this class.

On the field, 641 ground control points (GPSs) were picked according to the defined classes. About 356 random points (55%) were used to explain the spectral signature and 285 (45%) were used for image validation. The field reconnaissance allowed the establishment of five (5) land use land cover classes described in **Table 3.2.**

TABLE 3.2: Description of Land Use Land Cover Classes for Classification

Land use land cover	**Description**
Bareland	Area made up of gravel and untarred road

Settlement	Areas inhabited and tarred road built over a years
Agriculture	Lands logged farms in the past, Areas used for cultivation.
Forest	Bobiri forest reserve and higher trees (Opened and closed canopy) above 15m.

KNUST

The MLC accuracy assessment relies on overall accuracy and kappa coefficient. They were calculated based on error matrices. Kappa is a degree of conformity to meet the standard requirement (Fernandes, 2003). The Kappa coefficient is given by the **Formula 3.**

K varies from 0 (full disagreement) to 1 (full agreement). According to Foody, 1992:

- If $0<K<0.4$, the classified results is poor.
- If $K<0.75$, the classified result is fair.
- And if $0.75<K<1$, the classified result is the best. It happens when overall accuracy is higher than 60%.

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})} \longrightarrow \quad \textbf{3}$$

Where
N: Total number of pixels in all the ground truth classes r:

Number of row in the matrix

Xi i: Number of row I in the column i

X_{i+}: Total of row i

$X_{+}i$: Total of column i

W J SANE NO BADWENMA

KNUST

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Results

Fifteen band combinations were selected and subdivided into:

- Only original bands;
- Combine original transformed bands.

4.1.1. 3-Band Image Classifications

The B 2-4 and B 3-5 have similarity in their results. The observation showed that B 2-4 identified more agricultural and ground soil areas while water body is more represented in B 3-5. The PCA and TC images were respectively for analysis and transformations. The PCA results seemed better classification due to its brightness, greenness. TC image classified mostly forest and water areas as well as settlement. They have labelled as **A, B, C, and D** in **FIGURE 4.1**.

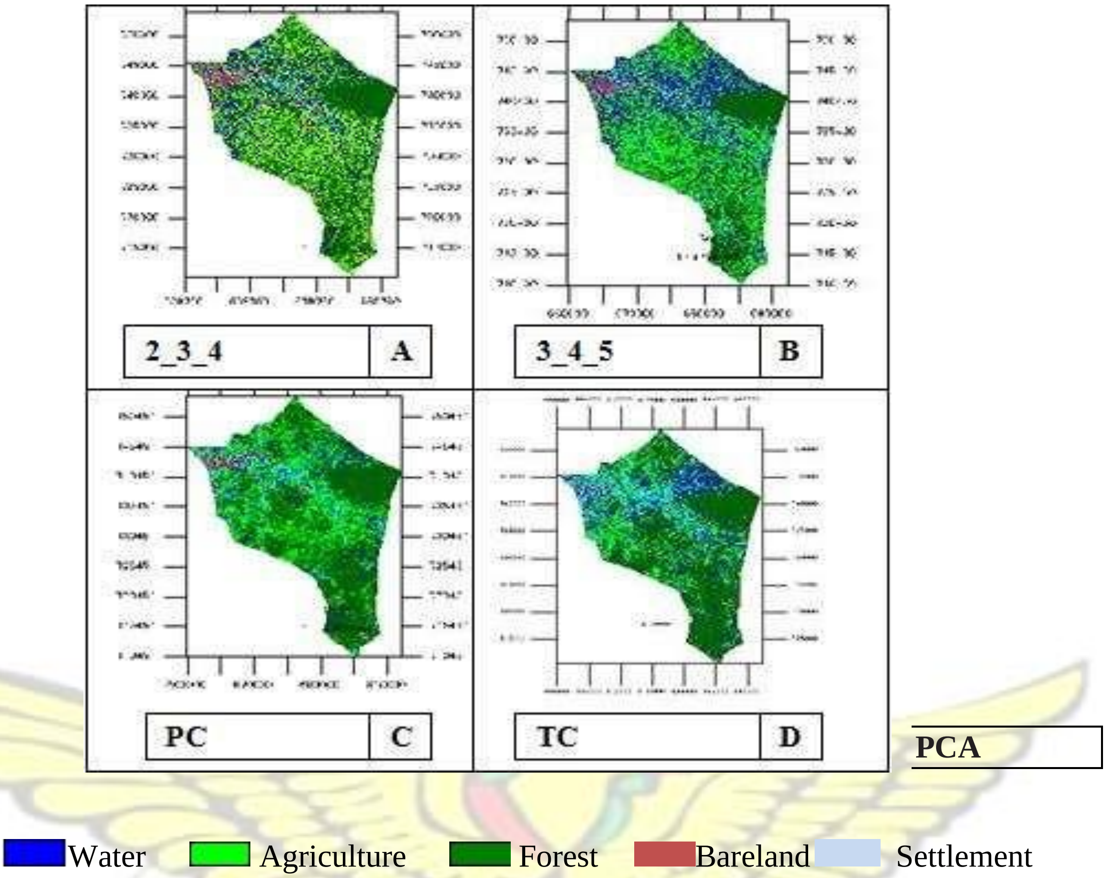


FIGURE 4.1: Three Band Combinations Classification

4.1.2. 4-Band Image Classifications

In all four (4) original band combinations roads were lines in cyan colour. The image observations indicated that Bareland and settlement were similar, all showed green vegetation (more cultivation areas) in their results. The B 3-5, 7 only showed few water areas in as compared to the others. Their Kappa and overall accuracy values seemed closer to the standard margin. The image classifications were labelled as A, B, C and D in **FIGURE 4.2:**

