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Geo-Economic Assessment of Tropical Rainforest Tree Ecosystem Service Functions and the Anthropogenic Willingness-To-Pay for its Conservation

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Abstract:- Ecosystem services are the many and varied benefits that humans freely gain from the natural environment and from properly-functioning ecosystems. The main objective of this research was to assess the tree cover distribution, ecosystem service awareness and value to respondents within the study area.

The tree cover assessment was implemented using the ISODATA classification of the MOD44B product sourced from the LPDAAC archives. The ecosystem service awareness was assessed using simple percentage distribution and a normalized Likert scale. The WTP characteristics of respondents were assessed using a simple percentage analysis and a double-bonded contingent valuation analytical approach.

The results showed that the percentage of tree cover within the study area ranged from 10% to 66% tree cover. The average tree cover within the study area was ≈ 15%. Approximately 13.1% of the state had some form of percentage tree cover. The assessment of the tree ecosystem service awareness among respondents within the study area showed knowledge of the existence of these services and a high level of conversance with the various forms. The WTP characterization shows that 85% of the respondents were willing to pay for the retention and regeneration of trees within their immediate environment.

Keywords:- *Remote-Sensing; Tree-Cover; Landmass; Ecosystem-Services; Willingness-to-Pay.*

I. INTRODUCTION

Forest Cover refers to all lands more than one hectare in area, with a tree canopy density of more than 10 per cent irrespective of ownership and legal status (Okojie, 2017; The Club of Rome, 2014). Such lands might not essentially be a recorded forest area. This includes orchards, bamboo and palm groves (data.gov.in, 2015). Tree cover consists of tree patches outside the recorded forest area apart from forest cover and which is less than the minimum mappable area (1 ha). Tree cover which is defined structurally as the proportional and vertically projected area of vegetation (including leaves, stems, branches, etc. of woody plants) beyond a given height affects terrestrial energy and water exchanges, photosynthesis and transpiration, net primary production, carbon and nutrient fluxes (Feng, Sexton, Channan and Townshend, 2017). Tree cover also provides a measurable feature upon which forest cover may be defined. Variations in tree cover over time can be used to monitor and retrieve site-specific accounts of forest disturbance, succession, and degradation (Anderson-Teixeira et al., 2015).

The accessibility and widespread use of remotely-sensed imagery make it simple to evaluate a site and quantify tree canopy cover density without visiting the site (Jiang et al., 2016). Remotely-sensed tree canopy cover density has become the principal criterion for urban forestry conventions in many countries (Tigges, Churkina, and Lakes, 2017). Measurements of global tree canopy cover have been produced at varying scales. However, most of these depictions are static, and those possessing multiple time are neither intended nor sufficient for consistent, long-term monitoring (Feng et al., 2017). Moreover, although a considerable part of the change has been shown to occur at resolutions below 250 m (ground sampling distance of 6.25Ha), current long-term, Landsat-resolution datasets are either produced as static layers or with annual and five- or ten-year temporal resolution (Hansen and Loveland, 2012).

Ecosystem services are the numerous and diverse benefits that humans freely gain from the natural environment and from properly-functioning ecosystems (Barnaud and Antona, 2014; Kull, Arnauld de Sartre and Castro-Larrañaga, 2015). While scientists and environmentalists have deliberated ecosystem services unreservedly for decades, the Millennium Ecosystem Assessment (MA) in the early 2000s popularized the concept (Millennium Ecosystem Assessment Program, 2005). There, ecosystem services are grouped into four broad classes namely provisioning functions, such as the production of food and water; regulatory functions, such as the control of climate and disease; supportive functions, such as nutrient cycles and oxygen production; and cultural functions, such as spiritual and recreational benefits.

In order to aid in informing decision-makers about these services, ecosystem services are being ascribed economic values. In figure 1 below is a conceptual diagram explaining ecosystem services and their interactions with the various aspects of human wellbeing.

The main objective of this research was, therefore, to assess the tree cover distribution, ecosystem service awareness, and value to respondents within the study area. Specifically, this research sought to assess the tree cover distribution within Ogun State, assess the ecosystem service awareness of respondents within Ogun State and assess the ecosystem service value of trees within Ogun State, Nigeria.

