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# MULTIVARIATE ANALYSIS OF VAREATION IN SOIL ORGANIC CARBON STOCK FOR DIFFERENT LAND USES IN MAKURDI

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## ABSTRACT

This study quantitatively gives an insight to the amount of soil organic carbon that has been stocked in different land uses in Makurdi Benue state of Nigeria using three analytical approaches. The Google earth map and the supervised classification (SC) method were used for identification of land use type and sampling locations within the study area. Seven different land uses were identified in Makurdi using soil survey standard test method for organic carbon while the physical properties relevant for estimation of SOC stock were used to classify the soil at each land use, Multivariate analyses were performed for possible correlation, degree of variation and spread of SOC stock within locations and among land uses. The Similarity and significant differences among the land used and their SOC stocks were also tested at 0.05 level of significance by one way analysis of variance. The analytical methods result confirmed that it has taken much of the soil organic carbon stocked in the forested land and wet land which were found to be relatively high with wide range of variability according to individual box plot and 95% CIs. This carbon stock when loss is likely to increase emission from the soil system. The investigated SOC stock was used to develop the SOC stock map of Makurdi based on the land uses as a pilot project for land use administration in Benue state.

**KEYWORDS:** Land use, supervised classification Soil organic carbon stuck, Multivariate analyses Makurdi.

## INTRODUCTION

The effects of land uses (LU) on soil organic carbon (SOC) have been well documented but the information on spread and variability is scarce among developing countries. The trend in the distribution may be similar to some extent but sometimes inconsistent because of many factors such as soil type, cropping systems, residue management, and climate (Reicosky *et al*., 1995). The dynamics of SOC stock and the role soil may play in the accumulation of atmospheric carbon reflect the changes in soil quality and productivity. Information's on altering the nutrient dynamics through immobilization– mineralization processes has been lacking according to Dong *et al.* (2012a, 2012b). Such changes include particulate organic carbon (POC) that contain coarse fraction of organic matter that are considered intermediate between active and slow fractions of SOC. It changes rapidly due to management practices according to (Cambardella and Elliott, 1992) and has not been documented for Makurdi and environs. These soil fractions are likely to be more sensitive to management practices than the total SOC as possited by Awale *et al.* (2013) and are the fine indicators of soil quality which influence soil function in specific ways (e.g., immobilization– mineralization). For these reasons there is urgent need to increase our knowledge and understanding of the variations that may exist in SOC among land uses in developing countries of the world. This study seeks to investigate the variability of SOC stock from different land uses in Makurdi Benue state of Nigeria. The study will provide information on the long-term effects of land uses and soil managements on SOC stabilization and its different fractions such as effects on the chemical and physical properties of the soil, water infiltration ability, moisture holding capacity, nutrient availability, and the biological activity of microorganisms.

## MATERIALS AND METHODS

### The Study Area

Makurdi local government area (LGA) is domiciled in Benue state, North central geopolitical zone of Nigeria. The headquarters is the town of Makurdi and consists of several districts and villages. Makurdi LGA shares boundaries with the Guma and Gwer west LGAs and with parts of Nasarawa state. The current estimated population of Makurdi LGA is put at 401,762 inhabitants with the area hosting members of diverse ethnic affiliations (Benard, 2021). It is located between latitudes $7^o\ 35^I$ - $7^o 53^I$ N and longitudes $8^o\ 24^I$ - $8^o\ 42^I$ E. Makurdi lies entirely in the River Benue flood plains and serves as a link between the southern and northern Nigeria (Figure 1), urban area covers a land area of $800km^2$. The changes in administrative status have contributed to the tremendous growth and spatial expansion of

Makurdi southwards and northwards of River Benue, into rural and suburban areas of Kanshio, Yaikyo, Apir, Adaka, Adeke and Poor (in the south bank) and Anter, Akiki and Agan (in the north bank).

