UPDATING THE MAPPING, CLASSIFICATION AND SUITABILITY EVALUATION OF THE SOILS OF OWAN EAST LOCAL GOVERNMENT AREA OF EDO STATE, NIGERIA

BY

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A THESIS SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D) DEGREE IN SOIL SCIENCE OF THE UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

MARCH, 2021

CERTIFICATION

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DEDICATION

This work is dedicated to Almighty God whose grace has always distinguished me and to my Parents for their unrelenting support.

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ABSTRACT

The soils of Owan East Local Government Area of Edo State were studied in order to update the classification, mapping and suitability evaluation done by Federal Department of Agricultural Land Resources (FDALR 1985).

Soil mapping was at the reconnaissance scale; soil classification was according to the USDA and WRB systems while suitability evaluation was patterned after FAO guidelines, as modified by several scientists for rubber, oil palm, cacoa, maize and cassava. Reliability of the soil maps were determined by the variability indices of: Coefficient of Variation (CV), Variance Ratio Test (VRT), Inter – class Correlation Coefficient (P_1), Relative variance (RV) and its Complement (1 – RV). Validation of the updated work was done through a free soil survey procedure and suitability assessment for rubber on the 17.7 ha parcel of land for RRIN within the project area.

The study revealed that six major mapping units were found and classified as Alfisols/Lixisols, (occupying some 66,160.26 ha), Inceptisols/Cambisols (37,803.07 ha) and Entisols/Arenosols (19,471.17 ha). The FDALR work showed two mapping units classified as Alfisol/Lixisol and without areal distribution of the units. In terms of the reliability of the soil maps for the study area, the results showed that the findings in this study is quite superior to that of the FDALR. In terms of suitability for the selected crops, for the current findngs, 70,201.5 ha (56.87%) was best suited for maize, cassava and cocoa, while 26, 624.49ha (21.57 %) was best suited for cocoa only. An area of 19,471.17 ha (15.77%) was best suited for maize, cassava and rubber while an area of 7,137ha was found not suitable for any of the 5 crops under study. The FDALR study had the same tree crops examined for their suitability, no area was rated unsuitable and only one map was used to represent all the crops, while for arable crops, no specific crop was mentioned and it had only one map and two suitability classes. For Indices of variability: FDALR study had 46 % homogeneity within mapping units by CV while it was 87 % for the 2019 findings. For variance ratio test (VRT), no property was significantly different for the 1985 study while for the 2019, 13 properties were significantly different; Intra class correlation coefficient (pi) , in the 1985 work only CEC was accurately predicted (pi > 0.5) while in the 2019 work 7 properties were accurately predicted (pi > 0.7); for Relative variance only one property, CEC was accurately predicted compared with 9 properties (RV = 0.26 – 0.53) - 1985 and 2019 respectively. The results of the 17.71ha classification and suitability ratings agreed with that of the updated findings – being largely Inceptisol/Cambisol and only marginally suitable for rubber cultivation. Thus it can be concluded that while the FDALR study served its purpose as a pioneering attempt and hence overdue for updating. The study was highly necessary for accurate prediction of crop performance and sustainable management of the study location.

CHAPTER ONE

1.0 INTRODUCTION

Land is an indispensable natural resource for most of the essential human activities in any region or country. As population and economic activities increase, land degradation problem worsen due to the increasing demand on it to meet the food and fiber needs of the people.

Soil survey is a systematic examination, description, classification and mapping of the soils in a given area (Brady and Weils, 2002). A soil survey generally involves soil classification, mapping and land evaluation and the results are contained in survey report. However, these are various types of soil surveys: Schematic, Exploratory Reconnaissance, Semi- Detailed, Detailed and Intensive Soil Surveys (Esu, 1999).

Land evaluation, is the interpretation of soil survey data in order that every hectare of land could be used in accordance with its capability, suitability and limitations (FAO, 2007). To minimize the misuse of soils in a given location, the land needs to be properly classified according to its suitability for the proposed kind of use. This requires a proper organization of land and soil data in such a way that could be interpreted and applied for agricultural development. This is in line with (Ogunkunle, 1988), that observed that farmers are more interested in land evaluation reports that show the capability or suitability of their land for agricultural production in terms of expected yield per hectare, than reports on soil classification and its maps.

Updating becomes imperative, due to the advancement in knowledge, science and technology. The first draft of the soil map of the world was presented to the 9th congress of the ISSS held at Australia in 1968; the legend of the map has undergone many revisions while in 1998 the system was replaced by the world reference Base for Soil resources (WRB). The latest version of WRB was presented during the 18th World Congress of Soil Science (WCSS) at Philadelphia in 2006. In 1960, the 7th Approximation of the United States Department of Agriculture (USDA).In 1975, the final text of Soil Taxonomy with ten soil orders. In 1994, one additional soil order, Andisols, and in 1998 another one was added, Gelisols.

In Nigeria, there have been various attempts to classify soils by many Soil Scientists; Moss (1957), Smith and Montgomery (1962), (soils in Western Nigerian), Eastern soils were classified by Jungerius (1964), while Klinkenberg and Higgins (1968) attempted the classification of Northern Nigeria soils and an updated work was done by Esu (1983) on dark clay soils of Biu plains, Nigeria. Ogunkunle (1983) updated the classification of soils in NIFOR which was initially done by Vine (1956), attempt to evaluate the Soil Map of Nigeria FDALR (1990) and Kwara state by Olaniyan (2003)

The first soil survey report for Bendel state (now Edo and Delta states), as a region, was done by FDALR in 1985 and almost all references at regional, State and even Local government levels had been made to it. The present study site – Owan East LGA is a part of the same old work and it became necessary to test the reliability of this work in view of the dynamics of pedological, social, agricultural interventions for the past 35 year aimed at validating and or modifying these conclusions as it affects Owan East LGA.

1.1 **Objectives of Study**

The main objective of this study is to update the mapping, classification and suitability evaluation of the work done by the Federal Department of Agricultural Land Resources (FDALR, 1985) on Bendel State for Owan East Local Government Area, Edo State.

The Specific Objectives of this study were to:

1. identify the soil types through soil survey at reconnaissance level; classify the soils according to established USDA and WRB guidelines and produce a soil map
2. determine the suitabilities of the various soils types for the cultivation of some selected crops (Rubber, oil palm, Cacao, maize and cassava);
3. compare the 1985 version of the classification and evaluation of this LGA with the current findings in terms of objectives above; and
4. use the soil map for the 17..71 ha belonging to RRIN and its suitability for rubber cultivation to validate the accuracy of the soil map by established tests of variability.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Land and Soil Interaction

Soil is considered one of the world's limited, non-renewable resources. Under cropland conditions, it takes between 200 and 1000 years for 2.5cm of topsoil to form (Piementel *et al*., 1995). It is the long term capital on which nations build their resources (Wilding and Lin, 2006). Soils cover most lands of the earth, but regarding their service for humans they are limited and largely non-renewable resource (Blum, 2006). According to Soil Survey Staff (2003), soil is the natural medium for the growth of plants. Soils are affected by human activities, such as industrial, municipal and agriculture, that often result in soil degradation and loss or reduction in soil functions. In order to prevent soil degradation and rehabilitate the potentials of degraded soils, reliable soil data are the most important prerequisite for the design of appropriate land-use systems and soil management practices as well as for a better understanding of the environment.

Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface including those of the near-surface climate, the soil and terrain forms. The surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations. The human settlement pattern and physical results of past and present human activity, such as terracing, water storage or drainage structures, infrastructure, buildings (United Nations, 1995). Land is an indispensable resource for the most essential human activities: it provides the basis for agriculture and forest production, water catchment, recreation, and settlement. The range of uses that can be made of land is limited by environmental factors including climate, topography and soil characteristics, and is to a large extent determined by demographic, socio-economic, cultural and political factors such as population density, land tenure, markets, institutions, and agricultural policies.

Land management is a somewhat broader concept than soil management. Soil management considers many aspects of production, such as, water use and availability, crop rotations and nutrient management, erosion control. Land management goes beyond agricultural uses of soil or land.

2.2 Soil and land evaluation in a historical context

In a global context, the utilisation of the soil productivity function in agriculture requires not only soils but also appropriate climate and human activity. Methods for the evaluation of the potential for the productivity of soil are known as land evaluation methods (FAO, 2007).

Land evaluation is defined as 'the process of assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation (FAO, 1976). It is the interpretation of soil survey data in order that every hectare of land can be used in accordance with its capacity, suitability and limitations (FAO, 2007). Land evaluation is primarily the analysis of data about the land (its soils, climate, vegetation, and so on).

Historically, land evaluation developed from soil science. As soil is the most important component of the land resource, soil evaluation is crucial to land evaluation (Rossiter, 1996). In many cases, there is no clear differentiation between soil and land evaluation (Van Diepen *et* *al*., 1991; van de Steeg, 2003). Climate as a main precondition for the production of plant biomass varies over larger spatial scales than soil. Approaches to evaluate the productivity potential of soils from a more regional perspective in similar climates (fields, agricultural regions, smaller countries) tend to prefer the term "soil" for their object of assessment and rating. Approaches coming from a more global perspective (globe, continents, larger countries) tend to emphasise the role of climate and humans in biomass production and favour the term "land". The latter became dominant over the past 40 years, whilst evaluations of the productivity potential of "soil" have a long history, beginning with farming and animal husbandry. Ahrens J.R., Rice T.J., Eswaran H. (2002) stated: "pedology and soil science in general have their rudimentary beginnings in attempts to group or classify soils on the basis of productivity. Early agrarian civilizations must have had some ways to communicate differences and similarities among soils." At the beginning of the 19th century the German agronomist A. D. Thaer created a 100 point rating system for the productivity potential of soils based on texture, lime and humus content (Feller C.L., Thuries L. J.-M., Manlay R. J., Robin P., Frossard E., 2003). It is one example of a predecessor for some of our current evaluation schemes of agricultural soil quality (Gavrilyuk, 1974; Feller *et al*., 2003).

2.3 Historical Developments of Soil Classification

As man seems to have a natural tendency and urge to sort out and classify the natural objects of his environment, soils are no exception. The evolution of soil classification according to Buol *et al* 1980), can be subdivided into five general periods namely: (i) early technical period, (ii) period of founding of pedology by the Russian group of soil geneticist, (iii) early American period, (iv) Middle period of general development of soil classification and soil surveys also known as Marbut period and (v) the present modern period of quantitative pedology.

2.3.1 Early Technical Period

The early technical period in classification of soils had its inception in Western Europe in the middle and later parts of the nineteenth century. Thaer (1853) established six kinds of soil (clay, loam, sandy loam, loamy sand, sand and humus) which was based on textural properties. Fallou (1862) devised a soil classification largely based on geologic origin and lithologic composition of what is now called parent material (residual soils and alluvial soils). In 1886, Richthofen came out with a classification with a strong geologic basis and similar to Fallou's system (Residue soil types and Accumulated soil types). The above classifications were mainly technical, prepared for a specific purpose or objective and using factors or characteristics, not properties of the soils as differentiating characteristics.

2.3.2 Period of Founding of Pedology

During the latter part of the early Technical period in Russian, after an increasing temperature and annual rainfall which left their imprints on the relatively uniform parent material producing distinct soil differences and these differences were noted by the founder of modern pedology, Dokuchaev. He was the first to understand the full significance of soil differences and thereby established the concept of soil as a natural body formed by the actions of a set of soil- forming factors producing genetic layers in the parent material. Also in 1886, he published a work on classification of soils based on the properties and soil – forming factors of the soils.

2.3.3 Early American Period

This period was approximately between 1899- 1922. During this period the operational programs of the United States soil survey was biased towards geologic techniques and nomenclature. Whitney (1909), developed and published the first American soil classification system related to soil survey and used it as a basis for soil mapping operations. This was a broad classification according to physiographic regions and the particle size distribution (texture) of the soil. In1912, Coffey was apparently the first in United States to propose soils as independent natural bodies that should be classified on the basis of their own properties. He stated that differences in soil properties were due to climatic and associated differences in vegetation from place to place.

2.3.4 Middle American period

The Middle American period was named after Marbut due to his tremendous work in the evolution of soil taxonomy. He de-emphasized the geologic nature and origin of soil materials as developed by Whitney. He introduced the soil forming factors based on climate and vegetation. His ideas on classification were in successive steps (Marbut, 1922: 1927), which formed his master work on soil classification published in the Atlas of American Agriculture (Marbut, 1935). This included the establishment of the soil profile as the fundamental unit of study, preparation of the first truly multi- categorical system of soil taxonomy. He establish the criteria for soil series which is still in use today. As new information and evolution of concepts took place, in 1983, Baldwin *et al*, Published the USDA Yearbook of Agriculture, this classification marked the Beginning of a truly comprehensive and quantitative soil classification.

2.3.5 Modern Quantitative Period

This period began with the revisions of the 1938 USDA yearbook classification by Thorp and Smith (1949) and by Riecken and Smith (1949). In these revisions, great soil groups were added and definitions were revisited and sharpened. The development of this new comprehensive system was by a series of approximations which were circulated for criticism and comments and in 1960,'' The 7th Approximation" was published by Soil Survey Staff.

Till date, soil classification is still undergoing additional revisions and various upgraded editions have been published and hopefully will continue to be published.

2.4 Indigenous Soil Classification (Vernacular)

Indigenous soil classification development started in the 60's with anthropologists' ethnoscience research and the discovery and publication of 'indigenous knowledge success stories', and continued in the 70's by the development of Farming Systems Research philosophy and the sprouting of formal studies on indigenous knowledge. It has however, led to many research sscientists and extension workers recognizing that rural people in many developing countries have a rich understanding of their resources (Thrupp 1989, Warren 1989). According to Altieri (1990), indigenous knowledge, also referred to as ethnoscience, traditional, local, folk, and native knowledge can be defined, relative to agriculture as accumulated knowledge, skill and technology of local people derived from their direct interaction with the environment. Pawluk *et al*. (1992) agreed that information is passed on through generations and refined into a system of understanding of natural resources and relevant ecological processes. Given the central role of soil resources in subsistence production, and the fact that soil, as a renewable resource on the human time scale, is a major aspect of sustainable agriculture (Marten & Vityakon 1986, Pawluk *et al*. 1992), the indigenous knowledge of soils, or ethnopedology, has recently received more attention (Pawluk *et al*. 1992). As imported ideas and scientific interpretation of tropical soils have failed to bring about desired results, it has become more and more apparent that the knowledge of people who have been interacting with their soils for a very long time can offer many insights about sustainable management of tropical soils (Hecht 1990, Osunade 1992b). Ethnopedology encompasses many aspects including indigenous perceptions and explanations of soil properties and soil processes, soil classifications, soil management and knowledge of soil-plant interrelationships (Williams & Ortiz-Solorio 1981, Hecht 1990).

There has been some notable intention to distinguish between 'physical' and 'perceptual' dimensions of soil classification. The 'physical' dimension concerns the most readily observable criteria that farmers use to differentiate their soils, namely soil characteristics that can be discerned by sight, feel, taste or smell (Osunade, 1992a). The two most obvious physical characteristics of soil, which are texture and colour, are found to be the basis of many indigenous soil classifications throughout the world. Criteria of the 'perceptual' dimension are not as concrete as those in the physical dimension nor are they always readily recognized (through the senses) as soil characteristics. Examples are soil workability, suitability classes for certain crops, sensitivity to certain agricultural problems, and non-agricultural classes based upon the use of soil such as building and pottery material.

Differentiating criteria are a first step in forming a classification. Hypothetically, indigenous soil perception might range from unstructured observations of individual attributes, through soil classification, to highly developed taxonomies (Williams and Ortiz-Solorio, 1981). The difference between classification and taxonomy is the absence in the former and the presence in the latter of hierarchical relationship between (groups) of soil classes. Classifications and taxonomies can be called ‘formal’ when they are commonly accepted, used and agreed upon by the indigenous group (Ettema, 1994).

Some notable studies have had the objective to testing the ‘validity’ and ‘objectivity’ of indigenous classifications, using technical analysis methods (Bellon and Taylor, 1993) and clustering programs and other statistical procedures (Stacishin de Queiroz & Norton 1992, Behrens 1989). Their conclusions were that distinctions made by indigenous people were all scientifically valid and statistically testable. Soil quality ranking by indigenous perception and scientific method gave similar results (Bellon and Taylor, 1993).

Much more interesting are the nature of the classifications and how western soil classifications relate to them. Indigenous classifications tend to be much more shallow compared to western classifications (Osunade, 1989; Williams and Ortiz – Solorio, 1981), for which there appear to be two reasons which are partly overlapping. While indigenous soil classification seems primarily functional in orientation, common western soil classifications divide their soils primarily based on knowledge about pedogenesis (Williams and Ortiz-Solorio, 1981). Secondly, indigenous taxa seem to be derived from the properties of the surface horizon only (not that people are not aware of the vertical dimension, but it is ignored for taxonomic purposes), while main diagnostic features that differentiate western soil taxa are the character and sequence of soil horizons. In other words, the perception of the taxonomic unit is two-dimensional for indigenous classifications, and three – dimensional for western classifications (Williams and Ortiz – Solorio, (1981), resulting in a fundamental difference between indigenous and many western soil classifications.

Thrupp (1989) argues that in order to legitimize indigenous knowledge, it should not be necessary to measure and 'scientize' it in terms of formal Western methods and scientific principles since the value of such knowledge has been proved over centuries and scientific systematization may misinterpret the cultural value and subtle complex nuances of these knowledge systems. While agreeing with this point, Ettema (1994) expressed the opinion that analyzing indigenous knowledge using 'our scientific methods' could still yield many valuable lessons for scientists and extensionists and provide complementary information useful for both the indigenous people and the formal Western scientists.

2.5 Types of Soil Classification

Soil classification is a dynamic subject from the structure of the system itself to the definitions of classes and in the application in the field. It can be approached from both the perspective of pedogenesis and from soil morphology (Avery, 1980).

There are two broad types of soil classification namely: taxonomic or scientific classification and technical classification (Esu, 1999). The technical classification widely used are USDA Land Capability Classification system (Klingebiel and Montgomery, 1961) and FAO Land Suitability Classification (FAO, 1976) while taxonomic classification systems are World Reference Base for Soil Resources (WRB, 2007) and the USDA soil taxonomy system (Soil Survey Staff, 2003).

2.5.1 FAO-UNESCO Soil Map

In 1961, the preparation of the FAO/ UNESCO soil map of the world project at a scale of 1: 5,000,000 began in response to a recommendation of the International Society of Soil Science (ISSS) at its 7th congress held at Madison, Wisconsin in 1960. After the preparation of succession drafts, the first draft of the soil map of the world was presented to the 9th congress of the ISSS held at Australia in 1968. Since then, the legend of the map has undergone many revisions. The soil map consists of 28 major soil groupings, subdivided at the second level into

153 soil units and its objective is to correlate all units of the various soil maps in the world to obtain a wide inventory of soil resources (Esu, 1999).

In 1998 this system was replaced by the World Reference Base for Soil resources (WRB 2007).

2: 5: 2 World Reference Base for Soil Resources (WRB)

WRB aims to establish an international reference base for soil classification. A Working Group of the International Union of Soil Sciences (IUSS) with collaboration of soil scientists from all over the world has worked out and tested proposals for WRB, leading to the publication of the World Reference Base for Soil Resources by FAO in 1998. It was endorsed by the IUSS as the union's system of soil classification during the 16th World Congress of Soil Science in 1998 in Montpellier, France. The latest version of WRB was presented during the 18th World Congress of Soil Science (WCSS) at Philadelphia in 2006. It replaced the FAO Legend for the Soil Map of the World (WRB 2007)

The classification is a practical grouping into reference groups that share an assemblage of features which cause distinct behaviour. That is, ecological function and implications for soil management. So, the WRB is two-tier system of soil classification:

Tier 1 :32 First Level Major Soil Groups (the "Reference Base") – these are intermediate in conceptual level between orders and suborders of Soil Taxonomy; major differences in terms of pedogenesis, geography, and use potential.

Tier 2: Second-level subdivisions – using defined combination of over 120 uniquely defined qualifiers for specific soil characteristics.

A list of prefix and suffix qualifiers for each Reference Group which are added to the

Reference soil group (RSG) name to indicate detailed soil properties. Prefix qualifiers are of two types: typically associated with the RSG (thus effectively acting as subgroups) and intergrades to other RSG. Suffix qualifiers provide additional details on diagnostic horizons; chemical, physical and mineralogical soil properties; surface characteristics; general texture; colour; and miscellaneous properties. The RSG are arranged in a hierarchical key, whereas the qualifiers for each RSG are presented as a list, out of which all that apply to the soil being classified must be named. Names are intended to be as connotative as possible, using traditional soil names. In 2010, Guidelines for constructing small-scale map legends using the WRB were published.

2: 5 :3 USDA Soil Taxonomy system

In 1951, the soil survey staff, soil conservation service of the United States department of Agriculture (USDA) started the development of a new system of soil classification. In 1960, the 7th Approximation was published for criticism, adapted, changed over the years, and in 1975, the final text was published under the title: "Soil Taxonomy: A basic system of soil classification for making and interpreting soil survey" by Soil Survey Staff the edition contained ten soil orders. In 1994, one additional soil order, Andisol, and in 1998 another one was added, Gelisol.

This system is a hierarchical multi-categorical system with six categories, from highest to lowest levels of generalization. They include the order, suborder, great group, subgroup, family, series (Esu, 1999)

The objectives of the system are to:

(a) organize soil series in increasingly – general groups for interpretations

(b) support semi-detailed and reconnaissance mapping directly with the defined classes

(c) facilitate correlation within and among regions: the more similar the soils, the closer they should be in the classification

(d) organize knowledge about soils relations.

2.6 Soil Classification in Nigeria

In Nigeria, there have been various attempts to classify soils by the following Soil Scientists; Moss (1957), Smith and Montgomery (1962), (soils in Western Nigerian), Jungerius (1964),soils in Eastern Nigeria while Klinkenberg and Higgins (1968) (soils of Northern Nigeria and an updated work was done by Esu (1983) on dark clay soils of Biu plains, Nigeria. Ogunkunle (1983) updated the classification of soils in NIFOR which was initially done by Vine (1956). The above classifications were all based on parent material position in the toposequence and texture at specified depths for a particular area.

