Forest Canopy Cover Assessment and Tree Benefits in Okomu National Park, Nigeria

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Original Research Article

ABSTRACT

The functions and benefits of forest canopy cannot be over-emphasized. Hence, there is need for the assessment of forest canopy cover and tree benefits in Okomu National Park, Nigeria. Assessment of different land cover types, quantification of forest trees and the environmental services they provided and lastly, the monetary value of environmental services provided by the forest was estimated. The Okomu National Park shapefile was used to determine the 'Define Project Area' tool and Google Mapmaker to determine and cross reference boundary. An i-Tree Canopy software was used to analysis tree canopy coverage throughout Okomu National Park, Nigeria. This study derived eight (8) specific categories of tree canopy data which includes annual benefits based on canopy cover percentages. The categories include: carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter less than 2.5 microns (PM2.5), sulfur dioxide (SO_2), particulate matter greater than 2.5 microns and less than 10 microns (PM10*), carbon dioxide sequestered annually in trees (CO_2seq) was 369,974.94T, while carbon dioxide stored in

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trees) CO_2stor) (not an annual rate) was 9,291,459.06T. Carbon monoxide (CO) has the least amount in tonnes with 33.33T. The particulate matter category less than 2.5 microns (PM2.5) which has less quantity had more monetary value (USD523,66835) than particulate matter greater than 2.5 microns and less than 10 microns (PM10*) with monetary value of USD183,90714.

Keywords: Environmental services; i-Tree canopy; sequestration; particulate matter.

1. INTRODUCTION

Forest is defined internationally as "land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees that are able to reach these thresholds in situ" [1]. According to [2], it constitutes the largest terrestrial ecosystem with a robust capacity to provide a variety of services and functions. In developing countries, there is so much pressure from deforestation and degradation on forests due to heavy dependence on forest products their sources for livelihoods [3]. Therefore, this unprecedented pressure to convert forests into land for food production to support the increasing human population has adversely affected tree canopy cover over the years. Canopy cover defined as 'the proportion of the forest floor which is covered by the vertical projection of the tree crowns, so that only the gaps between individual crowns are observed [4]. As been explained in biology, canopy cover is the aboveground portion of a plant community or crop, formed by the collection of individual plant crowns [5,6,7]. Forest canopy is very important because it is one of the chief determinants of the microhabitat within the forest. It affects plant growth and survival, hence determining the nature of the vegetation, and wildlife habitat [8].

Periodic assessment of changes in the forest canopy cover (CC) is critical in the monitoring of forest areas because CC is the main criterion in the international definition of forest [8]. Quantifying tree canopy cover has been identified by many authors [9,10,11] to be one of the first steps in the management of the urban forest. Unfortunately, there are considerable uncertainties in undertaking estimates of a tropical forest area and its changes [9]. This explains why this study is very important and apt. The benefits of forests and trees in the lives of many people appears obvious through the many uses made of tree products, including foods, medicines, fodder, fibres, fuels, for construction, fencing and furniture [12]. Indeed, forests and other tree-based production systems such as agroforests have been estimated to contribute to the livelihoods of more than 1.6 billion people worldwide [13]. Microclimate regulation by trees in agroforestry systems, such as through the provision of a canopy that protects crops from direct exposure to the sun (reducing evapotranspiration), from extreme rainfall events and from high temperatures, can also promote more resilient and productive food-cropping systems [14]. One of the major services that forests offer is carbon sequestration; approximately 2.5 billion tons carbon is absorbed annually [15]. About 12% of the total anthropogenic carbon emissions come from deforestation [16]. Notwithstanding the contributions of forests to carbon sequestration, much of the world's forests, particularly tropical forests, are suffering from severe deforestation and degradation, contributing to increased carbon emission [17]. In order to accurately quantifying the amount of CO_2 by sink and source, reliable forest area and canopy cover estimations is very important [18]. This is considered against the backdrop of [19] revelation, that information on forest area and deforestation in tropical countries is highly uncertain, often up to 50% of error. This could be attributable to lack of technical capacity and lack of both trained human power as well as infrastructure amongst developing tropical countries. In such situations, when and where there are technical in-efficiencies, it would be important to critically scrutinize and choose the most feasible methods and technologies [19]. It is pertinent to state that, digital image classification and mapping methods in general require a high level of technical skill, and technical software [20]. The deployment of geospatial technologies in assessing forest canopy underscores the need for the further reduction of uncertainties of the estimates [21].

