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# DEPTH-DISTRIBUTION PATTERN OF ORGANIC CARBON ALONG RIVER JAKARA: APPLICATION OF EQUAL-AREA SPLINES TO URBAN AGRICULTURAL SOILS USING R.

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**ABSTRACT**

This research was conducted along the bank of River Jakara in metropolitan Kano, Kano state, Nigeria (latitude 11º 25' N and 12° 47' N and longitude 8° 22' E to 8° 39' E and lies 472m elevation). Three profile pits were sunk and four soil samples were collected according to profile depth of 30 cm intervals (0-30, 30-60, 60-90, and 90-120 cm). The research aimed to assess the fitness and validity of the equal-area spline functions on vertical distribution of organic carbon in the study area. The algorithm (one profile function) displayed organic carbon (OC g/kg) content decreased down the profile depth across all the three soil pits. The fitness and validity of the model ($R^2$) ranged in the order 0.85, 0.93 and 0.94 with RMSE of 2.09, 1.47 and 1.32 respectively between the measured and predicted organic carbon value in the study area.

**Keywords:** *Population, natural resources, urban growth*

## INTRODUCTION

In a developing country like Nigeria, a substantial proportion of the population lives in and around metropolitan areas and large cities. This includes an area that has been labelled as the 'peri-urban interface', where livelihoods depend, to some extent, on natural resources (Brook and Davila, 2000). Since the 1960s, a dramatic increase in urban growth as a result of increased numbers of rural poor migrating to cities combined with high levels of grinding poverty in most African cities has heightened concern for the 'urban crisis' In recent years, considerable interest has been shown in the practice of urban agriculture, as poverty and malnutrition have become widespread in the cities of many developing countries and more urban dwellers being born into impoverished families and in some cases not-so-poor families are slipping below the poverty line (Mougeot, 2005). Numerous studies have shown that urban agriculture play an important role in providing valuable food security and income generation among urban households (Egziabher *et al.*, 1994; Lynch *et al.*, 2001).

Urban agriculture has provided some range of benefits, but still it has been strongly opposed by government agencies, and remains marginal in the urban planning process. This is because of a variety of negative health, environmental, economic and cultural impacts (Binns and Lynch, 1998), implying there are proponents who believe that urban agriculture is damaging to the environment however, majority agrees that it could be the solution to a number of other important environmental constraints (Binns and Lynch, 1998; Mougeot, 1994). Urban centers can be considered vast nutrient sinks, because unlike rural areas, household waste and market refuse are not returned to production but contribute to urban pollution and health risks (Cofie *et al.*, 2001). According to Sweet (1999) urban centres produce most of the world's waste and between a third and a half of this waste goes uncollected. In some African cities (Lagos, lbadan, Kano, Enugu, Accra, Kinshasa) the situation appears even worse as figures for formal waste collection range from 11% to 44% for households (Asomani-Boateng and Haight, 1999). Yet urban waste has great potential because it can be exceedingly nutrient rich: the disposal of the waste on the urban plots could be, at the same time, a supply of nutrients and an alleviation of the waste disposal problem, that is the closing of the nutrient cycle ( Esrey and Andersson, 2001; Drechsel *et al.*, 2002).

Urban agriculture is a common practice in many cities around the world including Kano, Nigeria, where it is a centuries old practice (Dokaji 1978). Although time has modified the system, the principal feature remains the use of stream water to irrigate land at the banks. Urban agriculture is not a new phenomenon in Kano (Olofin *et al.*, 1997); it began long before the 1960s in some parts of the city, and became widespread after the general economic downturn in the late 1980s, when the urban poor struggled to improve their livelihoods. Olofin (1996) conducted a study and established that men, between ages of 30 to 70 years, undertake urban crop production during both dry and wet seasons. The inputs are rudimentary hoes, machetes and sickles as implements, and seeds from their own stocks or bought in the open markets. A few had access to improved seeds, fertilizers and pesticides, many relied on household refuse, animal droppings and ash for manure. Vegetable production by irrigation during the dry season is undertaken on flood plains, floodable low terraces and depressed, seasonally flooded upland areas, subject to the availability of water either on the surface or in dug up ditches. It is practiced along the streams of Challawa, Getsi, Jakara,and Salanta with leafy vegetables being the main crops for the consumption of the city dwellers (Binns *et al*. 2003). Highly polluted urban waste streams are used for irrigation throughout the year in the sites, supplemented by a few tube wells. Flooded low terraces and upland depressions are irrigated with available water usually at the beginning of the dry season. Depending on water availability they may be irrigated towards the end of the dry season, after which the crops are left to mature with the onset of the rains. The plots are left fallow after the first crop for the cultivation of staples during the wet season. Plot sizes are very small, averaging 0.2 ha per farm family in the intra-urban areas and 0.5 ha in suburban areas. Some of these urban sites are vacant lands belonging to government.