2.7 Land Evaluation

Over the past 20 years, specific soil and land evaluation systems have been developed. Examples of these systems are the US LESA system (Pease and Coughlin, 1996) and the Canadian Land Suitability Rating System for Agricultural Crops (LSRS, Agronomic Interpretations Working Group, 1995). Examples of those national soil and land capability classifications are the US capability classification (Klingebiel and Montgomery, 1961; Helms, 1992), the UK system developed by the Macaulay Land Use Research Institute (Bibby *et al*., 1991), the New Zealand land use capability system (Lynn *et al*.,2009) and the soil fertility classes for agriculture in Australia (Hall, 2008).The LESA system consists of a soil evaluation component Storie Rating and other factors that contribute to the suitability of land for agriculture, like location, surrounding use and infrastructure. The LSRS system is mainly based on soil attributes and climate factors (Agronomic Interpretations Working Group, 1995). Other countries with substantial agricultural production and fast growing demands like China and Brazil intend to implement quantitative evaluation systems of soil and land productivity (Peng *et al*., 2002; Bacic *et al*., 2003; van de Steeg,2003; Zhang *et al*., 2004). Also in Russia there are efforts to establish contemporary soil, land information and evaluation systems (Karmanov *et al*., 2002; Yakovlev *et al*., 2006). In the Ukraine, Medvedev *et al*. (2002) developed an evaluation system of the suitability of land for growing cereals based on soil information and climate data. In Hungary, a modern land evaluation system is being established, containing on-line soil evaluation, which is based on the real-time calculation of De-Meter soil fertility index using GIS to produce soil maps at a scale of 1:10 000 (Tóth T. *et al*., 2007). All these soil and land evaluation systems are specific in approach, data and scale and their outputs are rarely comparable. Approaches that have been developed for larger countries cover a broader variability of soils and climate and seem to have a better potential for evaluation of agricultural soil quality in trans-national studies. Menjiver *et al* (2003), evaluated the land suitability for olive plant in Spain. They selected 35 pedons in the study area for land evaluation. Their results showed that on the basis of FAO guideline, the most limiting factors in the study area were the high level of soil moisture and the intensity of slope. In this system all the area fell to N1 class (currently non suitable).

Besides productivity ratings, in many countries, classifications of agricultural land limitations (steep lands, dry lands, stony lands), or final allocations to categories like “prime farmland” have been mapped. Those capability classes use nominal, categorical data, useful for land use planning but not for more detailed productivity assessments within these categories. Data of modern national or federal state soil and land information systems provide tailored medium scale capability classifications. Soil suitability classifications express soil productivity potentials in terms of the possibility of growing specific crops. In the nineteenth century in German States, soil suitability classification systems using classes ranging from "Prime wheat soil" to "Rye soil" or "Oats soil" were common, and were based on the work of Thaer and others (Meyers Lexikon, 1925). As requirements of plants regarding the functional status of soil may differ, all recent soil productivity relevant classifications must have a certain stratification or orientation on crops or groups of crops. Cereals are a basic source of human food supply and while they reflect differences in agricultural soil quality, some systems (Rothkegel, 1950; Agronomic Interpretations Working Group, 1995; Mueller *et al*., 2007) refer to cereals or cereal-dominated rotations. In the UK, soil suitability classifications have been developed for specific purposes such as direct drilling or reduced tillage. Such systems emphasise the limitations of soil structure and drainage status (Cannell *et al*., 1978). The presence of climatic data within land use capability classification systems means that such systems can accommodate climate parameters projected into the future. Thus climate change scenarios can be used to identify future changes in land capability (Brown *et al*., 2008).

2:7:1 The Objective of Land Evaluation

Dent and Young (1981) stated that the fundamental purpose of land evaluation is to predict the consequences of change. Prediction is needed on the suitability of the land for different forms of production of their benefits, and the consequences of such changes upon the environment. They further stated that, as with soil surveys, the detailed purposes of land evaluation vary with the physical, economic and social context, with the scale and intensity of the study and with the aims of the user.

Land evaluation supports many other disciplines. It may be used for many purposes, ranging from land use planning to explore the potential for specific land uses or the need for improved land management or land degradation control. The primary objective of land evaluation is the improved and sustainable management of land for the benefit of the people. The aims of land evaluation, as given in the original Framework, remain wholly valid; where these refer to the identification of adverse effects and benefits of land uses, there is now greater emphasis on environmental consequences and on wider benefits and environmental and ecosystem services. Land evaluation is primarily the analysis of data about the land –its soils, climate, vegetation, etc. – in terms of realistic alternatives for improving the use of that land. It is true that uses which are socially or economically unrealistic, for example large-scale mechanized agriculture in areas already densely settled, are excluded at an early stage, and left out of the analysis, land evaluation is nonetheless still focused upon the land itself, its properties, functions and potential. Development projects, whether through international aid or by national governments, are directed at alleviating economic and social problems, hunger and poverty in particular. There is a clear focus upon the people, the farmers and rural communities. It might therefore appear that land evaluation would be out of touch with the 'people first' view. This is not, and has never been, the case. There is a danger that the current focus on participation may lead to a neglect of the physical limitations of soil, climate, etc., that constrain rural land use. Land evaluation provides this vital element, helping to avoid the costly mistakes that have resulted from investment in forms of land development unsuited to local environmental conditions. Land evaluation, even in the expanded form, by no means amounts to the whole process of rural land development. It is a contributory element, linking various kinds of natural resource survey (soil survey, agro-climatic analysis, water resources appraisal, etc.) with technological aspects (agronomy, forestry, etc.) and with economic and social analysis. There is a particular need for land evaluation wherever the problems of farmers are caused or compounded by problems of the land, e.g. soil fertility decline, erosion, increased frequency of droughts due to climatic change.

The demands for natural resources information have widened – from emphasis on specialist data; to land evaluation, predicting the potential of land for one or more uses; to land use planning involving consideration of land use problems and opportunities, generation of a range of land use options, and making choices between these options (Dent and Young, 1981; FAO, 1993). Land use planning serves to guide decisions on land use in such a way as to ensure optimal production and profitability on a sustained basis. Soil survey interpretation gives practical value to soil survey in land use planning as it allows the practicing farmer to know the relative soil suitability of the land available to him for the land use types (LUTs) which he intends to invest on.

2.8 Land Evaluation Systems

Some of the widely accepted systems include the Land Capability Classification (LCC), land Suitability Evaluation (LSE), Fertility Capability Classification (FCC), the Productivity Indices (Storie index) and Irrigation Capability Classification (ICC).

However, according to Van Diepen *et al*. (1991), most of the evaluation systems were derived from the USDA Land Capability Classification (Klingebiel and Montgomery, 1961); Irrigation Capability Classification (USBR, 1978) and Storie Index (Edwards, 1970) supported with local expert knowledge and adapted for various land utilisation types.

2.8.1 **USDA Land Capability Classification** (LCC)

The USDA Land Capability Classification (LCC) (Klingebiel and Montgomery, 1961) is the most widely used system with numerous adaptations and was established by the US soil Conservation Service for the purpose of farm planning. The criteria used to classify Land Capability are: slope, texture of soil, depth of soil material, and drainage. In this classification system, soils are grouped according to their potentials and limitations, if any, for sustained production of common crops. This classification system places all soils in eight capability classes. The higher the number, from Class I-VIII, the greater the risk of soil damage or limitations for use. With good soil conservation management, soils in Classes I, II, III, and IV, are suitable for cultivation. Soils in Classes VI and VII, with good soil conservation management, are suited for pasture, woodland and wildlife. Soils in Class VIII generally are non-productive for agricultural purposes and are recommended for wildlife habitat. LCC only considers relatively land characteristics and does not take into consideration the socio – economic factors and also tends to tilt towards arable crop production under a monoculture regime.

2.8.2 **Land Suitability Evaluation** (LSE)

FAO, framework for land evaluation (FAO, 1976) introduced land suitability evaluation based on the realisation that the USDA land capability classification did not recognize other kinds of cultivation technique besides mechanical cultivation or other land uses such as perennial cropping (Esu, 1999). The interpretation went beyond that of soil surveys to include climate, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. Land suitability is an appraisal and grouping, or the process of appraisal and grouping, of specific types of land in terms of their absolute or relative suitability for a specified kind of use (FAO, 1976).

According to Purnell, (1979) and Van Diepen *et al*., (1991), this framework is an approach and not a method and is comprised of six principles namely:

a) Land suitability is defined for a specific kind of use;

b) land evaluation is essentially economic, social and political context of the concerned area;

c) evaluation requires a comparison between two or more alternative kind of use;

d) evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land;

e) the evaluation must propose a use that is sustainable

f) the evaluation processes require a multidisciplinary approach

FAO (2007), reviewed the Framework, to include some socio- economic factors which were expanded to include institutions (like legal structures, property rights etc), land tenure systems, markets, labour, transport, population, political and policy factors.

The classification includes four categories: orders, classes, sub classes and units. There are two orders (S, N), which reflect the kind of suitability (S for suitable and N for unsuitable) for a specified land utilization type. There are three classes very (S1), moderately (S2), marginally (S3) suitable under the order S and two classes currently not suitable (N1), or permanently not suitable (N2) under the order N, reflecting degree of suitability within the order as seen in the table below:

Order	Class	Description
Suitable	S1 (Highly suitable)	Land having no, or insignificant limitations to the given type of use
	S2 (Moderately suitable)	Land having minor limitations to the given type of use
	S3 (Marginally suitable)	Land having moderate limitations to the given type of use
Not suitable	N1 (Currently not suitable)	Land having severe limitations that preclude the given type of use, but can be improved by specific management
	N2 (Permanently not suitable)	Land that have so severe limitations that are very difficult to be overcome

The appraisal of the classes, within an order is done according to evaluation of land limitations. The sub classes reflect the kinds of limitations or the main kinds of improvement measures required within a class. They are indicated by a lower case subscript, for example (erosion-e, drainage-d, rockiness-r) using lower case letters following the Arabic numeral used for the class. The land suitability unit distinguishes types of land having minor differences in management or improvement requirements. The units are distinguished by upper case letters that are placed at the end. There is no limit to the number of units examined within a subclass.

2.8.3 Fertility Capability Classification (Sanchez *et al*., 1982)

Fertility capability classification as postulated by Buol *et al* (1975) and modified by Sanchez *et al* (1982) is a technical soil classification system that focuses quantitatively on the physical and chemical properties of the soil that are important to fertility management. Information required by the system is obtained from soil profile descriptions and associated field data, laboratory analysis data and soil classification. The system does not rank soil, but rather it states the soil properties important to management decisions, which will differ by crop type and management system. The system is applicable to upland and wetland rice crops, pasture, forestry, and agro forestry needs under high- or low-input systems. The system provides management statements for the classified soil and lists the general adaptability of various crops. Sanchez *et al*. (2003), advocated recently the use of FCC for soil quality assessment in tropical regions.

2.8.4 Productivity indices

The most known parametric system is the Storie Index (Storie 1933, 1978), also known as the index of productivity of the University of California (Edwards, 1970) but there is a host of systems and many have provided locally useful results. These are mostly multiplicative indices tied to soil properties and are used for ranking of soils with respect to yield. Soil properties important to favourable rooting depth and available water capacity are the prime choice. Some productivity indices rely on a few critical soil properties such as pH and bulk density to rate soils (Pierce *et al*., 1983; Kiniry *et al*., 1983). Sys *et al*., (1991b) expressed the effects of unfavourable land characteristics on the land production potential using a soil index. The soil index is calculated by multiplying numerical rating values attributed to each characteristic, after matching the collected or measured data with the requirements for the cultivation of a specific crop (Laya *et al*., 1998).

2.9 Choice of Land evaluation methods

The choice of land evaluation method for planning purposes depends on several factors which basically include purpose, scale and cost. If a general purpose evaluation is desired, the land capability classification and its variants may be adopted but when specific land use types are the focus, the land suitability evaluation is usually employed. Studies in Nigeria however have shown that suitability classes derived from generally accepted land evaluation systems could be at variance with real situations in the farmers field (Oluwatosin, 1991). This is because the ratings of land characteristics in these systems sometimes may not agree with its impacts on the actual performance of crops. This necessitates the selection and computation of land characteristics that are relevant to the crop being considered in the farm plot, the ecological zone and the region / country at large (Oluwatosin and Ogunkunle, 1993 and Okusami, 1997)

2:10 Soil Variability

Indices of soil variability that have been employed by various authors include coefficient of variation (CV), variance ratio (F) test, intra – class correlation coefficient (Pi), relative variance (RV) and its compliment (1- RV). The Coefficient of variation effectively gives a measure of the variability of properties concerned within the mapping units and hence of the whole area, the CV of the each property (<15% is low; moderate (15 -35%) and >35% is high while for the each pedon soil property it is expected to be lower than the whole area value, it is measured by (CV = 100 S / X) .The Relative variation measures the variation within the mapping units compared with between the mapping units. For variance ratio test (VRT) - **(**index of heterogeneity between mapping units). This is expressed as the number of parameters that are significantly different, the more properties that are significantly different authenticates the number of profile represented**,** its formula is $VRT = S_2B / S_2w$.

Intra – class Correlation Coefficient (P_1) – formula is $Pi = \frac{S^2 B}{S^2 w + S^2 B}$ this is the index of the predictive capacity of the maps. A $P_1 = 1$. means 100 % accuracy while a value of Pi=0 means zero accuracy, the larger the value of P_1 the greater the predictive capacity of the map. Relative variance (RV) and its Complement (1 – RV). This is an index of the homogeneity within mapping units, hence the smaller the values the more homogenous are the mapping units. High variability within the mapping units >0.5 is an indication of likely poor field mapping, poor definition of mapping units, laboratory errors, restrictions of map scale, landscape complexity (Olaniyan, 2003). The following are some of the scientists that have employed the use of the various indices of soil variability: Beckett and Webster

(1971). Wilding and Drees (1978), Umweni (1985), Areola (1982),Ogunkunle (1986), Ogunkunle (1989), Olaniyan and Ogunkunle (2007), Tabi and Ogunkunle (2007) and Obi *et al* (2010).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Areas:

This study was carried out in Owan East Local Government Area of Edo State, located within latitudes 6.45 ° and 7.15°N and longitudes 5.40 ° and 6.10 ° E. It has vegetation comprising of Woodland and tall grass savannah. Parent material is of mixed geological composition of Older granite, undifferentiated meta- sediments, Undifferentiated Basement complex and Imo clay shale group. It has a land area of about 123,434.5 ha and an annual mean rainfall of about 1507mm.

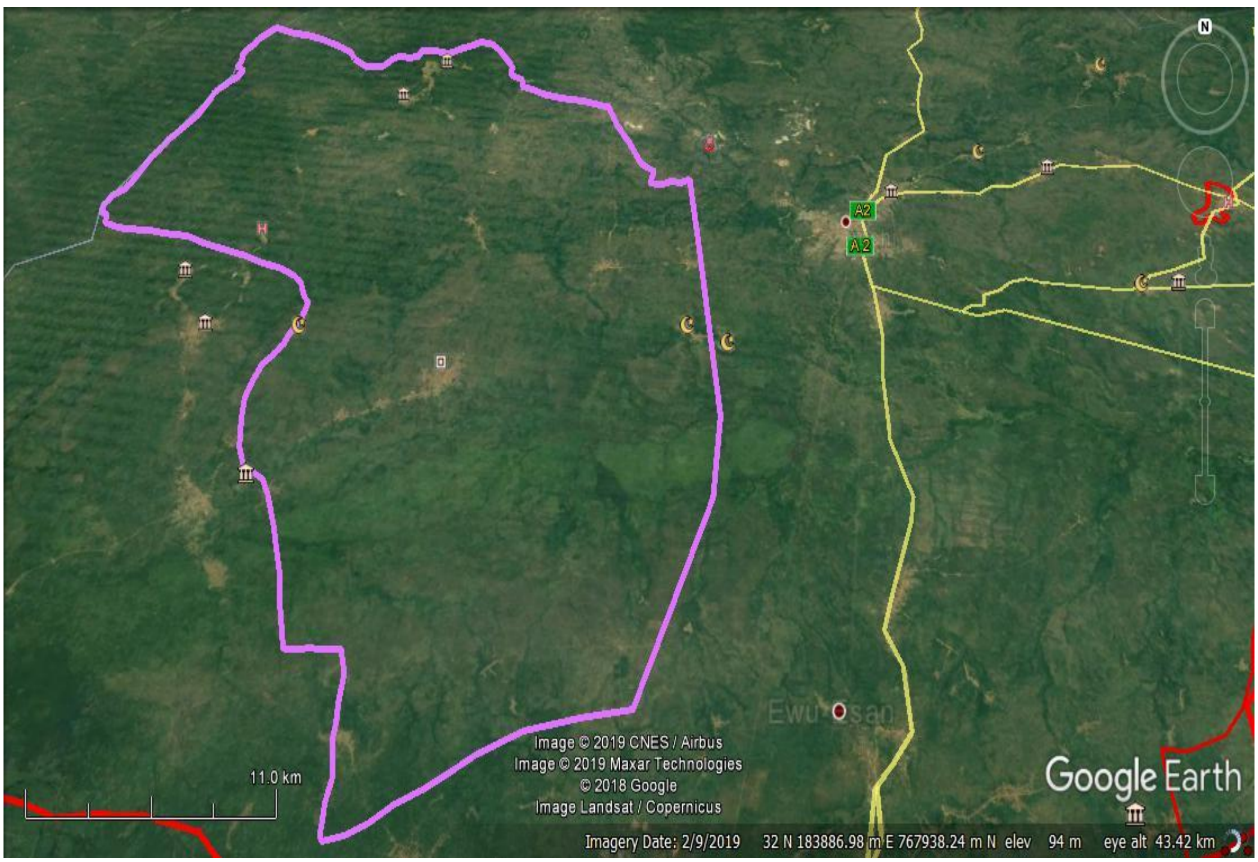

Figure 3: 1: Google imagery of Owan East Local Government Area of Edo State (verged purple).

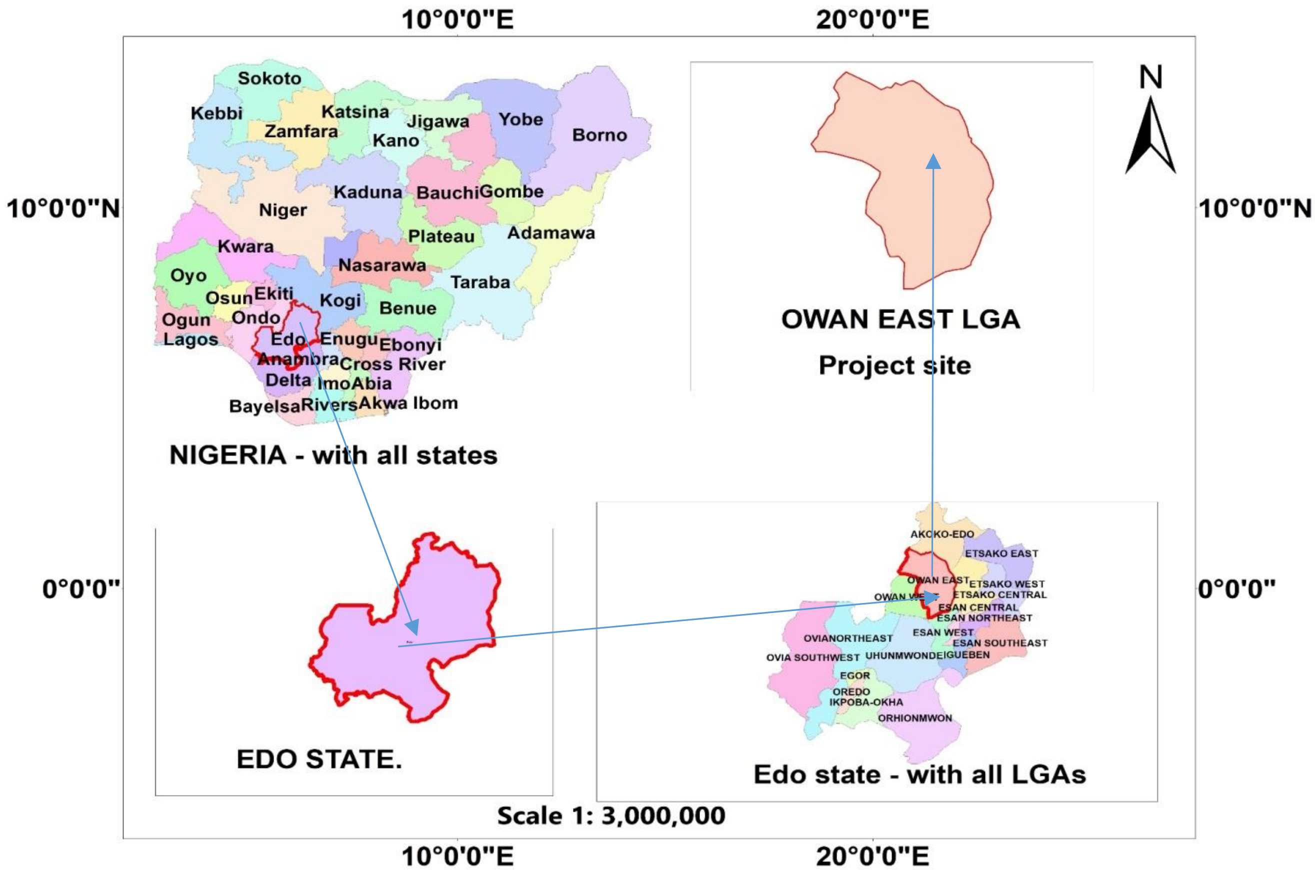

Figure 3: 2: Location map showing the study site.

