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Geospatial Distribution of Soil Reaction in Central Southeastern Nigeria.

***Onyechere A.U.[1], Onweremadu E. U.[1], Aririguzo B. N.[1] and Ahukaemere C. M.[1]**

[1]Department of Soil Science and Technology, School of Agriculture and Agricultural Technology, Federal University of Technology, Owerri.

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Corresponding Author's E-mail Address:

email: onyechere.adaobi@gmail.com

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ABSTRACT

The study applied Geographic Information System (GIS) in the Study of Soil Acidity Distribution in Soils of Central Southeastern Nigeria from six different parent materials, namely Imo Clay Shale, Ajali Sandstone, Asu River group, Afikpo Sandstone, Ogwashi-Asaba formation and Bende Ameki formation. Free soil survey method was used to site the eighteen profile pits investigated. The pits were geo-referenced with a hand held Global Positioning System (GPS) Receiver. Routine laboratory analyses were conducted on soil samples from the field study. Microsoft Excel was used to analyse the mean and percentage coefficient of variation of the results. Geostatistical Wizard of Arc GIS 10.2 software was used for the descriptive statistics, semivariogram and cross validation. Ordinary kriging method was also performed for interpolation and developed into attribute maps. The average pH in water was highest in soils formed on Asu river group (6.04-7.14) and lowest in soils formed on Ogwashi-Asaba formation and Bende-Ameki formation (5.47-6.48). The geostatistical analysis revealed that there was high spatial variability of soil properties analysed at different geographical scales however, the soil analysed showed moderate spatial dependency. The Gaussian model gave the best fitted model for the semivariogram presenting a semi variance with lowest nugget and highest spatial autocorrelation. The result of the cross validation showed that the models made a moderate prediction for pH. The map revealed that soil pH followed an observable pattern with soils of Anambra State being more acidic (lower pH level) when compared with the soils of Enugu and Ebonyi State.

1.0 Introduction

Low pH which is expressed as acidity is one of the most common environmental threat to crop production in the humid tropical soil of Southeastern Nigeria (Nottidge et al.,2009). Soil pH depend on the rock which the soil was formed and the weathering processes that act on the soil in a given time. The tropical soils of Southeastern Nigeria are highly weathered and nutrient leaching is intense due to the prevailing climatic condition (Onweremadu et al., 2007 and Ahukaemere, et al., 2016). These processes tend to lowering of the pH, base saturation, cation exchangeable capacity, organic matter of the soils leading to dominance of acidic cations. Onweremadu (2022) reported that acidity is one of the problems of soils of central Southeastern Nigeria. The acidic nature of the soils of Southeastern Nigeria reduces the solubility of plant nutrients, their availability to plant and also the growth of nitrogen fixing bacteria in legumes hence leading to low fertility status. Soil pH affects the mobility, solubility and the adsorption of many pollutants to soil colloids making it a critical factor in predicting the likelihood of pollutant contaminating the ground water (Brady and Well 2012). The information regarding the soil pH and spatial distribution in the soils of Southeastern Nigeria is still insufficient. Most at times, it is impossible to take sample from every location of interest. Geographic Information System (GIS) is a tool that is based on computer and it is use for creating, manipulating, analysing, storing and displaying information based on its location (Maliene, et al., 2011, Kent and Vujakovi 2020). It employs the use of Geostatistics which is a collection of methods that enable you to predict through assumption the value of location where no sample is collected and also ascertain the certainty of the prediction. Geostatistics predict the value of unsampled location by taking into account the spatial autocorrelation of a given value of the sampled location. (Ripendra, et al.,2019). Geostatistical techniques also analyse the certainty or accuracy of the predictions and it can be used to measure any soil properties that exhibit spatial dependence (Webster and Oliver, 2001). GIS can display its results in form of maps. Soil map displays soil information in easy and systematized manner base on the underlying soil properties and its distribution in a given geographical area (Skye, 2005) in such a way that everyone can understand it.

2.0 Materials and Methods

This section presents a description of the study area and the test specimens and the laboratory procedures of the various tests conducted in this work.

