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# THE IMPACT OF DEFORESTATION ON SOIL CARBON STORAGE AND CLIMATE CHANGE IN OKENE, KOGI STATE, NIGERIA

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## Abstract

The stocking and sequestering of increasing atmospheric carbon dioxide ($CO_2$) and the reduction of green- house gas (GHG) emissions that result from improving the carbon sink are two important ways that forested land contributes to the fight against global warming. The purpose of the study is to estimate the rate of car- bon Storage (CS) in Okene, Kogi State Nigeria, as well as the volume of deforestation and its impact on CS. To gauge the changes in carbon stock, stock-difference and gain-loss methods were employed. The gain-loss method predicts gains and losses based on off-take and growth rates, while the stock-difference approach uses actual measurements of carbon stocks over a given period of time. These two methods presuppose that changes in carbon stock and $CO_2$ flows to or from the atmosphere are equal. To quantify the decline of the forest, geographical studies and satellite imagery were used. Comparing the area covered by forest in the same region at two distinct eras allowed researchers to determine the annual rate of change. The outcome showed that tree cover loss (TCL, kg/ha) was decreased in 18 local government regions (LGAs). As a

**Keywords:**
Deforestation, Soil, Carbon, Storage, Climate, Change



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result, through- out the baseline consideration period of 2010 to 2022, Etasko East (EE) and Okene West (OW), Okene South East (OSW), and Okene North have had the least loss in tree cover. The increased demand on human survival brought on by the expanding population may provide an explanation for this observation and discovery. As a result of this development, forests underwent transformation and were used to produce food, build cities and homes, and generate energy. The region with the highest rates of tree cover loss and deforestation was associated with the highest CS, which was calculated at 2700 tC/ha at OSW, and the lowest CS value point at 22.2 tC/ha at Or Okene, Kogi State Okene, Kogi State (OE). As a result, OSW showed that dense forests had higher biomass carbon storage than grazing land and open forests. In conclusion, the study showed that Okene, Kogi State State has a significant potential for raising the level of carbon Storage in order for the state to generate a profit from the sale of carbon stock and enhance climate change mitigation efforts.

## Introduction

As more national and international organizations, as well as all privately and publicly owned businesses allowed to use these resources, advocate sustainable practices, it is crucial to monitor natural resource stocks around the world. However, in reality, it is frequently challenging to implement laws pertaining to the sustainable use of natural resources at all levels of government as well as by international non-governmental organizations (NGOs) looking to gauge progress and identify offenders. The ef- fective collection of systematic data at appropriate scales, separated into reasonable temporal segments, for a pe- riod of sufficient duration, is the first crucial step in any fair-minded environmental assessment strategy. Only then can the phenomenon in question be evaluated effectively and objectively. Due to lax rules, insufficient enforcement resources, and corruption in the face of expanding inter- national markets, Nigeria has battled illegal logging and deforestation for a long time. The primary means of support for many people and a key factor in the



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economic development of many na- tions are the forest ecosystems. They are vital natural resources that provide a variety of ecosystem services, like regulating the balance of atmospheric carbon and, thus, preventing climate change. The global carbon cycle benefits greatly from the presence of forests. Depending on the particular management regime and activities, they might operate as generators or sinks of carbon. Forests are important natural carbon sinks that help to store atmospheric carbon in biomass and soil. It is among the most effective strategies for limiting the accumulation of greenhouse gases in the atmosphere. The global cycle of carbon via the environment is significantly influenced by microbes and plants. People receive ecosystem services, which are advantages from ecological processes that are essential to their existence and quality of life. Some of these ecological services include providing food, storing carbon, cycling nutrients, filtering air and water, and re- ducing floods.

Carbon stocking is the capture and storage of car- bon that would somehow be produced and kept in the atmosphere or terrestrial systems. Terrestrial systems, especially plants, represent an important carbon store, estimated globally at 638 Gt, of which 44 % is present in plant biomass. Carbon stock varies across forest types. While an average of 303 tons of carbon $ha^{-1}$ is retained in tropical forests, 66 tons of carbon $ha^{-1}$ and 44-ton $ha^{-1}$ are retained in temperate and boreal forests, respective- ly. Through the process of photosynthesis, growing trees and other flora take in $CO_2$ from the atmosphere. Plants generate carbohydrates from $CO_2$ and water using the energy of sunlight. However, in addition to absorbing $CO_2$ through photosynthesis, forests also release $CO_2$ as a result of plant respiration and cellular decomposition. Whether an ecosystem is acting as a source or sink of carbon depends on the net balance of $CO_2$ uptake and release. The largest levels of carbon stock are found in young forests, and as forests mature, they tend to be- come less abundant. Carbon stock refers to the amount of carbon that is absorbed by growing vegetation and stored in wood, other biomass, and soil organic matter. More carbon is stored and sequestered by



