



An Appraisal of Forest Degradation and Carbon Sequestration of Effan Forest Reserve in Kwara State

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An Appraisal of Forest Degradation and Carbon Sequestration of Effan Forest Reserve in Kwara State

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Abstract- This study describes an effort to estimate amount of forest degradation and carbon sequestration for Effan Forest Reserve using remote sensing/GIS techniques. The study adopted 14 sampled plots-simple randomly based method, Remote Sensing –Land Use/Land Cover based method for change detection, Vegetation Difference Normalized Index (NDVI) to determine vegetation reflectance, field data and use of allometric model equation for biomass and carbon sink estimation. The Results revealed that there was decrease in the Gmelina arborea plantation in which so many trees were harvested thereby converting part of the reserve to Sapling/Shrubs (i.e. re-generating part). Despite the fast regenerating capacity of Gmelina arborea, there is increase in the number of Sapling/Shrubs size in the Reserve which is an evidence of forest degradation between 2001 and 2006. The vegetation reflectance also revealed that vegetation reflectance is high in 2001 and is low in 2006 which also confirms an evidence of forest degradation. The total above-ground biomass and carbon sink of the Reserve estimated shows that Standard trees class triples that of Sapling size class. The carbon sequestration capacity is expressed in the following order of magnitude: Standard > Pole > Sapling sized trees. Standard – sized trees have better CO₂ sequestration potential than the Sapling and Pole – sized. However, both had high carbon sequestration potential in the future due to presence of large number of trees belonging to small DBH size classes. Moreover, the forest stand of Effan Reserve has a total sequestration capacity of 40,294.8 metric tons of CO₂.

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1. INTRODUCTION

Forest degradation is broadly defined as a reduction in the capacity of a forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic and environmental changes. The main causes of degradation vary globally, including unsustainable

logging, poor agricultural practices, invasive species, fuel wood gathering, livestock grazing, and wildfire with synergistic effects.

Forest degradation is a widespread global concern and an important contemporary issue for several United Nation (UN) organizations and conventions. These groups include the UN Convention on Biological Diversity (CBD), which set a global target for restoration of at least 15% of degraded ecosystem by 2020 (Convention on Biological Diversity 2010); the UN Forum on Forests that has an objective to reduce Forest degradation; the UN Convention to Combat Desertification (UNCCD) that consider degradation on dry lands; and the UN Framework Convention on Climate Change (UNFCCC) that proposes to recover degraded forests as carbon sinks. Recent climate negotiation have initiated the concept of reducing emissions from deforestation and forest degradation (REDD) to mitigate climate change through forest management, including the restoration of degraded forest (UNFCCC, 2010). Along with deforestation, forest degradation has major consequences for human societies and biodiversity, and significantly contribute to greenhouse gas emissions (Secretariat of the Convention on Biological Diversity 2002, Parry et al. 2007, van der Werf et al. 2009, Mery et al. 2010).

The increased concentration of GHGs in the atmosphere attributes to the change in the world's climate. GHGs destroy the ozone layer allowing the ultra violet rays to pass towards the earth surface. The intense heat emitted in the earth surface through radiation has hazardous effect on plants, animals, human race, and its total environment. Forest trees are considered as an important factor in mitigating climate change because of their role in carbon sequestration – the process of removing carbon dioxide (CO₂) from the atmosphere and 'storing' it in plants that use sunlight to turn CO₂ into biomass and oxygen (ACIAR, 2008).

Carbon sequestration occurs both naturally and as a result of anthropogenic activities and typically refers to the storage of carbon that has the immediate potential to become carbon dioxide gas. In response to growing concerns about climate change resulting from increased carbon dioxide concentrations in the atmosphere, considerable interest has been drawn to the possibility of increasing the rate of carbon

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sequestration through changes in land use and forest and also through geo-engineering techniques such as carbon capture and storage.

Forests sequester store more carbon than any other terrestrial ecosystem and are important natural 'brake' on climate change. When forests are cleared or degraded, their stored carbon is released into the atmosphere as carbon dioxide (CO₂). Tropical deforestation is estimated to have released of the order of 1–2 billion tons of carbon per year during the 1990s, roughly 15–25% of annual global greenhouse gas emissions (Malhi and Grace 2000, Fearnside and Laurance 2003, 2004, Houghton 2005). The largest source of greenhouse gas emissions in most tropical countries is from deforestation and forest degradation. In Africa, for example, deforestation accounts for nearly 70% of total emissions (FAO 2005). Moreover, clearing tropical forests also destroys globally important carbon sinks that are currently sequestering CO₂ from the atmosphere and are critical to future climate stabilization (Stephens et al 2007).

