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The Role of Rapid Response Technique (Landsat 4 – 5 TM) in Vegetation Change Detection. Case Study: Delta and Edo states of the Niger Delta Area of Nigeria

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Abstract: *This paper investigates the use of Rapid Reponse (Remote Sensing) Techniques and GIS in mapping out vegetation land cover of Delta and Edo in Niger Delta region of Nigeria between 1990 and 1999.This was done to determine the extent of changes which had occurred between that period of time. Landsat 4-5 of December 1990 and December 1999 were used.Layer stacking of 1, 2, 3, 4, 5 and 7 were performed. Pre-processing was performed to remove the hazy nature. The imageries were assigned using Signature Editor. Supervised classification was performed using maximum likelihood operation to derive the vegetation land cover map.*
NDVI was used to detect areas of vegetation decline, and Density Slice technique was applied to detect vegetation change densities which were categorized on the bases of very-very high to very-very low density. The study showed that the vegetation cover of the area has significant change between 1990 -1999.
Key Words; *Vegetation,Change detection,Remote Sensing,GIS*

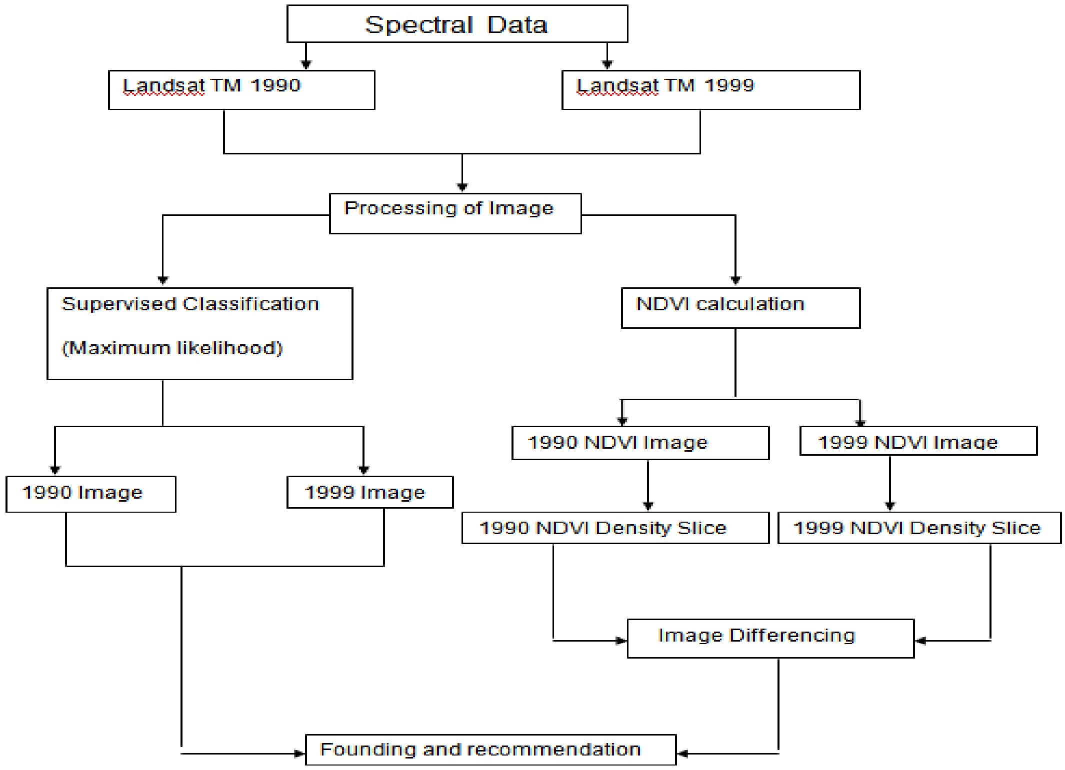
I. Introduction

The study of vegetation land cover is usually propelled by the desire to know, the nature, in quantitative terms, extent and rate of their changes as well as the objective baseline information on which to assess and plan for future environmental policy. Vegetation land cover pattern of an area is the consequences of socio-economic and natural influences and the nature of usage by man in time and space. Forests are declining as a result of severe agricultural and demographic pressure. For this reason, information on vegetation land cover and the likelihood of their maximum use is very important for the selection, planning and implementation method in order to maximize the increasing desire for human needs and welfare. The information will also help in monitoring the pattern of usage in vegetation and land which resulted from changing demands of population growth. Vegetation land cover changes are always caused by anthropogenic pressure such as increase in population and natural incidence related to inter-annual or decadal differences in climate and intrinsic vegetation dynamics (Boakye et al., 2008).

Several areas of the World are currently passing through rapid and wide ranging changes in land use and vegetation, especially the current rates of the World vegetation land cover changes are mostly affected in the Africa forest and woodland where slash and burn agriculture is greatly practice (Duaze, 2004). Forest is exploited for different reasons such as logging for timber, slash and burning for farming, and pasture development (Boakye et al., 2008). The spatial extent of vegetation land cover is necessary at all times in order to equip scientist and policy maker in times of decision making.