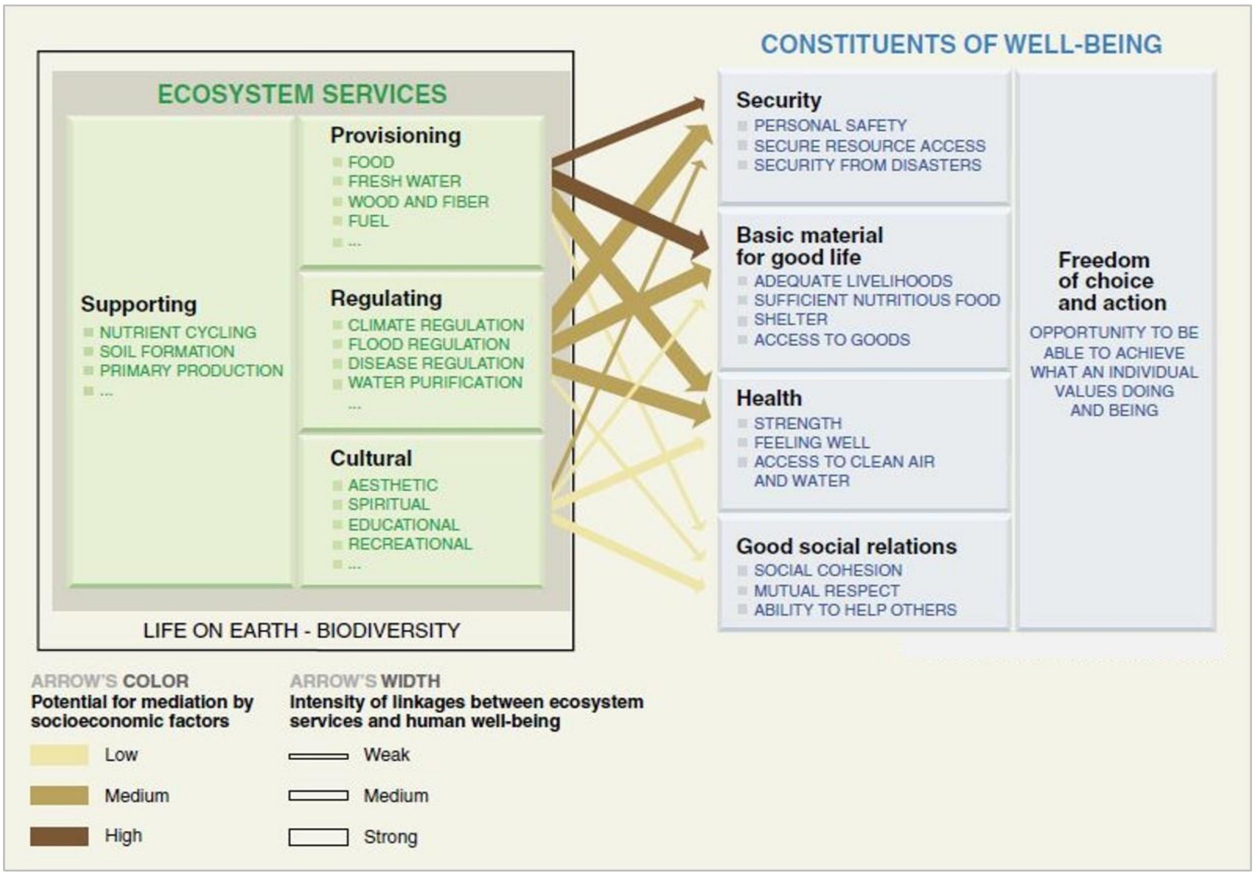

Fig 1:- Conceptual Diagram, Source; Millennium Ecosystem Assessment, 2005

II. MATERIALS AND METHODS

A. Study Area

➢ *Geolocation*

According to the Ogun State Government (2019), Ogun state was created on the 3rd day of February 1976. It was extracted from the old Western Region of Nigeria and named after the Ogun River which runs across it from North to South. The state is bordered to the East by Ondo State, North by Oyo and Osun States and South by Lagos State and the Atlantic Ocean and West by the Republic of Benin. Abeokuta which is the capital and largest urban centre is about 90 kilometres from Lagos State (Ogun State Government, 2019).

➢ *Demography*

Ogun State is populated predominantly by the Egbas, Ijebus, Yewas, Remos and Aworis belonging to the Yoruba ethnic group. It also has minority groups such as the Ketu, Ikale, Ilaje, Ohori, Anago and Egun. There is also a significant amount of Nigerians from other parts of the country besides foreign nationals (Ogun State Government, 2019).