Conventional field measurement of canopy cover is labour intensive, time consuming and very expensive. In addition, many tropical forest areas are very difficult to access during fieldwork. This explains why there are some platforms for free and open source software such as Geo-Wiki, VIEW-IT, Sky Truth and i-Tree Canopy, developed by different bodies, including

academic institutions to enhance the monitoring of canopy cover [22]. Reference data gathered using satellite imagery with different spatial resolutions under different forest conditions has been used to provide forest area and forest cover change estimates [23]. FAO for instance, designed a software system called Collect Earth as an open source tool that helps to collect, analyze and compile reports on LULC through visual image interpretation based on freely available satellite images mainly with the Google Earth platform [20]. Of all the open source software platforms, i-Tree Canopy software was used in this work because if its versatility and user-friendly capabilities. Thus, the aim of this study was to assess the forest canopy cover status and Tree Benefits of Okomu National Park, Nigeria.

1.1 Objectives

The specific objectives of the study are to:

i.   Assess the different land cover types of Okomu National Park,
ii. Quantify forest trees and the environmental services they provide and
iii. Estimate the monetary value of environmental services provided by the forest.

2. MATERIALS AND METHODS

2.1 Study Area

The Okomu National Park, formerly the Okomu Wildlife Sanctuary is one of the richest park in Nigeria, is a forest block within the 1,082 km² Okomu Forest Reserve in the Ovia South-West Local Government Area of Edo State in Nigeria. The distance of the park is 60 km North West of Benin City [24]. The park holds a small fragment of the rich forest that once covered the region, and is the last habitat for many endangered species because of its richness. Overtime, the park has been experiencing decrease as villagers begin to encroach on it for farming activities, and also increase in population. The size is now less than one third of its original size [25]. These annual estimates are based on values in lbs./acre/yr. and \$/T/yr.; carbon dioxide storage is a total biomass amount.

2.2 Environment

The Osse River defines the eastern boundary of the park [12], while Okomu River forms the western boundary [24], The range of Rainfall is between 1,524 and 2,540 mm per year [26,27], the 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 species are *Kapok, Celtis zenkeri, Triplochiton scleroxylon, Antiaris africana, Pycnanthus angolensis and Alstonia congoensis* among others [28]. The park is probably the best example of mature secondary forest in southwest Nigeria [29].

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 [30]. Visitors can stay at chalets built on stilts, just outside the park entrance, surrounded by fig trees that are often occupied by Mona monkeys [25]. Guides are available for forest walks, and will point out such things as termite nests and the many medicinal plants [31].

2.3 Methods

An i-Tree Canopy software was used to analysis tree canopy coverage throughout Okomu National Park, Nigeria.

There are three (3) steps employed in the assessment of forest cover namely;

1. Determining boundary outlines
2. Defining land cover class descriptions
3. Accurately identifying point data during analysis

2.4 Determining Boundary Outlines

The Okomu National Park shapefile was used to determine the 'Define Project Area' tool and Google Mapmaker to determine and cross reference boundary.

2.5 Defining Land Cover Class Descriptions

Tree, non-tree and water were the cover class data captured. This is due to the nature of the National Park.