Forests play an important role in the sequestration of carbon; particularly the conservation of forests yields the greatest potential for reducing greenhouse gas emissions. As for the estimation of carbon sequestration, several methods have been proposed such as the sampling of ground biomass, flux tower, model estimation, and remote sensing technique (Aerial Survey Office of Forest Bureau, 2009). Among these methods, remote sensing is an effective and large-scale method to estimate carbon sequestration based on net primary productivity (NPP) and absorbed incident photosynthetically active radiation (APAR) (Monteith, 1972). Therefore, it can improve the problem of spatial discontinuity for the sampling of ground biomass and the observation of flux tower. Previous studies such as Sun and Zhu (2000), Zhu et al. (2005, 2006), Jiang (2009) applied different scales of remote sensing images to estimate net primary productivity and then analyze the change of carbon sequestration.

In Nigeria, the eco-climatic zones range from the very humid fresh water mangrove swamps, in the south to the semi arid Sahelian zone in the north (Salami and Balogun 2004). These varied zones support a variety of vegetation, among which the most extensive vegetation zones are Savannas in the north and forest in the south.

Forest and forest plantation are very important natural resources relied upon by man for food, furniture, fuel wood, timbers, animal and plants to mention a few. In both developed and developing countries, exploitation of these forest resources take place consistently for various purposes which varies from commercial to non commercial, need for space in road construction shifting agriculture, firewood harvesting, construction of residential building, sand excavation etc.

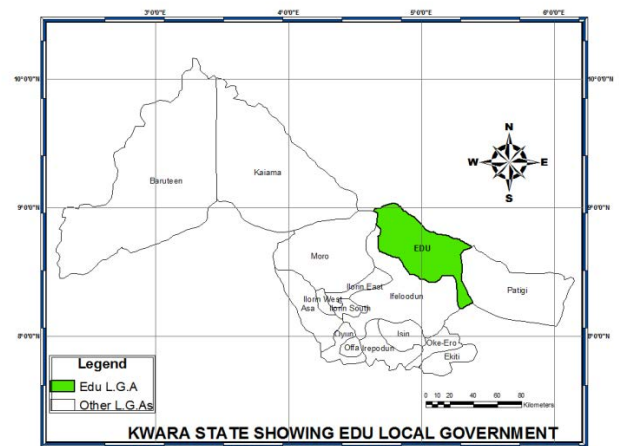
This study aim to assess the rate of Forest Degradation and Carbon Sequestration of Effan Forest Reserve Area of Kwara State, using GIS and remote sensing techniques

II. RESEARCH METHOD AND DESIGN

a) Location and description of Study Area

Effan Forest Reserve is located in Edu Local Government Area of Kwara State. The Local Government is made up of three districts; Lafiagi, Shonga and Tsaragi with the headquarter at Lafiagi. The reserve lies within Longitude 5°18' to 5°23' East of Greenwich Meridian and Latitude 8°47' to 8°50' North of the Equator. The forest reserve covers a stream plus a strip of dry lands surrounding the stream with a width of 5-10metres. The strip of dry land surrounding the stream was planted with *Gmelina arborea* specie plantation from 1975 to 1981. The total area of the reserve is 14.35 square kilometer which is equivalent to 1435 hectares which was originally acquired by government under the public lands ordinance (1975).

The area is characterized by tropical hinterland climate with two alternate distinct wet (May – October) and dry season (November – April), the length of the raining season is over 180days. The soils here is developed cretaceous sedimentary basement complex, which is sandy alluvium type predominantly shallow soil and low level of organic matter, hydromorphic soils are dominant in the lowest part of the Effan Stream thereby attracting rain fed agriculture and animal rearing during season because of the availability of pasture and water for livestock. Food crops such as maize, guinea corn, groundnut, yams and rice are cultivated by the natives and other ethnic groups living around the area.