➢ *Climate*

This area is classified as **Aw** (Tropical savanna climate with non-seasonal or dry-winter characteristics) by Köppen and Geiger. The temperature here is on average 27.1 °C. Precipitation is on average 1238 mm. The least amount of rainfall occurs in January with an average of 13mm. In June, the precipitation reaches its peak, with an average of 197 mm. The temperatures are highest in March, at about 29.1 °C. At 25.1 °C on average, August is the coldest month of the year. The variation in the precipitation levels between the driest and wettest months varies at 184 mm. The variation in annual temperature is approximately 4.0 °C (Climate-Data, 2017).

➢ *Vegetation*

In terms of vegetation, the state can be divided into three distinctive zones. Where the state shares a boundary with the Atlantic Ocean, the vegetation is of a swampy type with mangroves and other edaphic trees. There is also rainforest vegetation in some section of the state while the state capital (Abeokuta) and some areas are characterized by derived forest vegetation, having been altered by human activities (Solanke, 2015).

B. Datasets and Datasets Description

During the course of this work, both secondary and primary data were utilized. The secondary data was utilized in the first phase of the research. This comprised of MODIS/Terra remote sensing imagery sourced from the Land Processes Distributed Active Archive Center (LPDAAC). The MOD44B Version 6 Vegetation Continuous Fields (VCF) product which was used is a global depiction of surface vegetation cover as progressions of three ground cover components namely per cent tree cover, per cent non-tree cover, and per cent non-vegetated ("LP DAAC," 2017). VCF products provide a constant, quantifiable representation of land surface cover at a 250-meter pixel spatial resolution, with a sub-pixel depiction of per cent cover in reference to the three ground cover components (Dimiceli, et al., 2015).

Primary data was utilized for the second phase of the research which encompassed both the respondents' socioeconomic characterization and tree ecosystem service perception and valuation. This dataset was generated from fieldwork using semi-structured questionnaires. This data, among others, had a socioeconomic aspect, ecosystem service awareness aspect and a dichotomous choice-contingent valuation modelling (DC-CVM) aspect.

C. Sampling Design

The sampling design adapted to fulfil the second phase of this research was a multi-stage sampling design incorporating Stratified, Purposive and Random sampling techniques at the various (3) stages.

The first stage involved the stratification of the study area based on the percentage of tree cover per unit area. Due to the large area to be covered and data availability, the smallest unit area considered for the percentage tree cover determination was 6.25ha. This produced 5 distinct strata. The second stage involved the purposive selection of 5 inhabited locations in close proximity to forested areas within each of the identified strata. The third stage involved the random selection of 60 respondents from each selected location. In total, the sampling size was 1200 respondents. The sampling intensity was 0.02% of the projected population of Ogun State.

D. Analytical Approach

- The stratification of the study area into the various percentage tree cover classes was done by implementing an equal interval value range classification on the LPDAAC acquired MODIS imagery within the ArcMap 10.6 working environment. This process outputted a classified/stratified image which served as the basis for the second phase of data collection and analyses.
- Socioeconomic characterization of the respondents was done by dis-aggregating each socioeconomic indicator into classes and then describing the relative prevalence of each class using percentage distributions.
- The perception of the ecosystem services was assessed using a normalized likert scale ramped between 0 and 1 wherein the relative magnitude of awareness improved as the perception level approached the upper limit of the scale, 1.

❖ NLS = $\sum Xi / X_{max}$

Where,

NLS = Normalized Likert Score

X_i = Individual awareness score for each ecosystem service

X_{max} = Maximum possible score for each ecosystem service

- The willingness-to-pay (WTP) for ecosystem service retention and regeneration was assessed using;

❖ Percentage Assessment; y = $\frac{\sum Yi}{n} x\ 100$

x = $\frac{\sum Xi}{n} x\ 100$

Where,

y = Percentage of respondents willing to pay for eco-service retention and regeneration

x = Percentage of respondents unwilling to pay for eco-service retention and regeneration

Yi = Respondents willing to pay for eco-service retention and regeneration

Xi = Respondents unwilling to pay for eco-service retention and regeneration

n = Sample Size

❖ Following the approach of Hanemann (1984), Hanley, et al., (2016) and Okojie (2014), the DC-CVM that terminated into a logit model was used to derive the coefficients of the bid and socioeconomic covariates through the maximum likelihood estimation approach (Hanemann, 1984; Hanley, et al., 2016; Okojie, 2014). This assessment as conceptualized through the Willingness-To-Pay (WTP) from the farmers' perspective is as derived from the following models:

$$Li = \frac{1}{[1 + e^{-(\alpha+\beta x_i)}]}$$

Where:

Li = Respondent acceptance probability to the bid offered.