Soil attributes vary continuously down the profile (Ponce-Hernandez *et al*., 1986) thus, soil depth functions are created to display depth wise variation of soil attributes. Jenny (1941) made the earliest attempt of drawing free hand curves among soil parameters however, more advanced method evolved over time of constructing continuous depth functions (Russell and Moore, 1968). A more general continuous depth function is the equal-area spline function of which is the application and mathematical expression of this function (Ponce-Hernandez *et al.,* 1986; Bishop *et al.,* 1999; and Malone *et al.,* 2009).

Obviously continuous soil depth functions like equal-area splines have an edge in predicting soil attributes at any certain depth. A robust and precise method of fitting continuous functions of soil parameters is the use of smoothing splines (Erh, 1972) and equal-area splines function (Ponce-Hernandez *et al*., 1986). Essentially, a spline function is a set of local quadratic functions tied together with 'knots' that describe a smooth curve through a set of points. Bishop *et al,*. (1999) demonstrated their superiority over other continuous soil depth functions when predicting various types of soil properties.

R is a statistical and graphical programming language which was implemented in 1992 by Robert Gentleman and Ross Ihaka, University of Auckland in New Zealand. R is an implementation of the S language which was made by John Chambers in the Bells laboratories. R software is maintained by R Development Core Team, with lots of Packages pending on profession.

Various studies have established the presence of some heavy metals in some domestic and industrial effluents discharged into this metropolitan River (Jakara), and in the waters used for irrigation (Binns *et al.,* 2003; Wakawa *et al*., 2008). It has also been established that some farmers use sludge along these river as manure for crop production, which has both negative and positive effects on soil's physico-chemical properties and with their associated health hazard (Olofin, 1999; Tanko, 2004). None of these studies have gone further to investigate the vertical distributions of nutrients (organic carbon) using equal-area splines in R.

The aim of this research work is to assess the fitness and validity of the equal-area spline functions for distribution of soil organic carbon along River Jakara in Kano metropolis, Kano State Nigeria.

## MATERIALS AND METHODS

**Description of the Study Area:** Kano metropolis is situated between latitude 11º 25' N and 12˚ 47' N and longitude 8˚ 22' E to 8˚ 39' E and lies 472m above sea level. Kano metropolis is bounded by Madobi and Tofa Local Government Areas (LGAs) to the south west, Gezawa LGA to the east, Dawakin Kudu LGA to the South East and Minjibir LGA on the North East. Kano metropolis is made up of eight (8) LGAs, namely Dala, Fagge, Gwale, Kano municipal, Nasarawa, Tarauni and parts of Ungogo and Kumbotso Local Government. Kano metropolis is the third largest town in Nigeria after Lagos and Ibadan with a population of 2,826307 (NPC, 2006).

River Jakara is located on latitude 12˚ 49' N to N12˚ 25' N and longitude 8˚58' E to 8˚ 66' E near Airport road bridge in a high-density residential area of Kano Metropolis, Kano state, Nigeria. Substantial vegetable production takes place on the South West side of the road, and crops are irrigated by domestic wastewater released from the residential areas of Kano's ancient walled city, Sabon-Gari, and Gwagwarwa into the Jakara channel and serves as the main drain for built-up areas along the way. Some small-scale tanneries are located in certain parts of the old city, where effluent are discharged into the Jakara channel. According to UNDP (1978) and Bichi (2000), the dry season flow of River Jakara is almost entirely made up of municipal sewage and industrial discharges which are drained into the Jakara dam.

**Details of Field Work:** Field studies were carried out along the bank of River Jakara. Three profile pits were sunk during the peak of irrigation activities and soil data were generated based on profile depth (30, 60, 90 and 120 cm) in each profile pit. Soil samples were kept in labeled sampling bags and taken to the laboratory for analysis.


___Figure 1. Aerial image of the study area (River Jakara) in Kano metropolis showing sampling points

**Laboratory Analysis:** The bulk soil samples were air-dried, gently crushed and sieved to obtain the fine soil fractions (>2mm). The samples were labeled and stored in plastic containers and later subjected to organic carbon analysis using standard methods as outlined in ISRIC/FAO (2002).

Soil organic carbon (OC) was determined by the wet oxidation method of Walkley and Black (1934) as described by Nelson and summer (1982). One gram of the finely ground air-dried soil sample was weighed into 250ml volumetric flask and 10ml of 1M $K_2CrO_7$ added. Ten milliters (10ml) concentrated sulphuric acid ($H_2SO_4$) was added to increase temperature and hasten the reaction. The content of the flask was allowed to stand for thirty (30) minutes, after which the mixture in it was diluted to 250ml with distilled water. Excess dichromate was back titrated with ferrous sulphate using barium diphenylamine sulphate as indicator.