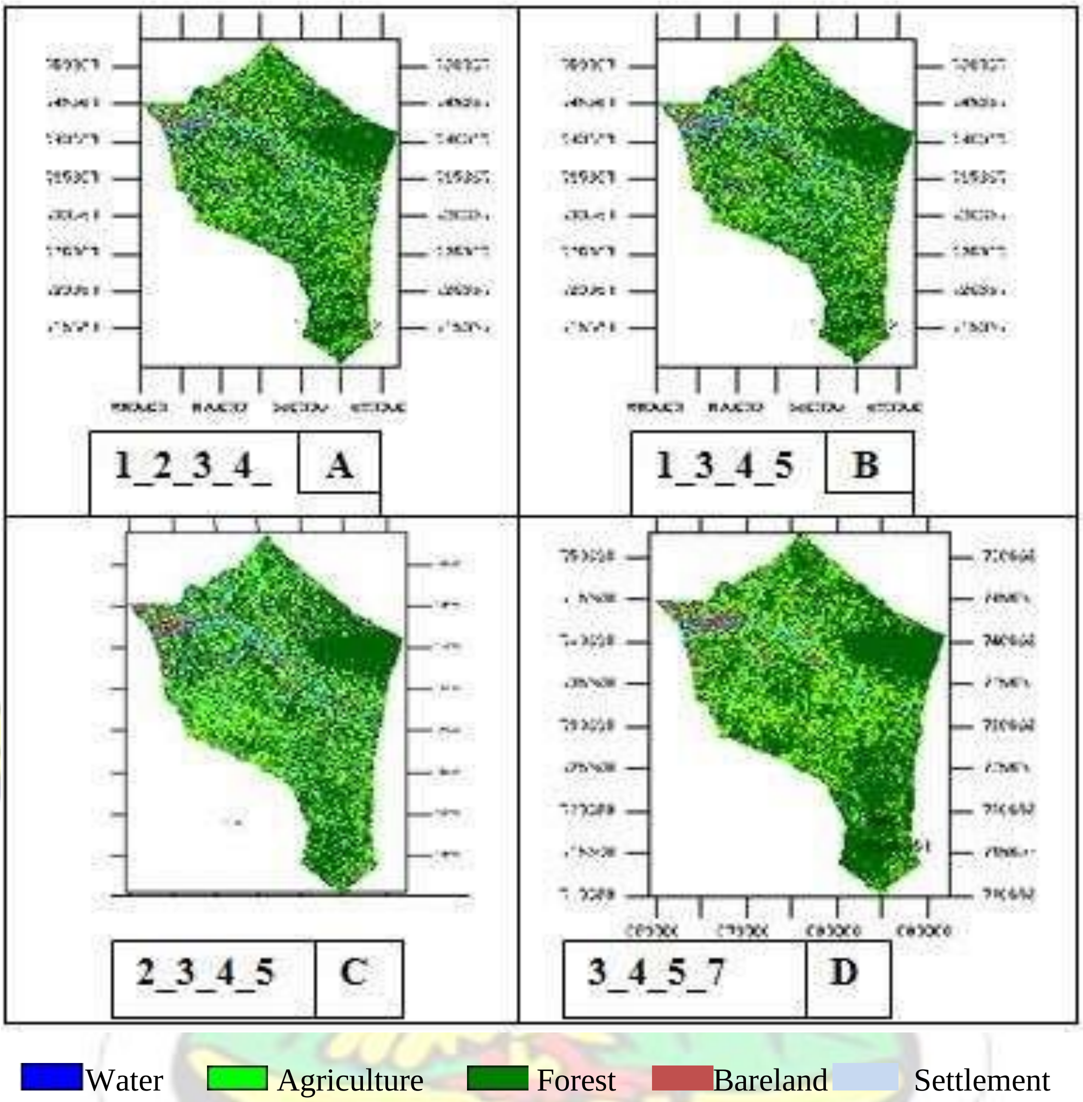


FIGURE 4.2: Four Band Combinations Classification

The mixed original and transformed bands presented differences in their results. They all showed brightness in their classification. In their observations, slightly water was found in B 4-5, PC1, TC2 as compared to others. Water represents at least 60% in B 4-5, 7. All the mixed bands showed settlements. The cultivations areas were clearly showed within these three band combinations; B 3-5, TC1; B 4-5, TC1, NDVI and 4, 5, TC1, TC2. In B 4, 5, PC1, NDVI, water existed but less than in B 4, 5, 7 PC1. Bareland were shown across the road in B 4, 5, PC1, NDVI as well as settlement. The B 4, 5, 7, PC1 and B 3-5, TC1 also showed settlement (see **FIGURE 4.3**).