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forests than any other terrestrial ecosystem, making them an essential natural «brake» on climate change. The stored carbon in forests is released as $CO_2$ when they are destroyed or cleared. The second-leading contributor to global warm- ing is deforestation and forest degradation. A substantial global carbon sink is destroyed when tropical forests are cleared, which contributes about 20 % of anthropogenic carbon emissions.

Deforestation currently accounts for approximately 18 % of global carbon emissions and is the third largest source of emissions. Reducing emissions from defo- restation and degradation is now recognized as a critical component of climate change mitigation. A good un- derstanding of the carbon dynamics of forests is therefore important, particularly about how carbon stocks vary in relation to environmental conditions and human land-use activities. Average values of biomass carbon densi- ties for the major forest biomes are used as inputs to climate-carbon models, estimating regional and national carbon accounts, and informing policy debates. Modified natural forests and plantation forests have drawn the most interest in carbon accounting. Because of the ar- gument that primary forests, especially very old forests, are unimportant in addressing the climate change issue because their carbon exchange is at equilibrium, carbon offset investments prioritize planting young trees because of their quick growth, which provides a higher sink ca- pacity than old trees, and/or coverage, and as a result, the significance of modified forests is rising.

According to, deforestation has dominated land use changes globally and has had a negative influence on the environment by generating biodiversity loss, climate change, and land degradation. Carbon inputs and outputs must balance out to produce carbon reserves. As a result, it typically exhibits a positive correlation with the quantity of both above- and below-ground plant litter. As a result of intricate interactions between the biotic and abiotic environments as well as the dyna- mics of carbon input, carbon is converted and stabilized in the soil. As a result of these intricate and poorly un- derstood relationships, carbon stock is regarded as an ecological property.



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Therefore *the study aimed* at assessing the significant effects of forest deforestation on carbon stocking in Okene, Kogi State State with a view to providing sustainable solutions to the menace of deforestation and setting up holistic af- forestation strategies to construct a substantial window for carbon stocking.

