FOREST DEGRADATION AND CARBON SEQUESTRATION IN EFFAN FOREST RESERVE, EDU LOCAL GOVERNMENT AREA, KWARA STATE

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ABSTRACT

This study estimated the forest degradation, carbon dioxide sequestered and stored in the forest trees of Effan Forest Reserve using Remote Sensing/GIS techniques. LandSat Enhaced Thematic Mapper (ETM$^+$) of 2001 and 2006 were sourced, 14-sampled plots were randomly taken as reference points and above-ground biomass and carbon sink were estimated. Remote Sensing – Land Use/Land Cover based method was use for change detection, Vegetation Difference Normalized Index (NDVI) used to determine vegetation reflectance, field data and allometric model equation were used 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 (re-generating part). Despite the fast regenerating capacity of Gmelina arborea, there was 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 was high in 2001 but low in 2006 which also confirms an evidence of forest degradation. The total above-ground biomass and carbon sink of the Reserve estimated showed that Standard trees class tripled 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 CO_2 *sequestration potential than the Sapling and Pole – sized. However, both will have high carbon sequestration potential in the future due to presence of large number of trees belonging to small Diameter at Breast Height (DBH) size classes. Moreover, the forest stand of Effan Reserve has a total sequestration capacity of 40,294.8metric tons of* CO_2.

Keywords: Degradation, *Gmelina arborea,* Above-ground biomass, carbon sequestration, climate change.

INTRODUCTION

Forest degradation is broadly defined as reduction in the capacity of forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic and environmental changes. The main forces 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 sets 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 considers degradation on dry lands; and the UN Framework Convention on Climate Change (UNFCCC) that proposes to recover degraded forests as carbon sinks. Recent climate negotiations 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 contributes 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 are 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 (CO_2) from the atmosphere and 'storing' it in plants that use sunlight to turn CO_2 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 CO_2 gas. In response to growing concerns about climate change resulting from increased CO_2 concentrations in the atmosphere, considerable interest has been drawn to the possibility of increasing the rate of carbon 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 CO_2. 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 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 CO_2 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 forest yields which has 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 vary from commercial to non commercial, such as need for space in road construction, shifting agriculture, firewood harvesting, construction of residential building, sand excavation among others. Generally, these have continued to increase the amount of carbon dioxide and other greenhouse gases emitted into the atmosphere, thereby aggravating the effect of climate change. Hence, the need to quantify the rate of forest degradation and delineate carbon sequestration capacity of Effan forest reserve using remote sensing and GIS techniques.

MATERIALS AND METHODS

Study Area

Effan Forest Reserve is located in Edu Local Government Area of Kwara State (Fig.1). The Local Government is made up of three districts; Lafiagi, Shonga and Tsaragi with its headquarters at Lafiagi. The reserve lies within Longitude $5^{0}18^{'}$ to $5^{0}23^{'}$ East of Greenwich Meridian and Latitude $8^{0}47'$ to $8^{0}50'$ 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).

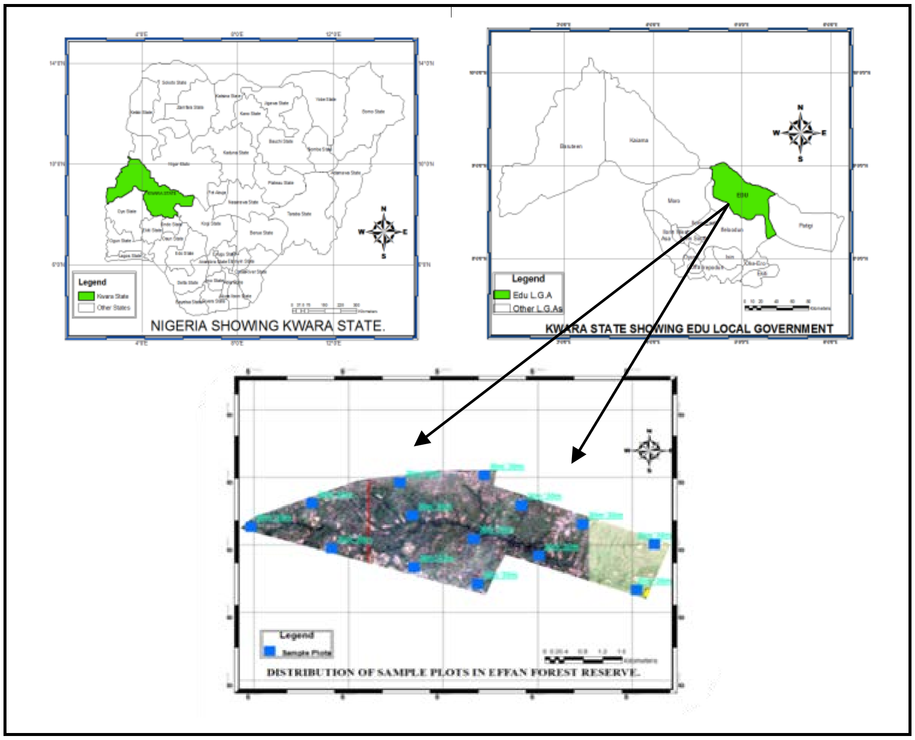

Figure 1: Location of Effan Forest Reserve Kwara State.