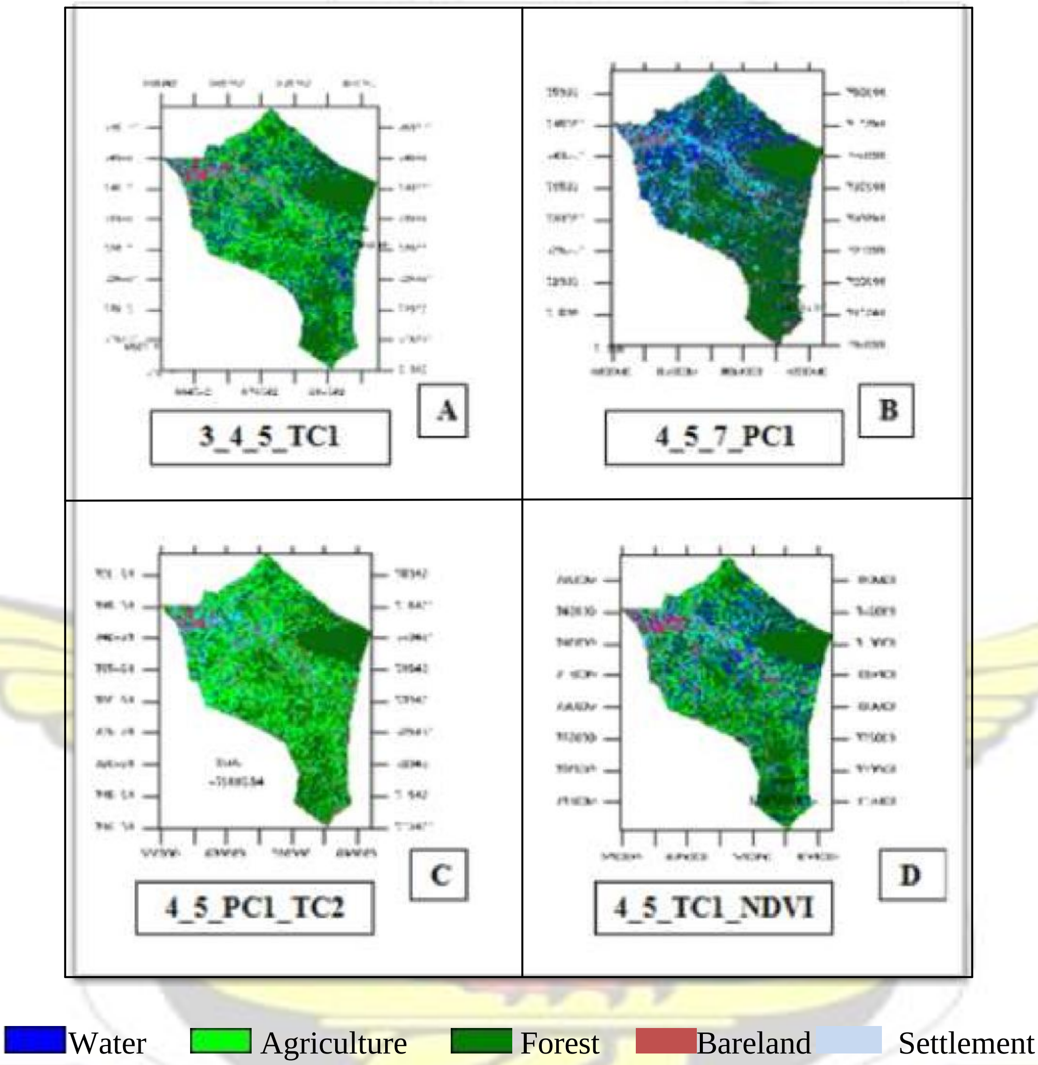
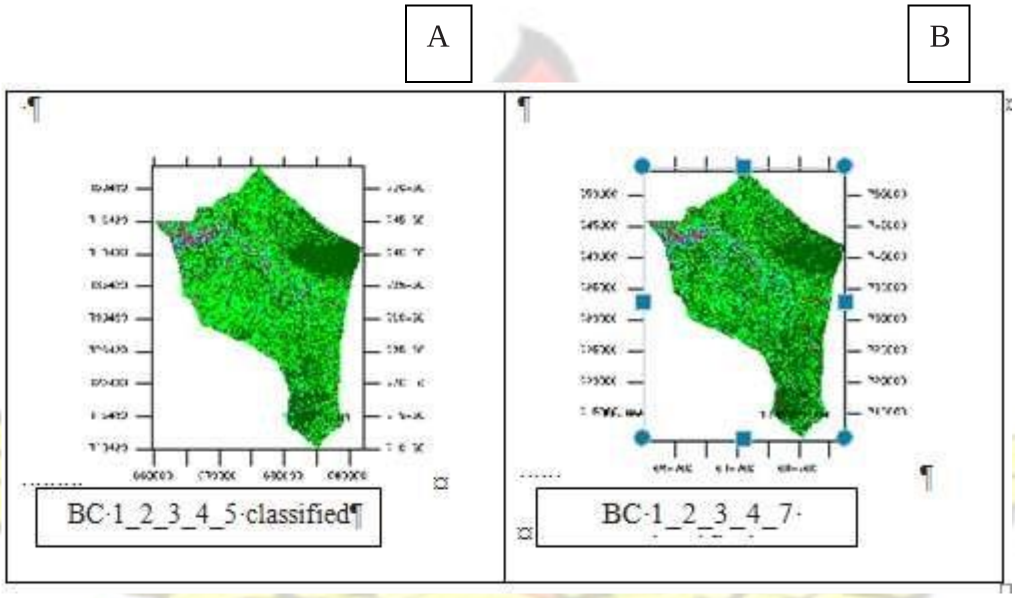


FIGURE 4.3: Four mixed; Original and Derived Band Combinations Classification

4.1.3. 5-Band Image Classifications

The five band combinations observation did not show that water. Settlement and Bareland seemed similar showed and they were also found within the forest. In the B 1-4, 7, forest was found everywhere and agriculture activities were reduced in quantity. Road was a lines in cyan colour (see **FIGURE 4.4**.).

KNUST



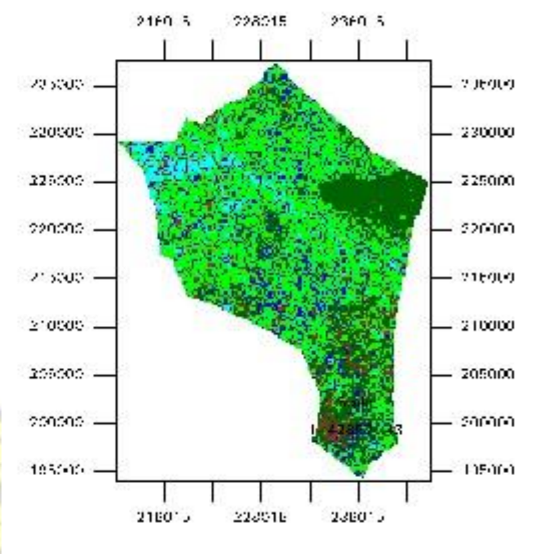
Water Agriculture Forest Bareland Settlement

FIGURE 4.4: Five Bands Combinations Classifications

4.1.4. 6-Band Image Classification

In the original image with all six (6) bands (**Figure 4.5**), Bareland were found at the South part of the study area and a little found in the North West as it was shown in other image classifications but surrounded by settlements. Water was found everywhere as well as agricultural activities. Bare land, settlement, water and some agricultural activities were found within the Bobiri reserve forest (see **FIGURE 4.5**.)

KNUST



Water Agriculture Forest Bareland Settlement

FIGURE 4.5: Six Band Combinations Classification

4.2. Accuracy Assessment

The **TABLE 4.1.** shows the accuracies of different band combinations classification through their Kappa statistics and overall accuracy values. From the **TABLE 4.1**, PCA image classification gave the highest results following by B 1-4 and B1-5, 7.

The B 3-5, B 2-4 and TC results were lesser than the standard value (K<0.85 and OA <0.8) their result were not good as compared to the classification of four, five and six band combination. In between PCA and TC (90% and 73%), the given result showed the potentiality of PCA for transforming and analyzing Ejisu Juaben Municipality LULC data (see **FIGURE 4.6**).

The accuracy for four original band combinations seemed similar but differed from their kappa that showed the superiority of B1-4 over all the rest (see **TABLE 4.1**.).

The five band combinations have shown good result and they did not classify water but showed more contrast in Greenness, Settlement and Bareland (see **Appendix B10, B11**).

