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Soil pH and Electrical Conductivity: A Case Study of Damaturu, Northeast Nigeria.

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Abstract – The problem of environmental impacts due to soil amendments as a result of climate change, mineral content and soil texture among other factors cannot be overemphasized. The aim of this research work is to determine the spatial variations of the soil pH and electrical conductivity of stations within the study area. The method used in sample collection is the surface scraping and digging to a depth of about 20 cm where each location coordinates is taken using a Global Positioning System (GPS). The samples are stored in labelled plastic containers and taken for laboratory ex-situ measurements. A pH and electrical conductivity meter method is used in the measurement of our parameters. The range for the spatial dependence for both soil pH and EC was found to vary from 3.50 to 7.20 and 37.00 to 315.00 µS/cm respectively. Whereas the nugget, sill and range from the semi-variogram parameters were 0.00342, 0.02344, 0.0960 and 1708.00, 3691.00, 0.2160 for pH and EC respectively. The soil pH result is found to vary from strongly acidic < 5.0 to neutral > 6.5 and the spatial variations of conductivity runs from north to south with low conductivity whereas in the west and eastern zones exhibit high conductivity. This makes soil pH and conductivity a good tool for precision agriculture.

Index Terms – soil pH, electrical conductivity, ex-situ measurements, and spatial variations

1 INTRODUCTION

Soil is considered in different perspective depending on who is interested in using it being it a soil scientist, agriculturist, geologist or an engineer. Land soils are normally considered as the fine earth which covers surfaces as a result of in-situ weathering of rock materials or accumulation of mineral matter transported by water, wind or ice [1]. To the agriculturist it is a substance that plants grow on and obtain their nutrients, water and support. The problem of soil acidity or alkalinity and electrical conductivity (EC) has a lot of effects to the agriculturist as regards his plants healthy growth and crop productivity. This if identified and corrected can improve the productivity of agricultural lands. The pH of a soil is a measure of the active acidity, that portion of hydrogen ions that is active in soil solution where the negative logarithm of hydrogen concentration is used as an indicator and is measured in pH units [2], [3]. Salinity usually refers to the presence of soluble salt in the soil and pH may probably affect the solubility of salts [4]. The EC is a measurement of dissolved materials in aqueous solution which relates to the ability of the material to conduct electrical current through it [2], [5]. The aim of this study is to characterize the soil in the study area in terms of the spatial variations of the soil pH and EC.

Other research works have been done on pH and EC among which is the work of Marosz [6] on soil pH, electrical conductivity values and roadside leaf sodium concentration at three sites in central Poland. Bruckner [5] carried out water and soil characterization using pH and electrical conductivity. Also, [7] carried out the spatial variability of soil properties in the Jammu district of Jammu and Kashmir. Other works on the spatial variability of soil properties are the works [8], [9], [10], [11], [12] [13]. Among these studies none did characterized soil in terms of the spatial variations in pH and electrical conductivity of Damaturu as such we found it necessary to carry it out.

Soil pH measurement has been used as a predicator of various chemical activities within the soil, useful tool in making management decisions on the type of plants suitable location and a rough indicator of plant availability of nutrients in the soil [2]. On the other hand the EC is used in the measurement of properties that correlates with it such as soil texture, cation exchange capacity, drainage conditions, organic matter level, and salinity and subsoil characteristics [14]. EC is used to provide indirect composite measure of variables that influence soil quality [15] and is also used to map out the spatial variability of soil within a production field [16]. Also, EC has been described as one of the simplest, least expensive soil measurement available to precision farmers, where a detailed information about the spatial characteristics of their farming operations can be collected in addition to field attribute maps [15].

2 MATERIALS AND METHDS

2.1 The Study Area

The area is located between latitude 11°40'N to 11°48'N and longitudes 11°54'E to 12°01'E. It has an area of 2,366 km2 [17] and a population of is 100,995 according to 2006 census [18] and falls within the Sahel Savannah with sparse grass-cover [19], [18]. The area exhibits a tropical dry season condition [20]. The hottest months are March, April and May with temperatures varying from 39° to 42° [21]. Annual rainfall ranges from between 500 mm to 1000 mm and the rainy season starts normally from June to September [22]. The main source of water supply is groundwater wells within taps in residence (10 – 15%), free public taps (20 – 25%) and private taps requiring payment (60 – 70%) [23]. In most villages of Damaturu there is no public water supply system and water is obtained from private vendors and nearby streams. The crops grown during raining season include maize, corn, rice, millet, beans and cassava among others while wheat, rice, pepper, vegetables and fruits are their irrigated crops [24]. The soil types of Damaturu are clay, gumbo, shale with minor proportions of sand and gravel [20], [25].