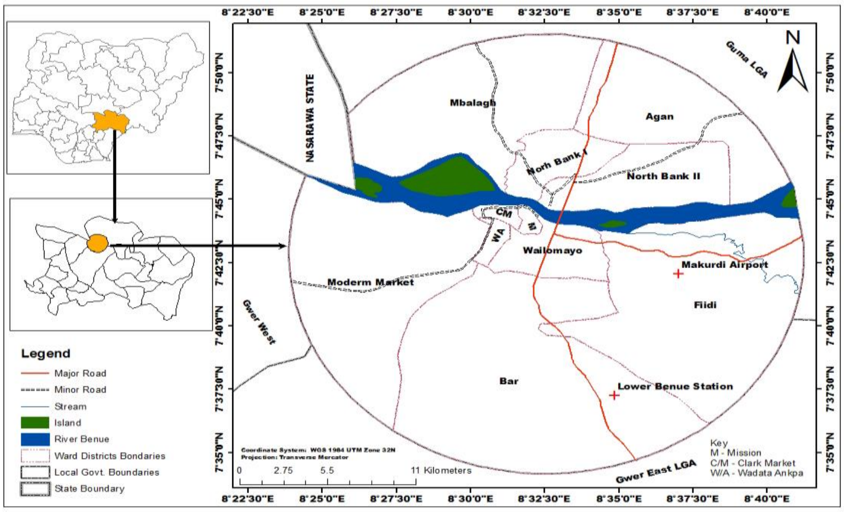


**Figure 1: Map of Makurdi Local Government area (Benard, 2021).**

According to national population census data (NPC 2006), the population of Makurdi was 239 889 people in 1991 and 300 096 people in 2006, representing an increase in population density from 300 to 375 persons/km$^2$. The projected population of Makurdi in 2020 is 460,000 people based on 3.0% growth rate per annum (Benard, 2021). Makurdi urban area is subdivided into eleven political divisions known as council wards. The council wards that cover the metropolitan area are Mission, Clark/Market, Wadata/Ankpa, North Bank I and Wailomayo. Fiidi, Modern Market and North Bank II constitue the suburban councl wards and the rural council wards comprise Bar, Mbalagh and Agan (Figure 6). It is widely believed that in Makurdi urban area, 60%, 30% and 10% of the population live in metropolitan, suburban and rural areas.

**Sampling Procedure**

The Google earth map of Makurdi (Figure 2) was used for identification of land use type and sampling locations within the study area. The supervised classification (SC) method of land use was adopted to detect changes in LU for purpose of identifying new LU types. The SC of satellite images is an effective tool to detect and quantify current LU of an area based on their spectral emittance. Secondly, field work was conducted and the coordinates of the LU types on the ground taken. Field work is necessary because different LU materials with same spectral signature can easily be detected and separated. Thirdly, the coordinates of LU types obtained during filed work help to identify the actual LU type. Lastly, the area of each of the LU types was computed in square meters ($m^2$) and then converted to square kilometers ($km^2$).


**Figure 2: Map of Makurdi showing sampling locations based on land use/land cover type.**

Source: Adopted from Google earth satellite imagery.

Fourteen (14) agricultural profile (AP) horizon topsoil samples were taken from the seven categorized structure in Makurdi at 0–30 cm depth using soil auger. The test soils were non-calcareous, in which soil carbon was only in the organic form. Prior to analyses, all visible plant and animal residues were removed from soil samples. Standard Test Method for Particle-Size distribution using sieve method was performed using a 0.2 mm sieve to determine the percentage of fine and coarse aggregates.

**Survey Method**

The survey method for this study was soil survey standard test method for organic carbon which estimates organic carbon in soils. The method measures only the amount of carbon in soil humus but not charcoal or coal. Different levels may exist but the highest is commonly found in surface soils although wide variations from almost zero to above 15% C are possible. For saline soils, the presence of C will produce a positive interference (>0.5% C) at the surface. The determination of SOC was based on three analytical methods for purpose of comparism; 1) Walkley-Black chromic acid wet oxidation; 2) The modified method of wet combustion (WC) with photometric carbon determination and 3) The dry combustion (DC) method.

