Journal of Research in Forestry, Wildlife & Environment Vol. 15(4) December, 2023
***E-mail:** jrfwe2019@gmail.com; jfewr@yahoo.com*
http://www.ajol.info/index.php/jrfwe

jfewr ©2022 - jfewr Publications
ISBN: 2141 – 1778
Ogbodo et al., 2023

ESTIMATION OF EMISSIONS FROM TROPICAL DEFORESTATION SCENARIOS IN ANAMBRA STATE USING THE GLOBAL FOREST WATCH REMOTE SENSING TOOL

Ogbodo J. A.[1,2,3], Okeke F. I.[2], Moka E. C.[2], Uzodinma V. N.[2] and Odey P.O.[3]

[1]Sahelian Institute for Bamboo Research and Entrepreneurship Development (SIBRED), Nnamdi Azikiwe University, P.M.B. 5025, Awka, Nigeria.
[2]Department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus (UNEC), Nigeria.
[2]Department of Forestry and Wildlife, Nnamdi Azikiwe University, P.M.B. 5025, Awka, Nigeria

***Corresponding author**: *ja.ogbodo@unizik.edu.ng;*

ABSTRACT

The overall objective of this paper is to assess the impacts of deforestation scenarios in Anambra state, Southeastern Nigeria with open-source remote sensing datasets of the Global Forest Watch Tool. Methodologically, tree cover gain-and-loss status of tree cover including rates of deforestation related carbon emissions were quantified in Anambra State using the open-source remote sensing platform of Global Forest Watcher (GFW). From the results of the analysis, ten (10%) of Anambra State gained 6.76kha of trees spanning a total of 47.0 kha of land during 2000 - 2010. This value equals 1.5% of Anambra' total landmass. In contrast, Anambra state lost a total of 1.52 kha of tree cover to deforestation activities. The results also show that, Awka South LGA (19,740 tons of CO_2eq) emits the highest amount of carbon emissions resulting from tropical deforestation in Anambra State. Next to Awka South LGA, is Nnewi South records a total of 13,400 tons of CO_2eq, Onitsha North (12,100 tons of CO_2eq), Nnewi North (6,440 tons of CO_2eq); Awka North (1,890 tons of CO_2eq) and Onitsha South (1480 tons of CO_2eq) emits the least amount of carbon emission from deforestation in Anambra state. Conclusion, the Global Forest Watcher is a viable open-source remote sensing tool for tropical deforestation's emission mapping in Anambra state. It is therefore recommended in this paper that, there is need for government at both the state and local government levels to intensify tree planting interventions towards mitigating the impacts from carbon emissions resulting from deforestation activities.

Keywords: Anambra State, Carbon Emissions, Deforestation Scenarios, Global Forest Watcher, Remote Sensing, Tree Cover Gain, Tree Cover Loss

Correct Citation of this Publication
Ogbodo J. A., Okeke F. I., Moka E. C., Uzodinma V. N. and Odey P.O. (2023). Estimation of emissions from tropical deforestation scenarios in Anambra State using the global forest watch remote sensing tool. *Journal of Research in Forestry, Wildlife & Environment*, 15(4): 52 – 62.

INTRODUCTION

Tree cover is a highly important component of the natural environment. Generally, tree covers contribute significantly to purifying the surrounding air and to the reduction in environmental hazards. Therefore, forest trees

can affect the concentration of air pollutants, directly removing pollutants and emissions from the atmosphere (Ogbodo *et al*., 2020). Ogbodo *et al.,* (2020) further reported that, tropical forest trees enable societies to becoming more resilient to the effects of climate change and contributes to mitigating erosion, improve air quality and sequester carbon dioxide within the context of the United Nations Framework on reducing emissions from deforestation and forest degradation (REDD+).

Nigeria is signatory to Reducing Emissions from Deforestation and forest Degradation (REDD+) since Year 2012 (FMoE, 2013). To effectively implement REDD+ objectives, however, requires not only funding, but clear metrics for measuring, reporting and verifying (MRV) the effectiveness of measures taken. Therefore, by signing onto REDD+, it means that Nigerian government has pledged to be more committed to ending tropical deforestation and combating climate change through periodic monitoring, reporting and verification (MRV) of forest resources in order to obtain compensation, especially, from the Global Green Climate Fund. In the framework of the ideology of nature-based offsets, the Green Climate Fund provides funding for forestry programs and projects that support the sustainable conservation and preservation of the world's surviving tropical forests in order to meet critical biodiversity and climate targets, including the improvement of livelihood targets. Nature-based offsets have been presented as a way to fund their protection while providing money for rural and Indigenous communities who live in forests and other important ecosystems, all paid for those who pollute (Greenfield, 2023).