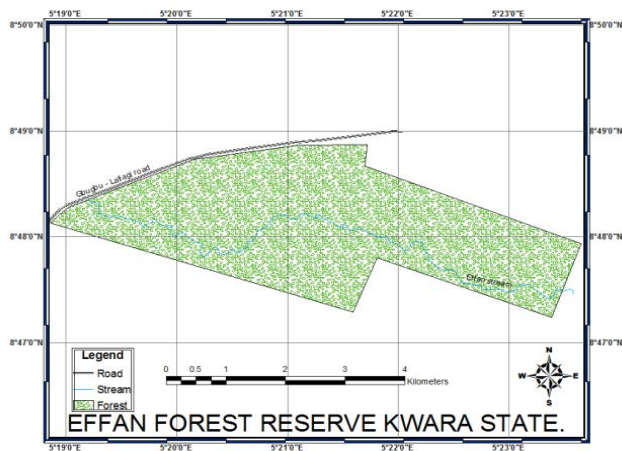


Figure 1 : Location of Effan Forest Reserve Kwara State

b) Data used

The data assembled for this study include; Satellite image – Landsat Enhanced Thematic Mapper (ETM⁺) of 2001 and 2006 (Band 1, 2, 3 & 4), Google Earth image of 2013. Topographic Map of Lafiagi (sheet 203, Scale 1:100,000) Nigeria of 1968 by Bureau of Lands under Survey department. Field Equipments – GPS, diameter tape 3metre, measuring tape 100metre, digital camera and fieldwork data sheet. Software's – Arc GIS 10.0 version, Idrisi Selva, Microsoft word, Microsoft Excel, and Microsoft PowerPoint.

c) Methodology

The research method for this study followed two major steps i.e. fieldwork, data collection & preparation, and remote sensing & GIS analysis.

d) Delineation of the forest and quantifying the extent of forest degradation

Image Importation – All the four (4) bands of the LandSat ETM⁺ images of 2001 and 2006 was imported in the Idrisi Selva and as well as into the ArcMap environment and were given unique identifier to make a difference between them, because much data would be generated without deleting the initial raw data. Image Carving/sub-setting – The four (4) bands of the LandSat ETM⁺ of 2001 and 2006 images imported was windowed / carved based on the latitude and longitude of the study site. The carved images was then exported to the Idrisi Selva environment which was reformatted and geo – referenced using the Re-Sample module. Image composition – despite the fact that all the bands were imported its not all that was used for the work but were tried for better interpretation for training sites later used for classification. The image composition with the greatest variability was chosen for signature training to achieve the best signature separation and avoid classes' mix-up. Image classification – the supervised classification (Maximum classification) was carried out with the development of training site from signature of three (3) classification schemes: *Gmelina arborea*,

Shrubs/Sapling and water body in the Idrisi Selva environment. Also the calculation of the area coverage by each scheme was determined in hectare. Map composition – the classified maps was exported back to ArcMap environment for completeness and cartographic representation and exported for presentation. There are growing bodies of potential tools that can be used to study and monitor these large complex ecosystems (Haase and Haase, 1995, Steven *et.al*, 2005 and Rao and Rogers, 2006).

e) Vegetation reflectance of Effan Forest Reserve

The NDVI approach is based on the fact that healthy vegetation has low in the visible portion of the electromagnetic spectrum due to chlorophyll and other pigment absorption and has high reflectance by the mesophyll spongy tissue of green leaf (Campbell, 1981). Band 4 and 3 of the two images was used using the NDVI model, which is a simple linear combination of the visible and near infrared bands with its values ranging from -1 to +1. Healthy vegetation is represented by NDVI values between 0.1 and 1.0, while non- vegetated surfaces such as water body, bare ground yield negative values. This was used for quantitative assessment of vegetation and moisture degradation.

f) Estimates of Above-Ground Biomass and Carbon Sink

The above-ground biomass and carbon sink was estimated through Fieldwork, data collection & preparation which involves going to the field in order to collect relevant information in the area of study. For this particular study, the necessary information that was collected in the field includes: Establishment of sample plots, measurement of diameter at breast height (DBH), measurements of latitude and longitude of each sampled plots, and taking of photographs were all determined in the field.

g) Establishment of Sample Plots in Study Site

The study site covered an area of 1,435 hectares of *Gmelina arborea* specie plantation. Sampling plots measuring 30 m x 30 m (900m²) were established within the study area. The 30m x 30m dimension of sampled plots was based on pixel resolution of the LandSat image acquired. The plots size was cordoned with a rope so that the perimeter of a plot can be seen. There was 14 sampled plots (quadrants) established and simple-random sampling method was used in the selection of sample areas in the study site.

