

**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.**

SCP12/13/H/1106

**A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D.) DEGREE IN APPLIED
GEOPHYSICS OF THE DEPARTMENT OF GEOLOGY, FACULTY OF
SCIENCE, OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.**

2016

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.

.....
Prof. M.O. Olorunfemi
(Supervisor)

.....
Date

DEDICATION

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

ACKNOWLEDGEMENTS

Worthy to be praised is God almighty, the giver of wisdom, knowledge and understanding, who guided this research from dream to reality.

I immensely appreciate my supervisor, Prof. M.O. Olorunfemi, for counting me worthy to pioneer the field of Agrogeophysics on Nigerian soil. His professional prowess and wealth of experience in science nourished this research to its present state. His keen attention and quick review of my manuscripts were legendary. The grace of God upon him will be perpetual.

The Department of Applied Geophysics of the Federal University of Technology, Akure gave me a good foundation in the field of Applied Geophysics. My sojourn in that Department may have been impossible without the assistance of Prof. M.O. Olorunfemi and Prof. J.S. Ojo, who both ensured my admission into the Department at the eleventh hour. By the grace of God, that gesture of assistance has brought me thus far. I sincerely acknowledge everyone who partook in the foundation laying, most especially my undergraduate thesis supervisor, Dr. G.M. Olayanju.

The members of staff of the Department of Geology, Obafemi Awolowo University, Ile-Ife among whom are Prof. M.A. Rahaman, Prof. S.B. Ojo, Prof. V.O. Olarewaju, Prof. J.O. Ajayi, Dr. S.A. Adekola, Dr. A.A. Adepelumi, Dr. D.E. Falebita, Dr. O. Afolabi, Dr. Tunde Olorunfemi, Dr. Adetunji, Dr. A.A. Oyawale, Mr B.M. Salami, Mr. T. Adesiyani and Mr. Ademola Aderoju encouraged me in no small measure by their display of love and sincere expectation of the success of this research.

Prof. A.O. Oyinloye, Dr. O.L. Ademilua and Dr. O.F. Adebayo are profoundly acknowledged for their administrative assistance during their tenures as Head of Department of Geology of the

Ekiti State University, Ado-Ekiti. The united support of all the members of staff of that Department is also very well appreciated.

Dr. O.L. Ademilua, Dr. J. Fatoba, Dr. O.J. Akintorinwa, Dr. O.G. Bayowa and Dr. F. Akinluyi who are my superiors and professional coaches continually encouraged me throughout the duration of this project. I pray for their progress.

This research affiliated me to several experts in the Field of Agricultural Sciences, prominent among them are, Prof. D.J. Oyedele and Prof. A.A. Amusan of the Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife; Prof. A.S. Fasina, Prof. F.A.S Dairo, Dr. O.J. Ayodele, Dr. S.O. Omotosho and Dr. J.O. Aruleba all of the Faculty of Agricultural Sciences, Ekiti State University, Ado-Ekiti. These erudite scholars assisted me with relevant materials and technical advice. Some of them even allowed me to attend their lectures. The crop and soil segments of this research are credited to their supports.

Mr. Adebayo Ojo and Mr. Lekan Afolagboye who are currently pursuing Ph.D. degrees in China, shared their privileges of unlimited access to scientific journals with me by their prompt transmission of relevant publications at my request.

In order to ensure an appropriate record of the unflinching assistance that I got from the individuals involved in different data acquisition stages of this research, I acknowledge their support by mentioning their names in this piece. They are, Dr. A.O. Talabi, Pastor J. Agbebi, Mr. M.K. Alofe, Late Mr. Ajayi, Egbebi Iyiola, Awosola Olusola, Ola Toluse, Ukanah Mary, Aribigbola Ebiyinka, Oladuji Olaoluwa, Oyebode Wemimo, Onyeulo Sunday, Bolarinwa Olalekan, Akinyose Olufemi, Taiwo Emmanuel, Olonilua Olalekan, Adeapin Samuel, Dayo Adediran, Ojo Foluke, Lawal Adebayo, Akanji Olatunji, Babalola Adeniyi, Ogundare

Oluwaseun, Ibigbami Alaba, Ololade Roqeeb, Afolayan Emmanuel, Ajibua Olawale, Oyenuga Adebowale, Dada Morakinyo, Timothy Olawumi, Olusola Iginla and Mr. P.S. Dada. Their endeavors will also be blessed.