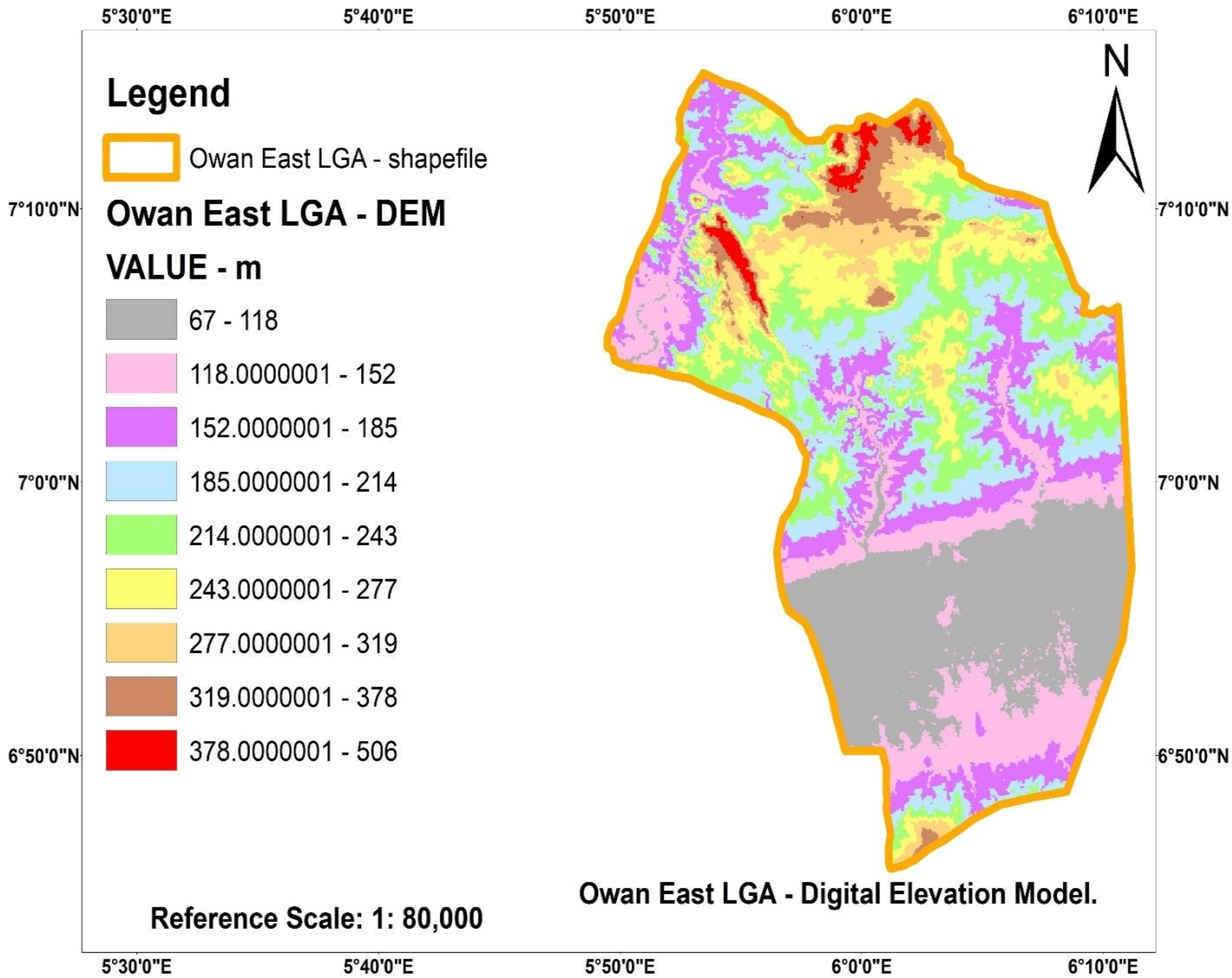

Figure 3:3: Digital Elevation model - DEM (created from the SRTM of Nigeria) of the Area

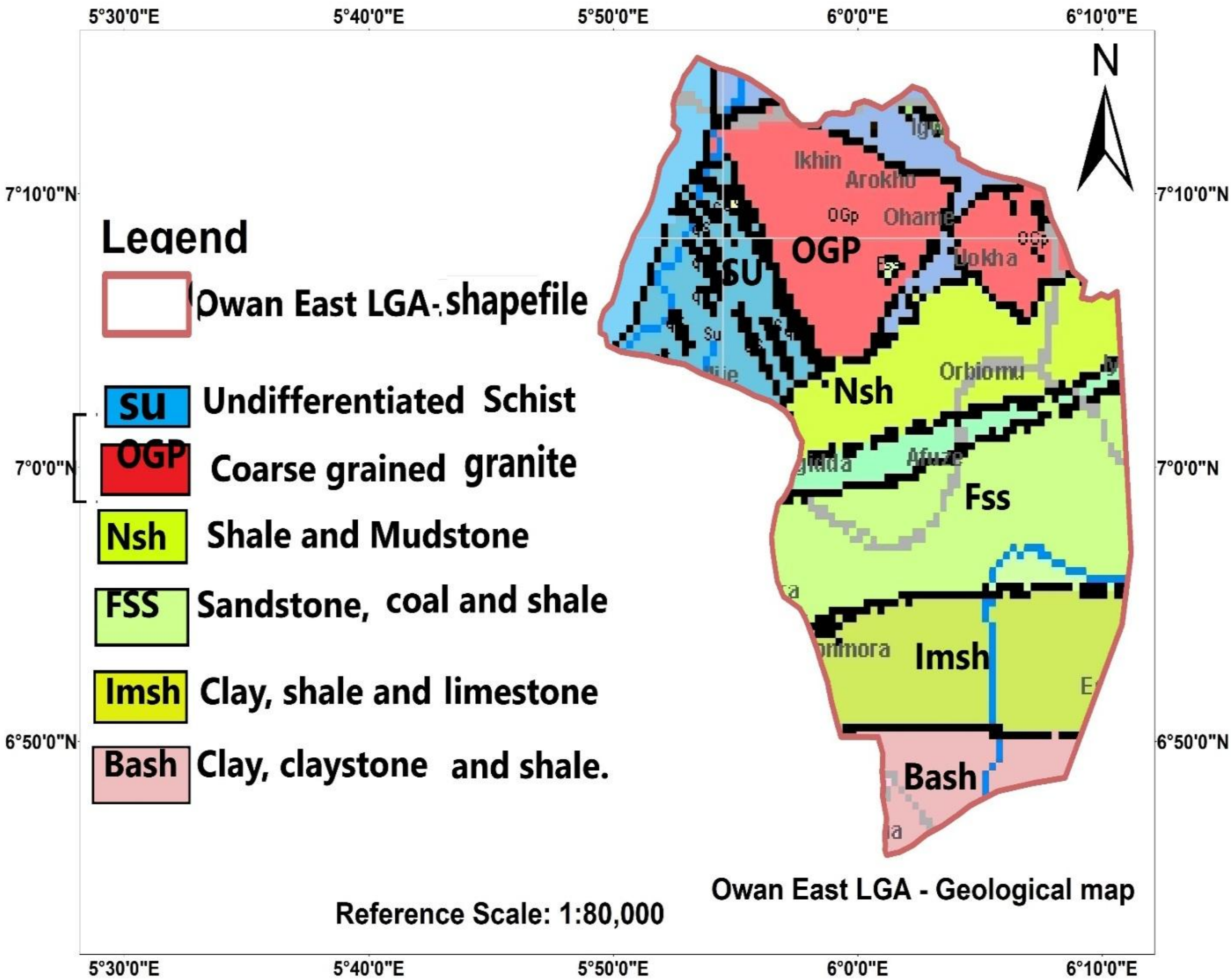

Figure. 3: 4: Geological map of study site (Culled from Geological map of Nigeria)

Figure 3: 5 1985 FDALR – Soil map of Bendel State.

3.2 Soil Survey:

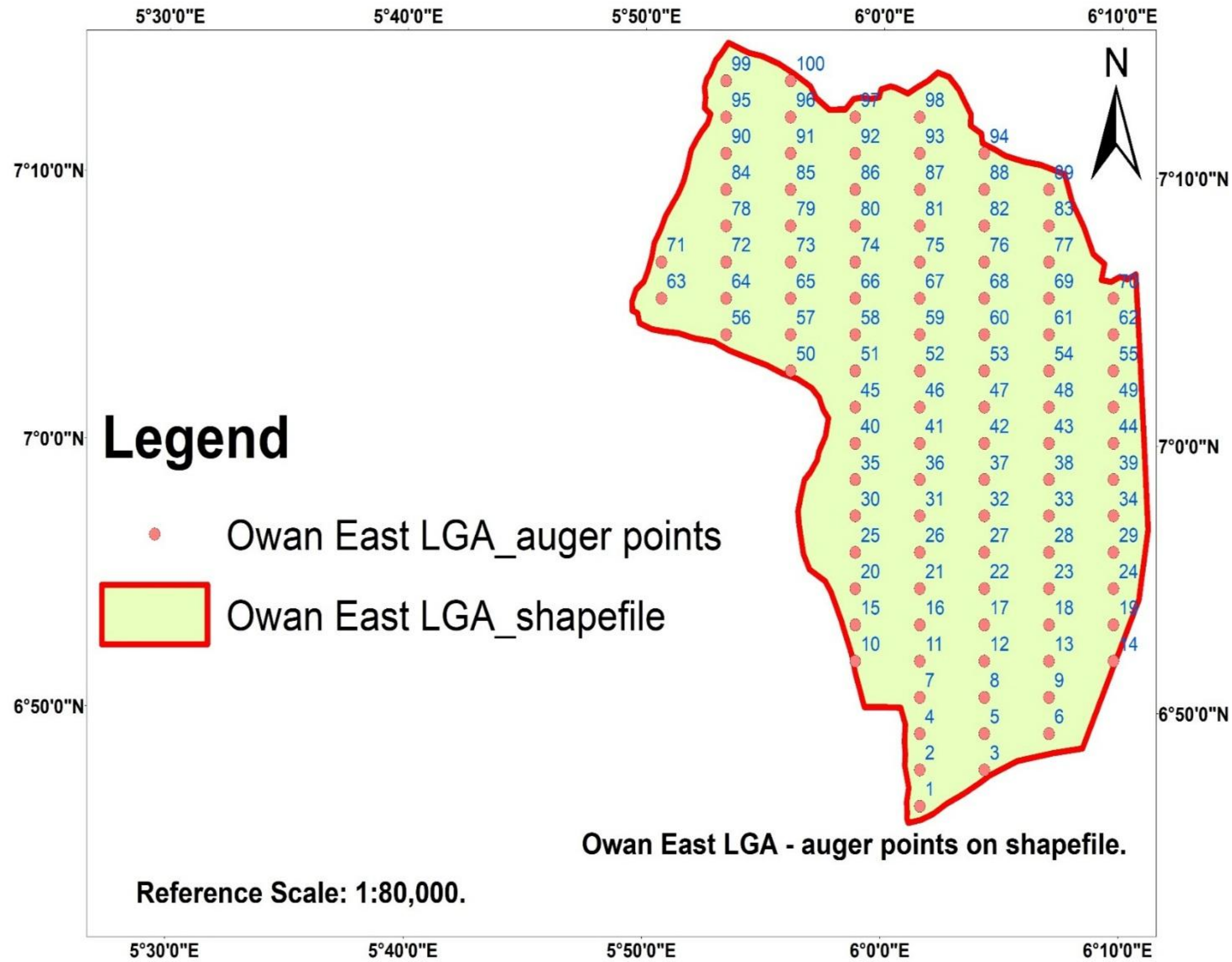

Figure. 3:6 Owan East LGA Shapefile with auger point positions

The area of about 123,434.5 ha was mapped at a reconnaissance level on a scale of 1: 250,000 (Dent and Young, 1981) giving 100 auger sampling points which were examined at 0- 30, 30- 60, 60-90 and 90-120 cm depths for morphological properties such as colour, texture, consistency etc. Based on similarities in morphological properties, topographical positions in the landscape and other features of soil formation importance, six mapping units were identified. 2m x 2m x2m profile pits were sunk at representative points for each mapping unit and described according to the procedure described in the Guidelines for Soil profile description (FAO, 2006). Samples were collected from two to three points in the pedogenic horizons and bulked - from bottom upwards. Similarly, the RRIN site of 17.71ha was surveyed using free survey method and had 24 sampling points and three mapping units identified.

The 1985 version of the soil map of Owan East LGA was extracted from the 1985 FDALR soil map by georeferencing, digitization and masking using Arcmap 10.3 software.

3.3 Laboratory Analysis.

The soil samples were air dried and passed through a 2mm sieve and then analyzed for their various properties using the following standard procedures:

Particle size analysis was carried out using Bouyoucous hydrometer method (Gee and Bander 1986; Gee and Or, 2002).

Bulk density was determined by a ratio of the dry mass to volume from the undisturbed core samples (Grossman and Reinsch, 2002).

The soil pH was determined using a 1:1 soil to water suspension and in calcium chloride using glass electrode pH meter (Maclean, 1982).

Available phosphorus was determined by Bray P.I solution (Anderson and Ingram, 1993).

Total Nitrogen was determined by micro-Kjedahl method (Bremmer and Mulvaney, 1982).

Organic carbon was determined by wet dichromate acid oxidation method (Nelson and Sommers, 1982).

Exchangeable acidity was extracted with 1N KCl and determined titrametrically (Anderson and Ingram, 1993).

Exchangeable bases was extracted with 1N NH_4OAc buffered at pH 7.0, K and Na was read on EEL flame photometer and Ca and Mg by EDTA titration (IITA, 1978).

The Effective Cation Exchange Capacity (ECEC) was determined by the summation of exchangeable bases and exchangeable acidity (Tan, 1996).

Percentage Base Saturation (B.S %) was calculated as the sum of bases divided by ECEC and then multiplied by 100.

Extractable micronutrients (Fe, Cu, Mn and Zn) was obtained by leaching the soil with 0.1N HCl and the concentration of the elements determined by the Atomic Absorption Spectrophotometer.

3.4 Soil Classification

Based on profile description and laboratory analysis, the soils were classified using guidelines of USDA Soil Taxonomy (Soil Survey Staff, 2010) , World Reference Base for soil resources (FAO, 2006) and the local classification (Soil Series) using Smyth and Montgomery (1962). Soil maps were produced for the study area which showed the distribution and extent of the different mapping units.

3.5 Crops selected for the suitability study:

1. Tree crops – Rubber *(Hevea brasiliensis)*

   Oil palm *(Elaeis guineensis)*

   Cocoa *(Theobroma Cacao)*

2. Arable crops - Maize *(Zea mays L.)*

   Cassava *(Manihot esculenta)*

3.6 Land Evaluation

The suitability of the soils for Rubber, Oil palm, cocoa, maize and cassava were evaluated according to the modified FAO Framework (FAO, 2007). The Conventional Non- Parametric Approach was the suitability method used for this study. It involved determining suitability classes by matching the soil characteristics with land requirement for Rubber, Palm oil, Cocoa, Maize and Cassava (Appendice 11-15) respectively using the suitability criteria of Sys (1985) as modified by Orimoloye and Akinbola (2013) for rubber; Senjobi and Ogunkunle, (2010) for Oil Palm; Fasina *et al*, (2007) for Cocoa; Sys (1985) and Verdoodt and Van Ranst (2003) for both Maize and Cassava. The suitability class (aggregate) of a pedon is that indicated by the most limiting factor (FAO, 1984).

3.7 Data Analysis: This was done using descriptive statistics involving multiple comparison of pedon soil properties using SPSS because of unequal pedon horizons/layers. Anova results were employed in the calculation of soil variability indices as follows:

3.7.1 Coefficient of variation (CV), given as:

$$CV = 100\, S/ X$$

Where S= Standard deviation

X = Mean

3.7.2 Intra – class correlation coefficient (Pi)

$$Pi = \frac{S^2 B}{S^2 w + S^2 B}$$

Where, Pi = intra – class correlation coefficient

$S^2 B$ = the between –unit variance

$S^2 w$ = the within – unit variance

But for more than 2 classes and unequal sizes, Webster (1971)'s modification applied:

$$Pi = \frac{b - w}{b + w (a_0 - 1)}$$

$$a_0 = \frac{1}{m-1} \left(n - \frac{\sum_{i=1} ai^2}{n} \right)$$

where b = between class mean square

w = within class mean square

m = number of classes

n = total number of samples taken from all the classes

ai = the different number of samples that make up the individual classes.

3.7.3 The Variance ratio (F) test (VRT), at $p < 0.05$ which is given as

$$VRT = \frac{S^2 B}{S^2 w}$$

Where $S^2 B$ = the between –unit variance

$S^2 w$ = the within – unit variance

3.7.4 Relative variance (RV) and its compliment (1- RV), given as

$$RV = \frac{S^2 w}{S^2 T}$$

Where, $S^2 w$ is variance pooled within mapping unit

$S^2 T$ is the total variance of soil property

RV was calculated for each property. using the results from ANOVA.

1 – RV may be regarded as the proportion of the total variance accounted for by mapping (Ogunkunle and Chikezie, 1990). Hence, 1 – RV =1 gives a perfect mapping and 1-RV = 0, means a worthless map.

CHAPTER FOUR

4.0 RESULTS

The results of the Soil survey and classification of Owan East LGA (project site) in 1985, 2019 and RRIN outstation are in Table 4.1.

4.1 Classification

Table 4:1: Particle size, chemical properties and classification of the 1985 study of Owan East LGA

M.U	pH	O.C	N	P	Ca	Mg	Na	K	CEC	Clay	Silt	Sand	T.C	USDA
		← gkg^{-1} →		$mgkg^{-1}$	←		($cmol\ kg^{-1}$)		→	←	($g\ kg^{-1}$) →			
CP 6	4.8	1.44	0.175	8.80	0.28	0.08	0.05	0.02	4.75	100.0	77.0	823	LS	Lithic
	5.9	0.48	0.088	6.50	0.70	0.30	0.03	0.12	19.23	130.0	17.0	853	LS	Haplustalf
CP 2	4.5	1.92	0.188	17.20	1.04	0.06	0.04	0.08	2.80	100.0	67.0	833	LS	
	5.9	0.92	0.088	6.10	2.30	0.80	0.04	0.03	4.50	180.0	67.0	753	SL	Typic
	4.9	0.76	0.064	5.60	1.65	0.50	0.05	0.03	4.75	157.0	57.0	786	LS	Paleustalf
	5.0	0.84	0.063	5.60	0.71	0.08	0.02	0.08	4.50	170.0	47.0	783	SL	
	5.7	0.24	0.023	4.80	0.88	0.03	0.03	0.02	3.50	100.0	67.0	873	SL	
	5.7	0.24	0.023	5.00	0.70	0.04	0.03	0.05	3.60	116.0	57.0	887	SL	

CP 2. CP 6 : The identified mapping units; T.C – textural class

Source: FDALR (1985)

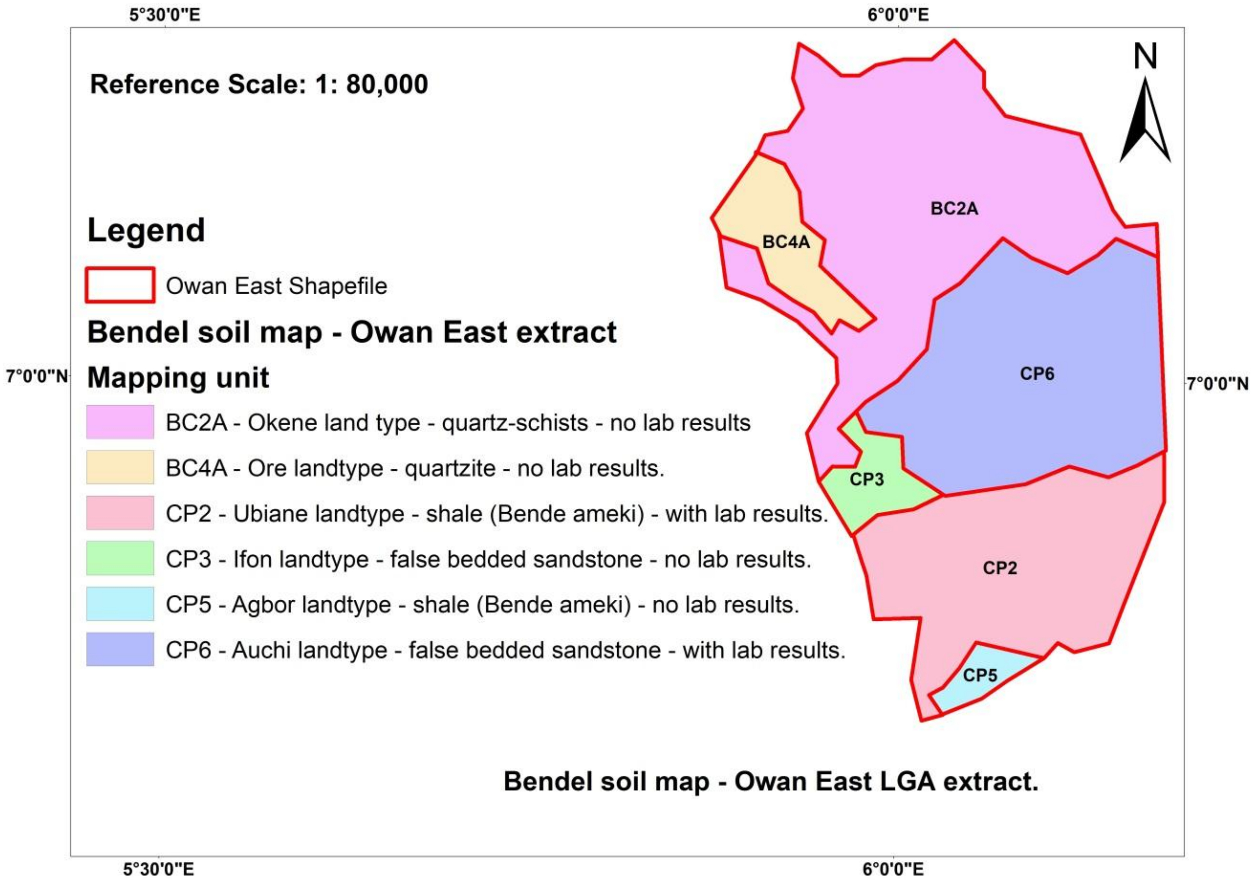

Figure. 4:1.Soil map of Bendel State – Owan East LGA extract.