βi = Vector representing the coefficients of all covariates.

Xi = Vector representing all covariates

The covariates are as follows:

X_1 = Bid, X_2 = Sex, X_3 = Age, X_4 = Household size, X_5 = Level of education, X_6 = Income, X_7 = Marital Status (Yes = 1; No = 0)

The Cooper and Loomis (1992) procedure for the determination of mean WTP is as follows (Cooper & Loomis, 2006):

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$P^- = 1/|\beta|*\ln(1+\exp a)$ …………………. (2)

Where:
a = Intercept, β = Coefficient of bid &P- = Restricted mean WTP.

III. RESULTS AND DISCUSSION

The geospatial analysis of percentage tree cover within the study area showed it ranges from 10% to 66% tree cover. The average tree cover within the study area was ≈ 15% with a standard deviation of 8.63%. The output of the image classification was 4 tree cover classes and 1 non-tree cover class. These are 0% tree-cover, 0% to 20% tree-cover; Class 1, 20% to 40% tree-cover; Class 2, 40% to 60%; Class 3 and 60% to 80% tree-cover; Class 4. The prevalent class within the study area was the first and lowest tree density class i.e. 0% to 20% tree-cover class (coded red on figure 1). It covered a land area of 1504.99 km^2 (150,499 Ha). This was approximately 9% of the total land area of the state. In total, 13.1% of the state had some percentage tree cover. Figure 2 also showed a downward trend in land area coverage with an increase in percentage tree-cover. This implies that the higher percentage of tree cover is now very limited in occurrence.

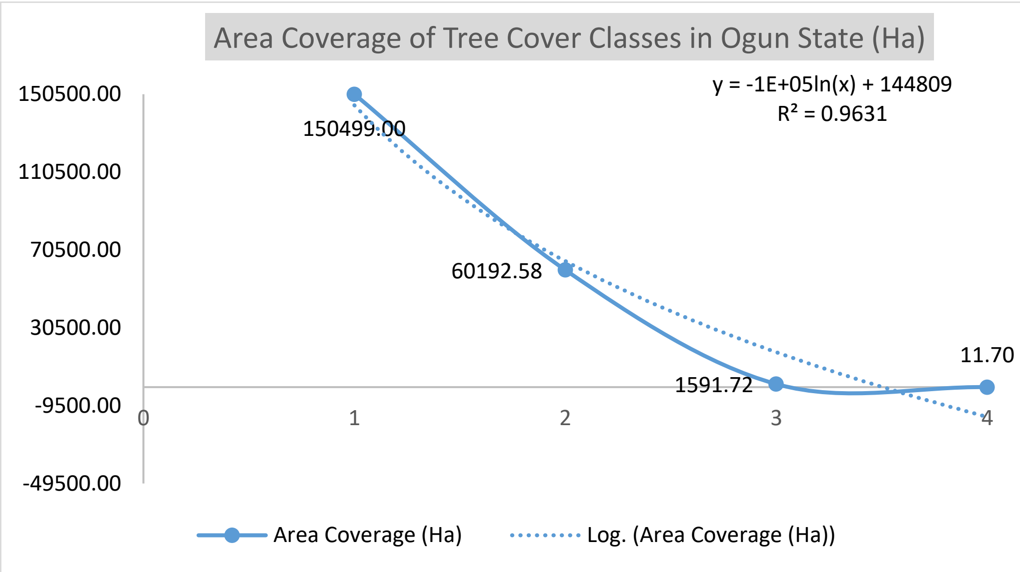

Fig 2:- Area Coverage of Forest Percentage Tree Cover Classes, Source; Data Analyses, 2019