According to (Boake, 2008) land use and land cover change in Niger Delta region is increasing in resent time and generating widespread environmental problems that required to be mapped. This is a serious matter that should be look into because change in the pattern of vegetation land cover will also affect change in socio-economic conditions, and monitoring such distortions is very useful for organized actions at the national and international standard. For instance, mapping of reserved forests always and woodland with the use of remote sensing is necessary for faster provision of information to government so as to enlighten them on the level of encroachment. Vegetation is very important for human well being, because it is the foundations for living in the World through the ecological functions which regulates the water and climate resources (Lahaussois, 1997). If vegetation is seriously degraded, then the ability to work as the regulators of the ecological system will also lost, resulting to food reduction, erosion hazards, soil fertility reduction, enhancing the loss of animal life, and also resulting to danger in sustainability of goods and service. Increasing deforestation will not only influence land degradation of the natural resource base but will also affect the degradation of biodiversity, if forests are adequately managed in a sustainable manner they will enhance several benefits to human, to the national economies and to the environment by providing timber, fuelwood, oxygen, protection of soil, water resources and habitat conservation (Lahaussois, 1997). But any refusal to carry out adequate sustainability of forest management scheme and exercise will amount to major negative effects such as climate change, landscape destruction, biodiversity loss, floods, pollution and acid rains (Lahaussois, 1997).

METHODOLOGY



II. Materials and data sources

Satellite data

To conduct detection of changes in a vegetation land cover, a multitemporal Satellite data Landsat 4-5 TM (Thematic Mapper) of December 1990 and December 1999 Imagery was used. The multispectral data was downloaded from USGS Global Visualization Viewer (http://glovis.usgs.gov/). In the Landsat 4 – 5 TM data a resolution of 1000m (derive from the resolution menu in USGS glovis visualization viewer) was used, and the scene information ID is LT41890561989344xxx02. The characteristics of the data are shown in the table 3.1:

Table: 3.1. Showing the characteristics Landsat 4 – 5 TM

Year	Satellite	Sensor	Max. Cloud	Latitude	Longitude	Path	Row
1990	Landsat 4-5	4 – 5 TM	30%	5.80	6.20	189	56
1999	Landsat 4-5	4 – 5 TM	30%	5.80	6.20	189	56

Spatial data

The shape file used in depicting the map of the study area is a map library data product, which was downloaded from http://www.maplibrary.org/stacks/Africa/Nigeria/index.php.

Software

All image processing was performed using ERDAS Imagine version 9.3 software in this project. ArcGIS software 9.3 was also used to create a thematic map .

Microsoft's Access and ESRI's ArcGIS 9.3 were used to process the transition error matrix table. The Spatial Analyst in ArcGIS 9.3 was used in finding the data classes combinations, the data were later imported to Microsoft Access to create a cross tabulation query which organized the data into a matrix.

In NDVI density slice, the Spatial Analyst tool in ArcGIS was also used to categorise the images into different vegetation densities through the reclassification process.
Microsoft Excel office 2007 was used in conducting all the statistical functions such as percentage and values, and also for plotting of graphs and histograms for analysis and interpretations.

III. Methods of Data Analysis

The methods used in the data analysis of this study are as follows:

- Supervised Classification (Maximum Likelihood)
- Normalized Difference Vegetation Index (NDVI)
- Calculating and comparing the Area in hectares of the resultant vegetation land cover for each study year.
- Image Differencing.
- Comparing the transition error matrix of 1990 and 1999.

Supervised Classification (Maximum Likelihood)

The technique used in the vegetation land cover classification is the Maximum Likelihood supervised classification. This is the most used supervised classification and it relies on the principle that the training data statistics in each band are normally distributed. Supervised classification starts with defining the areas that will be used as training sites for the various vegetation land cover, and the selected training sites are labeled pixel by pixel (Omo-Irabor and Oduyenu, 2006).
The training areas were classified based on 7 different vegetation and land cover classes namely: Built Up area, Industrial area, Light Mangrove forest, Heavy Mangrove forest, Water, Mix Deciduous forest, and Agricultural area.

Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is an image transformation that depended on the variance between the near-infrared and red wavelengths (e.g. Landsat TM bands 4 and 3, respectively).
The equation for NDVI = (NIR — R) / (NIR +R)
The result of spectral reflectance peak in the near-infrared range is seen in healthy vegetation, Normalized Difference Vegetation Index (NDVI) is an important technique to assess and detect vegetation vigour and health, and to calculating the biomass.

Calculating and comparing the Area in hectares of the resultant vegetation land cover for each study year.

Between 1990 and 1999 the calculation and comparison of the vegetation land cover statistics helped in identification of the extent and percentage of change. This was done through creating a table indicating the area in hectares and the percentage change for a given year (1990 and 1999) measured against each vegetation land cover class.
The percentage change used in determining the extent of change was calculated by dividing observed change by the sum of change multiplied by 100.

$$\text{Percentage change} = \frac{\text{Observed change} * 100}{\text{Sum of change}}$$

Image Differencing

Image differencing which is a change detection technique was used to determine the changes between 1990 – 1999 images. Image differencing is the process that involves the subtraction of digital pixel value of an image from one date from the corresponding pixel values for a different date (Digirolamo, 2006). The 1990 image was subtracted from the 1999 image this was achieved by applying the operators' tool.
Image Differencing = year 2 – year 1,
Where year 2 => 1999, and year 1 => 1990.
The Image Differencing method is favourable because of its simplicity of computation, accuracy, and ease of interpretation (Hayes & Sader, 2001).

The Transition Error Matrix

The transition error matrix was used to compare the likelihood of change of pixel that might change from one class to another class from 1990 to 1999.

Satellite Data Pre-processing

Pre-processing is the rectification procedures for the geometry and radiometry of raw satellite data and the presence of noise (Gayer 2008). Various methods of correction have to be processed before images could be used for data analysis. Geometric distortions occur as a result of the earth's curved surface, the satellites movement and oblique viewing angles of the sensors. The purpose is to align all image elements into their appropriate spatial position and, if need be, also be put into certain map projection such as Universal Mercator Projection (UTM). Noise reduction is used to correct undesirable disturbance that came from malfunctions of detectors or failures in the chain of analogue and digital signal processing.