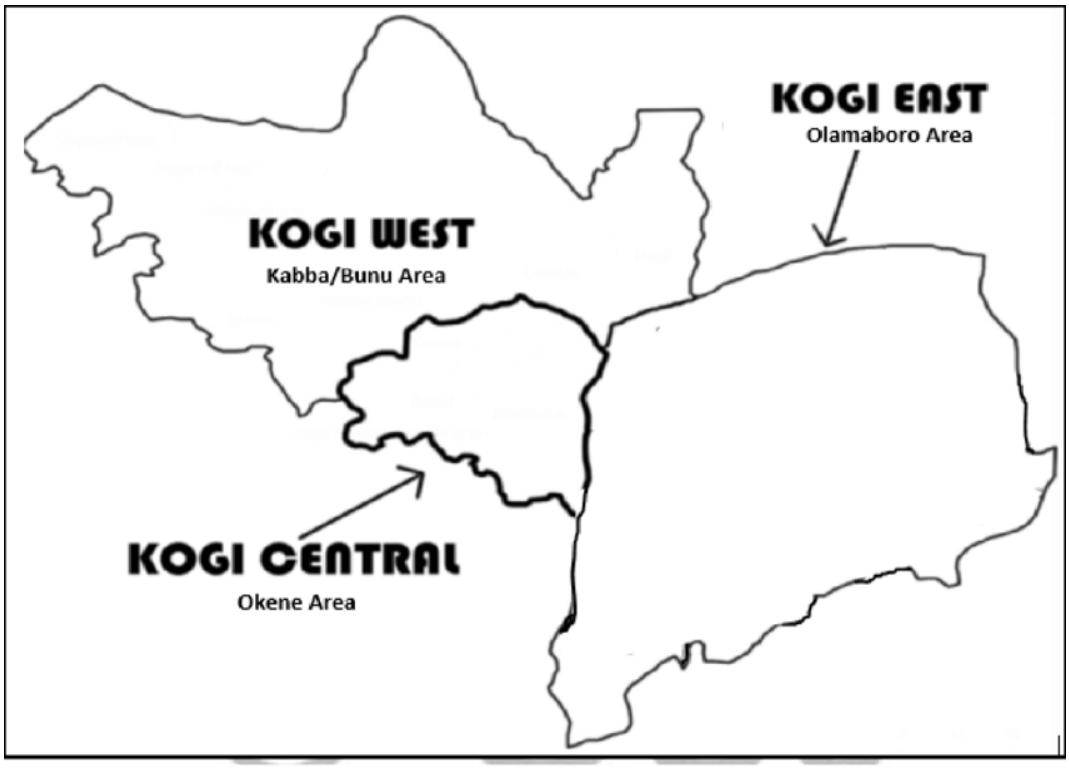
Climate change and global warming arising from anthropogenic-driven emissions of greenhouse gases and land-use and land-cover change have emerged as one of the most important environmental issues in the past few decades (Singh et al., 2013; Tilakasiri, et al., 2016). The continued build-up of greenhouse gases may force changes to the climate system including increases in mean global temperatures. The global mean surface air temperature has been found to have risen by about 0.74°C from 1906 to 2005 and been attributed mostly to a rise in greenhouse gases (Intergovernmental Panel on Climate Change - IPCC, 2007). Deforestation is the removal of forest or stand of trees where the land is thereafter converted to a non- forest use (Dictionary of Forestry, 2008). It is the clearing or thinning of forests, the cause of which is normally implied to be human activity (Encyclopedia Britannica, 2012). Many people do not even know that this problem exists, although it may be occurring right in their own neighborhoods. Deforestation affects climate change because it releases the carbon stored in the plants and soils and alters the physical properties of the surface (Bala et al., 2007). The status of Forest in Nigeria shows that as at 1897, Nigeria had 60 million hectares of forest as woodland. There was an array of plant species which according to Nigeria Environmental Study/Action Team (NEST, 1991), were above 4,614 out of which 255 were endemic. Threatened species of Nigerian flora due to deforestation are about 480 which represent about 10% of the total plant species. NEST (1991) put the number of gazette forest in Nigeria at about 1,160 covering an estimated area of l0 million.



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## Materials and Methods

### Study Area




Okene is a town in the Nigerian state of Kogi. The town is based in a Local Government Area of the same name. Okene runs along the A2 highway. It had an area of 328 $km^2$ and a population of 320,260 at the 2006 census.The predominant people are the Ebira of central Nigeria and the Ebira language is spoken. The postal code of the area is 264. Okene is the birthplace of American Hockey League player and National Hockey League prospect Akim Aliu.[3] Another prominent Nigerian hailing from Okene is Engineer Joseph Makoju, the former managing director of the Power Holding Company of Nigeria and currently the Honorary Adviser to Mr President on Electric Power and the Honorary Adviser to the President/CEO Dangote Group on Strategies. Okene is the birthplace of Governor Yahaya Bello and Governor-elect of Kogi State Ahmed Usman Ododo. Popular actress and entrepreneur Mercy Johnson also comes from Okene.



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**Data Collection**

Numerous techniques are used to measure national deforestation. The degree of deforestation, bio-geographic factors (such as the seasonality of forests, relief, and cloud cover), and cost all in- fluence the monitoring techniques chosen. The rate of deforestation in the 18 local government areas was estimated using real-time areas' tree cover loss per hectare, primary forest content per hec- tare, tree cover loss percentage, and primary forest content per- centage. Additionally, relevant tree loss and deforestation figures from 2010 to 2021 were gathered from the Department of Forestry, Mi- nistry of Environment, Okene, Kogi State State, Nigeria. Satellite imagery and geo- graphical studies were used to assess the decline of forests. By comparing the area covered by forest in the same location at two distinct dates, the annual rate of change was estimated.

The stock-difference and gain-loss approaches measure carbon stock change diffe- rently but equally well. In the stock-difference ap- proach, carbon stocks were physically measured over a spe- cific time interval, as shown in Fig. 3. The gain-loss method estimates gain and losses based on off-take and growth rates. These two approaches assume $CO_2$ flows to or from the atmosphere equal carbon stock changes and estimated as also shown in the equations in the Fig. 3 as described in Field carbon stock was measured using LI-7825 $CO_2$ Isotope Analyzer which measures four (4) most abundant $CO_2$ gas isotopologues in air and reports $\delta^{13}C$, $\delta^{17}O$, and $\delta^{18}O$ with high preci- sion and accuracy.