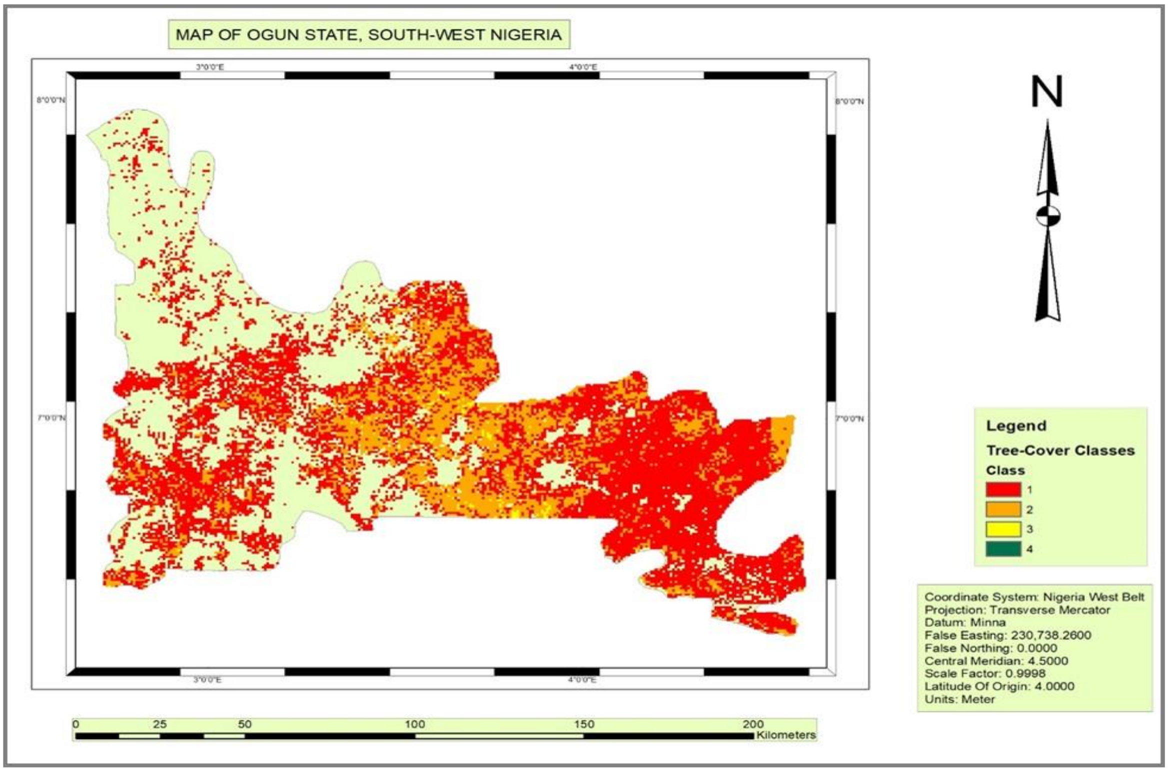

Fig 3:- Tree Cover Density within the Study Area, Source; Data Analyses, 2019.