h) Classification of Tree Stands and Data Collection

The *Gmelina arborea*, regardless of age, were classified into Sapling i.e. young tree (≤ 10 cm), Poles size (10 – 30 cm), and Standard size trees (≥ 30 cm), according to their diameter at breast height (DBH). The number of trees found inside the perimeter of each classification, was tallied and recorded. Moreover, the diameters at breast height (d.b.h) of the sampled trees

were determined using a Diameter measuring tape. The geographical location or coordinates of each sampled plots was also determined in the field and recorded with the aid of hand held GPS.

i) Biomass Computation per Tree

Diameter at breast height (d.b.h) that is measured from the field was used to determine the biomass of individual trees. The allometric equation developed by Chave et al (2005) was adopted to estimate the biomass since the equation can be used regardless of tree diameter. The equation utilizes data from 2410 trees from 27 study sites across the tropics. The study also concludes that differences in the biomass equations between study sites are small if wood density variation is accounted for. The major significant factor is the forest type.

Equation for dry forests was utilized in this study since the study area has a total annual rainfall below 1500mm. The general equation is as follows:

$$W = \rho \cdot \exp(\beta_0 + \beta_1 \ln(D) + \beta_2 \ln(D)^2 + \beta_3 \ln(D)^3)$$

Where: W = Tree above ground biomass in kilogram,

ρ = wood specific gravity (0.64g/cm³ for *Gmelina arborea*),

D = is tree diameter at breast height in centimeter, and

$\beta_0 = -0.667$, $\beta_1 = 1.784$, $\beta_2 = 0.207$, and $\beta_3 = -0.0281$

For trees with 2 or more stems, biomass was computed by calculating it separately and adding the biomass of each stem.

j) Biomass Computation per Class

The total above-ground biomass of trees per sampled plots was multiplied by the number of trees per plot. Then, the biomass from all sampled plots per class was added to represent the biomass for each class. The biomass values were then converted to tons/hectare or Metric tons/hectare (Appendix B).

k) Carbon Content

Secondary data for the average carbon content of tree of *E. camaldulensis* Dehnh at 45% was adopted from the study of Sermpong and Chongrak (2002) which is consistent with the default value of carbon content for all species specified by IPCC. The carbon content value was used to determine the carbon density for all the three classes of *Gmelina arborea* plantation.

l) Carbon Storage and Sequestration Capacity per Class

Carbon density or the amount of carbon stored by each class was determined using the following equations adapted from the study conducted by Sales (2004):

$$\text{Carbon density} = \text{Biomass}_T \times \%C$$

Where: Carbon density = total amount of carbon stored by each class expressed as tons of C per hectare (metric tons C/ha).

m) Change Maps of Carbon Sinks:

The change maps of carbon sinks was produced in the ArcMap environment using the Kriging Interpolation in the Spatial Analyst tools. The field biomass data that was generated is linked together with the NDVI values to produce the changed maps of carbon sinks.

III. RESULTS AND DISCUSSION

a) Delineation of the Forest and Extent of Forest Degradation

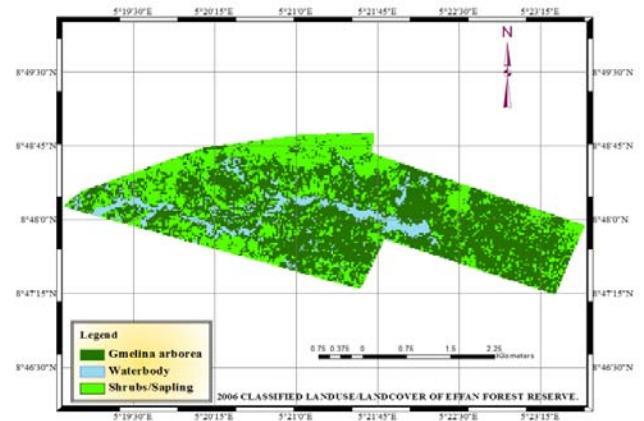


Figure 2 : Classified land use/Landcover changes of Effan Forest Reserve (2001)

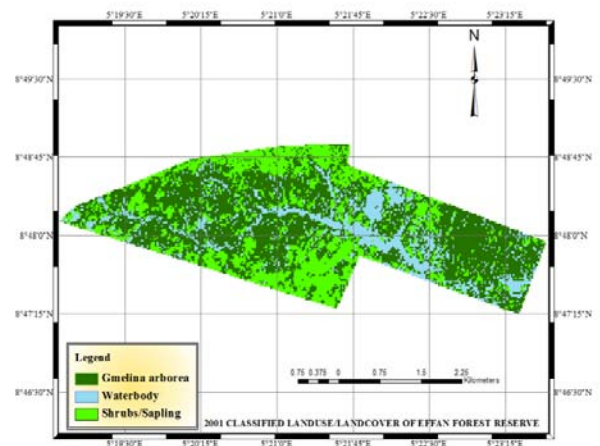


Figure 3 : Classified land use/Landcover changes of Effan Forest Reserve (2006)

Figure 2 and 3 shows illustrate the land use / land cover classification map of Effan Forest Reserve for the year 2001 and 2006. Three (3) categories of land use / land cover were identified; these are: *Gmelina arborea* plantation, Shrubs/sapling and water body.

