International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

Geospatial Analysis of Some Soil Chemical Properties at White Nile Sugar Scheme, Sudan

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***Abstract*— *Agriculture is the backbone of the Sudan's economy. Sudanese agriculture ranges from traditional rain-fed to irrigated one. Sudan experiences sugar production from cane since decades. White Nile Sugar Company, as the most recent sugar company in the Sudan, was used to be the study area. Soil management is a key step for sustainable and feasible use of land for agricultural activity. Soil chemical properties are governing factor in determination of suitability of soil for different crops. Digital soil mapping is widely used in corporation with conventional methods to enhance the productivity and efficiency of production inputs. Geostatistical techniques for soil properties mapping is an important tool for land evaluation, assessment and management. This research aims to study the spatial distribution of some soil parameters in order to improve the management system in the scheme. Chemical and Physical Properties Data from White Nile Sugar Company (2006) executed by Land and Water Research Centre, Wad Medani were used. The total number of collected soil samples were 5174 samples representing 2567 Auger sites at 0- 30cm in depth.2470 soil auger data were used in interpolation. The data was introduced into GIS environment from excel format to one shape file. Five layers were produced to represent the spatial distribution of pH, EC, Ca++, Mg++, Na+ and SAR. [1]*

The soil of scheme is generally slightly heterogeneous. It is medium alkaline, non-saline, non-sodic with some scatter pockets of salinity and sodicity. The southern part of the scheme is affected by salinity and sodicity. This study concluded that geostatistical tools improve high efficiency in mapping the spatial distribution of soil traits. Therefore, this study recommends application of geostatistical tools in zonal-based management practices for better productivity

***Keywords*— *Soil Spatial distribution, Geostatistics, Sudan, Sugarcane.*

I. Introduction

Soil is crucial ecosystem for life; it is the essential growing medium and habitat for billions of organisms, contributing to biodiversity (FAO, 2015). Soil is the basis of agro- ecosystems that provides food, fiber and fuel (FAO, 2015). Spatial distribution of soil properties is essential step towards proper sustainable planning and management of land for suitable land use to reduce negative environmental impacts and to maximize profitability. Soil mapping is traditionally done by soil surveyors who well know the area, spend much time in the field, take augers at regular intervals, and in this way draw a field soil map that is later digitized and printed (Soil Science Division Staff. 2017). Traditional mapping is a time consuming, labor intensive and less detailed display.

The International working group on digital soil mapping (WG-DSM, 2016) defines digital soil mapping as "the creation and the population of a geographically referenced soil databases generated at a given resolution by using field and laboratory observation methods coupled with environmental data through quantitative relationships. Digital soil mapping improves accuracy and remove outliers (WG-DSM, 2016). Furthermore the need for reducing sampling densities on the field and land scale (WG-DSM, 2016) Moreover to investigate the possibilities of deriving soil maps in digital form using geostatistics (USDA, 2021). These will serve the relevant application in: understanding the spatial structure and distribution of soil properties, minimizing fertilization, avoiding soil degradation, precision farming and crop management, sustainable development and to support decision makers with such information for future planning. Geostatistics offers an alternative approach where spatial correlation (or autocorrelation) of variables can be quantified through variogram analysis (Webster and Oliver, 2001; Neilson, 2008, Olea, 2009) and subsequent accurate mapping.

Precise agriculture as site-specific soil management is promising approach to increase the productivity of existing arable lands while minimizing the over utilization of natural resources (Mulla and Schepers, 1997). Traditional soil management does not account for the natural field scale soil variability and considers agricultural fields in a particular area as more homogenous units (Vitharana, 2008). This applies to White Nile Sugar (WNSC) farms where the management practices considered the field areas as homogenous units (the soil variability within the different fields). This study aimed to map some soil chemical properties showing its geographic distribution in the study area as starting step for better management.

