GEOPHYSICAL AND PERMEABILITY ASSESSMENT OF SOIL SPATIAL VARIABILITY OF COCOA RESEARCH FARM IBADAN, SOUTHWESTERN NIGERIA

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Abstract

Site specific management has been the recent trend in assessing agricultural soil quality to optimizing productivity. This research stemmed from variations observed in pods yield by cocoa trees at Cocoa Research Institute of Nigeria.

Soil conductivity (EC), volumetric water content (VWC), thermal properties and soil permeability were assessed at the root zone (0.3 m) to delineate soil's management areas within cocoa farm. Spatial evaluations were conducted during the wet and dry seasons. A total of twenty-seven lines were occupied consisting of 912 and 906 EC/VWC data points during wet and dry seasons respectively on a non-saline soil (<2000 μS/cm) using Allied resistivity earth meter (EC) and VG-meter-200 soil moisture meter (VWC). KD2PRO was used in evaluating the thermal regime during wet (90 data points) and dry (89 data points) seasons; and permeability test conducted on ten soil samples. EC_a map was generated using ARCGIS software classified the soil into zones of low, medium and high EC.

Variation in VWC is synonymous to EC distribution in soils. Strong correlation of 0.971 (wet season) and 0.806 (dry season) existed between EC and VWC. Regions of high EC/VWC were characterized by soils of low thermal diffusivity, high specific heat, high thermal conductivity and weak to moderate correlations were generated between these thermal properties and EC/VWC. Soil permeability (k) studies revealed that soils from high EC section have low permeability (0.000126 to 0.000431 cm/sec) suggesting slow/moderately slow/moderate infiltration rate classified to be silty sand/dirty sand while electrically less conductive soils were characterized with high permeability (0.000437-0.004109 cm/sec) indicating moderate to moderately rapid infiltration associated with nutrient leaching and water depletion, categorized as silty/dirty sand/sand/fine sand. These techniques mapped out zones of abundant pods yield to be sections of high EC/VWC, low k and vice versa.

Introduction

Site-specific management ensures that the rate of application of variable on an agricultural field is effectively managed such that uniform application of input is dissuaded in order to address potential yield-limiting factors within the farm zones (Fraisse et.al. 2001). Soil electrical conductivity has wide applications in agronomy and soil science (Ekwue and Batholomew 2011; Corwin and Lesch 2013). Electric properties of soil have yielded positive results in assessing spatial variation of soil materials due to relationship between these properties and soil make-up. The amount of water being held by soils depends on their texture and structure. Grisso et. al. (2009) suggested that areas lacking water have clear cut textural differences from those with abundant water which can be identified using EC, the degree of their conductivities tends to provide information on their water holding capacity.

Crops' productivity is dependent on soil moisture, temperature, soil texture, chemical properties, field holding capacity, nutrients (Lipiec et. al., 2013; Chen et. al. 2015; Dong et. al. 2016). Rise in soil's temperature tends to lower/decrease the viscosity of its water content, thereby increasing the mobility of the ions due to dissociation of molecules in it. Scherer et. al. (2013) reported that plants extract more water from upper section of the root zone and less water extraction from the lower part of the root zone.

This investigation was derived from observations made on cocoa plants at Cocoa Research Institute of Nigeria (CRIN), in which some of the cocoa trees planted at same season produced less pods as compared with other having higher number of pods. The cocoa farm lies between latitude 7.221090º and 7.222100ºN, and longitude 3.861127º and 3.861950ºE which is situated on migmatite gneiss complex.

Methodology

The apparent soil electrical conductivity (EC_a) was measured using allied geophysical earth resistivity meter, Wenner electrode array was applied at a constant intra-electrode spacing of 0.4 m (40 cm). Cocoa field was divided into 27 lines (N-S direction) and resistivity data were taken at 3 m interval with intra-line spacing 3 m. Digital VG-Meter-200 soil moisture meter was used in this study to sense the volumetric water content at every spot where resistivity measurements were taken. Thermal properties at the root zone were analyzed at 90 and 89 locations within the cocoa farm using KD2Pro during wet and dry seasons respectively. Thermal analyses were carried at the root zone, pits of 30 cm deep were dug and the sensor was carefully positioned in the soil at 30 cm depth and measurements were taken at every 12 m interval along a traverse having intra-line spacing of 9 m. Ten disturbed soil samples were collected at 0.3 m depth from regions of high, medium and low conductivity/VWC and the test was conducted using falling head permeameter produced by ELE International.