**Analytical Procedures**

**Chemical dichromate oxidation (Wacklay Black Method/wet oxidation)**; A bountiful amount of soil was weighed into a dry tarred 250 mL conical flask (between 0.5 g and 1 g for topsoil). 10 mL 1 N $K_2Cr_2O_7$ was added and the flask swirled gently to disperse the soil in the solution. 20 mL concentrated $H_2SO_4$ was added directing the stream into the suspension. Immediately the flask was swirled until the soil and the reagent mixed. 200 °C thermometer was inserted and heated while swirling the flask and the contents over a gas burner and gauze until the temperature reaches 135 °C (approximately ½ minute). The set up was set aside to cool slowly on an asbestos sheet in a fume cupboard. Two blanks (without soil) were run in the same way to standardize the $FeSO_4$ solution. When cooled (20–30 minutes), it was diluted to 200 mL with deionized water and proceed with the $FeSO_4$ titration using the "ferroin" indicator. 3 or 4 drops of Ferroin indicator was added and titrated with 0.4 N $FeSO_4$. As the end point is approached, the solution took a greenish colour and then changes to a dark green. At this point, the ferrous sulphate was added drop-by-drop until the colour changes sharply from blue-green to reddish-grey. % of Organic Carbon in Soil (R) is calculated as below

$$R = \frac{(V_1 - V_2)\ x\ N\ x\ 0.003\ x\ 100}{W}\ x\ C \qquad (1)$$

Where;

W - Weight of sample; $V_1$ - Blank Titre value; $V_2$ - Titre value of the sample; N - Normality of $K_2Cr_2O_7$ (Here it is 1N); C - Correction Factor (1.334, 1.724)

**The modified method of wet combustion:** This method use photometric carbon determination to measures organic carbon content according to the dichromate approach, using combustion at 160°C for 30 minutes as reported by Nikitin, 1999; Slepetiene and Butkute, 2003). The sample was weighed and placed in 100 mL Erlenmeyer flasks; 5 mL of chromous mixture (using 0.2 M potassium dichromate solution in diluted (1:1) sulphuric acid) was added (Aleksandrova and Naidenova, 1976). Wet combustion was performed according to the Nikitin modification in a thermostat and combustion time was measured from the moment the temperature in the thermostat rose to 160°C. Combustion procedure in the thermostat allowed us to minimize temperature variations.

**The dry combustion (DC) method (Ignition);** The dry combustion (DC) method belongs to the suite of direct carbon determination methods, by which organic carbon is determined according to the amount of $CO_2$ released during combustion. The DC method was invented with the development of analytical techniques associated with the new-generation of automatic analyses. The analyzers Vario EL III (Germany) (Vario EL operating instructions 2002) automatically analyses and computes sample SOC.

### Estimation of SOC stock

The organic SOC obtained from laboratory analysis was used to calculate SOC stock per unit area of land. The coarse fraction was first determined during sample preparation by sieve analysis using 2mm diameter sieve. Following this the coarse fraction was weighed and the proportion determined using equation 2

$$\text{Coarse fraction} = \frac{total\ weight - weight\ of\ fraction < 2mm}{total\ weight} \qquad 2$$

The carbon stock for the profile per $Km^2$ was calculated as in equation 3 using the proportion of coarse fraction relationship as in equation 2.

$$C_i = BD_i(1 - CF_i\ x\ d_i x\ OC_i \qquad 3$$

Where; $C_i$ is the carbon stuck of the ith profile, $BD_i$ is the bulk density if ith profil, $CF_i$ is the coarse fragment content of the ith profile, $OC_i$ is the soil content of the organic carbon, $d_i$ is the thickness of the profile.

### Multivariate Analysis

The data set were grouped and statistically analyzed for possible correlation of components of SOC stock fractions, individual 95%. CI and box plot for inference about the degree of spread and variation based on pooled StDev, The one way analysis of variance was performed on the soil organic carbon for test of significantly ($p < 0.05$) variation by land use. Individual plot and box plot was also performed for comparism of similarity and variation according to locations using minitab 16 software.