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II. Materials and Methods

The study was carried out in White Nile State, which is located in the east side of the Khartoum-Rabak highway extending from K 120 to K 180, subtended by latitudes 14º20' N, and 13º45'N and longitudes 32º15'E and 32º40'E, covering a total area of 154,920 feds (65066.4 ha), as shown in Figure (1).

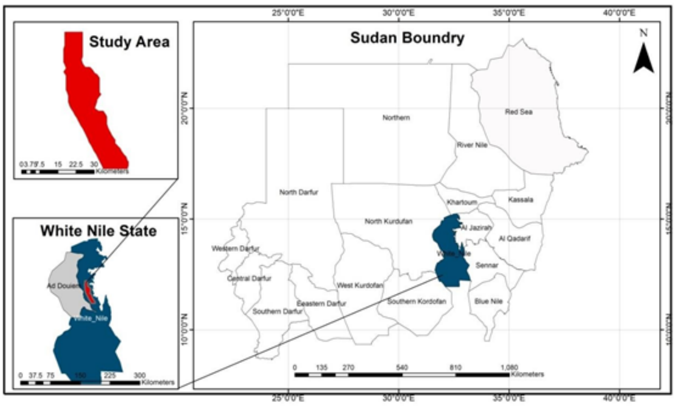

Figure 1: The Location Map of the Study Area

Georeferenced soil chemical properties of White Nile Sugar Company were used in this study. The ancillary data was produced by Land and Water Research Centre, Wad Medani in 2006. The total numbers of collected soil samples were 5174 samples representing 2567 Auger sites at 0-30cm in depth. 2470 soil auger samples were used in interpolation. The analyzed soil parameters include Sodium Adsorption Ratio (SAR), soil reaction (pH), calcium and magnesium (Ca-Mg), sodium (Na) and electrical conductivity (EC) and determined according to standard methods described by Richard (1954) and Page et al. (1982). ArcGIS version 10.2 and SPSS17.0 Software was used in spatial analysis. Table manipulation function was used in the process of data analysis to select by attribute layers having extreme values in order to exclude extreme values (outliers).Data management tool was applied to drop unnecessary fields. Geostatistical Analyst Kriging method (Ordinary) was conducted for soil parameters using 75% of the total dataset for model while 25% for the validation of the model using a log transformation type, first order of trend removal, exponential kernel function, staple for the model type, a lag size of 500m, 0 degree for the search angle, 4 sectors with offset 45^0 for the sector type and a 12 number of lags. Reclassify tool of spatial Analyst was performed for soil parameters in order to classify the study area based on the standard limits (values) used in the description of the individual mapping units according to US classification standards (Richard, 1954).

III. Results and Discussions

The result indicated that pH ranges from 6.6-9.0. Medium Alkaline condition (MA) dominated all over the study area (Figure 2 & 3). Very alkaline (VA) areas formed scatter pockets throughout the scheme. This can be attributed to the geological formation of the study which is basic rocks.

