ISSN No:-2456-2165

# Assessment of Forest Carbon Stocks on Forest Degradation in the Oyimo Forest Reserve, Ondo State, Nigeria

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**Abstract:- This study assessed the amount of carbon stock in the Oyimo forest reserve in Ondo Statewith the view to determine the above ground biomass (AGB) and belowground biomass (BGB), estimate the organic carbon content and evaluate the soil organic carbon sequestered. The SDG 15.3.1 embedded in plugin quantum geographic information system (QGIS) was the method used to carry out the analysis. In this SDG 15.3.1 there are indicator for quantifying carbon stock and sub-indicator to measure forest degradation. The results showed that initial forest area was 59,413 hectares; initial non-forest area was 245 hectares (ha), total biomass was 3,535,543 tonnes of C, loss of carbon was 127,703 tonnes of C and total carbon emission during the years was 468,669 tonnes of $CO_2$e.From land cover of soil organic carbon of sub-indicator the area with no data was 19.01 hectares, degraded area was 18,727.849 hectares, stable area was 29,032.919 hectares and improved area was 11,9780.2184 respectively. The estimation of Carbon stock gives an idea about the quantity and quality of carbon available in the area and also how it behaves in ecosystem, where the carbon is ultimately degraded to carbon emissions to the atmosphere causing global warming and climate change, which affect entire ecosystem significantly. Therefore, Trend. Earth can be used to assess the Carbon stocks of a given forest and also can be found as the best method to calculate soil organic carbon (SOC) due to measurement of carbon and degradation, low cost and less time requirement.**

***Keywords:-*** *Carbon estimation, degradation, biomass, land cover, Trend. Earth and QGIS.*

## I. INTRODUCTION

Forests play an important role in the Earth's climate system, in a numerous ways. Most importantly for global climate change, they capture carbon dioxide from the atmosphere and convert it, through photosynthesis, into living biomass: tree trunks, roots, branches and leaves. Forests also store carbon in forest soils, absorbed through leaf litter, plants and soil organisms, and organic components, all influenced by factors such as local climatic conditions and forest management. Estimates of the carbon stored in the Oyimo forests reserve is very significant[1].Carbon sequestration (CS) refers to the storage of carbon in a stable form through direct and indirect fixation of atmospheric carbon dioxide[2].Assessing the amount of carbon stored in the forest ecosystem periodically is a means of determining the emitted into the atmosphere due to deforestation and degradation[3].

Soil organic carbon (SOC) levels are directly related to the amount of organic matter contained in soil and SOC is often how organic matter is measured in soils[4].Soil organic carbon levels result from the interactions of several ecosystem processes, of which photosynthesis, respiration, and decomposition are keys.Photosynthesis, decomposition, and respiration rates are determined partly by climatic factors, most importantly soil temperature and moisture levels. For example, in the cold wet climates of the northern latitudes, rates of photosynthesis exceed decomposition resulting in high levels of SOC.

Carbon sequestration potential may be determined by an understanding of both the historic SOC stocks under natural vegetation prior to conversion to other uses and the influences of those land uses on carbon loss. Land uses and management that reduce carbon inputs or increase losses compared to natural vegetation result in reductions in SOC over time, creating a soil carbon deficit relative to the levels of carbon that previously existed in the soil.The purpose of this work is to estimate the carbon stock in the study area determine the total carbon content and evaluate the sequestered.

## II. STATEMENT OF THE RESEARCH PROBLEM

Loss of forest organic carbon content can limit the soil's ability to provide nutrients for sustainable plant production. This may lead to lower yields and affect food security. Less organic carbon also means less food for the living organisms present in the soil, thus reducing soil biodiversity.Loss of soil organic matter reduces the water infiltration capacity of a soil, leading to increased run-off and erosion. Erosion in turn reduces the organic matter content by washing away fertile topsoil. Under semiarid circumstances this may even lead to desertification.There is an urgent need to measures to avoid, reduce and reverse forest carbon loss to prevent the environment as to continue to enjoying services and functions of biological diversity in Oyimo forest reserve for social and economic benefit.