## RESULTS

Determination of SOC methods is aimed at making all analytical procedures user-friendly, safe, time-efficient and economical. This study has compared three chemical SOC determination methods on seven land use classification in Makurdi. Tables 1 presents the results of field work conducted on the supervised classification of satellite images and the coordinates of the LU types for the sampling locations in the study area (Lower Benue and Agan for cultivated LU, North bank and High level for urban built up, Agan forest and Lower Benue forest for forested land use, cattle market and oracle farm for grazing land, Agbo and Idye basing for wetland, Naka and Aliede roads for wood/grass land and river Benue banks at Wadata and north banks for water land).

**Table 1: Description of Sampling Locations.**

| No | Sample Nomenclature | Land Use | Locations | Longitude | Latitude |
|---|---|---|---|---|---|
| 1 | $A_1$ | Cultivated | Lower Benue | 7.668440 | 8.545772 |
| 2 | $A_2$ | Cultivated | Agan | 7.345236 | 8.548950 |
| 3 | $B_1$ | Urban Built up | North Bank | 7.761323 | 8.557859 |
| 4 | $B_2$ | Urban Built up | High Level | 7.712454 | 8.526406 |
| 5 | $C_1$ | Forested | Agan Forest | 7.754997 | 8.557424 |
| 6 | $C_2$ | Forested | Lower Benue | 7.647701 | 8.556231 |
| 7 | $D_1$ | Grazing | Cattle Market | 7.758461 | 8.541642 |
| 8 | $D_2$ | Grazing | Oracle Farm | 7.709519 | 8.495576 |
| 9 | $E_1$ | Wetland | Agbo Basin | 7.734273 | 8.493903 |
| 10 | $E_2$ | Wetland | Idye Basin | 7.718567 | 8.527065 |
| 11 | $F_1$ | Wood/grass | Naka Road | 7.795915 | 8.276129 |
| 12 | $F_2$ | Wood/grass | Aliede Road | 7.668015 | 58.545315 |
| 13 | $G_1$ | Water | RBBW | 7.720976 | 8.536620 |
| 14 | $G_2$ | Water | RBBN | 7.755722 | 8.529130 |

RBBW = River Benue Bank at Wadata; RBBH=River Benue Bank at North Bank

The result for the evaluation of SOC based on the described methods and other non-exchangeable properties is as presented in Table 2. The forest land use in lower Benue recorded the highest concentrations of SOC based on the three applied method of evaluations at 2.99 kg/m$^2$ for wakley black (wet oxidation), 5.16 kg/m$^2$ for wet combustion and 6.33 kg/m$^2$ for dry combustion (ignition method). The lowest were recorded in urban built up in north bank as 0.22kg/m$^2$ for wakley black (wet oxidation), 0.38 kg/m$^2$, for wet combustion and 0.66kg/m$^2$ for dry combustion (ignition method). The minimum and maximum values of pH, SOC (wet oxidation, wet combustion and dry combustion) and AP were 0.08, 0.14, 0.66, and 2.99kg/m$^2$, 5.16kg/m$^2$, 6.33 kg/m$^2$ and while their StDev were also 0.77, 1.33, 0.68 respectively.

Table 3 presents the result for the SOC stock for the 14 sampling locations based on the mean SOC from the three analytical methods. BDi ranged from 1.34 kg/m$^2$ at wood/graaland in Alede road to 1.90 1.34 kg/m$^2$ in grazing land at cattle market; CFi was lowest a (28.4%) at oracle farm grazing land and highest (41.8%) at high level in urban built up, Di . the mean SOC and the corresponding SOC stock were lowest (0.42 and 0.1229 respectively) at urban built up in north bank and highest (4.82 and 1.101 Kg/m$^2$ respectively) at lower Benue forested land). It was closely followed by the grass lands (0.927 Kg/m$^2$).