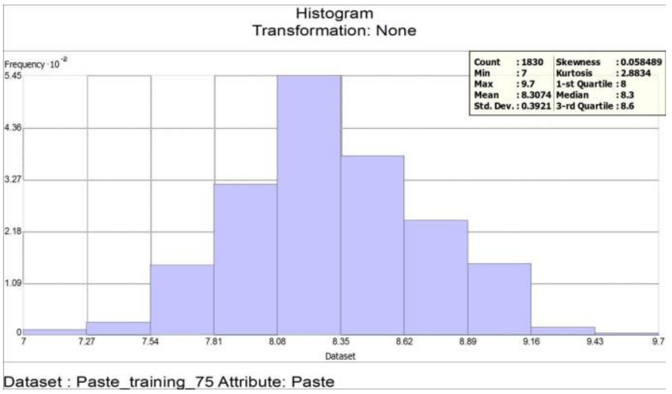

Figure 2: Soil pH Distribution

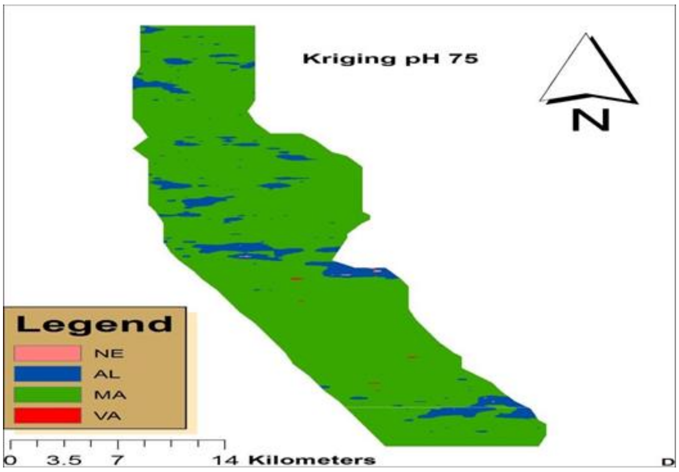

Figure 3: Soil pH Spatial Distribution

Sodium Adsorption Ratio (SAR) values ranged from 10 - 25 (Figures 4 & 5). The study area was generally slightly sodic (LS), while sodic (S) soils covered the south part; however moderately sodic (MS) and sodic soils distributed as scatter pockets throughout the study area. This might be due to natural variation as result of soil forming factors.

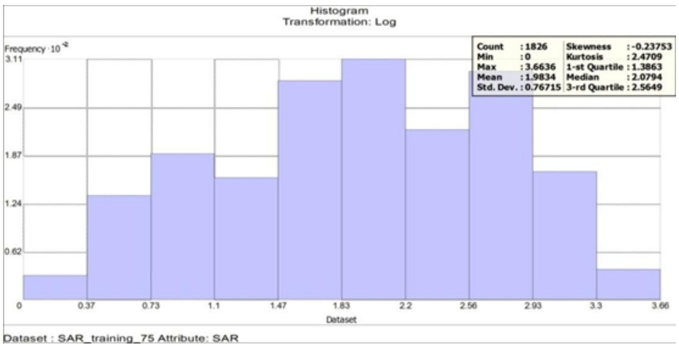

Figure 4: Soil SAR Distribution

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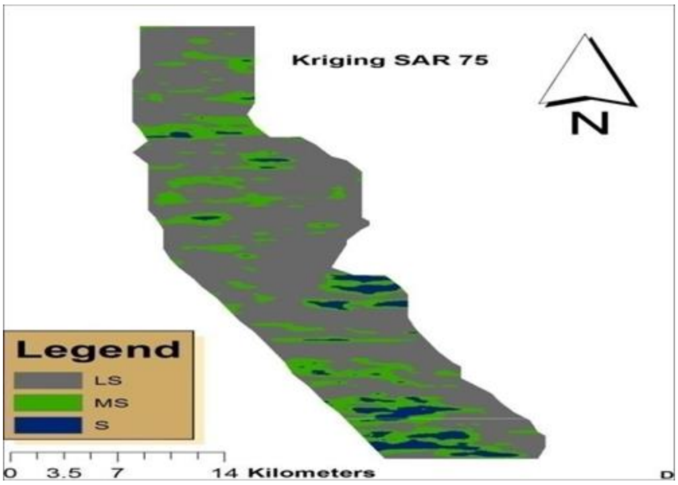

Figure 5: Soil SAR Spatial Distribution

Soil salinity as indicated by electrical conductivity (ECe) ranged between 4 – 12 dS/m (Figure 6). Generally, the study area was non-saline (NS) while there were a scattered pockets of slight salinity (GS) and medium salinity (MS) at the north part of the study area as well as at the south west part (Figure 7). This might be attributed to the presence of relatively low lying areas (depressions) at which salt carried by water could accumulate.