Unfortunately, Nigeria's forest vegetation is declining steadily due to deliberate removal of forest trees to pave way for mineral exploitation, urban sprawl, agricultural expansion and infrastructural development. As a result, the percentage reduction in forest cover of Nigeria for 2004 - 2015 increases from 60% (2004) to 7.70% (2015) (Ogbodo *et al*., 2017). This outcome shows that the percentage of forest area in Nigeria falls below the FAO's recommended 25% (minimum threshed) of national forest area coverage (Ogbodo and Okeke, 2022).

FAO (2014) defines **a tree** as any tall plant with a long woody stem, called a trunk, which has leaves and branches growing from it (FAO, 2014). FAO (2014) further states that a forest tree must be defined by the length of its trunk. But, the title of our presentation bothers on 'deforestation'. However, deforestation cannot be explained without first, knowing what a forest is. According to FAO (2020), a forest is "any portion of land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in-situ*.

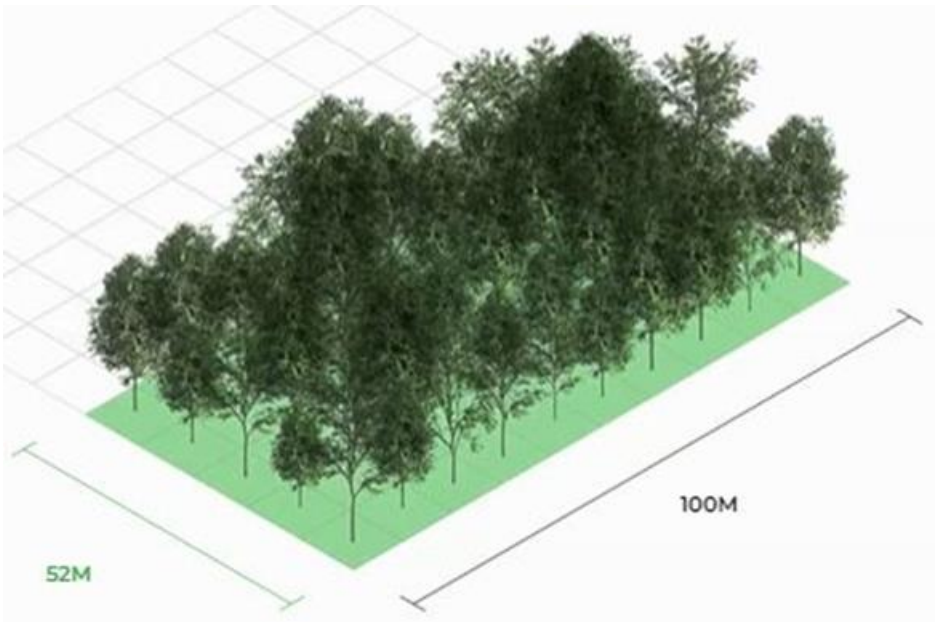

Figure 1: Forest means a group of trees occupying at-least an equivalent size of a typical football pitch.

Again, 'the use of word '*in-situ'* in the FAO definition places an emphasis on conservation of 'natural forests. And the world over, you can only find a natural forest with diverse species only in the tropical countries as Nigeria; hence, the term: 'tropical forests (Figure 2).

On the other hand, deforestation is defined as the process of converting forest cover into other landcover types (Ogbodo, 2013). The clearing of tropical forests across the Earth has been occurring on a large-scale basis for many centuries. Deforestation occurs in many ways. Most of the clearing is done for agricultural purposes: grazing cattle or farming crops. Commercial logging is another common form of deforestation, cutting trees for sale as timber or pulp production. There are other reasons for deforestation, such as to construct towns, roads or dams which later floods large downstream areas.