Source: FDALR (1985)

Table 4: 2: Chemical Properties of the six mapping unit of Owan-East LGA - 2019

Profile no	Depth	pH	E.C	O.C	N	P	Ca	Mg	Na	K	H	Al	ECEC	B.S	Fe	Zn	Cu	Mn
	(cm)		µScm^{-1}	← gkg^{-1} →		mgkg^{-1}	← cmolkg^{-1} →							(%)	← mgkg^{-1} →			
1 Ap	0 -26	6.9	73.00	0.89	0.06	2.32	6.96	1.07	0.40	0.40	0.40	-	9.23	95.66	64.00	1.88	0.47	10.46
Bt1	26 -85	5.8	32.00	0.75	0.05	2.00	3.26	0.88	0.16	0.16	0.70	-	5.16	86.43	50.50	1.83	0.08	8.74
Bt2	85 -139	4.7	25.00	0.29	0.01	0.75	1.23	0.40	0.14	0.14	0.60	0.55	3.06	62.41	36.57	1.05	.030	1.56
2 Ap	0 -16	6.4	208.00	1.41	0.12	7.33	3.56	0.96	0.36	0.12	0.40	-	5.40	92.59	0.72	10.20	1.14	ND
AB	16 -42	5.8	73.50	0.48	0.03	4.35	2.48	0.72	0.35	0.07	0.30	-	3.92	92.35	0.43	9.42	0.87	ND
Bt1	42 -92	5.3	74.50	0.45	0.02	3.36	1.68	0.58	0.34	0.05	0.30	-	2.95	89.83	0.39	7.85	0.73	ND
Bt2	92 -180	4.7	44.10	0.16	0.01	2.91	1.44	0.32	0.33	0.03	0.20	-	2.32	91.38	0.27	7.06	0.52	ND
3 Ap	0 -30	6.3	395.00	2.00	1.13	10.12	3.12	1.04	0.47	0.32	0.50	-	5.45	90.83	3.09	26.68	1.41	2.29
AB	30 -70	6.0	243.00	0.59	0.04	2.49	2.64	0.96	0.43	0.10	0.30	-	4.43	93.23	1.49	19.61	1.25	2.05
Bt1	70 -127	5.7	522.00	0.45	0.03	2.30	2.08	0.72	0.37	0.08	0.30	-	3.55	91.55	1.28	13.30	1.02	ND
	127- 180	4.8	650.00	0.32	0.02	2.12	1.52	0.48	0.36	0.05	0.20	-	2.61	92.34	0.63	9.42	0.85	ND
4 Ap	0 -11	6.8	296.00	2.11	0.13	1.28	8.32	2.16	0.28	0.28	0.20	-	11.24	98.22	22.13	5.75	2.57	45.89
AB	11 – 67	6.6	112.00	0.58	0.04	1.20	5.60	1.44	0.23	0.13	0.30	-	7.70	96.10	25.46	3.24	0.52	9.99
B1	67 -124	4.5	74.00	0.26	0.02	1.07	2.00	0.88	0.18	0.07	0.70	-	3.83	81.72	24.27	1.57	0.05	1.09
B2	124 -180	4.4	72.00	0.11	0.008	0.40	0.96	0.64	0.17	0.05	0.30	0.70	2.82	64.54	21.70	1.26	0.06	0.67
5 Ap	0 -17	7.1	247.00	2.14	0.26	11.16	13.04	4.48	0.46	0.44	0.10	-	18.52	99.46	81.35	8.89	5.37	61.50
Bt1	17 -58	6.7	95.00	0.83	0.06	9.01	4.80	3.12	0.44	0.30	0.30	-	8.96	96.65	64.59	4.76	1.24	32.37
Bt2	58 -88	6.3	81.00	0.64	0.04	5.43	3.60	2.96	0.30	0.16	0.40	-	7.42	94.60	69.04	3.61	0.34	31.22
Bt3	88 -120	6.2	67.00	0.26	0.02	0.27	3.28	2.72	0.28	0.11	0.50	-	6.89	92.74	66.64	3.50	0.68	25.44
6 Ap	0-12	7.4	284.00	3.36	0.22	2.62	15.44	5.20	0.26	0.26	0.20	-	21.36	99.06	64.68	14.65	0.14	42.30
Bt1	12 – 36	7.1	272.00	0.86	0.06	1.16	13.20	4.96	0.21	0.20	0.20	-	18.77	98.93	111.41	10.20	0.24	24.66
B	36 -72	6.8	172.00	0.51	0.04	0.72	12.80	3.48	0.20	0.19	0.20	-	16.87	98.81	160.80	10.15	2.04	9.68
Bt21	72 -109	6.5	130.00	0.48	0.04	0.64	11.96	2.80	0.18	0.15	0.30	-	15.39	98.05	96.80	9.89	4.85	9.05
Bt22	109 -145	6.4	95.00	0.26	0.02	0.47	11.44	1.92	0.17	0.07	0.40	-	14.00	97.14	40.93	8.74	17.58	7.81
Bt23	145 -180	5.8	56.00	0.10	0.01	0.12	9.28	1.84	0.16	0.06	0.40	-	11.74	96.59	84.84	6.38	11.11	6.09

Table 4:3: Selected Physical Properties of the six mapping units of Owan-East LGA

Profile no		Depth	Clay	Silt	Sand	T.C	Gravel	Ksat	B.D
			←	gkg-1	→				
1	Ap	0 -26	58.00	35.00	907.00	S	7.09	16.72	2.42
	Bt1	26 -85	232.00	56.00	712.00	SCL	64.42	7.39	1.68
	Bt2	85 -139	240.00	52.00	708.00	SCL	77.15	8.27	1.37
2	Ap	0 -16	64.00	34.00	902.00	S	0.64	5.80	1.60
	AB	16 -42	107.00	19.00	874.00	LS	-	1.50	1.70
	Bt1	42 -92	198.00	550.00	252.00	SiL	-	3.10	1.60
	Bt2	92 -180	195.00	600.00	205.00	SiL	-	2.80	1.60
3	Ap	0 -30	400.00	100.00	500.00	SC	13.19	37.50	1.30
	AB	30 -70	398.00	101.00	501.00	SC	22.27	0.50	1.50
	Bt1	70 -127	503.00	100.00	397.00	C	35.27	0.40	1.60
		127- 180	521.00	80.00	399.00	C	33.60	0.30	1.70
4	Ap	0 -11	43.00	35.00	922.00	S	0.92	9.50	1.48
	AB	11 – 67	68.00	20.00	912.00	S	-	5.63	1.48
	B1	67 -124	108.00	15.00	877.00	LS	-	18.12	1.58
	B2	124 -180	117.00	11.00	872.00	LS	-	14.78	1.76
5	Ap	0 -17	43.00	40.00	917.00	S	61.01	3.69	1.68
	Bt1	17 -58	143.00	30.00	827.00	LS	56.89	2.28	1.98
	Bt2	58 -88	178.00	15.00	807.00	SL	65.60	-	1.88
	Bt3	88 -120	213.00	10.00	777.00	SCL	58.56	-	-
6	Ap	0-12	53.00	55.00	892.00	S	26.01	0.15	1.66
	Bt1	12 – 36	107.00	30.00	863.00	LS	74.56	2.86	1.91
	B	36 -72	138.00	25.00	837.00	LS	55.60	21.12	2.11
	Bt21	72 -109	173.00	21.00	806.00	SL	-	0.07	1.78
	Bt22	109 -145	198.00	16.00	786.00	SL	-	1.93	1.71
	Bt23	145 -180	261.00	11.00	728.00	SCL	-	3.16	1.20

1:T.C –textural class: 2: B.D – bulk density

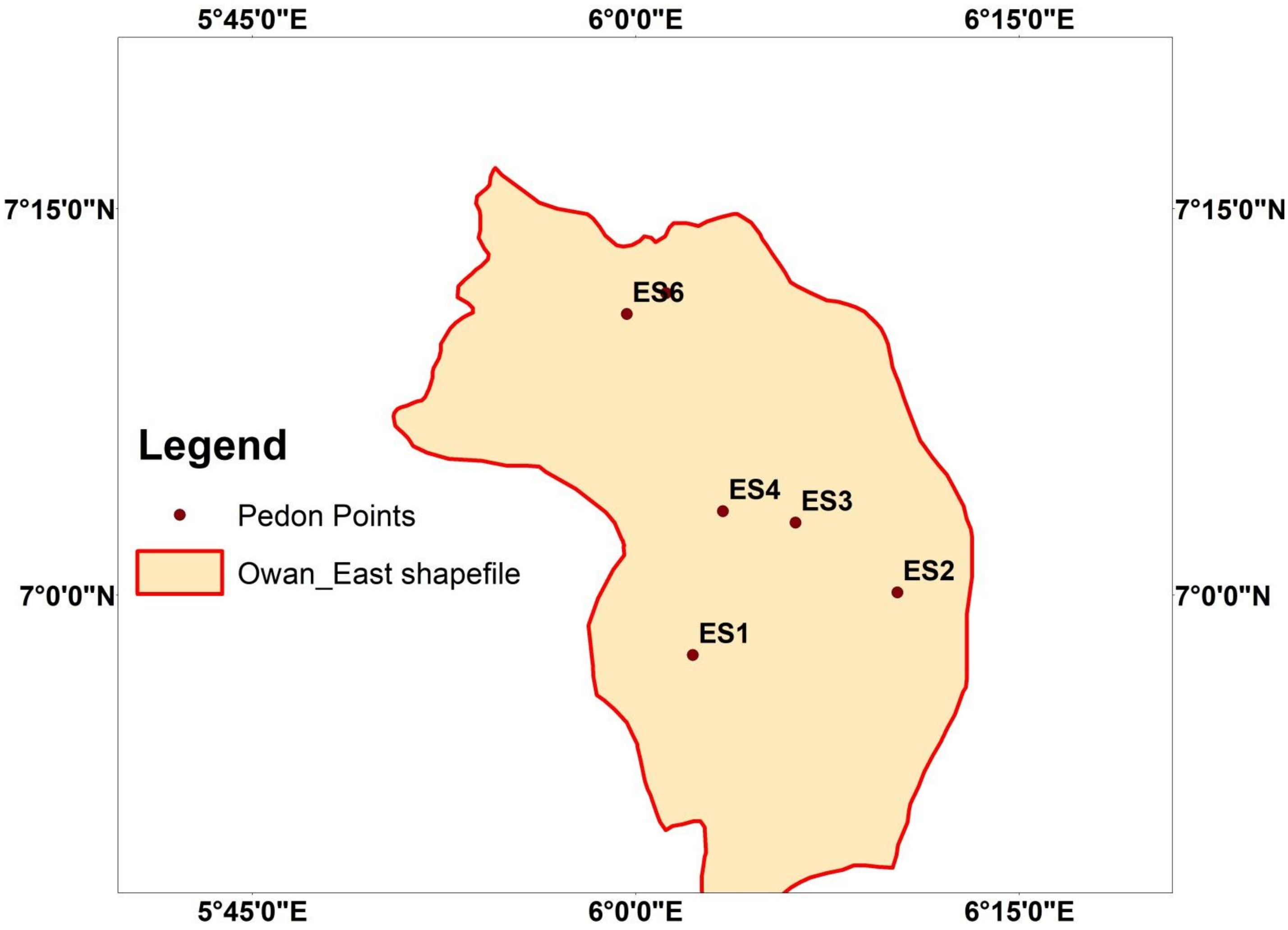

Figure 4:2: Pedon Points

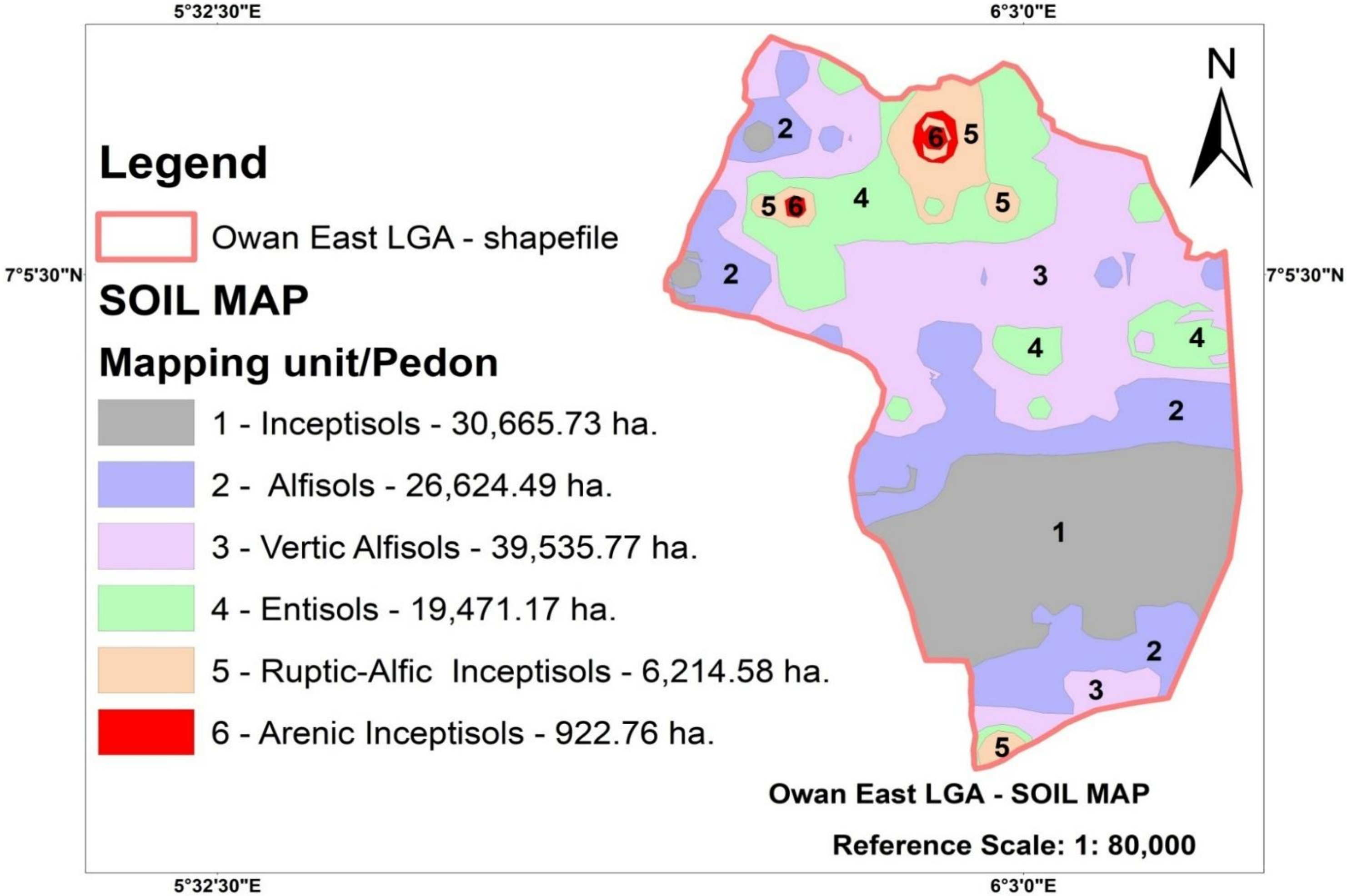

Figure 4:3: Soil map of Owan East LGA – 2019

THE TYPICAL SOILS OF THE SIX MAPPING UNITS

PEDON 1 Lower slope, seasonally poor, light to medium in texture. Parent material is Sandstone, Coal shale, Ruptic –Ultic Dystrudept, - 30,665.73 ha

PEDON 2 Mid lower slope, somewhat poorly drained, sand to silty loam. Parent material Sandstone, coal shale, Rhodic Kandiudalf, - 26,624.49 ha

PEDON 3 Mid slope, fairly well drained, heavy texture (sandy clay to clay). Parent material shale,mudstone, - .Aquic Kandiudalf - 39,535.77 ha

PEDON 4 Mid slope, Excessively drained, Sand to loamy sand. Parent material Quartz / Schist, - Mollic Udarent, - 19,471.17 ha

PEDON 5 Upper slope, moderately well drained, light to middle texture (sand to sandy loam). Parent material quartz / undifferentiated Schist, - Ruptic – Alfic Eutrudept - , 6,214.58 ha

PEDON 6 Upper slope, well drained, light to medium texture (sand to sandy clay loam). Parent material Quartz grained granite, - Arenic Eutrudept - , 922.76 ha

Table 4: 4: Classification of the soils of Owan East LGA – 2019.

M.U	Soil Taxonomy	Soil WRB	mapping unit area(ha)	Percentage (%)
1	Ruptic–Ultic Dystrudept	Haplic Petroplinthic Cambisol (Skeletic Densic)	30,665.73	24.8
2	Rhodic Kandiudalf	Vertic Lixisol (Rhodic, Siltic)	26,624.49	21.6
3	Aquic Kandiudalf	Gleyic Vetic Lixisol (Clayic, Oxyaquic)	39,535.77	32.0
4	Mollic Udarent	Ferralic Rubic Arenosol (Hyperochric, Dystric)	19,471.17	15.8
5	Ruptic–Alfic Eutrudept	Haplic Petroplinthic Cambisol (Skeletic Eutric)	6,214.58	5.0
6	Arenic Eutrudept	Haplic Pisoplinthic Cambisol (Chromic, Calcaric)	922.76	0.7

M.U; mapping unit

Figure.4.2 and Table 4.4 describe the soils of the Project site in terms of location, distribution, classification and areal coverage. The soils are majorly Alfisols/Lixisols,(occupying 66,160.26 ha), Inceptisols/Cambisols (37,803.07 ha) and Entisols/Arenosols.(19,471.17 ha) expressed in six mapping units and represented by six pedons as described and shown below.

MAPPING UNIT 1

The soils of this area occupies approximately 30,665.73 hectares of the study area. They are characterized by pale brown colour (10YR $^{6}/_{3}$) at the surface horizon and dark red (10R $^{3}/_{6}$) at the subsurface horizon with sandy surface overlying sandy clay loam subsurface. The soil increase in clay content with increasing depth. The soil structure is granular at the surface and platy at the subsurface horizons and extremely stony at the subsurface. The soil s well drained, with about 7. 09% gravel content and presence of concretion at the subsurface horizons, with few mixed roots at d surface to no roots at the subsurface horizons. The bulk density of the soils range from 2.41g/cm^3 at the surface to 1.36 g/cm^3 at the subsurface. Hydraulic conductivity (Ks) range between 16.72 cm^3/hr at the surface to 8.27 cm^3/hr at sub-surface horizon with no define sequence in its distribution within the profile. The soils firm to extremely firm in consistencies with wavy clear boundary at the surface to broken diffuse subsurface horizons and absence of mottles. The organic carbon (OC) content of the soils of this mapping unit was generally low and ranged from 0.89% to 0.29% but it decreased regularly with increase in soil depth. Similarly, the total nitrogen Is low, the value decreased down the profile and range from to 0.061% to 0.014%. The reaction of the soils of this mapping unit range from (pH 4.7 to 6.9) and the base saturation range from 62.41 to 95.67%. The calcium (Ca) content of the soils Is moderate (6.96 cmol/kg to 1.23 cmol/kg) but decrease down the profile while the quantity of the exchangeable magnesium (Mg) is high with a range of (1.07 cmol/kg to 0.40 cmol/kg) and it decrease regularly with increasing soil depth. The exchangeable potassium (K) present in the soils is low (0.40 cmol/kg) at the surface and very low (0.14 cmol/kg) at the subsurface. Similarly, the available phosphorus (P) content of the soils of this mapping unit is very low on the surface (2.32 mg kg^{-1}) to (0.75 mg/kg) at the subsurface horizon. The value decrease regularly with increasing soil depth.

Plate 1: Pedon 1

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MAPPING UNIT 2

The soils of this area occupies approximately 26,624.49 hectares of the study area. The soils is very deep and are characterized by black colour (10YR 2/1) at the surface horizon and red (2.5 4/8) at the subsurface horizon with sand, loamy sand surface texture to silty loam sub surface. The soil clay content increases with depth. The soil structure is blocky in the surface and platy down the profile and many mixed roots at the first two horizons. The soil is poorly drained, with about 0.64% gravel content and no concretion. The bulk density of the soils range from 1.7g/cm3 at the surface to 1.6g/cm3 at the subsurface. Hydraulic conductivity (Ks) range between 5.8 cm3/hr at the surface to 1.5 cm3/hr at sub-surface horizon with an irregular pattern down the profile. The soils are loose to firm in consistencies with clear smooth boundary at the surface to wavy diffuse subsurface horizons and no mottles. The organic carbon (OC) content of the soils of this mapping unit is generally low and range from 1.41% to 0.16% but it decrease regularly with increase in soil depth. Similarly, the total nitrogen is low, the value decrease down the profile and range from to 1.122% to 0.010%. The reaction of the soils of this mapping unit range (pH 4.7 to 6.4) and the base saturation > 89%. The calcium (Ca) content of the soils is moderate (3.56 cmol/kg to 1.44 cmol/kg) but decrease down the profile while the quantity of the exchangeable magnesium (Mg) is high with a range of (0.96 cmol/kg to 0.32 cmol/kg) and it decrease regularly with increasing soil depth. The exchangeable potassium (K) present in the soils is low (0.12 cmol/kg) at the surface and very low (0.03 cmol/kg) at the subsurface. Similarly, the available phosphorus (P) content of the soils of this mapping unit is 7.33 mg kg-1 at the surface and 2.91 mg/kg at the subsurface horizon. The value decrease regularly with increasing soil depth.

Plate 2: Pedon 2

MAPPING UNIT 3

The soils of this area occupies approximately 39,535.77 hectares of the study area. The soils are very deep and are characterized by black colour (10YR 2/1) at the surface horizon and light gray (10R 7/1) at the subsurface horizon with sandy clay to clay texture all through the profile. The soil increase in clay content with increasing depth. The soil structure is sub angular blocky in all the horizons and many coarse roots at the surface. The soil is fairly well drained, with about 13. 09% gravel content and no concretion. The bulk density of the soils range from 1.3g/cm3 at the surface to 1.7 g/cm3 at the subsurface. Hydraulic conductivity (Ks) range between 37.5 cm3/hr at the surface to 0.3 cm3/hr at sub-surface horizon with a regular pattern down the profile. The soils firm to extremely firm in consistencies with wavy clear boundary at the surface to wavy diffuse subsurface horizons and presence of mottles from the top to the third horizon. The organic carbon (OC) content of the soils of this mapping unit range from 2.0% to 0.32% but it decrease regularly with inscrease in soil depth. Similarly, the total nitrogen is low, the value decrease down the profile and range from 1.131% to 0.023%. The reaction of the soils of this mapping unit range (pH 4.8 to 6.3) and the base saturation > 90%. The calcium (Ca) content of the soils is moderate (3.12 cmol/kg to 1.52 cmol/kg) but decrease down the profile while the quantity of the exchangeable magnesium (Mg) is high with a range of (1.04 cmol/kg to 0.48 cmol/kg) and it decrease regularly with increasing soil depth. The exchangeable potassium (K) present in the soils was low (0.32 cmol/kg) at the surface and very low (0.05 cmol/kg) at the subsurface. Similarly, the available phosphorus (P) content of the soils of this mapping unit is 10.12 mg kg-1 at the surface and 2.12 mg/kg at the subsurface horizon. The value decrease regularly with increasing soil depth.