Haze reduction in Radiometric Enhancement was applied to the Landsat 4-5 TM 1990 – 1999 to correct the effects of bluish (haze) in imagery. The images projections are in Universal Transverse Mercator (UTM) and the WGS-84 datum. The raw Landsat 4-5 TM of 1990 – 1999 images were converted from Tag Image file format (Tiff) to image (.img) format with the use Erdas Image 9.3 to enable the compatibility of other Erdas Imagine files. The landsat 4-5 TM were subset after the layers were stacked from multitemporal TM bands of 1, 2, 3, 4, 5, and 7 to depicted the areas that were used for classification and analysis. The band combinations used were band 4, 3, 2 the false colour.

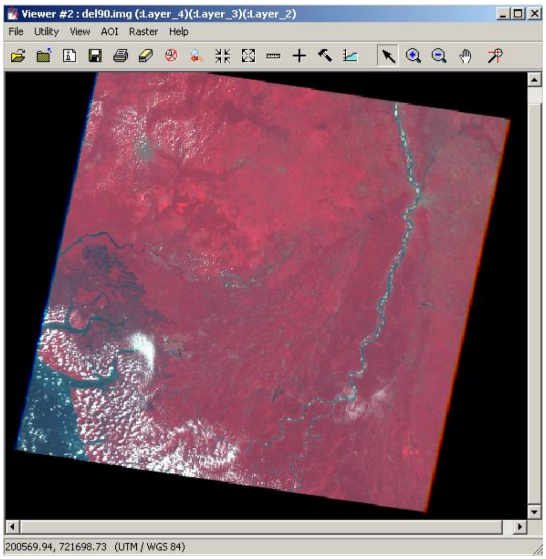


Figure 4.1: showing Landsat 4-5 TM 1990

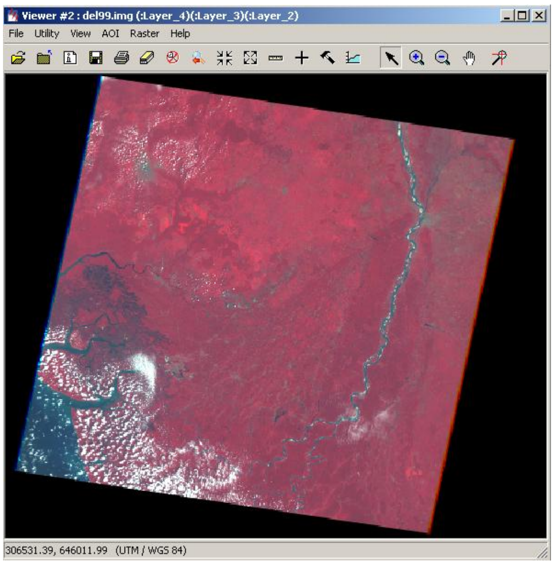


Figure 4.2: showing Landsat 4-5 TM 1999

Landsat 4-5 TM 1990 – 1999 after applying haze reduction

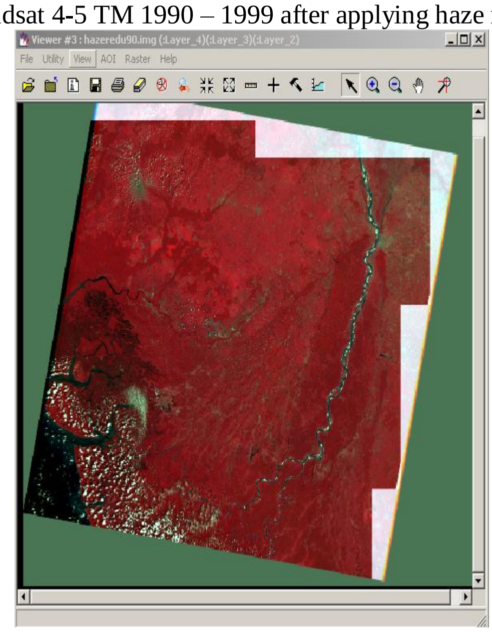


Figure 4.3: showing Landsat 4-5 1990

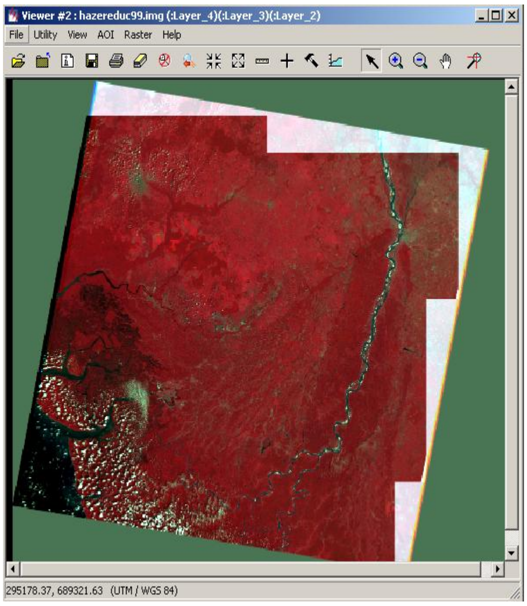


Figure 4.4: showing Landsat 4-5 TM 1999

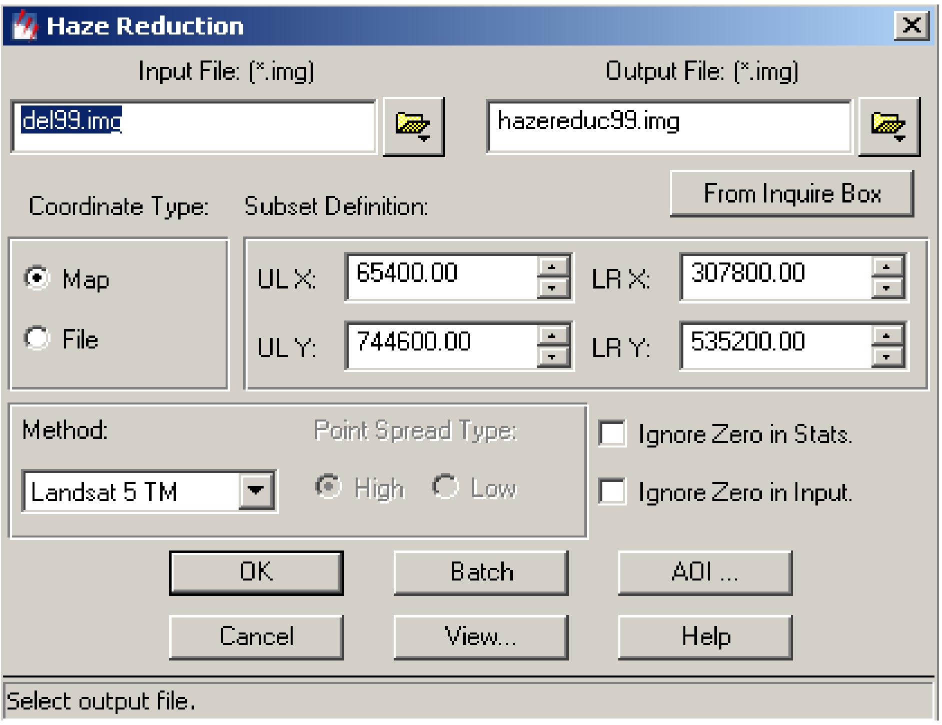


Figure 4.5: Haze reduction diologbox

Landsat 4-5 after appliing subsetting to remove the rough edges and ready for analysis