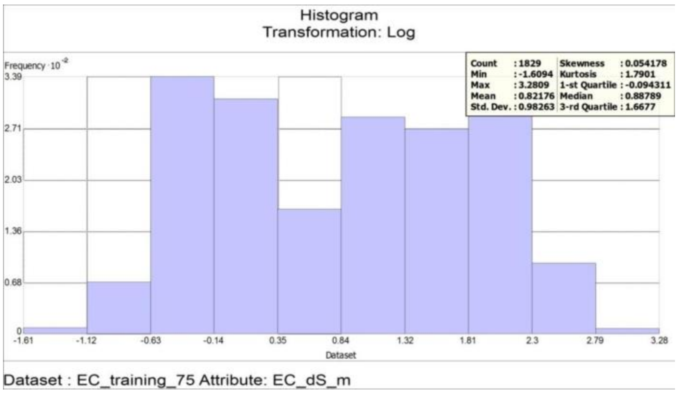

Figure 6: ECE Distribution

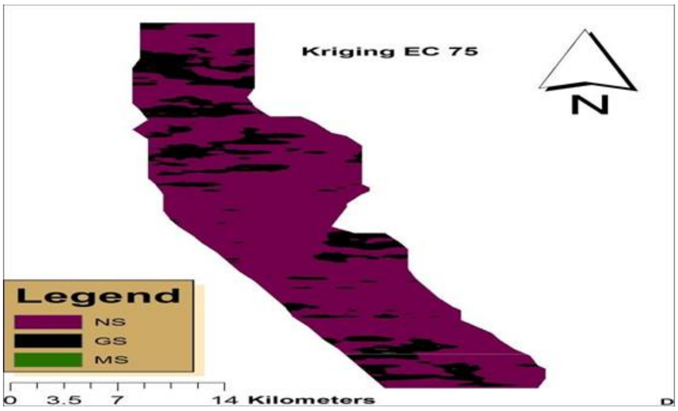

Figure 7: Soil ECe Spatial Distribution.

Calcium plus magnesium (Ca + Mg) concentration ranged from 1.41 – 28.2 meq/l (Figure 8). High values of Ca + Mg covered the northern part with scattered pockets at the south part while however medium concentration was evenly distributed throughout the study area (Figure 9).

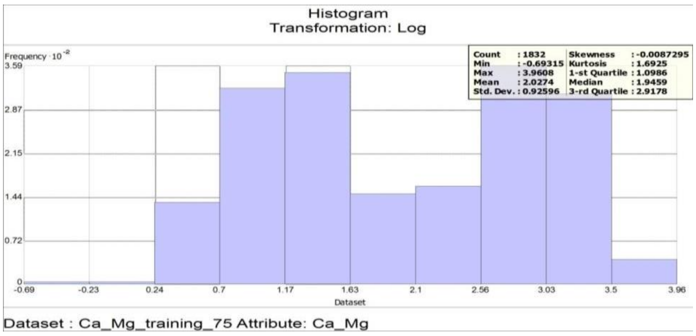

Figure 8: Soil CA+MG distribution.

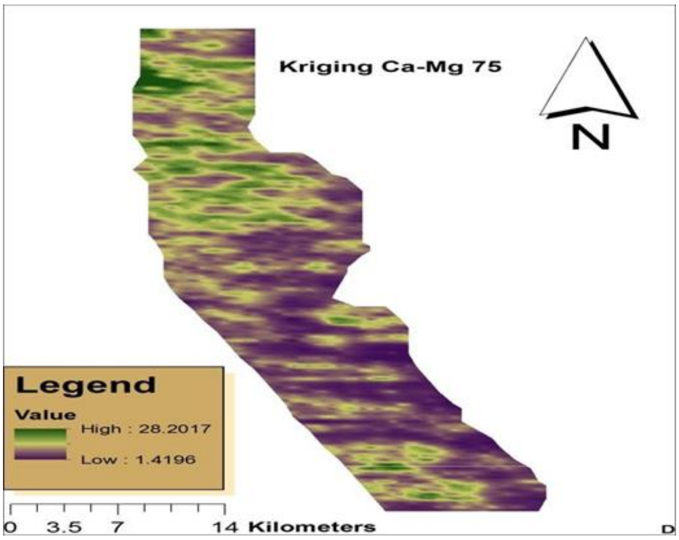

Figure 9: Soil Ca & Mg Spatial Distribution.

