International Journal of Basic Science and Technology
May, Volume 11, Number 2, Pages 107117 - 124 http://www.ijbst.fuotuoke.edu.ng /117
https://10.5281/zenodo.15521365 ISSN 2488-8648

Estimation of above-Ground Biomass in Gambari Forest Reserve, Nigeria Using Landsat Operational Land Imager (OLI) Data

*[1] Mephors, J. O., [1] Afolabi, O.S., [2] Adeoti, O.O. and [3] Okoiyele, A.J.

[1]Department of Environmental Modelling and Biometrics, Remote Sensing and GIS Section,
[2]Department of Environmental Modelling and Biometrics, Dendrology section,
[3]Department of Environmental Modelling and Biometrics, Climate Change Section,
Forestry Research Institute of Nigeria, Ibadan, Nigeria.

Article Information

Article # 100259
Received: 14th Feb.,. 2025
Revision: 11th March. 2025
2nd Revision: 26th April. 2025
Acceptance 24th May 2025
Available online:
27th May, 2025.

Key Words
Sample Plots,
Regression Analysis.
Above-Ground Biomass,
Diameter at Breast Height,
Normalized Difference
Vegetation Index,

Abstract

The study estimated the amount of carbon stock in Gambari Forest Reserve, Nigeria by measuring tree parameters diameter at breast height (DBH) and height in the forest reserve. Seven (7) sample plots (30m by 30m) were laid out in the reserve of tree species greater than 10 cm diameter at breast height and their total heights were collected. Tree attributes were measured and converted into carbon estimates using an allometric relationship. Regression analysis and correlation coefficient techniques were developed using normalized difference vegetation index (NDVI) generated from Landsat 8 OLI (Operational Land Imager) imagery of the year 2020 as a dependent variable and above-ground biomass (AGB) estimates from field plots as the independent variable. The estimate of AGB was 71535.989 Mg ha^{-1} (Metric tons per hectare), the carbon dioxide sequestered was 7145.0448tCO_2-e ha^{-1} (tons of CO_2/ha^{-1}), the carbon dioxide emitted was 262537.08tCO-e ha^{-1} (tons of CO^2/ha^{-1}), and weight of carbon in the tree was estimated at 1946.879 Mg ha^{-1} (Metric tons per hectare). The regression analysis between NDVI and AGB showed a value of R^2 of 0.540631 which suggests that NDVI predicts 54.1 % of the variation in AGB, while the correlation coefficient between AGB and NDVI showed a value of 0.735276 which suggests 73.5% variation between AGB and NDVI and equally suggests a high correlation. When estimated, plot 2 has the highest biomass of 20763.19 (metric tons), followed by plot 3 with 17347.63 (metric tons). The more parameters (heights and DBH) measured, the more the total above-ground biomass, weight of carbon, CO_2 sequestered and emitted will be achieved

***Corresponding author:** justinaalagbe@gmail.com

Introduction

Nigeria covers an area of 92.4 million hectares; out of this, 9.7 million hectares (about 10%) of the country, consists of forest reserves and only a small portion of this forest is lowland rainforest (Salami *et al.*, 2016). In the late 1990s, it was estimated that only 1.19 million hectares of lowland rainforest remained in the country about 288,000 hectares of which were designated as official forest reserves (Blaser *et al.*, 2011; Salami *et al.*, 2016). The unique forest ecosystems provide several roles not only in timber and non-timber production for economic benefit but forests significantly function to form a major component of the carbon reserves in the world's ecosystems (Trexler and Haugen, 1995). Natural forests store a large quantity of carbon and there is currently great interest in assessing that quantity accurately because, when forests are cleared, the carbon is converted to carbon dioxide in the atmosphere (Condit, 2008). The mass of living organisms in a forest is called the biomass; most of the biomass in a forest is in trees. Approximately 13 million ha of world forest was lost between 2000 and 2010, implying an increase in the amount of carbon dioxide in the atmosphere (Fearnside and Laurance, 2004; Gibbs *et al.*, 2007; Gibbs and Brown, 2007; Nyamugama and Kakembo, 2015). Africa's forests are disappearing at a rate approximately four times more than that of the world average. A study by the United Nations Environment Programme (UNEP) conducted in 2006 estimated that 70% of forests in West Africa would be decimated by 2040 (Nyamugama and Kakembo, 2015). Deforestation and forest degradation contribute to atmospheric greenhouse gas emissions through the combustion of forest biomass and the decomposition of the remaining plant material (Ramankutty *et al.*, 2007).