**Equal-Area Spline Functions:** The generalized equal-area spline model of Bishop *et al.,* (1999) was adopted in this study and the model is when data are averages over horizons in a soil pit profile. According to Malone *et al.,* (2009) the model assumed that true soil properties vary smoothly with depth which is translated into mathematical term. Depth is denoted by z, and the depth function describing the true attribute values by f(z); which means that f(z) and its first derivative f'(z) are both continuous and that f'(z) is square intergrable. *f*(z) represent a spline function which can be found by minimizing:

$$\frac{1}{n}\sum_{i=1}^{n}(Ci - fi)\quad ^{2} + \lambda\int_{Z0}^{Zn} f'\,(Z^{2})\,dz$$

The first term describes the fidelity (goodness of fit) to data and the second one measures the roughness of function *f*(z), expressed by its first derivative *f*0(z). Parameter λ controls the trade-off between the fit and the roughness penalty (Bishop *et al.* 1999). The choice of lambda is itself a non-trivial problem. When non prior information is available, many authors recommend using a lambda value between 0.01 and 0.1.

**Technical Steps (Equal Area Splines Using R):**

In R environment, the easiest way to apply equal-area splines is using the function plot_Soilprofile from ithir package (Malone *et al.*, 2017). The function plot_Soilprofile has several arguments. One of the arguments is the lambda value mentioned before. The proposed default value is 0.1 and another argument for this function is the target standard depths. The function produces spline-estimated values at these depths. However, this function also produces spline-estimated values at 1 cm increments.

**R Scripts:** The equal-area Splines with R was implemented using the plot_soilprofile function embedded in the ithir package in R which was developed by Brendan P. Malone from University of Sydney. The plot_soilprofile function consist of the following usage and arguments which was run across all the three soil pits (Malone *et al.,* 2017);

plot_soilProfile(data, vals, depths, label="").

Splines were fitted to each of the 3 profile data at 30 cm depth (0-30, 30-60, 60-90, 90-120 cm) using R script codes (Malone *et al*., 2017).

```
# data were imported to R using the read.csv function
sal<- read.csv(file.choose(), header = T)
# the plot_soilprofile function was used
plot_soilProfile(data = sal, vals = sal$C.gkg.1, depths =
sal[,2:3], label = 'C.gkg.1')
# ea_spline function
eaFit<- ea_spline(sal, var.name = "C.gkg.1", d = t(c(0, 30, 60,
90, 120)), lam = 0.1, vlow = 0, vhigh = 1000, show.progress =
T)
# plotting plot_ea_spline was made using the below script
par(mfrow = c(3, 1))
for (i in 1:3){
plot_ea_spline(splineOuts = eaFit, d = t(c(0, 30, 60, 90, 120)),
maxd = 120, type = i, plot.which = 1, label = "OC(gkg-1)
TypicPlagganthrep")}
```

## RESULTS AND DISCUSSION

**Table 1. Organic carbon of the study area.**

| **Depth (cm)** | pH ($H_2O$) | P1 (OC g/kg) | pH($H_2O$) | P 2 (OC g/kg) | pH($H_20$) | P 3 (OC g/kg) |
|---|---|---|---|---|---|---|
| 0-30 cm | 7.59 | 22.1 | 8.14 | 20.1 | 7.90 | 18.8 |
| 30-60 cm | 8.03 | 12.2 | 8.35 | 18.9 | 8.01 | 16.6 |
| 60-90 cm | 8.02 | 10.0 | 8.12 | 10.6 | 8.28 | 8.1 |
| 90-120 cm | 7.90 | 7.7 | 8.07 | 6.0 | 8.72 | 5.0 |
| RMSE | | 2.09 | | 1.48 | | 1.33 |

Footnote: OC = organic carbon, P = profile, pH = soil reaction

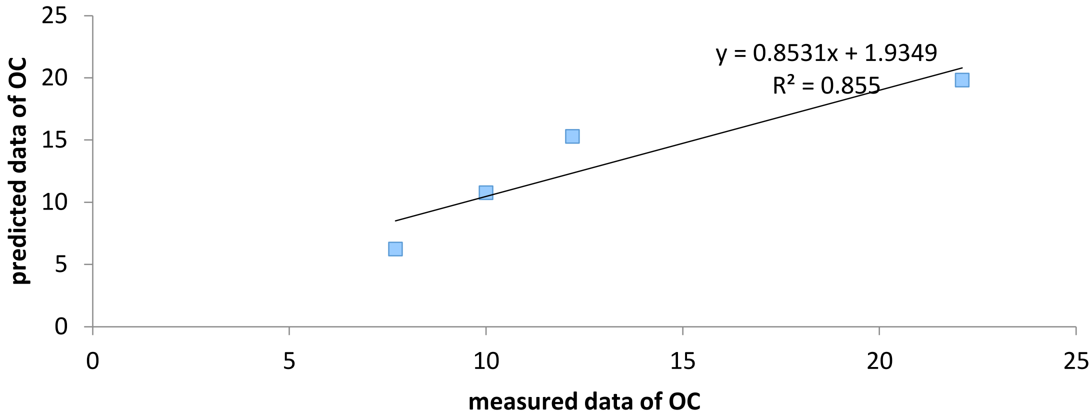


Fig. 2: Validation of measured soil organic carbon between measured vs. predicted soil organic carbon at 0-30, 30-60, 60-90 and 90-120 cm.