**Table 2: SOC by Land Uses in Makurdi.**

| No | Sample Nomenclature | Land Use | Locations | SOC | | |
|---|---|---|---|---|---|---|
| | | | | Wet Oxidation | Wet combustion | Dry Oxidation |
| 1 | $A_1$ | Cultivated | Lower Benue | 0.55 | 0.96 | 1.40 |
| 2 | $A_2$ | Cultivated | Agan | 0.76 | 1.31 | 2.20 |
| 3 | $B_1$ | Urban Built up | North Bank | 0.22 | 0.38 | 0.66 |
| 4 | $B_2$ | Urban Built up | High Level | 0.36 | 0.62 | 1.20 |
| 5 | $C_1$ | Forested | Agan Forest | 1.92 | 3.30 | 5.06 |
| 6 | $C_2$ | Forested | Lower Benue | 2.99 | 5.16 | 6.33 |
| 7 | $D_1$ | Grazing | Cattle Market | 0.66 | 1.13 | 2.01 |
| 8 | $D_2$ | Grazing | Oracle Farm | 0.96 | 1.65 | 2.20 |
| 9 | $E_1$ | Wetland | Agbo Basin | 0.81 | 1.38 | 1.98 |
| 10 | $E_2$ | Wetland | Idye Basin | 0.08 | 0.14 | 0.40 |
| 11 | $F_1$ | Wood/grass | Naka Road | 1.34 | 2.20 | 3.10 |
| 12 | $F_2$ | Wood/grass | Aliede Road | 1.18 | 2.03 | 2.98 |
| 13 | $G_1$ | Water | RBBW | 0.44 | 0.76 | 1.32 |
| 14 | $G_2$ | Water | RBBN | 0.36 | 0.62 | 0.69 |
| Min | | | | 0.08 | 0.14 | 0.66 |
| Max | | | | 2.99 | 5.16 | 6.33 |
| StDev | | | | 0.77 | 1.33 | 1.68 |

**Table 3: SOC stock by Land Uses in Makurdi.**

| No | Sample Nomenclature | Land Use | Locations | BDi (Kg/m$^3$} | CFi (%) | Di (m) | Mean SOC (Kg/m$^2$) | SOC Stock (Kg/m$^2$) |
|---|---|---|---|---|---|---|---|---|
| 1 | $A_1$ | Cultivated | Lower Benue | 1.42 | 34.1 | 0.3 | 0.97 | 0.271 |
| 2 | $A_2$ | Cultivated | Agan | 1.38 | 34.0 | 0.3 | 1.42 | 0.388 |
| 3 | $B_1$ | Urban Built up | North Bank | 1.74 | 41.2 | 0.3 | 0.42 | 0.1293 |
| 4 | $B_2$ | Urban Built up | High Level | 1.81 | 41.8 | 0.3 | 0.72 | 0.2267 |
| 5 | $C_1$ | Forested | Agan Forest | 1.52 | 30.6 | 0.3 | 3.42 | 1.0823 |
| 6 | $C_2$ | Forested | Lower Benue | 1.41 | 36.0 | 0.3 | 4.82 | 1.101 |
| 7 | $D_1$ | Grazing | Cattle Market | 1.90 | 28.5 | 0.3 | 1.26 | 0.5135 |
| 8 | $D_2$ | Grazing | Oracle Farm | 1.85 | 28.3 | 0.3 | 1.60 | 0.6366 |
| 9 | $E_1$ | Wetland | Agbo Basin | 1.56 | 36.0 | 0.3 | 1.39 | 0.4163 |
| 10 | $E_2$ | Wetland | Idye Basin | 1.58 | 31.0 | 0.3 | 2.00 | 0.654 |
| 11 | $F_1$ | Wood/grass | Naka Road | 1.44 | 30.0 | 0.3 | 3.10 | 0.9374 |
| 12 | $F_2$ | Wood/grass | Aliede Road | 1.34 | 30.5 | 0.3 | 2.06 | 0.5755 |
| 13 | $G_1$ | Water | RBBW | 1.62 | 33.4 | 0.3 | 0.84 | 0.2718 |
| 14 | $G_2$ | Water | RBBN | 1.68 | 34.1 | 0.3 | 0.55 | 0.1826 |

