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Ecological and Biodiversity Status of Okomu National Park, Edo State Nigeria (Case Study: The White Throated Guenon)

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Abstract

Conservation of biodiversity is an essential issue due to increasing climate change and anthropological factors. Various rich biodiversity zones are greatly threatened and degrading with an alarming rate therefore it's required to safeguard these zones and their habitats at regional and local levels. In order to implement significant conservation schemes, exhaustive information on the distribution of species on a temporal basis are required. Geographic information systems and remotely sensed information provide an analytical platform for linking habitat features and animal distribution in a spatial context. This project aims at feasible assessment and analysis of the ecology and biodiversity status in Okomu National park, Edo state, Nigeria using various remote sensing and GIS techniques. Through this associated environmental factor indicative of suitable habitat of the endangered fauna species were mapped within the extent of the Okomu National Park. Multi date satellite imageries (Landsat TM 1986, Landsat ETM 1999 & Landsat ETM+ 2016 of 30m spatial resolution respectively) were obtained and used for the study. The factors and individual weights were identified through multi criteria evaluation using analytical hierarchical process and expert knowledge. The resultant suitability indexed model provided a basis for the identification of potential habitat corridors. The spatial culmination of the data used is an important step towards providing information to decision makers on habitat suitability and the mapping.

Keywords: Conservation of Biodiversity; Remotely sensed information; Analytical Hierarchical Process (AHP); Multi-criteria Evaluation; Okomu National Park; Habitat Suitability Analysis

Introduction

Spatial ecology is the study of patterns and processes occurring in a geographic space or landscape that influence characteristics of plant and animal populations such as densities, distributions, and movements [1]. Remote Sensing techniques and use of GIS for mapping the endangered species can be conducted to help in understanding the environmental factors (including land, soil, climatic conditions, etc.) responsible for the extinction of species. The absence of reliable information and sound assessment methods in ecological studies can have the most profound consequences for conservation of biodiversity and for the identification of indicator species that can predict changes in a given ecosystem [2]. Data for these purposes could be acquired using both ground based and remote sensing methods. Ground based methods of data acquisition include field observations, collection of in-situ data and measurements and land surveying activities, whereas remote sensing methods are based on the use of image data acquired by sensors of different types such as aerial camera, scanner, or radar [3].

Plants can be distinguished from other terrestrial surfaces by their specific absorption and reflection patterns. Specifically, plants absorb red and blue wavelengths of light and reflect green and infrared wavelengths. This absorption characteristic is dependent upon the physiological status of the plant and may be considered as a measure of greenness. Other land-based surface features exhibit different light absorption and reflection patterns and can therefore be easily distinguished from vegetative land-cover. As most of the animal species in Okomu are herbivores, their habitats can be determined and analyzed easily by vegetation monitoring and LULC analysis.

The spatial location of ecologically sensitive areas is fundamental for wildlife conservation. Traditionally, the distribution of species is represented by either point or ranged maps. However, these maps are criticized for not being representative enough and provide inadequate information on the distribution of species. The deficiency of both information and knowledge in species distribution and abundance is likely to hinder the reliable location of ecological sensitive sites, which in turn can limit the effectiveness of zoological garden/park and reserve planning process. Remote sensing, GIS and habitat models are essential tools that foster ecological monitoring and biodiversity, a sustainable approach to wildlife conservation and management.

Species and habitat types are non-randomly distributed. The basic needs of different species have implications on their distribution as they reflect essential environmental characteristics that related to their life support system including food, water, nesting sites, shelter, evasion of potential enemies, etc. [3] classified the ecological factors into resource, direct, and indirect gradients. Among various types of factors, indirect gradients are usually used as environmental predictors for species distribution modeling primarily because they can effectively be derived from remote sensing imagery and extracted geographical information database. Remote sensing identifies and retrieves land cover characteristics, particularly vegetation types at broad spatial extents [4]. In early days, vegetation map derived from aerial photos or satellite images were used as the only predictor to map species habitats. While Geographic Information System stores precise locations of land attributes related to topography, hydrology, man-made structures etc., these spatial data can be further manipulated and analyzed to generate other relevant environmental variables through various analytical tools. The observed species distribution always shows significant correlation with these environmental variables. Suitable habitat of different species can then be modeled and localized by establishing relationship between field records and environmental gradients through modeling process.

This research study aims at assessing the synergy between the animal species and certain influencing factors on their survival within the ecosystem. This requires extensive study of the rate of change in environmental structure, land use dynamics and climatic variations across the region.

Study Area

The Okomu National Park, formerly the Okomu Wildlife Sanctuary, is a forest block within the 1,082 km^2 Okomu Forest Reserve in the Ovia South-West Local Government Area of Edo State in Nigeria. The park is about 60 km North-West of Benin City. The park holds a small fragment of the rich forest that once covered the region and is the last habitat for many endangered species. It continues to shrink as villages encroach on it and is now less than one third of its original size. Powerful corporations are involved in plantation development and logging concessions around the park, which also pose a threat.

Environment

The park is drained by the Osse River which defines its eastern boundary. The Okomu River forms the western boundary. Rainfall is between 1,524 and 2,540 mm per year. Soils are acidic, nutrient-poor sandy loam. Vegetation is Guinea–Congo lowland rain forest, including areas of swamp-forest, high forest, secondary forest, and open scrub. Among the common trees are Kapok, Celtis zenkeri, Triplochiton scleroxylon, Antiaris africana, Pycnanthus angolensis and Alstonia congoensis. The park is probably the best example of mature secondary forest in southwest Nigeria. The park is accessible to tourists and has well marked trails. There are two tree houses, one 140 feet high in a silk-cotton tree, from which visitors can view the park from above and observe bird life. Visitors can stay at chalets built on stilts, just outside the park entrance, surrounded by fig trees that are often occupied by Mona monkeys. Guides are available for forest walks and will point out such things as termite nests and the many medicinal plants.

Fauna

The park has diverse fauna, with 33 species of mammals including the African buffalo and the endangered African forest elephant. Elephant sightings are rare, although in 2007 a one-year-old elephant carcass was found, unlikely to have died from natural causes. Park officials claim that elephant poaching no longer occurs, despite the high prices commanded for ivory in Lagos. There is a population of the vulnerable white-throated guenon, a primate. Although no thorough study of the primate population has been done since 1982, chimpanzees were reported to be present in the region in 2009. The number of chimpanzees estimated to live in the Okomu Forest reserve was guessed to be 25–50 in 2003, and some may use the national park at times. Other animals found in the park include dwarf crocodiles, red river hog, sitatunga, warthog, civet cat, Maxwell's duiker, grass cutter, Mona monkey, Thomas's galago and tree pangolin. About 150 species of birds have been identified. These include Angolan pitta, grey parrot, wrinkled hornbill, fish eagle, hawks, woodpeckers, great owl, grey hornbill, cattle egret, black-casqued hornbill, yellow-casqued hornbill, Sabine's spinetail, Cassin's spinetail, black spinetail, white-breasted negrofinch, chestnut-breasted negrofinch, pale-fronted negrofinch and yellow-throated cuckoo.

Terrestrial mollusks seem exceptionally vulnerable to extinction, and low diversity may indicate subtle environmental problems. A survey of land mollusks in a small area of the forest found 46 species in 11 Mollusca families, of which Streptaxidae snails accounted for over a third. This is much lower diversity than has been found in Cameroon and Sabah. However, it may be due to the very limited sample in just one area. Perhaps of greater interest to most visitors, the park has over 700 species of colorful butterflies.

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Threats

The park is vulnerable to threats as emerging factors such as poaching, and logging activities contribute to the degradation of the park. Visitors must follow strict regulations to avoid degrading the environment. However, the park is threatened by large-scale illegal logging, the expansion of large rubber and oil-palm plantations nearby, and incursions by the teeming human population involved in farming and hunting.

The protected area of the Okomu National Forest is too small and too vulnerable. Without further efforts to improve protection, it is unlikely that the forest will remain viable long into the future (Figure 1).