Plate 3 : Pedon 3

MAPPING UNIT 4

The soils of this area occupies approximately 19,471.17 hectares of the study area. They are characterized dark reddish brown colour (5YR 3/1) at the surface horizon and Yellowish red (5YR 4/6) at the subsurface horizon with sandy surface overlying loam sand subsurface. The soil increase in clay content with increasing depth. The soil structure was crumbs at the surface and sub-angular blocky at the subsurface horizons. The soils were well drained, with about 0.92% gravel content and no concretion from the surface to the subsurface horizons, with many mixed roots at the surface to no roots at the subsurface horizons. The bulk density of the soils range from 1.48g/cm3 at the surface to 1.76 g/cm3 at the subsurface. Hydraulic conductivity (Ks) range between 9.5 cm3/hr at the surface to 18.12 cm3/hr at sub-surface horizon with no define sequence in its distribution within the profile. The soils are loose to friable in consistencies with smooth clear boundary both at the surface and subsurface horizons and absence of mottles. The organic carbon (OC) content of the soils of this mapping unit is generally low and range from 0.11% to 2.11% but it decrease regularly with increase in soil depth. Similarly, the total nitrogen is low, the value decreased down the profile and range from to 0.134% to 0.008%. The reaction of the soils of this mapping unit range (pH 4.4 to 6.8) and the base saturation is > 90%. The calcium (Ca) content of the soils is moderate (8.32 cmol/kg to 0.96 cmol/kg) but decrease down the profile while the quantity of the exchangeable magnesium (Mg) is high with a range of (2.16 cmol/kg to 0.64 cmol/kg) and it decrease with increasing soil depth. The exchangeable potassium (K) present in the soils is low (0.28 cmol/kg) at the surface and very low (0.05 cmol/kg) at the subsurface. Similarly, the available phosphorus (P) content of the soils of this mapping unit is very low on the surface (1.28 mg kg-1) to (0.40 mg/kg) at the subsurface horizon. The value decrease regularly with increasing soil depth.

Plate 4: Pedon 4.

MAPPING UNIT 5

The soils of this mapping unit occupies approximately 6,214.58 ha of the study area. They are characterized by Black (5YR 2.5/1) at the surface horizon and dark reddish brown (5YR 3/4) at the subsurface horizon with sandy clay surface over lying sandy loam subsurface. The soil increase in clay content with increasing depth. The soil structure is crumb at the surface and sub-angular blocky to platy at the subsurface horizons. The soils are moderately drained, with < 65% gravel content and concretion from the surface to the subsurface horizons. The bulk density of the soils range from 1.68 g/cm3 at the surface and it increase with increasing depth to 1.88 g/cm3. Hydraulic conductivity (Ks) range between 3.69cm3/hr at the surface to 2.28 cm3/hr at sub-surface horizon. The soils are loose to firm in consistence and there were no presences of mottles in all the horizons. The organic carbon (OC) content of the soils of this mapping unit is generally low and range from 0.26% to 2.14% but it decrease regularly with increase in soil depth. Similarly, the total nitrogen is low, the value decreased down the profile and range from to 0.021% to 0.264%. The reaction of the soils of this mapping unit range from slightly acidic to neutral (pH 6.20 to 7.10) and the base saturation is > 90%. The calcium (Ca) content of the soils is low to moderate (3.28 cmol/kg to 13.04 cmol/kg) but decrease down the profile with increase depth while the quantity of the exchangeable magnesium (Mg) is high (2.72 cmol/kg) to very high (4.48 cmol/kg) and it decrease down the profile with increase depth. The exchangeable potassium (K) present in the soils is very low (0.11 cmol/kg) at the subsurface and high (0.44 cmol/kg) at the surface. Similarly, the available phosphorus (P) content of the soils of this mapping unit is low on the surface (11.16 mg kg-1) and very low (0.27 mg/kg) at the subsurface horizon. The value decrease regularly with increasing soil depth.

Plate 5: Pedon 5

MAPPING UNIT 6

The soils of this mapping unit occupy approximately 922.76 hectares of the study area, the soils are very deep. They are characterized by very dark grayish brown colour (10YR 3/2) at the surface horizon and dark gray (7.5YR 4/1) at the subsurface horizon with sand surface over lying sandy clay loam subsurface. The soil increase in clay content with increasing depth. The soil structure was crumbs at the surface and sub-angular blocky at the subsurface horizons. The soils are well drained, with 75% gravel content and no concretion from the surface to the subsurface horizons. The bulk density of the soils range from 1.66 g/cm3 to 2.11 g/cm3 in the profile and followed an irregular pattern. Hydraulic conductivity (Ks) range between 0.07 cm3/hr to 21.12 cm3/hr at with no define sequence in its distribution within the profile. The soils are loose to firm in consistencies; there are no presences of mottles in all the horizons. The organic carbon (OC) content of the soils of this mapping unit is generally low and range from 0.10% to 3.36% but it decrease regularly with increase in soil depth. Similarly, the total nitrogen is low, the value decrease down the profile and range from to 0.009% to 0.221%. The reaction of the soils of this mapping unit range from slightly acidic to alkaline (pH 5.8 to 7.4) and the base saturation is > 90%. The calcium (Ca) content of the soils is high (15.44 cmol/kg to 9.28cmol/kg) but decrease down the profile while the quantity of the exchangeable magnesium (Mg) is high (1.84 cmol/kg) to very high (5.20 cmol/kg). The highest value of Mg+ was recorded at the surface but decrease regularly with increasing soil depth. The exchangeable potassium (K) present in the soils is very low (0.06

Cmol/kg) at the subsurface and high (0.26 Cmol/kg) at the surface. Similarly, the available phosphorus (P) content of the soils of this mapping unit is very low ranging from 0.12 mg kg-1to 2.62 mg/kg) at the subsurface horizon. The value decrease regularly with increasing soil depth.

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Plate 6: Pedon 6.

Table 4:5: Chemical and physical properties of RRIN out station, Otuo, Owan East LGA

	Depth		O.C	N	P	Ca	Mg	Na	K	EX. A	ECEC	B.S	Clay	Silt	Sand	T.C	Fe	Zn	Cu	Mn
			(gkg^{-1})		($mgkg^{-1}$)	←		(cmolkg^{-1})			→	%	←	(gkg^{-1})	→		←	($mgkg^{-1}$)		→
	0 -13	6.7	1.75	0.42	3.75	3.39	3.66	0.82	0.04	0.40	8.41	94.06	94	54	852	S	153	6.70	1.90	156
OT1	13 -33	6.8	1.27	0.31	5.07	5.84	3.62	1.07	0.04	0.20	10.77	98.14	94	54	852	S	167	12.40	3.10	229
	33 – 62	6.4	0.82	0.20	2.36	5.51	4.52	1.08	0.09	0.60	11.60	96.55	134	114	752	LS	185	4.50	2.50	245
	62 – 105	6.4	1.49	0.36	4.94	8.38	4.77	0.68	0.14	0.30	14.27	97.90	54	74	872	S	214	4.40	2.70	148
	105 -140	6.4	0.67	0.17	1.11	5.34	4.36	0.95	0.08	0.20	11.93	98.32	294	54	652	SCL	220	3.60	3.20	177
	140 -180	6.3	0.46	0.11	0.49	6.29	4.57	1.15	0.06	0.60	12.67	95.26	214	94	692	SCL	191	3.30	2.90	230
	0 -17	6.2	1.73	0.42	1.67	4.62	3.50	0.85	0.05	0.40	9.42	95.75	194	74	732	SL	150	5.80	3.00	365
OT 2	17 -45	6.2	1.10	0.27	3.41	2.02	2.18	0.81	0.04	0.40	3.45	88.41	134	34	832	LS	85.30	3.00	2.40	174
	45 -78	6.2	0.65	0.15	2.50	1.95	1.85	1.08	0.04	0.40	5.32	92.48	54	134	812	S	80.60	4.90	2.00	163
	78 -115	5.5	0.65	0.15	1.95	2.63	2.18	0.92	0.04	1.00	6.77	85.23	174	74	752	SL	56.90	2.90	1.40	48.50
	0 -12	6.7	1.92	0.46	5.21	8.16	3.08	0.91	0.05	0.20	12.40	98.39	174	74	752	SL	211	6.50	1.70	89.60
OT 3	12 --35	6.8	1.17	0.28	11.40	6.61	2.39	0.93	0.44	0.30	10.67	97.19	194	54	752	SL	146	3.50	1.30	37.40
	35 -65	6.8	0.43	0.11	5.63	3.67	5.26	0.91	0.27	0.20	10.31	98.06	194	54	752	SL	112	5.70	1.20	2.90
	65 -90	6.5	0.43	0.11	0.56	2.83	6.21	0.93	0.27	0.50	10.84	95.39	174	54	772	SL	193	3.00	1.30	3.50
	90 -120	5.2	0.24	0.06	3.27	3.51	6.74	0.91	0.47	0.60	13.23	87.91	232	54	712	SCL	198	7.20	1.50	2.60

T.C- textural class

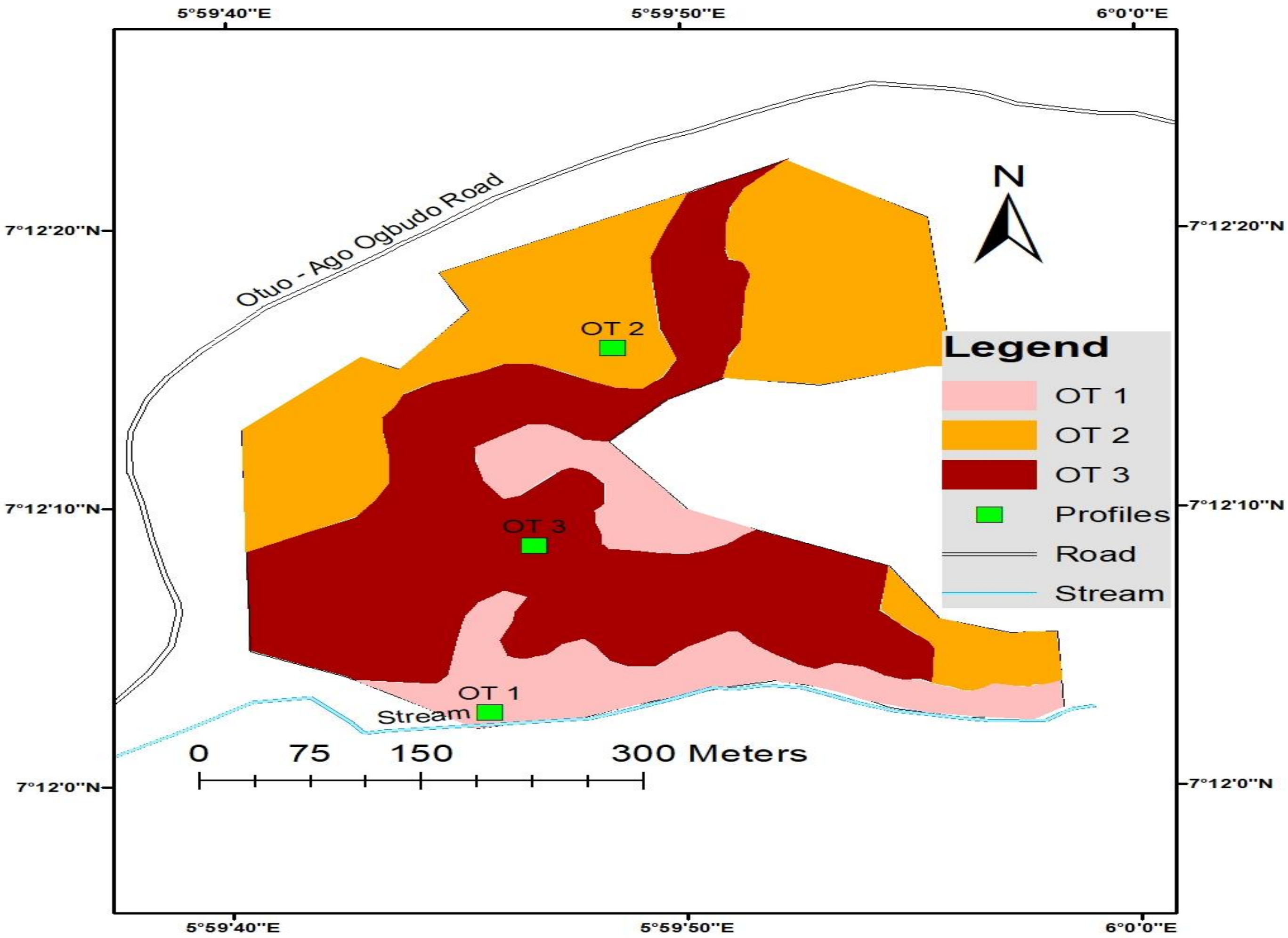

Figure. 4:4: Soil map of RRIN out station, Otuo

Table 4. 6: Classification of RRIN out station, Otuo

M.U	Soil Taxonomy	Soil WRB	mapping unit area(ha)	Percentage (%)
OT 1	Typic Kandiudalf	Nitic Lixisol (Hypereutric, maganiferric)	2.68 ha	15.13%
OT 2	Ruptic-Alfic Dystrudept	Haplic Ferallic Cambisol (Skeletic, Dystric)	6.90 ha	38.96%
OT 3	Ruptic-Alfic Eutrudept	Haplic Ferallic Cambisol (Densic, Eutric)	8.13 ha	45.91%
Total			17.71 ha	100%

M.U; mapping unit

PEDON 1

The soils of this mapping unit occupies approximately 2.68 hectares of the study area, the soils are characterized by grayish brown colour (10YR 5/2) at the surface horizon and brown (10YR 4/3) at the subsurface horizon with loamy sand surface over lying sandy clay loam subsurface. The soil increase in clay content with increasing depth. The soils are sub angular blocky in structure all through the profile with diffuse clear to wavy diffuse boundary across the horizon with presences of mottles in the third horizons and many coarse roots to the fifth horizon. The organic carbon (OC) content of the soils of this mapping unit is generally low and range from 1.75% to 0. 46% but it decrease regularly with increase in soil depth. Similarly, the total nitrogen is low, the value decrease down the profile and range from 0.042% to 0.11%. The reaction of the soils of this mapping unit range slightly acidic (pH 6.7 to 6.3) and the base saturation is > 90%. The calcium (Ca) content of the soils is (3.39 cmol/kg to 6.29 cmol/kg) but is irregular in its distribution pattern the profile while the quantity of the exchangeable magnesium (Mg) is high (2.56 cmol/kg to 0.32 cmol/kg). The highest value of Mg+ is recorded at the surface but decrease regularly with increasing soil depth. The exchangeable potassium (K) present in the soils is very low (0.03 cmol/kg) at the subsurface and high (0.27 cmol/kg) at the surface. Similarly, the available phosphorus (P) content of the soils of this mapping unit is high on the surface (19.63 mg kg-1) and low (1.90 mg/kg) at the subsurface horizon. The value decrease regularly with increasing soil depth.

Plate 7: Pedon 1.

PEDON 2

The soils of this mapping unit occupies approximately 6.90 hectares of the study area, the soils are characterized by reddish brown colour (5YR $^4/_4$) at the surface horizon and dark red (2.5YR $^3/_6$) at the subsurface horizon with sandy loamy surface over lying loamy sand subsurface. The soil increase in clay content has an irregular pattern down the profile with a range of 19.4% to 5.4%. Mid slope / Hill creast physiographic position. The soils are crumbs to blocky in structure with wavy clear boundary through the horizon with absence of mottles and many coarse roots to few and fine roots down the horizon. The organic carbon (OC) content of the soils of this mapping unit is generally low and range from 1.73% to 0. 65% but it decrease regularly with increase in soil depth. Similarly, the total nitrogen is low, the value decrease down the profile and range from to 0.042% to 0.15%. The reaction of the soils of this mapping unit range slightly acidic (pH 5.5 to 6.2) and the base saturation is > 85%. The calcium (Ca) content of the soils is (1.95 cmol/kg to 4.62 cmol/kg) but was irregular in its distribution pattern the profile while the quantity of the exchangeable magnesium (Mg) is high (3.5 cmol/kg to 1.85 cmol/kg). The highest value of Mg^+ is recorded at the surface but decrease regularly with increasing soil depth. The exchangeable potassium (K) present in the soils is very low and it range from 0.05 cmol/kg to 0.04 cmol/kg. Similarly, the available phosphorus (P) content of the soils of this mapping unit range from 1.67 mg kg^{-1} to 3.41 mg/kg following an irregular pattern.

Plate 8: Pedon 2

PEDON 3

The soils of this mapping unit occupies approximately 8.13 hectares of the study area, the soils are characterized by dark reddish brown colour (10YR $^3/_4$) at the surface horizon and brown (10YR $^4/_3$) at the subsurface horizon with sandy loamy surface over lying sandy clay loam subsurface. The soil increase in clay content has an irregular pattern down the profile with a range of 17.4% to 23.2%. Mid slope undulating physiographic position. The soils are blocky to platy in structure with wavy clear boundary to smooth clear across the horizon with presence of mottles at the fourth and fifth horizons and many mixed roots to very few and fine roots down the horizon . The organic carbon (OC) content of the soils of this mapping unit is generally low and range from 1.92% to 0. 24% but it decrease regularly with increase in soil depth. Similarly, the total nitrogen was low, the value decrease down the profile and range from to 0.46% to 0.06%. The reaction of the soils of this mapping unit range slightly acidic (pH 5.2 to 6.8) and the base saturation is > 87%. The calcium (Ca) content of the soils is (2.83 cmol/kg to 8.16 cmol/kg) but is irregular in its distribution pattern the profile while the quantity of the exchangeable magnesium (Mg) is high (2.39 cmol/kg to 6.74 cmol/kg). The highest value of Mg^+ is recorded at the sub surface and its distribution is irregular. The exchangeable potassium (K) present in the soils is very low with a range of 0.05 cmol/kg to 0.47 cmol/kg. Similarly, the available phosphorus (P) content of the soils of this mapping unit range from 0.56mg kg^{-1} to 11.40 mg/kg following an irregular pattern.

Plate 9: Pedon 3

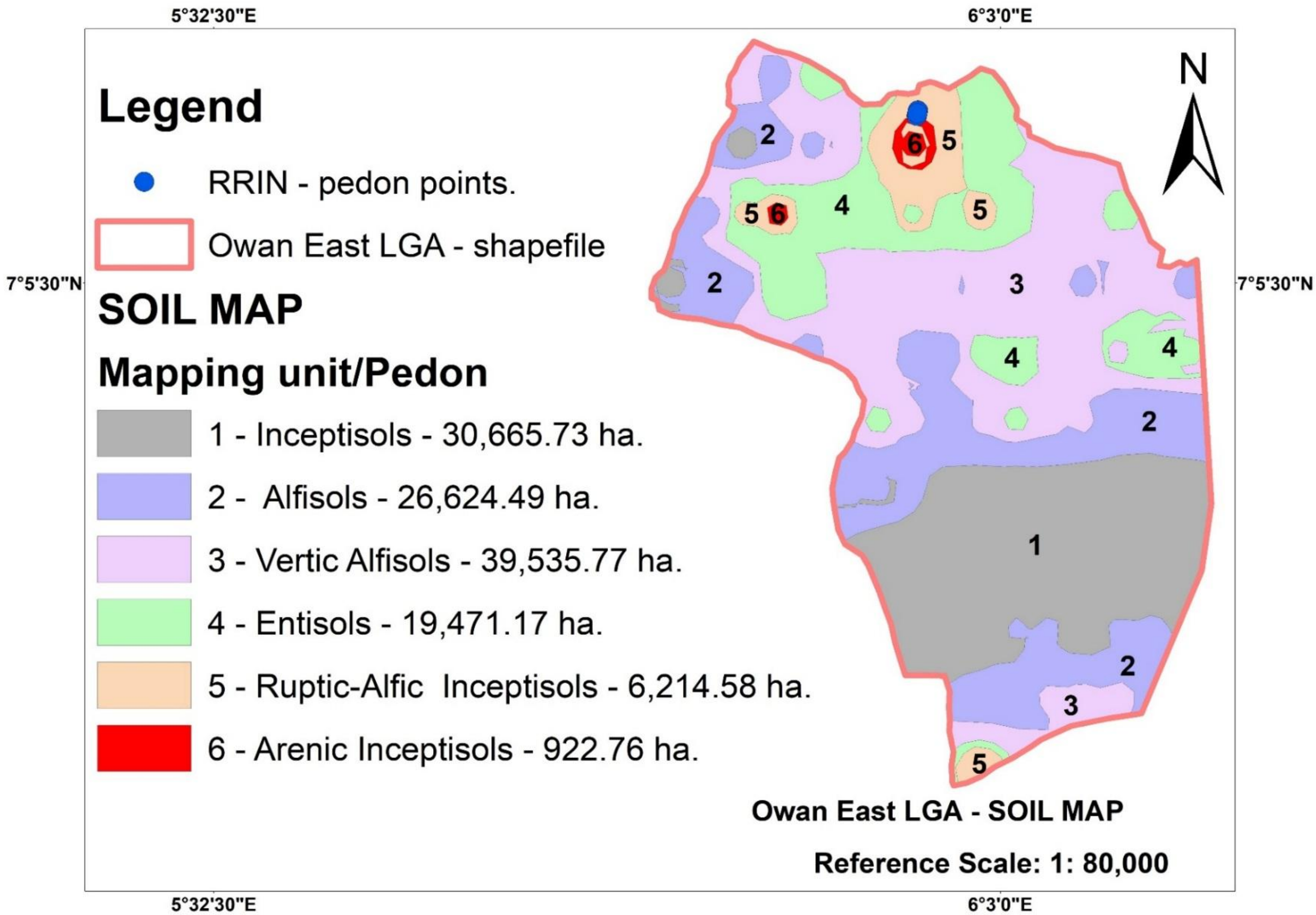

Figure. 4.5: **Map of Owan East LGA showing the RRIN outstation, Otuo, Owan East LGA**

From the RRIN out station classification and its location in the 2019 produced soil map of Owan East LGA, the high predictive accurancy of the findings can be seen, the out station has two soil orders (alfisols 2.68 ha and Inceptisols 15,03 ha) which fell into mapping units 5 and 6 whose classification are Inceptisols. Infact, the inceptisol is above 80% of the total area and also two of the soil profiles of RRIN substation are about the same for mapping unit 5 of 2019 project site.

4.2 LAND SUITABILITY EVALUATION

The Land Suitability classes of the pedons for the five (5) selected crops are shown in Tables 4: 7; 4:8; 4:9; 4:10; 4:11 while the suitability maps are shown in Figures 4:5: 4:6; 4:7; 4:8; 4:9.; 4:10; 4:11 and the criteria used for the evaluation are contained in Appendix 11 – 15.