2.1 Description of the Study Sites

The study was carried out on three states of Southeastern Nigeria. Southeastern Nigeria is located within the coordinates of 4° 47' 35''N/7° 54' 26'' E and 7° 7' 44'' N / 8° 27' 10''E. The three states considered include Anambra, Enugu and Ebonyi. Anambra State has a coordinate of 6° 20′ 0″ N, 7° 0′ 0″ E and an area of 4,844 km^2 (1,870 sq mi), Enugu States has a coordinate of 6° 27′ 10″ N, 7° 30′ 40″ E and an area of 7,161 km^2 (2,765sq mi) and Ebonyi State has coordinate 6° 15′ 0″ N, 8° 5′ 0″ E and an area of 5,533 km^2 (2,136 sq mi). The Southeastern Nigeria has a tropical climate with rainfall and humidity increasing towards the south typify by uniformly high temperature and a seasonal distribution of rainfall. Anambra has average temperature of 25.9 °C and average rainfall of 1386 mm in a year, Enugu has average temperature of 26.3 °C., and average rainfall is 1730 mm in a year, while Ebonyi has average temperature of 27.7 and average rainfall of 1918 in a year. (climate-data.org 2019). The underlying geology consists of heterogeneous materials (Egede, 2013). Most of the vegetation are drastically altered by anthropogenic activities.

2.2 Soil Sampling

A free soil survey approach guided by geology maps was used in locating sampling points. Areas that were undisturbed or with little disturbance were mark for sample collection. In all, a total of 18 profile pits were dug and described; three profile pits were dug at two selected parent materials from each of the selected states and genetic horizons were carefully observed. Softness, colour, presence of root, and presence of macro fauna were the criteria for delineation and samples were collected from the bottom layer to the topmost layer. Hand held GPS receiver was used to geo-referenced all sites

2.3 Laboratory Analysis

Soil pH was measured in 1:2.5 soil/water suspensions ratio (Hendershot, et al., 1993).

2.4 Geostatistical Analysis

The open street map was used to develop the shape files of the area of interest and the GPS information was also added to developed point shape file in order to place it in the rightful geospatial position with the use of Arc GIS 10.2 software The pH data was also digitally encoded in the GIS database to generate attribute map. Descriptive Statistics were performed to monitor the normality of the spatial distribution of this soil properties and log transformation was done to aid interpolation. The Geostatistical Wizard of the Geostatistical analyst extension of Arc GIS 10.2 was used to perform the geostatistical analysis of this research. The ordinary kriging (OK) interpolation method was used for prediction of the values of the unmeasured sites (unsamples locations) (Wang, 2018). Semivariogram was used as the basic tool to examine the spatial distribution structure of the soil pH based on the regionalized variable theory and intrinsic hypotheses (Nielsen and Wendroth 2003). The theoretical semivariogram models used was the Gaussian Model. The spatial dependence was rated according to method detailed by Cambardella et al., (1994). Cross-validation technique was adopted for evaluating and comparing the performance of Ordinary Kriging interpolation method.

3.0 Results and Discussion

The results of pH of the soils studied were presented in Table 1. Generally, the pH values of the soils studied were acidic irrespective of their parent materials. Onweremadu et al., (2007) and Ahukaemere, et al.., (2016) reported similar findings in some soils of Southeastern Nigeria.

The average pH in water was highest in soils formed on Asu river group (6.04-7.14), followed by soils formed in Ajali sandstone, and next is soils formed on Imo clay shale. Soils of Afikpo sandstone, Ogwashi-Asaba formation and Bende-Ameki formation falls within the same range (5.47-6.48). The nature of the parent material, degree of leaching, dominant clay mineralogy, plant uptake of basic and intensity of microbial and anthropogenic activities going on within the soils are likely the factors affecting the pH of the soil. Obalum and Chibuike (2017) have also reported differences in pH of soils of different parent material in Southeastern Nigeria. However, according to Landon (1991) pH range of 5.50 to 7.50 provides the most satisfactory plant nutrient levels for most crops and most of the soils studied falls within this range. It was also observed that pH exhibited low variation down the profile in all the soils studied.

