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# Assessment of Human African Trypanosomiasis Foci using Change Detection Algorithms

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**Abstract**

Environ-climatic change influences the occurrence and propagation of Human African Trypanosomiasis (HAT), focusing on two foci; Delta State and Jigawa State Nigeria where HAT has been reported. Geospatial and temporal based ground truthing exercise carried out to harvest HAT vector in Jigawa state did not yield any results; this indicates that the disease might have been phased out in the state. In the same vein, resurging of HAT disease in the Delta State has been reported of recent. Thus, a change detection analysis was conducted in a geographic information systems (GIS) environment, to investigate the foci landscape. Using normalised difference vegetation index (NDVI), normalised difference water index (NDWI) and tasseled cap transformation (TCT), changes with a lag time of two decades was assessed for the two foci. The analysis suggested that the landscape has changed considerably over the years that show Delta State as the potential active HAT foci as explained from the regression analysis of 0.9868 (99%) ahead of Jigawa state 0.0000 (0%) that can be regarded as non-active foci. However, on-going programs, such as afforestation, forestation, irrigation farming and water reservoir projects may result in re-introduction of favourable landscape, thus, re-invasion of the area by the HAT vector. Therefore strategies that will maintain the present HAT-free status of the non-active foci, without adverse effect on the environment should be a government priority. To effectively reduce or control HAT propagation, integrated prevention schemes should be developed and executed. The two HAT foci are of great economic importance; Delta State landscape is rich in hydrocarbons while Jigawa State is known for its extensive grazing and arable landscape.

**Keywords:** Trypanosomiasis, Afforestation, Foci, HAT, Landscape, Environ-climatic, Spatial, Irrigation

## 1.0 Introduction

Human African Trypanosomiasis (HAT) is a lethal disease resurging in both old and new foci. In Nigeria, there is a shift of the disease from the north to the southern part (Akiode & Oduyemi 2014). An adult female tsetse fly (HAT vector) can survive up to three months, reproducing up to ten times in that period and the vector - *Glosina palpalis* can fly up to 4km (Jordan 1986) within a given zone depending on suitable conditions such as relative humidity, land surface temperature, etc. HAT has restricted the cultural and economic development of the people in Sub-Saharan regions and prevented the introduction of stock farming in endemic areas, which resulted in much of tropical Africa not being converted into grassland for cattle (Steverding 2008). From an environmental angle, the presence of the HAT vector in the tropics has prevented vast portion of the rain-forest being depleted; thereby maintaining the natural ecosystem, and increased cattle number may result in less vegetal cover and eventually increase runoff and erosion as well as reduction in biodiversity (Symeonakis, Robinson & Drake 2007).

Physical landscape is very important to HAT propagation (Akiode & Oduyemi 2014), thus the need to assess the spatio-temporal changes in the HAT endemic foci. It has been reported that HAT is resurging in some foci in Nigeria, e.g. Delta State, where a recent HAT vector survey confirmed presence of *G. palpalis* (Dede and Mamman 2011), however, the disease seemed to have been phased out in Jigawa state due to the absence of the HAT vector, as a survey exercise carried out to harvest HAT vector in the area did not yield any results. NDVI, NDWI and TCT, derived from remotely sensed images, were used to assess the disparities/changes in the study areas landscape. This assessment is expected to aid policy makers to, strategize and execute environmental sustainable programs, towards efficient management of vulnerable and at risk of HAT areas.

 

*1.1 The Study Areas*

This study focused on two HAT foci in Nigeria; the Ethiope-east/ Ukwuani local government areas (LGAs) of Delta State and Dutse/Birnin-Kudu LGAs, Jigawa State (Figure 1). The Ethiope-east/ Ukwuani LGAs (between latitudes $5^{O}30$'N and longitude $6^{O}00$'E) were chosen because past studies (Osue et al. 2008, Akiode & Oduyemi 2014) confirmed evidence of HAT cases in the area and there has been evidence of trypanosomiasis in Jigawa State (between latitude: $11.00^{O}$N -$13.00^{O}$N; longitude: $8.00^{O}$E-$10.15^{O}$E) as far back as the 1970s. The two foci are in different ecological zones (Figure1). Delta State experiences the prevalence of tropical maritime air mass almost all year round, with little seasonal change in wind directions (Olaniran 1986). The climate is characterised by heavy rain falls, humidity that rarely dips below 60% and $26^{O}$C annual mean temperature (Leroux 2001). The major occupations include farming and fishing (Niger Delta Regional Development Master-plan 2006; Niger Delta Environmental Survey 1997). Jigawa State landscape is mainly plains covered by wooded savannah and shrub vegetation. The major livelihoods of the people are farming and animal rearing. The climate is characterised by relative humidity ranging from 80% to 23%, mean annual temperature of about 25°C and total annual rainfall ranges from 600mm in the north to 1000mm in the southern parts of the state Akiode, Oduyemi & Badaru (2014). There is an on-going afforestation and forestation program in the area. Also, irrigation farming and water reservoir projects are on-going in the area. These programs may influence HAT propagation.

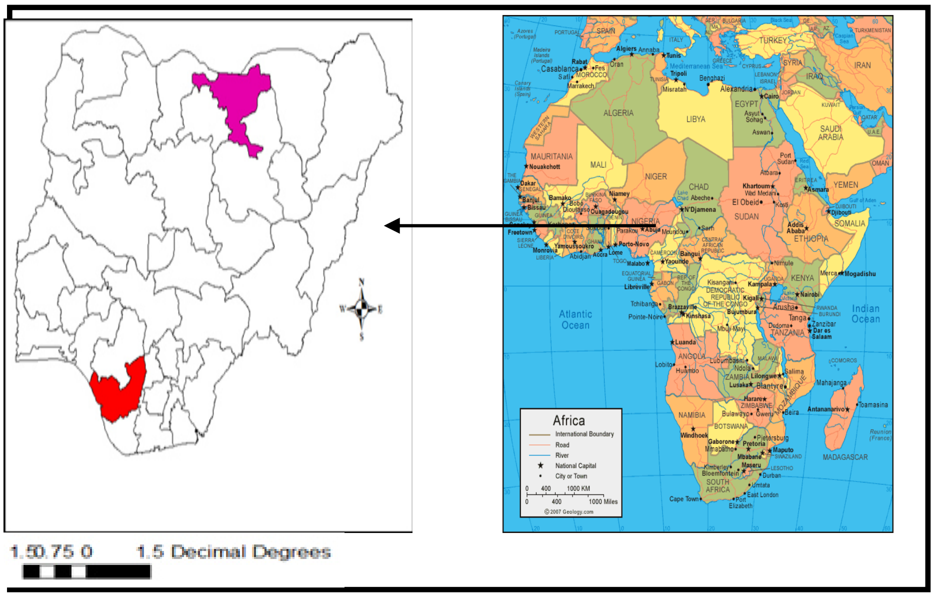


**Figure 1: Administrative map of Nigeria showing Jigawa state in pink and Delta state in red.**

 

