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ASSESSMENT OF SPATIAL VARIABILITY OF SOME SOIL PROPERTIES AT CENTRE FOR DRYLAND AGRICULTURAL RESEARCH FARM BAYERO UNIVERSITY KANO.

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The research was conducted at the Centre for Dryland Agricultural research farm with the aim of assessing the spatial variability of some soil properties and the degree of relationship between such properties. The boundary of the areas was delineated and georeferenced in ArcGIS environment, followed by digitization and creation of the shape file to represent the area. The fishnet of ArcToolbox was used to generate grid of 50 x 50 meter, and the centre of each grid was extracted and imported into Geographical Positioning System (GPS) to locate each of the sampling point. Composited soil samples were collected at the depth of 0-20cm, and the samples were prepared and analyzed based on the standard laboratory procedures. The results were subjected to descriptive statistic and geostatistics to generate the spatial representation of each parameter of the location. The result revealed that there was moderate variability in Clay, Iron and Cupper, while sand, silt, electrical conductivity, Zinc had a strong coefficient of variation (>75%). Highly Significant negative relationship was observed between sand, clay and silt, and highly significant positive relationship was also observed between clay and silt. Sand dominated all the mineral fractions and the content of micronutrient were rated moderate to high. Strong positive relationship was obtained between all micronutrient, except zinc and iron. Simple and ordinary krigging methods were used for the interpolation, with stable and exponential as best models for all the variables, except iron. Weak to moderate spatial autocorrelation was observed between all the parameters. Soil amendment should be used to improved the water holding capacity of the soil, and application of fertilizer bearing micronutrient should checked to reduced toxicity of these nutrients in the soil.

Key words: Geographical Positioning System, Georeferencing, descriptive statistic, krigging and Geostatistics

INTRODUCTION

Soil is heterogeneous complex of natural resources with marked variability across the landscape. Spatial heterogeneity of soil properties in any given landscape is a fact that has become well established (Amuyu, et al, 2013). This spatial heterogeneity is related to the variations in numerous factors, including the physicochemical properties of soil, topography, climate, parent material, land use patterns, and management practices (Wang, et al., 2010). Soil productivity, spatial and temporal variability in crop is mainly influenced by both intrinsic and extrinsic factors, intrinsic factors include soil forming factors such as parent material, climate, topography and time, while extrinsic factors may involved farm management practices and maintenance operations (Sun and Zhao, 2003). Variability of soil was easily observed in any cultivated field with differences in the crop performance at different growing stage. Bouma and Finke (1993) reported that soil variation can largely occurred on any scale within an areas, fields and regions and even whini few millimetre spacing in the field, Geographical information system (GIS) and remote sensing techniques were used to study spatial variability of soil with emphases on geostatistics. However, geostatistics takes into account both the structured and random characteristics of soil observations in data processing through a set of statistical tools, thus, spatial patterns can be described and modeled, un-sampled locations predicted, and the uncertainty attached to these predictions assessed (Goovaerts, 1998).

Precision Agriculture (PA) requires the use of geographical information system (GIS) to study the soils adequately. Gebbers and Adamchuk (2010) stressed that PA based geospatial technologies, such as global positioning system, geographical information system, remote sensing, geo-statistics and variable rate applications can be used for obtaining efficient nutrient management in crop fields

Soil survey evaluation is a tool to assess, manage and induce changes in the soil and to link existing resource concerns to environmentally sound land management practices and soil survey assessment Mohamed and Abdo (2011), Soil nutrient depletion and poor management are very important factor contributing to the poor crop productivity in many locations of Nigeria. It was reported by Folmer *et al*. (1998) that poor agricultural practices, export of nutrients by removal of crop biomass after harvesting and soil erosion are the most important factors contributing to the soil fertility decline. Many techniques have been used to study spatial distribution patterns of many soil properties, conventional statistics and geostatistics were widely applied (McGrath and Zhang 2003, Sepaskhah et al. 2005, Liu et al. 2006), and based on the theory of a regionalized variable (Webster and Oliver 2001). Therefore, geostatistics provides advanced tools to quantify the spatial features of soil parameters and allow for spatial interpolation to be conducted which may lead to creation of maps of the locations and be used for site specific management. The generated maps of the location are self-explanatory, site with nutrient depletion problems would be easily identified and general recommendation can be made judiciously from the maps. The objectives of this research is to assessed the spatial variability of some soil properties and to observed the relationship between such properties