3.1 Descriptive Statistics

The results of the descriptive statistics were presented on Table 2. The interpolation method that are used to generate a surface gives the best result if the data is normally distributed because there is high spatial heterogeneity in soil properties due to differences in geological and pedological processes at different scale. Log normal transformation was used to transform the data to conform to normal distribution according to Shapiro-Wilk test. The result was skewed to the right (positive skewness) with low coefficient of variation

3.2 Semivariogram.

The results of the semivariogram were presented on Table

Table 1. pH Result of soil down the profile.

Sample ID Horizon	Depth (cm)	pH (water)	Sample ID Horizon	Depth (cm)	pH (water)	Sample ID Horizon	Depth (cm)	pH (water)
			IMO CLAY SHALE					
OJ1	0-17	6.9	AS1	0-13	6.26	OG1	0-15	6.67
OJ2	17-42	6.75	AS2	13-29	5.91	OG2	15-46	6.15
OJ3	42-54	6.09	AS3	29-64	5.94	OG3	46-80	5.89
OJ4	54-121	6.01	AS4	64-125	6.15	Mean		6.24
OJ5	121-150	6.55	Mean		6.07	CV(%)		6.37
Mean		6.46	CV(%)		2.77			
CV(%)		6.12						
			AJALI SANDSTONE					
UHI	0-7	7.54	OV1	0-14	7.05	EE1	0-15	7.27
UH2	0-38	6.43	OV2	14-45	6.59	EE2	15-30	7.05
UH3	38-107	6.24	OV3	45-75	6.15	EE3	30-61	6.5
UH4	107-133	6.53	OV4	75-97	6.27	EE4	61-91	6.07
Mean		6.69	OV5	97-130	6.26	EE5	91-120	6.24
CV(%)		8.71	Mean		6.46	Mean		6.63
			CV(%)		5.67	CV(%)		7.8
			ASU RIVER GROUP					
IN1	0-15	6.05	IG1	0-7	7.45	AB1	0-9	6.72
IN2	15-34	5.95	IG2	7--28	7.26	AB2	9-25	5.89
IN3	34-64	5.87	1G3	28-50	6.7	AB3	25-44	5.89
IN4	64-89	6.03	Mean		7.14	AB4	44-70	6.1
IN5	89-120	6.32	CV(%)		5.46	Mean		6.15
Mean		6.04				CV(%)		6.39
CV(%)		2.81						
			AFIKPO SANDSTONE					
AP1	0-18	5.98	**AO1**	0-9	5.74	**AF1**	0-15	6.59
AP2	18-59	5.95	**AO2**	9-24	5.5	**AF2**	15-37	6.67
AP3	59-109	6	**AO3**	24-47	5.5	**AF3**	37-52	6.18
AP4	109-145	6.3	**AO4**	47-83	5.51	**AF4**	52-103	6.29
Mean		6.06	**AO5**	83-120	5.87	**AF5**	103-170	6.69
CV(%)		2.69	**Mean**		5.62	**Mean**		6.48
			CV(%)		3.05	**CV(%)**		3.6
			OGWASHI- ASABA FORMATION					
OB1	0-10	5.95	**OR1**	0-20	5.84	**OT1**	0-10	5.5
OB2	10-45	5.5	**OR2**	20-39	5.91	**OT2**	10-34	5.55
OB3	45-71	5.5	**OR3**	39-62	5.66	**OT3**	34-66	5.69
OB4	71-107	5.5	**OR4**	62-91	6.1	**OT4**	66-95	5.81
OB5	107-156	5.5	**OR5**	91-148	6.07	**OT5**	95-126	5.5
Mean		5.59	**Mean**		5.92	**OT6**	126-150	5.5
CV(%)		3.6	**CV(%)**		3.03	**Mean**		5.59
			BENDE-AMEKI FORMATION			**CV(%)**		2.32
NN1	0-10	6.15	**UM1**	0-6	5.97	**NK1**	0-6	5.5
NN2	10-25	5.75	**UM2**	6-25	5.28	**NK2**	6-28	5.34
NN3	25-65	5.95	**UM3**	25-65	5.91	**NK3**	28-53	5.5
NN4	65-94	5.75	**UM4**	65-102	6.06	**NK4**	53-92	5.5
NN5	94-149	5.68	**UM5**	102-150	5.92	**NK5**	92-125	5.5
Mean		5.86	**Mean**		5.83	**Mean**		5.47
CV(%)		3.29	**CV(%)**		5.35	**CV(%)**		1.31

3 and Semivariogram parameters (range, nugget, and sill) were shown Figure 1.