2.6 Accurately Identifying Point Data during Analysis

The i-Tree Canopy program determines cover class percentages through random pin point
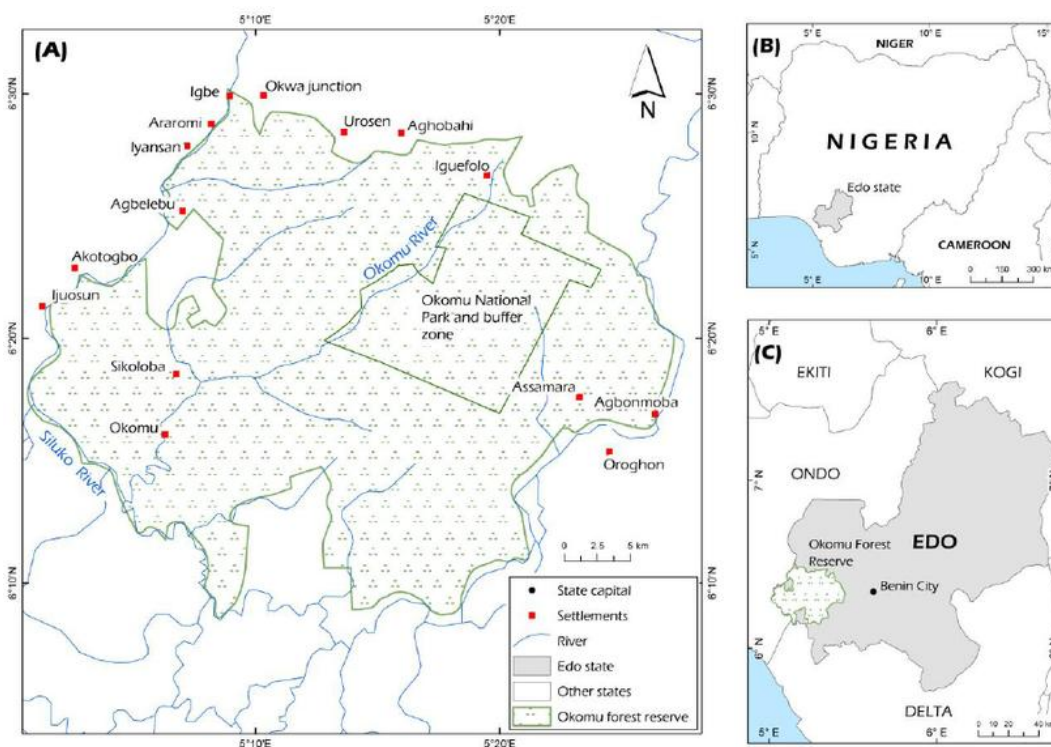
Fig. 1. Okomu National Park, Nigeria

detections overlaid on top of current Google Maps satellite imagery. Two hundred and ninety four (294) points were randomly defined for a statistically significant cover class characterization. For quality and standard estimation, the increase in the number of points, so the precision of the percentage estimate will increase as the standard error will decrease.

Calculating standard error and confidence internals from photo-interpreted estimates of tree cover. The i-Tree Canopy software includes detailed instruction on the science behind using photos to estimate tree cover percentages. In photo-interpretation, randomly selected points were laid over aerial imagery and an interpreter classifies each point into a cover class.

From this classification of points, a statistical estimate of the amount or percent cover in each cover class was calculated along with an estimate of uncertainty of the estimate (standard error (SE)). Out of 294 points been interpreted and classified in the study area as tree, non- tree and water. This served as a means to ascertain the tree cover within that park, 282 points were classified as tree, while, non-tree and water classification were 9 points and 3 points respectively.

3. RESULTS AND DISCUSSION

The results below showed the analysis of different land cover types, the environmental services they provide and estimation of the monetary value of environmental services provided by the forests in Okomu National Park, Nigeria.

3.1 Standard Error (SE)

To calculate the percent tree cover and SE, let: N = total number of sampled points (294) n = total number of points classified as tree (282), and p = n/N (i.e., 282/294 = 0.96) q = 1 – p (i.e., 1 - 0.96 = 0.0.04) SE = $\sqrt{(pq/N)}$ (i.e., $\sqrt{(0.96 \times 0.04 / 294)}$ = 0.0113) Therefore, tree cover in the study area was estimated at 96% with a SE of 1.13%. Based on the SE formula, SE is greatest when p=0.5 and least when p is very small or very large.

