IN-SITU SOIL RESISTIVITY MEASUREMENTS AS INDICES FOR SELECTED TOPSOIL PROPERTIES, AND MAIZE YIELD PREDICTION IN A BASEMENT COMPLEX TERRAIN OF ADO-EKITI, SOUTHWESTERN NIGERIA

BY

Akinola Bolaji ELUWOLE

B.Tech. (Applied Geophysics) FUTA;
M.Sc. (Applied Geophysics) O.A.U, Ife.

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CERTIFICATION

This research work was executed by Mr. Akinola Bolaji ELUWOLE in the Department of Geology, Obafemi Awolowo University, Ile-Ife under my supervision. The thesis has been read and approved as meeting part of the requirements for the award of Doctor of Philosophy (Ph.D.) Degree in Applied Geophysics.

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Prof. M.O. Olorunfemi Date

(Supervisor)

DEDICATION

This research is dedicated to God Almighty who is the greatest author.

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ABSTRACT

In-situ soil resistivity measurements and soil properties determination at two depth levels (3 cm and 50 cm) and maize tendering and yield determination were carried out at a pilot plot located within the Ekiti State University, Ado-Ekiti. This was with a view to establishing relationships between *in-situ* soil resistivity, soil properties and maize yield in a typical Basement Complex environment.

Wenner array platform for measuring soil resistivity at two shallow depth levels of 3 cm and 50 cm, was designed through computer modeling and field trial. Electrode spacings of 8 cm (0.08 m) and 130 cm (1.3 m) were selected for resistivity measurements at the selected depth levels respectively. The pilot plot was partitioned into 81 cells each having a dimension of 2 m by 2 m. Soil resistivity measurements were made at 729 stations at grid interval of 1 m and at the two selected depth levels. Eighty-one soil samples were collected per depth level at the midpoint of each cell. Soil properties such as moisture content, texture and pH that affect maize yield were determined for each soil sample. Maize was planted at seven hundred and twenty-nine stations, tendered to maturity and harvested for yield determination. The relationships between *in-situ* electrical resistivity, soil properties and maize yield were determined through descriptive statistics, cross plots, cross tabulations and spatial pattern analyses.

The resistivity of the surface layer varied between 214 and 2090 ohm-m, while that of the deeper layer varied between 284 and 1485 ohm-m. The soils at both depth levels were classified in terms of resistivity as clayey sand and sandy soil. The sandy loam and loamy sand soil textural

classes were observed to be present in the surface layer and deeper layers. The moisture content of the surface layer varied between 4.11 and 12.6%, while that of the deeper layer were between 4.95 and 10.93%. Moisture content values were classified in terms of their relationships with soil texture as Plant Available Water (PAW) and Permanent Wilting Point (PWP). The pH of the surface layer ranged between 5.1 and 6.9 and the values were classified as moderately acidic, slightly acidic and neutral. The deeper layer pH values were found to be predominantly characteristic of the moderately acidic pH range. Maize yield ranged between 27 and 600 g/m and the total yield was 112.02 kg/m^2. Yield values were classified as low-to-average yield and high yield. The loamy sand textural class was found to be associated mainly with the low-to-average yield category, while the high yield category was characteristic of the sandy loam textural class. Areas with relatively high resistivity were characterized by the low-to-average yield category while the relatively low resistivity zones with high yield. The moisture content regimes at both depth levels had equal cumulative relationship with maize yield. The slightly acidic pH category was prone to high yield.

The study concluded that *in-situ* soil resistivity could be used as index for soil properties such as texture, moisture content and pH and hence could be used as a tool for maize yield characterization.

CHAPTER ONE

INTRODUCTION

1.1 Preamble

Sustainable agriculture whose goal is to balance crop productivity, profitability, natural resource utilization, sustainability of soil-plant-water environment and environmental impact has been considered the most viable means of meeting future food needs for the world's increasing population. The soil upon which crop management is primarily dependent is inherently variable in its physical, chemical, and biological properties that determine yield potential. This fact complicates the identification and implementation of sustainable management practices. While farmers seek to manage land at a smaller level of resolution to improve economic and ecological outcomes, precision agriculture is an approach through which sustainable agriculture can be achieved.

Precision agriculture involves site-specific crop management (or site-specific management, SSM) which utilizes rapidly evolving information and electronic technologies to modify the management of soils, pests and crops in a site-specific manner as condition within a field changes spatially and temporarily (Elsevier, 2005). SSM has the potential to maximize agricultural production and economic return while conserving soil and water resources and enhancing soil quality (Wallace, 1994). Crucial aspects of SSM are quantification of yield in small areas of the field; quantification of the spatial variability of soil properties influencing yield; adjustment of inputs such as fertilizers, pesticides and seeding rates based on knowledge of soil and yield variability (Atherton *et al*., 1999). According to Bullock and Bullock (2000) the within-field variations in soil physico-chemical properties should be measured accurately through efficient methods to make SSM a reality.