The best fitted model was the Gaussian Model and it showed a low nugget of 0.002 (that is to say that there were low variabilities in the field data that cannot be explained by distance between the observations) and sill of 0.0049 at a range of 145385m revealing moderate spatial dependency (Cambardella et al, 1994). This was in line with the work of Webster and Oliver (2001) that noted that soil properties generally show spatial dependency.

Table 2: Descriptive Statistics of the pH of the Soils Analysed

Transformation Type	Mean	Median	Minimum	Maximum	SD	CV	Skewness	Kurtosis
Log	1.810	1.802	1.699	1.965	0.073	4.005	0.310	2.376

Table 3: Semivariogram Parameter

Model	Nugget	Partial Sill	Sill	Range (m)	Spatial Ratio	Spatial Class
Gaussian	0.0021	0.0049	0.007	145385	30	moderate

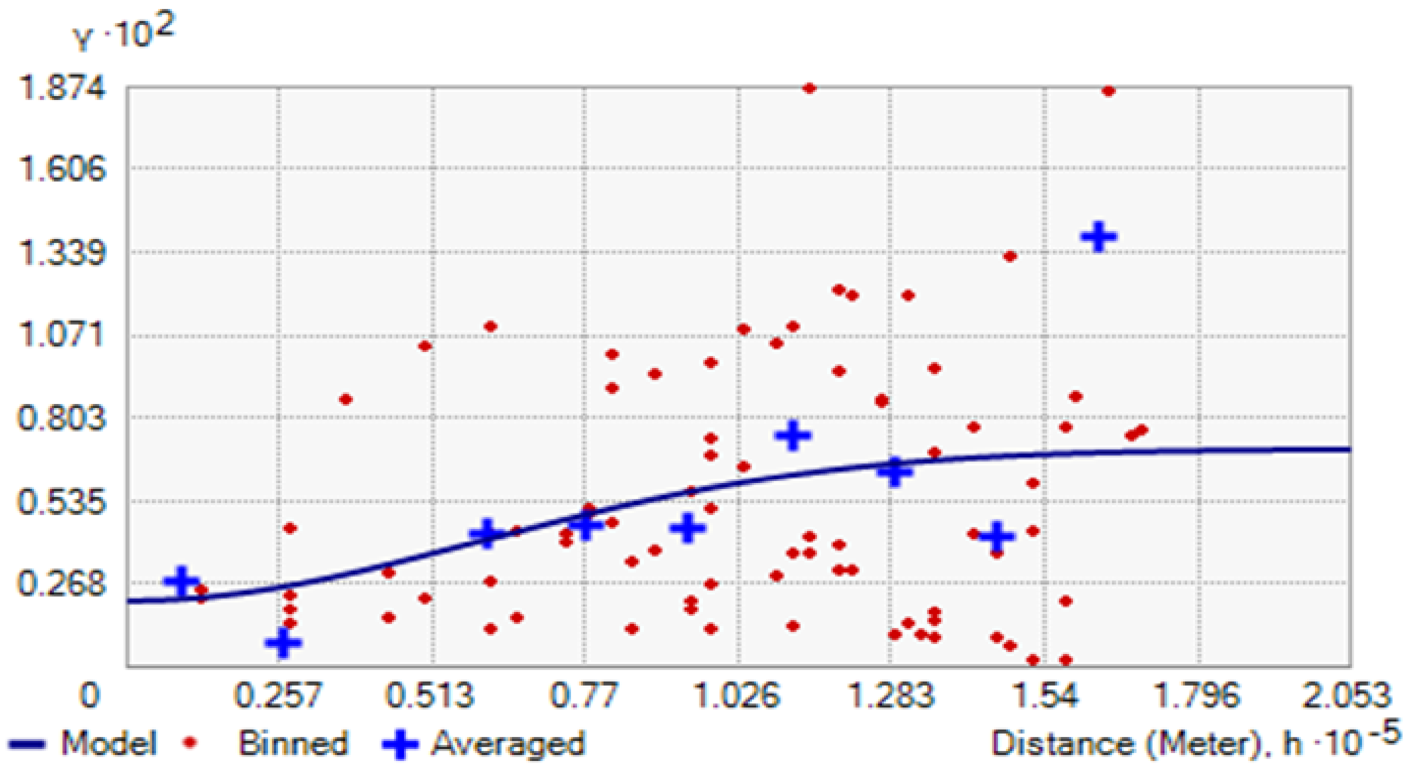
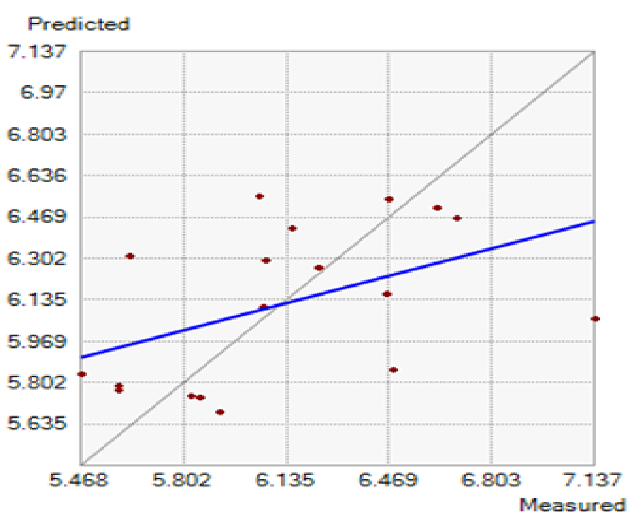