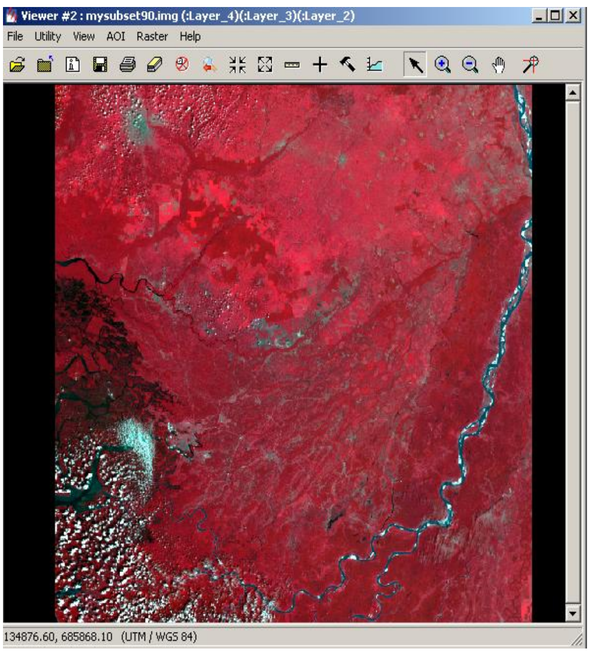


Figure: 4.6 Landsat 4-5 TM 1990 subset

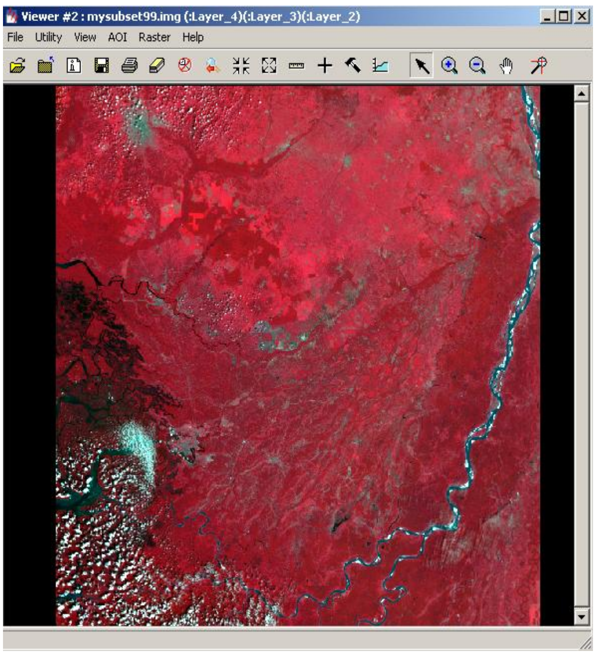


Figure: 4.7 1999 Landsat 4-5 TM subset

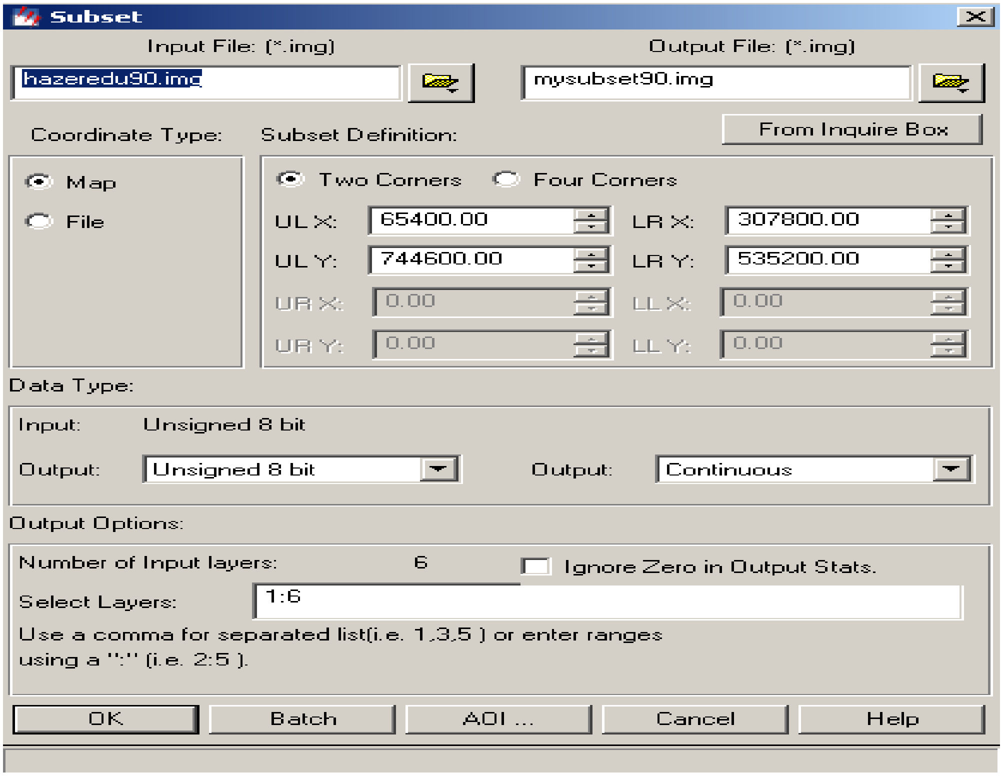


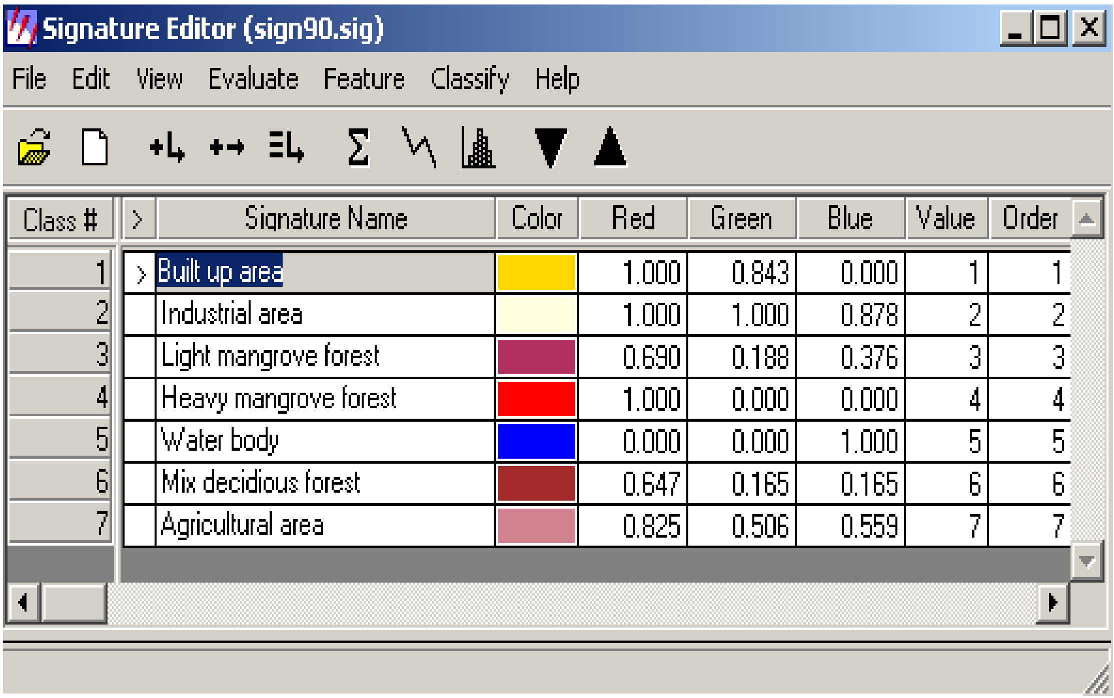
Figure: 4.8 Subset diologbox

IV. Classification

The most frequently used vegetation land cover change detection methods are classification comparisons of the land cover statistics, image overlay, change vector analysis, principal component analysis, image rationing and normalized difference vegetation index (Boakye et al. 2008, and Duadze 2004)