Geophysical methods have become an increasingly valuable tool in precision farming within a variety of agro-ecosystems in many developed countries, such as U.S.A, Canada, U.K., Russia, and many others. Several researchers among which are Jaynes *et al.* (1994), Fedetov and Pozdnyakov (2001), Johnson *et al.* (2001), Kravchenko (2002), Corwin *et al*. (2003) Serbin and Or (2004) and Allred (2011) have reported the successful applications of geophysical methods such as electrical resistivity (ER), self potential (SP), electromagnetic induction (EMI) and ground penetrating radar (GPR) to precision agriculture. The electrical resistivity and electromagnetic induction methods were reported to be relevant in determining in-situ soil electrical conductivity (EC) which is related to some soil properties such as moisture content, salinity, silt and clay contents, etc. The self potential method has been discovered to be relevant in plant growth and health monitoring; based on the influence of soil electrical potentials on plants. The application of geophysical methods in precision agriculture has assisted farmers to make informed decisions on "what to plant where, and when to plant what" on their farmlands (Kravchenko, 2002; Corwin *et al.*, 2003; Landviser, 2004; Corwin and Lesch, 2005). Crop yield estimation from geophysical data has also assisted in determining the economic viability of crops (Johnson *et al.,* 2001; Kravchenko, 2002; Corwin *et al.*, 2003; Pozdnyakova *et al.,* 2004; Corwin and Lesch, 2005 and Gish *et al.*, 2005).

The geospatial measurement of apparent soil electrical conductivity (EC_a) is one of the ground-based sensing technologies that is helping to bring SSM from a concept to a reality. In the 1970s, applications of EC_a measurements in agriculture were primarily for the measurement of salinity, but in recent times other soil properties and productivity have been determined indirectly via EC_a measurements (Jaynes, 1996). The electrical conductivity of a soil is determined by a combination of soil water content, dissolved salt content, clay content and mineralogy, and soil temperature (McNeill, 1980). In many fields, a single property (e.g. salinity) is the primary factor controlling soil electrical conductivity. Thus, once the correlation between electrical conductivity and this property is established, an EC_a survey can be used to map this soil attribute quickly and cheaply. EC_a measurements have been successfully used to measure soil water content (Kachanoski *et al*., 1988), clay content (Williams and Hoey, 1987); to determine cation exchange capacity (McBride *et al*., 1990), depth to clay pans (Doolittle *et al*., 1994), field-scale leaching rates of solutes and yield (Jaynes *et al*., 1995).

Natural disasters such as flooding, erosion and drought; man-induced disasters such as oil spills, indiscriminate deforestation and chemical pollution on land; and urbanization have greatly reduced the availability and quality of land required for agricultural purposes in Nigeria. These occasioned shortage of supply of many agricultural products. In order to make judicious use of the available farmland to ensure sustainable supplies of agricultural products, precision agriculture technology will need to be embraced.

Given the utility of EC_a as a surrogate for many important soil properties, this plot-scale pilot research intends to establish the relationship(s) between in-situ soil apparent resistivity (inverse of EC_a) and inherent soil properties that potentially affect crop yield (e.g. maize) in a typical Precambrian Basement Complex area of Ado-Ekiti, southwestern Nigeria.

1.2 Statement of Research Problem

Previous works such as Gish *et al*. (2005); Pozdnyakov *et al*. (2005); Eigenberg *et al.* (2006); Johnson *et al.* (2008); Wienhold and Doran (2008) have shown that soil electrical properties which can be determined by geophysical investigation are related to several soil properties essential for its fertility, plant growth and productivity. These properties include, soil salinity, bulk density, moisture content, surface soil thickness, gravel layers or lenses, sand, silt and clay contents, soil drainage, total soil organic matter content, Nitrogen, Phosphorus and Potassium (NPK) contents, soil pH and cation exchange capacity.

Available previous works carried out in Ekiti State such as Ogunkunle (1988); Fasina (1997); Fasina (2003); Shittu and Fasina (2004); Fasina (2005); Fasina and Adeyanju (2007); Fasina *et al.* (2009); and Ogunkunle (2009), cited in Fasina (2013) all showed that the soils were mainly evaluated, characterised and classified into soil orders and soil series using the conventional pedological method of taking disturbed soil samples and analyzing the samples for soil