MATERIAL AND METHODS

Study Area

The study was carried out at Centre for Dryland farm (CDA) of Bayero university Kano and the size of the farm is 35 hectares. The climate of the study areas is the tropical wet and dry type symbolized as AW by koppen (Adamu and Aliyu, 2012), Mean Annual rainfall of 750mm. Temperature is a very critical element in this areas and it is averagely warm to hot throughout the year at about 25± 7℃ (Olofin, 1978).

Field studies

The geographical poisoning system (GSP) was used to record the coordinate of the boundary of the study area. The data was used for georeferencing and digitization in Arcmap. Fishnet was used to create the grid of 50 x 50m and coordinates of the center of the grid was extracted and imported in the GPS for navigation to the sampling points. Composite surface soil samples were collected at the depth of 20cm, properly labeled and stored for analysis. The soil samples were dried, sieved and analyzed for various soil properties using standard procedures. The parameters considered for the study were particles distribution, soil pH, Electrical conductivity and micronutrients (Iron, Copper, Zinc and Manganese).

RESULTS AND DISCUSSION

The summary of all the parameters was presented in Table 1. Sand dominated all mineral fractions and clay was the least. The dominance of sand in the study area might be attributed weathering and nature of parent materials. The mean values of sand, silt and clay were 66.77%, 22.63% and 10.60% respectively. The mean of Soil pH was slightly acidic (6.29) with electrical conductivity of 27.26 dSm^{-3}. High variability was observed in all the soil properties, except in soil pH (low), clay, Iron and Copper which exhibit moderate variability. This variability might be linked to the nature of landscape as the area was characterized by having different slope position, which may affect the movement (leaching) and retention soil materials. Considering the symmetry of the data (normal distribution) only soil pH and silt had the value of skewness close to zero, and all the remaining soil properties were not normally distributed. The soil properties of the study area varied widely, and hence the data was transformed before subjecting it to further analysis. All the micronutrient were rated very high, far beyond critical limits reported by Esu (1991) for savanna soil of Nigeria, therefore the toxicity range of these nutrients in very high.

Table 1: Descriptive Statistics of the soil in the study area

	N	Minimum	Maximum	Mean	SD	Variance	Skewness	Kurtosis
Sand (%)	154	20.40	94.40	66.7725	15.94190	254.144	-1.072	0.653
Silt (%)	154	1.84	66.56	22.6213	11.12308	123.723	0.922	0.864
Clay (%)	154	1.60	47.76	10.6029	8.12040	65.941	1.869	4.620
EC (dSm-1)	154	7.20	130.30	27.2604	15.64130	244.650	2.573	12.285
pH	154	5.25	7.66	6.2887	0.48425	0.234	0.339	0.171
Zn (mg/kg)	154	4.48	87.23	20.9055	13.59933	184.942	1.718	4.256
Fe (mg/kg)	154	0.18	37.36	7.3380	6.82170	46.536	2.009	4.918
Mn (mg/kg)	154	0.44	2122.89	4.3461E2	332.14527	1.103E5	2.134	7.026
Cu (mg/kg)	154	0.43	50.19	8.2437	7.30467	53.358	2.532	9.250

Note: N=Number of samples, SD=Standard Deviation, Fe=Iron, Cu=Copper, Zn=Zinc and Mn=Manganese

The relationship between various soil parameters was assessed using Pearson correlation matrix as present in Table 2. Sand was negatively correlated with silt and clay and the correlation was highly significant. This finding revealed that sand and clay were inversely proportion to each other. Silt and clay were positively and significantly highly correlated with one another. Highly significant positive correlation was observed between all micronutrients, except zinc and iron. Yi et al. (2012) and Vukašinovic et al. (2015) reported the similar results for the relationship between micronutrients except for the moderate relationship between Fe and Mn. The correlation coefficient was higher between copper and manganese than any other micronutrients, and this might be attributed to the nature of parent materials and their similar adsorption-desorption behaviors with soil components like clay minerals and organic matter, influencing their mobility and availability within the soil, and similar finding was also reported by Luther III (2016)..