2.2 Sample Collection

The surface of the earth was removed using a backhoe and also digging a hole to an average depth of 20 cm with a spade, the samples were collected by scrape-slide vertically and horizontally for each point station using simple random sampling. A Global Positioning System (GPS) was used to take the location latitude and longitude for each point location where the soil sample was collected. The samples were then stored in plastic containers with labels for the 160 stations in preparation for ex-situ laboratory measurements.

2.3 Measurement Procedure

The collected soil samples were air-dried and passed through a 2 mm sieve. Each sample of soil was weighed 5 g and transferred into a beaker and 25 ml of distilled water was added. The solution was stirred well for about 5 – 10 minutes and was allowed to settle. The portion of the solution was separated by the use of filter paper after decantation. The filtrate was taken to another beaker where the probes of the pH and conductivity meter were inserted into the filtered solution for each sample and the pH and electrical conductivity (EC) was read from the pH meter and solubridge respectively.

2.4 Spatial Statistics and Mapping

Descriptive statistics was first used to determine the classical parameters before the application of geostatistics. Geostitistics has been described as a powerful tool for characterizing soil spatial variability [26]. The spatial variability of the soil pH and EC was investigated using geostatistics. According to Kavianpoor et al. [11] geostatistical data have abnormal distribution that may lead to high fluctuations in variograms and reduces the reliability of analytical results, hence normalization is necessary. The normalization was done based on the skewness of -1 to +1 range which is considered for normally distributed data [27]. The experimental variograms were determined from the spatial data according to the equation [9]:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x) - Z(x_i + h)]^2 \quad [1]$$

where Z is regionalized variables Z(x) and Z(xi+h) are measured sample values at xi and xi+h points N is the number of pairs separated with distances h (lag space). The spatial dependence for both pH and EC were calculated using semi-variance analysis to estimate the nugget, sill and range. The pH data was normally distributed, but EC data was log normal.

The semi-variogram for pH was best fitted using the exponential model while the EC data was best fitted using the spherical model. The digitization and generation process for maps was carried out with GS+ V10 software (Gamma Design Software) following ordinary kriging.

3 RESULTS AND DISCUSSION

The soil pH result was found to vary from strongly acidic <5.0 to neutral >6.5 and the variation of soil pH across Damaturu ranges from 3.50 low to 7.20 high with 5.24 as the mean value (Table 1). The sample variance was found to be 0.56 with a skewness close to normal. The parameters

Table 1. Descriptive Statistics of pH and EC for Damaturu, north east Nigeria.

Parameter EC(µS/cm)	pH	EC(µS/cm)
Minimum value	3.50	37.00
Maximum value	7.20	315.00
Mean	5.244	126.465
Standard Deviation	0.752	58.524
Sample Variance	0.56501	3425.11114
Skewness	-0.34(0.19)	1.15(0.19)
Kurtosis	-0.42(0.38)	0.94(0.38)

Log normal skewness and kurtosis for both pH and EC

obtained from the variogram for pH by correlation using the Gaussian model (Figure 1) for both nugget and sill were 0.00342 and 0.02344 (Table 2) respectively. Their proportion indicated 0.854 (85.4%) representing high spatial variability. The spatial dependence range was found to be 462.5 m. The range is an indicator of the different environmental factors [28]. The spatial variation map (Figure 2) has revealed that the soil pH distribution in the northern part of the study area had a pH >5.0 nearly neutral to alkaline.

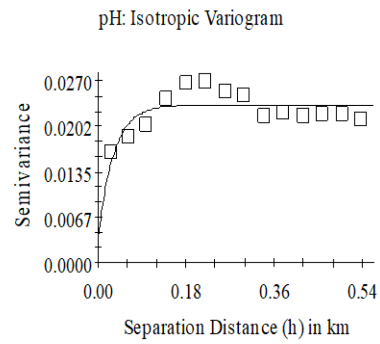

Figure 1. Semi-viogram of soil pH in Damaturu (h in km; **model: exponential)**

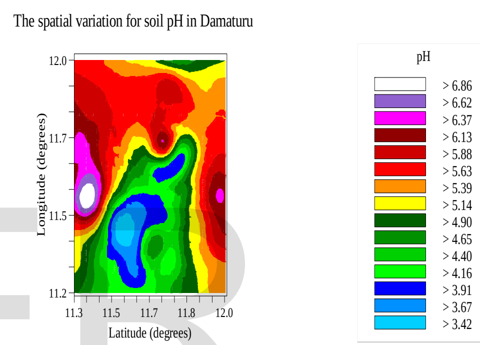

Figure 2. The spatial variation map for soil pH in Damaturu, north east Nigeria.