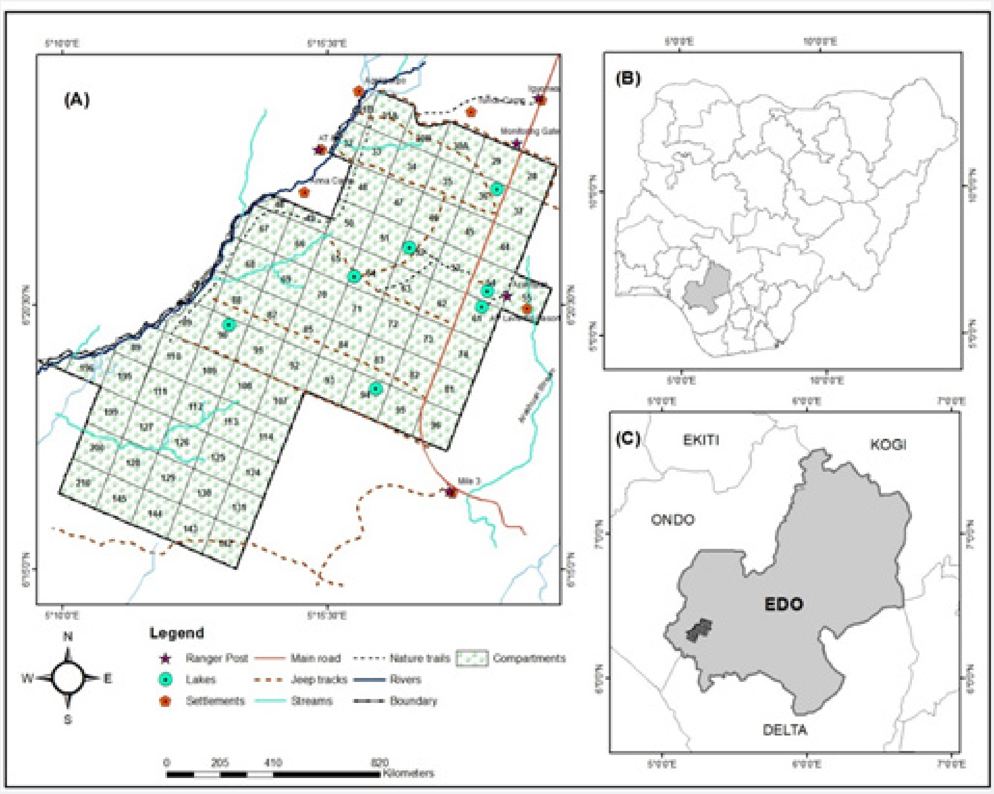

Figure 1: Map of the study area.

The White Throated Guenon

Habitat Requirements and Behaviour

Natural habitats provide wild animals with food, water, shelter, breeding space, cover and opportunity to roam and also to escape from predators. The description of the physical and biological properties of an animal's preferred habitat can be referred to as habitat use [5]. The knowledge obtained by such studies is integral to the successful conservation of habitat and is a precondition for the conservation of target species [5]. The knowledge acquired also allows man to manipulate the key habitat factors essential for the animals' survival [5] and is a prerequisite for the prediction of successful reintroduction of a species [5].

The White-throated guenon (Cercopithecus erythrogaster Pococki) is known to be endemic in Okomu National Park. Until recently, this species was thought to be very rare, but extensive surveys have revealed its presence at a number of formerly unknown sites [6]. Sclater's Monkey occurs in a region with a very dense human population and where most natural forest has been destroyed by logging, conversion to cultivated land and oil exploration [6]. Of particular concern for this species is severe fragmentation of remaining habitats and thus lack of connectivity among existing populations. Sclater's monkey is hunted throughout its range (except in the very few places where monkeys are held sacred), but it continues to persist due to preferential hunting of larger-bodied primate taxa and its small size, shy nature and adaptability [6]. The original habitat of this species would be moist tropical lowland forest, but due to severe habitat degradation, Sclater's Monkey now persists in remnant secondary, gallery/riparian and freshwater swamp forests. The species is also found in marginal forest and farm-bush in communities where monkeys are regarded as sacred [6]. The species is likely omnivorous, with a diet similar to other members of the C. cephus group: mostly fruits, seeds, insects and young foliage. Many Africa rainforest primates cluster into discrete communities, which are thought to reflect a shared historical

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relationship with the rainforest, which they inhabit, and to reflect similar dispersal limitations resulting from zoo-geographic barrier. Human activities are making it inevitable that many of the African primate populations and their habitats will disappear, more so that the rate of increase in human population is still very high [7]. There is no indication that this pattern of growth has changed. Even with such growth, environmental condition, inefficient techniques and lack of capital resources are causing the rate of food production to lag behind [8]. All these have led to an increase in subsistence living in the forest area, and hence, more negative impact on the fauna resources of the forest zone, which the primate populations constitute a large proportion. The white-throated monkey (Cercopithecus erythrogaster) is one of the world's most threatened primates. Although, the species is protected by the Nigeria endangered species decree number 11 of 1985, it is conserved and protected only in National Parks, Games Reserves and Wildlife Sanctuaries of which Okomu National Park is a major habitat for them. Deforestation often caused a disturbance in the habitat, leading to a decline in the number of animal species present either through death or migration to more stable habitats. Indiscriminate hunting is also another major problem causing population decline of many animal species in any habitat.

The least abundance of Cercopithecus erythrogaster recorded in some habitats might have been as a result of the fact that those ranges are located along the park boundaries, thereby subjecting the guenons to serious habitat disturbance ranging from poaching, illegal farming and illegal logging. The ever-green forest along the riverbank of the Okomu River, around Arakhuan stream and lakes which do not dry up completely in the dry season provide all the necessary ecological requirements for the animals especially during the dry season, thereby, attracting primate species and other wild animals in the park.

Daily activities of Cercopithecus erythrogaster in the Park include early morning and late afternoon feeding between 6.30 – 11.30am and 3.30 – 7.30pm respectively. They rest on top of trees canopy in the hot afternoon between 12.00 – 2.30pm. They equally spend their time to drink water daily before they retire to late night rest. This observation is similar to the report by [9] which explained that white-throated monkeys drink water to meet their body requirements and regulate their body temperature. It was observed that most primate species have over-lapping territories with white-throated guenon in the park. This means that these primate species share common habitat resources such as trees, water, breeding space and cover.

A summary of the habitat requirements of the White throated guenon as reviewed in the literature are described below:

a. Aspect of slope: Research and Observations found that the White throated guenon favour the North and West facing slopes and show a negative selection towards the South and South-Eastern facing slopes.

b. Degree of slope: Research and Observations have also found that 90% of the White throated guenon within the Arakhuan, Iguowan, Julius Creek and Baubui Creek ranges occur on slopes less than 25°.

c. Topography: The White throated monkeys tend to avoid lowland areas, preferring ridge terraces, tree heights and avoiding flat land and steep slopes [5]

d. Vegetation: The White throated monkeys show a preference for enclosed natural forestlands dominated by Bush pineapple trees (Myrianthus arboreus) and Elephant Okro trees (Desplazia supericapa)

Methodology

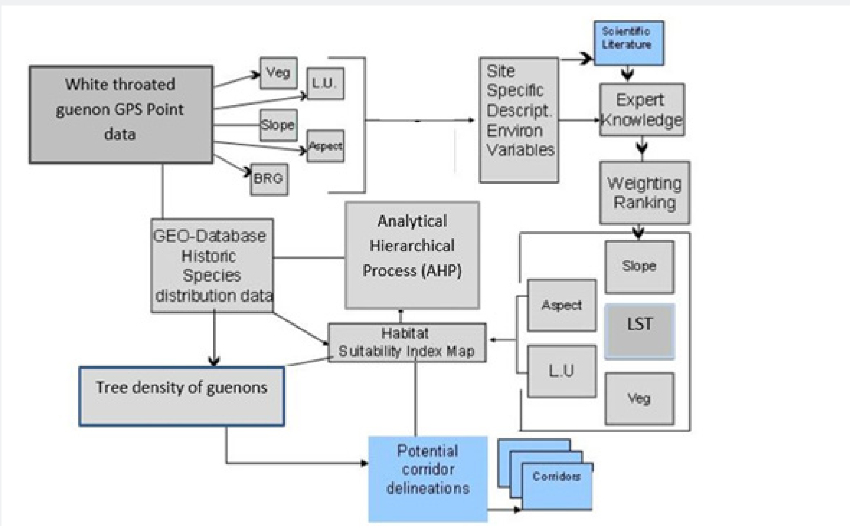

Figure 2: Work Flowchart.

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The methodology includes the sampling strategy, field data collection procedures, materials used, preparation of surface maps and an overview of the spatial modeling techniques [10-16]. The basis of the project process is the spatial overlay. The results of the spatial overlay were analyzed through a standard Multi-Criteria Evaluation technique using Saaty's (1980) Analytical Hierarchy Principle (AHP). The resultant habitat suitability model was then utilized in Habitat Suitability analysis of which a collation of the results was used to identify White throated guenon Conservation Areas and suitable habitat corridors for White throated guenons in Okomu National Park (Figure 2).