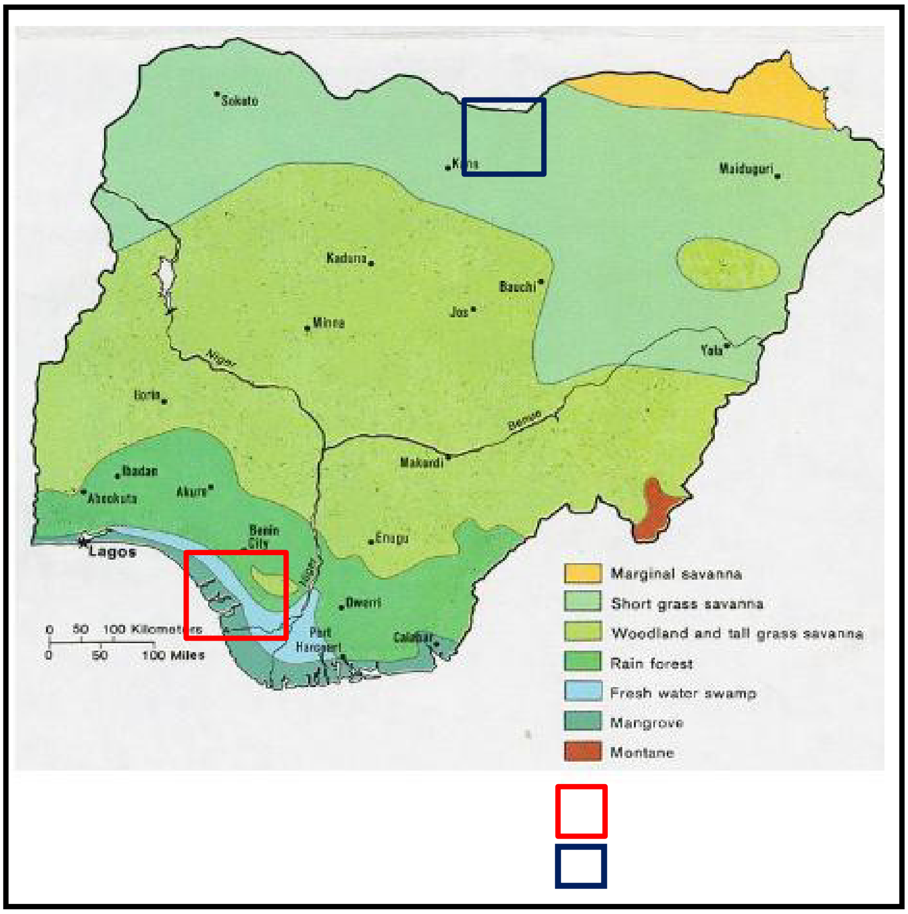


Figure 2: Ecological map of Nigeria, highlighting the study areas.

### *1.2 Change Detection*

Change detection using remote sensing (RS) methods involves the analysis of spatio-temporal as well as spectral characteristics of RS dataset so as to derive information about changes or no changes of a given landscape (Akiode, Oduyemi & Badaru 2014). Observing difference in the landscape characteristics could be based on different time (Singh 1989) or seasonal scale using two or more images epochs. The theory of change detection is that the spectral value of cells from datasets covering the same landscape but of different epochs will differ if the physical properties have altered overtime (Akiode, Oduyemi & Badaru 2014; Jensen 1986). There are varying change detection methods, for example, image algebraic method which includes tasseled cap transformation (Akiode, Oduyemi & Badaru 2014) and multi-date composite methods (Morisette 1997). The algebraic technique can be integrated with the multidate method because of its simplicity; a number of studies (Akiode, Oduyemi & Badaru 2014, Skakun, Wulder & Franklin 2003; Collins & Woodcock 1996; Cohen & Spies 1992) have employed and attested to its value. In order to explain the reason for the southward shift/disparities in the HAT spatial distribution in Nigeria, this study applies the algebraic technique and the multidate technique to simply detect the presence or absence of change (Currit 2005) in two HAT foci overtime and in space. Assessment of changes in the HAT foci is essential towards a better understanding of HAT propagation and effective plan to manage HAT and the disease ecology.

### *1.3 Vegetation Indices*

Vegetation Indices (VI) are intended to draw attention to particular vegetation property (ies) of the vegetal cover. Among the various VIs, NDVI is the most popular (Huete et al., 2008). NDVI is a measure of the amount of green vegetation (Tucker, 1979). It was first developed by Rouse et al., (1973) and has since been applied on a wider scale (Tucker et al., 1985). NDVI has been identified as one of the major determinants for HAT vector spatial distribution/survival (Green & Hay, 2002). The index is derived from the red and near-infrared waveband of satellite image, for example, Landsat images, using Equation 1 (Tucker, 1979):

$$NDVI = (near\text{-}infrared - red) / (near\text{-}infrared + red) \quad (1)$$

The NDVI index can range from -1 to +1, but before deriving the index from a given vegetal surface via a remotely sensed image, it is necessary to correct the image for atmospheric effects.

### *1.4 Normalised Difference Water Index*

NDWI (process of determining soil moisture content) that can be derived from RS data using the thermal emissions from soils in the microwave range (Guha & Lakshmi, 2002) has turned out to be reliable indicators for surface water in the local geographic setting (Dambach et al., 2012). Changes in vegetation growth patterns according to DeAlwis et al. (2007) must not be misinterpreted as related solely with soil moisture when comparing moisture content and vegetation indices because vegetation growth is dependent upon a number of environmental factors, soil moisture inclusive. As recommended by Ji, Zhang & Wylie, (2009), the NDWI derived from Landsat images can be defined as Equation 2

$$NIR - MIR / NIR + MIR \text{ i.e. } (band4 - band5 / band\ 4 + band\ 5) \quad (2)$$

### *1.5 Tasseled Cap Transformation*

Specific surface materials, for example, tasseled cap information (TCT) can be derive from satellite images using certain coefficients. TCT comprises of brightness, greenness and wetness components. The brightness component is a measure of overall reflectance of all the RS image bands. It is associated with bare or partially covered soil, man-made, and natural features. The greenness component is associated with biomass present, while the wetness component that is orthogonal to the brightness and greenness components is associated with soil moisture, water, and other moist features. TC has wider application among which is change detection (Han et al. 2007). The concepts and applications of tasseled cap are described in Crist & Kauth 1986; Kauth &Thomas 1976.

To interpret the result of the tasseled cap transformation, the z-score of the RS images pixel values can be calculated as Equation 3.

$$Z\text{-}score = [Pixel\ Value] - \mu / \sigma \quad (3)$$

Where: $\mu$ = mean of the image pixel, $\sigma$ = standard deviation of the image pixel

## 2.0 Material and Methods

### *2.1 Data Source and Management*

The data applied were projected to the World Geodetic System (WGS) 84 datum Universal Transverse Mercator (UTM) Zone 32N and stored in a personal geodatabase. The existing administrative map (base maps) of the Delta and Jigawa States, Nigeria were obtained from Mapmakerdata as shapefiles, imported into ArcMap to subset the study areas from the RS images used in this study. Ground control points (GCPs) data that served as test samples for land cover classification and accuracy assessment were obtained from different land cover types. The GCPs were obtained using Trimble Global Positioning System (GPS). The RS images used in this s tudy are shown in Table 1 while the environmental datasets derived mainly from Landsat images are presented in Table 2.