I also acknowledge Dr. Sola Akinwumiju for his prompt real-time online GIS assistance any time, every time. Mr. Demola Oni and Mr. Jide Okunnubi dutifully assisted in the processing and monitoring of some of the administrative forms that were vital to my studentship in the Postgraduate College.

I will live to remember the hospitality and display of motherly love that I got from Mummy Olorunfemi during the period of this research. She always ensured that I munched while I learnt. God bless her among women.

The families of Pa Gabriel Eluwole, Pastor. F.I. Eluwole, Honourable Dipo Eluwole, Pastor. G.A.O Oyeyemi, Pastor Kayode Awoyele, Pastor Moses Afolabi, Pastor D. Omojuwa, the Alos, Arc. S.S. Omoniyi, Mr. Elumide Elujoba, Mr and Mrs Opeyemi Kolawole, Mr and Mrs Isaac Otitoju and Deaconess Y. Omotunde are appreciated for their prayers towards my success.

Worthy to be acknowledged is the peace of mind which culminated into the successful completion of this research that I got from my darling wife, Feyisetan Olorunyomi. This indeed is a foretaste of a future of more successful novel researches.

Words alone cannot accommodate my appreciation to my parents, Engr. and Deaconess O.S. Eluwole who gave all the necessary support towards the actualization of this dream. They nurtured and nourished me with the best parental care. God will make them enjoy the benefits of their love for me in good health.

My beautiful sister, Abimbola Eluwole always ensured adequate supply of pastries, snacks and nourishing fresh drinks while Akintayo Eluwole, my brother assisted in my chores throughout the duration of this research. I had no distraction whenever I had these wonderful siblings around me; my productivity was always at its peak. I love them immensely.

I am humble to admit my human inadequacy, so I apologise to anyone whose contribution is in anyway not mentioned in these acknowledgements.

A.B. ELUWOLE,

2016

TABLE OF CONTENTS

	Page
Title Page	i
Certification	ii
Dedication	iii
Acknowledgements	iv
Table of Contents	vii
List of Figures	xii
List of Tables	xvi
List of Plates	xvii
Abstract	xix

CHAPTER ONE: INTRODUCTION

1

1.1	Preamble	1
1.2	Statement of Research Problem	3
1.3	Aim and Objectives of the Study	4
1.4	The Study Area	5
1.4.1	Location and Boundaries	5
1.4.2	Climate and Vegetation	5
1.5	Previous Works	7
1.6	Scope of Work	11
1.7	Research Assumptions	13
1.8	Contribution to Knowledge	13
CHAPTER TWO: REVIEW OF LITERATURE		14

2.1	The Geology and Hydrogeology of the Study Area	14
2.1.1	The Regional Geology	14
2.1.1.1	The Basement Complex of Southwestern Nigeria	14
2.1.1.2	Geology of the Area Around Ado-Ekiti	16
2.1.1.2.1	Local Geology of the Study Area	20
2.1.2	Hydrogeology	20
2.2	Soil and Its Properties	21
2.2.1	Physical Properties of Soils	23
2.2.2	Chemical Properties of Soils	25
2.2.3	Soil Organic Matter	27
2.2.4	Types of Soil	27

2.2.5 The Soils of Ekiti	29
2.3 Maize, Its Root System, Climatic and Soil Requirements	31
2.3.1 Root System	31
2.3.2 Climatic Requirements	33
2.3.3 Soil Requirements	33
2.3.4 Planting Seasons	34
2.4 Principles of the Electrical Resistivity Method	34
2.4.1 Factors Affecting the Electrical Resistivity of Earth Materials	35
2.4.2 The Elementary Theory	40
2.4.3 Electrode Configurations/Arrays	48
2.4.4 Surface Potential Due to Horizontal Beds	50
2.4.5 Hummel's Image Theory for 2-Layer Wenner Vertical Electrical Sounding	52



2.4.6	General Data Acquisition/Field Procedure in Electrical Resistivity Method	54
2.4.7	Data Presentation and Interpretation	56
CHAPTER THREE: RESEARCH METHODOLOGY		
3.1	Geophysical Investigation	58
3.1.1	Theoretical Electrical Resistivity Modeling	58
3.1.2	Field Electrical Resistivity Measurements	62
3.1.3	The Trial Measurement Stage	62
3.1.4	The Design and Development of the Electrode Array Platform	68
3.2	Soil Measurements	70
3.2.1	Soil Analyses	72
3.2.1.1	Soil Particle Distribution Analysis	75
3.2.1.2	Soil Moisture Content Determination	78