Inventory-based methods and country-specific conver- sion equations and models were used to determine carbon stocks in forest land and change over time. Standard-sized sampling areas (forest plots) were located on a sampling grid across forest land. The plots were permanent and monitored over time. Measurements of living trees, dead wood, and other plot-specific data were taken. These forest plot data were converted to carbon by applying explicitly developed methodologies. These methods vary between natural and planted



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forests. Allometric equations and mo- delling techniques were used to calculate natural and planted forests as indicated in equation (1).

Airborne scanning laser (LiDAR) data were used in conjunction with field measurements to improve the preci- sion of the carbon stock and stock change estimates for planted forests. These techniques enable the conversion of plot data to carbon units per forest area.

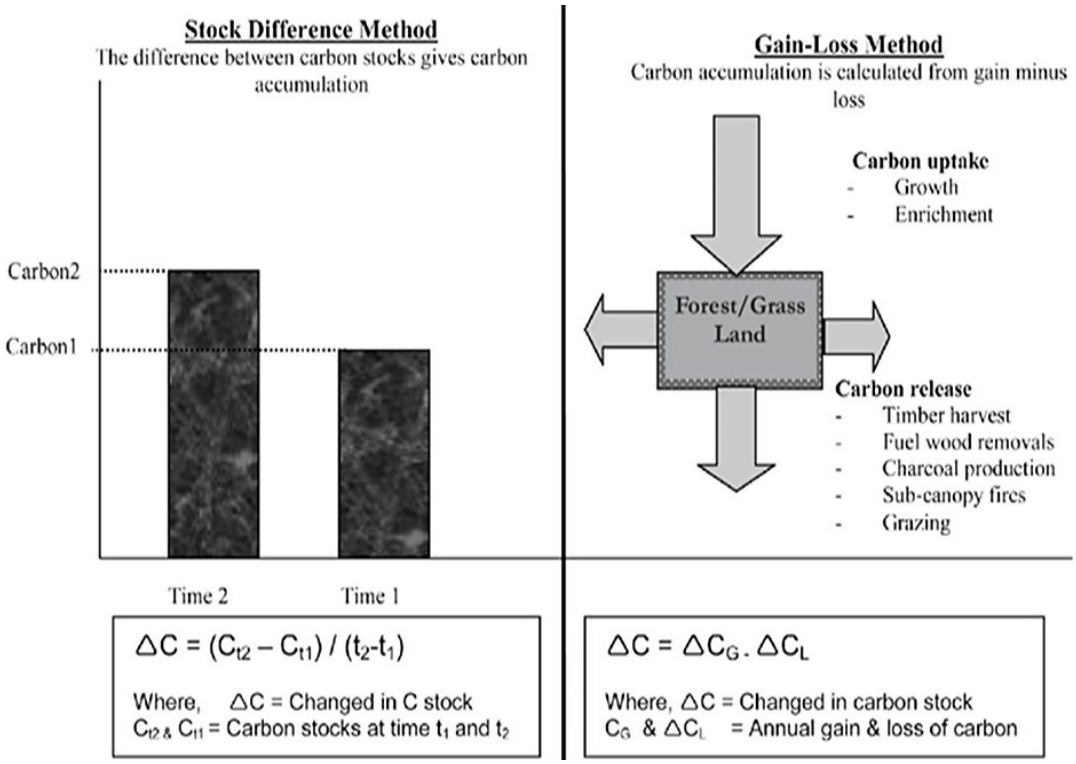



Fig. J. Estimating Carbon Stock Changes

The deforestation trends from 2010 to 2020 were analyzed using statistical tool of MAKE- SEN 1.0 software. To obtain the total carbon stock for the different forests in the 18 LGAs, the total carbon stock contained in the forests from 2010 to 2020 and the tree cover loss per hectare, primary forest content remaining per hectare, percentage of tree cover loss, and percentage of primary forest content remaining in the same period were determined using statistical metrics such as Duncan and ANOVA tests.



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The results of the ANOVA and Duncan tests were used to evaluate this research's goals and determine if there is a significant difference between the total carbon stocks and the rate of deforestation. Spatial window was used to represent the outputs.

**Results and Discussions**

The potential focus of the study is to evaluate and characterize the effects of deforestation on carbon stock in the eighteen (18) towns of Okene, Kogi State State, Nigeria. The data were acquired database on real-time values of tree cover loss per hectare, primary forest content remaining per hectare, percentage of tree cover loss, and percentage of primary forest content remaining for the eighteen local government areas in Okene, Kogi State State. The estimated tree cover loss in tons per hectare is presented in Table 1 and Fig. 4.

