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Geospatial temporal assessment and monitoring of land area carbon: Evidence from Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria

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Article

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Abstract

This study was conducted to monitor some area carbon in Adekunle Ajasin University Akungba (AAUA) Campus to encourage tree planting alongside her edifice and discourage high rate of deforestation. This study relies solely on the use of remote sensing data to estimate carbon sequestration between year 2014 and 2020. The objective of this study is to estimate the carbon sequestration capacity in the study area using remote sensing (RS) and geographical information system (GIS) with a view to enkindling the importance of trees or forest within the University campus. Consequently, Landsat 8 TM Satellite images of year 2014 and 2020 of the study area were obtained from United States Geological Survey (USGS). The spectral vegetation index (normalised difference vegetation index) was estimate using spectral bands 4 and 5. Ten areas were chosen for this study and their coordinates obtained using GPS receiver when visited. These areas were not developed in 2014 and not fully developed as at year 2020. Through normalised difference vegetation index (NDVI) spread using Water scaler, Evapotranspiration, Potential evapotranspiration (PET), Absorbed photosynthetic active radiation (APAR) and Fraction of absorbed photosynthetic active radiation (FAPAR). The biomass carbon values were generated and the mean biomass carbon values were obtained. It was observed that 2014 had a mean biomass of 7.83 kg/m^3 while the figure was 2.47 kg/m^3 for 2020. The biomass carbon values per hectare were obtained as 87.00 kg/m^3/ ha and 27.40 kg/m^3/ ha for 2014 and 2020, respectively. Total biomass carbon of 69, 951.62 kg/m^3 and 22, 031.93 kg/m^3 were sequestered in 2014 and 2020, respectively for the entire study area. Results of biomass carbon for the designated locations and year using t-test were significantly different at $P > 0.05$. Therefore, carbon sequestration in the year 2014 was higher and better than those obtained in the year 2020 and this reduction could be attributed to forest degradation or loss of vegetation in the study locations. For environmental and carbon friendly atmosphere, green plants are encouraged to be included within urban development plan in the university campuses.

Introduction

The climate change is one of the major concerns of researchers, scientist and policy maker in this present world. This environmental issue also attract economic, social and security issues. This issue has become the nightmare to human race and it is expensive to handle especially, for the developing country without the developed world. Anthropogenic activities are the main causes of climate change which include; urbanization, burning of fossil fuel, forest deforestation and forest degradation among other and this has been documented to increase gaseous pollutants in the atmosphere (Javanbakht *et al*., 2021). There are many gaseous pollutants that are usually released into the atmosphere by human activities and these include; carbon dioxide (CO_2), sulphur dioxide and nitrogen oxides to mention but a few. The CO_2 has become the substance covering the earth and traps heat on the earth surface which in turn increases the climate change effect with a major consequence of global warming.

To reduce the effect of global warming, CO_2 emission must be reduced or captured in order to ameliorate its resultant effects on humans and the environment. Reduction of CO_2 could be done with two basic approaches: reduction of carbon emission and sink through carbon sequestration. The carbon sequestration approach is the best since it is difficult to stop carbon emission and this could only be achieved through green plant carbon sinks (forest).

Forests ecosystem sequestered and store more carbon than any other terrestrial ecosystem and therefore, they are an important natural curb of climate change. Forest serves as carbon sinks, absorbing carbon from the atmosphere through photosynthesis and storing it in plant parts, as well as soil and other organic material within ecosystem (Ajayi and Faniseyi, 2017).

Forest ecosystem forms the largest potential carbon sink in the world. It covers about 40% of the world, which provides inevitable resources including timber production as well as different ecosystem services to the world population (Obade and Lal, 2013). Despite the vital benefits of the forest ecosystem, it is continuously under pressure from various anthropogenic activities, especially the tropical forests (Getahun et al., 2013) causing different greenhouse gases in which CO_2 is an important component. This justified the studies for assessing forest biomass to sequester carbon as part of a global mitigation effort. Quantity of carbon storage in the forest biomass has received special interest as a result of the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol.