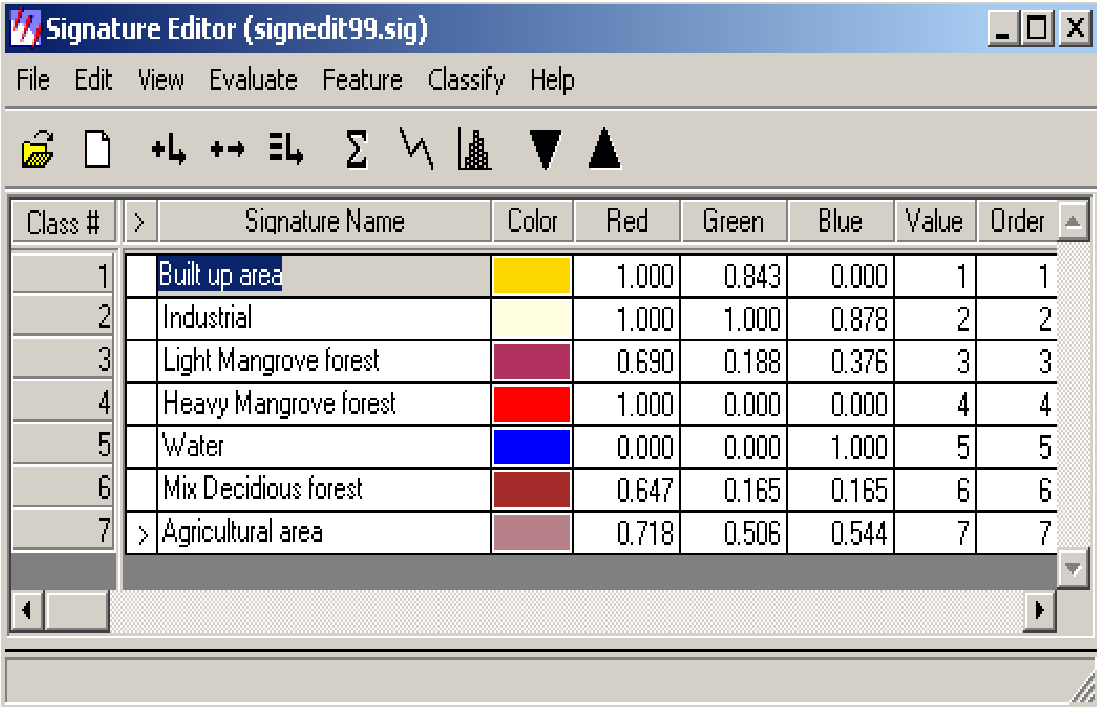
The Supervised Maximum Likelihood classification technique was used for change detection in each of the Landsat 4-5 TM data set to have the classification results by finding out the quantitative changes in the areas of the different vegetation land cover classes. It is the most obvious procedure of change detection that requires comparison of the classification maps that are produced independently; the statistics of a class in a given band are usually distributed and calculates the likelihood of a specific class pixel. According to (Sangavongse 1995), that the Maximum Likelihood Classification rule requires the operator to have the knowledge of the study area to enable efficient chosen of the representative training sets. The training sets of the 1990 – 1999 Landsat 4 – 5 TM represent a range of vegetation and land cover in the study area which are: built up area, industrial area, Light mangrove forest, heavy mangrove forest, water body, mix deciduous forest, and agricultural area. These training sets were used to generate the statistics that were input to the classification function, and also the author has prior knowledge of the study area. Each of the land cover classes area statistic was obtained through the classifications of the images of each date (1990 and 1999) separately, by using the Erdas Imagine software functions. The areas covered at a given land cover type for the different times were compared. Then the nature of changes either positive or negative in each land cover type 1990 and 1999 were observed. The maximum likelihood classification incorporated the pixel values (Digital Numbers) from multitemporal TM bands of 1, 2, 3, 4, 5, and 7 from each scene which relied on the signatures generated for each land cover class.

This is the procedure that always provides the most accurate results among the other techniques, but the problem is that it is time consuming and expensive to implement (Curran 1985).



Class #	>	Signature Name	Color	Red	Green	Blue	Value	Order
1	>	Built up area		1.000	0.843	0.000	1	1
2		Industrial area		1.000	1.000	0.878	2	2
3		Light mangrove forest		0.690	0.188	0.376	3	3
4		Heavy mangrove forest		1.000	0.000	0.000	4	4
5		Water body		0.000	0.000	1.000	5	5
6		Mix decidious forest		0.647	0.165	0.165	6	6
7		Agricultural area		0.825	0.506	0.559	7	7

Figure 4.9: 1990 Signature Editor showing the different vegetation land cover.



Class #	>	Signature Name	Color	Red	Green	Blue	Value	Order
1		Built up area		1.000	0.843	0.000	1	1
2		Industrial		1.000	1.000	0.878	2	2
3		Light Mangrove forest		0.690	0.188	0.376	3	3
4		Heavy Mangrove forest		1.000	0.000	0.000	4	4
5		Water		0.000	0.000	1.000	5	5
6		Mix Decidious forest		0.647	0.165	0.165	6	6
7	>	Agricultural area		0.718	0.506	0.544	7	7

Figure 4.10: 1999 Signature Editor showing different vegetation land cover.