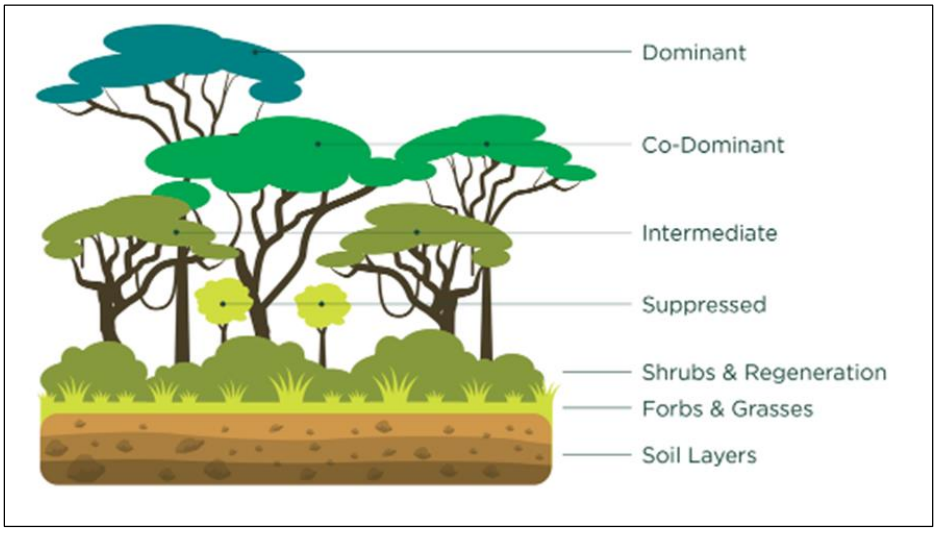

Figure 2: Vertical structure of a tropical forest Ecosystem

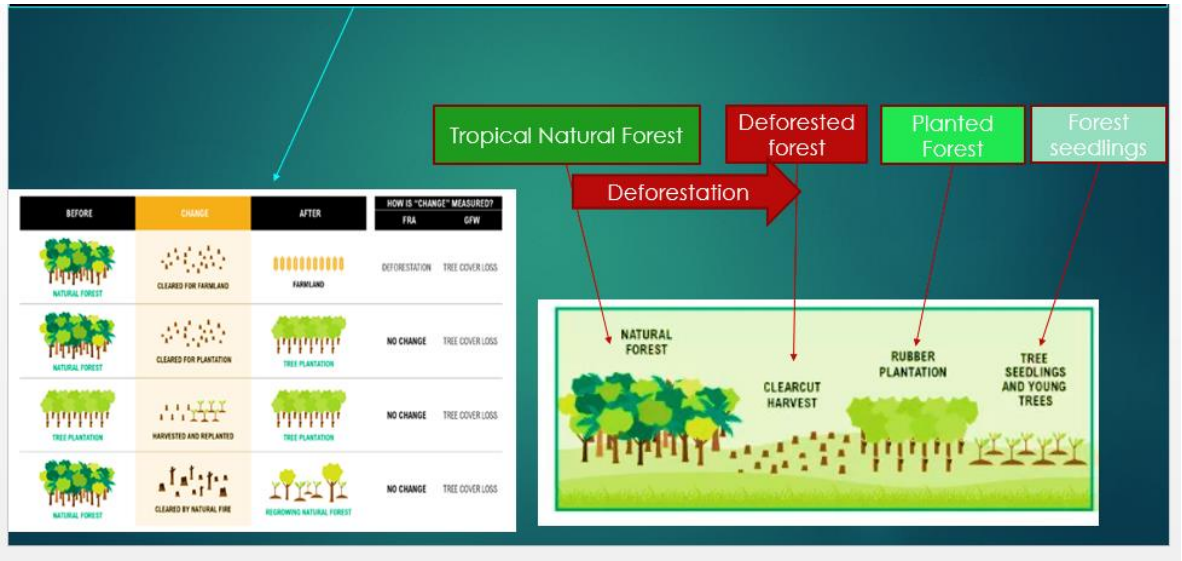

Figure 3: Illustrating Deforestation (WRI, 2023)

Human induced (i.e. anthropogenic) activities that prioritize economic gain are largely responsible for the rise in carbon emissions worldwide. According to the United Nations Environment Programme's (UNEP) annual report states that, by 2050, the use of hydrofluorocarbons (HFCs) could be responsible for emissions equivalent to 3.5 to 8.8 Giga tons (Gt) of carbon dioxide (Gt CO_2eq) (UNEP, 2011). This amount is similar to the current total annual emissions from the transportation sector (about 6-7 Gt) (UNEP, 2011).