Field Data Collection

The field data used in the model was collected at Arakhuan range of the park through a random field survey of the white throated guenon numbers within the compartments of the Okomu National Park. The Park authorities supported me with rangers to accompany me on the field survey to assess the status of white throated guenons on about 10 compartments within the Arakhuan, Iguowan, Julius Creek and Baubui Creek ranges. The white throated guenon population data, consisting of Global Positioning System (GPS) coordinates and population numbers were recorded [17-19].

Software Used

The following software packages were used in the course of this project:

a. Data entry & calculations EXCEL SPREADSHEETS

b. GIS processing ARCMAP 10.5

c. Imagery correction ENVI 5.3

d. Word processing MS WORD

GIS Data Layers

The data layers used in the analysis were Slope, Aspect, Land Cover, Okomu National Park Vegetation, and Elevation (Table 1). The variables were selected through a literary review process of the available habitat requirement studies relevant to the White throated guenon [20].

Table 1: Explanatory variables used in this study, together with their definitions.

Variables	Definition
Landcover	Categorical variable, Land cover types
Vegetation Type	Categorical variable, vegetation types
Land Surface Temperature	Continuous variable, expressed in degrees Celsius
Dem	expressed in degrees, classified into classes
Aspect	Continuous variable derived from a
Slope	Continuous variable derived from a DEM, expressed in degrees, classified into classes

White throated guenon Population Data

A vector GIS coincident for the 2013 White throated guenon population numbers was captured and digitized in ArcMap10.5 and recorded in the 2016White throated guenon census data set. The White throated guenon population size, GPS coordinates, and habitat type details were recorded from the field data collection process [21-25].

Digital Elevation Model

A digital elevation model (DEM) with a resolution of 90m was used [26]. The DEM was used to derive elevation, slope and aspect using the 3D Analyst and Spatial Analyst functions within the Arc Toolbox in ArcMap 10.5. The aspect was then reclassified into eight classes each representing N, NE, E, SE, S, SW, W and NW. The slope was reclassified into four classes, these were Gentle steep, High steep, Moderately High terrain, and Plain areas [27-29].

Land Cover

The Land Cover analysis was carried out using imageries from different years at a 30 years range in order to be able to study the land use dynamics of the park.

Okomu National Park Vegetation Types

The Okomu National Park vegetation layer was supplied by the Park authorities with notable vegetation succession that had been recorded. This information allowed for easier classification of the park's vegetation.

Multi-Criteria Evaluation Modeling

The univariate and multivariate statistical analysis provided the basis for the modeling procedure. Due to the wide-ranging nature of the non-continuous and continuous environmental variables, a common scale on which an inter-variable comparison could be made statistically was required. This process was made possible with the use of Analytical Hierarchy Principle (AHP) analysis (Saaty, 1980).

Developing Environmental Variable Class Weights

An AHP analysis was completed within the scope of this project to determine the overall weights given to individual variables necessary in the Multi-Criteria Evaluation. The AHP is a multi-criteria decision-making technique for the development of weights [6]. After decomposition, AHP requires the assessment of pair-wise comparisons and uses a linear 5-point continuous scale to quantify them. Saaty's use of pair-wise comparisons in judgment matrices has become a relatively widely accepted method for extracting quantitative information from day-to-day multi criteria decision making models (Eastman et al., 1995). To synthesize the priorities, Saaty's method uses the eigenvalue theory which is a modified least squares problem in AHP. Saaty's use of the eigenvalue theory entails the construction of a decision-making matrix by using the relative importance of alternatives in terms of each criterion [30].

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To measure the level of internal uncertainty Saaty (1980) proposed the use of an index to evaluate the reasonable level of consistency in the pair-wise comparisons. The consistency ratio (CR) involves the maximum right eigenvalue. The CR is designed in such a way that if CR< 0.10 (10%), the ratio indicates a reasonable level of consistency. If the CR> 0.10 (10%) there is an unacceptable level of consistency and indicates inconsistent judgments. Using the AHP, each environmental variable was ranked against other environmental variables.

The GIS based Multi-Criteria Evaluation that followed required separate weights to be assigned to each variable as a general measure of the variable's importance. A pair-wise comparison matrix was created in Excel (MS Office, 2016) and provided the platform for the AHP analysis. The number of pair-wise comparisons is given by the following formula: where n is the number of variables

$(n(n-1))/2$ Equation 1

The matrix was enumerated with a linear 9-to-1 scale ranking of importance (Saaty 1980) by comparing variables in a pair-wise fashion against one another. As proposed by Saaty (1980) a score of 9 implies absolute importance, decreasing to 1 representing equal importance). Such a scale is a one-to-one mapping between the set of discrete linguistic choices available to the decision-maker and a discrete set of numbers which represents the importance, or weight, of the previous linguistic choices. The priority vector was tabulated from the symmetrical matrix in order to calculate the maximum right eigenvalue (μ_max). Weights are determined by normalizing the eigenvector associated with the maximum eigenvalue of the (reciprocal) ratio matrix (Malczewski, 1999). A consistency check of the priority choices was then performed to ascertain the CR as stipulated in Saaty's (1980) work. The CR was a ratio of the consistency index (CI) and the random consistency index (RI)

$CI=(\mu_{max}-n)/(n-1)$ $CR=CI/RI$ Equation 2

The RI, as determined by Saaty, was considered to be the appropriate consistency index with which the CR could be identified. The results of the CR are described in results chapter. The AHP was instrumental in ensuring that perceived important variables received a higher rank relative to the environmental factors that were less influential to the distribution of White throated guenon in Okomu National Park. Each factor used in the analysis was thereby assigned weights ranging from 1 to 5. The field exercise was carried out by taking ground coordinates of selective points where certain species are found across the study area using a GPS and locating their habitats.

a. Habitat maps that display data layers of land cover, tree canopy cover, and tree species were created.

b. The landscape data for the habitat maps is derived from Landsat satellite images;

c. Locations within the extent of the satellite images are covered as the land-cover type and forest characteristics are recorded with handheld GPS device.

d. The data collected in the field is brought to the lab and converted to shapefiles.

e. These shapefiles are then used in ArcGIS Desktop (ArcInfo) software to create the three main raster map products: land cover, crown closure (the density of the forest canopy), and tree species composition, which are combined to derive habitat models.

f. Information on Land Use Land cover, vegetative cover analysis is analyzed to know the distribution of these species

Landscape structure is important when defining the habitats of certain animal species. Forest canopy information can reveal to researchers where certain animals are likely to be found. When mapping land cover; the trees, shrubs, wetlands, water, or barren regions of the study area were taken note of [31].

Results and Discussion

Land Use/Land Cover Change Analysis

Supervised image classification was carried out to assess the land use/land cover pattern of the Okomu National Park for the years 1986, 1999 and 2016 with Landsat imageries of the respective years. The aforementioned years were considered due to the fact that these were the only available imageries that were cloud cover free. Four classes were identified (Water Body, Thick Vegetation, Light Vegetation and Bare surfaces). The results were presented in maps and tables. Training samples were picked from the respective imageries and saved as signature files for the maximum likelihood classification of the study area.

Land Use/Land cover Classification for 1986

The land use/land cover change detection analysis was used to detect the vegetation abundance, water and the bare surfaces of the park relative to their contributions to biodiversity in the park. Analysis of the 1986 imagery summarized in (Table 1) and (Figure 1) reveals that major part of the park was covered by thick vegetation and Water body at (112.60 Km2) 67.30% and (37.32 Km2) 22.31% respectively. This reveals the biodiversity richness of the park as these characteristics support the natural ecosystem of the park (Table 2) (Figure 3).

Land Use/Land cover classification for 1999

The land use/land cover change detection analysis was used to detect the vegetation abundance, water and the bare surfaces of the park relative to their contributions to biodiversity in the park. Analysis of the 1999 imagery summarized in (Table 2) and (Figure 2) reveals that there is a relative increase in the Thick vegetation status of the park. This can be said to be evidence of sustainable conservation in the park. The observable increase in the vegetation

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status of the park notes a shift increase from (112.60 Km²) 67.30% to (122.30 Km²) 73.10%. This reveals the biodiversity richness of the park over the years as these characteristics support the natural ecosystem of the park (Table 3) (Figure 4).