Table 4: 7: Rubber suitability evaluation for the six Pedons

PARAMETERS	SUITABILITY CLASS					
Climate (c)	**1**	**2**	**3**	**4**	**5**	**6**
Annual rainfall (mm)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)
Length of dry season (mths)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)
Mean annual temperature (oC)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)
Permanent soil limitation (s)						
Effective Soil depth (cm)	139 (S3)	180 (S2)	180 (S2)	180 (S2)	120 (S3)	180 (S2)
Texture	SCL (S1)	S,SiL (S2)	SC, C (S2)	S,LS (S2)	S, SCL, SL (S1)	S,LS, SCL (S1)
Gravel (%) 0 – 15cm	7.09 (S1)	0.64 (S1)	13.19 (S2)	0. 92 (S1)	61.01 (N1)	26.01 (S2)
Topography (t)						
Slope gradient (%)	0-3 (S1)	2-5(S1)	8-12(S2)	2-5(S1)	28-37(N1)	38-56(N2)
Soil fertility (f)						
Subsoil pH	4.74 -5.8 (S2)	4.7 – 5.8 (S2)	4.8 -6.0 (S1)	4.4 – 6.6 (S1)	6.2 -7.10 (N1)	5.8 – 7.4 (S1)
ECEC (cmol /kg)	3.06 – 9.23 (S2)	2.32 – 5.4 (S3)	2.61 – 5.45(S3)	2.82 -11.24 (S2)	6.89 – 18 52 (S1)	11.74 -21. 36(S1)
Base saturation (%)	62 -96 (S1)	89 – 92 (S1)	90 -93 (S1)	64-98 (S1)	92-99 (S1)	96-99 (S1)
Organic carbon (%)	0.29 -0.89 (S3)	0.16 – 1.41 (S2)	0.32 – 2.0 (S1)	0.11 -2.11(S1)	0.26 – 2.14 (S1)	0.10 – 3.36 (S1)
Soil wetness (w)						
Depth to table water (cm)	139 (S3)	180 (S2)	180 (S2)	180 (S2)	120 (S3)	180 (S2)
Drainage	WD (S1)	SPD (S3)	FWD (S1)	WD (S1)	MD (S3)	WD (S1)
AGGREGATE SUITABILITY CLASS	**S3 (s,f,w)**	**S3 (f,w)**	**S3(f)**	S2 (c,s,w)	**N1 (s)**	**N2 (s)**
Size (Hectares)	**30,665.73**	**26,624.49**	**39,535.77**	**19,471.17**	**6,214.58**	**922.76**
% Coverage	**24.84**	**21.57**	**32.03**	**15.77**	**5.03**	**0.75**

WD-Well drained, SPD- Somewhat poorly drained, FWD- Fairly Well Drained, MD-Moderately drained, S1- highly suitable, S2 - moderately suitable, S3 - marginally suitable, N1- currently not suitable, N2- Permanently not suitable

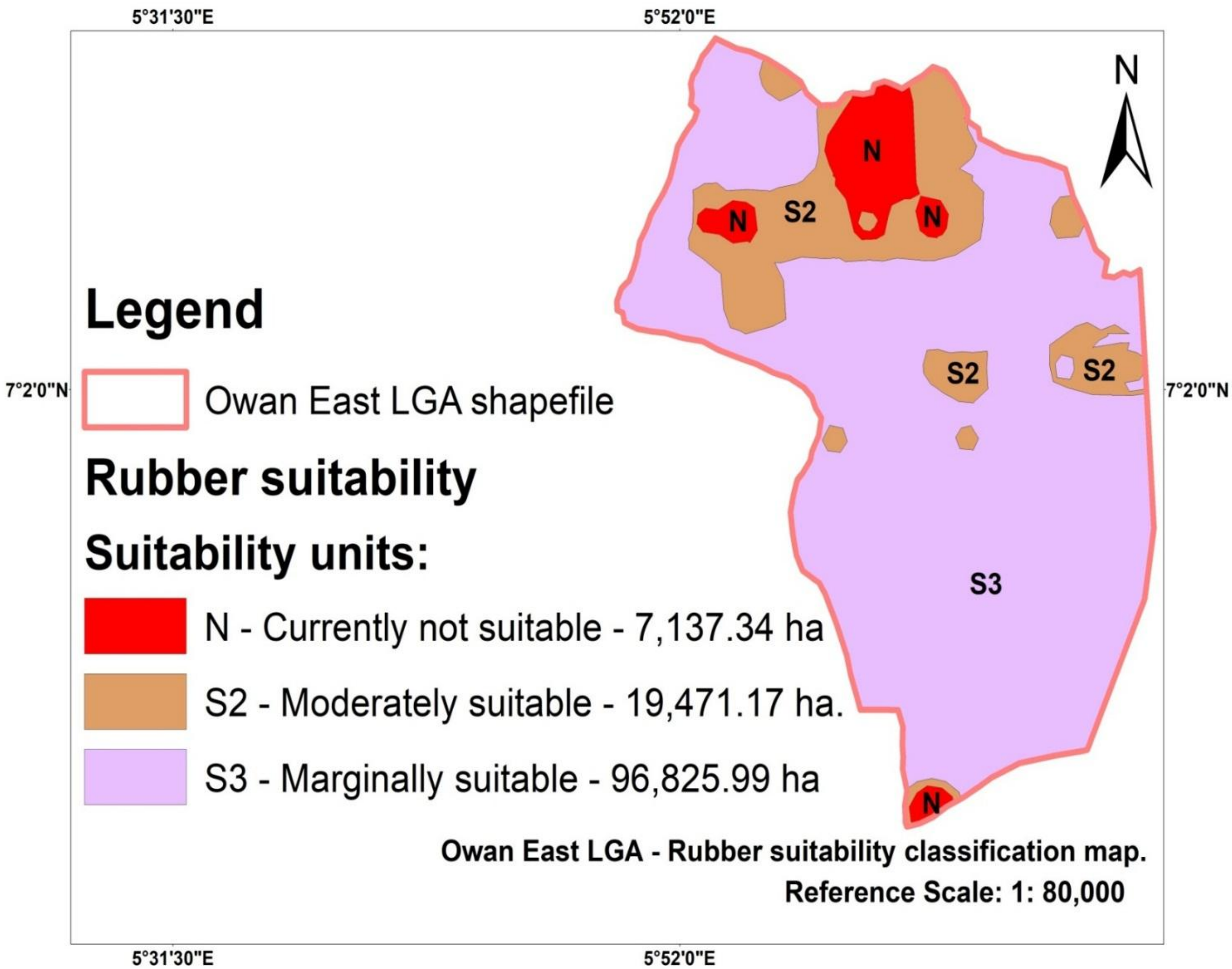

Figure 4:6: **Rubber suitability classification map**

Table 4:8: Oil Palm suitability evaluation for the six Pedons

PARAMETERS	**SUITABILITY CLASS**					
Climate (c)	**1**	**2**	**3**	**4**	**5**	**6**
Annual rainfall (mm)	1200 -1500 (S3)	1200 -1500 (S3)	1200 -1500 (S3)	1200-1500 (S3)	1200 -1500 (S3)	1200 -1500 (S3)
Length of dry season (mths)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)
Mean annual temperature (oC)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)
Permanent soil limitation (s)						
Effective Soil depth (cm)	139 (S1)	180 (S1)	180 (S1)	180 (S1)	120 (S1)	180 (S1)
Texture	SCL (S2)	S,LS,Si L (S3)	SC, C (S1)	S,LS (S2)	S,SL (N1)	S,LS, SCL (S1)
Gravel (%) 0 – 15cm	7.09 (S1)	0.64 (S1)	13.19 (S2)	0. 92 (S1)	61.01 (N1)	26.01 (S2)
Topography (t)						
Slope gradient (%)	0-3 (S1)	2-5(S1)	8-12(S2)	2-5(S1)	28-37(N1)	38-56(N2)
Soil fertility (f)						
Base saturation (%)	62 -96 (S1)	89 – 92 (S1)	90 -93 (S1)	64-98 (S1)	92-99 (S1)	96-99 (S1)
Organic carbon (%)	0.89 (S2)	1.41 (S1)	2.0 (S1)	2.11(S1)	2.14 (S1)	3.36 (S1)
Soil wetness (w)						
Drainage	WD (S1)	SPD (S1)	FWD (S3)	WD (S1)	MD (S3)	WD (S1)
Depth to table water (cm)	139 (S1)	180 (S1)	180 (S1)	180 (S1)	120 (S1)	180 (S1)
AGGREGATE SUITABILITY CLASS	**S3 (c)**	**S3 (c, s)**	**S3 (c)**	**S3 (c)**	**N1 (c, s)**	**N2 (c, t)**
Size (Hectares)	**30,665.73**	**26,624.49**	**39,535.77**	**19,471.17**	**6,214.58**	**922.76**
% Coverage	**24.84**	**21.57**	**32.03**	**15.77**	**5.03**	**0.75**

WD-Well drained, SPD- Somewhat poorly drained, FWD- Fairly well Drained, MD-Moderately drained, S1- highly suitable, S2 - moderately suitable, S3 - marginally suitable, N1- currently not suitable, N2- Permanently not suitable.

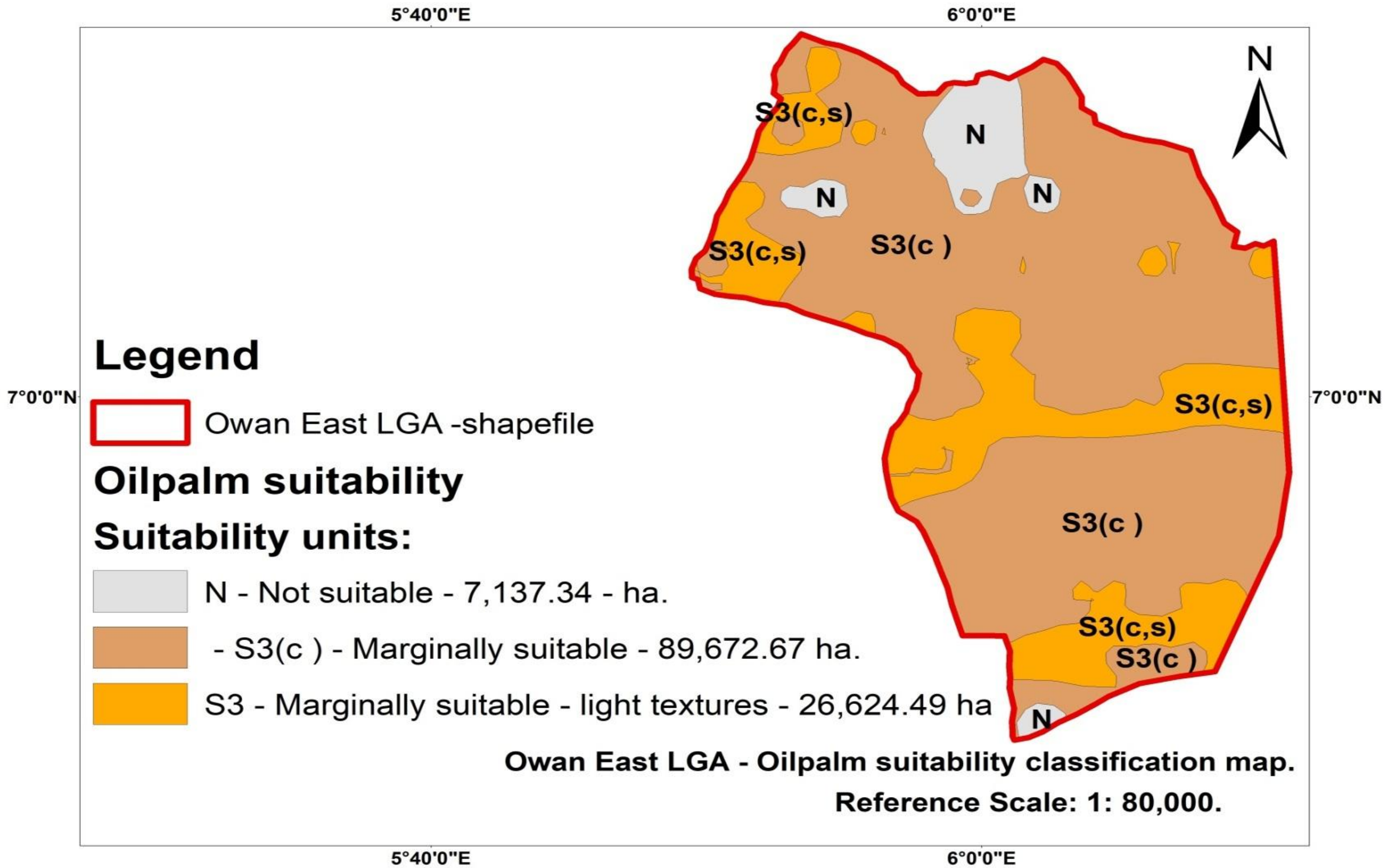

Figure. 4:7: **Oil Palm suitability classification map**

Table 4: 9: Cocoa suitability evaluation for the six Pedons

PARAMETERS	**SUITABILITY CLASS**					
Climate (c)	**1**	**2**	**3**	**4**	**5**	**6**
Annual rainfall (mm)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)
Length of dry season (mths)	3 (S2)	3 (S2)	3 (S2)	3 (S2)	3 (S2)	3 (S2)
Mean annual temperature (oC)	27 – 31 (S2)	27 – 31 (S2)	27 – 31 (S2)	27 – 31 (S2)	27 – 31 (S2)	27 – 31 (S2)
Permanent soil limitation (s)						
Effective Soil depth (cm)	139 (S1)	180 (S1)	180 (S1)	180 (S1)	120 (S2)	180 (S1)
Texture	S, SCL (S2)	S, SCL (S2)	SC, C (S2)	S,LS SCL (S3)	S, SL (S1)	S, LS,SCL (S3)
Gravel (%) 0 – 15cm	7.09 (S1)	0.64 (S1)	13.19 (S1)	0. 92 (S1)	61.01 (N2)	26.01 (S1)
Topography (t)						
Slope gradient (%)	0-3 (S1)	2-5(S1)	8-12(S2)	2-5(S1)	28-37(N1)	38-56(N2)
Soil fertility (f)						
ECEC (cmol /kg)	3.06 – 9.23 (S2)	2.32 – 5.4 (S2)	2.61 – 5.45(S2)	2.82-11.24 (S2)	6.89 -18.52 (S1)	11.74 -21. 36(S1)
Base saturation (%)	62 -96 (S1)	89 – 92 (S1)	90 -93 (S1)	64-98 (S1)	92-99 (S1)	96-99 (S1)
Organic carbon (%, 0-15)	0.89 (S1)	1.41 (S1)	2.0 (S1)	2.11(S1)	2.14 (S1)	3.36 (S1)
Soil wetness (w)						
Depth to table water (cm)	139 (S2)	180 (S1)	180 (S1)	180 (S1)	120 (S2)	180 (S1)
Drainage	WD (S1)	SPD (S1)	FWD (S2)	WD (S1)	MD (S2)	WD (S1)
AGGREGATE SUITABILITY CLASS	**S2 (c, s, f)**	**S2 (c, s, f)**	**S2 (c, s, f,w)**	**S3 (s)**	**N2 (s, t)**	**N2 (t)**
Size (Hectares)	**30,665.73**	**26,624.49**	**39,535.77**	**19,471.17**	**6,214.58**	**922.76**
% Coverage	**24.84**	**21.57**	**32.03**	**15.77**	**5.03**	**0.75**

WD-Well drained, SPD- Somewhat poorly drained, FWD- Fairly well Drained, MD-Moderately drained, S1- highly suitable, S2 - moderately suitable, S3 - marginally suitable, N1- currently not suitable, N2- Permanently not suitable.

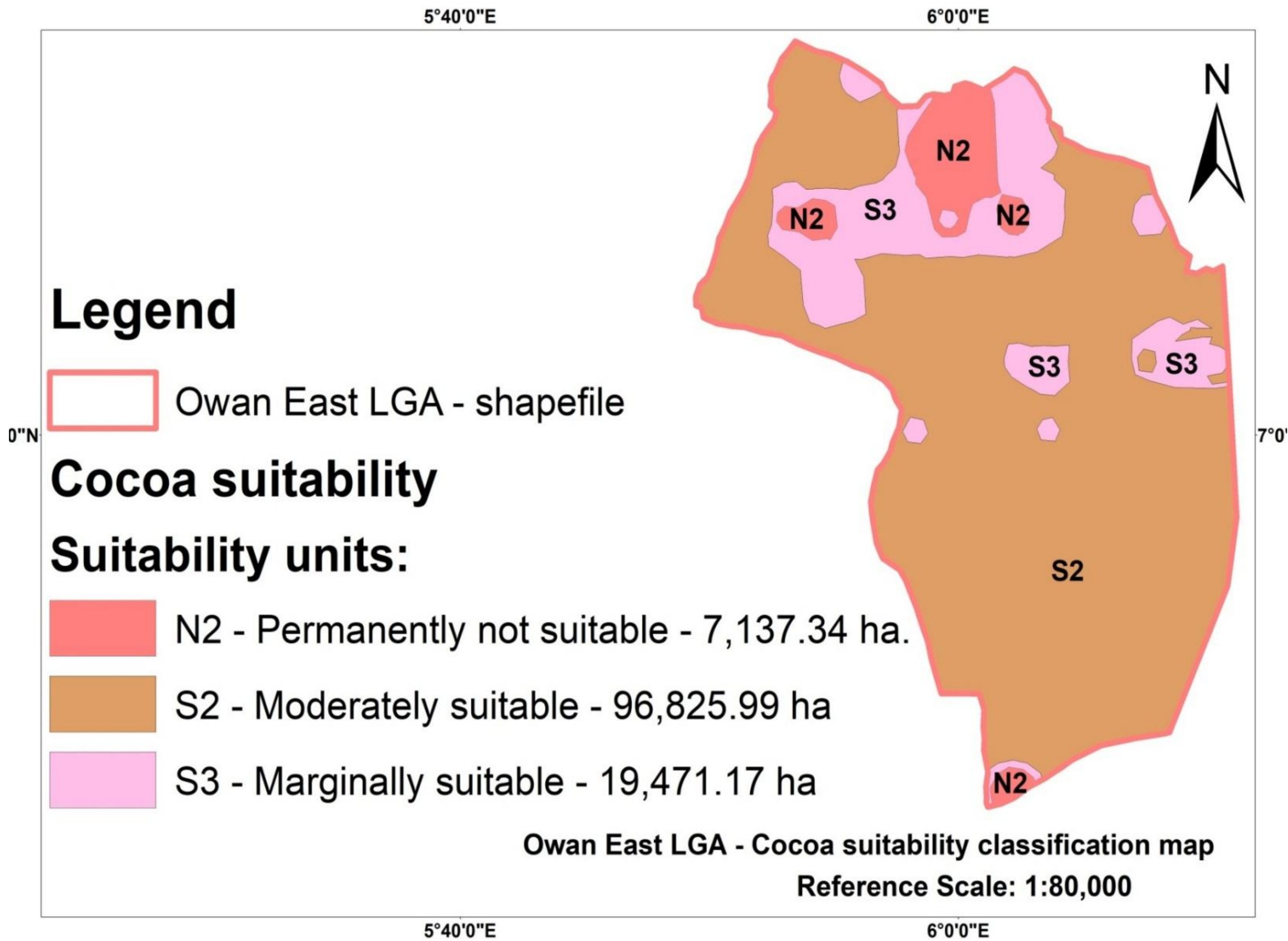

Figure 4:8: **Cocoa suitability classification map**

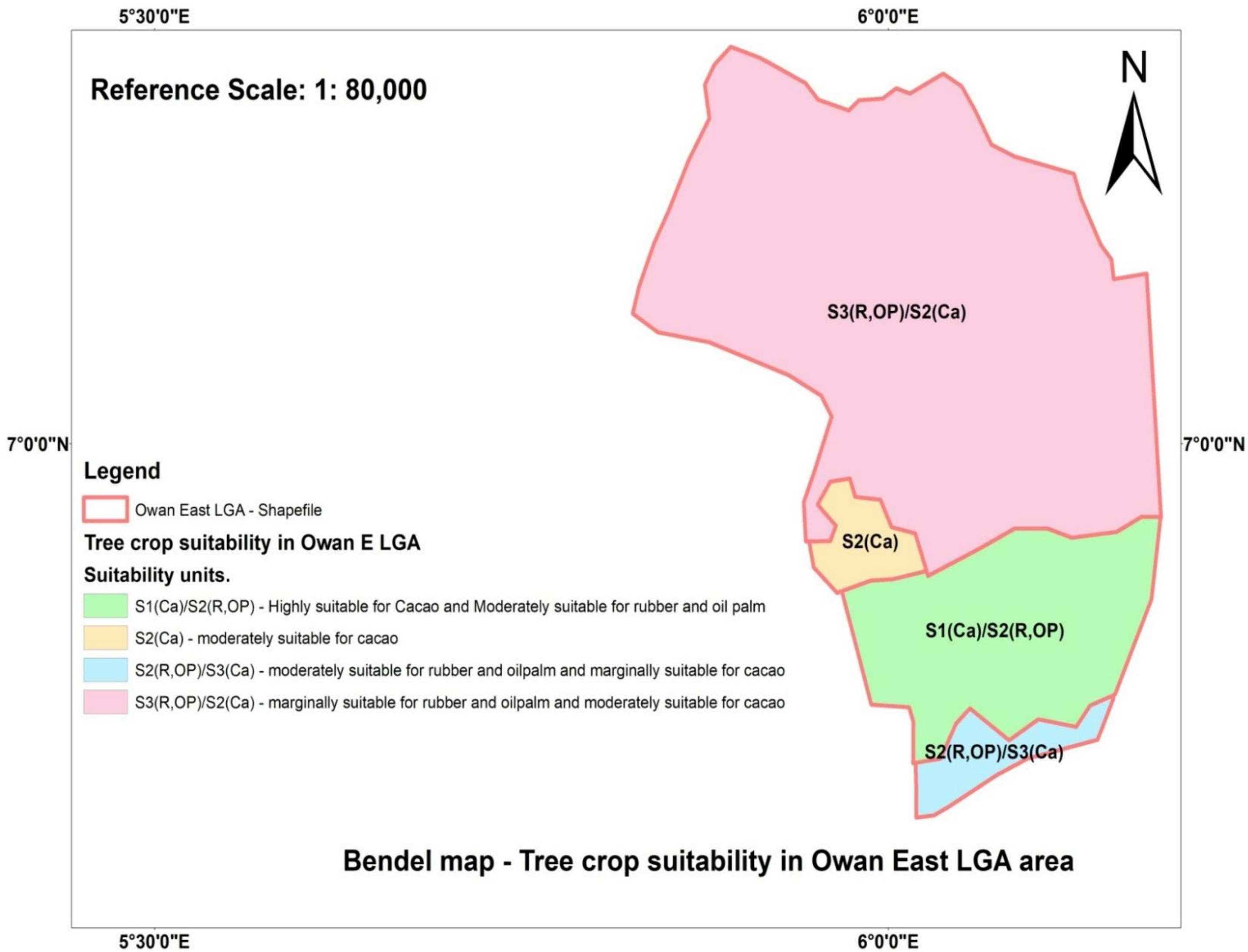

Figure. 4:9: **Bendel Map _Tree crop suitability**

The 1985 study had the same tree crop examined for its suitability, it was observed that no area as at that time was rated unsuitable and only one map was used to represent all the crops, unlike in this current findings some areas were found not suitable for all the tree crops and each crop has its own suitability map with Rubber *(Hevea brasiliensis)* (currently not suitable, moderately and marginally suitable); Oil palm *(Elaeis guineensis)*

(not suitable, marginally suitable with climate and soil as limitations); Cocoa (permanently not suitable, moderately and marginally suitable).