Table 2: Correlation between the soil properties

	Sand	Silt	Clay	Fe	Mn	Cu	Zn
Sand	1						
Silt	-.880**	1					
Clay	-.759**	.357**	1				
Fe	-0.157	.191*	0.047	1			
Mn	-0.128	0.073	0.152	.210**	1		
Cu	-.166*	0.13	0.148	.297**	.746**	1	
Zn	0.028	0.005	-0.061	0.077	.236**	.300**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Interpolation and Geostatistical analysis

The result of geostatistical analysis was presented in table 3. Ordinary kgriging was the best method for the interpolation of all the soils parameters, with exception of soil pH where simple kriging method was used. The best fitted model for most of the parameters was exponential, whereas, stable model was employed for electrical Conductivity. Moderate spatial tendency ratios were observed in soil pH, sand and silt, while weak and strong autocorrelation were obtained in clay and EC respectively. Beyond 42-56m range, the prediction of sand and clay were no longer correlated, thus the sampling points were independent to each other.

The spatial distribution of sand was present in figure 1, and the highest values were recorded at south-west and eastern part of the farm with values of more than 73%, and might be attributed to the physiographic position of the upper slope position of the area. Another reason for more sand content in these locations could probably due to washing away of the finer materials by action of wind or rain. Lower values of sand contents were obtained in the middle, north and western farm of the area. There was no defined pattern in spatial distribution of silt and clay, hence lower values were recorded where the highest values of sand was obtained (figure 2 and 3). No obvious trend was also observed in spatial distribution of soil pH and EC as shown in figure 4 and 5.

Table 3. Geostatistical results of some soil parameters.

Parameter	Model	Method	Partial Sill	Nugget	R^2	SDR	Range
pH	Exponential	Simple	0.095	0.138	0.77	59.2	16.8
EC	Stable	Ordinary	0.237	0.000	1.00	0.00	8.50
Sand	Exponential	Ordinary	0.043	0.057	0.52	57.0	45.9
Silt	Exponential	Ordinary	0.178	0.114	0.92	39.0	7.90
Clay	Exponential	Ordinary	0.114	0.448	0.35	79.7	42.0

Note: R^2 = Coefficient of determination and SDR= Spatial Dependency Ratio

The geostatistical analysis of micronutrient was presented in Table 4, and all the parameters were subjected to simple kriging methods. Different models were selected for each of the soil parameter. Zinc was fitted to exponential models, copper and manganese to stable model, while iron to hole-effect model. Strong autocorrelation was observed in copper and manganese between the sampling points with the range values of 2 and 1.4 m respectively. Moderate and weak correlation was observed in zinc and iron respectively.

The spatial distribution of micronutrient was not regular for all the variables, as there was no any defined pattern except for zinc where it was more concentrated in the western part of the farm and less values were observed in the eastern part of the farm (figures 6 -9).

Table 4. Geostatistical results of micronutrients

Parameters	**Model**	**Method**	**Partial Sill**	**Nugget**	**R^2**	**SDR**	**Range (m)**
Zn	exponential	simple	0.19	0.18	0.59	48.7	0.8
Cu	stable	simple	0.64	0.00	1.00	0.00	2.0
Mn	stable	simple	0.80	0.00	1.00	0.00	1.4
Fe	Hole effect	simple	0.27	0.86	0.54	76.12	9.0