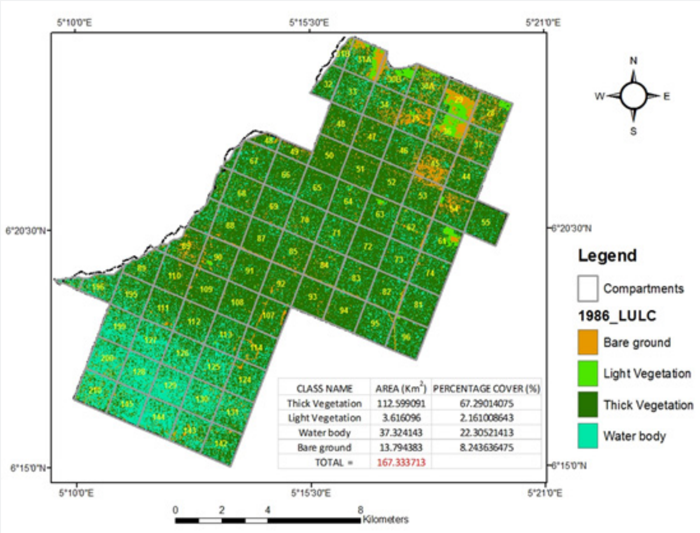

Figure 3: Showing Land use/land cover map of Okomu National Park in 1986.

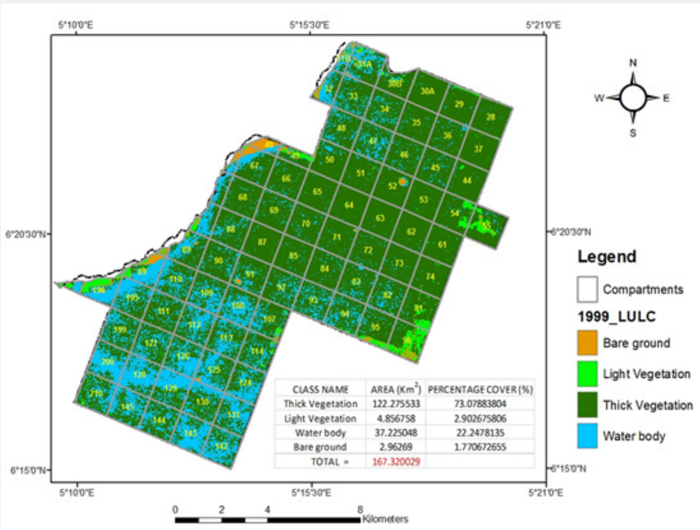

Figure 4: Showing Land use/land cover map of Okomu National Park in 1999.

Table 2: Showing the statistics of the LULC for 1986.

LULC Classes	Area Covered (Km²)	Area Covered (%)
Thick Vegetation	112.599091	67.29014075
Light Vegetation	3.616096	2.161008643
Water body	37.324143	22.30521413
Bare Surface	13.794383	8.243636475
Total	167.333713	100

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Table 3: Showing the statistics of the LULC for 1999.

LULC Classes	Area Covered (Km²)	Area Covered (%)
Thick Vegetation	122.275553	73.07883804
Light Vegetation	4.856758	2.902675806
Water body	37.225048	22.2478135
Bare Surface	2.96269	1.770672655
Total	167.320029	100

Land Use/Land cover Classification for 2016

Analysis of 2016 LULC is displayed in (Table 4) (Figure 4). The analysis shows that there has been a sudden increase in the light vegetation of the park probably due to riparian vegetation or growth on bare surface from 2.90% to 28.74% (4.86 - 46.26 Km^2) of the study area. Riparian vegetation is essential for maintaining high water quality in lakes and along shorelines but there is a need for the area with riparian vegetation be preserved in order to protect the water quality and habitat value of the area. The bare surface of the area has reduced from 1.77% to 0.07% (2.96 – 0.11 Km^2). It is also observed that there had been a decrease in the water body from 22.25% to 1% (37.22 – 1.60 Km^2). This is due to the fact that the park has been subjected to various constraining activities such as logging, encroachment, poaching and deforestation. These activities inhibit incessant evaporation, and this affects the water body expanse of the park. This would serve as a threat to the biodiversity community of the park (Figure 5) [32,33].

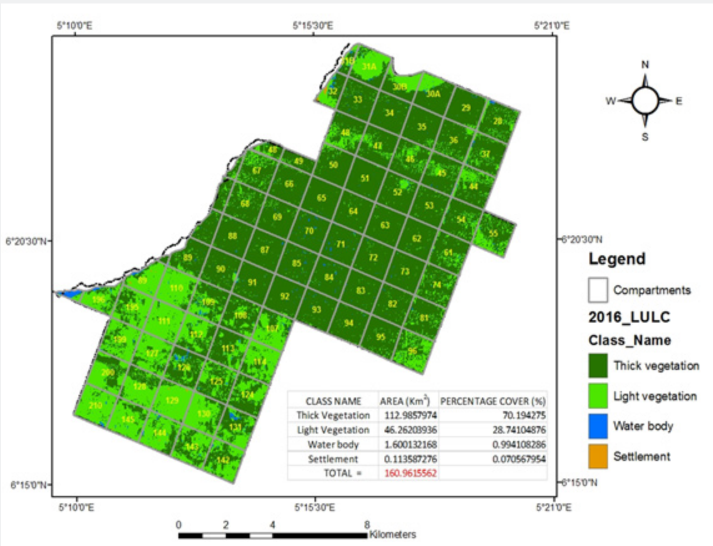

Figure 5: Showing Land use/land cover map of Okomu National Park in 2016.

Table 4: Showing the statistics of the LULC for 2016.

LULC Classes	Area Covered (Km²)	Area Covered (%)
Thick Vegetation	112.9857974	70.194275
Light Vegetation	46.26203936	28.74104876
Water body	1.600132168	0.994108286
Bare Surface	0.113587276	0.070567954
Total	160.9615562	100

Change Detection Analysis (1986 - 2016)

The analysis was undertaken to quantify and measure how the attributes (land use/land cover) of the park have changed from 1986 to 2016. The change detection observed were presented in the (Figure 6) (Tables 4 & 5). The gain and loss in area for each class was computed. Positive values indicate the gain in the area

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while the negative values indicate the loss in the area. From 1986 to 1999, it is observed that the vegetation became more distributed yielding gain. And this is a very important factor for effective biodiversity as a balanced ecosystem is established.

Table 5: Showing the net gain or loss between 1986 to 2016 in Sq.km.

YEARS	1986	1986-1999	1999	1999-2016	2016
LULC CLASSES	Area (Km^2)	Net gain or loss (Km^2)	Area (Km^2)	Net gain or loss (Km^2)	Area (Km^2)
Thick Vegetation	112.599091	9.676462	122.2756	-9.28976	112.9858
Light Vegetation	3.616096	1.240662	4.856758	41.40528	46.26204
Water body	37.324143	-0.099095	37.22505	-35.6249	1.600132
Bare Surface	13.794383	-10.831693	2.96269	-2.8491	0.113587
TOTAL	167.333713	-0.013684	167.32	-6.35847	160.9616

Table 6: Net percentage gain or loss from 1986 to 2016.

LULC Classes	1986-1999	1986-1999	1999-2016	1999-2016
	Net Gain Or Loss	%Net Gain Or Loss	Net Gain Or Loss	%Net Gain Or Loss
Thick Vegetation	9.676462	4.12%	-9.28976	-3.95%
Light Vegetation	1.240662	14.64%	41.40528	81%
Water body	-0.099095	-0.13%	-35.6249	-91.75%
Bare Surface	-10.831693	-64.64%	-2.8491	-92.61%
TOTAL	-0.013664	-46.01%	-6.35847	-107.30%

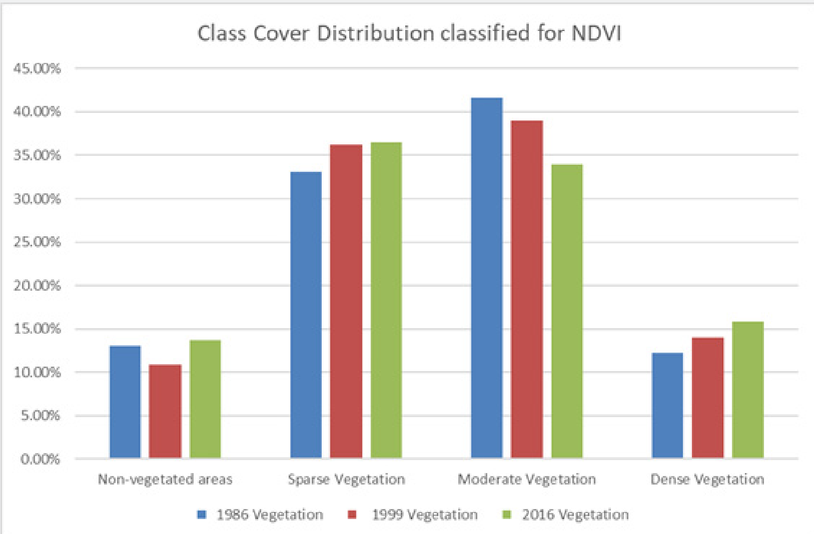

Figure 6: Classified Class Cover Distribution for NDVI.

