#7515 SPATIAL VARIABILITY AND MAPPING OF SELECTED SOIL QUALITY INDICATORS FOR PRECISION FARMING AT A SMALLHOLDING LEVEL IN MINNA, NIGERIA

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ABSTRACT

Smallholding farmers in Nigeria still practice blanket application of fertilizers, without considering spatial variations in soil properties across their fields. Understanding of spatial variability in soil properties is essential for precision farming, especially in this era of resource scarcity and high cost of fertilizers. This study was carried out to assess and map the spatial variability in selected soil quality indicators in a smallholder farm in Minna, North-central Nigeria, for site-specific management. Four-hectare field was selected for the study. The field was divided into subplots of 25 m x 25 m and serially numbered from 1 to 64. Each subplot was geo-referenced and soil samples were collected from 0-15 cm depth in 10 randomly selected subplots and sent to the laboratory for analysis. Field and laboratory data were analyzed using descriptive statistics. The data were then transferred into GIS software, SURFER 11, for interpolation and production of spatial maps of the selected soil quality indicators. Results indicated that the texture of the soils was sandy loam, pH was neutral; soil organic carbon and total nitrogen were low while phosphorus and potassium were medium. Spatial variability was low in sand, clay, bulk density and pH with their coefficient of variation (CV) ≤ 10 %. The CV for silt (28 %) and nitrogen (25 %) were moderate, while soil organic carbon (40 %), phosphorus (38 %) and potassium (36 %) were high. Correlation analysis indicated a non-significant (> 0.05) relationship between the micro-relief and spatial distribution of the soil properties within the farm. Based on the results, management practices related to soil organic carbon, nitrogen, phosphorus and potassium will require dividing the farm into relatively smaller homogenous units. This would help the farmers significantly in managing the spatial variability through application of the right quantity of fertilizers appropriate for each unit.

Keywords: Site-specific management, spatial variability, geospatial mapping

INTRODUCTION

Spatial variability in soil properties is a major global challenge and contributes to differences observed in growth, yields and quality of field crops (Jabro et al., 2010). Hence, knowledge of the spatial variability of soil properties is a prerequisite for site-specific management as it permits appropriate application of field inputs, e.g. fertilizer, irrigation water, herbicides etc. according to the spatial requirements of soil and crop.

Knowledge of spatial variability of soil properties in smallholder (peasant) fields for the purpose of site-specific management practices has been a major concern, particularly in Nigeria. Recent studies in a north-central state in Nigeria had revealed that farmers in this category are yet to understand that such phenomenon exists in soils (Abdulrasak et al., 2019). This could have accounted for differences usually observed in the growth and yield of their field crops. The way forward is to quantify the spatial distribution pattern of soil properties and construct reliable spatial variability map(s) of smallholding arable fields. Therefore, this study assessed and mapped the spatial variability of some soil quality indicators for site-specific management in a smallholding farm.

MATERIALS AND METHODS

Description of the Study Site

The study site is located at Gidan-Kwano, a suburb of Minna, Niger State, Nigeria, on latitudes 9º 30′ 27.150″ N and longitudes 6º 27′ 16.746″ E at 223-240 m above mean sea level. Minna lies within sub-humid tropical zone with mean annual rainfall above 1200 mm and mean daily temperature of 33 ºC which peaked at 40 ºC between February to March. Dominant soils are Ferric Luvisols, Ferric Acrisols and Ferric Cambisols (Ojanuga, 2006). The vegetation of the study area is southern Guinea wooded savanna of Nigeria. Maize, rice, sorghum, soybean, cowpea and yam are the major crops grown by smallholder farmers.

Soil Sample Collection and Laboratory Analysis

Four hectares field was selected for the study. The field was divided into subplots of 25 m x 25 m and numbered 1 to 64. Ten subplots were selected for sampling using random sampling technique. Geo-referenced soil samples and core samples for determination of bulk density were collected at the middle of the selected subplots at 0-15 cm depth, to allow for interpolation and production of spatial maps of some soil properties.

The air-dried samples for routine analysis were gently crushed and passed through a 2 mm mesh. The processed soil samples were analyzed for bulk density, particle size distribution, soil pH, soil organic carbon (SOC), total nitrogen (N), phosphorus (P) and exchangeable potassium (K), following the standard laboratory procedures outlined in the IITA's Soil and Plant Analysis Manual (IITA, 2015).

Data Processing and Digital Mapping

Data collected from the field and those determined in the laboratory were analyzed using descriptive statistics to obtain minimum, maximum, mean, standard deviation (SD) and Pearson correlation analysis (SAS Institute, 2015). Coefficient of variation (CV) was computed by dividing SD with mean for each attribute measured. Spatial variability ranking followed the guidelines outlined in Wilding and Drees (1983), in which CV values of 0-15, 16-35 and 36 % and above were ranked as low, moderate and high. The relationship between micro-relief and some soil properties were estimated using correlation coefficient whose significance was tested at 5 % level. Spatial variability maps were generated using GIS-software; SURFER 11 (Golden Software Inc., 2012).

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties

The texture of the soils was sandy loam. Average bulk density was 1.47 Mg m^{-3}. Soil reaction was neutral with mean pH value of 6.9, making the soil favorable for cultivation of many field crops. SOC and N were low; P was medium while K content in the soil was high. Thus, SOC and N are critical in soil quality management in the studied field.