**Table 1: Remotely sensed data used in this study**

| Data Type | Acquisition Date | Path/Row | Bands used | Spatial Resolution (m) | Source |
|---|---|---|---|---|---|
| **Landsat1 MSS** | 29/12/1972 | 202/52 | 4, 5, 6 | 82 | **LP DAAC (USGSEROS)** |
| **Landsat4 TM** | 21/12/1987 | 189/056 | 1, 2, 3, 4, 5 & 7 | 30 | **LP DAAC (USGSEROS)** |
| **Landsat5 TM** | 17/11/1986 | 188/52 | 1, 2, 3, 4, 5 & 7 | 30 | **LP DAAC (USGSEROS)** |
| **Landsat7 ETM+** | 30/12/2002 | 189/56 | 1, 2, 3, 4, 5 ,6 & 7 | 30 | **LP DAAC (USGSEROS)** |
| **Landsat7 ETM+** | 9/02/2003 | 188/52 | 1, 2, 3, 4, 5, 6 & 7 | 30 | **LP DAAC (USGSEROS)** |
| **Landsat7 ETM** | 21/01/2011 | 189/52 | 2, 3, 4, 5, & 7 | 30 | **LP DAAC (USGSEROS)** |
| **Landsat7 ETM** | **17/01/2012** | **188/52** | **2,3,4,5,6, & 7** | **30** | **LP DAAC (USGSEROS)** |

**Table 2.2: Environmental data and sources**

| Data | Source |
|---|---|
| **NDVI**<br>**NDWI**<br>**Land cover types** | **RS image**<br>**RS image**<br>**RS image** |

*2.2 Method*

The methods used are satellite image processing, land cover classification and change detection analysis. The Landsat 7 ETM+ images used were geometrically and radiometrically corrected to lessen or remove embedded sensor errors. The corrected images were then transformed to derive the environmental criteria (Table 2) required for this study.

*2.2.1 Geometric and Radiometric Correction*

All the images used for Delta State were registered to the 2002 Landsat ETM+ image, while the images used for Jigawa State were registered to the 2003 Landsat ETM+ image. The registration outcome root mean square error for both Delta State and Jigawa State were between 0.00003 and 0.05 pixels; (i.e. less than 1), and thus represents good quality registration. All the images used in this study were also radiometrically corrected using image-based dark object subtraction. The images digital number (which has no unit and any physical connotation) were converted to at-satellite spectral radiance and then to top-of-atmosphere (TOA) reflectance (for consistency in images' scene-scene). The at-satellite spectral radiance data (all image bands) and TOA reflectance data (all images bands excluding thermal bands) were derived using appropriate algorithms (details in Akiode & Oduyemi 2014).

*2.2.2 Satellite Image Transformation*

To derive the environmental datasets required for this study, the derived at-satellite spectral radiance and TOA spectral reflectance data were transformed using appropriate algorithms. The image transformations included:

- NDVI obtained for the study areas using the near-infrared (band 4) and red (band 3) components of the 1987 Landsat TM 4, 2002/2011 Landsat ETM+ and 1986 Landsat TM5, 2003/2012 Landsat ETM+ images, for study and control area respectively. NDVI was also retrieved from bands 5 and 6 of the 1972 Landsat MSS1 for the control area. The NDVI (Appendix 1; Figures 3 & 4) was retrieved from the images using Equation 1.
- NDWI for the study areas were derived from the spectral reflectance values of all the images used for NDVI, except the 1972 MSS1 image. The NDWI (Appendix 1; Figures 5 & 6) was extracted from the images using Equation 2.
- Tasselled cap transformation based on image spectral reflectance for the Landsat 7 ETM+ and Landsat 4 and 5 TM images, which covers the period between 1987 and 2002, and 1986 to 2003 for Delta State and Jigawa State, respectively was performed using brightness coefficients (Appendix 2). The transformation was carried out using the radiometrically corrected (spectral reflectance) bands 1, 2,3,4,5, and 7 of the images, to extract brightness components (Appendix 1; Figures 7 & 8).

*2.2.3 Land Cover Classification Systems*

Supervised land cover classification adapted from Anderson et al. (1976), were used to identify seven and five land cover classes, representing the main distinct classes in the Ethiope-east/ Ukwuani (Akiode & Oduyemi 2014) and Dutse/Birnin-Kudu LGAs, respectively. The land cover classes included; water bodies, shrub, mangrove, less dense forest, dense forest, cultivated area and built-up areas for the Ethiope-east/ Ukwuani LGAs (Akiode & Oduyemi 2014) and water bodies, wetland/flood plain, light vegetation/shrub, savannah grass and cultivated area for the Dutse/Birnin-Kudu LGAs. The classification result was evaluated using error matrix.

*2.2.4 Assessment of HAT Foci using Change Detection*

Due to the presence and none harvesting of tsetse fly in Delta State and Jigawa State respectively, it became necessary to investigate the disparities. This was necessary, as there was previous evidence of HAT in Jigawa State. To investigate the landscape characteristics of both foci, change detection assessment was used. The algebraic method was used to classify each image used separately, while the multi-date composite technique was used to assess and detect the presence or absence of change. The difference epoch images used to access change in the two foci are: 1987 Landsat TM 4, 2002/2011 Landsat ETM+ for the Ethiope-east/ Ukwuani LGAs and 1972 Landsat MSS1, 1986 Landsat TM5, 2003/2012 Landsat ETM+ images for the Dutse/Birnin-Kudu LGAs. The algebraic technique includes tasseled cap transformation (TCT). The TCT involved the brightness component only; this was because of the constraints associated with the RS images epochs available for this study. For example, Landsat 7 ETM+ acquired for years 2011 and 2012 has stripes and cloud cover. In order to obtain enough evidence of the level of change in the two HAT foci, NDVI and NDWI were calculated. These indexes were very vital to HAT propagation.

*2.2.4.1 Change Detection using Brightness Tasseled Cap Transformation*

The study areas were masked from the transformed images generated in section 2.2.2, after which statistical threshold was assigned to the pixel values of the transformed images. This was done by calculating the z-score (Equation 3) of the transformed images pixel values. Based on the z-score, the brightness map for each year was grouped into four categories namely:

- Least: for areas with least brightness value
- Low: for areas with low brightness value
- Moderate: for areas that are moderately bright
- High: for areas that recorded the highest brightness value

Example of the brightness tasseled cap transformation is presented in Figure 9. The brightness categorical map was overlaid on the land cover maps of the study areas in a GIS environment using 70% transparency. This was to view the land cover class that match each brightness category.