3.2 Canopy Cover Percentage

From the analysis in Fig. 2, the data revealed a canopy cover percentage for different cover class in Okomu National Park. The cover class categories include tree, this includes all tree

categories, while non-tree are all other surfaces except water, and water include any types of water. The tree category has a total percentage of 96% with 288 points, followed by water 9 points with 3%, and non-tree 3 points with 1%. Based on the purpose of the National Park for both flora and fauna conservation, the amount of canopy cover was much felt on the tree cover class. This information is both intuitive and revealing. The National Park exhibit high levels of canopy cover. Though, there are some areas with low forest density, while some areas are already reaching climax. In both cases, regeneration is important. There is need for proper maintenance of the forests to achieve better advantage over the benefits that tree canopy cover affords.

This study derived eight (8) specific categories of tree canopy data which includes annual benefits based on canopy cover percentages. The categories include: carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter less than 2.5 microns (PM2.5), sulfur dioxide (SO_2), particulate matter greater than 2.5 microns and less than 10 microns (PM10*), carbon dioxide sequestered annually in trees (CO_2 seq) was 369,974.94T, while carbon dioxide stored in trees) CO2stor) (not an annual rate) was 9,291,459.06T. Carbon monoxide (CO) has the least amount in tonnes with 33.33T.

The particulate matter category less than 2.5 microns (PM2.5) and particulate matter greater than 2.5 microns and less than 10 microns (PM10*) was compared in terms of quantity and monetary value. The particulate matter category less than 2.5 microns (PM2.5) was 87.94T compared to particulate matter greater than 2.5 microns and less than 10 microns (PM10*) with 606.23T. However, the quantities in tonnes did not in tandem with monetary values. The particulate matter category less than 2.5 microns (PM2.5) which was less in quantity had more monetary value (USD523,66835) than particulate matter greater than 2.5 microns and less than 10 microns (PM10*) with monetary value of USD183,90714.

The air pollutants were also quantified in tonnes as stated in Fig. 2. The i-Tree Canopy tool provides annual amount of air pollutants removed through dry deposition process by trees and associated monetary values. The air pollutants considered and estimated are six criteria pollutants as defined by the U.S. Environmental Protection Agency (EPA); carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2) and particulate matter (PM), which includes particulate matter less than 2.5 microns (PM2.5) and particulate matter greater than 2.5 and less than 10 microns (PM10*).

Cover class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	282	95.9±1.15
Non-Tree	All other surfaces	NT	3	1.02±0.59
Water	Any type of water	W	9	3.06±1.02
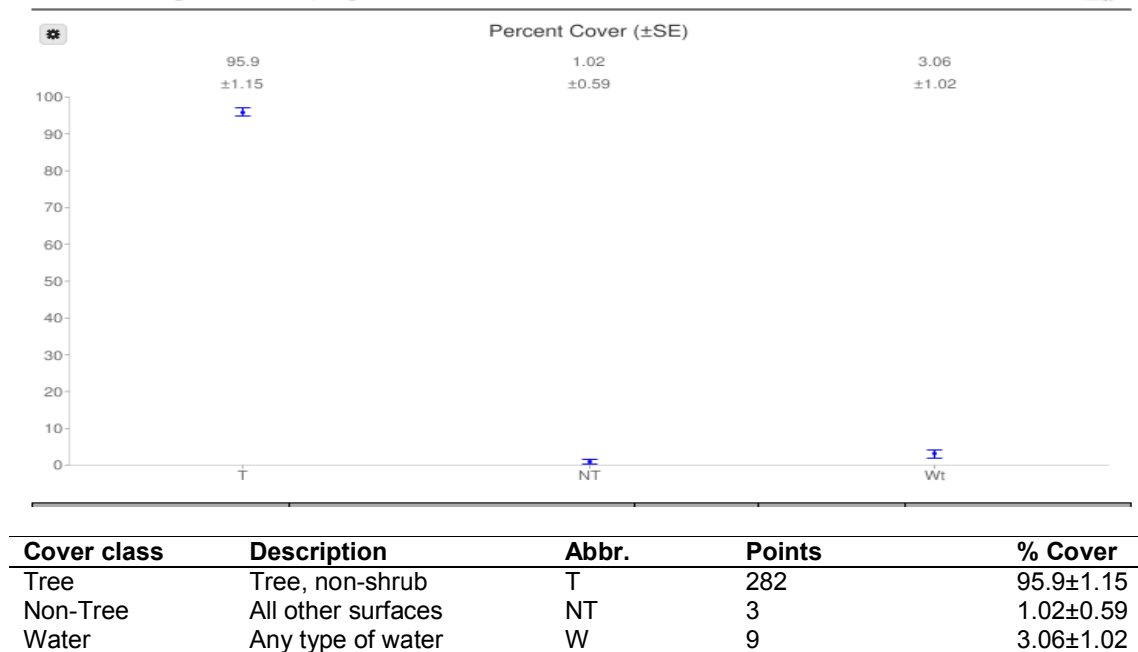
Fig. 2. Percent cover class of Okomu National Park, Nigeria