1990 image classification

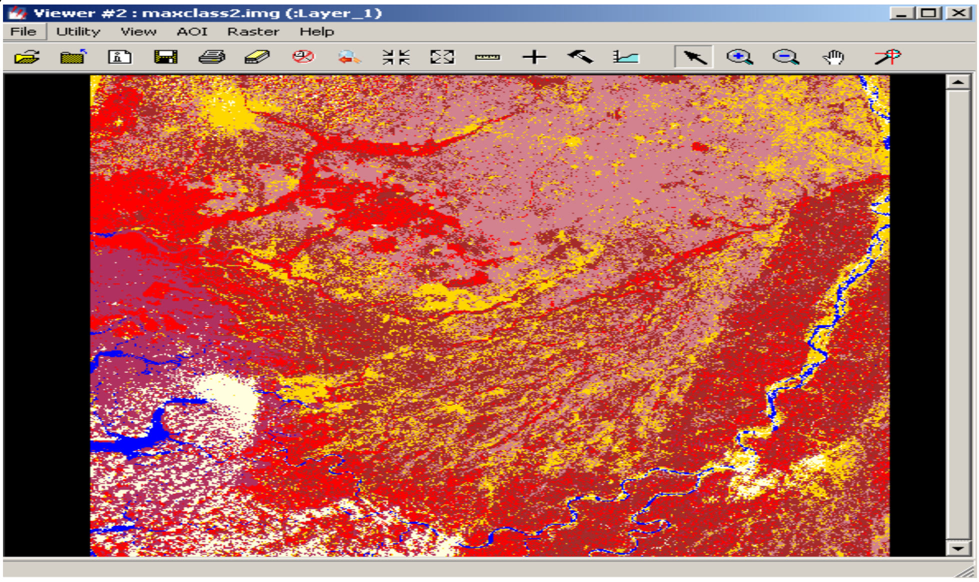


Figure: 4.11 showing different vegetation and land cover types of 1990

1999 image classification

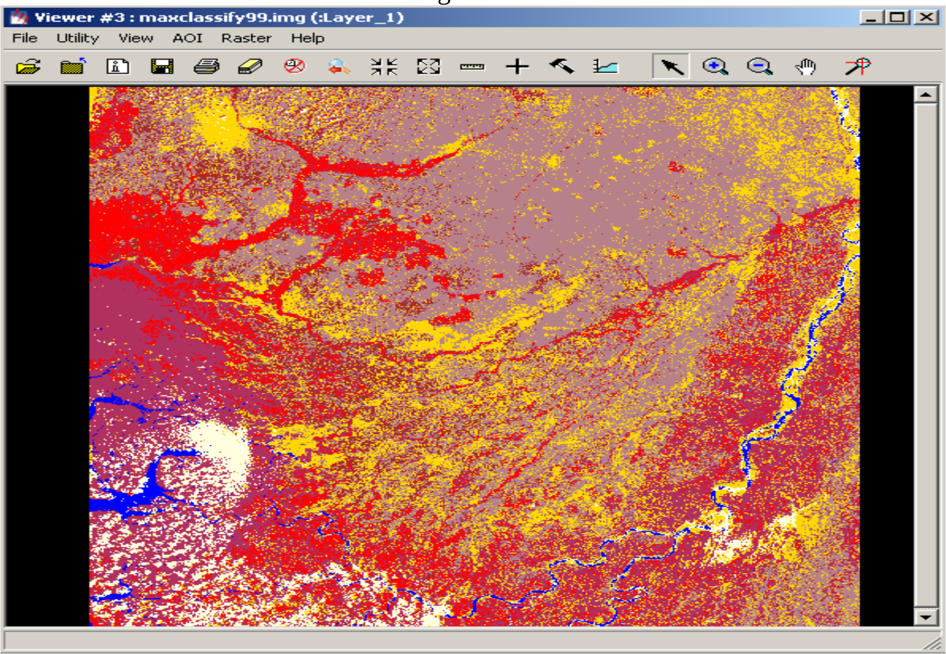


Figure: 4.12 showing different vegetation and land cover types of 1999

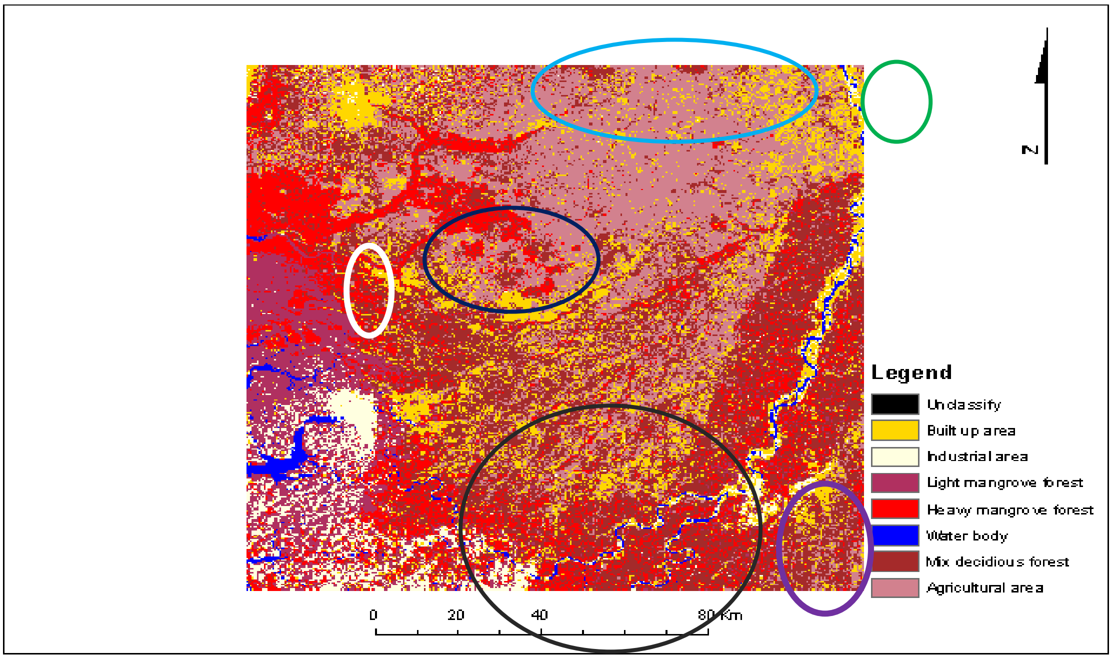


Figure: 4.13 classified image of 1990 indicating areas of difference

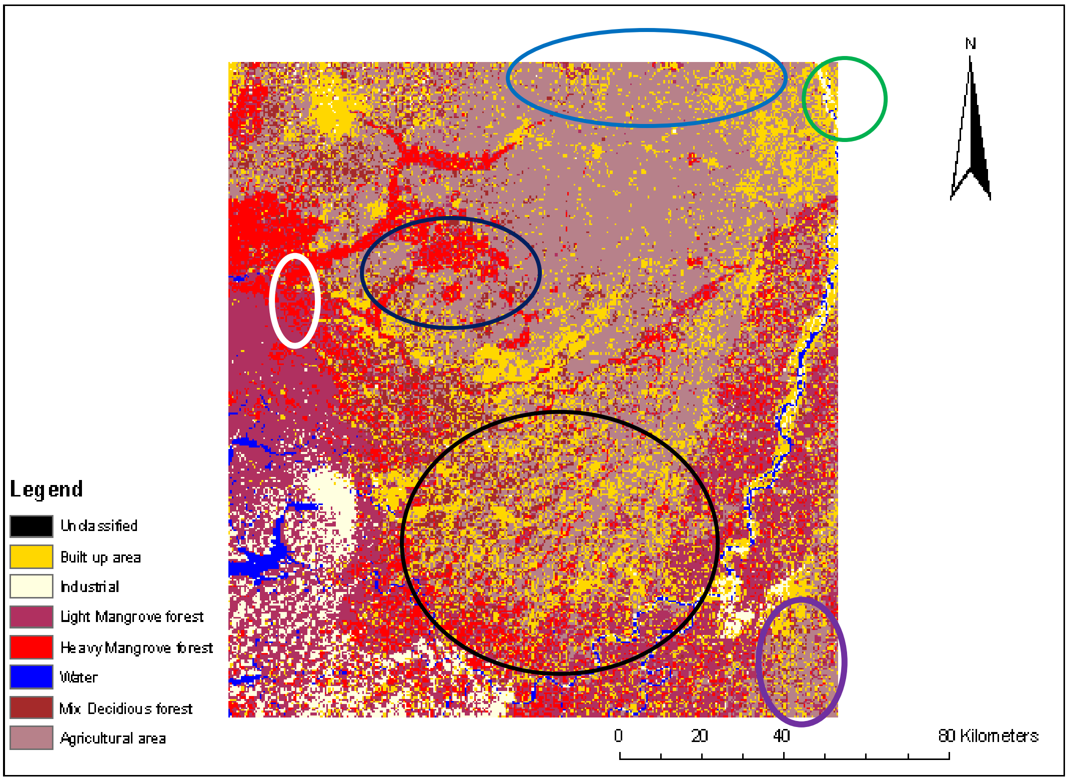


Figure: 4.14 classified image of 1999 indicating areas of difference

V. Ressults

From the classified Landsat imageries of 1990 and 1999, the table 4.1 showed the changes in the spatial extent of land covers after classification and table 4.2 showed the rate at which the changes where decreased and increased. Four classes namely Industrial area, heavy mangrove forest, water body, and mix deciduous recorded significant decrease. While three classes which are built up, light mangrove forest and agricultural area in the other hand recorded significant increase during the study period. Industrial area depicted a decrease of -3427 hectares (-0.12%), heavy mangrove forest -102493 hectares (-4.46%), water body -520.4 hectares (-0.01%) and mix deciduous forest with a significant decrease of -530789 hectares (-23.33%). The three other classes namely built up showed an increase of 119991 hectares (5.38%), light mangrove forest with a significant increase of 294693 hectares (13.09%), and agricultural area 210616 hectares (9.46%).

This depletion of heavy mangrove forest and mix deciduous forest would amount to reduction of natural cooling effects of evapotranspiration and shading of vegetation within the study area. Likewise the decrease in industrial area would result to loss of economic activities in the study area. Agricultural area recorded an increase, this imply that there would be much food for the people, but if adequate measures are not taken by appropriate authorities to control the rate of heavy mangrove forest and mix deciduous forest depletion.

The depletion rate will affect agricultural area and the subsequent result will amount to food reduction.

Figure 4.22 and figure 4.24 show the NDVI images of 1990 and 1999, bright areas indicate vegetative areas, and tan areas depicted non vegetative areas. The areas with more bright colours indicate areas with more vegetation or with more vegetative reflectance. From the NDVI images of 1990 and 1999 in the above mention figures, the lower contrast of the bright colour areas is not quite distinguishable for visual analysis. Hence, histogram equalizer contrast was applied to adjust the images contrast so as to have a uniform distribution of intensities as shown in figure 4.22 and 4.24. From 4.22 and figure 4.26 images it would be easier to distinguish areas with various degrees of vegetative reflectance from the highest to the lowest.