Owning to these agreements, countries are mandated to estimate and report CO2 emissions and removals by forests through effective Measuring Reporting and Verified (MRV) systems that comply with the guidelines of the Intergovernmental Panel on Climate Change, which is considered as an integral part of Reduce Emissions from Deforestation and forest Degradation (REDD+) implementation (Mauya *et al*., 2015). REDD + programme of the United Nations deploys results-based finance for incentive on carbon emissions reduction, based on a functional forest carbon measurement, reporting and verification (MRV) system (Gizachew *et al*., 2016).

Although, some technical challenges in measurement, reporting and verification have substantially contributed to the lack of progress for implementation of REDD + programme of the agreed countries. A functional measurement, reporting and verification to support REDD + programme requires estimates of the area of forest loss and gain as well as the corresponding carbon stock and changes over some period of time (Gizachew *et al*., 2016). These data are needed for the estimation of the actual emissions and the construction of forest reference emissions level, as a benchmark against which the actual emissions are compared (Gizachew *et al*., 2016).

A combination of accurate field inventory and remote sensing are expected to provide the carbon emission and sink results. Meanwhile, the developing global carbon markets, particularly because of the incorporation of a Clean Development Mechanism (CDM) in the Kyoto Protocol, require accurate and reliable methods to assess the sources and sinks of carbon in forest ecosystems (Deo, 2008). Consequently, this study aimed to utilize RS and GIS to estimate the carbon sequestration capacity in the University campus to enkindle the trees or forest importance.

The Study Area

The study was carried out in Adekunle Ajasin University Akungba Akoko, Ondo State, Nigeria. The University has an area of 8.04 km^2 and bordered by rock in the eastern part. Also, the University which is situated in Akungba-Akoko township in Akoko South-west Local Government Area of Ondo State. The university lies between latitudes 7^o 28" 9.15' to 7^o 29" 15.18’ North of the equator and longitudes 5^o 44" 15.96' to 5^o 46" 14.78’ East of Greenwich Meridian Ajayi and Arowosoge, 2018). The Akoko South-west Local Government has an area of 530 km^2 and a population of 308,300 as at the 2006 census. The study area used both urban and developing areas. Akungba-Akoko is a town with a mean annual rainfall of 1250 mm and the average temperature ranging between 18°C and 35°C. The town has it boundaries with Ikare-Akoko in the North, and Oba-Akoko in the South, having Supare-Akoko in the West and Iwaro-Oka in the East (Ajayi and Arowosoge, 2018).

Material And Methods

Some designated locations within AAUA were identified with the help of a seasoned forest taxonomist to identify where there were forests prior to development and forest degradation. Ten designated areas were chosen for this research considering the year of degradation and possible carbon potentials. These areas were marked and their coordinates obtained using GPS receiver when visited. Two Landsat 8 TM Satellite images of 2014 and 2020, respectively of the same month (July) were obtained from the United States Geological Survey (USGS). Conversion of digital numbers to absolute radiance value was carried out using ArcGIS 10.2 software. The digital numbers need to be converted to reflectance value in order to calculate vegetation indices. The ArcMap Raster Calculator was used as it is relate to raster satellite imagery. The band 4 and 5 of Landsat 8 TM image were extracted from the imagery and used to estimate the spectral vegetation index (NDVI) using Eq. 1.

Spectral Index (Ndvi)

$NDVI = \frac{\text{Float(b5−b4)}}{\text{Float(b5+b4)}}$ Eq. 1

Where; NDVI = Normalised Difference Vegetation Index, b4 = Spectral band 4, b5 = Spectral band 5

Carbon Sequestration

In this study, one type of spectral vegetation index was used which is NDVI, and its one of common and simplest vegetation index used in the estimation of biomass carbon (Alam, 2016). The value of this index ranges between − 1 and + 1. The carbon sequestration estimate can be derived according to the model of this vegetation index, using the FAPAR and APAR. The APAR is refers as Absorbed photosynthetically active radiation and Eq. 2 was used to estimate APAR value.

$APAR = FPAR \times f$ Eq. 2

Where; FPAR = the fraction of Photosynthetically active radiation (K×f), K = Solar radiation, f = constant expressed as − 0.161 + 1.257×NDVI

Biomass Carbon Estimation

To estimate biomass, light use efficiency ($\sum$) is required and is estimated in Eq. 3 (Field *et al.*, 1995). The biomass carbon is estimated by multiplying APAR and $\sum$ which is obtained in Eq. 4.