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 150days. The soils here is developed cretaceous sedimentary basement complex, which is sandy alluvium type predominantly shallow soil and low level of organic matter. The hydro-morphic soils are dominant in the lowest part of the Effan Stream thereby attracting rain fed agriculture and animal rearing during the dry 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.

METHODS

The data assembled for this study include 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 include Geographical Position System (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. The research methods followed two major steps i.e. fieldwork, data collection & preparation, and remote sensing & GIS analysis.

DELINEATION OF THE FOREST AND QUANTIFYING THE EXTENT OF FOREST DEGRADATION

The LandSat images of 2001 and 2006 were sourced from Global Land Cover Facility, 2013 which were inputted into Idrisi Selva software. The images were filtered, re-sampled using 14 Ground Control Points to validate the images and classified using the supervised classification (Maximum Likelihood classification) with the development of training site from signature of three (3) land cover classes; *Gmelina arborea,* Shrubs/Sapling and water body. Also area coverage by each class was determined in hectare. The classified maps were exported back to ArcMap environment for analysis and cartographic representation.

VEGETATION REFLECTANCE OF EFFAN FOREST RESERVE

The NDVI approach is based on the fact that healthy vegetation has low reflectance 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). Bands 4 and 3 of the two images were used for NDVI computation, 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. These were used for quantitative assessment of vegetation and moisture degradation of the reserve. The NDVI is expressed mathematically as;

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Where: NDVI=Normalized Difference Vegetation Index
NIR= Near Infrared band value
RED= Red band Value

ESTIMATES OF ABOVE-GROUND BIOMASS AND CARBON SINK

The above-ground biomass and carbon sink were estimated through the establishment of sample plots, measurement of diameter at breast height (DBH), latitude and longitude of each sampled plots, and taking of photographs were all determined in the field.

Establishment of Sample Plots in Study Site

The study site covered a total area of 1,435 hectares. Sampling plots measuring 30 m x 30 m (900m^2) 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 could be seen. There were 14 sampled plots (quadrants) established and simple-random sampling method was used in the selection of sample areas in the study site.

Classification of Tree Stands

The *Gmelina arborea*, regardless of age, were classified into Sapling i.e. young tree ($\leq$ 10 cm), Poles size trees (10 – 30 cm), and Standard size trees ($\geq$ 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 DBH of the sampled trees were determined using a Diameter measuring tape. The geographical location or coordinates of sampled plots were also determined in the field and recorded with the aid of a hand-held GPS receiver.

Biomass Computation

The measured DBH 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 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:

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

Where: W = Tree above ground biomass in kilogram,

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

D = is DBH in centimeter, and

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

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

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.

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.

Carbon Storage and Sequestration Capacity per Class

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

Carbon density = Biomass $_T$ x %C

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

Change Maps of Carbon Sinks

The change maps of carbon sinks were 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.

Results and Discussion

Land use/ Land cover Dynamics of Effan Forest Reserve

Figures 2 & 3 show the Land use / land cover classification of Effan Forest Reserve for the year 2001 and 2006. Three (3) categories of land use / land cover identified were *Gmelina arborea* plantation, Shrubs/sapling and water body. However, amongst the three (3) major classes identified, Shrubs/Sapling and the water body were identified as major land use practices depleting the reserve.

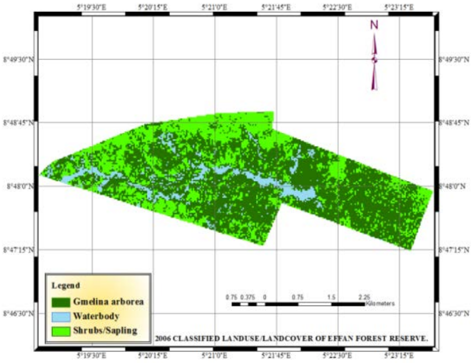

Figure 2: Classified land use/Land cover changes of Effan Forest Reserve (2001).