For four mixed; original and derived band combinations, the results could not compare the accuracy in terms of band combinations but they could use only their accuracies to identify the best spectral enhancement band for mapping as compare to the others. The results have shown that the B4-5, 7, PC1 did not show more interest in agricultural areas. B 4-5, TC1, NDVI and B 3-5, TC1 have the highest accuracy (86%) than B 4, 5, PC1, TC2 which has given 85%. The accuracy given by kappa statistics has shown that B 4. 5. PC1, NDVI is respectively more accurate than the B 3-5, TC1 (0.82 and 0.81) (**see FIGURE 4.6**). Knowing the NDVI band image and TC2 bands image were similar in function. To obtain the best transformation for greenness, comparison must be done between B 4. 5. PC1, NDVI (86%, 0.82) and the 4, 5, PC1, TC2 (85%, 0.8). The result has shown that the corresponding combination containing the NDVI band image was higher than the one contained TC2 band image (see **TABLE 4.1**). Then, the band combinations containing NDVI showed its superiority against TC in measuring greenness (healthy vegetation).

The six band combinations for Landsat 7 ETM+ accuracy result seemed good (Overall accuracy= 0.87 and Kappa= 0.82) after B1-4 but did not show to be an optimum band combinations (see **FIGURE 4.6**).

Table 4.1: Classification Accuracy of Selected Band Combinations

Band Combinations	Overall Accuracy	Kappa
PC1,PC2,PC3	90%	0.86
B 1,2,3,4	88%	0.84
BC 1,2,3,4,5, 7	87%	0.82
B 4,5, PC1, NDVI	86%	0.82
B 3,4,5, TC1	86%	0.81
B 2,3,4,5	86%	0.80
BC 1,2,3,4,5	86%	0.78
B 4,5, PC1, TC2	85%	0.8
B 3,4,5, 7	85%	0.78
BC 1,2,3,4, 7	84%	0.77
B 1, 3,4,5	84%	0.76
B 4,5,7, PC1	82%	0.74
B 3,4,5	79%	0.73
B 2,3,4	79%	0.69
TC1,TC2,TC3	73%	0.70

Overall accuracy and Kappa statistics for the classification accuracy

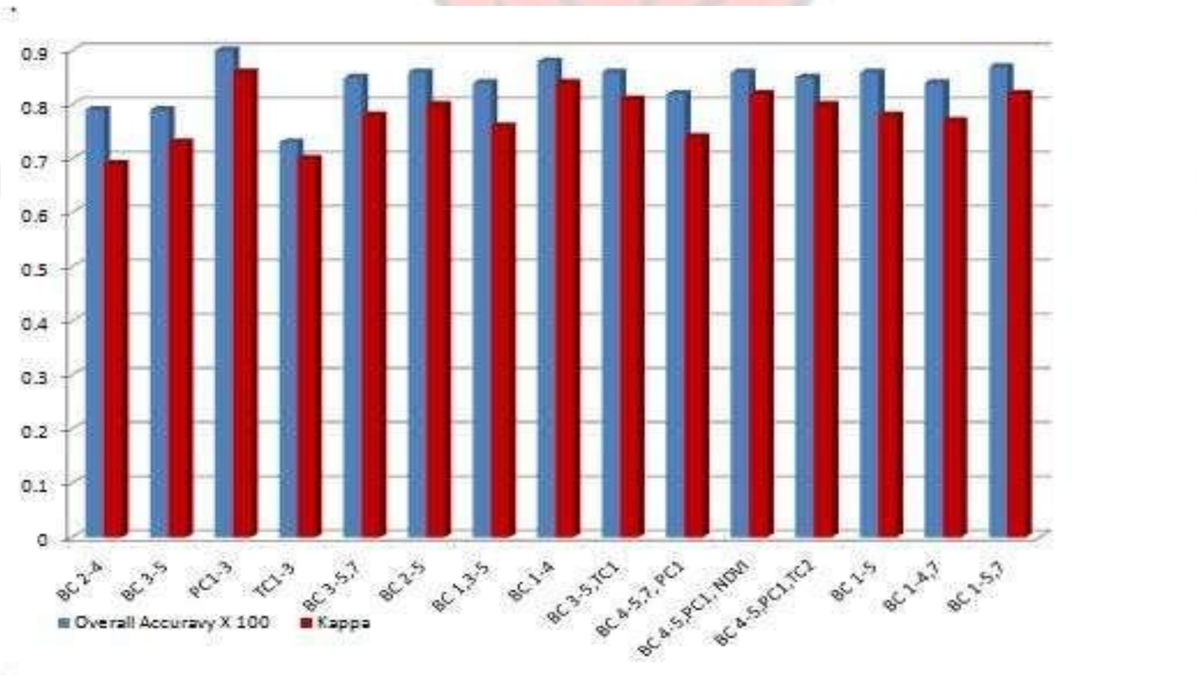


Figure 4.6: Overall accuracy and Kappa statistics for the first five accurate band combinations

4.2. Discussion

The **TABLE 4.1** shows the results of different classification images. Some results seemed similar according to wave length spectrum and the function of each algorithm. The linear transformation functions after merging with other original bands for classification have a purpose for image analysis and enhancement.

The NDVI in this study showed more vegetation quantity and ground contents within the study areas. The band combinations classification that contained NDVI (4-5, TC1, NDVI) seemed good than the band contained TC (4, 5, TC1, TC2). The comparison between their results proved that NDVI is more advised than TC for characterizing vegetation and mapping Ejisu Juaben Municipality LULC. The band 4-5, TC1, NDVI and 4-5, 7, PC1 were likely similar in observation, they did not classify healthy vegetation and agriculture areas. They all showed consistent water even where the canopies were found (see **Appendix.B.12**). The band combination B 4-5, 7, PC1 showed significant separability between vegetation and ground biomass contents. PC1 was a reference band for urban and water reflectance. The TC could not be used for mapping LULC within Ejisu Juaben Municipality but NDVI band may be used for mapping Ejisu Juaben green vegetation (see **TABLE 4.1**).

4.2.1 Land use land cover classification: Comparison of accuracy

After computing Kappa and OA, the accuracy comparison could be established.

Care must be taken on evaluating each kappa to get better information about the LULC. Most of the information were found within PC1, PC2, PC3 respectively followed by B 1-4 and B 1-5,7 according to their accuracy and Kappa coefficient; (90%, 0.86), (88%, 0.84) and (87%, 0.82). The Maximum likelihood classification was applied to two linear transformations namely PCA and TC transformations. The ratio image NDVI was to show greenness characteristics. Results have shown that PCA is the optimum band combinations of Landsat 7 ETM+ that showed optimum LULC within the study area. (See **FIGURE 4.6**).

The three bands results were not closer to the standard values. The five band combination were not able to classify water (see **Appendix B9, B10**) that meant, the combination of five bands in LULC in this study could not be compared to others due to its incapacity to identify water classes.