Table 7: Class Cover Distribution classified for NDVI.

Class Cover	1986 (Km^2)	1986 (%)	1999 (Km^2)	1999 (%)	2016 (Km^2)	2016 (%)
Non-vegetated areas	21.845657	13.05	18.21453	10.89	22.95034	13.72
Sparse Vegetation	55.374286	33.1	60.51847	36.17	61.10858	36.54
Moderate Vegetation	69.665319	41.63	65.21956	38.98	56.74768	33.93
Dense Vegetation	20.446717	12.22	23.36663	13.96	26.4473	15.81
Total	167.331979	100	167.3192	100	167.2539	100

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From 1999 to 2016, it is observed that the thick vegetation of the park has degraded owing to the fact that there are more logging activities and deforestation in the park. The increased light vegetation signifies increased cultivation and farming activities around the park. This is probably because the surrounding villages sought for other means of survival as their major means (hunting) have been taken from them by the park authorities which enforced it as poaching activities. This has served as a major biodiversity loss to the park (Table 6).

The park is subject to relative encroachment as the total area keeps on reducing over the years. The Net gain and loss was calculated by subtracting the area of the previous years from the recent years [34]. (Tables 5 & 6) shows the overall net percentage of area gained or lost from 1986 to 2016. This provides information on the degree of vegetation degradation, water body degradation in the Okomu National Park. It is calculated by adding the two areas for each class (one for the past year and the other for the recent year) and them the net gain or loss is divided by the area multiplied by 100. For e.g. ((gain or loss between 1986 and 1999) / (Area for urban in 1986 + Area for urban 1999)) *100. (Figures 7-12).

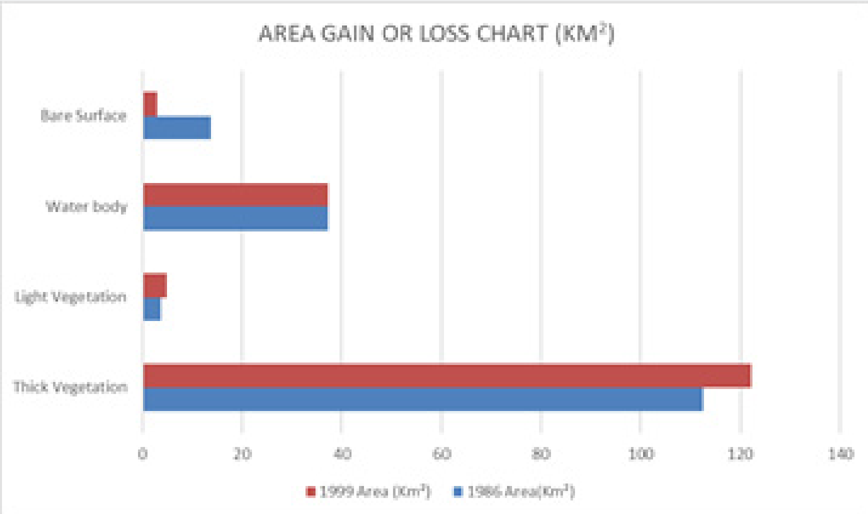

Figure 7: Area Gain or Loss Chart in Square Kilometers.

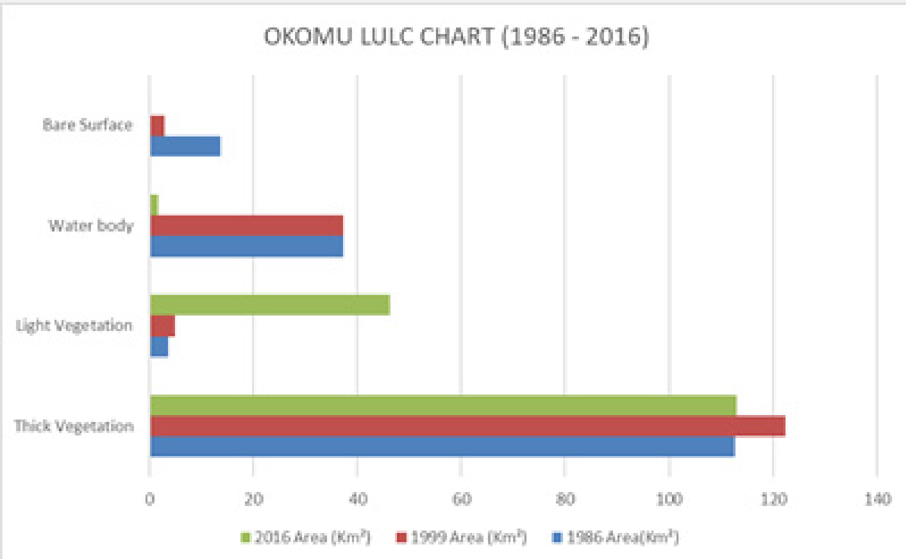

Figure 9: Okomu Land Use Land Cover Chart (1986 - 2016).

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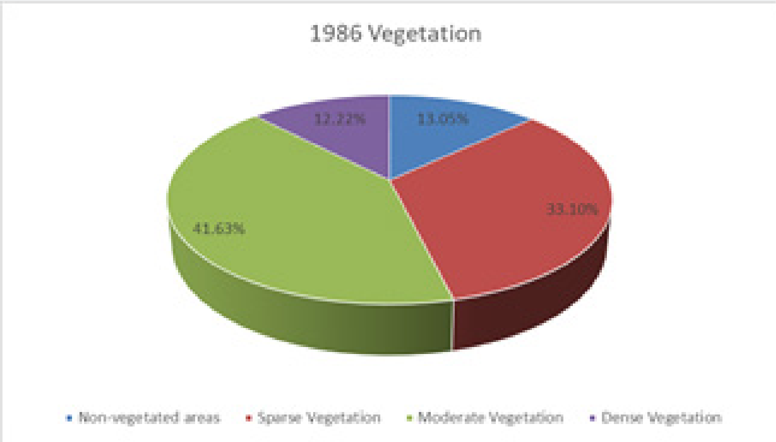

Figure 10: Pie chart Showing 1986 vegetation percentage distribution.

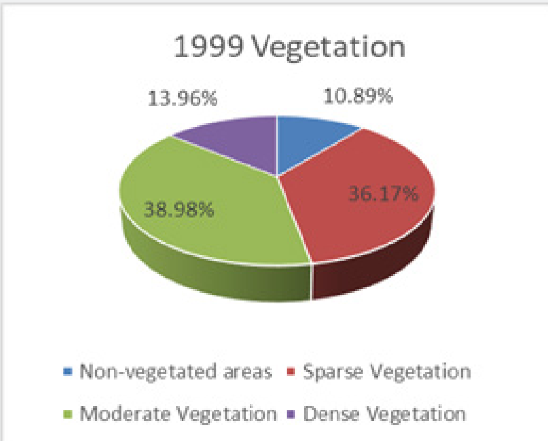

Figure 11: Pie chart Showing 1999 vegetation percentage distribution.

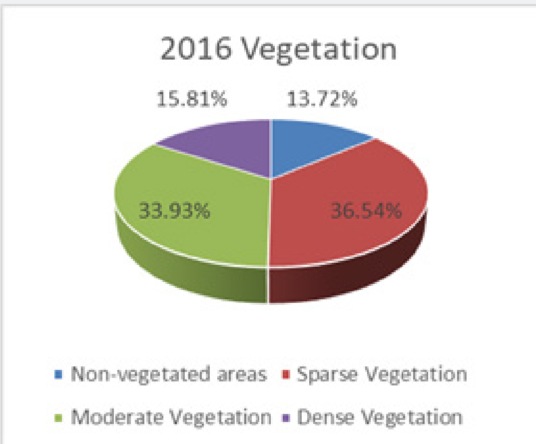

Figure 12: Pie chart Showing 2016 vegetation percentage distribution.

Digital Elevation Model (Dem)

The park is characterized by a uniform elevation based on the analysis carried out using the area DEM. The contour map of the area was also generated alongside the slope and aspect of the park.

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Elevation

The Elevation was also reclassified as well as the slope and aspect criteria. Below, shows the elevation across each compartment (Figures 13-15).

Slope

The classified slope criterion reveals that the park is generally a lowland coupled with the fact that the degree of sloppiness is relatively low. This supports biodiversity as there are reduced leaching and erosional activities (Figure 16).