Understanding about the socio-economic benefits of such sustainable forest carbon management practices is growing [5]. However, whether there are similar gains for biodiversity (either within the farmed landscape or through sparing the conversion of non-farmed habitats) is unclear. Similarly, we understand little of how the intended benefits of sustainable land management approaches, such as erosion control, improved water retention or enhanced soil fertility increase, might co-occur with other benefits, such as more biodiversity landscapes or improved ecosystem functions and ecosystem service provision.Land use and land cover change has resulted in substantial losses of carbon from soils globally, but credible estimates of how much soil carbon has been lost have been difficult to generate. But with remote sensing and geographic information system something can be done.

## III. JUSTIFICATION

The estimation of forest organic carbon involves field measurement, remote sensing and Geographic Information System (GIS) methods. However, while the field measurement method is most accurate, it becomes more challenging for large area estimation where it is a strenuous, expensive, time-consuming and destructive approach. As a result, remote sensing provides a synoptic means of obtaining geospatial information for inaccessible areas for monitoring vegetation, land use land cover (LULC) change. Remote sensing and GIS is considered as a set of powerful tools to process spatially referenced data and this spatial data can be used to identify conflict, analyses impacts over time and find a suitable solution for a specific problem. The plugins in quantum geographic information system (QGIS) designed for sustainable development goals is capable to estimate forest organic carbon, even for long period.

## IV. AIM AND OBJECTIVES

The aim of the study is determination of forest organic carbon and forest degradation in Oyimo forest reserve.
Specific objectives:

*A. Assessment of organic carbon stocks of Oyimo forest reserve for the period of investigation.*

- Assess the soil organic carbon or matter of the Oyimo forest reserve of its ecosystem services.
- Assess the forest biomass and forest diversity in the Oyimo forest reserve.

## V. STUDY AREA

- **Study Location**

  Oyimo forest reserve is geographically located at Latitude 7.3590 N and 7.2880 N and Longitude 5.6340 E and 5.6470 E in Supare, Akoko South West Local Government, Ondo State, Nigeria. The landmass of Akoko southwest local government is 481.04 square kilometers and the total population is 239,486 as of the 2006 population census [6].

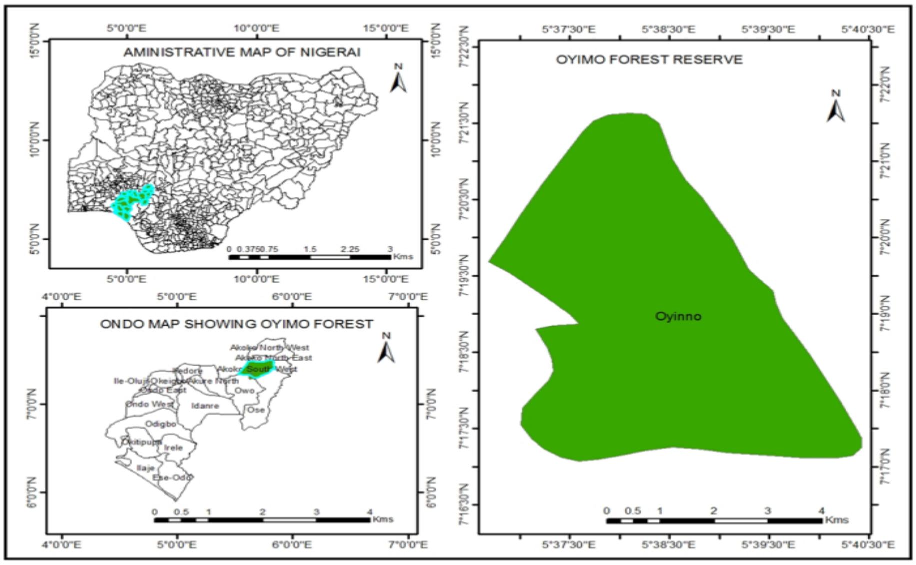


Fig. 1: Study Area Map

*A. Vegetation*

The natural vegetation of Oyimo forest reserve is of the lowland tropical rainforest type, composed of a variety of hardwood timbers. The rainforest in Oyimo is among the vegetation that represents the climax of the Nigerian forest. An important aspect of the vegetation of the study area is the prevalence of tree crops. The major tree crops include cocoa, coffee, rubber oil palms and citrus, cocoa being the most prevalent over most of the local government.It is also important to note that rubber and oil palms have been cultivated in large plantations in the Local Government Areas. Trees that are not native have also been introduced as forest plantations. These exotics have been used to revegetate large portions of harvested old forest reserves in Ondo state for all forest reserve. They include mainly Tectonagrandis (teak) and Gmelinaarborea (pulp wood).