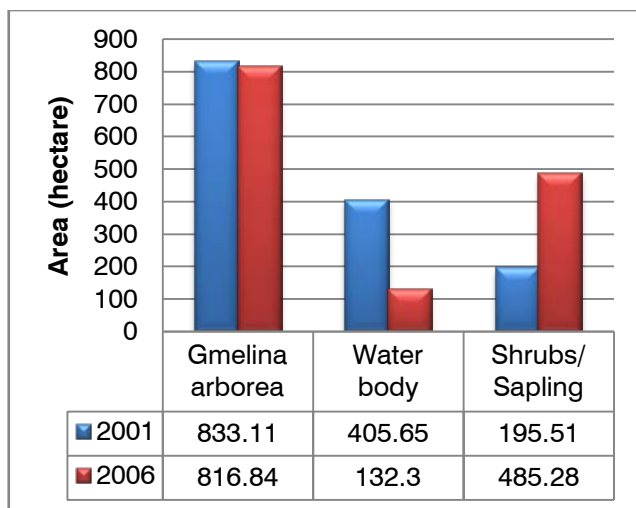


Figure 4 : Chart showing the spatial extent of land cover changes (2001 to 2006)

Figure 4 shows the spatial extent of the 2001 and 2006 land use / land cover practice in this Effan Forest Reserve were determined in order to ascertain the causes of forest degradation. The results reveal that there is a small decrease in *Gmelina arborea* plantation between 2001 and 2006 from 833.11 hectares of forest plantation (58.09%) to 816.84 hectares of forest plantation (56.95%) which is a loss of about 16.27 hectares or 1.95% during the five (5) years intervals.

However, amongst the three (3) major classes identified, two distinct classes were identified as land use practices to be the contributing factor that are partially depleting the reserve; they are the Shrubs/Sapling and the water body in this study. Shrubs/Sapling (i.e. regenerating part) area alone account for 13.63% of deforestation in 2001 and rises up to 33.83% in the year 2006 in which the *Gmelina arborea* are cut down while water body account for 28.26% of degradation in year 2001 and reduces drastically to 9.22% in 2006. All these activities were leading to degradation of the forest plantation.

Furthermore, It was found that shrubs/sapling increased immensely in size from 2001 to 2006 (5 years) i.e. for good 5 years so many trees were harvested in the reserve for fuel wood and charcoal, making matches stick, packing cases, making quality toys and picture frames, timber which is used for construction in roofing houses and as well as for other ornamental works (Plate 1). However, with the tremendous increase in the rate of Shrubs/Sapling and as well decrease in water body within that short period of time, it has a fundamental impact on the Reserve since (*Gmelina arborea*) in the reserve is a fast growing specie, though the percentage of degradation is small.



Plate 1 : Image showing *Gmelina arborea* plantation of the Reserve

b) Vegetation Reflectance of Effan Forest Reserve

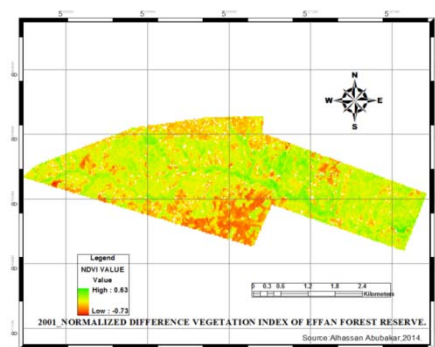


Figure 5 : Vegetation Index Map of Effan Forest Reserve (2001)