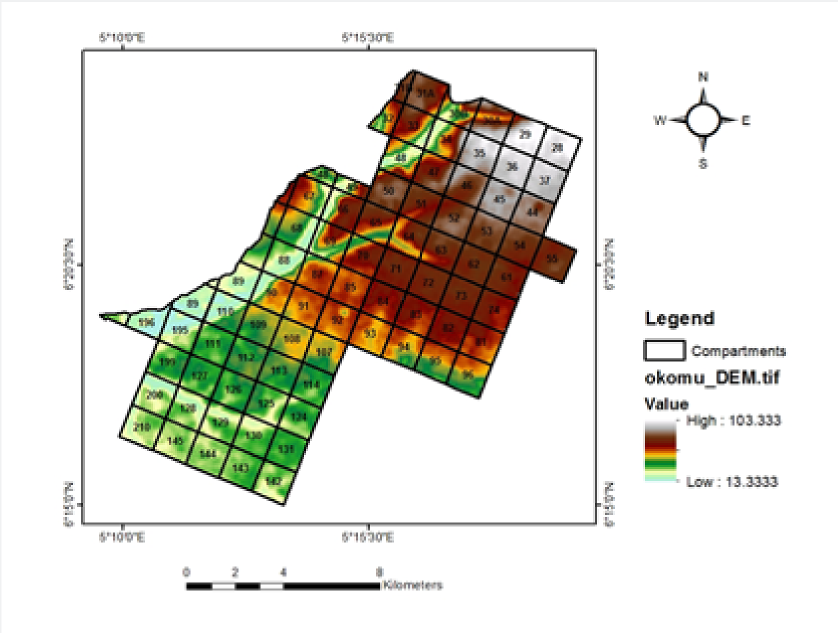

Figure 13: Okomu DEM map.

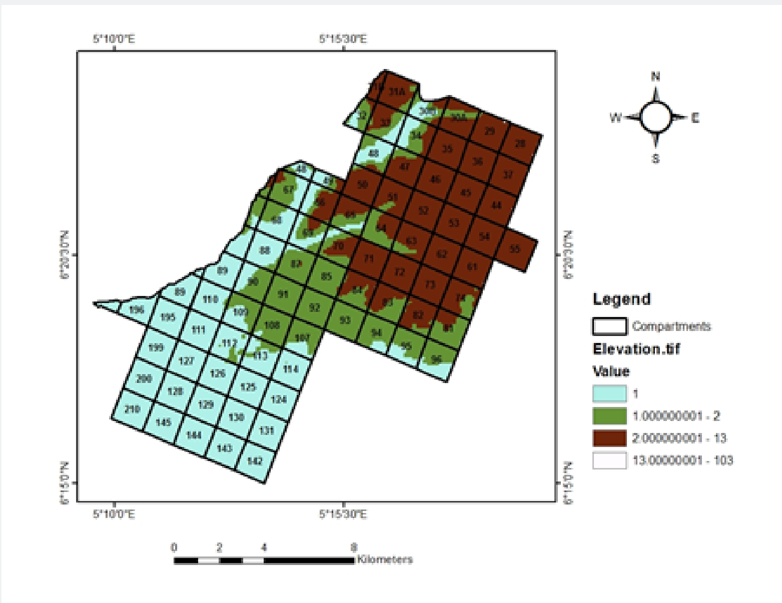

Figure 14: Reclassified Elevation criteria.

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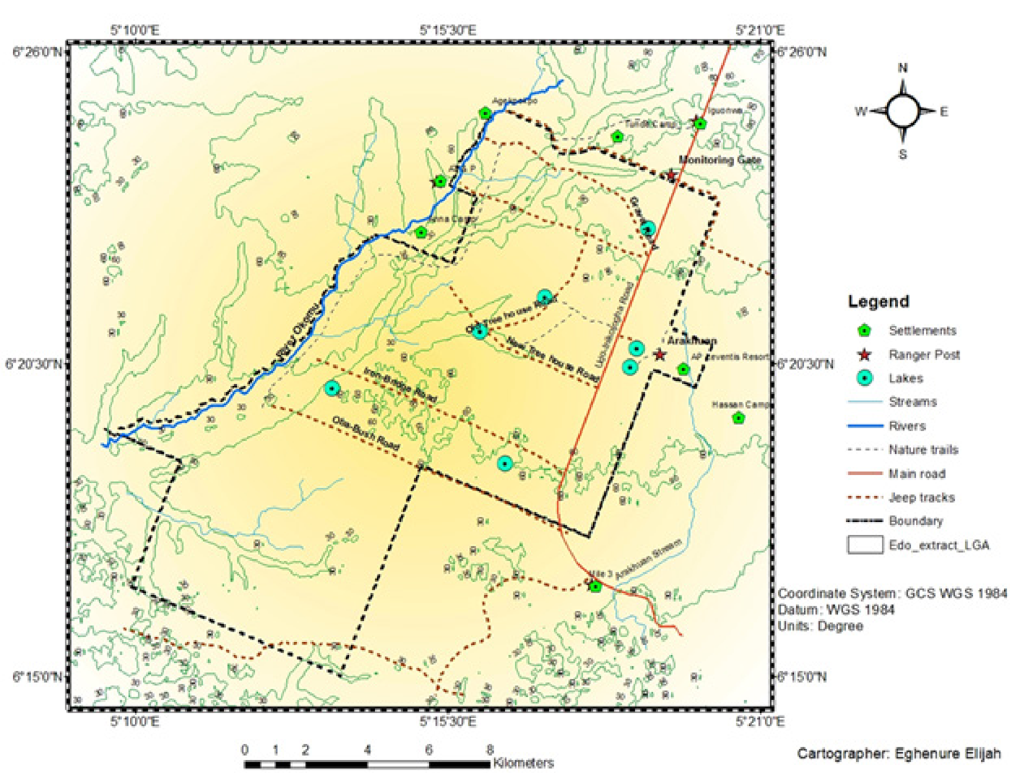

Figure 15: Topographic map of the park.

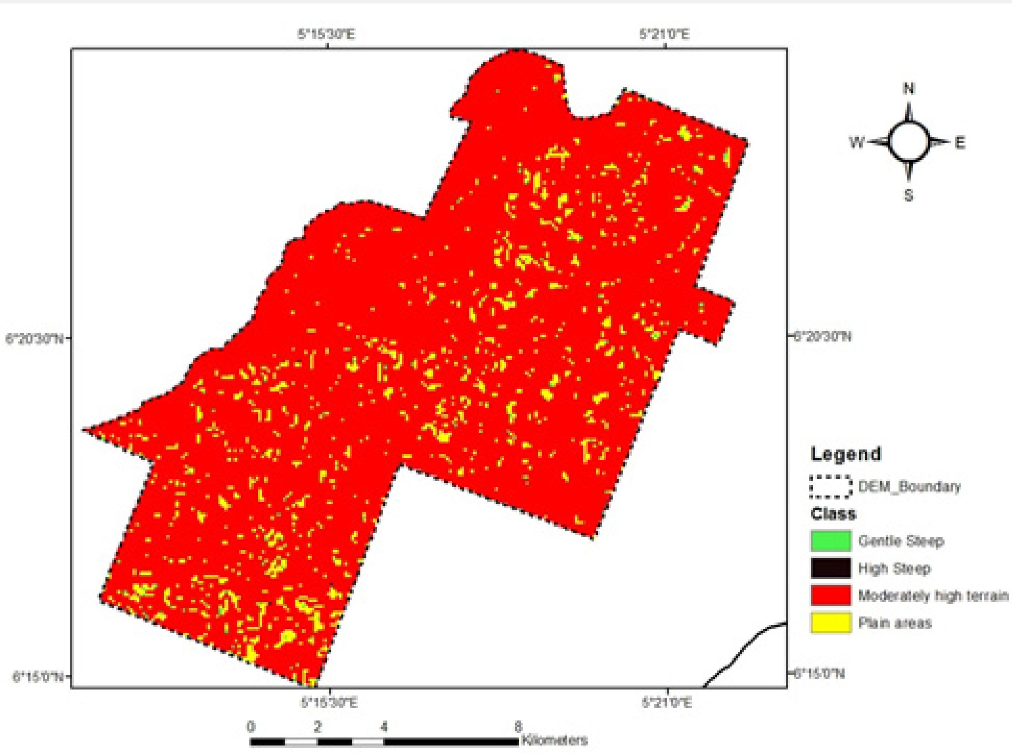

Figure 16: Slope classification of the area.

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Aspect

The aspect of the area reveals the direction with which the terrain is sloping. The aspect was also reclassified for the purpose of Habitat Suitability index. Also, the aspect reveals relatively degraded areas in terms of the sloppiness value and direction represented (Figure 17).