*B. Climate*

The climate of Oyimo forest reserve, Akoko south west, Ondo states in the south western part of Nigeria, is that of Tropical Rain Forest type, with distinct wet and dry seasons. The Oyimo forest reserve in Ondo state, the wet season is warm and overcast, the dry season is hot and partly cloudy, and it is oppressive year round. Over the course of the year, the temperature typically varies from 18.9 $^0$C to 32.8 $^0$C and is rarely below 15.6 $^0$C or above 35 $^0$C.

## VI. METHODOLOGY

### *A. Data Acquisition and Analysis*

The only acquired data was shape file of study forest (e.g. Oyimo forest shape file).The Natural Earth Administrative Boundaries provided in Trends.Earth, are in the public domain. The boundaries and names used, and the designations used, in Trends.Earthwhich do not imply official endorsement or acceptance by Conservation International Foundation, or by its partner organizations and contributors.

## VII. ANALYSIS

The whole analysis was carried out in Quantum Geographic Information System (QGIS), mainly Trends. Earth in plugin of QGIS. Trends.Earth (formerly the Land Degradation Monitoring Toolbox) is a platform for monitoring land change using earth observations in an innovative desktop and cloud-based system.There are a number of components to the Trends. Earthtool. The first is a QGIS plugin supporting calculation of indicators, access to raw data, reporting, and production of print maps. The code for the plugin, and further instructions on installing it if you want to modify the code, are in trends. Earth github repository. The Trends. Earth QGIS plugin is supported by a number of different Python scripts that allow calculation of the various indicators on Google Earth Engine (GEE). These scripts sit in the "gee" subfolder of that github repository.

Trends. Earth allows the user to compute each of these sub-indicators in a spatially explicit way generating raster maps which are then integrated into a final SDG 15.3.1 indicator map and produces a table result reporting areas potentially improved and degraded for the area of analysis. Most of the indicators are; organic carbon, forest biomass (above and below ground biomass), soil organic carbon, land cover and soil productivity. Soil productivity has some sub indicators; productivity state, productivity trajectory and productivity performance.

Productivity Trajectory: A Mann-Kendall non-parametric significance test is then applied, considering only significant changes those that show a p-value off 0.05. Positive significant trends in NDVI would indicate potential improvement in land condition, and negative significant trends potential degradation[7].

Productivity State: The Productivity State indicator allows for the detection of recent changes in primary productivity as compared to a baseline period.

Productivity Performance: The Productivity Performance indicator measures local productivity relative to other similar vegetation types in similar land cover types or bioclimatic regions throughout the study area.If observed mean NDVI is lower than 50% than the maximum productivity, that pixel is considered potentially degraded for this indicator.

## VIII. RESULTS AND DISCUSSION

### *A. RESULTS*

Figure 2 shows the result of organic carbon of Oyimo forest from 2000 to 2020. The result demonstrate areas that are forest loss over the years, area that was no loss of forest, area that there was non-forest (non-forest does not mean no forest, this area can be farmland or cultivated land) and area there was no data to assess what is happening in the study area.