The four original band combinations classification results were significant except the kappa value of B 1, 3, 4, 5 and B 3, 4, 5, 7 which was lesser than the standardized (K>0.80). The B 1, 2, 3, 4 seemed the best band after the PCA. Its overall accuracy and the kappa coefficient for each class proved that the B 1-4 was ranked among the best band combinations that yield better LULC classes (**FIGURE 4.6**).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The following conclusions were arrived at the end of the study.

- The PCA image classification with 90% accuracy and Kappa coefficient of 0.86 is more accurate as compared to the others. Hence, PCA image classification is the best due to its kappa coefficient and Overall accuracy.

- The result has found that the six band combinations of Landsat 7 ETM+ can also be used as optimum band due to its results (Kappa and Overall) which are beyond the accuracy requirements (Foody, 1992).

5.2. Recommendations for Further Work

From the study, I recommend the following:

- Other image classification methods apart from the maximum likelihood method should be used for classifying the various band combinations of Landsat TM/ETM.

- Image classifications be conducted using the optimum band combination for higher accuracy.

- The classification of the band combination could be performed using areas with different land use land cover classes.

KNUST

REFERENCES

Adubofour F. Thesis (2011). Application of Remote Sensing and GIS for Forest Cover Change Detection using yearly Landsat TM and ETM in the forest reserve of Owabi catchment in Kumasi, Ghana). April, 2011.

Alvarez, R., Bonifaz, R., Lunetta R.S., Garcia C., Gomez G., Castro, R., Bernal A. and Cabrera, A.L. ;(2003): Multi temporal land cover classification of Mexico using Landsat MSS imagery. International Journal of Remote Sensing 24, 2501–14.

Apan A., Kelly R., Jensen T., Butler D., Strong W., and Basnet B; (2002). Spectral discrimination and separability analysis of agricultural crops and soil attributes using Aster imagery, Australasian Remote Sensing and Photogrammetry, September 2002.

Asner G., (2001). Cloud Cover in Landsat Observations of the Brazilian Amazon, International Journal of Remote Sensing, in press. http://bgc.colorado.edu/asner publications Landsat Amazon clouds.pdf.

Asubonteng, (2007), Identification of land use/cover transfer hotspots in the Ejisu Juaben District, Ghana, March, (2007) Thesis. International Institute for Geo-information Science and Earth Observations'. Enscheda, the Netherlands.

Benefoh T., (2008). Assessing LULC changes effects on ecosystem services in Ejisu Juaben District, Ghana. (2008). Thesis.

Bruzzone L, Prieto Fernandez., (2000). Automatic analysis of the difference image for unsupervised change detection. IEEE Transactions on Geosciences and Remote Sensing 38: 1171-1182.

Bruzzone, L., and Serpico S.B., (2000). A technique for feature selection in multiclass problems, International Journal of Remote Sensing, 21:549-563.

Campbell B.J., (1996): Introduction to Remote Sensing (Second Edition). Taylor and Francis, London.Centre for image Analysis, Swedish University of Agricultural Sciences, and Uppsala University.

Ceamanos X, Waske B, Benediktsson JA, Chanussot J, Fauvel M, Sveinsson JR. A classifier ensemble based on fusion of support vector machines for classifying hyperspectral data. International Journal of Image and Data Fusion. 2010;v.1:293–307.

Chaowei Yang, Wong David, Qianjun Miao , (2010). Computers Advanced Geo-information Book Isbn =1439810613.

Chavez, P.S, (1982). Statistical method to select Landsat MSS ratios, Journal of Applied Photographic Engineering, Vol. 8, 1982.

Cohen W.B., (1991). Response of vegetation indices to change in three measures of leaf, water stress. Journal of Photogrammetric Engineering and Remote Sensing. vol 57 (1), p.195.

Lex Comber *et al*., (2005). "What Is Land Cover? " Environment and Planning B: Planning and Design (32): 199–209.

Congalton, R. G. Oderwald, and Mead R. A.; (1983). Landsat classification accuracy assessment using discrete multivariate analysis statistical techniques, Photogrammetric Engineering and Remote Sensing, 49:1671–1678.

Crist, E. P., and R. C. Cicone. ;(1984). Application of Tasselled cap concept to simulated Thematic Mapper data, Photogrammetric Engineering and Remote Sensing, 50:343–352.

Dong J, Zhuang D, Huang Y, Fu J. Advances in multi-sensor data fusion: algorithms and applications. Sensors. 2009;v.9:7771–7784.

Donnay, Bamsley, and Longley, (2001). Remote sensing for analysis in urban sector. New York: Taylor and Francis.

Foody G.;(1992). On the Compensation of Chance agreement in the use of accuracy assessment image classification. Photogrammetric and Remote Sensing. 58 (10): 1459-14600.

Foody, G. M., (2002). Status of land covers, based on the accuracy assessment of classification. Remote Sensing of Environment, 80(1). pp. 185-201.

Franklin, S.E. and Wulder, M.A. ;(2002): Methods of Remote sensing in medium spatial resolution of satellite data within large land cover areas classification. Progress in Physical Geography26, 173–205.

Ehlers M, KlonusS, Astrand P.J. Rosso. P.; (2010). MMS image fusion for pan sharpening in Remote Sensing. Int. Journal of image and data fusion, v.2, p. 151. 165, 2010. Netherlands.

Fernandes R., Butson C., Leblanc S., Latifovic R., 2003. Landsat-5 TM and Landsat-7 ETM+ based accuracy assessment of leaf area index products for Canada derived from SPOT-4 VEGETATION data. Canadian Journal of Remote Sensing 29 (2), 241–258

Gaespenu and Associates, 1996. A medium term for planning Ejisu-Juabeng Distict development (1996- 2000).

Golmehr E., (2009). Thesis: Current Land Use Mapping for Application of Remote Sensing Techniques in: Study of Northern Parts of Kolhapur, India, 2009).

Haack, B and Jampoler S.;(1995). Colour composite comparisons for agricultural purposes, Int. Jrnl of Remote Sensing, 16(9): vol 9. pp 1589-1598.

Hall J.B and Swaine M.D, 1976. Ecology Classification of closed forest canopy in Ghana. Journal of Ecology. 64: 913-951

Harding, David J., Bufton, Jack L., and Frawley, James J. ;(1994), Satellite Laser Altimetry of Terrestrial Topo: Vertical Accuracy as a Function of Surface Slope, Roughness, and Cloud Cover, IEEE Transactions on Geosciences and Remote Sensing, Vol. 32 No. 2.