Table 4:10: Maize suitability evaluation for the Pedons

PARAMETERS	**SUITABILITY CLASS**					
Climate (c)	**1**	**2**	**3**	**4**	**5**	**6**
Altitude (m)	159 (S1)	113.8 (S1)	258 (S1)	332 (S1)	320 (S1)	-
Annual rainfall (mm)	1200 -1500 (S1)	1200 -1500 (S1)	1200 -1500 (S1)	1200 -1500 (S1)	1200 -1500 (S1)	1200 -1500 (S1)
Length of dry season (mths)	3 -4 (S1)	3 -4 (S1)	3 -4 (S1)	3 -4 (S1)	3 -4 (S1)	3 -4 (S1)
Topography (t)						
Slope gradient (%)	0-3 (S1)	2-5(S1)	8-12(S2)	2-5(S1)	28-37(N1)	38-56(N2)
Soil physical Characteristics(s)						
Depth to table water (cm)	139 (S1)	180 (S1)	180 (S1)	180 (S1)	120 (S1)	180 (S1)
Drainage	WD (S1)	SPD (S3)	FWD (S2)	WD (S1)	MD (S1)	WD (S1)
Coarse fragment	<15 (S1)	<35 (S3)	<15 (S1)	<15 (S1)	<55 (N2)	<15 (S1)
Texture	S, SCL (S1)	S, SiL (S1)	SC, C (S1)	S, LS (S1)	S,SL, SCL (S1)	S, LS,SCL (S1)
Fertility Characteristics (f)						
Base saturation (%)	62 -96 (S1)	89 – 92 (S1)	90 -93 (S1)	64-98 (S1)	92-99 (S1)	96-99 (S1)
Organic carbon (%)	0.29 -0.89 (S1)	0.16 – 1.41 (S1)	0.32 – 2.0 (S1)	0.11 -2.11(S1)	0.26 – 2.14 (S1)	0.10 – 3.36 (S1)
AGGREGATE SUITABILITY CLASS	**S1**	**S3 (s)**	**S2 (t, s)**	**S1**	**N2 (t, s)**	**N2 (t)**
Size (Hectares)	**30,665.73**	**26,624.49**	**39,535.77**	**19,471.17**	**6,214.58**	**922.76**
% Coverage	**24.84**	**21.57**	**32.03**	**15.77**	**5.03**	**0.75**

WD-Well drained, SPD- Somewhat poorly drained, FWD- Fairly well Drained, MD-Moderately drained, S1- highly suitable, S2 - moderately suitable, S3 - marginally suitable, N1- currently not suitable, N2- Permanently not suitable.

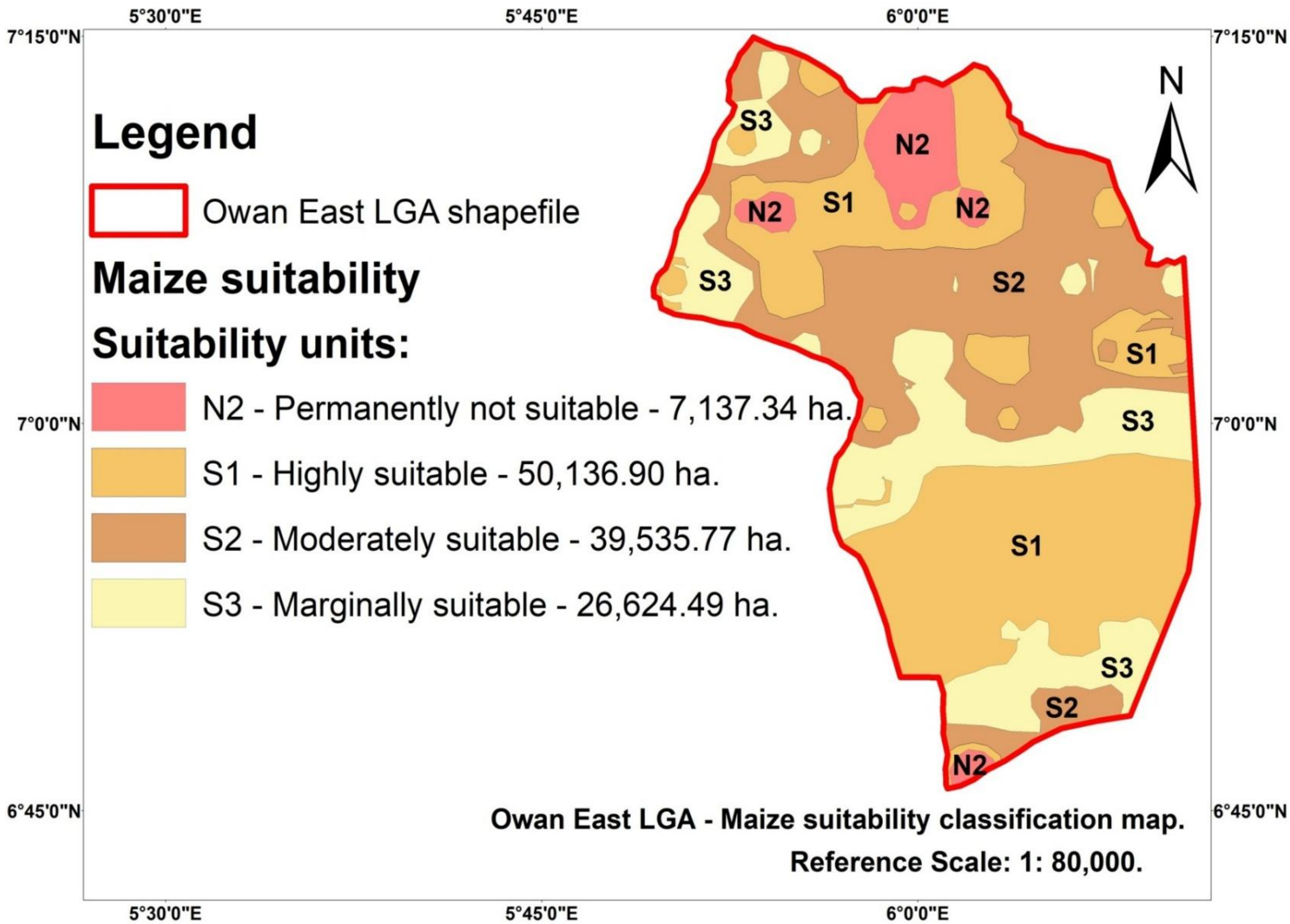

Figure 4:10: Maize suitability classification map

Table 4:11: Cassava suitability evaluation for the Pedons

PARAMETERS	SUITABILITY CLASS					
Climate (c)	**1**	**2**	**3**	**4**	**5**	**6**
Altitude (m)	159 (S1)	113.8 (S1)	258(S1)	332(S1)	320 (S1)	
Annual rainfall (mm)	1200 -1500 (S1)	1200 -1500 (S1)	1200 -1500 (S1)	1200 -1500 (S1)	1200 -1500 (S1)	1200 -1500 (S1)
Length of dry season (mths)	3 -4 (S1)	3 -4 (S1)	3 -4 (S1)	3 -4 (S1)	3 -4 (S1)	3 -4 (S1)
Mean annual temperature (oC)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S2)	27 – 31 (S2)	27 – 31 (S2)
Topography (t)						
Slope gradient (%)	0-3 (S1)	2-5(S1)	8-12(S2)	2-5(S1)	28-37(N1)	38-56(N2)
Soil wetness (w)						
Flooding	No risk (S1)	No risk (S1)	No risk (S1)	No risk (S1)	No risk (S1)	No risk (S1)
Drainage	WD (S1)	SPD (N1)	FWD (S2)	WD (S1)	MD (S2)	WD (S1)
Soil Physical Characteristics (s)						
Clay (%) structure	<35 (S1)	<35 (S1)	<35 (S1)	<35 (S1)	<35 (S1)	<35 (S1)
Depth (cm)	139 (S1)	180 (S1)	180 (S1)	180 (S1)	120 (S1)	180 (S1)
Coarse Fragment	7.09 (S2)	0.64 (S1)	13.19 (S2)	0.92 (S1)	61.01 (N2)	26.01 (S2)
AGGREGATE SUITABILITY CLASS	**S2 (s)**	**N1 (w)**	**S2 (t, w)**	**S2(s)**	**N2 (t,w, s)**	**N2 (t)**
Size (Hectares)	**30,665.73**	**26,624.49**	**39,535.77**	**19,471 .17**	**6,214.58**	**922.76**
% Coverage	**24.84**	**21.57**	**32.03**	**15.77**	**5.03**	**0.75**

WD-Well drained, SPD- Somewhat poorly drained, FWD- Fairly well Drained, MD-Moderately drained, S1- highly suitable, S2 - moderately suitable, S3 - marginally suitable, N1- currently not suitable, N2- Permanently not suitable.

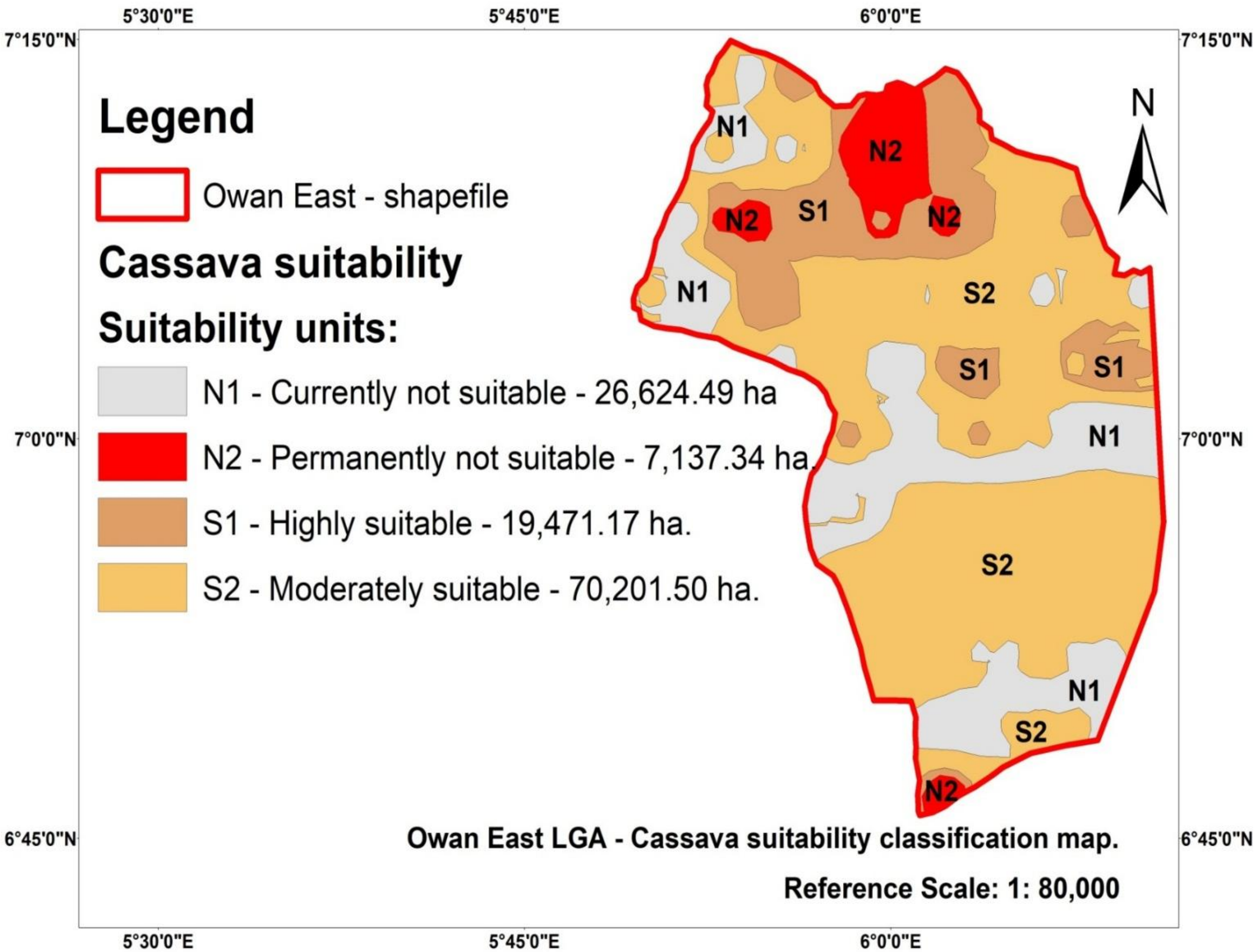

Figure.4:11: Cassava suitability classification map

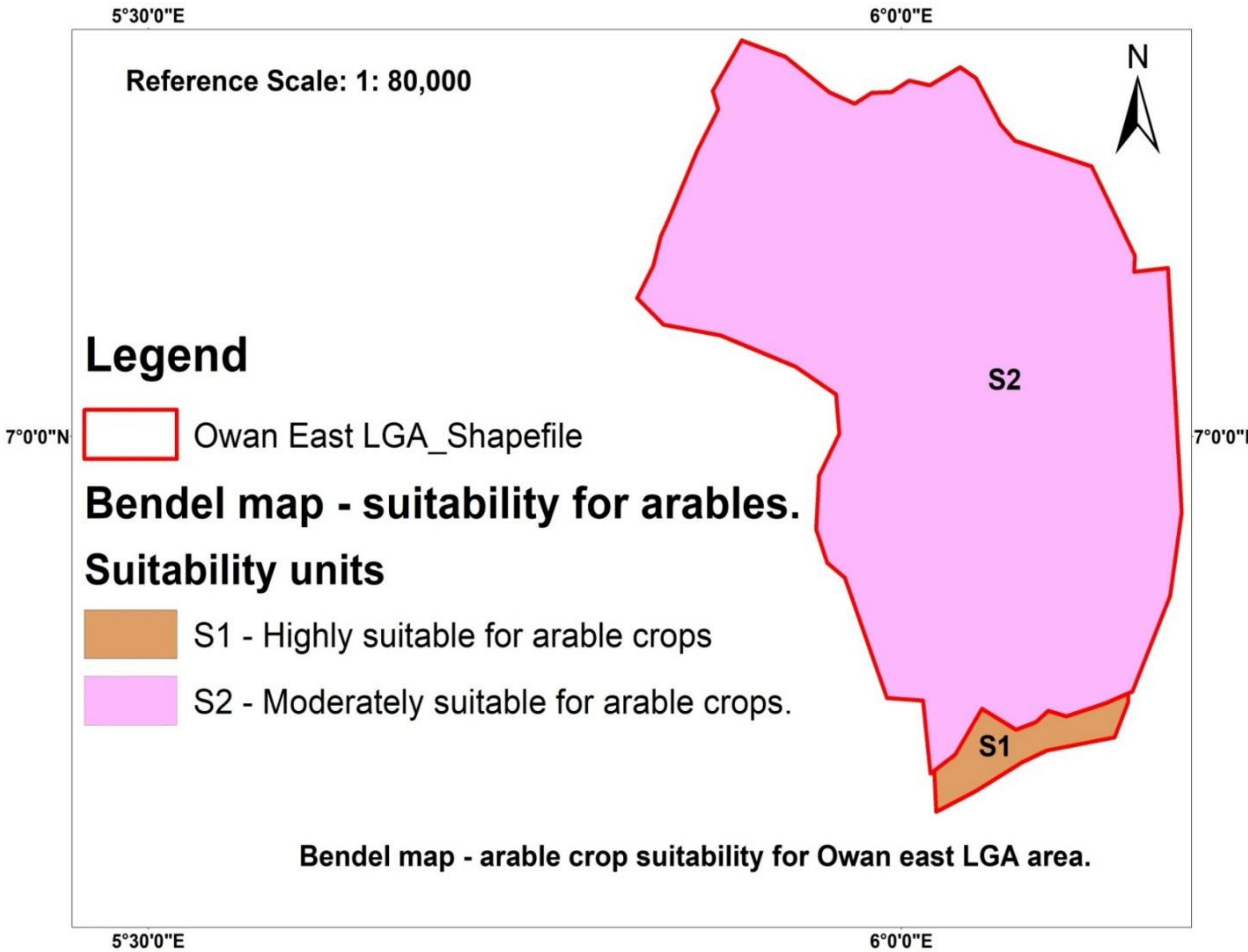

Figure 4:12: Bendel map_ Arable suitability classifications

For Arable crop. In their suitability no specific crop was mentioned and it had only one map and two suitability classes, this current findings covers maize (permanently not suitable, highly, moderately and marginally suitable) and cassava (currently not suitable, permanently not suitable and moderately suitable) had a map each for each crop.

Table 4:12: Suitability Summary Table

CROPS	PEDON 1	PEDON 2	PEDON 3	PEDON 4	PEDON 5	PEDON 6
RUBBER	S3(s,f,w)	S3(f,w)	S3(f)	S2(c,s,w)	N1(s)	N2(s)
OIL PALM	S3(c)	S3(c.s)	S3(c)	S3(c)	N1(c,s)	N1(c,t)
COCOA	S2(c,s,f)	S2(c,s,f)	S2(c,s,f,w)	S3(s)	N2(s,t)	N2(t)
MAIZE	S1	S3(s)	S2(t,s)	S1	N2(t,s)	N2(t)
CASSAVA	S2(s)	N1(w)	S2(t,w)	S2(s)	N2(t,w,s)	N2(t)

From the summary (Table 4:13), it was deduced that Pedon 1 which occupies an area of 30,665.73 ha and a percentage covering of 24.84% is best suited for maize, cassava and cocoa, while Pedon 2 which occupies an area of 26, 624.49 ha and a percentage covering of 21.57 is best suited for cocoa. Pedon 3 with 39,535.77 ha and 32.03% is best suited for the cultivation of maize, cassava and Cocoa, while Pedons 4 which covers an area of 19,471.17 ha and a percentage coverage of 15.77% is best suited for maize, cassava and rubber. Pedons 5 and 6 were found not suitable for any of the 5 crops under study and these areas covered some 7,137.34 ha.

In terms of intercrop, the suggested crop combination will be: Pedons 1 and 3 are either maize or cassava with cocoa; pedon 2 would be maize and cocoa while pedon 4 would be either maize or cassava with rubber.

Table 4:13: Rubber suitability evaluation for RRIN out station, Otuo, Owan East LGA

PARAMETERS	**SUITABILITY CLASS**		
Climate (c)	**1**	**2**	**3**
Annual rainfall (mm)	1200 -1500 (S2)	1200 -1500 (S2)	1200 -1500 (S2)
Length of dry season (mths)	3 -4 (S2)	3 -4 (S2)	3 -4 (S2)
Mean annual temperature (oC)	27 – 31 (S1)	27 – 31 (S1)	27 – 31 (S1)
Permanent soil limitation (s)			
Effective Soil depth (cm)	180 (S2)	115(S3)	120(S3)
Texture	SCL (S1)	LS,SL (S2)	SL (S2)
Topography (t)			
Slope gradient (%)	0-2 (S1)	8 -13 (S1)	5 -7 (S2)
Soil fertility (f)			
Subsoil pH	6.3 -6.8 (S1)	5.5 – 6.2 (S1)	5.2 -6.8 (S1)
ECEC (cmol /kg)	8.41 – 14.27 (S1)	3.45 –9.42 (S2)	10.31 – 13.23 (S1)
Base saturation (%)	62 -96 (S1)	89 – 92 (S1)	90 -93 (S1)
Organic carbon (%)	0.46 -1.75 (S1)	0.65 – 1.73 (S1)	0.29 – 1.92 (S1)
Soil wetness (w)			
Depth to table water (cm)	180 (S2)	115 (S3)	120 (S3)
Drainage	PD (N1)	VPD (N2)	PD (N1)
AGGREGATE SUITABILITY CLASS	**N1 (w)**	**N2 (w)**	**N1(w)**
Size (Hectares)	**2.68**	**6.90**	**8.13**
% Coverage	**15.13**	**38.96**	**45.91**

PD- Poorly drained, VPD- Very poorly Drained, N1- currently not suitable, N2- Permanently not suitable

4.3 VARIABILITY ASSESSMENT

Table 4:14: Statistical Measures of Variability of Soil Properties of the 1985 Study

Parameters	pH	Ca	Clay	Silt	Sand	P	OC	CEC	K	Mg	N	Na
CV(%)	10.5	62.4	25.2	32.5	8.8	55.5	68.3	90.9	67.3	118.9	70.1	29.2
Variance	0.018	2.224	0.635	0.750	1.757	0.005	0.075	5.412	0.498	0.063	1.29	0.30
Ratio	NS	NS	NS	NS	NS	NS	NS.	NS	NS.	NS	NS.	NS
RV	1.16	0.85	1.05	1.04	0.90	1.17	1.15	0.61	0.77	1.15	1.03	0.0
1-RV	-0.16	0.15	-0.05	-0.06	0.10	-0.17	-0.15	0.39	0.23	-0.15	-0.03	1.0
Pi	-0.32	0.23	-0.10	-0.07	0.16	-0.33	-0.30	0.52	0.0	-0.30	0.06	0.0

Table 4:15 Homogeneity within Mapping units – CV Index – 1985

Parameters	pH	Ca	Clay	Silt	Sand	P	OC	CEC	K	Mg	N	Na
Whole area CV(%)	10.5	62.4	25.2	32.5	8.8	55.5	68.3	90.9	67.3	118.9	70.1	29.2
Pedon 1 (CV %)	14.5	60.6	18.4	90.3	14.2	21.3	70.7	85.4	101	81.9	46.8	35.4
Pedon 2 (CV %)	10.6	52.5	26.3	13.5	6.9	65.4	75.1	19.3	54.6	128.4	81.6	30.0

Pedon 1= 6/12 =50%; Pedon 2 = 5/12 = 41.7 % - mean = 46 %

Table 4:16: Statistical Measures of Variability of Soil Properties – Owan East LGA - 2019

Parameters	BD	Ca	Clay	Cu	EC	ECEC	Fe	Gravel	K	Ksat	Mg	Mn	N	Na	OC	P	pH	Sand	Silt	Zn
CV(%)	26.10	79.60	71.60	181.50	90.46	68.50	96.70	110.20	71.30	132.60	78.70	129.20	221.60	36.50	98.30	104.80	14.50	30	183.3	75
VRT	0.45 NS.	10.21*	14.34*	1.70 NS.	7.32*	10.25*	14.18*	5.31*	1.54 NS.	0.93 NS.	9.76*	4.55*	0.80 NS.	7.43*	0.11 NS.	3.17*	1.82 NS.	4.82*	3.03*	9.66*
RV	1.13	0.34	0.26	0.87	0.43	0.34	0.27	0.53	0.92	1.01	0.35	0.58	1.04	0.45	1.23	0.69	0.85	0.56	0.70	0.36
1-RV	-0.13	0.66	0.76	0.13	0.57	0.66	0.73	0.47	0.08	-0.01	0.65	0.42	-0.04	0.55	-0.23	0.31	0.15	0.44	0.30	0.64
Pi	-0.13	0.69	0.76	0.14	0.60	0.69	0.76	0.51	0.11	-0.02	0.68	0.46	-0.05	0.59	-0.27	0.34	0.17	0.48	0.33	0.68

Table 4:17: Homogeneity within mapping units – CV Index – 2019.