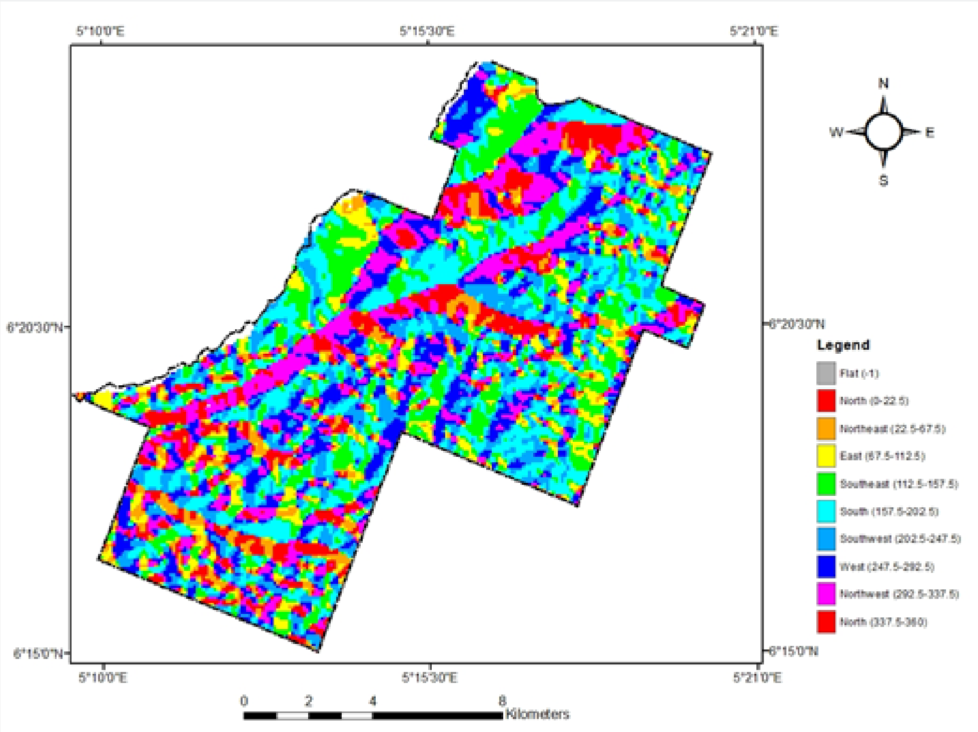

Figure 17: Aspect of the terrain.

Vegetation Types: Analysis Of Normalized Difference Vegetatio Index (Ndvi)

Analysis of NDVI Maps (Vegetation Degradation) in Okomu National Park

The NDVI images were all reclassified into four classes each. The classes include Non-vegetated areas which could mean water body, Dense vegetation, Moderate vegetation, and Sparse vegetation. These vegetation classes were designated in an increasing order of vegetation vigor. (Table 6) shows the threshold and the distribution of vegetation cover classes across the different years. The vegetation classification maps in (Figures 13-15) clearly illustrate the spatial patterns of vegetation cover distribution within the study area. The Reclassified image of 1986 shows that the vegetation cover is dominated by moderate vegetation accounting for about 42%, followed by sparse and dense vegetation accounting for about 33% and 12% respectively. The Non-vegetated areas accounts for 13% comprising of certain farmlands, pathways and transects. It is observed that dense vegetation increase in 1999 to 14% and moderate vegetation reduced to 39% with sparse vegetation at 36%. Moreover, by the end of 2016, the moderate vegetation shows an increase in % value and the dense vegetation and sparse vegetation as well decreased showing the moderate vegetation taking over the vegetation structure of the park and that indicated more of agricultural activities within the park with respect to decrease in dense vegetation comprising of forest covers. The LULC of 2016 that showed more increase in vegetation in the previous discussion now explains better with NDVI that the increase was due to moderate vegetation of the areas which indicates the prevalence of agriculture activities within the park (Table 6) (Figures 18-20).

Relationship between NDVI and Land Surface Temperature (LST)

This was carried out by inputting the break point values of the NDVI and LST. Also, plotting their relationship on Microsoft Excel by plotting the LST Values against the NDVI Values. This was done in order to create a function that shows how the vegetation is affected across the study area (Table 7).

Habitat Suitability Analysis

Habitat Suitability Index is based on functional relationship between wildlife and habitat variables. Suitability index scale

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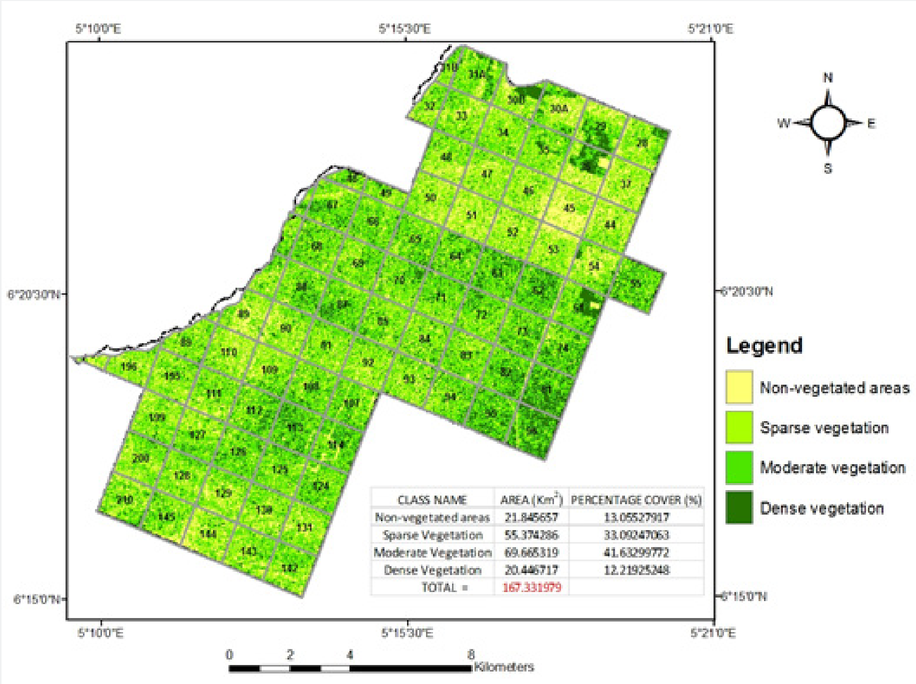
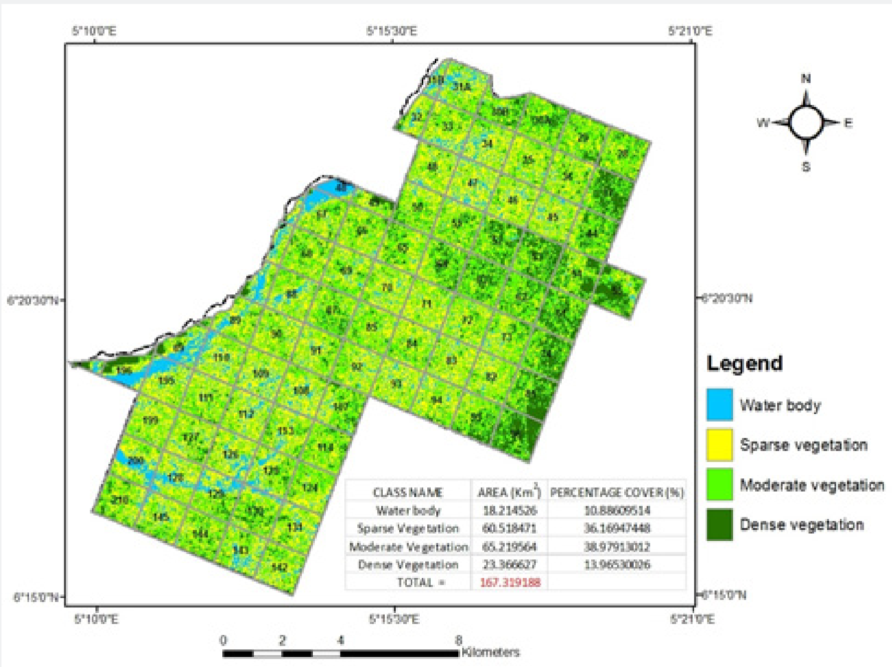
ranges from 0 to 1. Life requisites for a species cannot occur within a single raster cell (map pixel). Therefore, certain factors are considered using the Analytical Hierarchical Process (AHP). Such variables could mean; Land Use Land Cover, Vegetation type, Slope of the area, Aspect, Elevation and the Land Surface Temperature (LST).



CLASS NAME	AREA (Km^2)	PERCENTAGE COVER (%)
Non-vegetated areas	21.845657	13.05527917
Sparse Vegetation	55.374286	33.09247063
Moderate Vegetation	69.665319	41.63299772
Dense Vegetation	20.446717	12.21925248
TOTAL =	167.331979	

Figure 18: Vegetation map for 1986.