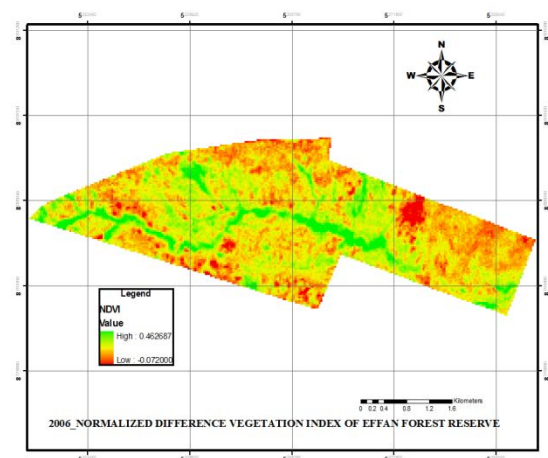


Figure 6 : Vegetation Index Map of Effan Forest Reserve (2006)

Figure 5 and 6 shows the vegetation reflectance of Effan Forest Reserve for the year 2001 and 2006. The 2001 have an NDVI values which ranges from - 0.73 to 0.63 indicate a high biomass. As at this time, the number of Shrubs/Sapling (i.e. regenerating part) is very low signifying that the Reserve is still intact.

However, the 2006 image vegetation reflectance is very low, conversely with an NDVI values ranging from -0.072 to 0.46 indicate a decrease in the biomass of the Reserve. This re-affirms that there was decrease in the number of *Gmelina arborea* plantation in the Reserve as so many trees were cut-down and there is high level of *Gmelina arborea* re-generation (Sapling/Shrubs).

From these, the changing pattern of vegetation reflectance during 2001 and 2006 periods revealed that, the NDVI values in 2001 image indicate a high biomass. Conversely vegetation reflectance is low in 2006 image likewise in NDVI value indicate a decrease in the biomass of the Reserve which is an indication of forest degradation.

c) Estimates of Above – Ground Biomass and Carbon Sink

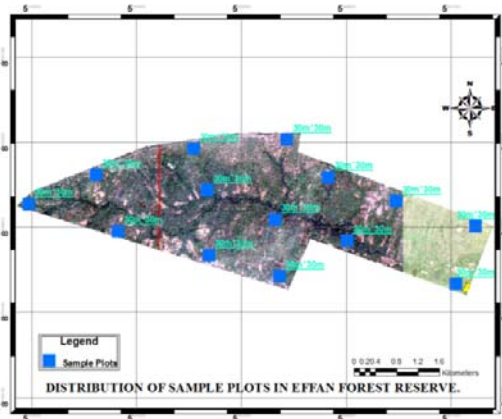


Figure 7 : Locations of Sampled Plots in the Study Area

A total of 14 randomly sampled plots were selected, each plot measuring (30m x 30m) quadrant with an area of 900m² was used in this study. *Gmelina arborea* was the dominant tree species observed in the study area (Fig. 7).

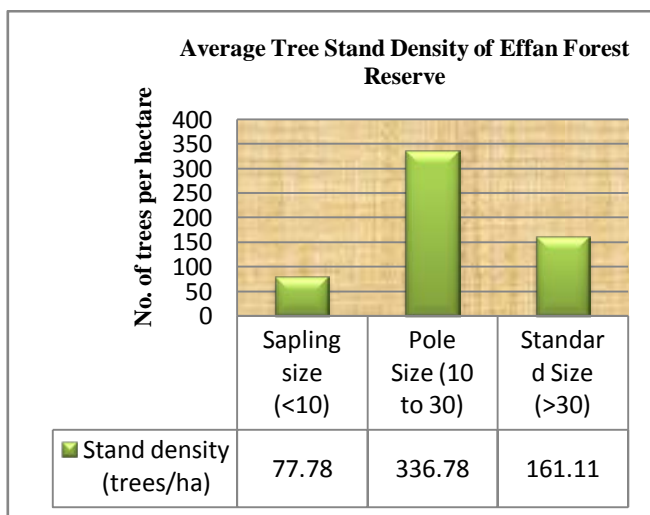


Figure 8 : The distribution of sampled trees in the study site

A total number of trees measured were 652 ranging in diameter at breast height (d.b.h) from 7.0 to 63.65cm which were classified into various classes. The Sapling i.e. Young tree class with diameter at breast height (d.b.h) below 10cm have an average Stand density of 77.78trees/ha, the Pole size tree with diameter at breast height (d.b.h) ranging from 10 to 30cm have an average Stand density of 336.78trees/ha and the Standard tree with diameter at breast height (d.b.h) greater than 30cm have an average Stand density of 161.11trees/ha which were measured for above-ground biomass shown in the Figure 8.