Table 1: Tcee Eovec loss tcend fcom fl010–fl0flfl

| N/S | Towns | Long | Lat | Z (ton/k) |
|---|---|---|---|---|
| 1 | Okene, Kogi State | D.1105□E | 7.5555□N | fl.D5 |
| Fl | Egoc | 5.57flfl□E | D.5D71□N | 0.78 |
| 5 | Esan Dentcal | D.fl1D4□E | D.D888□N | fl.8D |
| 4 | Esan Noctk East | D.545D□E | D.7flD7□N | 5.5D |
| 5 | Esan West | D.1515□E | D.D8DD□N | 0.Dfl |
| D | Estsako Dentcal | D.4505□E | 7.0057□N | fl.11 |
| 7 | Estsako East | D.4505□E | 7.flDfl7□N | 1.71 |
| 8 | Estsako West | D.fl801□E | 7.0080□N | 1.5D |
| D | Igueben | D.fl58D□E | D.5888□N | fl.45 |
| 10 | Ikpoba Okka | 5.D87D□E | D.1D4D□N | –1.D4 |
| 11 | OcOkene, Kogi State-Okene, Kogi State | 5.5407□E | D.flflD8□N | 0.Dfl |
| 1fl | Ockionmwo | 5.D855□E | D.11D4□N | 0.47 |



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| | | | | |
|---|---|---|---|---|
| 15 | Okene Noctk | 5.D057□E | D.5047□N | fl.ofl |
| 14 | Okene Soutk West | 5.5105□E | D.4D55□N | 0.55 |
| 15 | Owan East | D.ofl5D□E | 7.0DDD□N | 1.fl5 |
| 1D | Owan West | 5.85D5□E | D.Dfl7D□N | –0.1D |
| 17 | Esan soutk East | D.4D50□E | D.Dfl14□N | –fl.ofl |
| 18 | Wkunmwonde | 5.D855□E | D.457D□N | fl.18 |

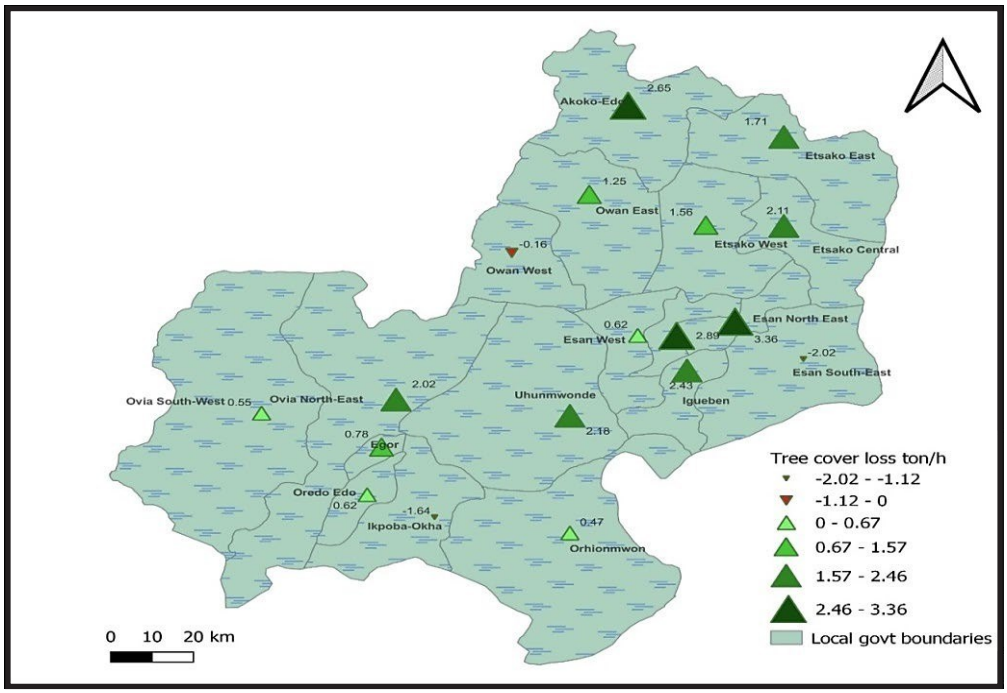
The result shown in Fig. 4 depicts the decline in tree cover (Kg/ha) across the 18 LGAs in Okene, Kogi State State. All of Okene, Kogi State State's local government areas, with the ex- ception of three (3) LGAs, showed consistent increases in the reserve forest's loss of forest cover. For instance, between 2010 and 2022, there would be reductions of 1.64 ha, 0.16 ha, and 2.02 ha at Ikpoba Okha, Owan West, and Esan South East, respectively. As a result, Esan North East had the highest average yearly total loss of tree cover, followed by Esan Central and Akoko Okene, Kogi State with 3.36 ha, 2.89 ha, and 2.65 ha, respectively (Table 1 and Fig. 4). This observation and finding may be ex- plained by the rising pressure on human survival brought on by the growing population. Due to this development, forests were transformed and used for energy production, urban and housing development, and food production. This result is consistent with several studies [3]. Also the finding showed similarity to the study of authors of [18] which indicated that depletions of the forest to the tune of 5,715.8 ha (50.2 % of the original forest cover), whereas agricultural land had increased by 5,146.9 ha (732.4 %), thus the degradation of the forest, shrub land increased by 1,548.3 ha (239 %). According to the overall defores- tation trends in Okene, Kogi State State from 2010 to 2020 based on tree cover loss and primary forest content, there were 10.5 hectares of land with no tree cover in 2010 and 12 hec- tares in 2011.