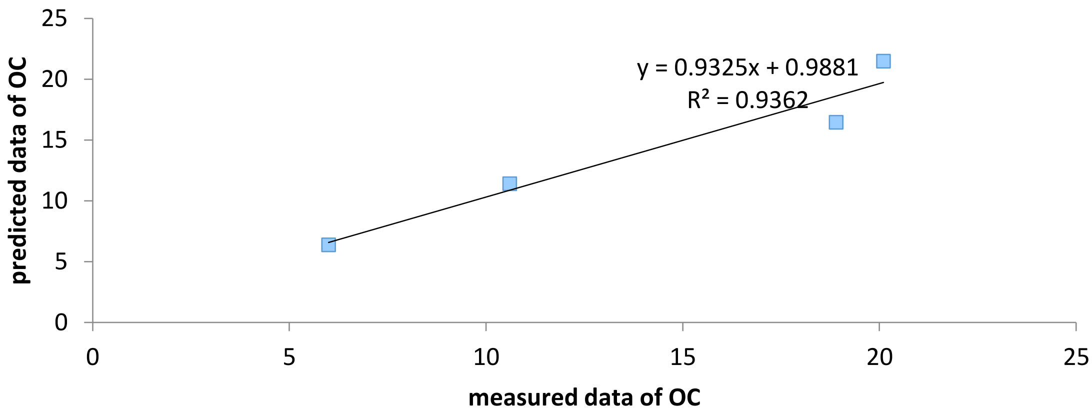


Fig. 3: Validation of measured soil organic carbon between measured vs. predicted soil organic carbon at 0-30, 30-60, 60-90 and 90-120 cm.

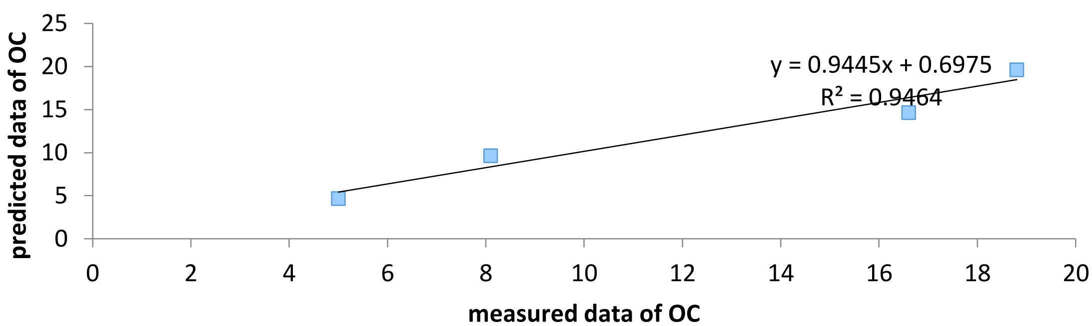


Fig. 4: Validation of measured soil organic carbon between measured vs. predicted soil organic carbon at 0-30, 30-60, 60-90 and 90-120 cm.