As the amount of carbon emissions in the atmosphere continues to rise, extreme climate change events are becoming more frequent and intense all over the world. This increase in carbon dioxide and climate change rates is causing significant impacts on forest growth, dynamics, and overall structure. In Nigeria, the land-use change and forestry sector (38.2%) is responsible for the highest amount of greenhouse gas (GHG) emissions, followed by the energy sector (32.6%), solid waste (14.0%), agriculture (13.0%), and industrial processes sector (2.1%) (Ode, 2022); Ekundayo, 2015 and Afolayan, 2019). Therefore, it is crucial to monitor the carbon emissions from deforestation in Anambra amidst increasing forest cover depletion rates in Anambra State (Ogbodo and Okeke, 2022). Generally, optical remote sensing data are the most abundant and have been widely used in land cover change, forest disturbance, and vegetation growth monitoring (Jiang *et al.*, 2022. Modern remote sensing markets offer multiple sources of Very High Resolution (VHR) Optical Sensors suitable for monitoring forest health and valuing tree-level carbon storage benefits. Such VHR optical satellite imagery include: GeoEye, RapidEye, Worldview-3 and QuickBird. These images are widely used in mapping forest trees to obtain more accurate and precise results in support of implementation of the United Nations Framework on Reducing Emissions from Deforestation and forest Degradation (REDD+) (Ogbodo *et al*., 2015).

However, persistent rising cost of acquiring such data is still a key problem that limits periodic tropical forest assessments in low-income countries (Ogbodo *et al*., 2014). For example, according to Vrieling *et al*. (2012), QuickBird image, covering a size of 267, 667km^2 at a single time, was costing almost five million Euros in 2012. Such related high prices of Very High-Resolution Optical Sensors make it difficult to be

applied on a large scale by researchers in the Nigerian emerging economy having a substantial, impoverished rural sector (Udeme *et al*., 2021). The cost of acquiring Optical imagery is now well beyond the scope of many environmental researchers in Nigeria. Such high financial costs (usually in thousands of US Dollars or Euros depending on where the market is located) for acquiring these very high resolutions remotely sensed imagery for the identification of individual tree species/crowns can limit effective forest health and carbon storage benefits over extensive areas in developing countries such as Nigeria - where numerous citizens are living on less *than US$1.90 per day* (Lakner *et al*., 2022). On 29 January, 2023, the sum of *858.45 Naira was obtained as the equivalent value to US$1.90 via www.oanda.com/currency-converter*.

Freely available Open-source remote sensing data help in curbing the issues relating to high cost of data acquisition. Hence, the first reason why the Global Forest Watcher (GFW) is applied in this study. The Global Forest Watcher is a free mobile and web-based Platform for the frontlines of forest protection. The second reason that necessitate this study is that, there is a dearth of information in the online scientific literature domains regarding the exact amount of carbon emission regarding deforestation activities in Anambra state amid increasing deforestation activities (Ogbodo *et al*., 2022).

Methodology

Study area: This study was conducted in Anambra state (Figure 5). Anambra State (lat. 5.94140° and long. 7.59801°) is located in Southeast Nigeria. Anambra state naturally endowed with a more verse vegetation covers of protected tropical forests and mangroves (Ogbodo *et al*., 2017). According to Global Forest Watch (2020), the Guinean forest-savanna and Cross-Niger transition forests are two of the various ecosystems that make up Anambra. The climate in Anambra is primarily equatorial, with dry seasons. Tropical and Subtropical Moist Broadleaf Forests cover most of the region (Global Forest Watch, 2020). Savannas, shrublands, and portions of tropical and subtropical grasslands are also available.

Figure 4: Shapefile boundary of Anambra State as visualized in the GFW portal

There are two distinct seasons in the study area: the rainy season, which runs from April to October which is a lower temperature, and the dry season that runs from November to March and has afternoon temperatures that reaches 38°C (100°F) but are generally cooler at night (NBS, 2017). Everywhere in the study area typically experiences nonstop rain throughout the month of August, following which a brief dry season known as the "August break" begins. Nonetheless, the state receives 2000–3000 mm annually (NBS, 2017).