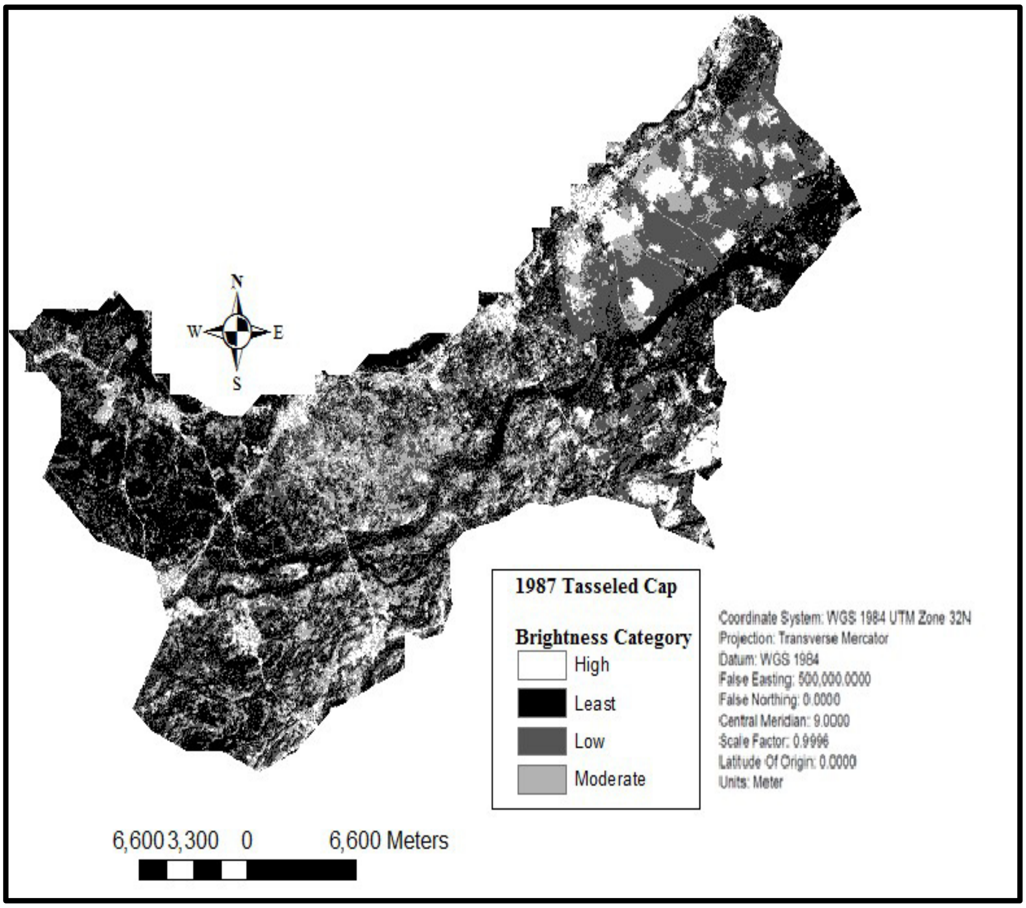


**Figure 9: 1987 Tasseled cap transformation brightness components for the Study area**

*2.2.4.2 Change detection using NDVI and NDWI*

The NDVI and the NDWI were reclassified into two classes based on their pixel values. The pixels with negative values were classified as “NDVI/NDWI Negative” and pixels with positive value were classified as “NDVI/NDWI Positive”. To establish change, the differences between the resulting calculations were found.

## 3.0 Results and Discussion

*3.1 Tasseled Cap Transformation*

The comparison of the brightness categorical map with the land cover maps revealed the land cover classes in each category as presented in Table 3, while the brightness index changes between 1987 to 2002 and 1986 to 2003 for the Ethiope-east/ Ukwuani and Dutse/Birnin-Kudu LGAs are presented in Tables 4 & 5, respectively.

 

**Table 3: Land cover classes within the tasseled cap brightness compartment**

| | Ethiope-east/ Ukwuani LGAs | Dutse/Birnin-Kudu LGAs |
|---|---|---|
| **Brightness Category** | **Land Cover Class** | **Land Cover Class** |
| Least | Water body, Mangrove | Water body, Wetland/flood plain |
| Low | Dense forest, Less-dense forest | Light vegetation/shrub |
| Moderate | Mixture of Shrub, Cultivated area, Less-dense forest | Mixture of Savannah grass, Cultivated area, Light vegetation/shrub |
| High | Built-up area, Cultivated area | Cultivated area/sand |

**Table 4: 1987 – 2002 brightness tasseled cap transformation for Ethiope-east/ Ukwuani LGAs**

| | 1987_Landsat7 ETM+ | | 2002_Landsat7 ETM+ | | Change Detected | |
|---|---|---|---|---|---|---|
| **Brightness Category** | **Area ($Km^2$)** | **Area (%)** | **Area ($Km^2$)** | **Area (%)** | **Change ($Km^2$)** | **Change (%)** |
| Least | 252.9 | 33 | 221.6 | 29 | -31.3 | -4 |
| Low | 285.4 | 37 | 319.2 | 42 | 33.8 | 5 |
| Moderate | 157 | 21 | 170.5 | 22 | 13.5 | 1 |
| High | 72 | 9 | 56 | 7 | -16 | -2 |
| **Total** | **767.3** | **100** | **767.3** | **100** | | |

**Table 5: 1986 – 2003 brightness tasseled cap transformation for Dutse/Birnin-Kudu LGAs**

| | 1986_Landsat7 ETM+ | | 2003_Landsat7 ETM+ | | Change Detected | |
|---|---|---|---|---|---|---|
| **Brightness Category** | **Area ($Km^2$)** | **Area (%)** | **Area ($Km^2$)** | **Area (%)** | **Change ($Km^2$)** | **Change (%)** |
| Least | 240.6 | 10.37 | 120.0 | 5 | -120.6 | -5.37 |
| Low | 693.6 | 29.9 | 443.04 | 19 | -250.56 | -10.9 |
| Moderate | 867.2 | 37.36 | 1016.10 | 44 | 148.9 | 6.64 |
| High | 519.2 | 22.37 | 741.41 | 32 | 222.21 | 9.63 |
| **Total** | 2320.6 | 100 | 2320.6 | 100 | | |

From Table 4, the least category result indicated that water bodies and mangrove area reduced by 4% between 1987 and 2002 Ethiope-east/ Ukwuani LGAs. This may be as a result of human activities; parts of the mangrove have been opened up for farming or cultivation and other activities. Farming is an activity associated with the HAT vector feed habitat zone (Akiode & Oduyemi 2014). It may also be that the water depth has dropped. The low category indicated a 5% increase in the forested area. The reason for this could be the transformation of parts of the dense forest. The vegetation in the transformed area has been opened up, thus, increasing the reflectance of the soil. Also, some farm produce such as cassava, which is one of the staple foods in the study area, when fully grown could be classified as shrub. The spectral reflectance of this crop could be mistaken for less-dense forest spectral reflectance. The moderate category showed a 1% increase over the 15 years. The reason for the low change in the category may be because of a mixture of different land cover classes, which may affect the soil reflectance. The high category revealed a 2% reduction in the area open to high soil reflectance within the built-up and cultivated areas. This may be due to the fact that open spaces within the built-up area are being converted to farm land, thereby reducing the reflectance value of the soil, thus, favouring active propagation of HAT within HAT vector habitat feed zone.

From Table 5, the least category indicated a 5.37% reduction in brightness of water bodies and flood plains in the Dutse/Birnin-Kudu LGAs. Reasons for this may include: increased land surface temperature, fadama or wetland farming and deforestation, which tends to open up the terrain leading to high evaporation. The low category showed a brightness reduction of 10.9% in the area covered by light vegetation (savannah forest) between 1986 and 2003. This could be because of grazing activities and deforestation as well as farming activities. The moderate and high categories revealed increases of 6.64% and 9.63% i n brightness, respectively. This increase may be attributed to socio climatic impact such as intense grazing, cultivation activities, desert encroachment as well as very high temperatures; apart from cultivation; these conditions, are not favourable for HAT propagation.

*3.2 NDVI*

The results on change detected in the Ethiope-east/ Ukwuani LGAs using NDVI are presented in Tables 6 – 8, while the result for Dutse/Birnin-Kudu LGAs (between 1972 and 2012) were previously published in Akiode, Oduyemi & Badaru (2014).