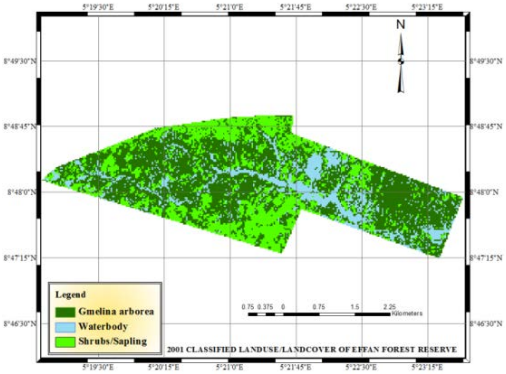

Figure 3: Classified land use/ land cover changes of Effan Forest Reserve (2006).

It is obvious from Table 1 that there was a small decrease in *Gmelina arborea* plantation between 2001 and 2006 from 58.09% to 56.95% which is a loss of about 16.27hectares or 1.95%, Shrubs/Sapling (i.e. regenerating part) area alone accounted for 13.64% of the area in 2001 and increased persistently to 33.83% in the year 2006. Furthermore, field work on determination of above ground biomass in 2013 confirmed decrease in *Gmelina arborea* as indicated by the increases in area occupied by Sapling size trees. An increase in this class is an illustration of deforestation occasioned by fuel –wood gathering and lumbering. The water body account for 28.26% of degradation in year 2001 and reduces drastically to 9.22% in 2006. All these have continued to aggravate degradation of the forest plantation.

Similarly, the immense increase in the size of shrubs /sapling within the timeframe as well as decrease in water body within that short period of time are a threat to the sustainability of the reserve and would have resulted in much carbon emission over the period under study. This conforms to the work of Sathaye *et al.* (2007) estimate that deforestation rates continue in all regions, particularly at high rates in Africa and South America. About 600 million ha is expected to be lost cumulatively by 2050. Using a spatial-explicit model coupled with demographic and economic databases, Soares-Filo *et al.* (2006) also predict that, under a business-as-usual scenario, by 2050, projected deforestation trends will eliminate 40% of the current 540 million ha of Amazon forests, releasing approximately 117,000 ± 30,000MtCO_2 of carbon to the atmosphere.

Table1: Land use/land cover dynamics over the examined period (2001- 2006).

Landuse/Land cover type	2001		2006	
	Area (ha)	(%)	Area(ha)	(%)
Gmelina arborea	833.11	58.08	816.84	56.95
Water body	405.65	28.28	132.3	92.24
Shrubs/sapling	195.51	13.64	485.13	33.83
TOTAL	**1434.27**	**100**	**1434.27**	**100**

Source: Analysis, 2013.

Vegetation Reflectance of Effan Forest Reserve

As evident in figures 4 and 5, the vegetation reflectance of Effan Forest Reserve for the year 2001 and 2006 shows that 2001 NDVI values ranged from - 0.73 to 0.63, an indication of high forest biomass. This was so since the number of Shrubs/Sapling (i.e. regenerating part) was very low within the Reserve. Conversely, the 2006 image vegetation reflectance was lower, with an NDVI values ranging from -0.072 to 0.46 indicating a decrease in the biomass of the Reserve. This affirmed the decrease in the number of *Gmelina arborea* plantation due to harvest and consequent increase in *Gmelina arborea* re-generation (Sapling/Shrubs) and ground truth confirmed this. Generally, the low NDVI values in 2006 indicated a decrease in the biomass of the Reserve, an indication of forest degradation.

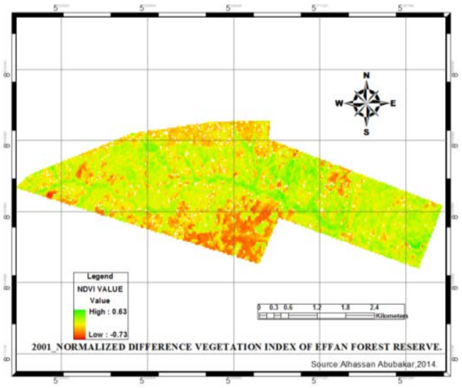

Figure 4: NDVI Map of Effan Forest Forest Reserve (2001).

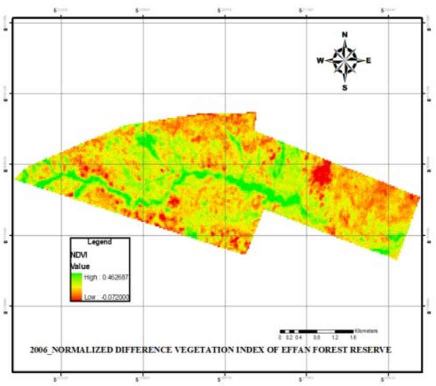

Figure 5: NDVI Map of Effan Forest Forest Reserve (2006).