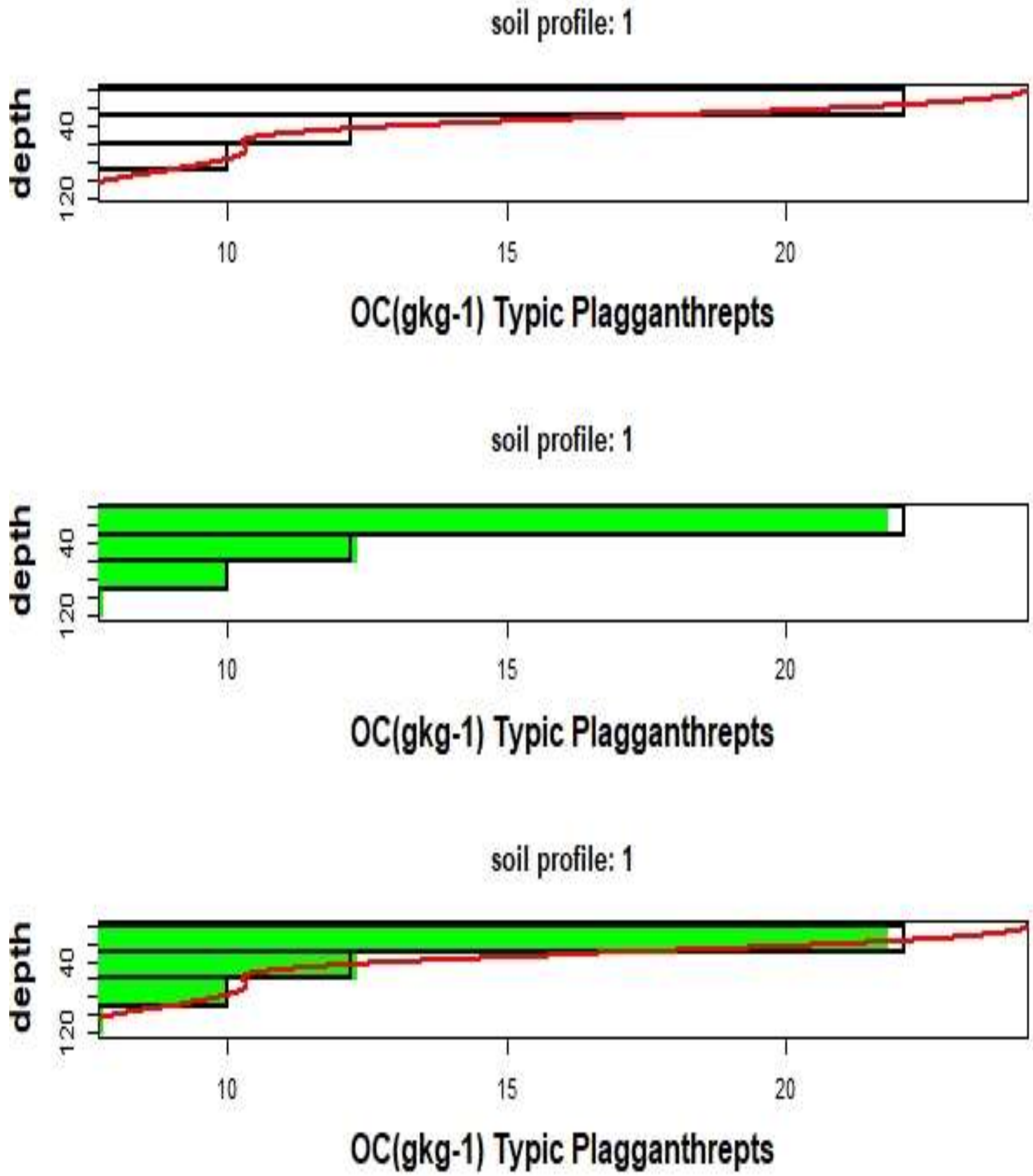


Fig. 5: Fitted splines of soil organic carbon in profile 1.