**Table 6: Percentage of NDVI change in the Ethiope-east/ Ukwuani LGAs between 1987 and 2002**

| | **NDVI_1987** | | **NDVI_2002** | | **Change Detected** | |
|---|---|---|---|---|---|---|
| **NDVI Category** | **Area (Km$^2$)** | **Area (%)** | **Area (Km$^2$)** | **Area (%)** | **Change (Km$^2$)** | **Change (%)** |
| NDVI Positive | 613.5 | 80 | 515.5 | 67 | -98 | -13 |
| NDVI Negative | 153.8 | 20 | 251.8 | 33 | 98 | 13 |
| **Total** | **767.3** | **100** | **767.3** | **100** | | |

**Table 7: Percentage of NDVI change in the Ethiope-east/ Ukwuani LGAs between 2002 and 2011**

| | **NDVI_2002** | | **NDVI_2011** | | **Change Detected** | |
|---|---|---|---|---|---|---|
| **NDVI Category** | **Area (Km$^2$)** | **Area (%)** | **Area (Km$^2$)** | **Area (%)** | **Change (Km$^2$)** | **Change (%)** |
| NDVI Positive | 515.5 | 67 | 386.2 | 52.6 | -129.3 | -14.4 |
| NDVI Negative | 251.8 | 33 | 386.2 | 47.4 | 96.2 | 14.4 |
| **Total** | **767.3** | **100** | **734.2** | **100** | | |

 

**Table 8: Percentage of NDVI change in the Ethiope-east/ Ukwuani LGAs between 1987 and 2011**

| | NDVI_1987 | | NDVI_2011 | | Change Detected | |
|---|---|---|---|---|---|---|
| **NDVI Category** | **Area ($Km^2$)** | **Area (%)** | **Area ($Km^2$)** | **Area (%)** | **Change ($Km^2$)** | **Change (%)** |
| NDVI Positive | 613.5 | 80 | 386.2 | 52.6 | -227.3 | -27.4 |
| NDVI Negative | 153.8 | 20 | 386.2 | 47.4 | 232.4 | 27.4 |
| **Total** | **767.3** | **100** | **734.2** | **100** | | |

From Tables 6 - 8 and the NDVI change detection analysis for Dutse/Birnin-Kudu LGAs (between 1972 and 2012) previously published (Akiode, Oduyemi and Badaru (2014), there was decrease in NDVI in both study areas within the study period, except for the period between 2003 and 2012 in the Dutse/Birnin-Kudu LGAs (Akiode, Oduyemi and Badaru 2014), which showed an increase. This may be as a result of afforestation programme on-going in the area. The overall result showed that between 1987 and 2011, the rate of NDVI change in the Ethiope-east/ Ukwuani LGAs was 27.4% while between 1972 and 2012 the rate of NDVI change in the Dutse/Birnin-Kudu LGAs was 43.4%. The NDVI decrease indicated an increase in bare surface in both areas, which may affect the propagation of HAT as vegetation is vital to the survival of HAT vector. The NDVI analysis revealed that a total 33.1$Km^2$ and 518.2$Km^2$ area were not included in the NDVI calculation for 2011 and 2012 for the Ethiope-east/ Ukwuani LGAs and Dutse/Birnin-Kudu LGAs, respectively. This was because of the presence of stripes in the Landsat7 ETM+ data used. The stripes return no data value, thus, the no data voids were not accommodated in the NDVI calculation. This might have affected the overall result. The higher rate of NDVI decreased in the Dutse/Birnin-Kudu LGAs despite the 11.6% increase between 2003 and 2012, is an indication of unfavourable environment for HAT vector survival.

*3.3 NDWI*

The results on change detected in the Ethiope-east/ Ukwuani LGAs using NDWI are presented in Tables 9 - 11 while the result for Dutse/Birnin-Kudu LGAs (between 1986 and 2012) were previously published in Akiode, Oduyemi and Badaru (2014).

**Table 9: Percentage of NDWI change in the Ethiope-east/ Ukwuani LGAs between 1987 and 2002**

| | NDWI_1987 | | NDWI_2002 | | Change Detected | |
|---|---|---|---|---|---|---|
| **NDWI Category** | **Area ($Km^2$)** | **Area (%)** | **Area ($Km^2$)** | **Area (%)** | **Change ($Km^2$)** | **Change (%)** |
| NDWI Positive | 101.5 | 13 | 90 | 12 | -11.5 | -1 |
| NDWI Negative | 665.8 | 87 | 677.3 | 88 | 11.5 | 1 |
| **Total** | **767.3** | **100** | **767.3** | **100** | | |

**Table 10: Percentage of NDWI change in the Ethiope-east/ Ukwuani LGAs between 2002 and 2011**

| | NDWI_2002 | | NDWI_2011 | | Change Detected | |
|---|---|---|---|---|---|---|
| **NDWI Category** | **Area ($Km^2$)** | **Area (%)** | **Area ($Km^2$)** | **Area (%)** | **Change ($Km^2$)** | **Change (%)** |
| NDWI Positive | 90 | 12 | 102.4 | 14 | 12.4 | 2 |
| NDWI Negative | 677.3 | 88 | 632.6 | 86 | -44.7 | -2 |
| **Total** | **767.3** | **100** | **735** | **100** | | |

**Table 11: Percentage of NDWI change in the Ethiope-east/ Ukwuani LGAs between 1987 and 2011**

| | NDWI_1987 | | NDWI_2011 | | Change Detected | |
|---|---|---|---|---|---|---|
| **NDWI_ Category** | **Area ($Km^2$)** | **Area (%)** | **Area ($Km^2$)** | **Area (%)** | **Change ($Km^2$)** | **Change (%)** |
| NDWI Positive | 101.5 | 13 | 102.4 | 14 | 0.9 | 1 |
| NDWI Negative | 665.8 | 87 | 632.6 | 86 | -33.2 | -1 |
| **Total** | **767.3** | **100** | **735** | **100** | | |

From Tables 9 -11 and the NDWI change detection analysis for Dutse/Birnin-Kudu LGAs (between 1986 and 2012) previously published (Akiode, Oduyemi and Badaru 2014), the margin of NDWI change in both HAT foci appeared almost the same. Between 1987 and 2011 the rate of change in the study area was 1% while that of the control area between 1986 and 2012 was 1.5%. The study area assessment covers 24 years, while the control area covers 26 years. This rate of change might be as a result of a similar factor for both areas.

*3.4 Regression Analysis*

Figure 10 shows the relationship that exists between HAT vector's habitat; breed, feed and rest zones (Akiode & Oduyemi 2014) in Delta state. The Figure 10 illustrates that a positive relationship actually exists between the variables of HAT of which the coefficients of determination $R^2$ are 0.9868 (99%). The Figure 10 also shows a high strength in the relationship and that test of significance of parameters estimate level shows that both values exceed the critical values. Therefore, the study concludes that both values are statistically significant. Whereby, Figure 11 shows that no-relationship exists in Jigawa state.