$$y = -136.5x + 371$$
$$R^2 = 0.7335$$
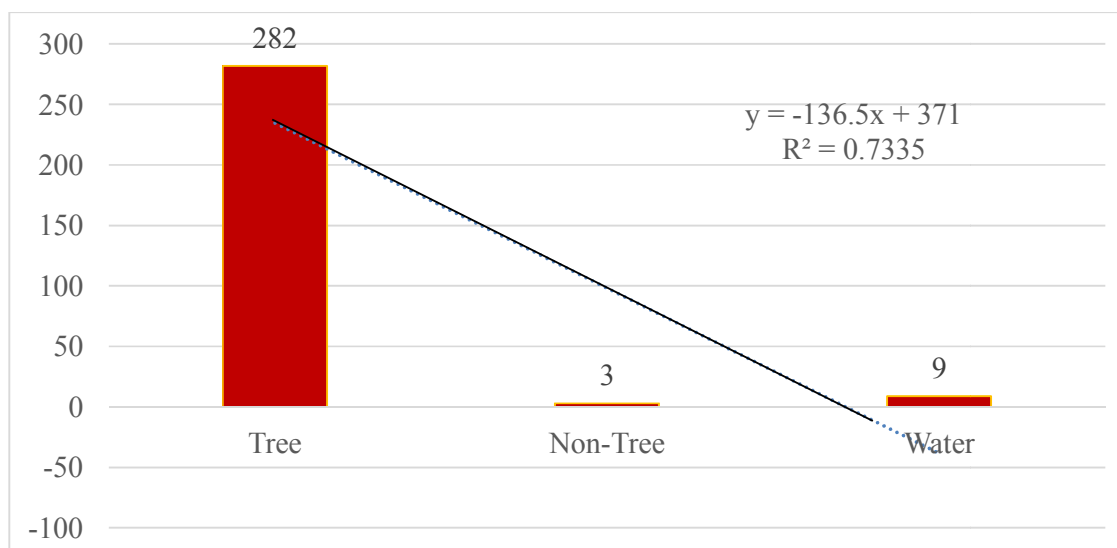
Fig. 3. Linear regression percent cover in Okomu National Park, Nigeria

Land Cover (km² ±SE)