Estimates of Above – Ground Biomass and Carbon Sink

The analysis of biomass distribution varies across the forest as the growth characteristics of the trees increases i.e. DBH as shown in (Fig. 6). These revealed that the Sapling size trees has the biomass ranging from 42.47 to 123.27metric tons/ha, the Pole size trees from 123.28 to 204.07metric tons/ha and the Standard size trees ranging from 204.08 to 284.47 metric tons/ha. Standard size trees have the highest biomass content at 284.47metric tons/ha. Therefore, the biomass density value was in increasing order from Sapling to Standard size trees. The rapid increase in biomass content recorded is due to the characteristics of *Gmelina arborea* for fast growth.

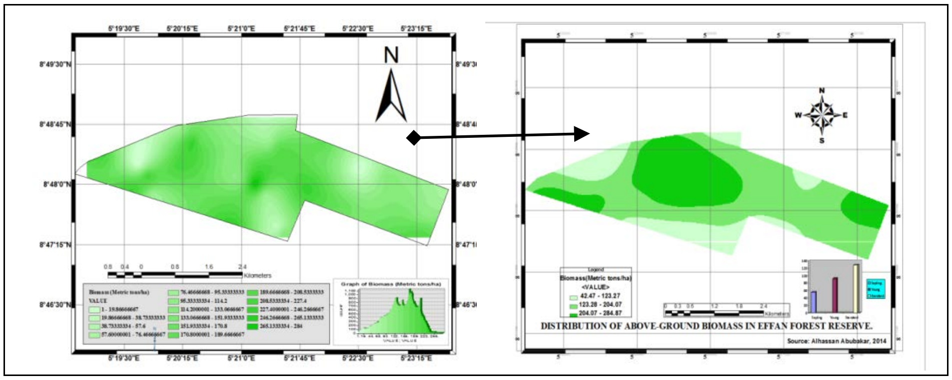

Figure 6: Distribution of Above-ground biomass of Effan Forest Reserve.

Furthermore, the amount of CO_2 sequestered and stored were dependent on the amount of biomass of trees, specifically on the variable trunk diameter for different classes of *Gmelina arborea* plantation. 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. 7). The Standard size tree had the highest biomass and capacity to sequester carbon while the Sapling size has the least capacity. Capacity of the plantation to carbon sequestration start to decline as the rotation age is achieved like the case of Standard size trees, 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. Therefore, majority of the carbon content stored in the Reserve fall under the Pole size class which is evident from the area covered.

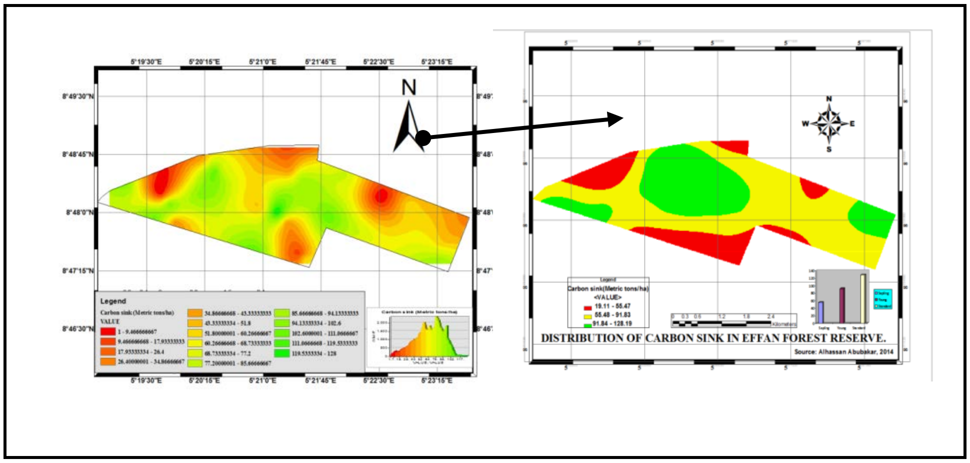

Figure 7: Distribution of carbon Sink in Effan Forest Reserve.

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 with a total biomass of 89,544metric tons and 40,294.8 metric tons of CO_2 sequestration capacity. Thus, the *Gmelina arborea* plantation can reduce the increasing amount of CO_2 concentration in the atmosphere, thereby mitigating the effect of climate change. 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 vary among tree species. This study may not have been using a large number of sampled trees with significantly varied morphological characteristics.

In addition, CO_2 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 concluded that carbon sequestration potential in different forest types tended 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 effects 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 CO_2 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 (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/mitigation of the smallholders to climate change.

CONCLUSION

It is apparent from this study that the Reserve underwent reduction in biomass between 2001 and 2006. So many trees were cut-down for domestic and industrial uses which lead to the reduction in the biomass of the Reserve which also shows a 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 CO_2. 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 CO_2 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 CO_2 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.

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