The past 10 to 20 years have brought disturbing evidence that human activities contribute to high carbon dioxide (CO_2) concentrations and this might cause significant changes in future global climatic conditions (Wallington *et al., 2004).*

May, Volume 11, Number 2, Pages 117 - 124 http://www.ijbst.fuotuoke.edu.ng /118
https://10.5281/zenodo.15363231 ISSN 2488-8648

Forests, soils, oceans and atmosphere are agents for the storage of carbon; Forest ecosystems support a variety of life forms and maintain huge global biodiversity (Shi and Singh 2002; Khaple *et al*., *2016)*. The net carbon release from tropical deforestation was estimated at 1.6 ± 0.4 Gt C annually, accounting for 21% of the global carbon annually which is almost equivalent to 20 to 65% of the emissions from fossil fuels (Houghton, 1991; Khaple *et al*., 2016). Due to alarming rates of anthropogenic interference, the CO_2 concentration in the atmosphere has increased by 15 to 25% over the past 100 years (Haripriya, 2000; Khaple *et al*., 2016).

Over the past century, human activities like burning fossil fuels, deforestation and urbanization have resulted in high concentrations of CO_2 and other greenhouse gases in the atmosphere (Tripathi *et al*., 2010). Carbon sequestration is the process of transferring and securing storage of atmospheric CO_2 into other long-lived carbon pools that would otherwise be emitted or remain in the atmosphere (Lal, *et al*., 2007; Balasundram *et al*., 2011). Carbon exists as carbon dioxide in the atmosphere and constitutes about 0.04% of the atmosphere (Vashum and Jayakumar, 2012). The carbon sequestered or stored on the forest trees is mostly referred to as the biomass of the tree or forest.

The Kyoto Protocol and REDD$^+$ (2009) programme have to some extent created a global awareness of carbon emission, but there is still a lot to be done in taking stock of major carbon pools in different parts of the world. Biomass assessment is important for national development planning as well as for scientific studies of ecosystem productivity, carbon budgets, etc. (Parresol, 1999; Zianis and Mencuccini 2004; Zheng *et al*., 2004; Pandey *et al*.,2010; Devagiri *et al*., 2013). Recently biomass has been increasingly used to help quantify pools and fluxes of greenhouse gases (GHG) from terrestrial biosphere associated with land use and land cover changes LULC, (Cairns *et al*., 2003).

Previous studies have also reviewed the application of RS data for qualitative change detection of deforestation through land use/cover classification and quantification of forest above-ground carbon stock changes, to estimate carbon stocks, for example, a research work on biomass estimation of Gambari Forest Reserve using allometric equations was made available by (Mbaekwe and Mackenzie, 2008).

In Nigeria however, not so much has been done using GIS and RS techniques to assess Carbon pools of our different forest, especially in the South-western parts with development growing rapidly. There is an urgent need to take stock of our carbon pools to position us for the REDD $^+$ programme (Reducing Emissions from Deforestation and Forest Degradation) which is aimed at reducing global carbon emissions. This study focuses on carbon estimation, specifically in terms of above-ground biomass with the specific objectives of conducting a field measurement to determine tree parameters and comparing Carbon from the field measurements and estimation from satellite imageries.