Analysis of deforestation and tree cover rates with Global Forest Watch Tool

In this study in Anambra State, forest cover removal and emission rates were computed and ranked for Anaocha, Anambra East and Aguata Local Government Areas of Anambra State. Equally, carbon emissions resulting from tropical deforestation rates for Awka South LGA, Awka North, Nnewi South, Onitsha North, Nnewi North, and Onitsha South were analzed and compared. Methodologically, first, the tree cover gain-and-loss status of the forest reserves found within the five (5) states making up the Southeastern Geopolitical Zone of Nigeria were characterized using the Global Forest Watcher (GFW). The Green Forest Watch (GFW) Tool displays a yearly tree cover loss/gain, defined as stand level replacement of vegetation greater than 5 meters, within the selected area. The GFW's tree cover loss dataset was made available through a collaboration between the University of Maryland in the USA, Google, USGS, and NASA, and uses Landsat satellite images to map annual tree cover loss/gains at a 30 × 30-meter resolution (GFW,2023). For the analysis in the Green Forest Watch platform, after every GIS shapefile of AOI was uploaded unto the GFW's version 1.10 portal, forest variables such as tree cover gain and loss, tree cover height, carbon emissions resulting from deforestation and potential carbon sequestration rate were analyzed on the GFW portal. The percentage tree cover gains and losses within Anambra State during Year 2000 – 2020 were extracted from the Global Forest Watcher.

RESULTS

As at 2010, 10% of Anambra was tree cover covering a land of 47.0 kha (thousands of hectares) while non-Forest stood at 412.0 kha. Whereas, between 2000 and 2010, Anambra State gained 6.76 Kilometers of hectares (kha) of tree cover. This rate equals to 1.5% of its total extent of Anambra State landmass. The state landmass in hectares according to NBS is 486,500 ha (NBS, 2010). In terms of deforestation rate, Anambra State lost 1.52 kha of tree cover. That is equivalent to a 4.5% decrease in tree cover since 2000.

Figure 5 shows the results of deforestation emissions (carbon dioxide) rates into the atmosphere between Year 2001 and 2021 in six (6) Local Government Areas in Anambra State.

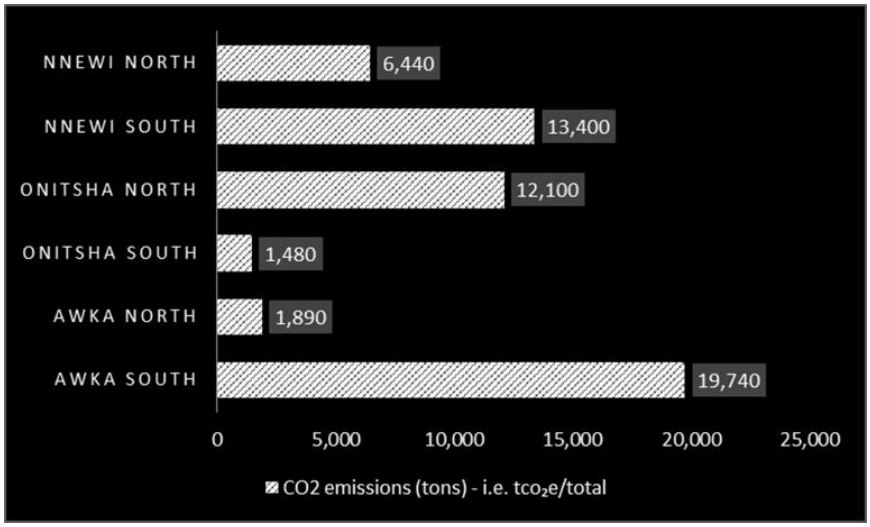

Figure 5: Comparison of rates of deforestation emissions (carbon dioxide), 2001 – 2021

Based on Figure 5, the follow deductions have been made:

i. **Awka North:** In 2010, Awka North had 5.26kha of tree cover, extending over 14% of its land area. In 2021, it lost 8.72ha of tree cover, equivalent to 1,890 tons of CO_2 emissions (CO_2-eq). According to the European Environment Agency - Glossary, based on: IPCC Third Assessment Report (2001), CO_2-eq is defined as a carbon dioxide equivalent or CO_2 equivalent is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming.

ii. **Awka South:** Equally, within the same period of 2001 – 2021, an average of 936t per year was released into the atmosphere as a result of tree cover loss in Awka South. In total, 19,740 tons of CO_2eq was emitted in this period.

iii. **Onitsha North:** Between 2001 and 2021, an average of 574t per year was released into the atmosphere as a result of tree cover loss in Onitsha North. In total, 12,100 tons (i.e. 12.1 kilotons - kt) of CO_2eq was emitted in this period. Forest land wise, from 2001 to 2021, Onitsha North lost 18ha of tree cover, equivalent to a 7.5% decrease in tree cover since 2000.