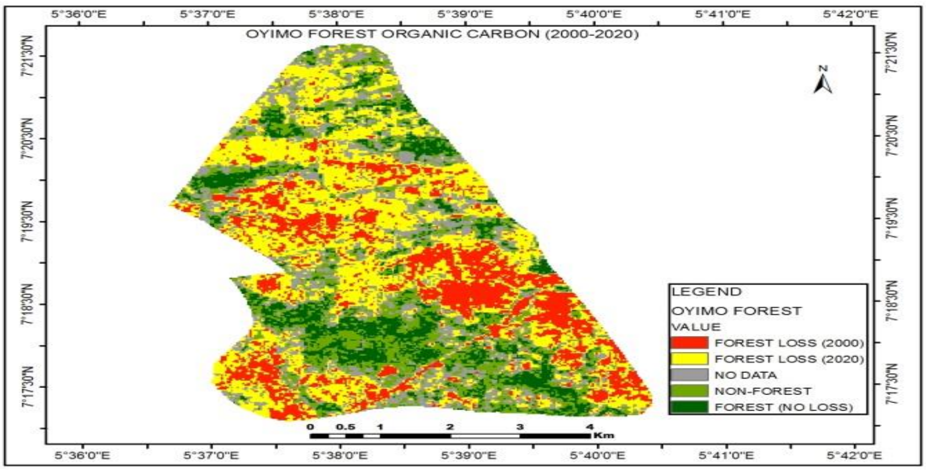


Fig. 2: Organic Carbon of Oyimo forest reserve

Table1: show report of base line summary table of organic carbon estimation from 2000 to 2020. From the results, initial forest area was 59,413 hectares; initial non-forest area was 245 hectares (ha), total biomass was3, 535,543 tonnes of C, loss of carbon was 127,703 tonnes of C and total carbon emission during the years was 468,669 tonnes of $CO_2e$. The least forest loss during the years was 10ha, and the highest forest loss during the years was 416. The least of emission of carbon for the years was 2,521 tonnes of $C0_2e$ and highest was 101,513 tonnes of $C0_2e$. One can observe carefully that there is balance in the emission of carbon and the forest loss. Where there was lowest forest loss in 2003 there was lowest emission of carbon and also where there was highest loss of forest in 2017 there was highest emission of carbon in during the years.

ISSN No:-2456-2165

| Summary of carbon loss due to degradation* | | | | | |
|---|---|---|---|---|---|
| Baseline land cover | | | | | |
| | | Area (hectares) | Percent of total area | Total biomass (tonnes of C): | |
| | Initial forest area: | **59,413** | 99.4% | 3,535,543 | |
| | Initial non-forest land area: | 345 | 0.6% | | |
| | Water area: | 0 | 0.0% | | |
| | Missing data: | 0 | 0.0% | | |
| | **Total:** | **59,758** | **100.0%** | | |
| Land cover change summary | | | | | |
| | | Baseline year: | 2000 | | |
| | | Final year: | 2020 | | |
| | Forest loss over period (hectares): | | **1,858** | | |
| | Loss of carbon over period (tonnes of C) | | **127,703** | | |
| | Total carbon emissions over period (tonnes of CO2e): | | **468,669** | | |
| Carbon loss by year* | | | | | |
| **Year** | **Forest Loss During Year (ha)** | **Forest Cover at End of Year (ha)** | **Loss of Carbon During Year (tonnes of C)** | **Total Biomass at End of Year (tonnes of C)** | **Carbon Emissions During Year (tonnes of CO2e)** |
| 2001 | 93 | 59,320 | 7,326 | 3,528,217 | 26,886 |
| 2002 | 65 | 59,255 | 4,890 | 3,523,327 | 17,945 |
| 2003 | 10 | 59,245 | 687 | 3,522,640 | 2,521 |
| 2004 | 32 | 59,213 | 2,442 | 3,520,198 | 8,962 |
| 2005 | 39 | 59,174 | 2,895 | 3,517,303 | 10,626 |
| 2006 | 27 | 59,147 | 2,051 | 3,515,252 | 7,526 |
| 2007 | 34 | 59,114 | 2,487 | 3,512,765 | 9,128 |
| 2008 | 50 | 59,064 | 3,780 | 3,508,985 | 13,873 |
| 2009 | 83 | 58,981 | 6,195 | 3,502,790 | 22,735 |
| 2010 | 75 | 58,907 | 5,546 | 3,497,243 | 20,355 |
| 2011 | 53 | 58,854 | 3,917 | 3,493,327 | 14,374 |
| 2012 | 30 | 58,824 | 2,133 | 3,491,194 | 7,827 |
| 2013 | 160 | 58,664 | 9,772 | 3,481,422 | 35,863 |
| 2014 | 109 | 58,554 | 7,286 | 3,474,136 | 26,738 |
| 2015 | 204 | 58,351 | 13,023 | 3,461,114 | 47,793 |
| 2016 | 102 | 58,249 | 6,978 | 3,454,136 | 25,609 |
| 2017 | 419 | 57,830 | 27,660 | 3,426,476 | 101,513 |
| 2018 | 183 | 57,647 | 12,506 | 3,413,970 | 45,896 |
| 2019 | 92 | 57,555 | 6,130 | 3,407,840 | 22,498 |
| 2020 | 0 | 57,555 | 0 | 3,407,840 | 0 |