Study Area

Gambari Forest Reserve has a total area of 12562 hectares, it was from Ibadan Forest Reserve by a resolution of the Ibadan city council passed in September 1899, and the Mamu portion was later added by deed of gift. Both sections were consolidated to form the Gambari Forest Reserve in 1953 (Salami *et al*., 2016). Gambari Forest Reserve is located between latitude 7°10'51''N and longitude 3°52'34''E. Describing the natural Forest Reserve plot at 6.5km from CRIN (Cocoa Research Institute of Nigeria), on the Idi-Ayunre-Ijebu-Ode road, Oyo State. (Figure 1). Gambari Forest Reserve is bounded up by the compass direction on South East 44° by the following locations Idi Ayunre, Adebayo, Ibusogboro and Mamu in the South. These areas are along the same equatorial belt as the study area with a distance of about 200 m to 500 m between them and an altitude of 147 m with a total number of 600 people as of 1996 (Salawu, 2002; Salami *et al*., 2016). Gambari Forest Reserve has one of the most complex vegetation types with the highest number of plant species per unit area. The vegetation is dominated by woody trees to the exclusion of grasses; grasses are shade intolerant and cease to grow under such tall vegetation with a heavy total canopy (Whitmore, 1993). The topography of the study area is generally undulating with the presence of lianas, climbers, twiners, stranglers, scramblers and epiphytes which makes movement almost impossible. Among the valuable indigenous species are: *Terminalia spp* K. Shum (Afara), *Triplochiton scleroxylon* K. Shum (Arere, Obeche), *Irvingia garbonensis* (Oro), *Treculia africana*, among others. While exotic species such as G*melina arborea* (Gmelina) and *Tectona grandis* (Teak) are found in the study area. The study area lies at an altitude between 90 m and 147 m above sea level (Sanwo *et al*., 2015). The area is bounded by two Rivers (Rivers Ona and Awon). Gambari Forest Reserve's mean annual rainfall ranges between 1200 mm to 1300 mm with two distinct wet seasons, May-July and September-November and a short dry period in August. The major dry season occurs between December and March. Temperatures are high throughout the year with a mean annual value of about 27 ˚C and an annual range of 30 ˚C (Larinde and Olasupo, 2011; Adedeji *et al*., 2015). Monthly relative humidity at 0900 hr GMT is more than 80%, and at 1500 hr, the value fluctuates between 60 and 80% except during January and

https://10.5281/zenodo.15363231 ISSN 2488-8648

February when it drops below 60% (Oyeniyi and Aweto, 1986; Adedeji *et al*., 2015).

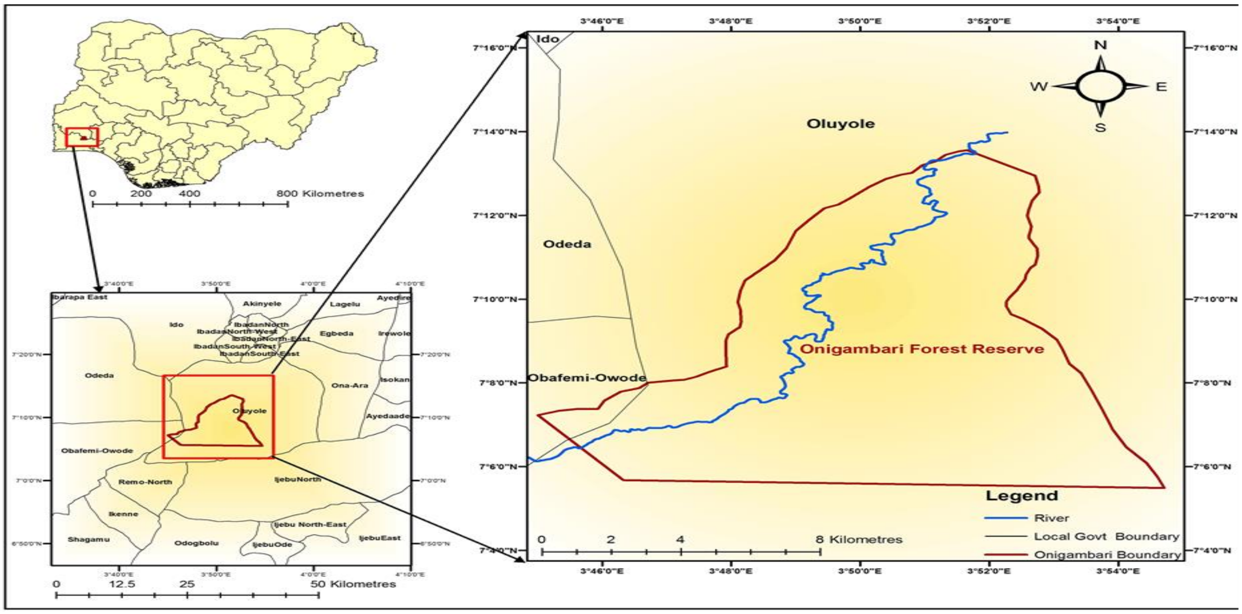

Figure 1: The map of the study area (Adapted from Adedeji *et al*. (2015).