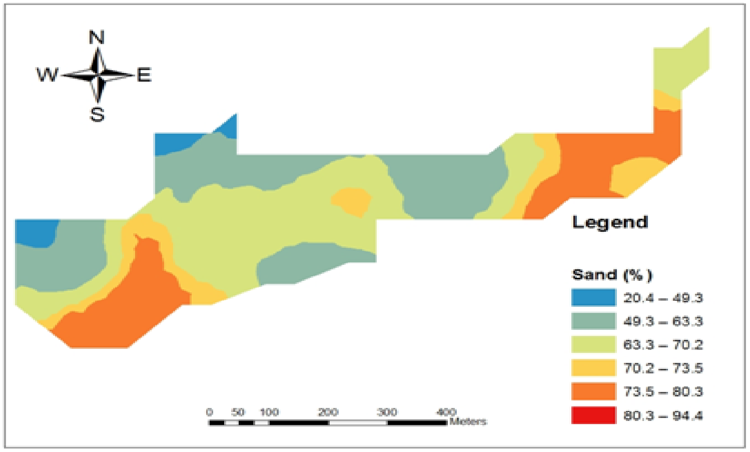

Figure 1: Spatial distribution of Sand

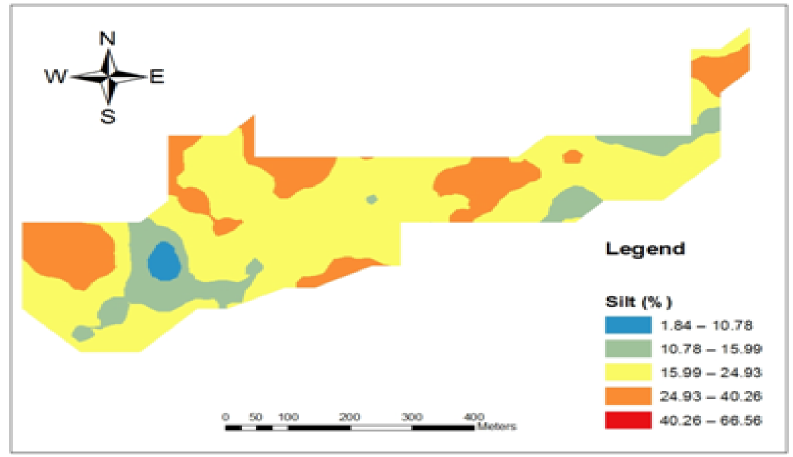

Figure 2: Spatial distribution of Silt

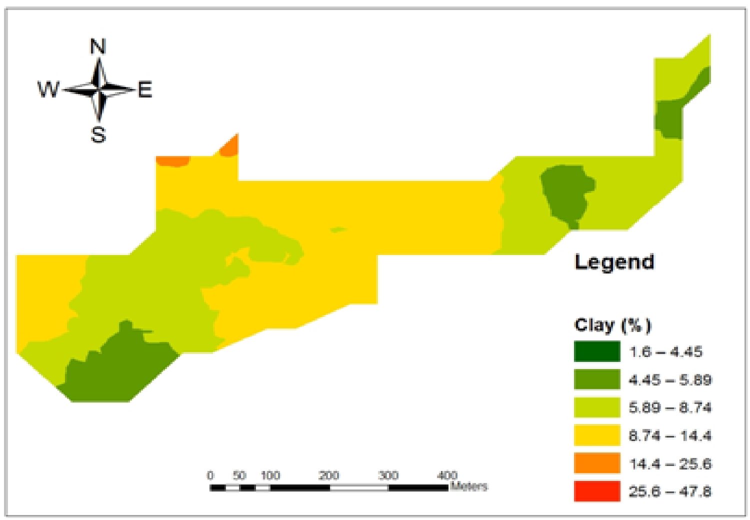

Figure 3: Spatial distribution of Clay

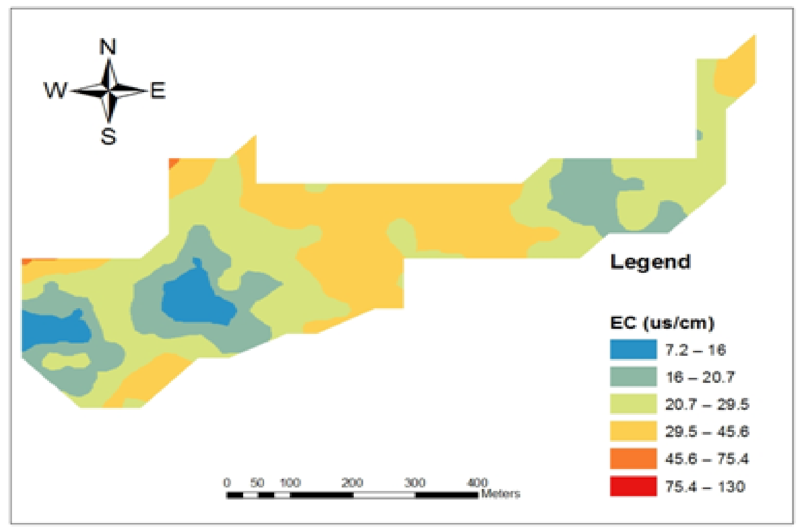

Figure 4: Spatial distribution of EC

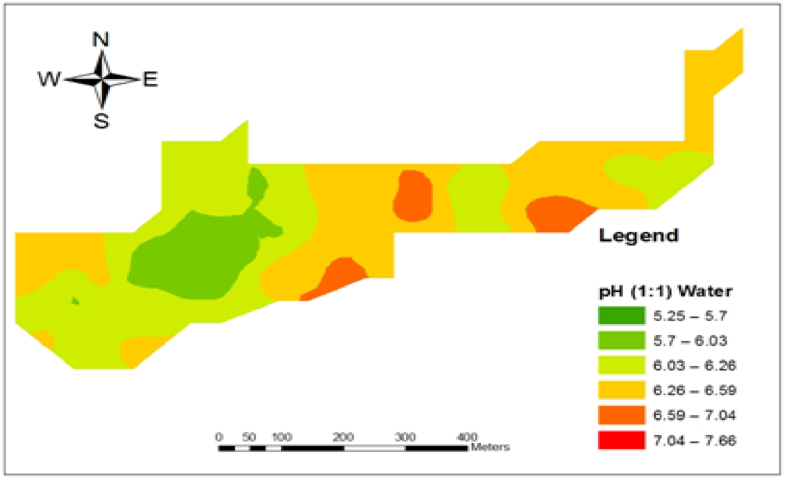

Figure 5: Spatial distribution of pH

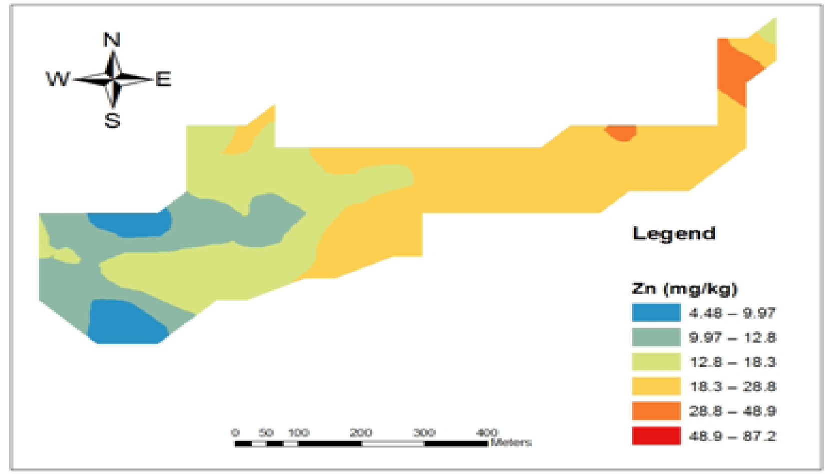

Figure 6: Spatial distribution of Zinc

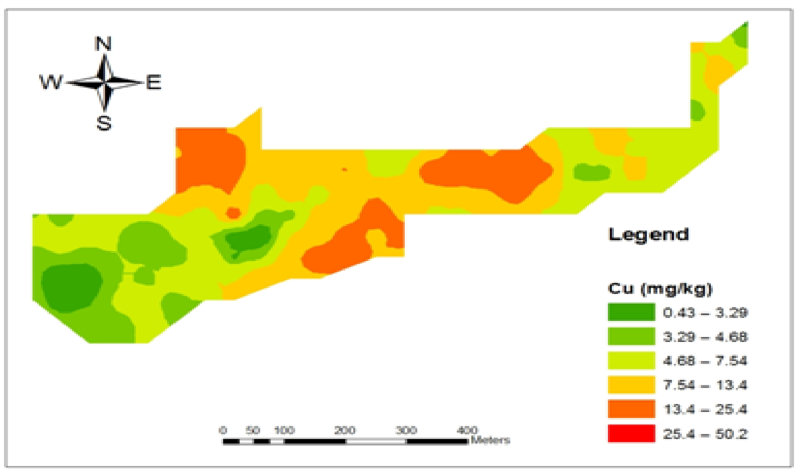

Figure 7: Spatial distribution of Copper

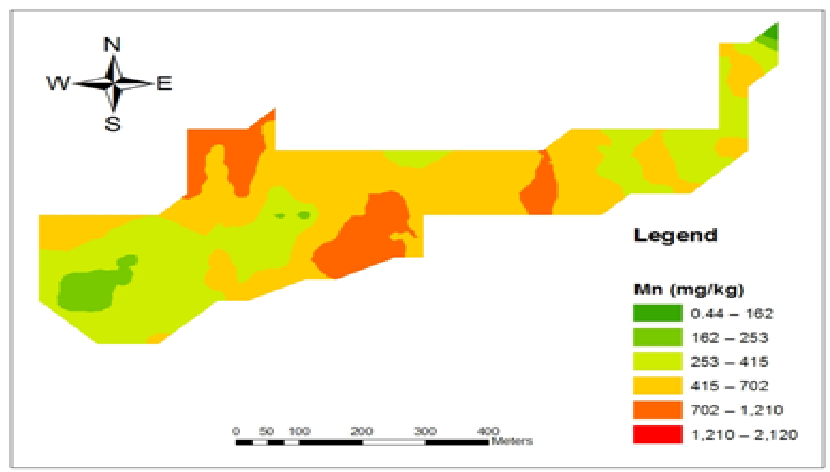