Figure 1 Semivariogram for pH



Regression function 0.3291 * x + 4.1034

Prediction Errors

Samples 18 of 18

Mean -0.0071

Root-Mean-Square 0.3980

Mean Standardized -0.0282

Root-Mean-Square Standardized 1.1826

Average Standard Error 0.3311

Figure 2: Results of Cross Validation for pH

3.3 Cross Validation.

The results from cross validation were presented in Figure 2**.** The cross validation was done by omitting a point (measured value), and the rest of the result was used to predict the value (predicted value) of this omitted point (measured point). The predicted value is then used to compared the measured value. According to ESRI (2020), for a prediction to be valid, the blue line and the gray line (1:1 line) should be close to each other, the Mean Error (ME) should be close to zero, the Root-Mean-Square Prediction Errors (RMSPE) and the Average Standard Error (ASE) should be close one another and the Root Mean Squared

Standardized Error (RMSSE) should be close to one. The results (Figure 2) showed the model made a moderate prediction because the blue line and the 1:1 line are not close but a little apart, the model was underestimating the variability since the RMSSE was greater than one even though the ME (-0.0071) was close to zero and the RMSPE (0.3980) and ASE (0.3311) was close to each other.

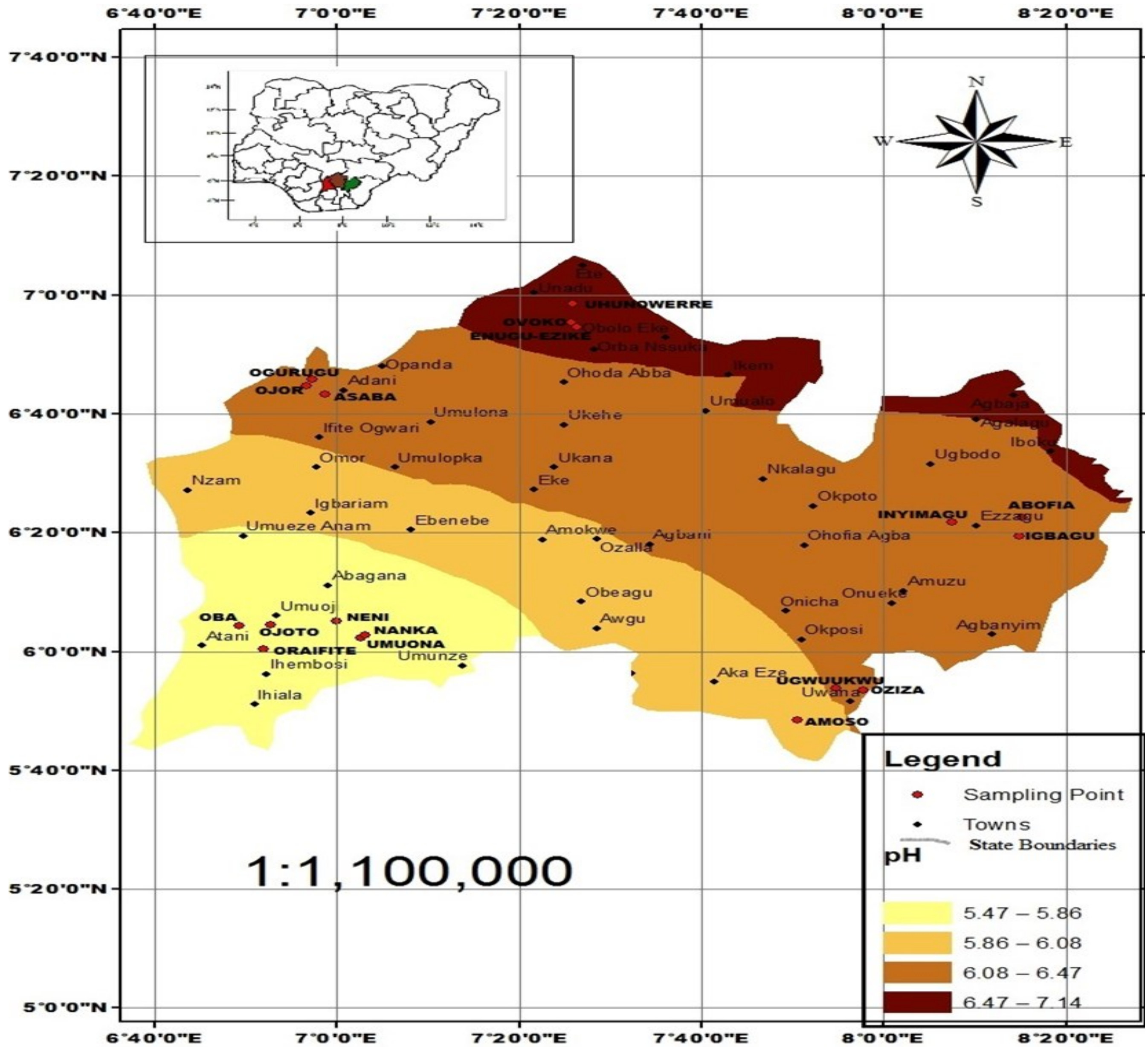


Figure 3: Kriged Map of the Study Area

3.4 Kriged Map.