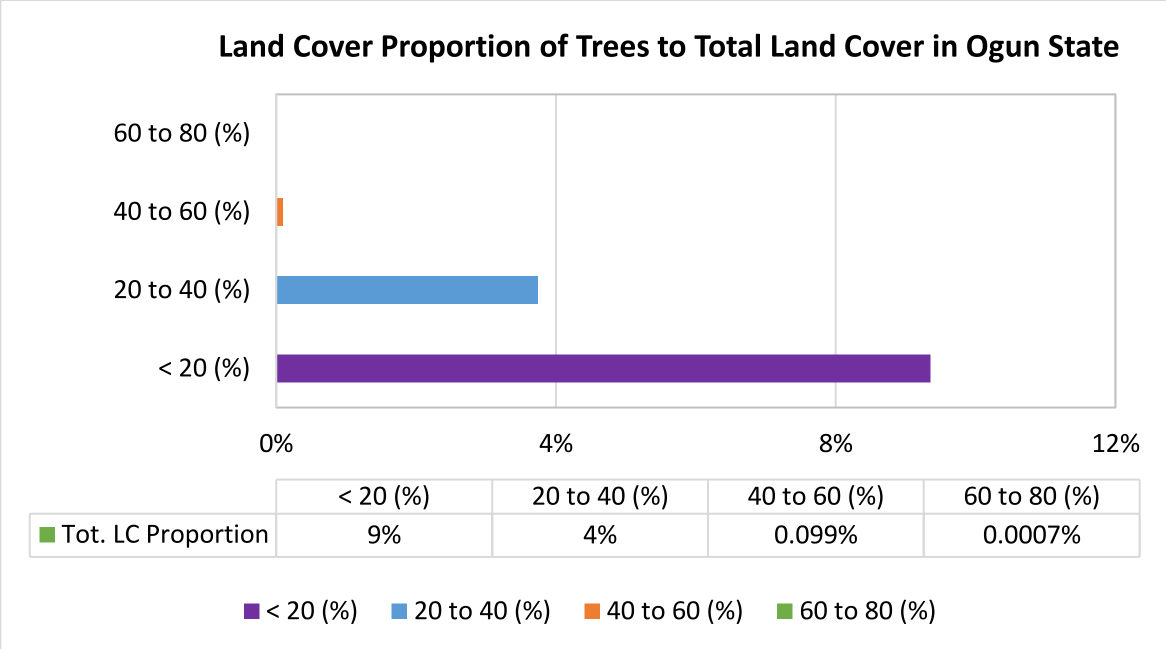

Fig 4:- Tree Cover Proportion to Total Land Area in Ogun State, Source; Data Analyses, 2019.

The assessment of the tree ecosystem service awareness among respondents within the study area showed, not just a knowledge of the existence of these services, but also a high level of conversance with their various forms. The awareness levels ranged from 50% to 98% awareness for the 10 functions outlined during the field survey, aggregating into a pooled average of 79%. The functions the respondents were most conversant with were shade provision (98%), recreation (95%), biodiversity conservation and wind-breaking (both at 91%). The function respondents were least aware of was the water-shedding function of trees (50%).

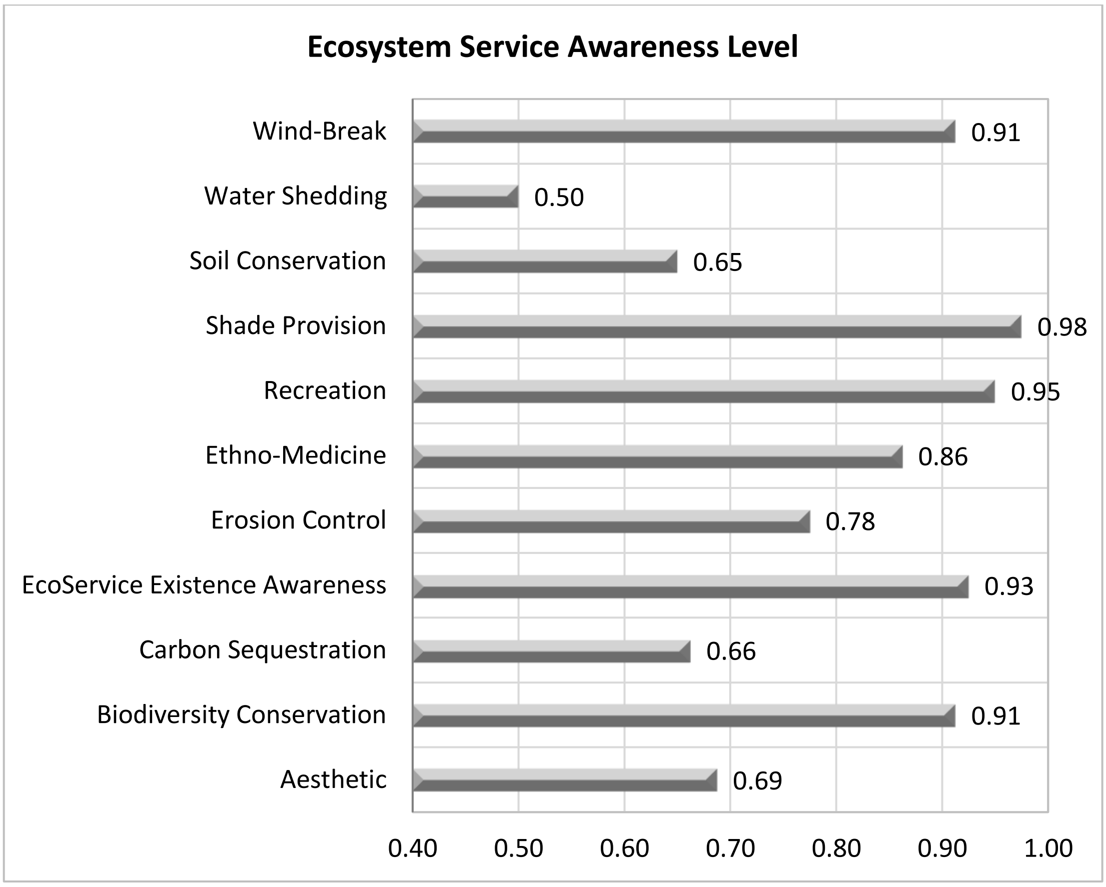

Fig 5:- Respondents' Tree Ecosystem Service Awareness, Source: Field Data Analyses, 2018.