iv. **Onitsha South:** Between 2001 and 2021, forests in Onitsha South emitted 70.4tCO_2e/year, and removed -950tCO_2e/year. This represents a net carbon sink of -880tCO_2e/year. The forest land lost in Onitsha South from 2001 to 2021, is 2ha of tree cover, equivalent to a 1.8% decrease in tree cover since 2000. , and 1.48kt of CO_2e emissions.

v. **Nnewi North:** Between 2001 and 2021, an average of 307t per year was released into the atmosphere as a result of tree cover loss in Nnewi North. In total, 6.44kt of CO_2e was emitted in this period. In terms of loss of forest land, Nnewi North lost 15ha of tree cover, equivalent to a 26% decrease in tree cover since 2000.

vi. **Nnewi South:** From 2001 to 2021, Nnewi South lost 25ha of tree cover, equivalent to a 8.8% decrease in tree cover since 2000, and 13.4kt of CO_2eq emissions.

Additionally, the ranking results of the forest status assessment for Anaocha, Anambra East and the Aguata is illustrated in Figure 6.

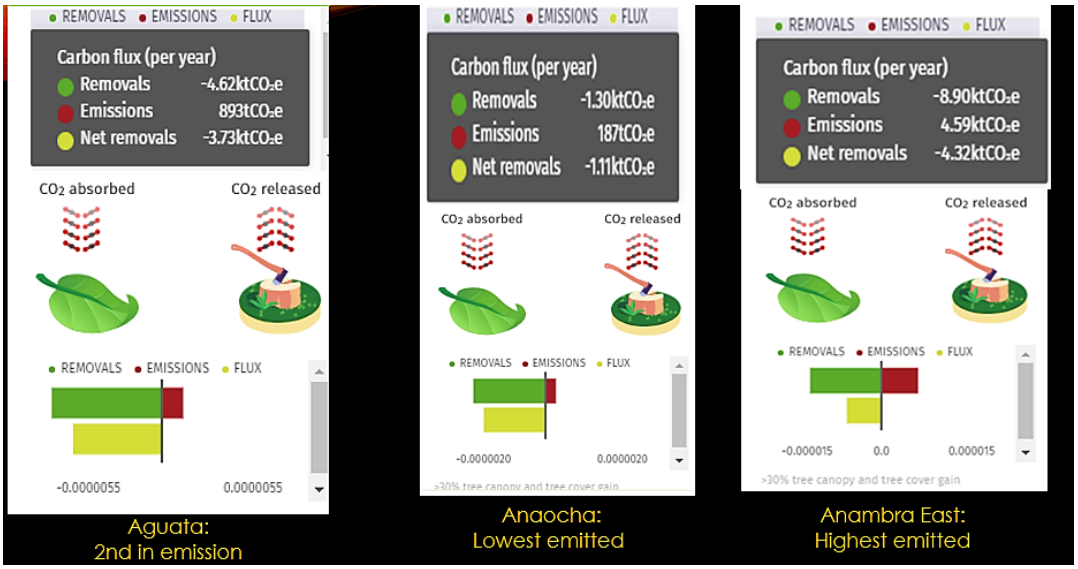

Figure 6: Forest cover removal and emission rates in Anaocha, Anambra East and Aguata Local Government Areas of Anambra State

From forest-related greenhouse gas fluxes (2001-2021) in Figure 6, Anambra East Local Government Area where Former Governor Willie Obiano hails from emitted 4.59 ktCO₂eq. which is the highest value. Aguata LGA of the incumbent Governor Charles Soludo is second with a total of 893 ktCO₂eq. while Anaocha of Former Governor Peter Obi emitted 187tCO₂eq. into the atmosphere in the same period. This result means the level of deforestation activities that took place in those areas as a result of the people's attitude and/or because of civil construction projects that have resulted to massive deforestation within the selected local government areas.

DISCUSSION

A report by the World Resources Institute (WRI, 2023) recently confirms that, deforestation in the tropical countries has a direct effect on local climate, making temperatures more extreme and increasing the risk of heat-related deaths. For instance, In January 2023, the United States National Oceanic and Atmospheric Administration (NOAA) reported that, Year 2022 was the hottest year ever on record in joint ranking with 2015, since the pre-industrial era (NASA, 2023). Similarly, the European Union's Copernicus Climate Change Service (Copernicus, 2023) also confirms that NASA's report that year 2022 was a year of climate extremes, with record high temperatures and rising concentrations of greenhouse gases (GHGs) in the atmosphere. Worst-still, the World Metrological Organization (WMO) reported on 16th April, 2023 that, the month of March 2023 was Earth's second warmest March on record. Meanwhile, before 2013, scientists had never recorded three consecutive years of such high CO_2 growth. But lately, they are reporting that, atmospheric CO_2 is now 50% higher than pre-industrial levels. According to Swallow *et al*., (2007), global-level studies of the economics of climate change mitigation indicate that, afforestation and avoided deforestation are among the most attractive investments for reducing net greenhouse gas emissions (i.e. total emissions less total sequestration).