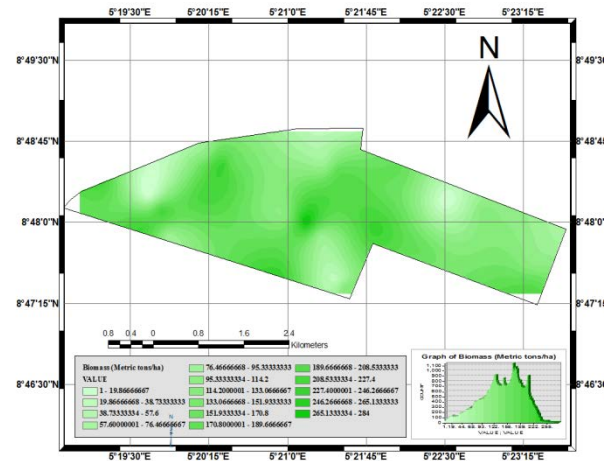


Figure 9 : Distribution of above- ground biomass in Effan Forest Reserve

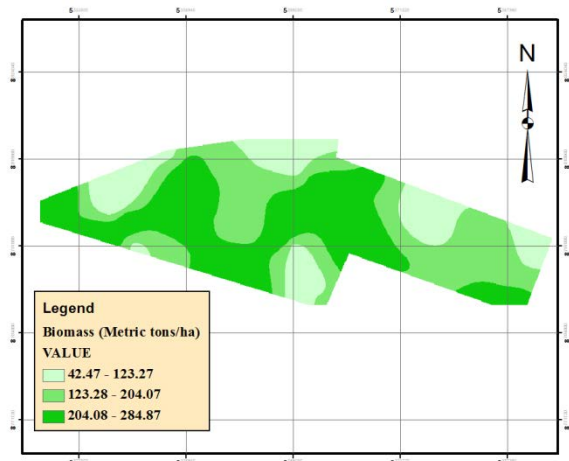


Figure 10 : Re-Classified map of Above – ground biomass

Figure 9 shows the biomass change of Effan Forest Reserve, the Standard size has the highest biomass and capacity to sequester carbon while the Sapling size has the least capacity. Capacity of the plantation to sequester start to decline as the rotation age is achieved like the case of Standard trees. This can be explained by the trend in tree growth that is, as the tree reached its Standard size, its growth starts to decline resulting to less carbon sequestered per year

but have the potential to store more carbon. If the biomass is kept in the plantations it will continue to store more carbon but its sequestration rate will reduce as the trees grow old.

The above – ground biomass map is also re-classified into three (3) Classes as shown in (figure 10) to represent the Sapling, Pole and Standard size classes. This reveals that the Sapling has the biomass ranging from 42.47 to 123.27metric tons/ha, the Pole size has the biomass ranging from 123.28 to 204.07metric tons/ha and the Standard size trees has the biomass ranging from 204.08 to 284.47 metric tons/ha. Therefore, majority of the biomass content in the Reserve fall under the Pole size class in terms of the area covered in the reserve.

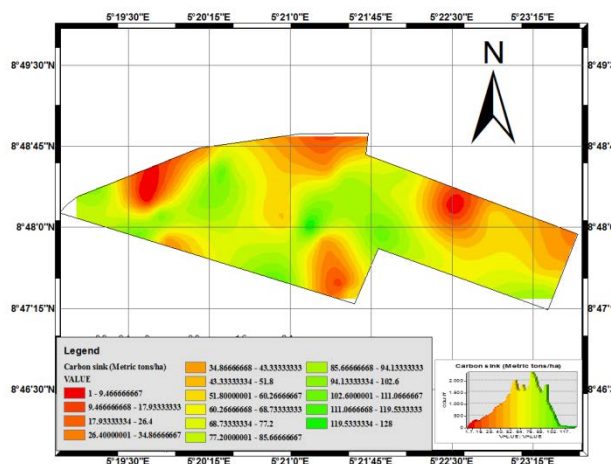


Figure 11 : Distribution of Carbon sinks in Effan Forest Reserve

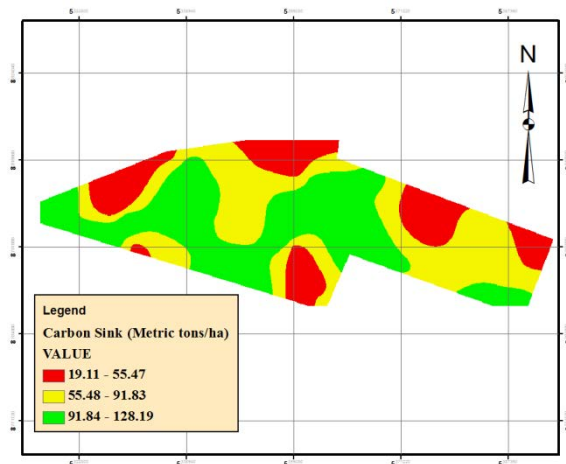


Figure 12 : Re-Classified map of Carbon Sink

The carbon stored and sequestered for different classes of *Gmelina arborea* plantation varies. The plantation had a storage of 19.11metric tons C/ha for Sapling Class, to 128.19metric tons C/ha for Standard size trees (Fig. 11). Standard size trees have the highest sequestration capacity to store carbon since its biomass