CLASS NAME	AREA (Km^2)	PERCENTAGE COVER (%)
Water body	18.214526	10.88609514
Sparse Vegetation	60.518471	36.16947448
Moderate Vegetation	65.219564	38.97913012
Dense Vegetation	23.366627	13.96530026
TOTAL =	167.319188	

Figure 19: Vegetation map for 1999.

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Considering the fact that certain species only survive under arboreal habitats, we also consider the proximity of streams and rivers as it invariably supports habitat suitability. Below is the table that shows the result from the Analytical Hierarchical Process (AHP) described in the methodology of the project (Table 8).

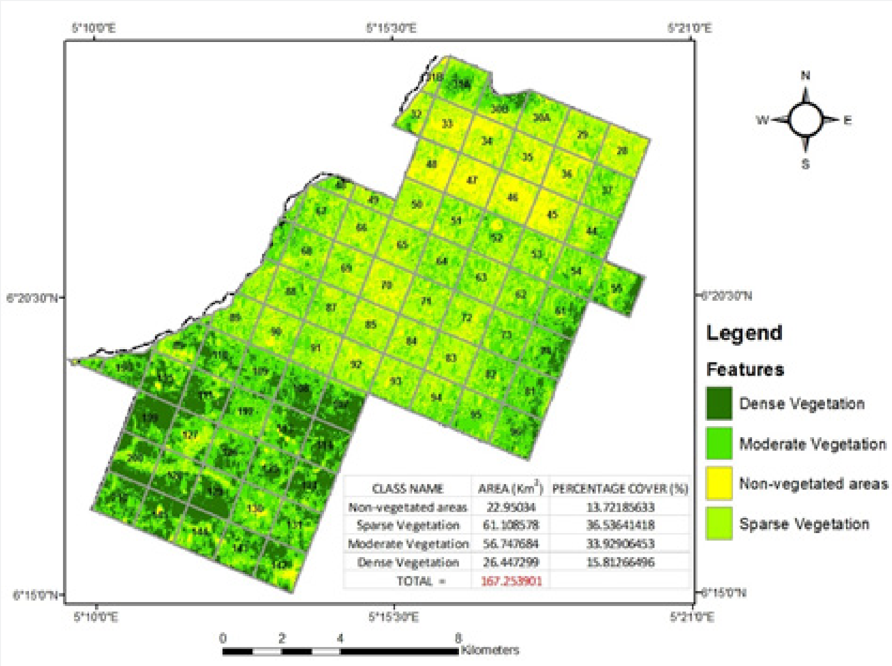

Figure 20: Vegetation map for 2016

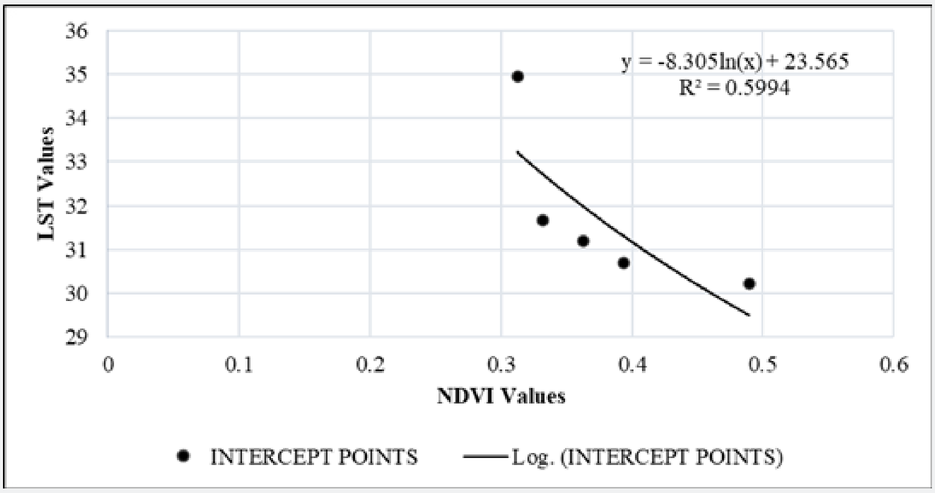

Figure 21: NDVI, LST Relationship chart.

Table 8: NDVI and LST Relationship.

S/N	NDVI	LST
1	0.489361703	30.22288794
2	0.393812032	30.69345607
3	0.363060413	31.19016688
4	0.332308795	31.66073501
5	0.312539897	34.95471191

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Weighted Priorities

These are the resulting weights for the criteria based on the Pair-wise comparisons (Table 9).

Decision Matrix

From the Suitability map generated, it is observed that the white throated guenons will be more distributed in compartment ranges of Arakhuan, Iguowan, Julius Creek and Baubui Creek. This is because of the favorable conditions supporting their survival such as Proximity to lakes and streams, densely distributed forest types with well-fruited tall trees. The rich biodiversity status of the Okomu National Park owes to the effective conservation measures implemented in order to protect threatened and endangered White throated guenons in the park (Table 10) (Figure 22).

Table 9: Pair-wise comparison table for AHP.

S/N	Variables	Priority	Rank	(+)	(-)
1	Land Use Land Cover	11.20%	4	5.10%	5.10%
2	Elevation	21.10%	3	5.50%	5.50%
3	Slope	27.80%	1	7.40%	7.40%
4	Aspect	24.70%	2	4.50%	4.50%
5	Vegetation type	7.60%	5	1.80%	1.80%
6	Land Surface Temperature	7.60%	5	1.80%	1.80%

Table 10: Decision matrix table for AHP.

S/N	1	2	3	4	5	6
1	1	1	0.5	0.33	1	1
2	1	1	1	1	3	3
3	2	1	1	1	5	5
4	3	1	1	1	3	3
5	1	0.33	0.2	0.33	1	1
6	1	0.33	0.2	0.33	1	1

Conclusion

In order to enhance higher population of the White throated guenons in the park, adequate conservation and management of plant and soil ecosystem should be improved as the habitat resources continue to serve as sources of food, cover and breeding spaces for the identified species that inhabit the park.

In the course of this project research, the following objectives were successfully met:

a) Mapping of the changes in the area over the years by carrying out Land Use Land Cover change detection; assessing the statistics of each year (1986, 1999 and 2016) and generating the comparison.

b) Generation of NDVI in order to assess the health status of the vegetation.

c) Carrying out Habitat Suitability analysis of the identified species.

d) Detecting areas where the species (White throated guenons) are concentrated across the park.

e) Successful mapping and measurement of transects along identifiable habitats of the species for population estimation and density.

Prior to the concluded analysis and assessment of the biodiversity status of the park, these processes have to be adopted for sustainable conservation of the species diversity.

Challenges encountered in the course of research

Research on these species must be carried out during dry seasons. This may not be unconnected with the fact that in the dry season, many thickets and vegetation must have been exposed through foliate destination thereby increasing visibility for game viewing, therefore making sighting of wild animals easier, whereas in the wet season the vegetation is usually overgrown, making sighting of wild animals very difficult due to very poor visibility. This was one of the challenges encountered in the course of my research.

Observed activities within the park

Evidence of poaching activity was recorded. The GPS units were also used to map park boundaries and other major features in the area. Using small GPS units, this work is ongoing and provides researchers with the ability to include field observations directly into the GIS. The more encroached areas were those at the edges of the park. This was expected since these parts were closer to human habitations and thus more easily accessible.

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Recommendation

Sequel to the research well conducted at the Okomu National Park, the following recommendations have been reached with supporting findings of this study.

a) Regular population census of Cercopithecus erythrogaster in the park should be conducted in every five years' interval to ascertain the population status of Cercopithecus erythrogaster for effective management policy.

b) The Park should improve the research Department through appointment of more wildlife experts and procurement of biological equipment so as to provide useful data and information on the existing wildlife species and their habitats which could serve as baseline information for adequate management.

c) Illegal activities in the park such as logging, farming, encroachment, wildlife habitat destruction by certain industries like; Osse rubber, Okomu oil and Iyayi Rubber companies should be totally discouraged as soon as possible so as to preserve the existing population of flora and fauna resources.

d) The park should encourage the establishment of more anti-poaching units especially along park boundaries for effective monitoring.

e) The park should always encourage the protection staff of the park through regular review of anti-poaching patrol allowance; training and retraining of park staff on modern park patrol techniques, to enable them detect and control activities of poachers in the park.

f) It is also very important for the park authority to establish a very good relationship with all the local communities adjoining the park boundaries such as Iguowan, Mile-3, Nikorogha, Udo, Ugolo, Okosa, Okomu-Ijaw, Ugbo, AT and P camp, Aiguobasimwin and Etete so that these communities could support the conservation efforts of the park.

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