The Kriged map are presented in Figure 3. The pH of the study area followed an observable pattern with the soils of Atani, Oba, Nanka and Ihiala in southern part Anambra having the lowest pH. This could be as a result of the higher amounts of rainfall in the study area and the associated increase in leaching out of the basic resulting to the dominance of acidic cations on the exchange complex of the soils. Soils in the northern part of Enugu and Ebonyi State having the highest pH could also be attributed to the reduced rainfall observe in such area. The soils of Nzam, Igbariam, Amokwe, Awgu, Akaeze and Amoso had pH between 5.86-6.08 while the soils from Ifete Ogwari to Opanda in Enugu State down to Uwana and up to Agalagu in Ebonyi State had pH 6.08 to 6.47. The variability in the degree of leaching and the dominant clay mineralogy must have contributed in the variation of pH.

4.0 Conclusion

The use of Geographical Information System was effectively applied in the study of soils of Southeastern Nigeria. There was high spatial variability in the pH of the soil analysed at different geographical scales however, the soil analysed showed moderate spatial dependency for pH. The Gaussian model was the best fitted model for the semivariogram presenting a semivariance with lowest nugget and highest spatial autocorrelation. The result of the cross validation showed that the models made moderate prediction for the soil pH. Generally, the soils of Anambra had lower pH level than soils of Enugu and Ebonyi States. The results of the coefficient of variation generally revealed that pH showed low variation down the profile in all the soils studied. This study revealed that there is great spatial heterogeneity in the soil. Soil pH followed an observable pattern across this geographical region and GIS is a very good technique that can portray such information in a way that it can be understood by everyone.