A loss of tree cover of nearly 9.5 hectares occurred in 2012, and from 2013 to 2014, it increased by 10 to 27 hectares. Between 2015 and 2017, the state's tree cover decreased by an increasing amount, from 11 hec- tares to



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39.5 hectares of land. The finding is supported by studies of [6, 9]. Hence, increase in tree cover losses could also be attributed to persistent fire outbreak in Okene, Kogi State State. Authors of [19] reported that annual area of fire- induced tree cover loss was highest in 2018 (1371 $km^2$), second highest in 2008 (1035 $km^2$) and third highest in 2015 (748 $km^2$). The result in Fig. 5 presents the total tree cover loss in each local government area in Okene, Kogi State State.






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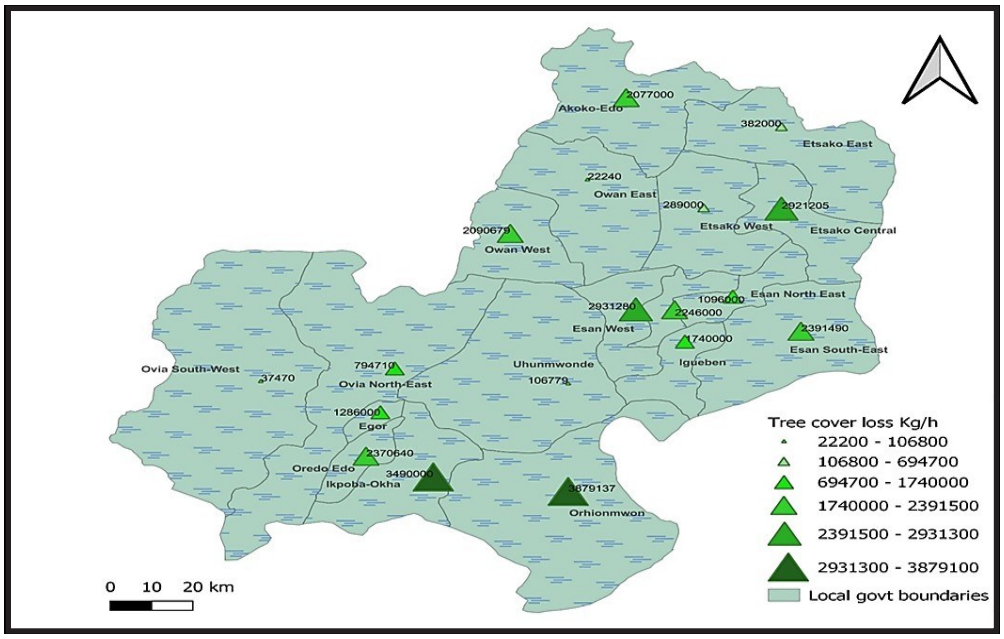



Fig. 5. Total tcee Eovec loss fcom fl010 to floflfl J.fl.