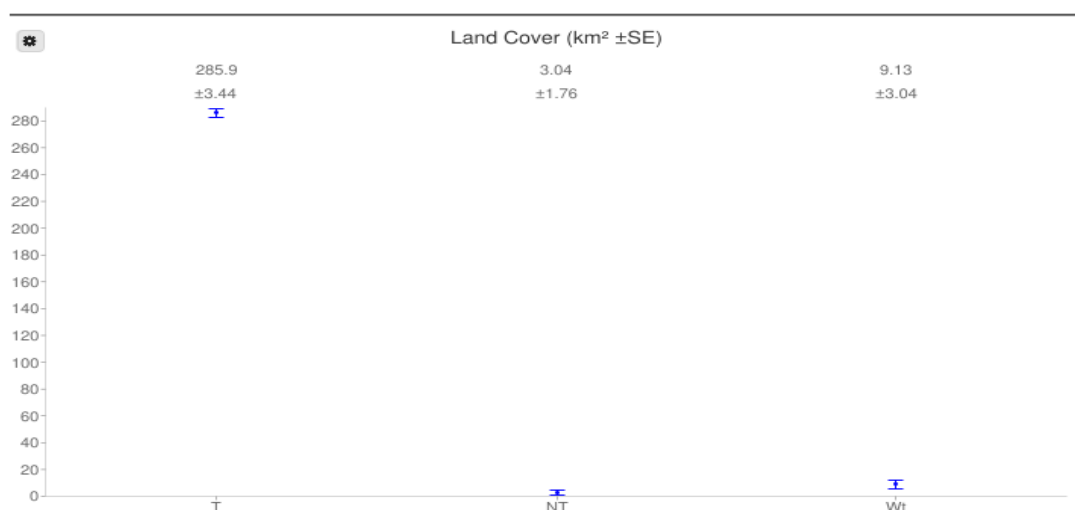| Cover class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	282	285.9±3.44
Non-Tree	All other surfaces	NT	3	3.04±1.76
Water	Any type of water	W	9	9.13±3.04

Fig. 4. Land cover estimated in area in Okomu National Park, Nigeria

3.3 Tree Benefits Estimates

The tree canopy data estimated at the study area includes annual benefits based on canopy cover percentages for eight specific categories. These includes carbon monoxide that was removed annually (CO), nitrogen dioxide removed annually (NO_2), ozone removed annually (O_3), particulate matter less than 2.5 microns removed annually (PM2.5), sulfur dioxide removed annually (SO_2), particulate matter greater than 2.5 microns and less than 10 microns removed annually (PM10*), carbon dioxide sequestered annually in trees (CO_2seq), and carbon dioxide stored in trees) CO_2stor) (not an annual rate). These annual estimates are based on values in lbs./acre/yr. and $/T/yr.; carbon dioxide storage is a total biomass amount.

Table 1. Air pollutants and derived estimation of tree benefits

Abbr	Benefit description	Valus (USD)	±SE	Amount	±SE
CO	Carbon monoxide removed annually	2,825.43	0.00	33.33T	0.00
NO$_2$	Nitrogen dioxide removed annually	4,864.33	0.00	181.72T	0.00
O$_3$	Ozone removed annually	253,324.60	0.00	1,809.85T	0.00
PM2.5	Particulate Matter less than 2.5 microns removed annually	523,668.35	0.00	87.94T	0.00
SO$_2$	Sulphur dioxide removed annual	850.19	0.00	114.52T	0.00
PM10*	Particulate Matter greater than 2.5 microns and less 10 microns removed annually	183,907.14	0.00	606.23T	0.00
CO$_2$Seq	Carbon dioxide sequestered annually in trees	17,147,324.78	0.00	369,974.94T	0.00
CO$_2$stor	Carbon dioxide stored in trees (note: this benefit is not an annual rate)	430,633,665.91	0.00	9,291,459.06T	0.00

The i-Tree Canopy tool provides annual amount of air pollutants removed through dry deposition process by trees and associated monetary values. The air pollutants estimated are six criteria pollutants defined by the U.S. Environmental Protection Agency (EPA); carbon monoxide (CO), nitrogen dioxide (NO$_2$), ozone (O$_3$), sulfur dioxide (SO$_2$) and particulate matter (PM), which includes particulate matter less than 2.5 microns (PM2.5) and particulate matter greater than 2.5 and less than 10 microns (PM10*). The default values (the multipliers) of air pollutant removal rates (gm-2 yr-1) and monetary values ($m-2 yr-1) for a unit tree cover were derived from i-Tree Eco analyses in the conterminous United States in 2010 (Nowak et al. in review). Three analyses were conducted;

1) Derivation of the total tree cover, evergreen percentage and leaf area index,
2) Estimation of air pollutant removals and concentration changes, and
3) Valuation of air pollutant removals.

4. CONCLUSION

These analyses were performed in Okomu National Park, Nigeria. This was then aggregated into the national-level values. i-Tree Canopy currently uses the national-level multipliers to estimate annual air pollutant removals and associated monetary values.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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