A pilot survey was conducted to determine the bid value range of respondents within the study area. The initial bid value range was determined to be between ₦5 and ₦20000. Pre-Analyses however, showed the presence of extreme outliers within the raw field data. Hence, a multiphase cluster analysis was adopted to determine the true bid value range of respondents and the results showed that the true bid range was between ₦5 and ₦300. However, the exclusion of bid values between ₦300 and ₦500 created a downward skew in the bid value data, so these were retained and the eventual bid value range was estimated to be between ₦5 to ₦500 and this is visualized in the boxplot above. This served as input for further field data collection and analyses.

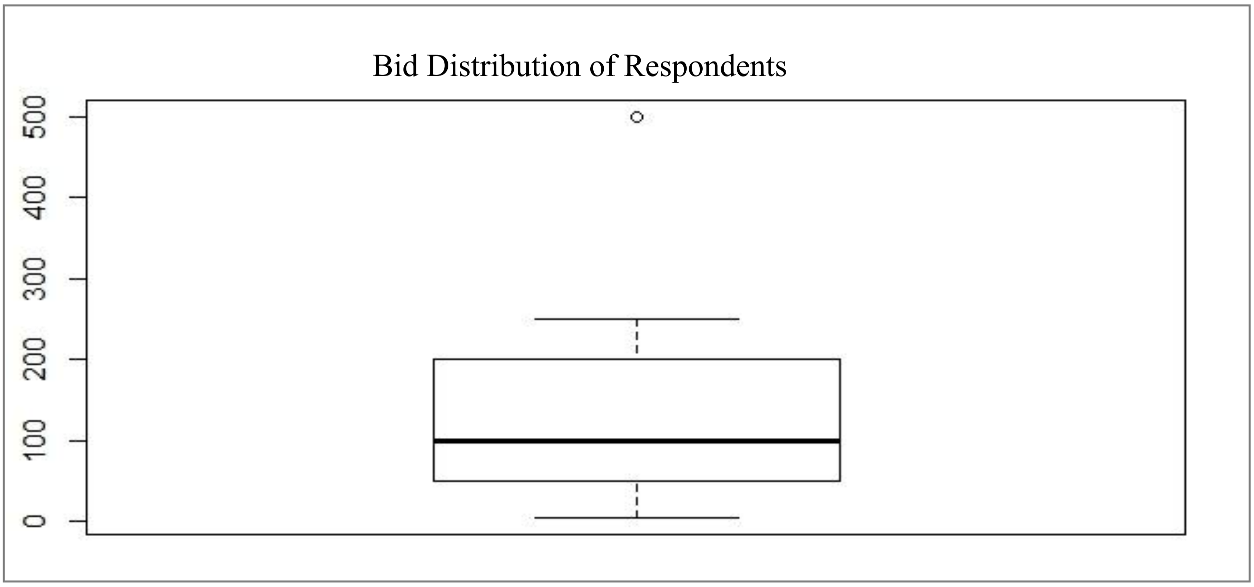

Fig 6:- Bid Value Range of Respondents within the Study Area, Source; Data Analyses (2019).

These WTP results are summarized in figure 8 and Table 1 below. They show that 85% of the respondents were willing to pay for the retention and regeneration of trees within their immediate environment. The mean WTP was inferred to be ₦43:30k per month. This value was projected to the population (5,710,151) yielding a Total WTP value of ₦247,249,527:08 per month. However, budgetary planning is mostly conducted annually which would require an annual value for the whole area. As such the Total WTP value was multiplied by 12 (number of months in a year). This gave an annual Total WTP value of ₦ 2,966,994,325:02k which could potentially be generated by the government in the form of environmental tax to maintain these services.