was also high at 286.29metric tons/ha. From Sapling to Standard size trees, a rapid increase in biomass was recorded and thus its storage capacity is due to the characteristics of *Gmelina arborea* for fast growth.

Furthermore, figure 12 shows the Re-classified map of carbon sinks into three (3) Classes representing the Sapling, Pole and Standard size classes. This revealed that the Sapling has the carbon density ranging from 19.11 to 55.47metric tons/ha, the Pole size has the carbon density ranging from 55.48 to 91.83metric tons/ha and the Standard size trees has the carbon density ranging from 91.84 to 128.19 metric tons/ha. Therefore, majority of the carbon content stored in the Reserve fall under the Pole size class as apparent (i.e. area covered) in figure 12.

d) Carbon Dioxide Sequestration Capacity of Effan Forest Reserve

In general, the Effan Forest Reserve in Kwara State has a total area of 1,435 hectares. This area has a total biomass of 89,544metric tons. A total of 40,294.8 metric tons was estimated to be the CO₂ sequestration capacity of the forest stand in Effan Forest Reserve. Thus, the *Gmelina arborea* plantation in Effan Forest Reserve can be useful to reduce the increasing amount of carbon dioxide concentration in the atmosphere, thereby mitigating the effect of climate change.

The parameters considered as wood density, diameter at breast height (d.b.h) may have interplayed, giving additional or compensatory effects. This can be further explained by the fact that the *Gmelina arborea* numerically showed to have the higher amount of carbon sequestered at older stages.

The work of Huy *et al.* (2008) however, revealed that biomass and carbon density varies among tree species. This study may not have been using a large number of sampled trees with significantly varied morphological characteristics. The carbon density value for *Gmelina* used in this study was obtained from the experiment reported by Sales *et al.* (2005) who studied the carbon density values at various ages of tree species in the Philippines.

In addition, CO₂ sequestration and storage were dependent on the amount of biomass of trees, specifically, on the variable trunk diameter. This conforms to the findings of Terakunpisut *et al.* (2007) who mentioned that carbon sequestration potential in the different forest types tends to be correlated to DBH and tree height. Moreover, the wood density did not differ much from different regions considered so that it did not have a notable effective at removing carbon dioxide from the air, thus, it is considered as one of the variables in computing for carbon density.

The value 40,294.8metric tons as the total CO₂ sequestration capacity of the Effan forest reserve area is sufficient enough to contribute to the mitigation of climate change. Based from the findings of Denman et

al. (2007) and as cited by Lasco *et al* (2009) it is estimated that about 60 Gt C is exchanged between terrestrial ecosystems and at atmosphere every year. Maintenance and expansion of this carbon sink in the study area may even showcase for the adaptation of the smallholders to climate change.

IV. CONCLUSION

It is apparent from this study, that so many trees were cut-down for domestic and industrial uses which lead to the reduction in the biomass of the Reserve and low vegetation reflectance. The *Gmelina arborea* plantation of the Reserve, regardless of their class, the bigger trees, particularly at their Standard sizes, sequestered the greatest amount of CO₂. Provided that these trees are allowed to grow and were not cut for any purpose at all, they continue to provide the safety net for the adverse effects of climate change. There is significant amount of carbon sequestered at the Effan Forest Reserve in Kwara State (with an area of 1435 hectares) shows the potential and significant CO₂ sequestration by trees. As it was noted, the sequestration capacity increases as the size of forest stand also increases. *Gmelina arborea* tree specie can be used in the reforestation program to help mitigate global warming, since it was also found to be fast regenerating specie and there was significant difference in terms of the rate of CO₂ sequestration capacity as these trees becomes mature. It is now suggested that the option to reserve carbon in the forests is by minimal intervention, with a gradual long – term increase in carbon stocks.

V. ACKNOWLEDGEMENT

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