Materials and Methods

Data Collection

The materials used in this study include handheld GPS for navigation, location of sample plots and recording of coordinate points. Surveyor tape and ranging poles were used to measure ground distance and sample plot locations. Measuring tape was used to measure out the size of DBH, and for laying sample plots. To measure the heights of the trees, a Haga altimeter was used. Diameter tape was used to measure the tree DBH.

Data analysis

Digital Image Processing

Radiometric and geometric errors of the Landsat satellite image of 2020 were verified to ensure data quality. The acquired Landsat image was pre-processed, where the radiometric corrections were carried out. The satellite image was further processed using ArcGIS 10.3. The normalized difference vegetation index (NDVI), which is highly sensitive to forest density and physiognomic vegetation classes, Tree population structure was characterized using Dbh and total tree height size classes.

Above-Ground Live Dry Biomass Calculation for Trees/Plot

The above-ground live dry biomass (AGB in metric tons) of a single tree as derived by (Chave *et al*., 2005; Komiyama *et al*., 2005) can be calculated below in (Equation 2) as:

was used to estimate carbon from satellite images. NDVI was calculated below in (Equation 1) using:

$$NDVI = \frac{NIR - R}{NIR + R} \qquad (1)$$

Where NIR = Near Infrared Band, and R = Red Band

Sampling Plot Techniques

A non-destructive sampling approach was adopted to assess the above-ground biomass of trees. A reconnaissance survey of the reserve was carried out to establish the baseline. Subsequently, transects were cut perpendicular to the baseline. Simple randomly, seven (7) transects 1m x 1m were selected. The transect was pegged at 30 m x 30 m intervals because of the Landsat image resolution used. Tree species, which could not be immediately identified in the field, were collected for identification at the Forestry Research Institute of Nigeria (FRIN) Ibadan herbarium, with the help of a taxonomist. Height measurements, Diameter at Breast Height (DBH) at 1.3 m above the ground, of all the trees with ≥10 cm DBH in the seven (7) sample plots were measured.

$$AGB = \left(\rho * exp^{\left(-1.499 + \left(2.148 * \ln(D)\right)\right)}\right) + (0.207 * ln(D)^2 - \left(0.207 * ln(D)^2 - \left(0.0281 * ln(D)^3\right)\right)^{0.001} \qquad (2)$$

Where ρ the wood density (g/cm3), D is the diameter at breast height (cm).

To Determine the Weight of Carbon-Dioxide Emitted

According to (De Wald *et al*., 2005) the amount of carbon dioxide that would be emitted to the atmosphere if trees in the sample plot were cut down and burned completely can be calculated below in (Equation 3):

$$CO_2 = \frac{CO_2}{C} * AGB \quad (3)$$

Where AGB is Above-ground Biomass (Mg ha^{-1}) Metric tons per hectare, CO_2 (ppm) parts-per-million is the molecular weight of carbon dioxide (3.6744), and C is Carbon.

To Determine the Dry Weight of the Tree

According to (De Wald *et al*., 2005) the average percentage of dry matter in a tree in the tropical forest is 72.5%, while the percentage of wet matter is 27.5%. The dry weight of a tree can be calculated as $(H * 0.725)$ Where h is the height (cm)

To Determine the Weight of Carbon in the Tree

According to De Wald *et al*. (2005) and Toochi (2018), the average carbon content is generally 50% of the tree's total volume. To determine the weight of carbon in the tree per plot is calculated as $(Dry\ weight\ of\ the\ tree\ * 0.5)$.

Where 0.5 = 50% of the tree's total volume.

H_0: NDVI coefficient = 0

H_1: NDVI coefficient

To Determine the Weight of Carbon-dioxide Sequestered

Carbon dioxide is composed of a molecule of carbon and two molecules of oxygen. According to (De Wald *et al*., 2005; Toochi, 2018) to determine the weight of CO_2 sequestered in trees per plot is calculated as$(Weight\ of\ C\ in\ the\ tree\ * 3.67)$.

Results and Discussion

Determination of Above-ground Biomass and NDVI storage capacity of the study area.

With the presence of more vegetation cover and positive correlation, the plot with the highest value of AGB and NDVI is plot 2 with 20763.19 (metric tons) and 0.623 NDVI value as shown below in (Table 1). NDVI = 0.4036 + 0.5 AGB this shows that the higher the NDVI (vegetation greenness), the higher the biomass (strong positive correlation values). AGB is predicted to increase by 9.51E-06 metric tons when NDVI reduces or goes down by 1 metric ton and with 0.403559 metric tons intercept.