$\sum = \sum_O \times T_1 \times T_2 \times W$ Eq. 3

Where; $\sum_O$ *is Global maximum which is a constant 2.5g/mJ,* $T_1 = 0.8 + 0.02 \times T_{opt} - 0.0005 \times (T_{opt})^2$, $T_2 = 1.185 \times [1 + exp^{[0.2\ T}{}_{opt}{}^{-10\ -\ T}{}_{month]}{}^{-1}] \times [1 + exp^{0.3[-\ T}{}_{opt}{}^{-10\ +\ T}{}_{month}{}^{]-1}]$, T_{opt} *= monthly temperature of the year,* T_{month} *= temperature of the month the imagery was captured*

$Biomass = APAR \times \sum$ Eq. 4

Where; APAR as obtained in Eq. 2 and $\sum$ *as obtained in Eq. 3*

Results

Table 1 shows the mean biomass carbon value for the ten locations selected within the campus using Landsat images of 2014 and 2020. It was observed that 2014 had a mean biomass of 7.83 kg/m^3, while 2020 had a mean biomass of 2.47 kg/m^3.

Table 1
Mean Biomass of the selected year

Year	Biomass (kg/m^3)
2014	7.83
2020	2.47
Total	10.30 ± 3.23

Biomass Carbon Accumulation

Results in Table 2 shows that biomass accumulation per hectare was 87.00 kg/m^3 for the year 2014 and the total biomass 69,951.62 kg/m^3. Also, for the year 2020 the biomass accumulation per hectare was 27.40 kg/m^3 and the total biomass was 22,031.93 kg/m^3 (Table 2).

Table 2
Total value of Biomass Accumulation for 2014 and 2020

Designated Year	Total Area (ha)	Mean Biomass(kg/m3)	Biomass (ha-1 kg/m3)	Total Biomass
2014	804.00	7.83	87.0045	69,951.62
2020	804.00	2.47	27.4029	22,031.93

Comparison Of Biomass Accumulation Of The Designated Year

The results of t-test for the biomass accumulation of the selected points for the two designated years were presented in the Table 3 and data show that there is significant difference (i.e. P > 0.05) between the biomass of the years estimated. Furthermore, Fig. 1 presented the graphical representation of the difference of the biomass accumulation over the two designated year.

Table 3
Analysis of variance of Biomass

t-Test: Paired Two Sample for Means		
	BIO2014	*BIO2020*
Mean	7.83119	2.46651
Variance	74.3156	9.306547
Observations	10	10
Pearson Correlation	0.977477	
Hypothesized Mean Difference	0	
Df	9	
t Stat	2.989183	
P(T < = t) one-tail	0.007611	
t Critical one-tail	1.833113	
P(T < = t) two-tail	0.015221	
t Critical two-tail	2.262157	

Discussions

Carbon Sequestration

The estimated value of carbon sequestration is based on the hectares of the land area and the biomass carbon per hectare value. The estimated forest area in 2014 is 804.0 hectares and 804.0 hectares in 2020. The forest area is constant in 2014 to 2020. The mean biomass is taken from the average of the calculated biomass carbon from the designated pixel, which is 7.83119 kg m^3 in 2014 and 2.46651 kg m^3 in 2020. The estimated value of carbon sequestration is 87.0132 kg m^3/ha in 2014 and 27.4057 kg m^3/ha in 2020, calculated based on the LandSat image pixel size and number pixel per hectare as well as area of the forest which was calculated through remote sensing and GIS. The mean value of forest carbon sequestration in 2014 increased more than that of 2020, although the forest area is the same. This might be due to urban development and forest degradation which in turn hampered biomass and carbon sequestration potential of the area. This could also be other factor such as solar radiation of the area. According to Clark *et al.*, (2001) and Ishii et al., (2007), that if there is reduction or increase in solar radiation there will be reduction or increase in biomass accumulation vis-versa. In addition, the biomass is decreased when there is forest area decrease, the carbon sequestration increased when the biomass is high (Alam, 2016).