Table 1: Summary table of organic carbon from 2000 to 2020

Table 2: Shows different biomass in the forest reserve represents possible above ground biomass and below ground biomass. This biomass can be seen in the table and their changes from pre-restoration level to final total biomass of potential carbon removal. From the result, Agroforestry was happen to be the least of biomass who pre-restoration level was 3,748,068 and final total biomass was 14,485,298 tonnes $C0_2e$. Eucalyptus plantation is one of the plants species happen to be the highest biomass of which the pre-restoration biomass was 37,883,296 and final total biomass was 48,620,525 tonnes $C0_2e$.

ISSN No:-2456-2165

| Potential carbon removals from restoration summary table | | |
|---|---|---|
| | **Value** | **Units** |
| **Total area of polygon:** | 59,758 | hectares |
| **Time since initiation of restoration:** | 20 | years |
| **Initial biomass:** | 10,737,229 | tonnes CO2e |

| Change in biomass with restoration | | |
|---|---|---|
| **Restoration approach** | **Change in biomass compared to pre-restoration levels (tonnes CO2e)** | **Final total biomass (tonnes CO2e)** |
| Natural regeneration | 10,228,039 | 20,965,269 |
| Agroforestry | 3,748,068 | 14,485,298 |
| Teak plantation | 25,854,827 | 36,592,056 |
| Eucalyptus plantation | 37,883,296 | 48,620,525 |
| Oak plantation | 11,167,998 | 21,905,227 |
| Other broadleaf plantation | 19,321,640 | 30,058,869 |
| Pine plantation | 14,241,579 | 24,978,808 |
| Conifer plantation | 15,362,000 | 26,099,230 |

Table 2: Potential carbon removals and change in biomass restoration

Figure3: shows the result of soil organic carbon over the years and some activities that have taken place in the study area, for the purpose of species and ecosystems estimate or prediction based on remote sensing and GIS monitoring information and ecosystem modelling simulation tools. The construction of new effective, successful, and science-informed management policies requires various-disciplinary approaches (from environmental and socioeconomic sciences) as well as the participatory involvement of local stakeholders, forest managers, and other relevant partners in the planning and decision processes, considering the institutional setting [8]. Because, carbon stored in soils contributes to a variety of soil functions, including biomass production, water storage and filtering, biodiversity maintenance, and many other ecosystem services.

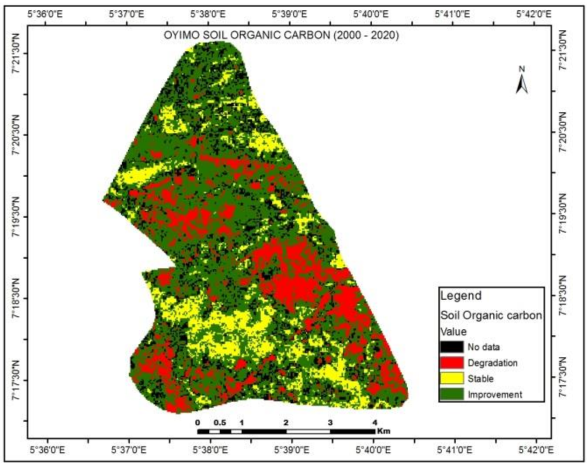


Fig. 3: Oyimo forest reserve organic carbon

Figure4: Shows the result of Oyimo forest reserve soil productivity state degradation from 2000-2012 versus 2012-2020. The green colour ramp represents improved area from degradation, yellow colour represent stable area and red pattern represent degraded area during the years of assessment.