 

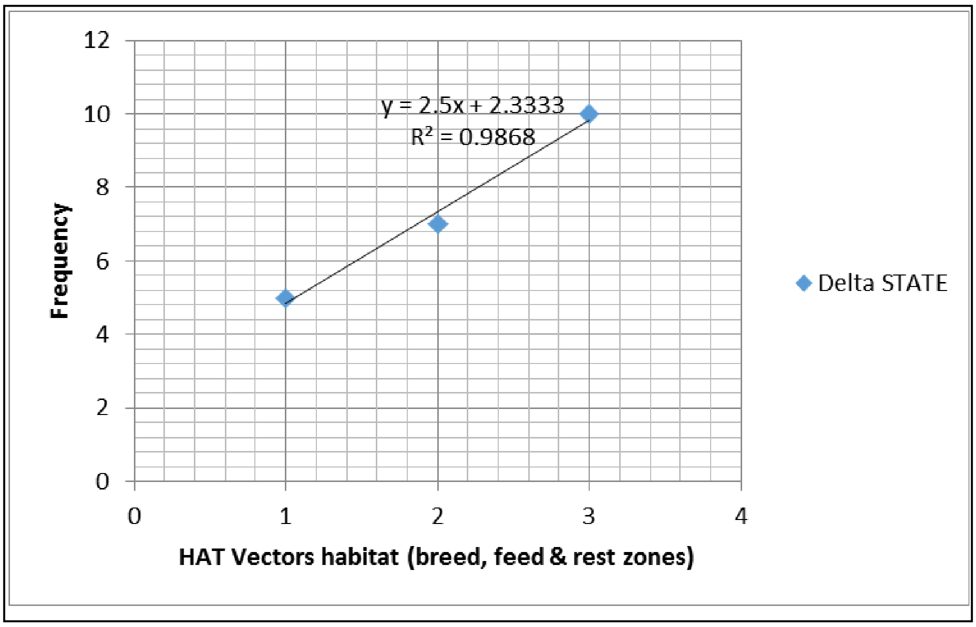


**Figure 10. The correlation of active foci and HAT**

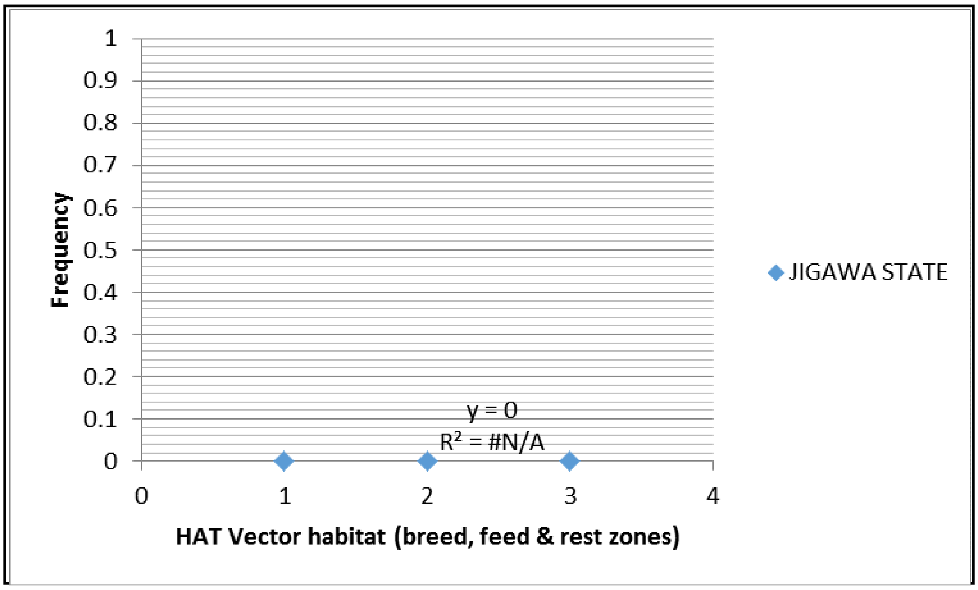


**Figure 11. The correlation of Non-active foci and HAT**

### 4.0 Conclusion

Due to presence and absence of HAT vector in Delta state and Jigawa state Nigeria, respectively. A change detection analysis was carried out to assess the changes in the two HAT foci over two decades. This was to investigate whether the disparities in the two foci was related to environ-climatic changes. From the change detection analysis, it was deduced that the landscape has changed considerably over the years. However, the level of change in Delta State is less than that of Jigawa State. Therefore, the absence of the HAT vector in Jigawa State may be because the landscape is not for now favourable. Presently, there is no evidence of the disease in the Jigawa State, but, there is an on-going afforestation and forestation program in the area. Also, irrigation farming and water reservoir projects are on-going in the area. If these programs continue, the implication for the Jigawa state may be re-introduction of favourable landscape, thus, re-invasion of the area by the HAT vector, while, the presence of HAT vector i n Delta State, probably resulted from the suitability of the regions landscape for the HAT vector. Thus, strategies that will maintain the present HAT- free status of the Jigawa state, without adverse effect on the environment should be a government priority; there is also need for constant surveillance of HAT in the Delta State. To effectively reduce or control HAT propagation, integrated prevention schemes should be developed and executed. Adequate funding and stakeholder's capacity building are required to develop and execute sustainable prevention programmes. Health policy must also be amended to support multidisciplinary approaches to disease prevention.

The major findings in this research are summarised as follows:

- The presence of HAT vector in Delta State, Nigeria, probably resulted from the suitability of the region landscape for the HAT vector.
- The absence of HAT vector in Jigawa State, Nigeria, may be because the landscape is not for now favourable.
- The considerable changes in the study areas could be attributed to environ-climatic change.
- The Delta State, Nigeria, can still be considered active HAT foci.
- The Jigawa State, Nigeria, is free of the HAT vector for now, thus can be regarded as non-active foci.

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User's Guide TASSELCP, "Generates a tasseled cap image from either an MSS or TM image" Available: http://dbwww.essc.psu.edu/lasdoc/user/tasselcp.html