The data were grouped and summarized by land use in accordance with Salifu *et al.*, (2012) and Xiao *et al.*, *(*2015), Results of one way ANOVA for the SOC stock from the different land uses are as presented on Table 4. From the Table S = 1.313; R-Sq = 48.76% and R-Sq (adj) = 0.00%. Table 5 is the Individual 95% CIs For Mean Based on Pooled StDev. The StDev were 0.321, 2.335, 0.238, 0.217, 0.3, 2.157 for cultivated, forested, grazing, urban built up, water, wetland and wood/grass land respectively. Further analyses were performed by individual value plot and box plot (Plate 1). Individual value plot is use to visualize data distribution of 50 or fewer samples however, it can be used for more than 50 samples but it will not assess data easily as all data points would be clustered densely. It provide us with intuition about the key characteristics of the data distribution and also give us information about the variability of the data. For that reason, we have to look at the spread of the data, If data is spread over a wider range; this suggests that data sample vary significantly. Individual value plot also helps us to find common values in a distribution. Common values appear as a cluster in the graph. The densest cluster gives the most common values present in our data. Individual value plot works best if the sample size is less than or equal to 50. The appearance of the graph can be affected by the sample size, as the image shows: if we have multiple groups in our plot, we can easily identify the difference in their centers. Figure 1 contains the data of 2 different distributions for each group. We can observe that the center of each distribution is different in each group.

**Table 4: One-way ANOVA: C1 (LU) versus C2 (SOC stock).**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| C1 | 7 | 9.85 | 1.41 | 0.82 | 0.606 |
| Error | 6 | 10.35 | 1.72 | | |
| Total | 13 | 20.20 | | | |

S = 1.313 R-Sq = 48.76% R-Sq(adj) = 0.00%

**Table 5: Individual 95% CIs For Mean Based on Pooled StDev.**

| Level | N | Mean | StDev | --------+---------+---------+---------+- |
|---|---|---|---|---|
| Cultivated | 2 | 1.197 | 0.321 | (----------*----------) |
| Forested | 2 | 3.176 | 2.335 | (----------*----------) |
| Grazing | 2 | 1.435 | 0.238 | (----------*-----------) |
| Urban Built up | 2 | 0.573 | 0.217 | (----------*----------) |
| Water | 2 | 0.698 | 0.200 | (----------*-----------) |
| Wetland | 2 | 1.902 | 2.157 | (-----------*----------) |
| Wood/grass | 2 | 2.213 | * | (---------------*---------------) |
| | | | | --------+---------+---------+---------+- |
| | | | | 0.0 2.0 4.0 6.0 |