Table 2. Semi-variogram parameters for pH and EC in Damaturu, north east Nigeria.

Parameter EC(µS/cm)	pH	EC(µS/cm)
Nugget	0.00342	1708.0000
Sill	0.02344	3691.0000
Proportion	0.85400	0.5370
Percent	85.4%	53.7%
Range (km)	0.0960	0.2160
Model	Exponential	Spherical
RSS	5.536E-05	2311732
R2	0.5120	0.6660

The north eastern and north western parts of the study area have pH < 5.0 and are acidic which may be as a result of high hydroxyl content in soil.

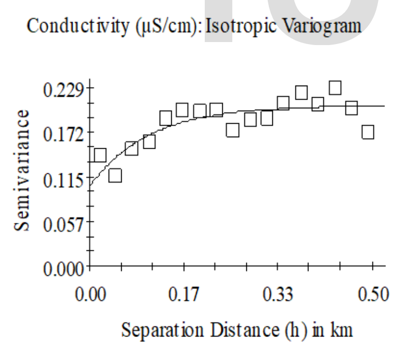

Figure 3. Semi-variogram of soil EC in Damaturu (in km; **model: spherical**)

The range for electrical conductivity (EC) is from 37.00 µS/cm to 315.00 µS/cm and 126.47 µS/cm is the mean value (Table 1). The variability of the EC was high with a sample variance of 3425.11 we obtained the nugget and sill parameters from constructing a variogram (Figure 2) and its subsequent normalization and kriging process. According to Robinson and Mettemicht [29] for a positive skewness of more than 0.5, the data require transformation to reduce the skewness. The skewness of the log transformed data was 0.19 for the variogram analysis carried out (Figure 3). The variogram derived values for nugget and sill were found to be 1708.00 and 3691.00 respectively. The range obtained from for the spatial dependence was 0.216 km and the proportion of the nugget and sill had an average spatial variability of 0.537 (53.7%). The EC map (Figure 4) presents the spatial variability of different parts of the study area showing that the high EC materials from the central part to the south eastern part which may be attributed to saline deposit materials.

The geostatistical parameters like nugget, sill and range for pH and EC differ largely (Table 2) indicating a different variability among them. This shows a non-relationship between pH and EC i.e. there is no correlation between pH and EC [30]. Other research works [31], [32] have also observed non-significant relationship between pH and EC.

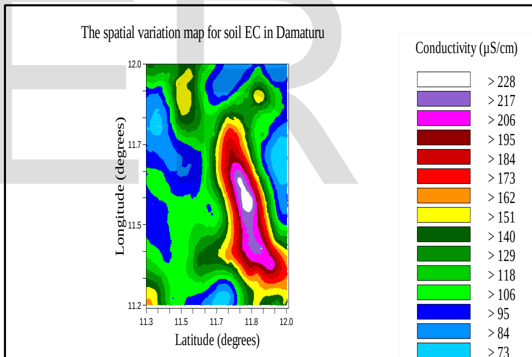

Figure 4. The spatial variation map for soil EC in Damaturu, north east Nigeria

4 CONCLUSION

The result obtained does not reveal any significant correlation between pH and EC. This means an acidic environment does not necessarily implies the presence of hydroxyl ion content. A saline environment could be acidic but is not in any way indicating the presence of hydrogen ions. The range for the spatial dependence for both soil pH and EC was found to vary from 3.50 to 7.20 and 37.00 to 315.00 µS/cm respectively. Whereas the nugget, sill and range from the semi-variogram parameters were 0.00342, 0.02344, 0.0960 and 1708.00, 3691.00, 0.2160 for pH and EC respectively. The soil pH result is found to vary from strongly acidic < 5.0 to neutral > 6.5 and the spatial variations of conductivity runs from north to south with low conductivity whereas in the west and eastern zones exhibit high conductivity.

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