3.2.1.3 Soil pH Determination	81
3.3 Maize Harvesting and Yield Determination	83
3.3.1 Maize Planting	83
3.3.2 Maize Harvesting and Yield Determination	86
3.4 General Data Processing and Interpretation	86
CHAPTER FOUR: RESULTS AND DISCUSSION	
4.1 Surface Layer Characteristics	89
4.1.1 Surface Layer Resistivity Map	89
4.1.2 Surface Layer Parametric Resistivity Data	89
4.1.3 Soil Textural Classification of the Surface Layer	95
4.1.4 Relationship Between Surface Layer Textural Classification and Resistivity	95
4.1.5 Surface Layer Soil Moisture Content Analyses	101



4.1.5.1 Relationship Between Surface Layer Moisture Content and Resistivity	104
4.1.6 Surface Layer pH Characteristics	108
4.1.6.1 Relationship Between Surface Layer pH and Resistivity	111
4.2 Deeper Layer Characteristics	119
4.2.1 Deeper Layer Resistivity Map	119
4.2.2 Soil Textural Classification of the Deeper Layer	119
4.2.3 Relationship Between Deeper Layer Textural Classification and Resistivity	119
4.2.4 Deeper Layer Moisture Content Analyses	126
4.2.4.1 Relationship Between Deeper Layer Moisture Content and Resistivity	126
4.2.5 Deeper Layer pH Characteristics	134
4.2.5.1 Relationship Between Deeper Layer pH and Resistivity	134

4.3	Maize Yield Analyses	141
4.3.1	The Maize Harvest Map	141
4.3.2	Maize Yield Map	141
4.3.3	Relationship Between Soil Characteristics and Maize Yield	145
4.3.3.1	Surface Layer Textural Classification and Maize Yield	145
4.3.3.2	Deeper Layer Textural Classification and Maize Yield	149
4.3.3.3	Surface Layer Apparent Resistivity and Maize Yield	153
4.3.3.4	Deeper Layer Apparent Resistivity and Maize Yield	157
4.3.3.5	Surface Layer Moisture Content and Maize Yield	162
4.3.3.6	Deeper Layer Moisture Content and Maize Yield	166
4.3.3.7	Surface Layer pH and Maize Yield	171
4.3.3.8	Deeper Layer pH and Maize Yield	176

4.4	Synthesis of Yield Analyses Results	184
4.5	Maize Yield Prediction from Soil Properties	188
CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS		
		192
5.1	Summary	192
5.2	Conclusions	195
REFERENCES		
		197
APPENDICES		
		209
Appendix A: Software Source Code for Hummel's Image		
Theory for 2-Layer Wenner Array		209
Appendix B: Theoretical Electrical Resistivity Modeling Data		
		214
Appendix C: Trial Electrical Resistivity Data		
		216
Appendix D: Trial Resistivity Model Curves		
		219



Appendix E: Surface Layer Total Resistivity Data	228
Appendix F: Surface Layer Parametric Resistivity Data	249
Appendix G: Surface Layer Soil Data	253
Appendix H: Deeper Layer Total Resistivity Data	256
Appendix I: Deeper Layer Parametric Resistivity Data	277
Appendix J: Deeper Layer Soil Data	281
Appendix K: Extracted Spatial Classification Data of Surface Layer Properties and Maize Yield	284
Appendix L: Extracted Spatial Classification Data of Deeper Layer Properties and Maize Yield	312



LIST OF FIGURES

Figure Page	Caption	
1.1	Map of Ekiti State University, Showing the Research Farm and the Pilot Plot.	6
2.1	Simplified Geological Map of Nigeria Showing Distribution of the Basement Rocks.	15
2.2	Geological Map of the Area Around Ado-Ekiti, Showing the Study Area	19
2.3	The Four Components of Soil.	22
2.4	Simplified Representation of Exchange Capacity.	26
2.5	Soil Association Map of the Area Around the Study Area.	30
2.6	A Matured Maize Plant.	32
2.7	The Approximate Range of Resistivity Values of Common Rock Types.	36
2.8	Current Flow Through a Cylindrical Conductor.	41