Simply put, FAO (2018) states that, 'a forest' can also mean a group of trees occupying at-least an equivalent size of a typical football pitch (Figure 1). In that sense, anyone, who has cleared group

of trees on at least, a portion of land that is equivalent to the size of a typical field is guilty of deforestation; *before* God and humanity; especially, with respect to Genesis 2:15; quote: "The LORD God took the man and put him in the Garden of Eden (i.e. tropical – natural – Forest) to work it and take care of it." That why the conservation of forest is of utmost importance to protecting our dear Planet Earth. Better-still, the reason why God created forests on the third (3rd) day (Genesis 1: 11), before making humans on the sixth (6th) day.

CONCLUSION

This study has proven the capability of open-source remote sensing platform such as the Global Forest Watch of the World Resources Institute (WRI) in quantifying the emissions rates from tropical deforestation scenarios in Anambra state, Southeastern Nigeria. 1.5% of Anambra State's landmass is covered tree cover in the period 2000 - 2010. In contrast, Anambra state lost a total of 1.52 kha of tree cover to deforestation activities. The results also show that, Awka South LGA (19,740 tons of CO_2eq) emits the highest amount of carbon emissions resulting from tropical deforestation in Anambra State. Next to Awka South LGA, is Nnewi South records a total of 13,400 tons of CO_2eq, Onitsha North (12,100 tons of CO_2eq), Nnewi North (6,440 tons of CO_2eq); Awka North (1,890 tons of CO_2eq) and Onitsha South (1480 tons of CO_2eq) emits the least amount of carbon emission from deforestation in Anambra state. In conclusion, Anambra East Local Government Area emitted 4.59 ktCO_2eq. as the highest emission value in 2001-2021. Whereas, Aguata LGA is ranked second with a total of 893 ktCO_2eq. and Anaocha third with 187tCO_2eq. emission level within the same period. It is therefore recommended in this paper that, there is need for government at both the state and local government levels to intensify tree planting interventions towards mitigating the impacts from carbon emissions resulting from deforestation activities.

REFERENCES

Afolayan, O. T.; Okodua H, Oaikhenan H, Oluwatoyin M. (2020). Carbon Emissions, Human Capital Investment and Economic Development in Nigeria. http://www.zbw.eu/econis-archiv/bitstream/11159/8307/1/1752183401_0.pdf

Ekundayo Mesagan Peter, (2015). Economic Growth and Carbon Emission in Nigeria. The IUP Journal of Applied Economics, Vol. XIV, No. 4, October 2015, pp. 61-75, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2705305

European Environment Agency, (2001). Carbon dioxide equivalent. Retrieved from https://www.eea.europa.eu/help/glossary/eea-glossary/carbon-dioxide-equivalent

FAO (2014). The Youth Guide to Forests. Retrieved from https://www.fao.org/3/i3856e/i3856e.pdf

FAO, (2018). World's Forests, the Natural Inquirer. Retrieved from https://www.fao.org/3/i0105e/i0105e.pdf

FAO, (2020). Terms and Definitions. https://www.fao.org/3/I8661EN/i8661en.pdf

FMoE – Federal Ministry of Environment, (2013). Nigeria REDD+ Readiness Programme. Retrieved from https://www.forestcarbonpartnership.org/sites/fcp/files/2013/Nov2013/Nigeria%20REDD%2B%20R-PP%20November_2013%5B1%5D_Final.pdf

GFW – Global Forest Watch, (2024). Global Forest Change, 2000-2022. Retrieved from https://storage.googleapis.com/earthenginepartners-hansen/GFC-2022-v1.10/download.html

Global Forest Watch, (2020). "Deforestation and Football Pitch Comparison." We Lost a Football Pitch of Primary Rainforest Every 6 Seconds in 2019. Retrieved from https://www.globalforestwatch.org/blog/data-and-research/global-tree-cover-loss-data-2019/?utm_campaign=LAUNCH:%202019%20Tree%20Cover%20Loss&utm_medium=bitly&utm_source=MonthlyRecap