Table 1: Above-ground biomass (AGB) of trees and their NDVI

Plots	AGB (METRIC TONS)	NDVI	PLOT LOCATION
1	5533.559	0.432	7°10'46.602"N 3°52'34.341"E
	20763.19	0.623	7°10'53.403"N 3°52' 35.333"E
3	17347.63	0.513	7°11'29.74"N 3°52' 33.317"E
4	7490.178	0.451	7°11'41.34"N 3°52' 28.89"E
5	5156.684	0.402	7°11'49.24"N 3°52' 45.107"E
6	8773.901	0.584	7°11'39.504"N 3°52' 25.27"E
7	6470.847	0.5	7°11'59.009"N 3°52' 58.087"E

Shown below in (Figure 2) is the NDVI classification of the study area generated from Landsat 8 OLI of the year 2020 showing each of the seven (7) sampling plot locations in the study area.

International Journal of Basic Science and Technology
May, Volume 11, Number 2, Pages 117 - 124 http://www.ijbst.fuotuoke.edu.ng /121
https://10.5281/zenodo.15363231 ISSN 2488-8648

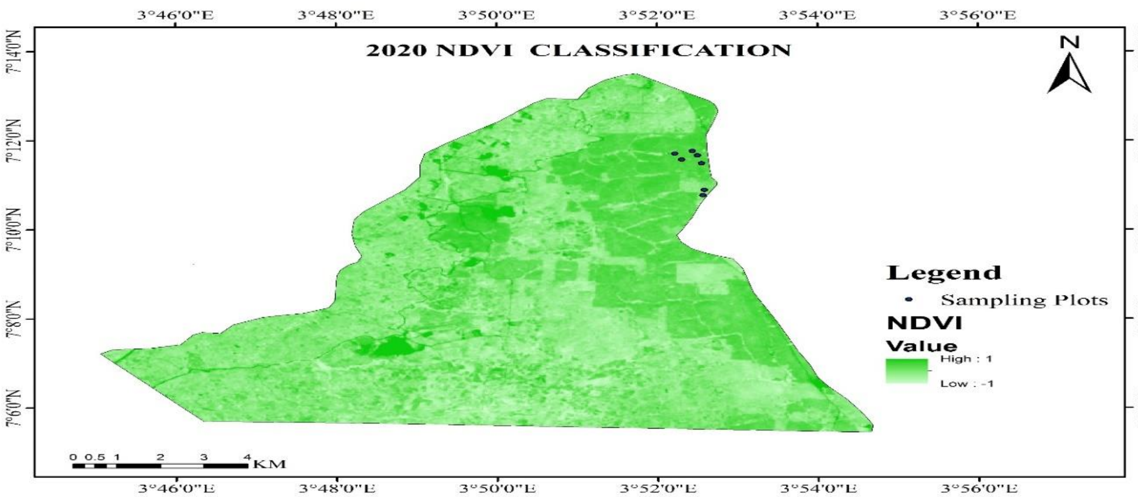

Figure 2: The NDVI of Gambari Forest Reserve, Nigeria 2020.

Regression Model

A regression model was developed as shown below using AGB stock estimates from field plots as an independent variable and NDVI values generated from Landsat 8 OLI of 2020 the dependent variable as shown below in (Figure 3).