Soil Na concentration ranged from 1.7 – 63.8 meq/l (9) as showed Figure (10). The study area was characterized by low to medium values of Na cation, however, high concentration of Na were recognized at the south west part of the study area (Figure 11). Very high concentration of Na cation was mapped as scatter pockets that distributed eventually in the study area.

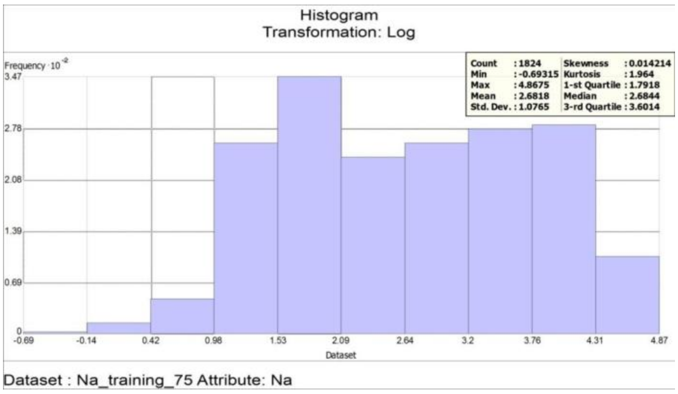

Figure 10: Soil Na Distribution.

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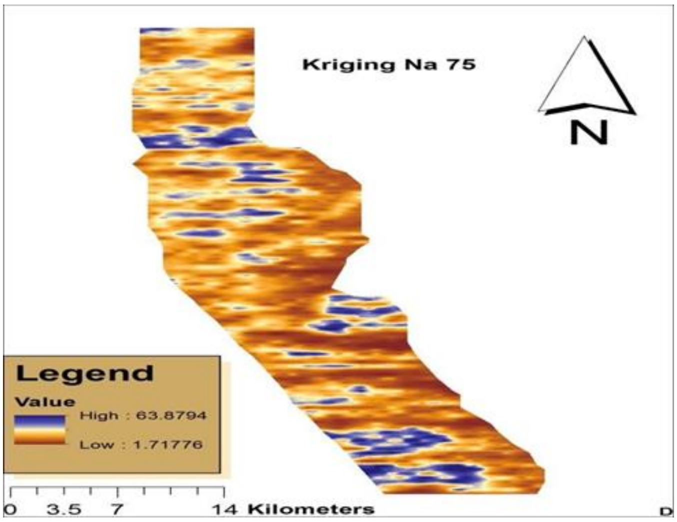

Figure 11: Soil Na Spatial Distribution.

IV. Conclusion and Recommendation

Soil spatial analysis indicated that the study area is mostly medium alkaline, slightly sodic, non-saline with some anomalies pocket scatters in the scheme. Soil content from calcium plus magnesium cations (Ca - Mg) are medium and evenly spatially distributed throughout the scheme. Soil Na cation concentrations is low to medium values with even spatial distribution.

The southern part of the scheme is affected by salinity and sodicity, high pH and high concentration of soil cations (Ca, Mg, and Na) due to the dominance of low lying areas.

Based on these findings, this study recommends the followings:

- Geostatistics methods are efficient in soil mapping and should be incorporated in management of this scheme to improve conservation and productivity of the land.
- Zone based soil management practices should be adopted since the areas is relatively heterogeneous, this include practices related with inputs addition and land preparation. Special management practices should be applied for the south part mainly to reclaim sodicity and salinity.

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