**Appendix**

*Appendix 1: Figures referred to in the study*

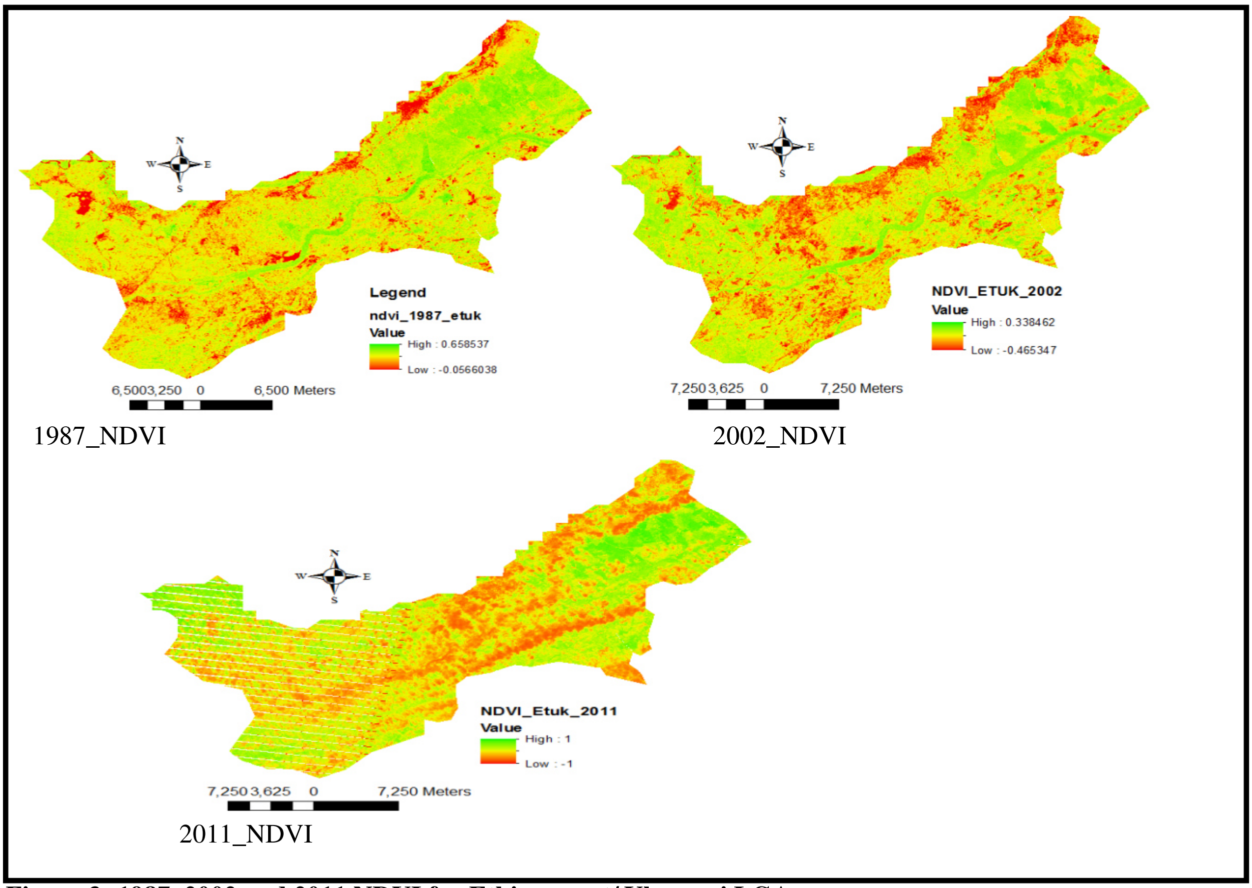


**Figure 3: 1987, 2002 and 2011 NDVI for Ethiope-east/ Ukwuani LGAs**

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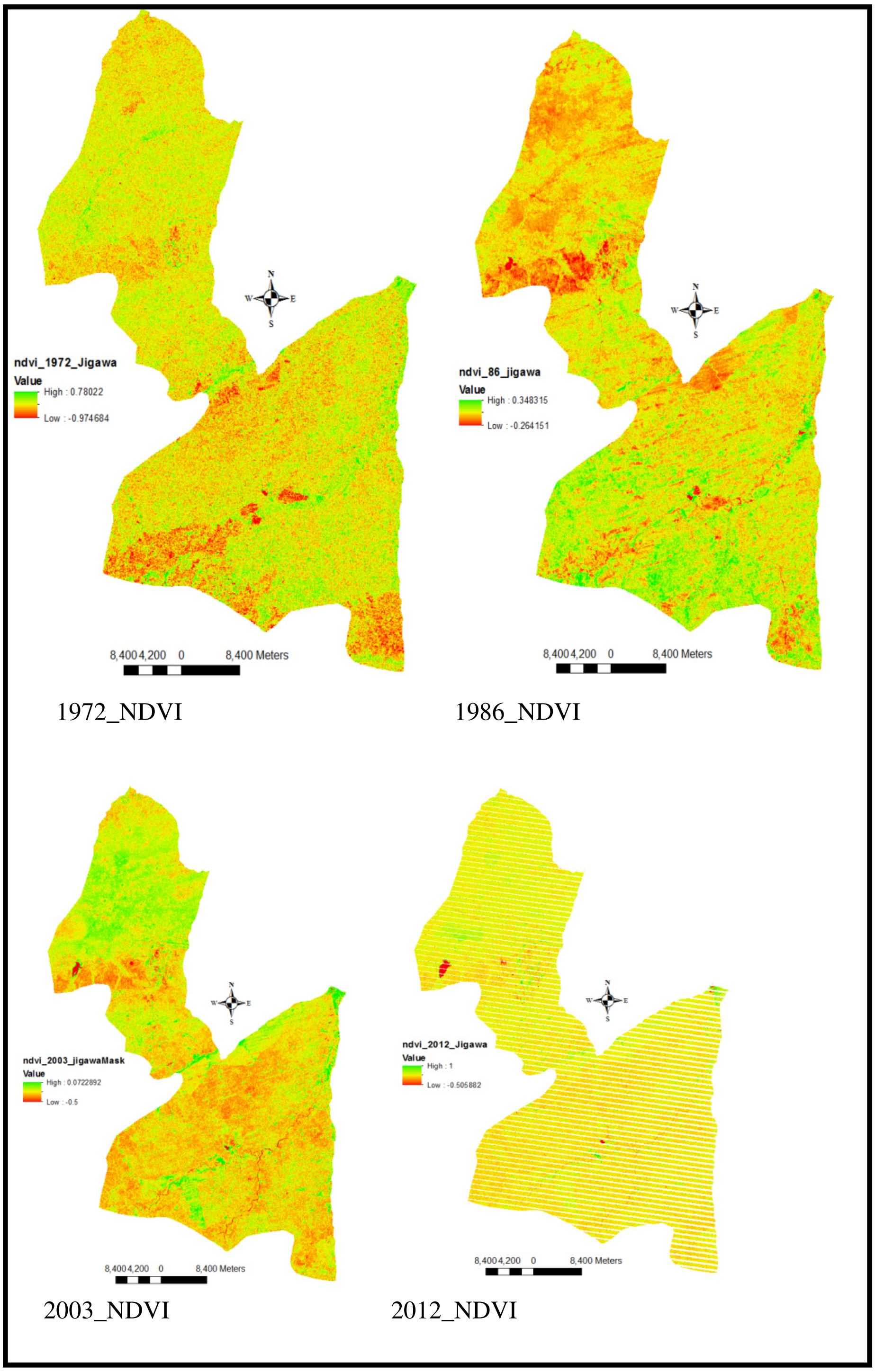