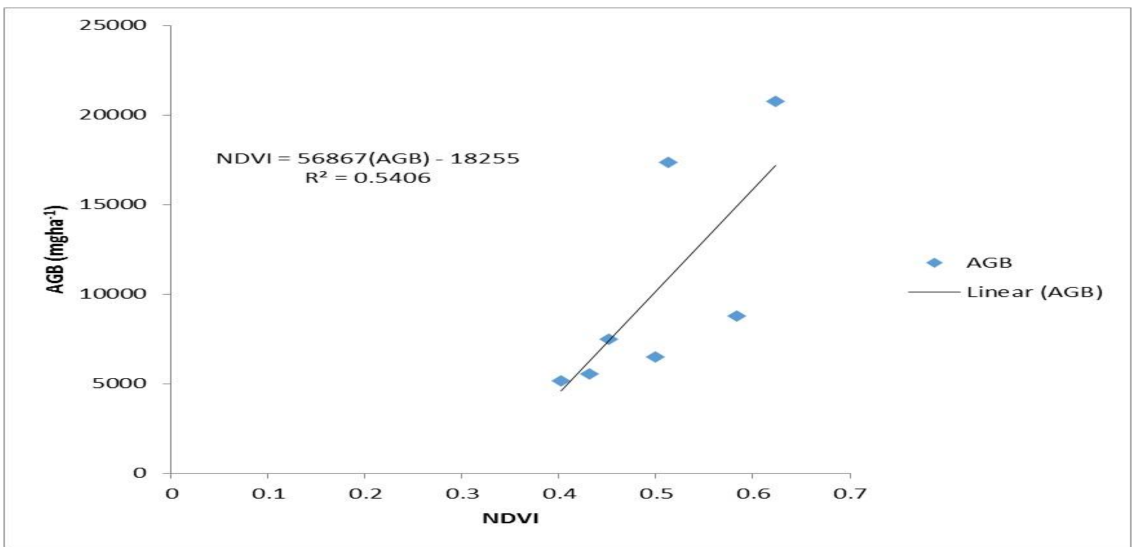

Figure 3: Graph showing the Relationship between AGB and NDVI

Regression analysis of AGB and NDVI

The output statistics of regression analysis, ANOVA and correlation coefficient between above-ground biomass of trees and NDVI's are shown below in (Tables 2, 3 and 4).

Table 2: Regression analysis between AGB and NDVI of Gambari Forest Reserve, Nigeria.

Regression Statistics	
Multiple R	0.735276
R Square	0.540631
Adjusted R Square	0.448758
Standard Error	0.059843
Observations	7

https://10.5281/zenodo.15363231 ISSN 2488-8648

Table 3: ANOVA analysis between AGB and NDVI of Gambari Forest Reserve, Nigeria

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.021073	0.021073	5.884503	0.059689
Residual	5	0.017906	0.003581		
Total	6	0.038979			

Table 4: Correlation coefficient between AGB and NDVI of Gambari Forest Reserve, Nigeria

	NDVI	*AGB*
NDVI	1	
AGB	0.735276	1

NDVI = 0.4036 + 0.5 AGB. NDVI. This revealed that the higher the NDVI (vegetation greenness), the higher the biomass (strong positive correlation values). AGB is predicted to increase by 9.51E-06 metric tons when NDVI reduces or goes down by 1 metric ton and with 0.403559 metric tons intercept.
H_0: NDVI coefficient = 0
H_1: NDVI coefficient ≠ 0
0.0596P – value for the regression suggests the significance of the regression, P – value for the NDVI coefficient indicates the significance and hence shows evidence to reject H_0. Evidence in this result showed confidence that NDVI has a low correlation with above-ground biomass. R^2 value 0.540631 suggests that NDVI accounts for or predicts 54.1 per cent of the variation in above-ground biomass. The correlation coefficient of 0.735276 predicts a 73.5 per cent variation between above-ground biomass and NDVI which equally suggests high a correlation as shown above in (Tables 2 and 4).

Conclusions

Remote sensing, being an advanced technology, is quite useful for quick and reliable estimations of vegetation biomass and carbon over large areas Remote sensing data are most sensitive to season, tree phonological character and degree of crown closure. Spectrally-based Normalized Difference Vegetation Index (NDVI), derived from RS platforms, is a common indicator used to monitor biophysical conditions and vegetation cover. The synergistic role of RS and GIS technologies in Carbon sequestration management was synthesized. The above-ground biomass (AGB) of Gambari Forest Reserve was estimated in metric tons according to each sampling plot and land cover categories as shown in the study; this is based on the tree measurement carried out. These relatively showed the average quantities of carbon stock in each sampling plot. This was validated by using remote sensing and geographic information systems through geospatial mapping. The study revealed that the more the parameters (height and DBH) measured, the more total above-ground biomass, weight of carbon, and CO_2 sequestered and emitted is achieved. The study recognized the AGB and its AVI categories. The regression analysis carried out between the NDVI vegetation indices and AGB indicates a weak relationship, where R^2 value is 0.540631 which suggests that NDVI predicts 54.1 per cent of the variation in above-ground biomass, therefore the regression shows a strong relationship. In the study correlation coefficient of 0.735276 between above-ground biomass and NDVI shows a strong correlation. The difference in the biomass estimates between the predicted and observed values was possibly due to the differences in the crown density and phonological conditions of the trees or vegetation types existing in the study area.