Heinl, M., Walde, J., Tappeiner, G., and Tappeiner U.;(2009). Classifiers vs. input variables. The drivers in image classification for land cover mapping. International Journal of Applied Earth Observation and Geo-information, 11(6). pp. 423-430.

Holme A.McR, Burnside D.G, and Mitchell, A.A.; (1987). The development of a system for monitoring trend in Western Australia. Australian Rangeland Journal 9:14-20.

Houghton R.A., Skole D.L., Nobre C.A., Hackler J.L., Lawrence K.T., and Chowmentowski W.H. ;(2000). Annual carbon from deforestation in the Brazilian Amazon, Nature, 403, 301-304.Human ecology, vol. 31, No. 2 June 2003. http://www.jstor.org/stable/4603470

Jamshid T, Naser L and Mina F, 2013. Satellite Image methods and Landsat 5 TM bands. Scientic Paper, EMU. Dept of Computer Engineering, Famagusta, North Cyprus.

Jensen JR.; (1996). Introduction of Digital Image Processing: Perspective of Remote Sensing, Englewood Cliffs, 2nd Edition., New Jersey, Prentice-Hall.

Jin S, Sader S.;(2005). Comparison of time series tasselled cap wetness and the normalized difference moisture index in detecting forest disturbances. Remote Sensing of Environment. 94: 364-372.

Kauth, R.J. and Thomas G.S. 1976. The tasselled Cap – A Graphic Description of the spectral-Temporal Development of Agricultural Crops as Seen by LANDSAT. Proceedings of the Symposium on Machine Processing of Remotely Sensed Data, Purdue University of West Lafayette, Indiana. pp. 4B-41 to 4B-51.

Klonus S, Ehlers M.; (2007). Image fusion using the Ehlers spectral characteristics preservation algorithm. GI-Science and Remote Sensing.2007; v.44:93–116.

Laba, M., Smith S. D., and Degloria S. D.;(1997). Land cover mapping with Landsat in the lower Yuna river watershed in the Dominican Republic, Int. Journal of Remote Sensing, 18:3011-3025.

Lillesand, M. T., Kiefer, R. W., & Chipman, J. W.; (2008). Remote Sensing and Image Interpretation, (6th Ed). Hoboken, NJ: Wiley.

Lu D. and Weng Q. ;(2007).Image survey: A methods and techniques for improving classification performance. International Journal of Remote Sensing, 28(5). pp. 823870.

Mausel, P.W.J. Kamber, and J.K. Lee; (1990). MSS data use to select Optimum band for supervised classification of. Photogrammetric Engineering and Remote Sensing

Miller.A.B, BryantE.S. and Birnie RW;(1998). Land cover changes analysis in the northern forest of New England using multi temporal landsat MSS data. International Journal of Remote Sensing, 19:245-265.

Moser G., Serpico S.B., Benediktsson J.A; (2013) - Land-Cover Mapping by Markov Modelling of Spatio-contextual Information in Very-High-Resolution Remote Sensing Images. Proceedings of the IEEE, 101: 631-651. doi: http://dx.doi.org/10.1109/JPROC.2012.2211551.

Murakami T., (2004). Classification accuracy using seasonal images in forest-cover types examined by a single band or band combinations, Journal of Forest Research, 9:211215.

Musick, B., and Pelletier, R.E; (1986). Response of some Thematic Mapper band ratios to variation in soil water content, Photogrammetric Engineering and Remote Sensing, 52(10): 1661-1668.

Naga J., Yothi B., Babu G.R., Murali Krishna; (2013). Thematic Classification of MMS imagery. Int Jrnal of Electronic and computer Science Engineering online at; www.ijecse.org.2013.

Nageshwara R., and Vaidyanadhan, R;(1981), Aerial Photo-Interpretation for Land Use studies in Krishna Delta (India), Geographical Book Review of India, 3,pp.226-236.

Nelson, R.F., 1983. Forest canopy Detection of change using Landsat MSS due to insect Activity. Journal of Photogrammetric Engineering and Remote Sensing, 49 (9):1303- 1314.

Osei, E. M. Jnr and Y. X. Zhou (2004). Land Cover Change Detection in West Jilin Using ETM+ image. Journal of Geo-scientific Research in N. E. Asia, 7(1), 74-84.

Osei Kingsley, Osei EM Jnr, Adwoa Sarpong, (2011). Comparisons of land cover classification Methods. Journal of Geomatic Vol 6 N_o 1 April 2012.

Pecora W., (1972). Remote Sensing of Earth Resources: Users, Prospects, and Plans, NASA's Long-Range Earth Resources Survey Program, Thirteenth Meeting, Panel on Science and Technology, Committee on Science and Astronautics, U.S. House of Representatives, January, 25, Washington D.C. U.s. Government Printing Office, 8 p.

Perera, K. and Tsuchiya, K.;(2009). Experiment change and mapping land cover in south eastern Sri Lanka utilizing 250m resolution MODIS imageries. Advances in Space Research, 43 (9). pp. 1349- 1355.

Pohl C, Van Genderen JL (1998). Multi-sensor image fusion in remote sensing: concepts, methods, and applications. International Journal of Remote Sensing.1998; v.19:823–854.

Price, K. P., Guo X., and Stiles J. M;(2002). Optimal Landsat TM and combinations and vegetation indices for discrimination of six grassland types in eastern Kansas. Int. Journal of RS, 2002, pp.1–12.

Priyakant, Lalit and Nick. Accuracy comparison of various band combinations using seasonal land use/land cover mapping: Australia (2012). Application paper. Corresponding Author; Photogrammetric Engineering & Remote Sensing Vol. 78, No. 3, March 2012.pp. 271-280.

Ricotta et al., 1999. The influence of principal component analysis on the spatial structure of a multispectral dataset. Int J Remote Sensing. Impact Factor: 1.65). 11/1999; 20(17):3367-3376. DOI: 10.1080/014311699211381

Rouse, J. W., Haas R. H., Schell J. A., and Deering D. W; (1973). Monitoring vegetation systems in the Great Plains with ERTS, Third ERTS Symposium, NASA SP-351 I, 309-317.

Ryan Coffey, Jan, (2013); what is LULC; Michigan State University Extension. Visithttp://www.msue.msu.edu *or* http://expert.msue.msu.edu, or call 888-MSUE4MI (888-678-3464).

Sader, S. A., Bertrand M, & Wilson, E. H; (2003). Satellite change detection patterns on an industrial forest landscape. Forest Science, 49(3), 341– 353.