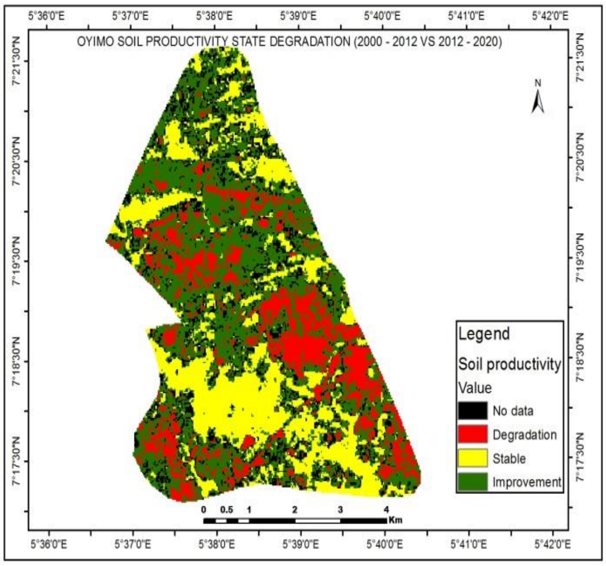


Fig. 4: Oyimo forest reserve soil productivity state degradation

Figure5: Shows the results of analysis of the Oyimo forest reserve soil productivity performance degradation during the year of analysis. The observation from the result showed that there are areas of degraded and non-degraded.

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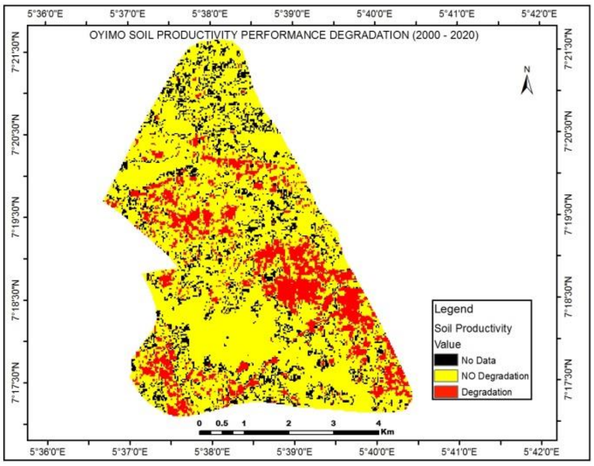


Fig. 5: Oyimo forest reserve soil productivity performance degradation

Figure 6: Shows the result of Oyimo forest reserve of soil productivity trajectory degradation of over the years of analysis. During the years of analysis it was observed that forest reserve was degraded significantly by P value of < 0.05 in red colour ramp in figure 6. There was also a significant improvement from degradation as a result of re-vegetation as directed by Ondo State Government and natural mean.

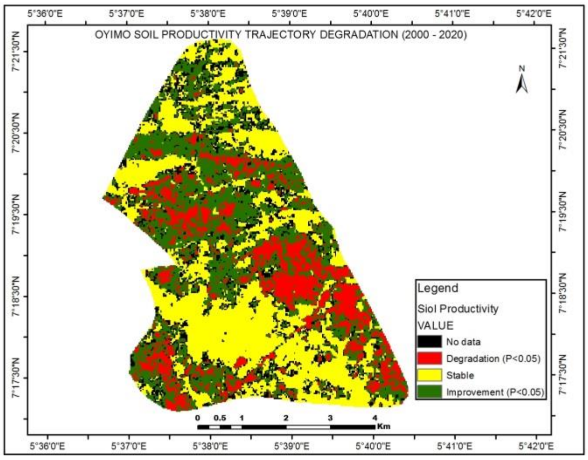


Fig. 6: Oyimo forest reserve soil productivity trajectory degradation

Table3: Shows the result of soil organic carbon land cover of Oyimo forest reserve during the years of investigation. The area with no data was 19.01 hectares, degraded area was 18,727.849hectares, stable area was 29,032.919hectares and improved area was 11,9780.2184 respectfully.