Results and Discussion

Electrical Conductivity and Volumetric Water Assessments

Twenty-seven profiles consisting of 912 and 906 data points were established at the cocoa field during wet and dry seasons respectively. Cocoa field EC_a data set showed moderate variability (60.97 %) during rainy period while high variation (64.11 %) occurred during the dry period. The variability of VWC recorded in the cocoa field was moderate but higher variation was observed in wet season (53.84 %) with respect to the dry period (33.40 %). The mean VWC was approximately 26 % in wet season while it was ~10 % at the peak of dry season; suggesting one-fourth and one-tenth of soil volume was filled with water respectively during wet and dry seasons. Correlation between VWC and EC_a (Figure 1) showed that as the VWC increases, ECa also rises linearly with it and coefficient of correlation (r) is 0.972 suggesting a strong correlation. Also relationship between volumetric water content and electrical conductivity in the dry season is linear, and a strong correlation existed between them with a coefficient of 0.807 (Figure 3). Electrical conductivity (EC_a) increases as the moisture content increases due to the fact that salt constituent (ions) extracted from soils increases with a rise in soil moisture content.

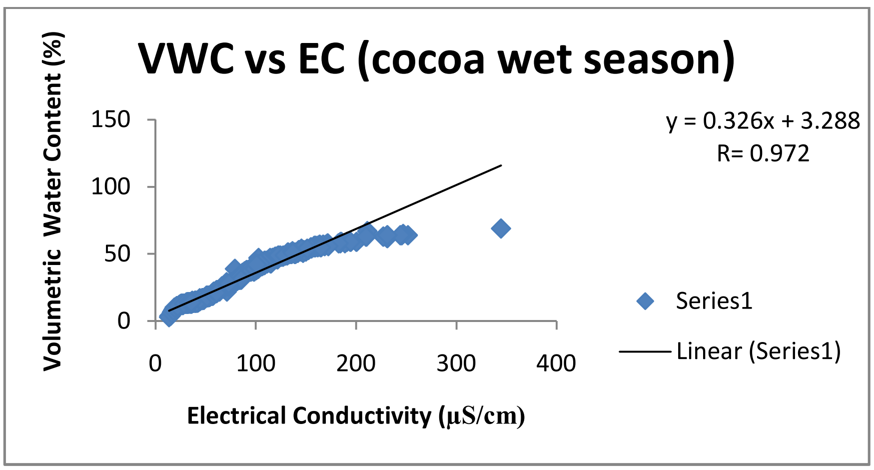

Figure 1: Variation of volumetric water content with electrical conductivity during wet season

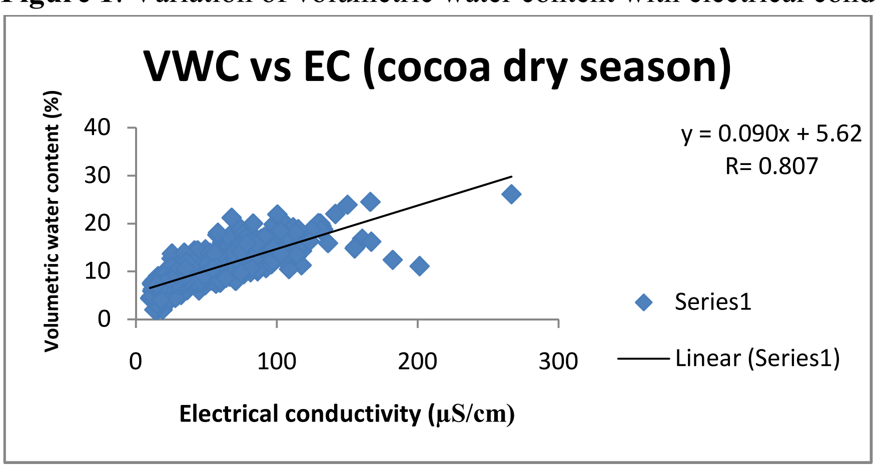

Figure 2: Variation of volumetric water content with electrical conductivity during dry season