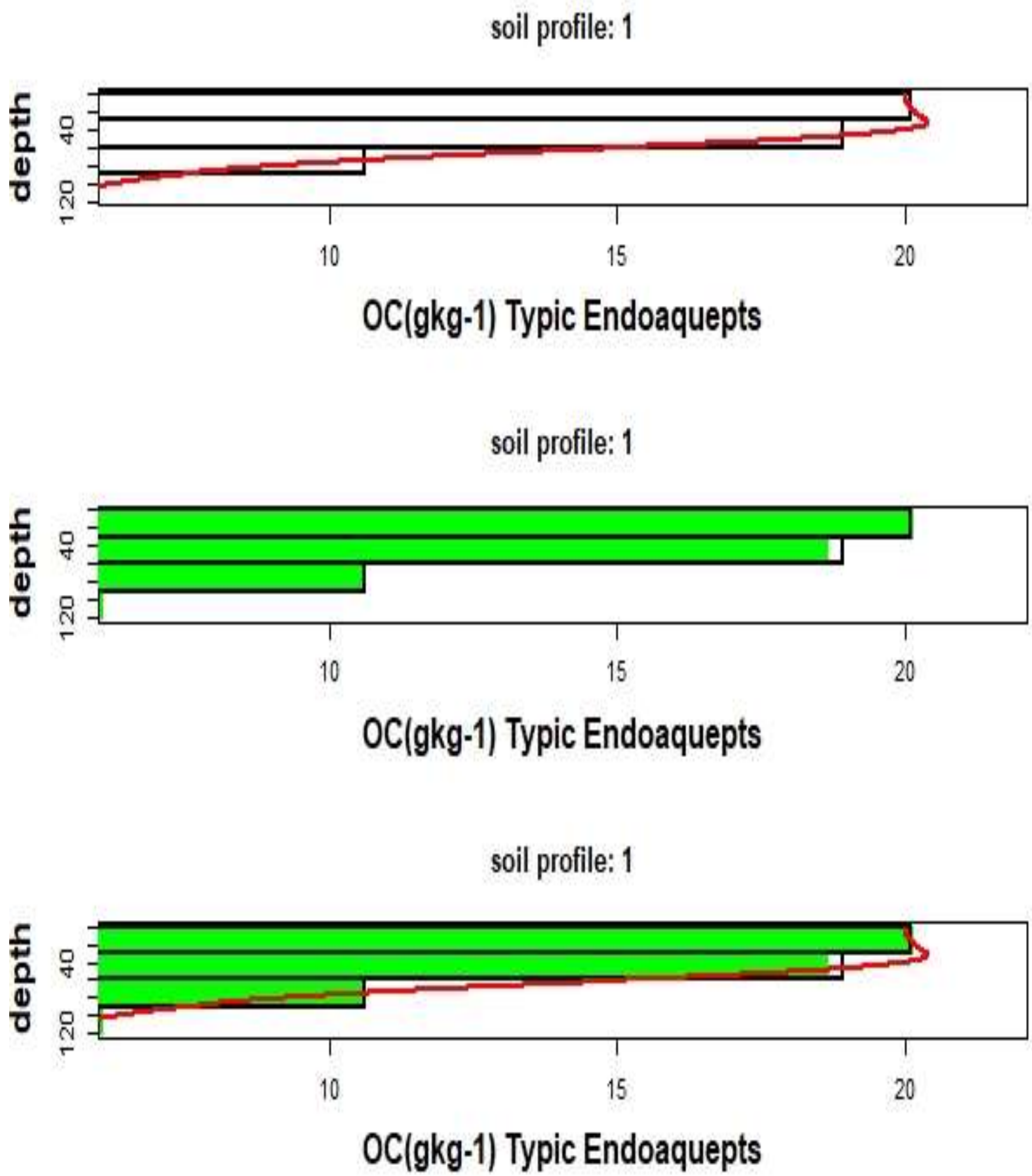


Fig. 6: Fitted splines of soil organic carbon in profile 2

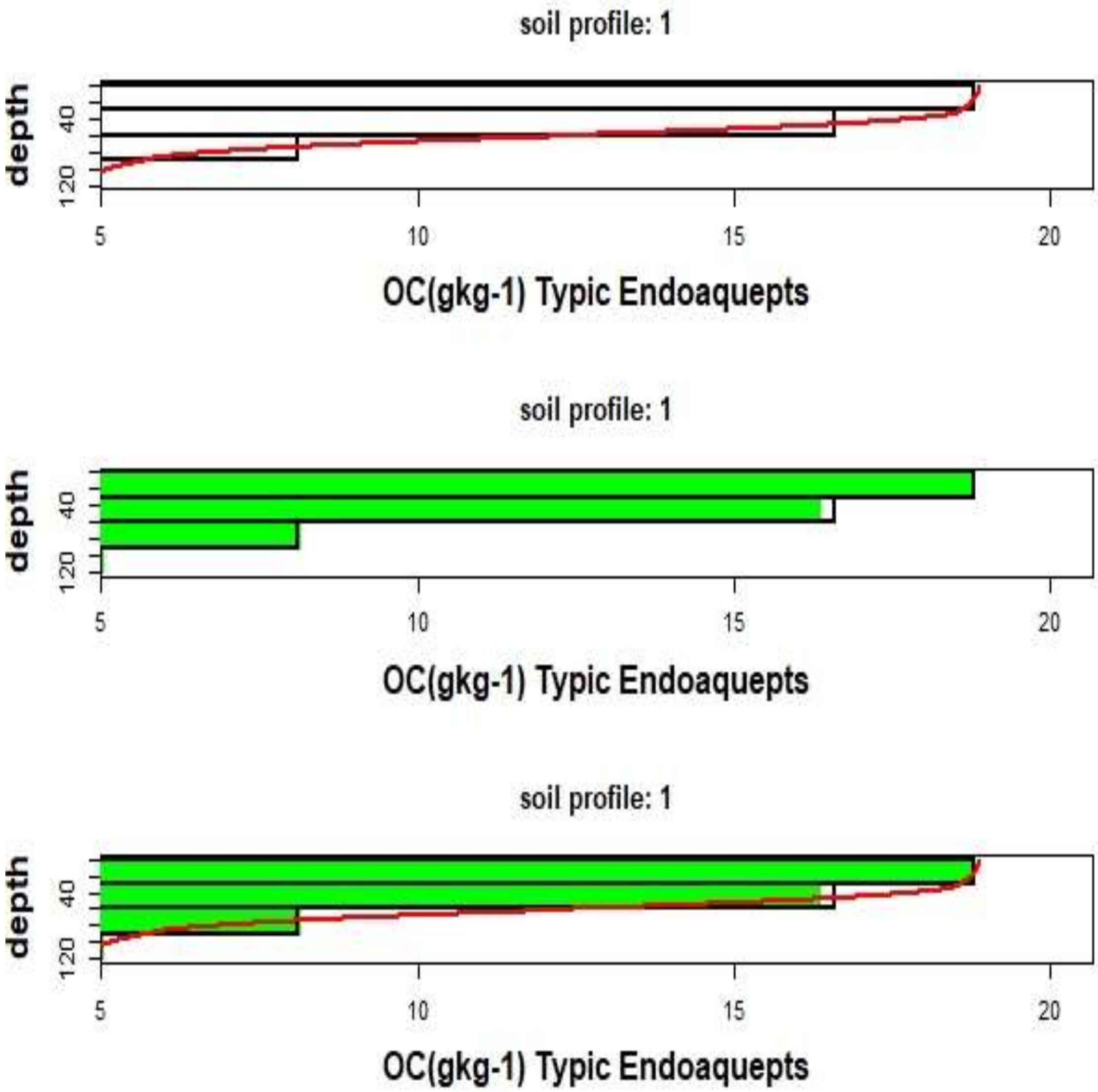


Fig 7: Fitted spline of soil organic carbon in profile 3

Generally, soils along the bank of River Jakara were slightly alkaline in pH and medium to high in organic carbon (Esu, 1991). However, the medium to high organic carbon values at the bank of River Jakara might be ascribed to application of domestic wastes by farmers and high human population of the areas which contributes to the waste generation, a fact stated by Binns *et al*., (2003), and also domestic and abattoir waste waters contain high levels of organic materials capable of enriching the soil (Brady and Weil, 1999). Across all the three studied soil profile pits, the values in surface horizons (A horizon) were much higher than those in the subsurface horizons (B horizon); there was a slight decrease in organic carbon (OC) content with increase in soil profile depth. The decrease in organic carbon with depth from the Ap horizons (0-30 cm) to the B horizons (30-120) might be attributed to immobilization of organic carbon by clay in the underlying horizons in forms of organo-clay-complexes (Mortland, 1970). The soil organic carbon values across the three soil pits were moderate but still within the values for soils found in Nigerian savannah that ranged between 8.0 – 29gkg$^{-1}$ (Jones, 1973) and is typical for savannah soils with sandy surface (Jones and Wild, 1975).

From this study, the predicted models of organic carbon accounted for about 80-90% accuracy ($R^2$) and such level of accuracy were reported by Ryan *et al.*, (2000) and Florinsky *et al.*, (2002) during digital mapping.

**CONCLUSSION**

From the results obtained, it can be concluded that all the three studied soils pits along the bank of River Jakara were generally

medium to high in organic carbon and they mostly tend to decrease down the profile pits.
The spline functions were flexible and sensitive to changes or variation of organic carbon movements down the profile pits which can be amendable therefore, they can be used in displaying the vertical variability of organic carbon within the soils of the study area.