Pooled StDev = 1.313

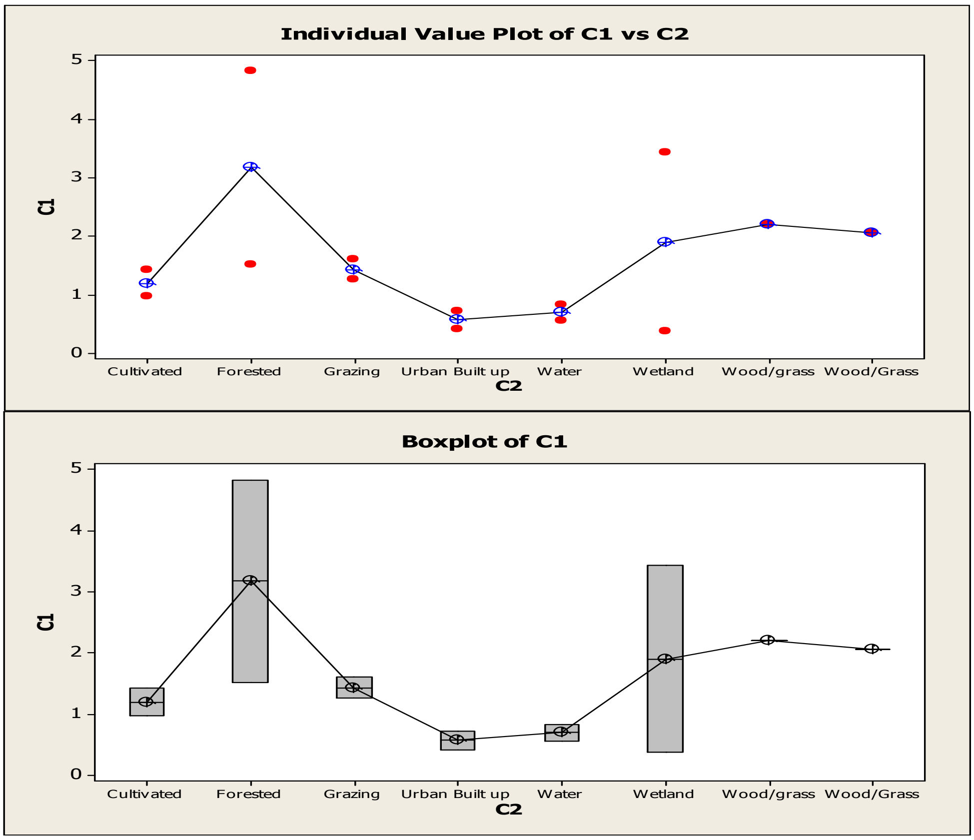


**Figure 1: Individual Value Plot of C1 vs C2 (Boxplot of C1).**

## DISCUSSIONS

**Soil carbon stock;** The lower SOC in the crop lands, urban built up and wetlands were due to repeated cultivation before sowing which is in agreement with the findings of Melero *et al.*, (2011); removal of crop residues according to Berry (2011), *Pan et al*. (2009); World Bank, (2008) and burning of crop residues during land preparation as opined by Yeshanew *et al.*, (2007) respectively. The current results indicated that the subsistence farming practices that have been followed by the smallholder farmers in the study area are exploitative in nature, and thus, have taken much of the soil organic carbon as compared to the forested land and wood/grass lands. This loss of organic carbon is likely to increase emission from the soil system. A land use type that enhances the organic carbon content and minimizes emission has to be put in place in order to fight climate change and its unfavorable impacts. It is well understood that management practices have impact on the balance between input and output in a given system as well as on the rate of decomposition of organic matter which is agreement with the findings of Melero *et al.*, (2011). Therefore, appropriate land use and management practices recommended by Lal (2006) and Pan *et al.* (2009) should be practiced. Also conservation tillage according to Lal *et al.*, (1997); no tillage and fertilization/ intensive agriculture in accordance with Wright and Hons (2005) and agroforestry recommended by Nair *et al.*,(2009) should be employed to enhance the carbon sequestration potential of croplands under subsistence low input farming.

The higher SOC stock in the forest might is attributed to the frequent addition of litter, the presence of network of roots, and modified microclimate, which retard decomposition rate of organic matter. This finding agrees with the findings of Noordwijk *et al.* (2002); Schmitt-Harsh *et al.* (2012), who reported higher SOC stock under forest than other land use types. Bewket and Stroosnijder (2003) also found high soil organic carbon in natural forest compared with grazing land, land under cultivation, and Eucalyptus plantation. Similarly, Fantaw (2007) reported high SOC in native forest compared with cultivated land and found a non-significant difference between native forest and grazing land. Noordwijk *et al.* (2002) and Schmitt-Harsh *et al.* (2012) also reported high SOC in disturbed forests compared with coffee based agroforestry. According to information obtained from local agriculture office, most of the land that represents the different levels of the variable 'land use' used to be under natural forest cover many decades ago which was indeed attested by the presence of some remnants of naturally grown trees in the land under different land uses today. Hence, conversion from the natural system to human managed system has resulted in the loss of significant amount of SOC (Lemenih *et al.*, 2005; IPCC, 2013; Janzen, 2004; Lasco, 2002; Vagen *et al*., 2005; Nyssen *et al* ., 2008; Houghton and Hackler 2000; Solomon *et al.*, 2002). The declining trend in SOC could be due to repeated disturbance of the soil after conversion of forest land into other land uses (Lemenih *et al*., 2005, Yeshanew *et al*., 2007, Shrestha *et al*., 2006).