References

Adedeji, O.H., Tope-Ajayi, O.O. and Abegunde, O.L. (2015). Assessing and Predicting Changes in the Status of Gambari Forest Reserve, Nigeria Using Remote Sensing and GIS Techniques. *Journal of Geographic Information System*, 7(3), 301-318.

Balasundram, S.K., Jeyanny, V. and Husni, M.H.A. (2011). Geo-Spatial Technologies for Carbon Sequestration Monitoring and Management. *American Journal of Environmental Sciences*, 7(5):456-462.

Blaser, J., Sarre, A., Poore, D. and Johnson, S. (2011). *Status of Tropical Forest Management*. International Tropical Timber Organization Technical Series No 38: Yokohama Japan, 420 p.

Cairns, M. A., Olmsted, L., Gradanos, J. and Argaeg, J. (2003). Composition and above-ground tree biomass of dry semi-evergreen forest on Mexico's Yucatan Peninsula. *Forest Ecology and Management*, 186(2003), 125-132.

Chave, J.C., Andalo, S., Brown, M.A., Cairns, J.Q., Chambers, D. Eamus, H., Fölster, F., Fromard, N., Higuchi, T., Kira, J.P., Lescure, B.W., Nelson, H.,

https://10.5281/zenodo.15363231 ISSN 2488-8648

Ogawa, H., Puig, B. and Yamakura, T. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145(1), 87–99.

Condit, R. (2008). *Methods for estimating aboveground biomass of forest and replacement vegetation in the tropics*. Center for Tropical Forest Science Research Manual: Smithsonian Tropical Research Institute. Tropical Forest Carbon Inventory, 73 p.

De Wald, S., Josiah, S. and Erdkamp, B. (2005). *Heating with Wood: Producing, Harvesting and Processing Firewood*. University of Nebraska - Lincoln Extension, Institute of Agriculture and Natural Resources: USA, 4 p.

Devagiri, G. M., Money, S., Sarnam, S., Dadhawal, V. K., Prasanth, P., Khapleh, A.K., Devakumar, A. S. and Hubballi, S. (2013). Assessment of above ground biomass and carbon pool in different vegetation types of south western part of Karnataka, India using spectral modelling. *Tropical Ecology*, 54(2), 149-165.

Fearnside, P.M. and Laurance, W.F. (2004). Tropical deforestation and greenhouse-gas emissions. *Ecological Applications*, 14(4): 982-986.

Gibbs, H. K., Brown, S., Niles, J. O. and Foley, J. A. (2007). Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environmental Research Letters*, 2(4): 1–13.

Gibbs, H.K. and Brown S. (2007). *Geographical distribution of woody biomass carbon stocks in tropical Africa*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory: Tennessee, U.S.A. NDP-055b, DOI: 10.3334/CDIAC/lue.ndp055.2007.

Haripriya, G. S. (2000). Estimates of biomass in Indian forests. *Biomass and Bio energy*, 19(250):245- 258.

Houghton, R. A. (1991). Tropical deforestation and atmospheric carbon dioxide. *Climatic change*, 19(1991):99- 118.

Khaple, A.K., Puttaiah, E.T., Devagiri, G.M. and Mishra, S.B. (2016). Vegetation Structure and Above Ground Biomass Carbon in Dry and Moist Deciduous Forests of Dharwad District in Karnataka, India. *47 International Journal of Environmental Sciences*, 5(2):89-97.

Komiyama, A., and Poungparn, S. and Kato, S. (2005). Common allometric equations for estimating the tree weight of mangroves. *Journal of Tropical Ecology*, 21(4), 471–477.

Lal, R., Stewart, B.A., Hansen, D.O. and Doraiswamy, P. (2007). Researchable Priorities in Terrestrial Carbon Sequestration in Central Asia. In: *Climate Change and Terrestrial Carbon Sequestration in Central Asia*, Lal, R., Suleimenov, M., Stewart, B.A. (eds.). Taylor & Francis Group London: Routledge, pp. 475-484.