Conclusions And Recommendations

The result of this research has provided valuable information on the deforestation trend in Adekunle Ajasin University campus, Akungba Akoko which showed that infrastructural development in the area has negatively affect its biomass carbon sequestration potential. The spatial carbon accumulations in the locations selected showed that the University campus could sequester high carbon if trees are retained alongside her edifice. The incorporation of trees retained or planted tree species with high carbon sequestration as sheds. This will increase the biomass carbon composition since infrastructural development is the major cause of loss of biomass carbon in the area. Therefore, allowing development in the area to continue without incorporating green areas will result to total loss of biomass carbon in the university campus. It is therefore recommended, to plant trees along every construction, expansion and infrastructure development projects.

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Figures

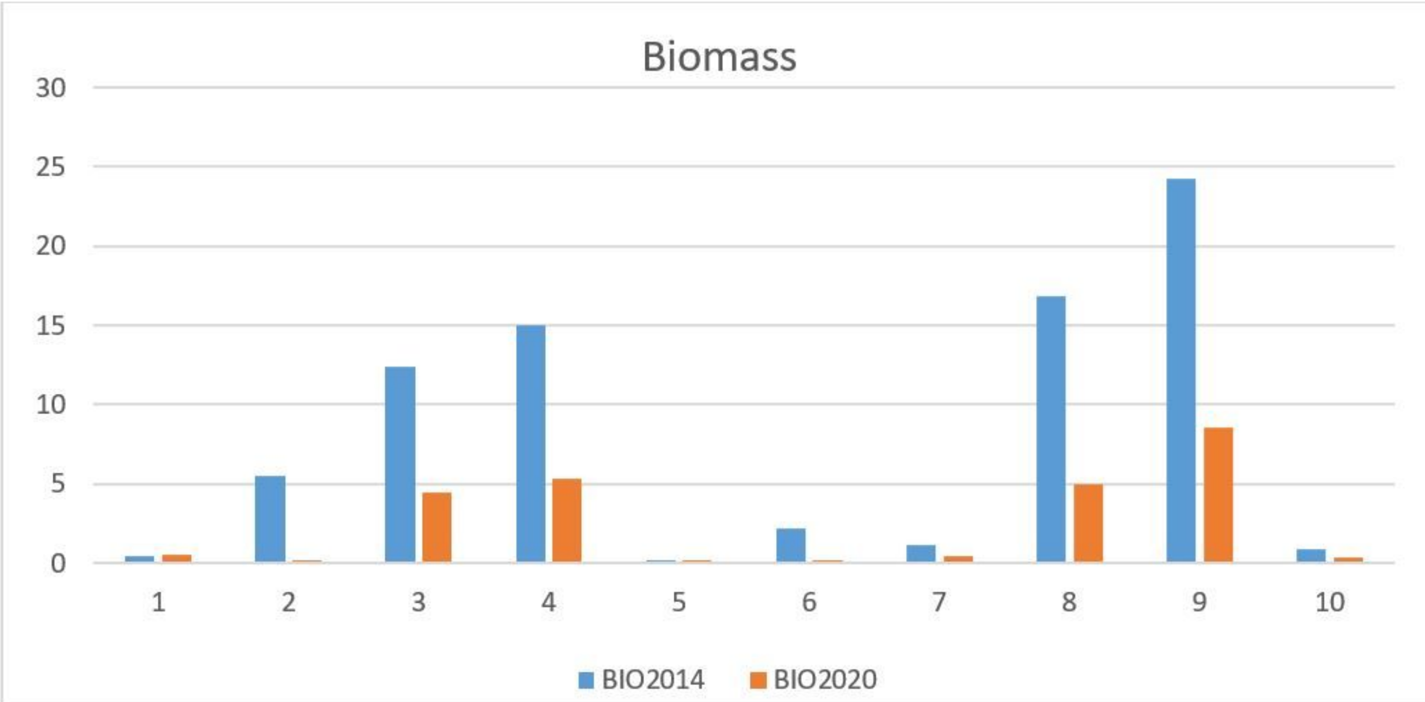

Figure 1

Graph showing Biomass Values for the two Designated Year