Spatial Variability of Soil and Land Attributes

The results summarizing the descriptive statistics of the soil and land attributes measured are presented in Table 1 and spatial variability maps of some soil quality attributes represented in Figures 1a-d. The micro-relief of the farm had low coefficient of variation (CV), implying low spatial variability in land configuration. Except silt with moderate CV, other soil physical properties measured had CV values < 15 %, also indicating low spatial variability. Seasonal tillage activities could have been responsible for such homogenization in those soil properties.

Table 1: Spatial variability of land and soil properties of a farmer's field in Minna, Nigeria

Parameter	Min.	Max.	Mean	SD	CV (%)	Spatial variability Ranking
Topography	223	240	228.90	5.80	3	Low
Sand (g kg^{-1})	662	772	719	38.89	5	Low
Silt (g kg^{-1})	60	140	102	28.60	28	Moderate
Clay (g kg^{-1})	158	198	179	18.53	10	Low
Bulk density (Mg m^{-1})	1.19	1.67	1.47	0.13	9	Low
Ph	6.5	7.4	6.9	0.28	4	Low
Organic carbon (g kg^{-1})	2.16	7.30	4.94	1.98	40	High
Total nitrogen (g kg^{-1})	0.06	0.12	0.08	0.02	25	Moderate
Phosphorus	5	18	10.90	4.12	38	High
Potassium	0.30	1.08	0.64	0.23	36	High

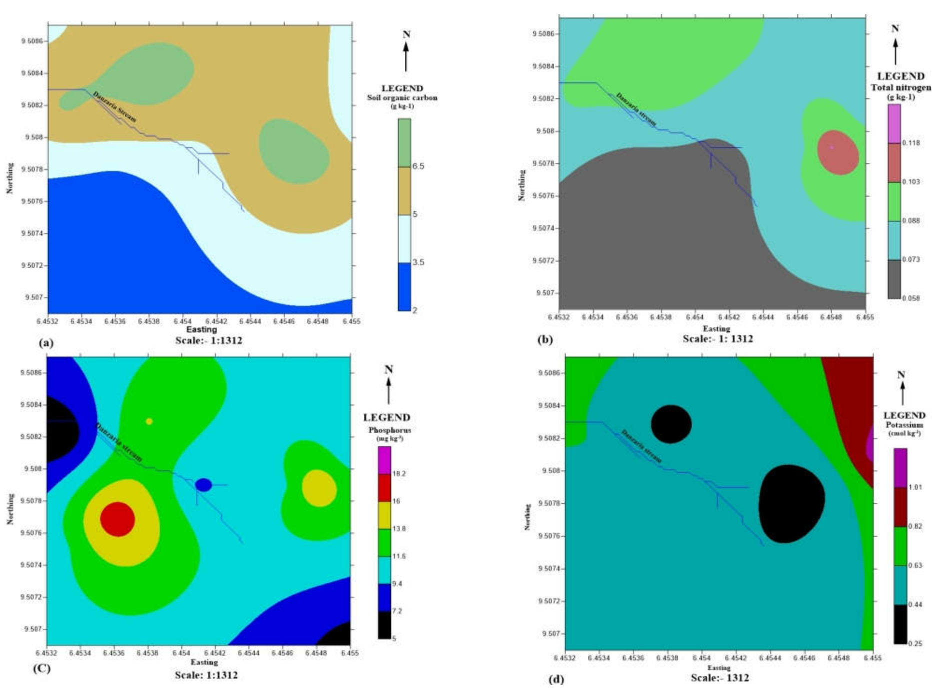

Figure 1. Spatial distribution of (a) soil organic carbon, (b) total nitrogen, (c) available phosphorus and (d) potassium in the surface soils of the studied site.

Spatial variability in chemical properties varied from low in pH, moderate in N, high in SOC, P and K. This variation could be attributed to differences in land use types (tuber and cereal crops) requiring different soil fertility management practices. Maniyunda et al. (2013) reported high spatial variability in SOC, N, P, K and S in some savanna soils which they attributed to differences in land use types, management and cultural practices and the socio-economic status of farmers. Thus, the implication of the current findings is that while issues related to soil reaction may be handled uniformly, management of SOC, N, P and K have to conform to their spatial variations in the soil. In this regard, it is appropriate to partition the field into relatively homogenous units for effective management.

Relationship Between Micro-Relief and Soil Properties

The Pearson correlation between the micro-relief of the farm showed non-significant ($P>0.05$) correlations with sand ($r = 0.403$), silt ($r = -0.514$), clay ($r = -0.082$), bulk density ($r = 0.419$), pH ($r = 0.310$), SOC ($r = -0.449$), P ($r = 0.009$), N ($r = -0.052$) and K ($r = 0.435$). This suggests that other pedogenic factors overshadowed the effect of topography on spatial distribution of soil properties within the confine of the farm.

CONCLUSIONS

On the basis of the soil texture, bulk density and soil pH, management practices related to soil compaction and soil reaction (pH) could be handled uniformly. Uniform/blanket soil fertility management should be discouraged due to high spatial variability, particularly for the amendment of SOC, N, P and K. Smallholder farmers in this part of Nigeria are encouraged to partition their farms into relatively homogenous management units to permit proportionate application of these nutrients. This may eliminate the possibility of some parts of their farms receiving insufficient of these nutrients, while other parts received in excess.

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