References

Ahukaemere, C.M., Onweremadu, E.U. Ndukwu, B.N and Nkwopara, U.N., 2016. Properties of Soils of Contrasting Lithosequences in South-Eastern Nigeria. *Futo Journal Series* 2(1): 48 – 56.

Brady, N.C and Weil, R.R., 2002. The Nature and Properties of Soils.13th Edition. *Pearsons Education Inc.* Prentice Hall, New Delhi, India.

Cambardella, C.A., Moorman, T.B., Novak, J.M.; Parkin, T.B., Karlem, D.L., Turco, R.F., Konopka, A.E. 1994. Field scale variability of soil properties in central Iowa soil. *Soil Science Society of American Journal.*, 58: 1501–1511.

Egede, E., 2013. Threats and Mitigation of Soil Erosion and Land Degradation in Southeast Nigeria. *Journal of Environment and Earth Science* 3(13): 95-102.

ESRI, 2020. ArcGIS Resources, Retrieved from https://desktop.arcgis.com/en/arcmap/latest /extensions / geostatistical-analyst/performing-cross-validation-and-validation.

Hendershot, W.H, Lalende H. and Duquette M. 1993. Soil reaction and exchangeable acidity in sampling and methods of Soil Science, *Lewis productions*, London. pp 142-145.

Kent, A. J. and Vujakovic, P. 2020. The Routledge Handbook of Mapping and Cartography. *Abingdon Routledge.* ISBN 9780367581046.

Landon, J.R. 1991. Booker Tropical Soil Manual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and sub Tropics. *Longman Scientific & Technical Publ*., Harlon.

Maliene V, Grigonis V, Palevičius V, and Griffiths S. 2011. Geographic information system: Old principles with new capabilities. *Urban Design International*. 16 (1): 1–6. doi:10.1057/udi.2010.25. S2CID 110827951.

Nielsen D.R, and Wendroth O. 2003. Spatial and temporal statistics—sampling field soils and their vegetation. Catena Verlag GMBH, Reiskirchen

Nottidge D. O., Balogun R. B., and Njoku N. R. 2009. Effect of Rice-Husk Ash on Exchange Acidity, Growth and Yield of Groundnut (Arachis Hypogaea L.) in an Acid Ultisol. *Global Journal of Agricultural Sciences.* 8(1): 1 – 6.

Obalum S.E. and Chibuike G.U. 2017. Air-drying Effect on Soil Reaction and Phosphorus Extractability from Upland-lowland Soils as Related to their Colloidal Stability. *Applied Ecology and Environmental Research,* 15 (1): 525-540.

Onweremadu E. U., Osuji G. E., Eshett E. T., Opara C. C and Ibeawuchi, I. I. 2007. Characterization of Soil Properties of Owner Managed Farms of Abia and Imo States, for Sustainable Crop Production in Southeastern Nigeria. *Journal of American Science.* 3(1): 28 – 37.

Onweremadu E. U. 2022. Sustainable Soil Management Practices for Problematic Soils of Southeast, Nigeria. In-training Manual on Good Agricultural Practices (GAP), Sustainable Soil Management Practices for Problematic Acidic Soils and Use of Soil Test Kit Boxes for farmers, Extension Agents and Agricultural Officers. NISS, Southeast Zone, UNN. pp 53-63.

Ripendra A., Mohammad S., Farhat A., Samira F., Sanjit K. D., Amjad A. and Ali F. 2019. Soil Physical Properties Spatial Variability under Long-Term No-Tillage Corn. *Agronomy*, 9(750): 1 – 17. https://doi.org/10.3390/agronomy9110750

Skye A.W., 2005. The spatial distribution of soil properties and prediction of soil organic carbon in Hayden Prairie and an adjacent agricultural field. A dissertation submitted to the Graduate Faculty in partial fulfilment of the requirements for the degree of Doctor of Philosophy, Iowa State University, Iowa. *Unpublished.*

Wang, S., Zhuang, Q., Jia, S., Jin, X., and Wang, Q. 2018. Spatial Variations of Soil Organic Carbon Stocks in a Coastal Hilly Area of China. *Geoderma*, 314: 8–19.

Webster R, Oliver M.A., 2007. Geostatistics for environmental scientists, 2nd Ed. *John Wiley & Sons Inc*. Chichester, England.