Satterwhite, M.B., (1984). Landsat MSS and Thematic Mapper bands and band ratios used to discriminate vegetation and soils. Proc. of 1984 Annual Conference of American Society of Photogrammetry, 2: 479-485.

Serra, P., X. and Sauri, D.;(2003). Different data from sensors used for change detection: some accuracy considerations. International Journal of Remote Sensing, 24, (16): 3311-3340.

Shalaby A., Tateishi R; (2007). Remote Sensing and GIS for Mapping and monitoring changes in LULC in the North western Coastal Zone of Egypt. Applied Geography, 27: 28-41.doi: http://dx.doi.org/0.1016/j.apgeog.2006.09.004.

Stenback, J.M., and Congalton R.G.;(1990). Thematic Mapper imagery used to examine forest understory, Photogrammetric Engineering and Remote Sensing. 56:1285-1290.

Stoney W.E,(1996). The Pecora Legacy Land Observation Satellites in the Next Century.

Paper on Landsat presented at the Pecora 13 Symposium, Sioux Falls, South Dakota, August 20-22, 1996, Landsat Program Homepage. geo.arc.nasa.govsge/ landsat/wes.html

Trotter, C. M., 1998. Characterizing the topographic effect at red wavelengths using juvenile conifer canopies. Int. Journal of Remote Sensing, 1998. Vol.19, no.11, 2215-2221.

Tso B and Mather P M, 2001. Classification Methods for Remote Sensing Data. New York, Taylor and Francis

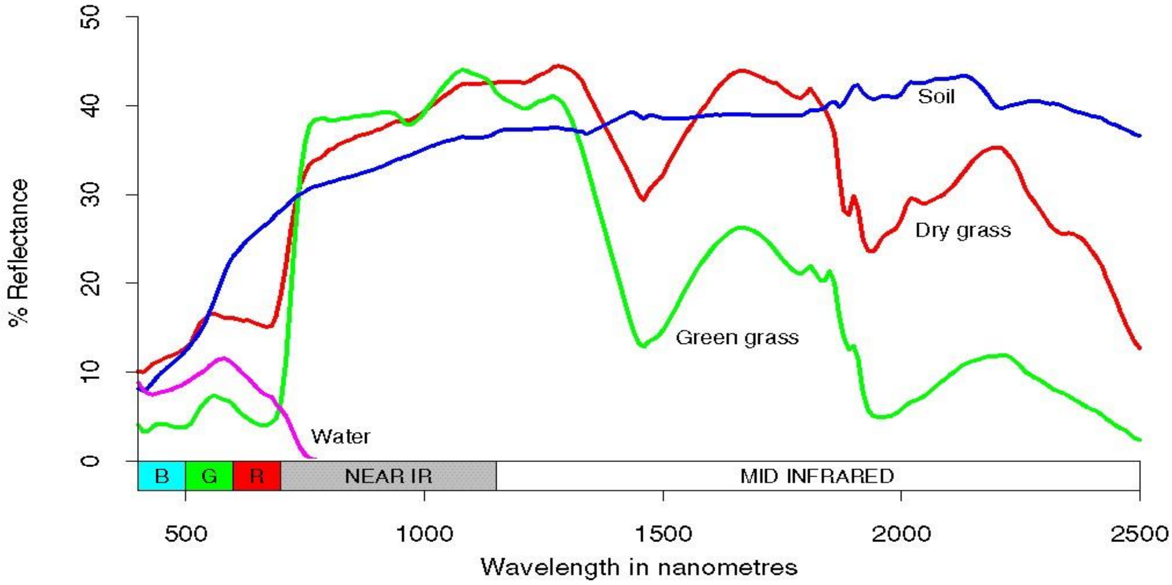
Wenbo W., Jing Y and Tingjun K.; (2008). Image fusion in remote sensing and its application in image classification, The Int Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII.

Wooten, Hugh H., and James R., 1957, Favorite uses of land agric in US from 1954. Dept of Agric, Agric research and Agric. Inf, bull, 168.

Zhang G.X., Cao Z.X., Gu Y.J.; (2005). A SV Mused with Hybrid Classifier used in Fuzzy Systems and Knowledge Discovery, Pt 1, Proceedings, Wang L., Jin Y., (Eds.) Springer-Verlag Berlin: Berlin. 3613: 1287-1296. doi:http://dx. doi.org/ 10.1007 /11539506_162

.

APPENDIX



A1: How Satellites sensors respond to the target

ERROR ACCURACY*OF B 2-4*

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	26	0	0	0	0	26	0%	100%
Agriculture	2	56	2	7	1	68	18%	82%
Settlement	1	40	24	0	2	67	64%	36%
Forest	0	0	0	78	0	78	0%	100%
Bare Land	0	1	1	2	42	46	91%	9%
Total Column	29	97	27	87	45	285		
EO	10%	27%	11%	10%	10%			
PA	90%	73%	89%	90%	90%			
O. Accuracy =93%								
Kappa= 0.9								

B1: B 2-4

ERROR ACCURACYOF B 3-5

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	34	0	0	1	0	35	3%	97%
Agriculture	18	95	2	20	0	135	30%	70%
Settlement	1	0	15	0	0	16	6%	94%
Forest	0	1	0	37	0	38	3%	97%
Bare Land	14	0	0	3	44	61	0%	100%
Total Column	67	96	17	61	44	285		
EO	49%	1%	12%	38%	100%			
PA	51%	99%	88%	62%	0%			
O. Accuracy = 79%								
Kappa = 0.73								

B2: B3-5

KNUST

ERROR ACCURACYOF TC1-3

	Water	Agriculture	Settlement	Forest	Bare Land	**Total**	**EC**	**UA**
Water	50	25	0	0	0	75	33%	67%
Agriculture	19	15	9	12	1	56	73%	27%
Settlement	0	0	39	1	4	44	11%	89%
Forest	0	0	0	74	0	74	100%	0%
Bare Land	0	5	0	0	31	36	14%	86%
Total Column	69	45	48	87	36	285		
EO	28%	67%	19%	14%	11%			
PA	72%	33%	81%	86%	89%			
O. Accuracy = 73%								
Kappa = 0.70								

B.3: TC1-3

ERROR ACCURACYOF PC1-3

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	26	2	0	0	0	28	7%	93%
Agriculture	4	131	0	0	0	135	3%	97%
Settlement	1	0	41	4	3	49	16%	84%
Forest	0	10	0	26	1	37	30%	70%
Bare Land	0	0	3	0	33	36	8%	92%
Total Column	31	143	44	30	37	285		
EO	16%	8%	7%	13%	11%			
PA	84%	92%	93%	87%	89%			
O. Accuracy= 9 0%								
Kappa= 0.86								