Thermal Assessments

There is positive correlation between thermal conductivity and electrical conductivity in the wet

(0.210) and dry (0.286) seasons, that is, an increase in thermal conductivity also favours increase in electrical conductivity; thermal conductivity also increased linearly with the volumetric water content at both seasons (0.239-wet, 0.314-dry) and thermal diffusivity displayed an inverse relationship with the electrical conductivity and volumetric water content. Seasonal assessment of Volumetric heat capacity (VHC) with the ECa and VWC exhibited a positive correlation.

Permeability Studies

Soils with low permeability ranging from 0.000126 cm/sec to 0.000431 cm/sec were categorized to have slow/moderately slow/moderate infiltration. Permeability of 0.001202 cm/sec obtained from soil in medium class electrical conductivity is suggestive of moderate infiltration rate while soils (0.000437-0.004109 cm/sec) in electrically less conductive section were classified to range from moderate to moderately rapid infiltration. Negative correlations occurred between permeability (k) and EC & VWC in the wet and dry seasons; indicates that as permeability increases, the conductivity (Figure 3) and VWC decreased.

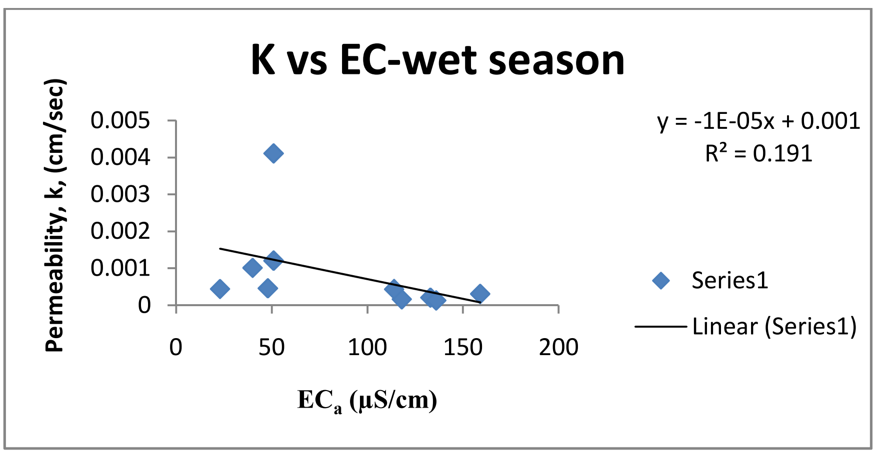

Figure 3: Plot of permeability versus electrical conductivity in the wet season.

Conclusions

Strong correlation existed between the scattered plot of VWC and EC_a indicating that ECa rises linearly with the VWC. The correlation analyses of thermal properties with electrical conductivity and volumetric water content indicated a weak to strong relationship. Thermal conductivity and volumetric heat capacity increase with soil moisture content/EC whereas thermal diffusivity reduces with an increase in soil moisture/EC, these properties aided in mapping out variations in soil moisture content. Areas of high thermal conductivity, high heat capacity and low diffusivity at cocoa field turned out to be regions of high pods yield. Permeability test conducted on soils within electrically high conductive section have low hydraulic conductivity whereas high permeability was noted on electrically low conductive soil. Leaching of soil nutrients due to low nutrient-retention capacity is peculiar with soil of low water-holding capacity and high permeability; and permeability varied inversely with the electrical conductivity and volumetric water content. Geophysical and permeability techniques are useful tools in assessing the variation in soil's nutrients in order to establish site specific management zones.

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