Greenfield Patrick, (2023). Carbon offsets on flights, food and even TV claim to help the planet – what if they don't? Retrieved from https://www.theguardian.com/environment/2021/may/04/carbon-offsets-used-by-major-airlines-based-on-flawed-system-warn-experts

Jiang, Fugen, Hua Sun, Erxue Chen, Tianhong Wang, Yaling Cao, and Qingwang Liu, (2022). "Above-Ground Biomass Estimation for Coniferous Forests in Northern China Using Regression Kriging and Landsat 9 Images" Remote Sensing 14, no. 22: 5734.

Lakner, C., Mahler, D.G., Negre, M. *et al*. (2022). How much does reducing inequality matter for global poverty? Journal of Economic Inequality volume. Springer Nature Switzerland AG. Volume 20, 559–585. https://doi.org/10.1007/s10888-021-09510-w

Ode Uduu (2022). What are Three Everyday Sources of Nigeria's Greenhouse Gas Emissions? Retrieved https://www.dataphyte.com/latest-reports/what-are-three-everyday-sources-of-nigerias-greenhouse-gas-missions/#:~:text=In%20Nigeria%2C%2038.2%20percent%20of,percent%20respectively%20to%20GHG%20emissions

Ogbodo, J. A. (2013). The potential of synthetic aperture radar for the detection of forest degradation signs in Congo-Brazzaville (Master's thesis, University of Twente). http://essay.utwente.nl/93984/1/John0Ogbodo-25983.pdf

Ogbodo, J. A., and Okeke, F. I. (2023). Spatial analysis of southeastern forest reserves in Nigeria using open geospatial data. African Geographical Review, 42(3), 232-248.

Ogbodo, J. A., Bichi, A. H., and Ogbodo, J. I. (2021). Analyzing The Progress, Pitfalls and Prospects for Attaining Environmental-Related Sustainable Development Goals in Nigeria. Animal Research International, 18(1),3990–4004.

Ogbodo, J. A., Obimdike, L. M., and Benison, Y. (2020). Remote Sensing for Urban Tree Canopy Change Detection with Landsat Satellite Data in Nnamdi Azikiwe University Awka – Nigeria. Indonesian Journal of Forestry Research, 7(2), 99–112.

Ogbodo, J. A., Tembe, E. T., and Peter, J. G. (2017). Assessing the issues and prospects of sustainable forestry in Nigeria. World Farmers Organization (WFO). https://www.researchgate.net/profile/John-Ogbodo-3/publication/314239587_Assessing_the_issues_and_prospects_of_sustainable_forestry_in_Nigeria/links/58bd45d2a6fdcc2d14e7483d/Assessing-the-issues-and-prospects-of-sustainable-forestry-in-Nigeria.pdf

Swallow, B, M. van Noordwijk, S. Dewi, D. Murdiyarso, D. White, J. Gockowski, G. Hyman, S. Budidarsono, V. Robiglio, V. Meadu, A. Ekadinata, F. Agus, K. Hairiah, P.N. Mbile, D.J. Sonwa, S. Weise. (2007). Opportunities for Avoided Deforestation with Sustainable Benefits. An Interim Report by the ASB Partnership for the Tropical Forest Margins, Nairobi, Kenya. https://www.asb.cgiar.org/PDFwebdocs/Report-on-Opportunities-for-Avoided-Deforestation-Sustainable-Benefits-web-low.pdf

UNEP - United Nations Environment Programme, (2011). Annual Report. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/8053/-UNEP%202011%20Annual%20Report-20121086.pdf?sequence=5&amp%3BisAllowed=y%2C%20French%7C%7Chttps%3A//wedocs.unep.org/bitstream/handle/20.500.11822/8053/-UNEP%202011%20Annual%20Report-20121086-french.pdf%3Fsequence%3D6&amp%3BisA=

Vrieling, A., Rahm, M., Mertens, B., Delloye, C., Mane, L., Cherubins, B., Nkoumakali, B., & Stephenne, N. (2012). The potential of satellite imagery to assess forest degradation in Congo and Gabon. Retrieved from http://www.reddiness-en.eu/uploads/WP3_Del3_2_20121114_final.pdf

WRI - World Resources Institute, (2023). Retrieved from https://www.wri.org/insights/deforestation-heat-stress-tropics