B.4:PC1-3

KNUST

ERROR

ACCURACY OF B3-5, 7

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	0	0	0	1	0	1	0%	100%
Agriculture	0	107	3	28	1	139	77%	73%
Settlement	0	2	14	0	5	21	30%	70%
Forest	0	0	0	78	0	78	0%	100%
Bare Land	0	0	0	3	41	44	7%	83%
Total Column	0	109	17	110	47	283		
O. Accuracy =85%								
Kappa= 0.78								

B5: B3-5, 7

ERROR ACCURACY OF B 2-5

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	3	1	0	1	0	5	40%	60%
Agriculture	2	102	2	27	0	133	23%	77%
Settlement	0	1	20	1	3	25	20%	80%
Forest	0	0	0	70	0	70	100%	0%
Bare Land	0	0	0	2	49	51	4%	96%
Total Column	5	104	22	101	52	284		
EO	40%	4%	9%	31%	6%			
PA	68%	96%	91%	69%	94%			
O. Accuracy =86%								
Kappa= 0.80								

B.6: B2-5

ERROR ACCURACY OF B 1, 3-5

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	1	0	0	0	0	1	100%	0%
Agriculture	1	106	2	28	0	137	23%	77%
Settlement	0	2	17	1	5	25	32%	68%
Forest	3	1	0	76	0	80	5%	95%
Bare Land	0	0	0	3	39	42	7%	93%
Total Column	5	109	19	108	44	285		
EO	80%	16%	11%	39%	11%			
PA	20%	84%	89%	61%	89%			
O. Accuracy =84%								
Kappa= 0.76								

B.7: B1, 3-5

ERROR ACCURACY OF

B1-4

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	17	9	0	0	0	26	35%	65%
Agriculture	0	102	1	2	3	108	5%	95%
Settlement	0	3	15	0	4	22	32%	68%
Forest	8	0	0	74	0	82	100%	0%
Bare Land	0	1	0	2	44	47	6%	94%
Total Column	25	115	16	78	51	285		
EO	32%	11%	6%	5%	14%			
PA	68%	89%	94%	95%	86%			
O. Accuracy=88%								
Kappa= 0.87								

B8: B1-4

ERROR ACCURACY OF *B1-5*

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	0	0	0	1	0	1	100%	0%
Agriculture	0	124	1	27	1	153	19%	81%
Settlement	0	2	16	0	4	22	27%	73%
Forest	0	0	0	61	0	61	100%	0%
Bare Land	2	0	0	3	43	48	10%	90%
Total Column	2	126	17	92	48	285		
EO	100%	2%	6%	33%	10%			
PA	0%	98%	94%	67%	90%			
O. Accuracy =86%								
Kappa= 0.78								

B9: B1-5

ERROR ACCURACY OF
ERROR ACCURACY OF *B1-4, 7*

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	0	0	0	1	0	1	100%	0%
Agriculture	0	92	2	28	3	125	26%	74%
Settlement	0	2	18	0	4	24	25%	75%
Forest	0	0	0	87	0	87	100%	0%
Bare Land	2	1	0	2	43	48	10%	90%
Total Column	2	95	20	118	50	285		
EO	100%	3%	10%	27%	14%			
PA	0%	97%	90%	73%	86%			
O. Accuracy =84%								
Kappa= 0.77								

B10: B1-4, 7

B *3-5, TC1*

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	22	0	0	0	0	22	100%	0%
Agriculture	5	85	5	17	4	116	27%	73%
Settlement	0	2	23		3	28	18%	82%
Forest	1	0	0	71		72	1%	99%
Bare Land	0	1	0	2	44	47	6%	94%
Total Column	28	88	28	90	51	285		
EO	21%	3%	18%	21%	14%			
PA	79%	97%	82%	79%	86%			
Overall = 86%								
Kappa= 0.82								

B11: B 3-5, TC1

ERROR ACCURACY OF *B4-5, 7, PC1*

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	20	0	0	1	0	21	4%	96%
Agriculture	6	3	6	28	0	43	93%	7%
Settlement	0	0	45	0	5	50	10%	90%
Forest	0	0	0	126	1	127	1%	99%
Bare Land	0	0	0	3	41	44	7%	93%
Total Column	26	3	51	158	47	285		
EO	23%	0%	12%	20%	15%			
PA	77%	100%	88%	80%	85%			

ERROR ACCURACY OF

O. Accuracy =82%	
Kappa= 0.74	

B12: B4-5, 7, PC1

ERROR ACCURACY OF *B 4-5, PC1, NDVI*

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	40	0	0	0	0	40	100%	0%
Agriculture	6	71	3	13	3	96	27%	73%
Settlement	0	1	24	0	0	25	4%	92%
Forest	0	0	0	45	0	45	0%	100%
Bare Land	1	1	10	2	65	79	18%	82%
Total Column	47	73	37	60	68	284		
EO	85%	3%	35%	25%	12%			
PA	15%	97%	65%	75%	88%			
O. Accuracy= 86%								
Kappa= 0.82								

B13:B 4-5, PC1, NDVI

B4-5, PC1, TC2

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	6	2	0	0	0	8	25%	75%
Agriculture	0	51	1	13	4	69	27%	73%
Settlement	0	11	25	1	4	41	40%	60%
Forest	1	0	1	75	0	77	3%	97%
Bare Land	0	4	0	0	86	90	5%	95%
Total Column	7	68	27	89	94	285		
EO	15%	35%	8%	16%	9%			
PA	85%	65%	92%	84%	91%			
O. Accuracy=85%								
Kappa= 0.8								

B14: B 4-5, PC1, TC1

ERROR ACCURACY OF BC (1-5, 7)

	Water	Agriculture	Settlement	Forest	Bare Land	Total	EC	UA
Water	11	5	0	0	0	16	30%	70%
Agriculture	4	84	0	18	1	107	21%	79%
Settlement	0	1	29	1	3	34	15%	85%
Forest	0	0	0	87	0	87	100%	0%
Bare Land	2	0	0	3	36	41	12%	88%

ERROR ACCURACY OF

Total Column	17	90	29	109	40	285
EO	35%	7%	0%	20%	10	
PA	65%	93%	100%	80%	90%	
O. Accuracy =87%						
Kappa= 0.82						

B15: B1-5, 7