**REFERENCES**

Ado, K. I. (2006): A publication of the Research and Documentation Directorate, Kano State Government: Investnent Opportunities in Kano Center of Commerce. ISBN 978-8092-08-X 1st Eds

Asomani-Boateng, R. and Haight, M. ( 1999). *Reusing organic solid waste in urban farming in African cities*: a challenge for urban planners. In: Agriculture urbaine en Afrique de /'Ouest.Une contribution a Ia securite alimentaire eta l'assainissement des villes I Urban Agriculture inWest Africa. Contributing to Food Security and Urban Sanitation. (Smith, O.B., ed.). Ottawa, Canada: CRDVCT A.

Bichi, M. H. (2000). Surface water quality in the Kano Industrial Environment, In: Falola, J. A., Ahmed, K., Liman, M. A. and Maiwada, A. (eds), issues in Land Administration and Development in Northern Nigeria, Proceedings of the National Workshop on Land Administration and Development in Northern Nigeria, Department of Geography Bayero University, Kano. pp. 305-313.

Binns, J.A., Maconachie, R.A., Tanko, A.I. (2003), *Water, Land and Health in Urban and Peri-Urban Food production:* the case of Kano, Nigeria, Land Degradation Development 14, 431-444

Binns, T. and Lynch, K. (1998). Feeding Africa's growing cities into the 21st century: the potential of urban agriculture. *Journal of International Development*10:777-793.

Bishop, T. F. A., McBratney, A. B., & Laslett, G. M. (1999). Modeling soil attribute depth functions with equal-area quadratic smoothing splines. *Geoderma*, 91(1–2), 27–45.

Brook, R.M. and Davila, J.D. (2000). The peri-urban interface: a tale of two cities. School of Agricultural and Forest Sciences, University of Wales and Development Planning Unit, University College London. Bethesda, Gwynedd, Wales, U.K.: Gwasg Ffrancon Printers. changes. *Soil Sci. Soc. Am. J.* 64:1904–1910.

Cofie, O., Dreschel, P., Amoah, P., Danso, G. and Gyiele, L. (2001). Improving rural-urban nutrient flows through urban and peri-urban agriculture. Rural-Urban Encounters: Managingthe Environment of the Peri-Urban Interface. DPU International Conference, London, U.K., 9-16.

Dokaji, A. A. *(*1978). *Kano Ta Dabo Cigari*. Northern Nigeria Publishing Company, Zaria. Pp 102.