Figure 8: Spatial distribution of Manganese

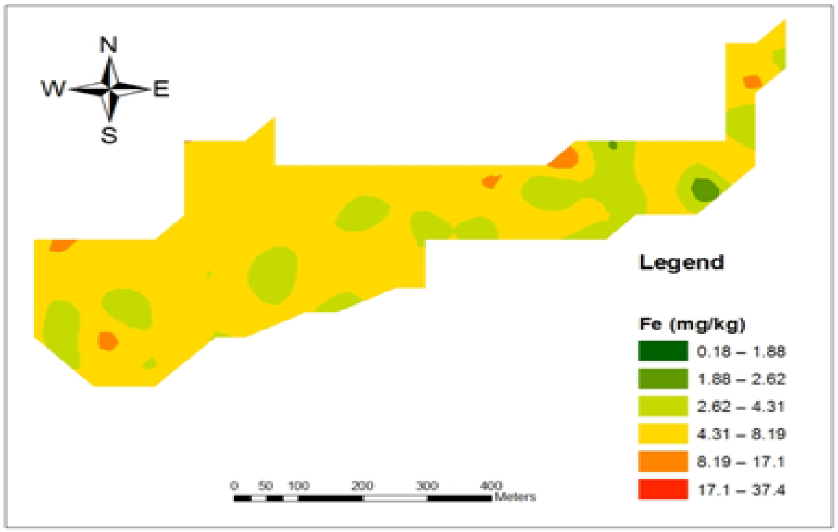

Figure 9: Spatial distribution of Iron

CONCLUSION

Sand dominated all the mineral fractions and the content of micronutrient were rated high to very high. Strong positive relationship was obtained between all micronutrient, except for zinc and iron. Simple and ordinary kriging were the best methods for the interpolation, while stable and exponential are best models for estimating all the soil variables, apart from iron where Hole-effect demonstrated higher performance. The soil pH, sand, silt and clay showed moderate spatial dependence. Electrical conductivity, copper and manganese had a strong autocorrelation, however, clay and iron had a weak spatial dependence. Very high content of micronutrients was observed, thus any further application of fertilizer need to be monitored.

RECOMMENDATION

Soil amendment should be in-cooperated in to the soil to improve the water holding capacity because of the sandy nature of the soil, and application of fertilizer bearing micronutrient should properly checked to reduced toxicity.

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