| Summary of SDG 15.3.1 Indicator | | |
|---|---|---|
| **Area (hectares)** | | **Percent of total land area** |
| Total land area: | 59,758 | 100.00% |
| Land area improved: | 11,9780.2184 | 20.045% |
| Land area stable: | 29,032.919 | 48.584% |
| Land area degraded: | 18,727.849 | 31.34% |
| Land area with no data: | 19.01 | 0.031% |

Table 3: Summary table of soil organic carbon land cover of Oyimo forest reserve

*B. DISCUSSION*

The assessment of carbon stock and sequestration for this report was carried out with data available in plugin of quantum geographic information system. From the results, initial forest area was 59,413 hectares; initial non-forest area was 245 hectares (ha), total biomass was 3,535,543 tonnes of C, loss of carbon was 127,703 tonnes of C and total carbon emission during the years was 468,669 tonnes of CO2e. The least forest loss during the years was 10 ha, and the highest forest loss during the years was 416. The least emission of carbon for the years was 2,521 tonnes of $CO_2$e and highest was 101,513 tonnes of $CO_2$e. One can observe carefully that there is a balance between the emission of carbon and the forest loss. At least where there was lowest forest loss in 2003 there was lowest emission of carbon and also where there was highest loss of forest in 2017 there was highest emission of carbon in during the years. That is the more the loss of forest in the study area the more the emission of carbon into the atmosphere.

The terrestrial carbon pools that are most often included in available maps are above ground biomass (AGB), below ground biomass (BGB) and soil organic carbon (SOC). Although SOC can be a substantial pool, which can be affected by land-use change, there is more limited spatial data available than for vegetation carbon. For biomass carbon, a number of globally consistent AGB maps are now available, either for the world as a whole or for the tropics [9], [10]. The quality of AGB data has progressed markedly in recent years, however, the existing products do not provide a consensus on the total amount of biomass carbon or its spatial distribution pattern, and in some cases show strong disagreement. Within the scientific community, no single method is considered definitive; some approaches may have advantages or disadvantages in particular areas or ecosystems, and a number of issues influence data quality.

Studies have demonstrated that changes in land-use are inevitably followed by changes in carbon stores [11]. Land-cover change has numerous ecological, physical and socioeconomic consequences. On the positive side, agricultural expansion may increase food production for a growing population, although it is unsure how productive the last exploited lands will be as they are typically the least favourable. There are numerous negative consequences with both known and unknown links and feedback mechanisms.Besides, changes in land-use can affect soil organic matter contents and fertility and also atmospheric $CO_2$ concentrations and global warming [12]. Hence, unlike the burning of fossil fuel, the anthropogenic carbon emission could be reversible through management of lands in favour of sustainable long-term carbon stores. Indeed, terrestrial carbon sequestration is proposed by scientists as an effective mitigation option because it combines mitigation with positive effects on environmental conservation and soil fertility [13].

## IX. CONCLUSION

From the analysis of forest organic carbon and biomass estimation, the integration of quantum geographic information system (QGIS)in GIS technology is a new approach for the study of biomass and carbon stocks on above ground and below ground of forest status. Estimated biomass, carbon accumulation in forest cover is quite good, which can be used as a reference for nature-oriented management onmapping carbon stocks and forest degradation.

Soil organic carbon (SOC) is a vital component of soil with important effects on the functioning of terrestrial ecosystems. Storage of SOC results from interactions among the dynamic ecological processes of photosynthesis, decomposition, and soil respiration. Human activities over the course of many years have led to changes in these processes and consequently to the depletion of SOC and the exacerbation of global climate change. Land uses and management that reduce carbon inputs or increase losses compared to natural vegetation result in reductions in SOC over time, creating a soil carbon deficit relative to the levels of carbon that previously existed in the soil. This deficit represents an opportunity to store carbon from conversions in land use and management when those changes result in either increased inputs or decreased losses of carbon.

## ACKNOWLEDGMENT

The Authors acknowledge the Department of Geography in Faculty of Environmental Science, Nasarawa State University, Keffi and National Space Research and Development Agency.

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