**Evaluation of carbon**

Carbon seques-tration was estimated in the study forest landscape for the years 2010 to 2022. The result in Fig. 6 showed increasing rate of carbon Storage in all the local government areas (LGAs). The highest CS between 1400–2800 tons/ha were obtained in regions like Okene-Southwest, Owan East, Etasko West, and Uhunmwonde, whereas the lowest carbon Storage rate between 735–768 tons were estimated in Orhionmwo and Ikpoba-Okha. The overall average annual carbon Storage rate of 3.65 $tCha^{-1}yr^{-1}$ was estimated. The most recent discovery may be related to REDD+ (Reducing Emissions from Defor- estation and Degradation) activities. Also, the result showed strong similiarity with the finding of REDD+ investigated in central Himalayan region which estimated carbon se- questration rate at 2.4 to 5.6 $tCha^{-1}yr^{-1}$ as reported [19]. Numerous farmers have started participating in tree plant- ing and complete afforestation for the past five years or so. This is strongly encouraged by the rising carbon price on a global scale, which results in reduced carbon emissions through carbon stocking. Additionally, the development of climate smart agriculture (CSA) and innovative

agricultural techniques that decrease the amount of total forest cover and forest clearance. Fig. 7 presents the relationship between the tree cover loss (ton-ha) and carbon stocking (tC/ha) over the eighteen local government areas (LGAs) in Okene, Kogi State State. Highest carbon Storage (CS) of 2700 tons/ha and lowest tree cover loss (TCL) of 22.2 ton-ha in Okene South West (OSW) from 2010 to 2020. According to the study, deforestation has an impact on the carbon reserves of forests and plants. Dense forests exhibited higher biomass carbon reserves as compared to grazing land and open forests. Because each land cover type has a different number of stems, density, and size of trees, there may be a significant variance in carbon between forest types. The loss of forest cover brought on by popula- tions encroaching on areas to obtain wood for fuel, building materials, more arable land, and animal feed, however, resulted in a drop in the overall carbon stock between 2010 and 2020.

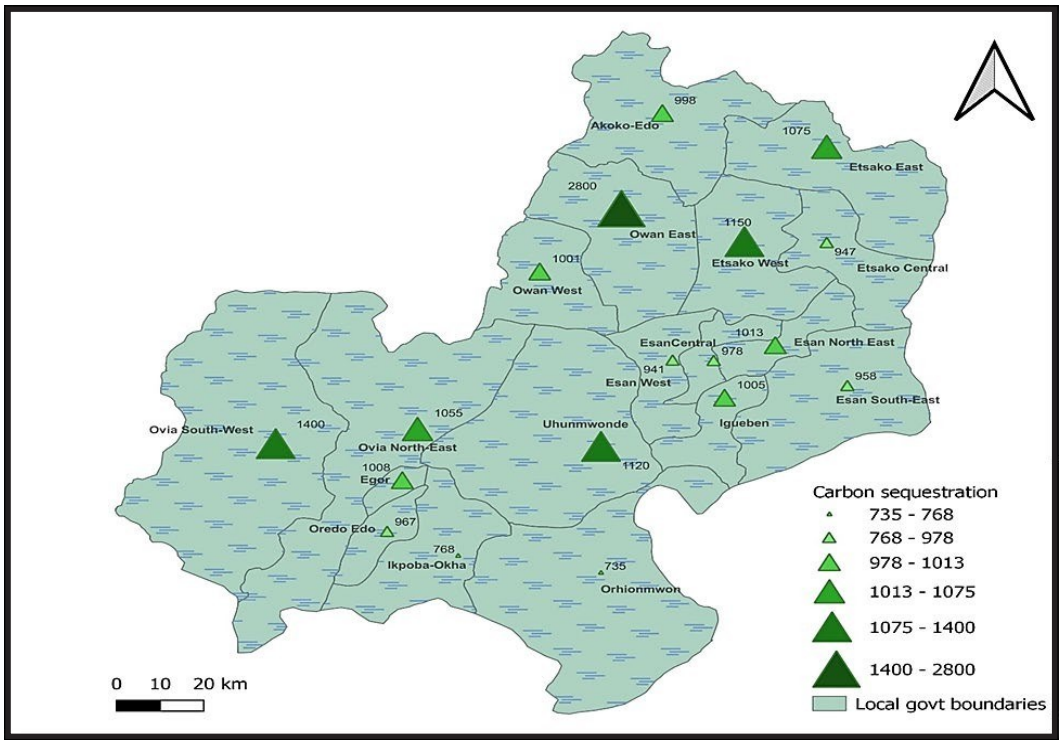
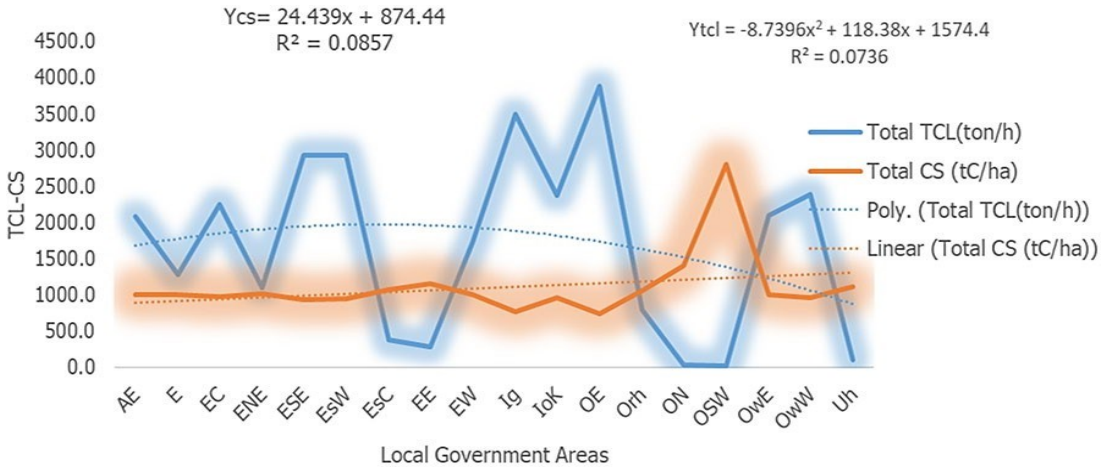