Figure 4.23 and 4.25 show the thematic maps of NDVI vegetation reflectance which range from -1 – 0.667 in 1990, and -0.586 – 0.667 in 1999. The higher the green colour the higher the vegetation reflectance vase versa. The values between -1 – -0.1652 indicate areas of no vegetation, while 0.166 – 0.667 indicate areas with vegetation, based on the degree of vegetation reflectance.

Change of NDVI density during the period of 1990 – 1999 recorded increase from very high to very-very low density exception of the very-very high density. The rate of decrease of the NDVI density is shown to be higher than the total number of increase from very-high to very-very low density. The very-very high density showed a decrease of 7.56%, while total increase from very high to very-very low was 7.55%. The low, very low, and very-very low density are areas of no vegetation such as built up, industrial area, and water body. The reduction of the very-very high density class which necessitated the increase of the other classes from very high to very-very low is caused by human activities such as logging, clearing of land for farming, and increase in population growth influencing the need to having new structures. The systematic surveys of the Niger Delta's flora and fauna were carried out during the 1990s, the survey reviewed that the forest and animal populations are under a great danger, the delta's second most timber species abura (Hallea ledermannii) once common in the area has been removed by extensive logging (Were 2001). Also pressure on the Niger Delta's remaining forest is due to increase in population and increase in infrastructure (Were 2001). The overcutting of the Niger Delta forest by an increasing human population poses serious threats to the forest (Tognetti 2001).

In the image difference figure 4.29 and 4.30, it shows that there is a significant difference of vegetation reduction most especially in the north-west area of the image and the area marked in yellow circle in the thematic map. From the thematic map of NDVI change image showed in figure 4.30, one would observe that the digital number (DN) value is -7 meaning a decrease in vegetation in 1999.

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