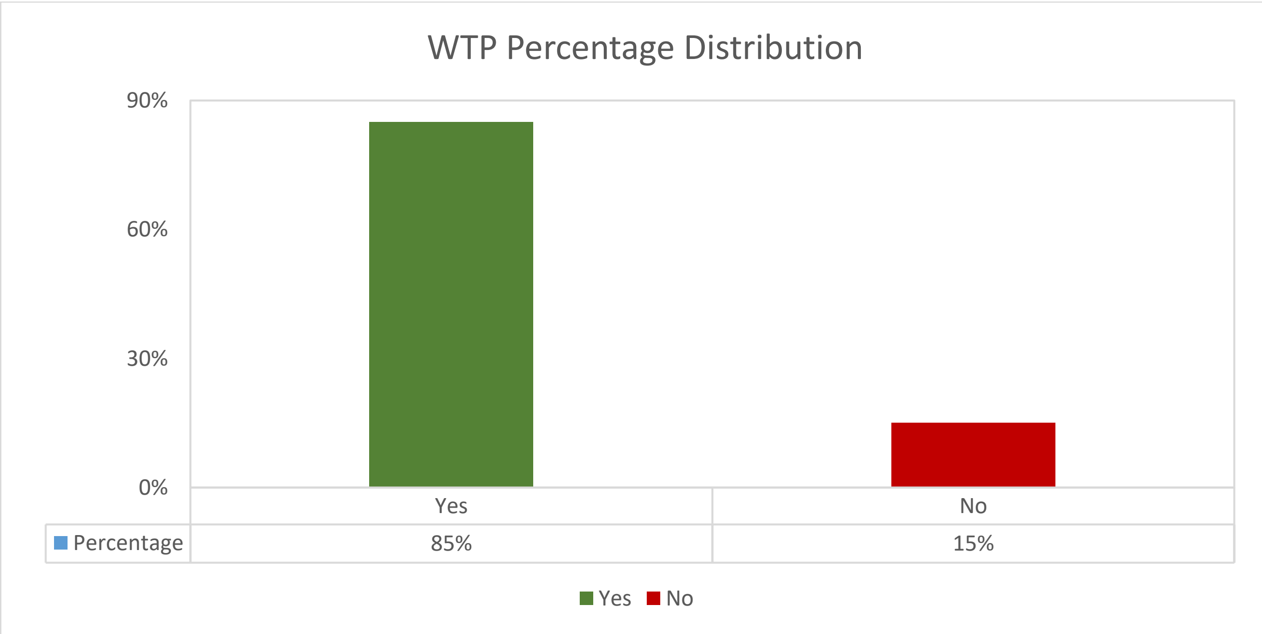

Fig 7:- Willingness-To-Pay Distribution within the Study Area, Source; Data Analyses, 2019.

	Variable	***Value***
Mean WTP/ Month	Intercept	-1.146
	Bid	-0.0063
	Restricted	43.3
Total WTP / Month	Mean WTP	₦ 43:30
	Population	5710150.741
	Total WTP	₦ 247,249,527:08
Annual DC;CVM Variables	Total WTP/Month	₦ 247,249,527:08
	Months in a Year	12
	Contingent Value per annum	₦ 2,966,994,325:02

Table 1:- Dichotomous Choice Contingent Valuation Modelling Matrix
Source; Data Analyses, 2019.

IV. CONCLUSIONS AND RECOMMENDATIONS

From this research, it can be concluded that there is a relatively high level of awareness pertaining to both the ecosystem services of trees and its various categories. Also, WTP results show that the vast majority of the population value the various ecosystem services of trees and are willing to pay for these services to continue to exist in perpetuity. The assessment of the forest area shows that only 13% of the study area exhibited tree presence, 8% of which was sparse indicating that there is very low tree cover percentage and this is of low density.

Also, from the results derived from this research, recommendations are made that future researchers should employ a higher statistical specificity within research conducted into topics pertaining to this field. The desired specificity includes an in-depth review of, not just ecosystem service awareness but also individual ecosystem service preference level in order to rank the ecosystem services on the basis of perceived importance. Also, awareness and preference for each individual ecosystem service should be included within the WTP modelling. An effort should also be made to delve into the effect of spatial proximity to trees (and their attendant services) to the valuation of ecosystem services i.e. include proximity/distance to trees providing the desired ecosystem services within WTP models.

CONFLICT OF INTEREST STATEMENT

This document is been submitted without, to the best of my knowledge, any known conflict of interest.

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