Larinde, S.L. and Olasupo, O.O. (2011). Socio-Economic Importance of Fuelwood Production in Gambari Forest Reserve Area, Oyo State, Nigeria. *Journal of Agriculture and Social Research (JASR)*, 11(1), 201-210.

Mbaekwe, E., and Mackenzie, J.A. (2008). The use of a best-fit allometric model to estimate above ground biomass accumulation and distribution in an age series of teak (*tectona grandis* L.F.) plantations at Gambari Forest Reserve, Oyo State, Nigeria. *Tropical Ecology*, 49(2), 259-270.

Nyamugama, A. and Kakembo, V. (2015). Estimation and monitoring of above-ground carbon stocks using spatial technology. *South African Journal of Science*, 111(9), 1-7.

Ramankutty, N. Gibbs, H.K., Achard, F., DeFries, R., Foley, J.A. and Houghton, R.A. (2007). Challenges to estimating carbon emissions from tropical deforestation. *Global Change Biology*, 13, 51–66.

Oyeniyi, O.L., and Aweto, A.O. (1986). Effects of Teak Planting on Alfisols Topsoil in South-western Nigeria. Singapore *Journal of Tropical Geography*, 7(2), 145-151.

Pandey, U., Kushwaha, S.P.S., Kachhwaha, T.S., Kunwar, P. and Dadhwal, V.K. (2010). Potential of Envisat ASAR data for woody biomass assessment. *Tropical Ecology*, 51(1), 117-124.

Parresol, B. R. (1999). Assessing tree and stand biomass: a review with examples and critical comparisons. *Forest Science*, 45(4):573-593.

Salami, K. D., Akinyele, A. O., Adekola, P. J. and Odewale, M. A. (2016). Tree species composition and regeneration potential of Onigambari Forest Reserve, Oyo State. *Direct Research Journal of Agriculture and Food Science*, 4(3): 39 - 47.

Salawu, A.A. (2002). *Participation of rural people in forest conservation. A case study of Onigambari forest Reserve*. B.Sc. project. Federal College of Forestry Jericho, Ibadan, Nigeria, Department of Forestry Technology: Nigeria, 32-33 p.

https://10.5281/zenodo.15363231 ISSN 2488-8648

Sanwo, S.K., Ige, P.O., Sosanya, O.S. and Ogunlaye, O.G. (2015). Tree species diversity and forest stands dynamics in a tropical rainforest in Southern Nigeria. *Malaysia Applied Biology*, 44(2), 65 – 73.

Shi, H., and Singh, A. (2002). An assessment of biodiversity hotspots using Remote Sensing and GIS. *Journal of the Indian Society of Remote Sensing*, 30(I &2):105-112.

Toochi, E.C. (2018). Carbon sequestration: how much can forestry sequester CO2? *Forestry Research and Engineering International Journal*, 2(3), 148–150.

Trexler, M.C. and Haugen, C. (1995). *Keeping it Green: Tropical Forestry Opportunities for Mitigating Climate Change*. World Resources Institute: Washington DC, 52 p.

Tripathi, S., Kr Soni, S., Kr Maurya, A. and Kr Soni, P. (2010). Calculating carbon sequestration using remote sensing and GIS. Remote Sensing & GIS. *Geospatial world*, 1-8.

.

Vashum K.T., and Jayakumar, S. (2012). Methods to Estimate Above-Ground Biomass and Carbon Stock in Natural Forests - A Review. *Journal of Ecosystem & Ecography*, 2(4):1-7.

Wallington, T. J., Jayaraman, S., Ole, J. N. and Ellie, J. H. (2004). Greenhouse Gases and Global Warming. In: *Encyclopaedia of Life Support Systems (EOLSS)*, Aleksandar Sabljic (eds). Oxford: UK, pp. 27.

Whitmore, T.C. (1993). *An Introduction to Tropical Rain Forest*. Oxford University Press; 2nd edition: United States, 296 p.

Zheng, D. J., Rademacher, J., Chen, T., Crow, M., Bresee, J., Le Moine, J. and Ryu, S. (2004). Estimating above ground biomass using Landsat 7 ETM+ data across a managed landscape in northern Wisconsin, USA. *Remote Sensing of Environment*, 93(3), 402-411.

Zianis, D., and Mencuccini, M. (2004). On simplifying allometric analyses of forest biomass. *Forest Ecology and Management*, 187(2), pp. 311-332