**Figure 4: 1972, 1986, 2003 and 2012 NDVI for Dutse/Birnin-Kudu LGAs**

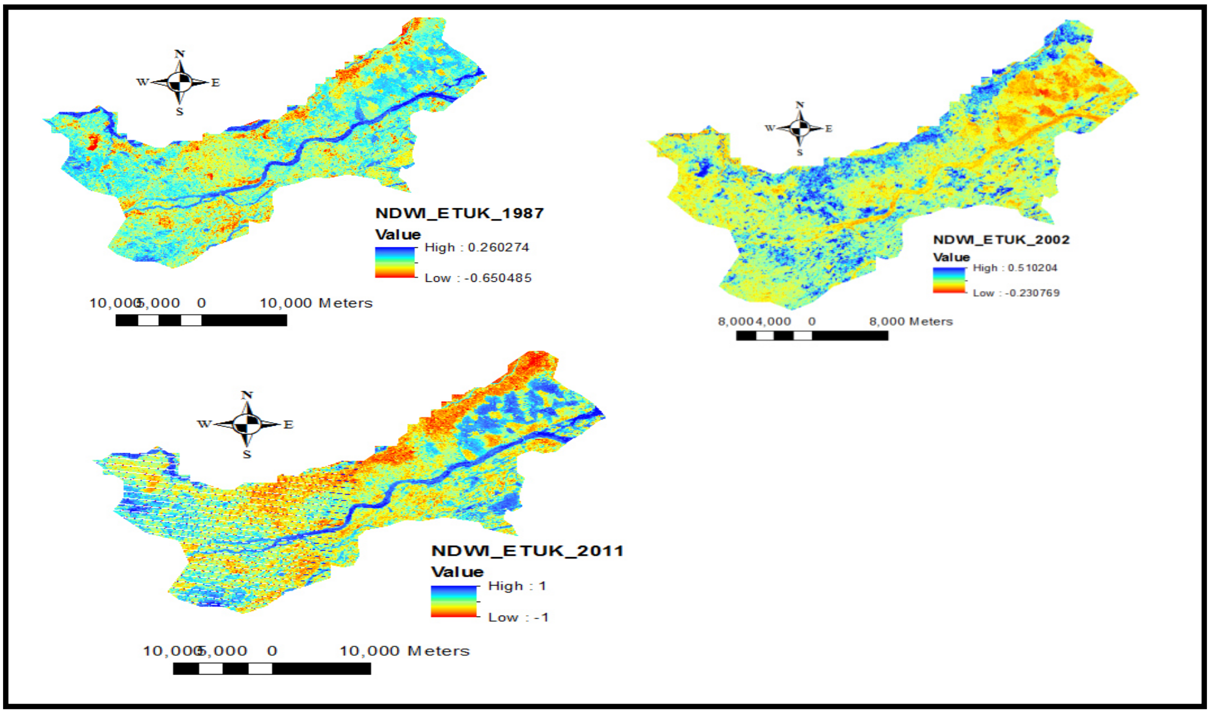


**Figure 5: 1987, 2002 and 2011 NDWI for Ethiope-east/ Ukwuani LGAs**

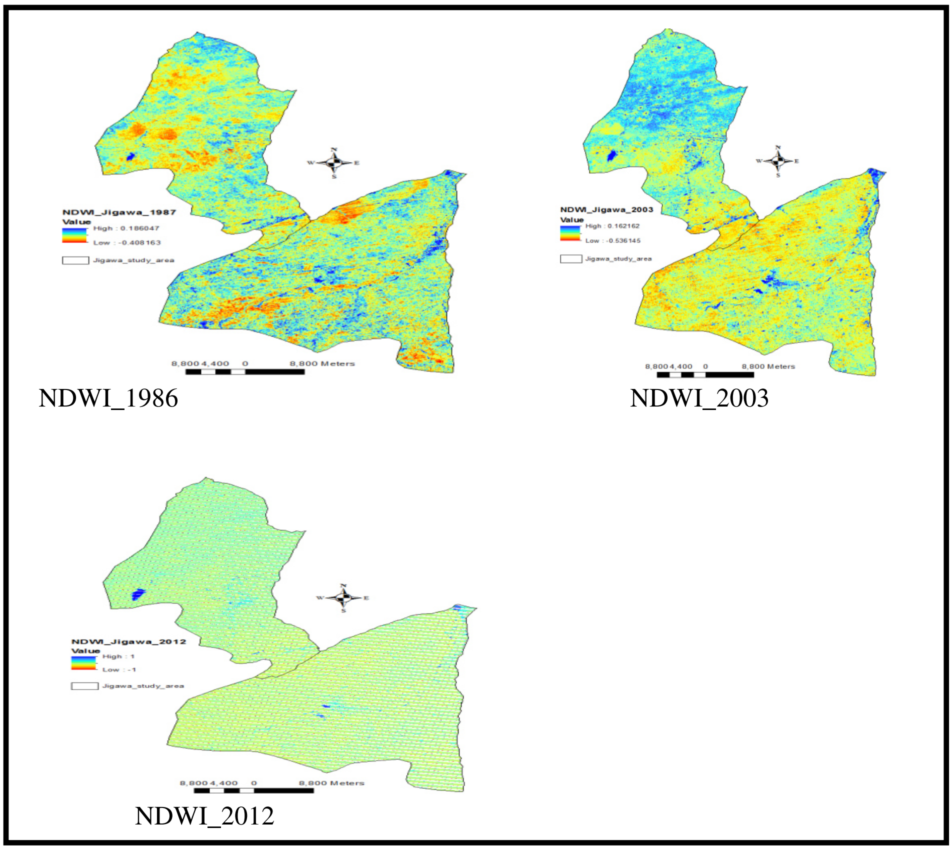


**Figure 6: 1986, 2003 and 2012 NDWI for Dutse/Birnin-Kudu LGAs**

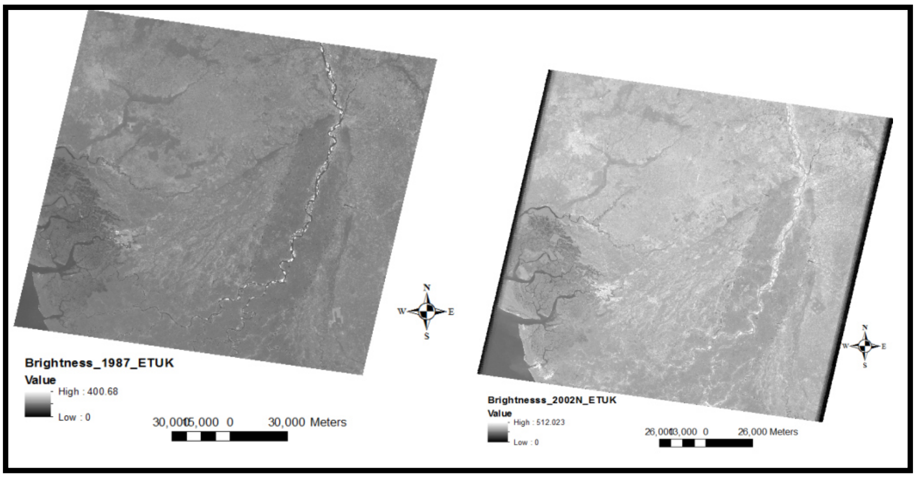


**Figure 7: Tasseled Cap Brightness Component Derived from 1987 and 2002 Landsat 4 TM and Landsat7 ETM+ Images for Delta State**

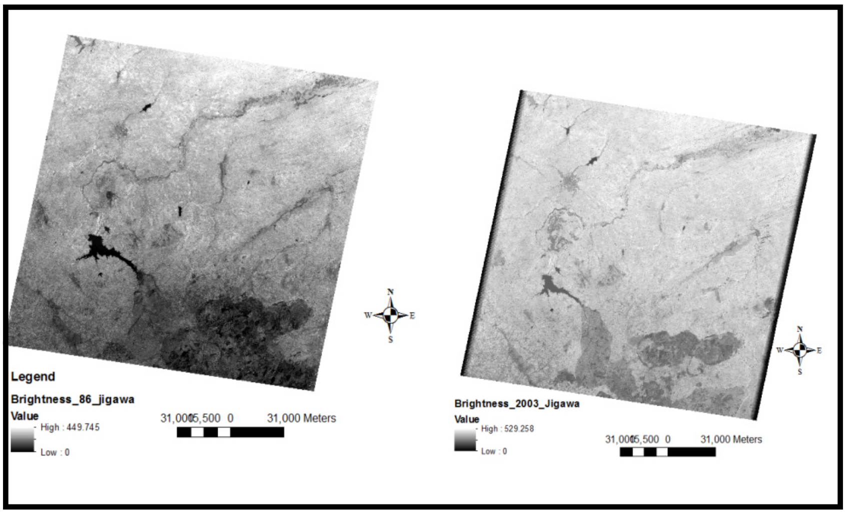


**Figure 8: Tasseled Cap Brightness Component Derived from 1986 and 2003 Landsat 5 TM and Landsat 7 ETM+ Images for Jigawa State**

*Appendix 2: Tasseled cap coefficients*

**Tasseled cap coefficients for Landsat 4 and 5 thematic mapper (TM) (User's Guide TASSELCP):**
Brightness coefficients for:

Landsat 5 TM: (0.2909, 0.2493, 0.4806, 0.5568, 0.4438, 0.1706)

Landsat 4 TM: (0.3037, 0.2793, 0.4743, 0.5585, 0.5082, 0.1863)

**Tasseled cap coefficients for Landsat 7ETM+ (Huang et al., 2002):**

Brightness coefficients: (0.3561, 0.3972, 0.3904, 0.6966, 0.2286, 0.1596)

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