2.9	Buried Point Source of Current in Homogeneous Ground.	43
2.10	Current Flow in a Hemispherical Earth Surface.	45
2.11	Generalized Form of Electrode Configuration in Resistivity Surveys.	46
2.12	Electrode Arrays in Common Use.	49
2.13	Images Resulting from Two Horizontal Beds.	51
3.1	Examples of Simulated Wenner Array Model Curves with Varying Layer Thicknesses and Resistivities.	59
3.2	Examples of Computer Aided Interpretation of Simulated Wenner Array Model Curves for Resistive Deeper Layer.	60
3.3	Examples of Computer Aided Interpretation of Simulated Wenner Array Model Curves for Resistive Surface Layer.	61
3.4	Field Layout, Showing Traverses and Stations.	63
3.5	Field Layout, Showing Field Trial VES Stations.	65
3.6	Examples of Type Curves Obtained from the Pilot Plot.	66
3.7	Field Layout, Showing Cells and Soil Sample Points.	73
3.8	Textural Triangle, Showing a Soil's Textural Group According to the Percentage	

Sand, Silt and Clay it Contains.

90

3.9 Relationship of Soil Texture with Soil Water Content.

80

4.1 Resistivity Map of the Surface Layer.

90

4.2 Chart Showing the Percentage Occurrence of the Two Resistivity-derived Soil Types within the Surface Layer.

91

4.3 Resistivity-derived Soil Map of the Surface Layer

92

4.4 Chart Showing the Percentage Occurrence of the Two Resistivity-derived Soil Types Obtained from the Parametric Data.

93

4.5 Parametric Resistivity Soil Map of the Surface Layer.

94

4.6 Soil Textural Classification Map of the Surface Layer

96

4.7 Superposed Soil Textural and Parametric Resistivity Contour Maps

99

4.8 Spatial Pattern Association Map of Resistivity-derived Soil and Textural Classifications.

100

4.9 Generalized Soil Map of the Surface Layer.

102

4.10	Soil Moisture Content Map of the Surface Layer.	103
4.11	Regression Analysis on Apparent Resistivity and Soil Moisture Content.	105
4.12	Bar Chart of Moisture Content Characteristics of Resistivity-derived Soil Types	107
4.13	Spatial Pattern Association Map of Moisture Content and Resistivity-derived Soil Classes.	109
4.14	Composite Map of Soil Moisture Content and Resistivity-derived Soil Classes.	109
4.15	pH Map of the Surface Layer.	112
4.16	Regression Analysis on Surface Layer Resistivity and pH	113
4.17	Bar Chart of the pH Characteristics of Resistivity-derived Soil Types.	116
4.18	Spatial Pattern Association Map of Surface Layer pH and Resistivity-derived Soil Classes.	117
4.19	Composite Map Surface Layer pH and Resistivity-derived Soil Classes.	118
4.20	Resistivity-derived Soil Map of the Deeper Layer.	
4.21	Soil Textural Classification Map of the Deeper Layer.	120
121		

4.22	Spatial Pattern Association Map of Resistivity-derived Soil and Textural Classifications of the Deeper Layer.	124
4.23	Generalized Soil Map of the Deeper Layer.	125
4.24	Moisture Content Map of the Deeper Layer.	127
4.25	Regression Analysis of Deeper Layer Moisture Content and Resistivity.	128
4.26	Bar Chart of the Relationship Between Deeper Layer Moisture Content and Resistivity.	130
4.27	Spatial Association Map of Deeper Layer Moisture Content and Resistivity	132
4.28	Composite Map of Deeper Layer Moisture Content and Resistivity.	133
4.29	Deeper Layer pH Map	135
4.30	Regression Analysis of Deeper Layer pH and Resistivity.	136
4.31	Spatial Association Map of Deeper Layer pH and Resistivity.	139
4.32	Composite Map of Deeper Layer pH and Resistivity.	140
4.33	The Maize Harvest Map.	142
4.34	Bar Chart of the Percentage Occurrence of the Yield Classes.	143
4.35	Maize Yield Map of the Pilot Plot.	144
4.36	Spatial Association Map of Surface Layer Textural Classification and Maize Yield	147
4.37	Maize Yield Prediction Based on Surface Layer Texture.	148
4.38	Spatial Pattern Association Map of Deeper Layer Textural Classes and Maize Yield	151
4.39	Maize Yield Prediction Based on Deeper Layer Texture.	152
4.40	Regression Analysis of Maize Yield and Apparent Resistivity.	154
4.41	Spatial Association Map of Surface Layer Resistivity and Maize Yield	156