Statistical analysis was performed by linear regression to test the significant relationship between land use type, the ANOVA indicated that the F-statistic which is the ratio of the mean squares treatment to the mean squares error is 0.86 meaning that there is greater variation between sample means relative to the variation within the samples. The p-value is lesser F than at $\alpha = .05$ hence it is conclude that we do not have sufficient evidence to say that there is a statistically significant difference between the means of the seven groups. It is an indication that soil organic carbon were not significantly ($p > 0.05$) affected by land use except for forested and wetland the SOC were significantly affected. It was not significantly affected by the interaction of land uses and location. The individual and box plot gives the visualization of the spread and significant difference between the LU. The plot attested that forest lands and wet lands has greater spread of SOC stock in Makurdi while the other land uses do not show significant difference among their varying location hence little or low spread. STAT software and Mintab 16 programmes were applied in developing the SOC map for the study area as in Figure 3.

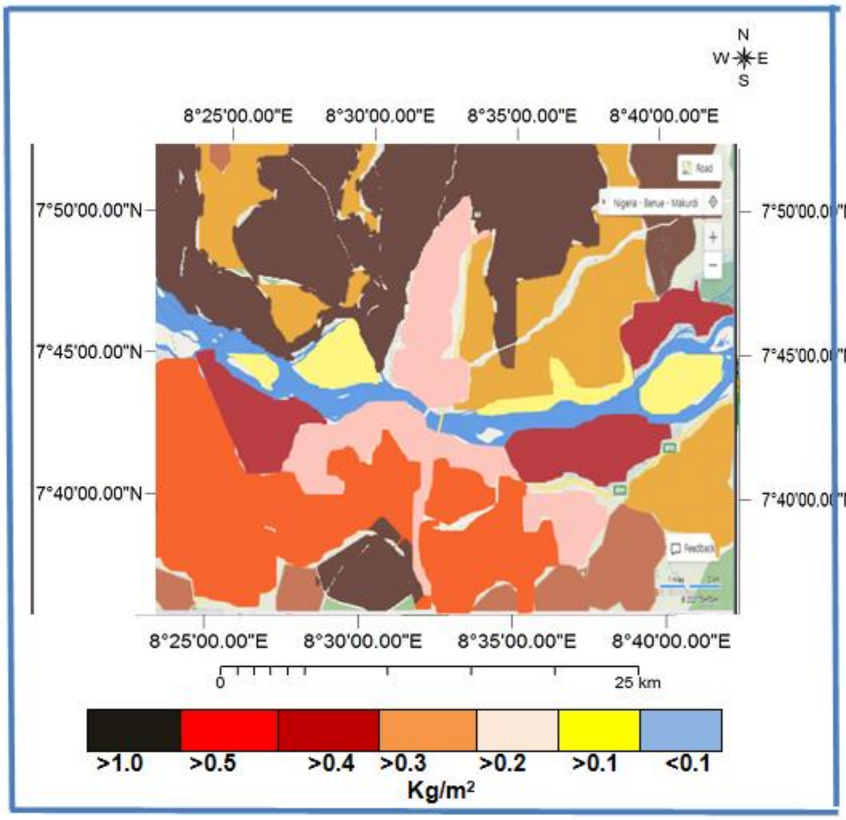


**Figure 3: SOC stock map of Makurdi.**

## CONCLUTION

The study has quantitatively given an insight to the amount of soil organic carbon that can be stocked in different land uses in Makurdi Benue state of Nigeria using three analytical approach. Seven different land uses were identified in Makurdi during the survey. It also indicated that the land use practice in the study area is exploitative in nature. Soil chemical properties were investigated and quantified, positive and high correlation was found among many. Similarity and significant differences among the land used and their SOC stocks were also tested at 0.05 level of significance by one way analysis of variance. Physical properties relevant for estimation of SOC stock were used to classify the soil and estimate the SOC stocks, The analytical methods result confirmed that it has taken much of the soil organic carbon stocked in the forested land which was found to be relatively the highest when loss and is likely to increase emission from the soil system. The study also developed the SOC stock map of Makurdi based on the land uses.

**Recommendations**

Hence, it is necessary to implement conservation-based production land use based on the following recommendations.

1. The present study highlights the importance of level carbon stock assessment for better and carbon friendly land use decision making.
2. The study, however, did not attempt to assess the carbon gain and loss as a function of each land use, so further study is needed to clearly map carbon sequestration potential of the watershed.

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