Drechsel, P., Cofie, 0., Vazquez, R. and Danso, G. (2002). *Technology development for municipal organic waste recycling for urban and peri-urban agriculture-A holistic approach.*E-conference, 2-14 February 2002 at www.ruaf.org

Edonga, R.N., Jock, J.N and Edonga, M.O. (2000). Evaluation of potential evapotranspiration by Adjusted Blaney Equation with microlysimeter at samara, NGS, Nigeria. Proceedings of 20th Ann. Conf. of SSSN. Oct., 30-Nov., 3rd, Ibadan

Egziabher, A.G., Lee-Smith, D., Maxwell, D.G., Memon, P.A., Mougeot, L.J.A., and Sawio, C.J. (1994). Cities feeding people. Ottawa, Canada: IDRC.

Erh, T.(1972). Application of spline functions to soil science.*Am J of Soil Sci*, 114(5): 333–338.

Esrey, S.A. and Andersson, I. (2001). *Ecological sanitation-Closing the loop*. Urban Agriculture Magazine 3:35-37.

Florinsky, I., Eilers, R., Manning, G., Fuller, L., (2002): Prediction of soil properties by digital terrain modlling, Environmental modeling and Software 17:295-311

Jenny, H. (1941). Factors of Soil Formation: a System of Quan titative Pedology. McGraw Hill, New York and London.

Jones, M.J. and Wild, A. (1975). Soil of West Africa Savanna. Commonwealth Agricultural Bureaux, Harpenden.U.K. pp.24Journal of Environmental Quality, 26:1038.

Lynch, K., Binns T. and Olofin, E. (2001), urban agriculture under threat: the land security question in Kano, Nigeria. Cities 18: 159 - 171.

Malone, P., Minasny, B. andMcBratney,B. (2017). Using R for Digital Soil Mapping, Springer International Publishing Switzerland, 96-100.

Malone, B.P., McBratney, A.B., Minasny, B. and G.M. Laslett, (2009). *Geoderma*. Vol 154(1-2): 138-152

Mougeot, J.L.A. (1994). African city farming from a world perspective. In: Cities feeding people (Egziabher, A.G., Lee-Smith, D., Maxwell, D.G., Memon, P.A., Mougeot, L.J.A., andSawio, C.J., eds.), pp.l-24. Ottawa, Canada: IDRC.

Mougeot, L. J. A. (2005) *AGROPOLIS: The Social, Political and Environmental Dimensions of Urban Agriculture*. Earthscan, London.

Nelson, D. W. and Sommers, L.E. (1982): In: Page, A. L. (ed) *Methods of Soil Analysis,* part 2. pp 570-571. Agro: Monograph. 9. ASA, Madison, Wisconsin, USA. New York.

NPC, "Nigeria national population census report, (2006). Retrieved from: Nigeria Population Commission (NPC) office, Kano state.

Olofin, E. (1996). Socio-economic sustainability of the fadama system in the dry lands of Nigeria. Geography 81: 377-380.

Olofin, E.A., Fereday, N., Ibrahm, A.T., Aminu, S.M., Adamu Y. (1997): *Urban and peri-urban horticulture in Kano, Nigeria.* Natural Resources Institute: Chatham

Ponce-Hernandez, R., Marriott, F.H.C., Beckett, P.H.T., 1986. An improved method for reconstructing a soil profile from analyses of a small number of samples. *Journal of Soil Science* 37, 455–467.

Russell, J.S. andMoore, A.W. (1968). Comparison of different depth weightings in the numerical analysis of anisotropic soil p rofile data. Transactions of the 9th International Congress of S oil Science 4, 205–213.

Ryan, P., McKenzie, N., Oconnell, D., Loughhead, A., Lappert., P., Jaquier, D. Ashton, L. (2000): Intergrating forest soils information across scales: spatial prediction of soil properties under Australian forest. *Ecology and management J* 138: 139-157

Sweet, L. (1999). *Room to live-Healthy cities for the urban century*. IDRC Briefing. Ottawa, Canada: IDRC.

Tanko, A.I. (2003) Land Tenure Arrangements And Peasantry In Sub-Saharan Africa: The Case In Northern Nigeria. Paper for Presentation at the Workshop on "Law and Poverty" organized jointly by the Social Science Academy of Nigeria and the Comparative Research Programme on Poverty (CROP) at Pioneer Technology, 4(1), 028 – 033.

UNDP (1987) Reclaimed water reuse in agriculture", Technical Report (in French), Vol. 1, 3rd Part, 69 p.+ annexes, Project RAB/80/011, Water Resources in the North African Countries, Rural Engineering Research Centre (Tunisia) - United Nations Development Program, May 1987.

Wakawa R. J, Uzairu A, Kagbu, J. A, Balarabe M. L. (2008): Impact assessment of effluent discharge on physicochemical parameters and some heavy metal concentrations in surface water of River Challawa Kano, Nigeria. *African Journal of Pure and Applied Chemistry* Vol. 2 (10), pp. 100-106.

Walkley, A., Black, I.A., (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37, 29–38.