4.42	Maize Yield Prediction in Terms of Surface Layer Resistivity.	158
4.43	Regression Analysis of Deeper Layer Resistivity and Maize Yield.	159
4.44	Spatial Association Map of Deeper Layer Resistivity and Maize Yield.	161
4.45	Maize Yield Prediction in Terms of Deeper Layer Resistivity	163
4.46	Regression Analysis of Surface Layer Moisture Content and Maize Yield	164
4.47	Spatial Association Map of Surface Layer Moisture Content and Maize Yield	167
4.48	Maize Yield Prediction in Terms of Surface Layer Moisture Content.	168
4.49	Regression Analysis of Deeper Layer Moisture Content and Maize Yield.	167
4.50	Spatial Association Map of Deeper Layer Moisture Content and Maize Yield	172
4.51	Maize Yield Prediction in Terms of Deeper Layer Moisture Content.	174
4.52	Regression Analysis of Surface Layer pH and Maize Yield.	175
4.53	Spatial Association Map of Surface Layer pH and Maize Yield.	177
4.54	Maize Yield Prediction in Terms of Surface Layer pH.	178
4.55	Regression Analysis of Deeper Layer pH and Maize Yield.	179
4.56	Spatial Association Map of Deeper Layer pH and Maize Yield.	182
4.57	Maize Yield Prediction in Terms of Deeper Layer pH.	183
4.58	Spatial Association Map of Soil Properties and Maize Yield.	189
4.59	Maize Yield Prediction in Terms of Soil Properties.	190
4.60	Comparison of Predicted and Observed Maize Yield Maps.	191



LIST OF TABLES

Table Page	Caption	
3.1	Summary of the Geoelectric Characteristics of the Surface and Deeper Layers	67
3.2	Summary of Resistivity-derived Soil	72
3.3	Soil pH Classifications.	82
4.1	Cross-tabulation of Soil Textural Classification and Resistivity-derived Soil Classification	97
4.2	Cross-tabulation of Surface Layer Moisture Content and Resistivity-derived Soil Classification.	106
4.3	Cross-tabulation of Surface Layer pH and Resistivity-derived Soil Classification.	115
4.4	Cross-tabulation of Soil Textural Classification and Resistivity-derived Soil Classification of the Deeper Layer	122
4.5	Cross-tabulation of Deeper Layer Moisture Content and Resistivity-derived Soil Classification.	129
4.6	Cross-tabulation of Deeper Layer pH and Resistivity-derived Soil Classification	137
4.7	Cross-tabulation of Maize Yield and Surface Layer Textural Classification	146
4.8	Cross-tabulation of Maize Yield and Deeper Layer Textural Classification	150
4.9	Cross-tabulation of Surface Layer Resistivity and Maize Yield	155



4.10	Cross-tabulation of Deeper Layer Resistivity and Maize Yield	160
4.11	Cross-tabulation of Surface Layer Moisture Content and Maize Yield	165
4.12	Cross-tabulation of Surface Layer Moisture Content and Maize Yield	170
4.13	Cross-tabulation of Surface Layer pH and Maize Yield	175
4.14	Cross-tabulation of Surface Layer pH and Maize Yield	181
4.15a	Analysis of Strength of Association Between Textural Classification and Yield	18
4.15b	Analysis of Strength of Association Between Resistivity and Yield	185
4.15c	Analysis of Strength of Association Between Moisture Content and Yield	185
4.15d	Analysis of Strength of Association Between pH and Yield	186
4.16	Cumulative Relationships of Soil Properties with Depth	187



LIST OF PLATES

Plate Page	Caption	
3.1	The Wenner Array Platform (WAP)	69
3.2	Field Operation of the Wenner Array Platform	71
3.3	A Field Snapshot Showing a Typical Sample Point Within a Cell	73
3.4	Stages of Sample Preparation	75
3.5	Plot Preparation Before Planting	81
3.6	The Western Yellow Open-pollinated Maize Variety	82
3.7	(a) Maize at Physiological Maturity, (b) Maize Harvesting and Labeling	84
3.8	Maize Yield Determination using a Digital Weighing Balance	85

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/m². 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