Fig. 6. Dacbon sequestcation fcom fl010 to floflfl



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Forestland consists of a variety of long-lived native tree species and a substantial amount of understory flora. So total carbon stocks are significantly impacted by the conversion of forest to grassland and cultivated land. The study is consistent with the studies of [20, 21].

The study is limited to Okene, Kogi State State, Nigeria. However, a recent analysis performed by the International Energy Agency reports that the need for $CO_2$ storage is positioned to increase from 40 million metric tons per year today to more than 5,000 million metric tons by the middle of the century [20]. Therefore, this study is significant to understand the relationship between forest deforestation and carbon Storage in Okene, Kogi State State. Increasing $CO_2$ storage suggests that complete afforestation with minimum deforestation should be encouraged. This will be essential to reducing global warming and, by consequence, mitigating the effects of climate change. In addition to climate change mitigation measures, complete afforestation is another eco- nomic index as the global carbon price continues to soar. It is important to conduct future research on this study to determine a drought-resistant tree or forest plantation with a large canopy coverage area and early maturity.

## Conclusions

The sustainability of both the environment and people depends in large part on forests. By preserving and sustain- ing biodiversity, they stop the extinction



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of species and uphold ecological balance. As a source of income, people also rely on forest products. The water cycle, carbon se- questration, and absorption of direct solar radiation by forests all have an impact on climate. Therefore, stopping the loss of forests is essential. The current study assessed the effects of deforestation on carbon stocking in all of Okene, Kogi State State's local government areas (LGAs). The result showed that tree cover loss (TCL, kg/ha) decreased in 18 local government areas (LGAs). As a result, throughout the baseline consideration period of 2010 to 2022, Etasko East (EE) and Okene West (ES), Okene South East (OSW), and Okene North have had the least loss in tree cover. For instance, between 2010 and 2022, there would be reductions of 1.64 ha, 0.16 ha, and 2.02 ha at Ikpoba Okha, Owan West, and Esan South East. As a result, Esan North East had the highest average yearly total loss of tree cover, followed by Esan Central and Akoko Okene, Kogi State with 3.36 ha, 2.89 ha, and 2.65 ha. In addition, there is a considerable correlation between the carbon stock (CS) and the rate of tree loss cover (TCL). Highest carbon Storage (CS) of 2700 tons/ha and lowest tree cover loss (TCL) of 22.2 ton-ha in Okene South West (OSW) from 2010 to 2020. According to the study, deforestation has an impact on the carbon reserves of forests and plants. Therefore, the outcome of this study can be used to create further posi- tive interventions to encourage forest regeneration in Okene, Kogi State State and thereby improve carbon Storage. Also, it is revealed that Okene, Kogi State State has a good chance of making internal money from the sale of carbon stock by stepping up and maintaining the current afforestation techniques.

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