Parameters	BD	Ca	Clay	Cu	EC	ECEC	Fe	Gravel	K	Ksat	Mg	Mn	N	Na	OC	P	pH	Sand	Silt	Zn
Whole area CV(%)	26.10	79.60	71.60	181.50	90.46	68.50	96.70	110.20	71.30	132.60	78.70	129.20	221.60	36.50	98.30	104.80	14.50	30.00	183.30	75.00
Pedon 1 (CV %)	29.60	76.10	58.20	124.60	59.80	53.90	27.20	75.30	62.00	47.70	44.10	68.20	58.90	62.00	48.80	49.10	19.00	14.70	23.40	29.30
Pedon 2 (CV %)	3.10	41.80	47.10	31.90	73.30	36.80	42.20	200.00	57.20	54.70	41.50	0.00	103.80	3.70	86.90	44.30	13.00	68.30	105.50	16.60
Pedon 3 (CV %)	11.20	29.60	14.40	21.80	38.50	30.30	64.40	39.70	89.70	191.70	31.60	115.80	179.00	12.70	93.00	91.90	11.40	13.20	10.70	43.80
Pedon 4 (CV %)	8.40	80.10	41.30	150.00	77.00	60.20	7.60	200.00	78.50	46.10	52.80	148.70	115.40	23.60	120.00	40.60	23.40	2.80	51.90	69.60
Pedon 5 (CV %)	67.30	74.80	50.80	122.60	68.40	52.20	10.70	6.30	58.90	121.70	23.80	43.00	117.00	25.20	84.40	73.60	6.30	7.20	58.00	48.80
Pedon 6 (CV %)	17.50	16.50	46.90	116.70	55.50	21.00	44.30	124.60	50.40	165.30	43.40	86.00	120.70	18.40	131.30	92.50	8.50	7.20	59.00	27.00

Pedon 1 = 17/20 = 85 % ; Pedon 2 = 18/20 =90 %; Pedon 3 = 18/20 = 90 %; Pedon 4 = 15/20 = 75 %; Pedon 5 = 95 %; and Pedon 6 = 17/20 = 85 % Mean value = 87 %.

Table 4:18: Summary Table –Statistical Measures of Variability of Soil Properties – RRIN outstation, Otuo, Owan East LGA

Parameters	pH	OC	N	P	Ca	Mg	Na	K	EA	ECEC	BS	Clay	Silt	Sand	Fe	Zn	Cu	Mn
Total CV(%)	7.30	55.60	54.90	77.40	44.20	37.50	13.10	105.50	51.90	29.80	4.50	41.70	37.70	8.20	33.20	47.90	34.00	34.00
Variance	1.41	0.25	0.25	1.52	3.37	4.42*	0.19	9.60*	0.99	11.20*	3.80	0.90	0.80	0.40	9.30*	0.50	10.80	8.40*
Ratio Test	NS	NS	NS	NS	NS		NS		NS		NS	NS	NS	NS		NS	*	
RV	0.94	1.12	1.12	0.93	0.91	0.67	1.13	0.45	1.02	0.41	0.71	1.01	1.03	1.08	0.46	1.08	0.42	0.49
1-RV	0.06	-0.12	-0.12	0.07	0.09	0.33	-0.13	0.55	-0.02	0.59	0.29	-0.01	-0.03	-0.08	0.54	-0.08	0.58	0.51
Pi	0.08	-0.18	-0.18	0.10	0.32	0.41	-0.20	0.64	-0.04	0.67	0.36	-0.02	-0.04	-0.14	0.63	-0.11	0.66	0.60

Parameters	pH	OC	N	P	Ca	Mg	Na	K	EA	ECEC	BS	Clay	Silt	Sand	Fe	Zn	Cu	Mn
Whole area CV(%)	7.3	55.60	54.90	77.40	44.20	37.50	13.10	105.50	51.90	29.80	4.50	41.70	37.70	8.20	33.20	47.90	34.00	34.00
M.U 1 (CV %)	3.1	46.90	45.90	65.80	27.80	11.50	18.70	50.40	47.90	16.90	1.80	61.10	34.20	12.00	13.80	59.10	17.50	21.40
M.U 2 (CV %)	5.8	49.50	51.90	32.20	44.50	30.10	13.00	11.80	54.50	40.40	5.10	44.50	52.20	6.10	42.80	34.60	30.60	69.90
M.U 3 (CV %)	10.7	83.80	81.20	76.60	46.50	40.50	1.20	56.00	50.50	11.00	4.50	12.20	15.40	2.90	24.30	35.70	14.30	139.50

Table 4: 19: Homogeneity within mapping units – CV Index – RRIN outstation, Otuo, Owan East LGA.

Pedon 1=14/18=77.8%; Pedon 2= 10/18 =55.6 %; Pedon 3= 10/18 = 55.6 %; Mean = 63 %

For the 1985 study (Table 4:15) of the 12 soil properties analyzed for CV, 2 were lower than 15% (pH, sand); while clay, silt, sodium were moderate between 15 -35% and calcium, potassium, organic carbon, CEC, potassium, magnesium and nitrogen were all high above 35% while in 2019; of the 20 soil properties analyzed (Table 4:17) only pH was low 14.5%, bulk density and sand were moderate while the other 17 properties (Ca, clay. Cu. EC, ECEC, Fe. Gravel, K, Ksat, Mg, Mn, N, Na, OC, P, silt and Zn) had high coefficients of variation, which shows that the soil properties were highly variable within the mapping units but heterogeneous between mapping units. For RRIN site, of the 18 properties analyzed, pH, Na, B.S, sand had low CV, ECEC, Fe, Cu, Zn had moderate CV and the other 10 properties had high CV values (Tsble 4:19).

For variance ratio test in 1985the mapping units were not significantly different for most of the properties thus indicating poorly separated mapping units but for the 2019 study, the mapping units were significantly different for 13 properties representing 65% of the properties, meaning that the six mapping unit were different from one another. For the RRIN site, of the 18 properties only 6 showed that the mapping units are different.

Intra – class Correlation Coefficient (Pi) for 1985 study, Table 4:14 showed that the Pi values ranged from (–0.33 to 0.52), only CEC had a value greater than 0.5 thus showing that it is only CEC that could be predicted by the soil mapping effort while Table 4:16 showed that the values ranged from -0.27 to 0.76, 9 of the soil properties had values greater than 0.5 and hence could be predicted by the current soil map. For, the RRIN site; the Pi ranged from -0.02 to 0.67, 5 of the soil properties had values greater than 0.5 and hence could be predicted by the soil map.

Relative variance (RV) and its Complement (1 – RV), only CEC had the lowest tolerable variability value of 0.61(61 %) for 1985 study, the 2019 findings showed within mapping unit homogeneity of 0.26 – 0.53 (26 – 53 %) for Ca, EC, ECEC, Mg, Na, Clay, Gravel content, Fe, and Zn. The RRIN site ECEC, Cu, Fe and K had the lowest tolerable variability value of 0.41 – 0.49 (41 -49%).

CHAPTER FIVE

5.0 DISCUSSION

Soil survey is very important to agriculture. However, the soil map must have a high predictive value for it to be useful for land use planning and sustainable crop production. While climate (rainfall and temperature) was relatively stable, topography and parent material were highly variable, thus becoming the active soil forming factors that shaped the degree of soil variability observed in the study area. Basement complex parent materials, undulating and rolling topographies combined to produce the different soil types found in the study site – Alfisols/Lixisols, Inceptisols/Cambisols and Entisols/Arenosols.

In terms of classification, the soils of the area were classified according to USDA (Soil Survey Staff, 2010) and (FAO, 2006). Pedons 1,5 and 6 fell under the order Inceptisol as they did not possess any of the other diagnostic horizons except a cambic subsurface horizon. On the basis of the soil moisture regime, they were placed under the Udepts. Pedons 5 and 6 were further classified dsue to its base saturation of 60% value and above, as an Eutrudepts,. While Pedon 5, due to its cambic horizon was further classified as Ruptic-Alfic Eutrudept Pedon 6, because of its texturial class, was further classified as Arenic Eutrudept . Pedon 1 fell under other Udepts and was classified as Dystrudepts. Dystrudepts that have in each pedon a 10 to 50 percent (by volume) illuvial parts that otherwise meet the requirements for an argillic horizon is classified as Ruptic-Ultic Dystrudept. Pedons 2 and 3 qualified for the Alfisols. The udic moisture regime of the location further placed them as Udalfs and both possessed the kandic horizon placing them as a Kandiudalfs . The presence of 50 percent colors that have a hue of 2.5YR or redder value placed pedon 2 as Rhodic Kandiudalfs while Pedon 3 possessed aquic conditions for some time in normal years (or artificial drainage) and hence classified as Aquic kandiudalfs.

Pedon 4 qualified for the Entisol order as they did not possess any distinct diagnostic horizon(s) other than a weak A horizon arising from slight organic matter accumulation. The udic moisture regime of the location further placed it as an Udarent and Udarent and its base saturation content further placed the soils as a Mollic Udarents.

According to WRB, Ruptic-Ultic Dystrudept. correspond to Haplic Petroplinthic Cambisol (Skeletic Densic) ; hence Pedons 5 and 6 corresponds to Haplic Petroplinthic Cambisol (Skeletic Eutric) and Haplic Pisoplinthic Cambisol (Chromic, Calcaric) respectively. Inceptisols of this location occupied a total land area of 37, 803.07 hectares or 36.8 % of the total land area. Pedons 2 and 3 correspond to Vertic Lixisol (Rhodic, Siltic) and Gleyic Vetic Lixisol (Clayic, Oxyaquic) respectively. Alfisols of this location covered some 66,160.26 hectares, representing 53.5 % of the total land area. Pedon 4 corresponds to Ferralic Rubic Arenosol (Hyperochric, Dystric). Entisols of this location covered some 19, 471.17 hectares, representing 15.7 % of the total land area.

The 1985 Bendel State extract of Owan East Local Government area fell under one soil order and was classified as Lithic Haplustalfs and Typic Paleustalf. The soils of the Rubber Research Institute of Nigeria fell under two soil orders Inceptisols and Alfisols, because the area has low rainfall and parent material is of basement complex The Inceptisols had a clay content increasing as depth increased, though without evidence of clay illuviation, Udic moisture regime and hence classified as Udept. Great group was Eutrudepts because of its base saturation level of 60 percent or more in the horizons due to its cambic horizon, pedon 3(OT 3) was further classified as Ruptic-Alfic Eutrudept. Other Udepts classified as Dystrudepts. that have in each pedon a 10 to 50 percent (by volume) illuvial parts that otherwise meet the requirements for an argillic horizon is classified as Ruptic-Alfic Dystrudept for pedon 2 (OT 2) . Pedon 1 (OT 1) is an Alfisols which has Udic Moisture regime, hence referred to as Udalfs. and possesses the kandic horizon placing it as a Kandiudalfs and belong to the sub group Typic kandiudalfs.

According to WRB, Ruptic-Alfic Dystrudept correspond to Haplic ferallic Cambisol (Skeletic Dystric) ; Ruptic-Alfic Eutrudepts. corresponds to Haplic ferallic Cambisol (Densic, Eutric) while Typic Kandiudalf corresponds to Nitic Lixisol (Hypereutric maganiferric).

The Inceptisols had an area coverage of 15.03ha (84.87%) while the alfisols was 2.68 ha (15.13%). This area of 17.71 ha classification was further used to confirm the accuracy of the 2019 generated Owan East Local Government Area, because the soil orders conformed with that of the updated 2019 map.

In terms of suitability, for the 1985 study, rubber, oil palm, cocoa were examined for its suitability, it was observed that no area as at that time was rated unsuitable for the tree crops and only one map was used to represent the crops, while for arable crop it had two suitability classes.

For the 2019 findings: Rubber was marginally suitable for pedons 1, 2, 3; moderately for pedon 4, while pedons 5 and 6 were currently and permanent not suitable. The moderately suitable area is 19,471.17ha, marginally suitable area is 96, 825.99 ha and not suitable area is 7,137.34 ha. Their various soil ranges from soil limitation, slope gradient, gravel content and fertility. Oil palm: pedons 1, 2, 3 and 4 were marginally suitable, of which pedons 1, 3,4 limitations are climatic, with an area coverage of 89,672.67 ha while pedon 2 is both climatic and soil texture with a size of 26,624.49 ha; pedons 5 and 6 had limitation defects by slope and gravel content and a coverage of 7,137.34 ha. Cocoa: is moderately suitable (96, 825.99 ha) for pedons 1,2,3; marginally suitable covering an area of 19, 471.17 ha for pedon 4 and permanently not suitable (7,137.34 ha) for pedons 5 and 6. Main defects were climatic, soil limitation, fertility, slope gradient and topography. Maize was highly suitable for pedons 1 and 4; pedon 2 marginally suitable; pedon 3 moderately suitable and pedons 5 and 6 were rated permanently not suitable. S1 has a coverage of 50,136.90 ha: S2 39,535.77 ha; S3 26,624.68 ha and N2 has 7,134.34 ha. Soil defects were mainly slope gradient and gravel content (topography). Cassava: pedons 1, 3 and 4 were moderately suitable (89, 672.67 ha) and pedon 2 was currently not suitable with drainage as defect (26, 624.49 ha) while 5 and 6 are permanently not suitable (7,137.34 ha).

Pedon 1 which is 30, 665.73 ha can be used to cultivate the 5 crops; pedon 2 has 26,624.49 ha can sustain the growth of rubber, oil palm, cocoa and maize. Pedon 3 has 39,535.77 ha can sustain the 5 crops same for pedon 4 (19,471.17 ha) while pedons 5 and 6 are either currently or permanently not suitable for all the crops.

For the RRIN site: rubber, OT 1 and 3 (10.81 ha) are currently not suitable for rubber while OT 2 (6.90 ha) is permanently not suitable for rubber cultivation, with a common limitation of drainage. The suitability classification indeed tallied with the rubber classification of mapping unit 5 of the 2019 work, which the area fell under.

In terms of reliability on the predictive capacities of both the 1985 and 2019 soil maps, a series of soil variability indices were employed. First was the coefficient of variation – CV(effectively gives a measure of the variability of properties concerned within the mapping units and hence of the whole area). 46 % of the properties studied were found to be lower in CV values than the CV values for the entire study site thus showing that the mapping units were only 46 % homogenous. This was 87 % for the 2019 and 63 % for RRIN, which suggests the superiority of the 2019 findings over all the others.

For variance ratio test (VRT) - (index of heterogeneity between mapping units). This is expressed in the number of parameters that are significantly different. In the 1985 work, not a single property was significantly different, meaning only one profile could have been sunk, but for the 2019 findings, 13 properties were significantly different representing 65% of the properties, that is, the six mapping unit were different from one another – implying that the mapping method employed was moderately accurate. For the RRIN substation, of the 18 parameters analyzed , 6 were significantly different representing one third of the properties, that is the mapping units were fairly accurate.

Intra – class Correlation Coefficient (P_1) – this is the index of the predictive capacity of the maps. A $P_1 = 1.$ means 100 % accuracy while a value of P1=0 means zero accuracy. The larger the value of P_1 the greater the predictive capacity of the map.. The 1985 study showed that the P_1 values ranged from –0.33 to 0.52, only CEC had a value of 0.52 which shows that the 1985 map for the Owan East could only marginally predict only one parameter – CEC. For 2019 soil map, it is to be observed that high predictive capacity of > 0.7 (ie > 70 %) was recorded for two parameters – clay and Fe, moderate predictive capacity for Ca, EC, ECEC, Mg, and Zn (0.6 – 0.7 – 60 to 70 %), and marginal predictive capacity for Sand, Silt, P and Mn (0.3 – 0.5 ie 30 to 50 %). It can be deduced thus, that the 2019 work has a much more higher predictive capacity than 1985 study. The RRIN site showed that the P_1 values ranged from –0.20 to 0.67 , K, ECEC, Fe, Cu and Mn had values greater than 0.5 which shows that the RRIN soil map could only marginally predict five properties.

Relative variance (RV) and its Complement (1 – RV). This is an index of the homogeneity within mapping units. Hence the smaller the values the more homogenous are the mapping units.

Again while only CEC had the lowest tolerable variability value of 0.61(61 %) for 1985 study, the 2019 findings showed within mapping unit homogeneity of 0.26 – 0.53 (26 – 53 %) for Ca, EC, ECEC, Mg, Na, Clay, Gravel content, Fe, and Zn. The RRIN site ECEC, Cu, Fe and K had the lowest tolerable variability value of 0.41 – 0.49 (41 -49%). High variability within the mapping units >0.5 is an indication of likely poor field mapping, poor definition of mapping units, laboratory errors, restrictions of map scale, landscape complexity (Olaniyan, 2003).

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY

This study was carried out in order to update the mapping, classification and suitability evaluation of the soils of Owan East Local Government Area of Edo State. The objectives were to update the map of Bendel State by Federal Department of Agricultural Land Resources (FDALR, 1985) for Owan East Local Government Area, identify the various soils and classify them according to USDA and WRB systems, and evaluate their suitability for rubber, oil palm, cocoa, maize and cassava.

The reconnaissance soil survey method was used to survey the 123, 435.5 ha area at a scale of 1: 250,000, Pedons were sunk to represent the identified mapping units, and routine soil analysis was carried on the samples collected from each profile. The data was used to classify the soils, determine the degree of suitability of the soils for maize, cassava, oil palm, cacao and rubber. Soil variability within and between the mapping units was evaluated statistically using Coefficient of Variance (CV), Variance Ratio Test (VRT), Intra – class Correlation Coefficient (P_1) , Relative variance (RV) and its Complement (1 – RV) as variability indices. for all the three maps – 1985, 2019 and RRIN. An area of about 17.71 ha was further surveyed using the free survey method to test the accuracy of the updated Owan East LGA reconnaissance map.

The suitability of the soils for the cultivation of rubber, cacao, oil palm, cassava and maize was evaluated.

The 2019 findings delineated six major soil types that were classified as Alfisols/Lixisols, Inceptisols/Cambisols and Entisols/Arenosols; 1985 identified two soil types classified as

Alfisols/Lixisols; and RRIN land had two soil types – Alfisols/Lixisols and Inceptisols/Cambisols.

The suitability for the selected crops revealed that 30,665.73 ha (24.84%) is best suited for maize, cassava and cocoa, 26, 624.49 ha (21.57%) is best suited for only cocoa. 39,535.77 ha (32.03%) is best suited for the cultivation of maize, cassava and Cocoa, while 19,471.17 ha (15.77%) is best suited for maize, cassava and rubber. However, 7,137 ha was found not suitable for any of the 5 crops under study. For, the RRIN site in terms of the suitability for rubber (10.81 ha) was currently not suitable, and (6.90 ha) permanently not suitable. The suitability classification agreed very well with the rubber classification result of the 2019 study, thus confirming the predictive capacity of the 2019 findings.

All the indices of variability employed to test the reliability and the predictive capacities of three maps showed the 2019 findings to be most superior to all the others.

6.2 CONCLUSION

In Edo state, the Federal Department of Agricultural Land Resources (1985) Soil Survey / Map of Bendel State has been the only major reference document on the soils of Edo state in terms of identification, classification and suitability evaluations for some 35 years. It became imperative to test its relevance and appraise the continued use of it for vital agricultural decisions/experiments predicated on the soil as a starting point. The three core areas of its usefulness were thus examined – identification and delineation of the various soil types present, their classification and practical relevance as expressed in the suitability of the soils for various land uses. Standard methods were employed in the study and results have shown that the FDALR work has served its purpose as a pioneering attempt and hence overdue for updating.

6:3 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. The 2019 Soil map and the classification of the identified soils of Owan East Local Government should replace that of the extract from the Bendel State map of Federal Department of Agricultural Land Resources (1985) to serve as a basis for subsequent soil work.

2. Before cultivation of any of the community crop under study , especially on large scale basis, the results of this study in terms of suitability ratings should be consulted.

3. The limitations to the successful cultivation of various crops studied in this project should be examined by way of further research with a view to identifying measures that will make the cultivation of these crops more profitable and sustainable.

4. More detailed soil survey is required for Owan East local Government Area and all the former areas of coverage of the 1985 FDALR work – now Edo and Delta states of Nigeria.

5. The updating of the soil map of local governments, states and Nigeria at large, should be initiated and financed by the government at Local, State and Federal levels

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APPENDICES

Appendix 1: Co – ordinates of auger points at Owan East Local Govt location

LINES	POINTS	N	E
ES 1	PT 1	6.777	6.038
ES 2	PT1	6.822	6.038
	2	6.822	6.06
	3	6.822	6.082
	4	6.822	6.104
	5	6.822	6.126
ES 3	PT1	6.867	5.994
	2	6.867	6.016
	3	6.867	6.038
	4	6.867	6.06
	5	6.867	6.082
	6	6.867	6.104
	7	6.867	6.126
	8	6.867	6.148
ES 4	PT 1	6.912	5.972
	2	6.912	5.994
	3	6.912	6.016
	4	6.912	6.038
	5	6.912	6.06
	6	6.912	6.082
	7	6.912	6.104
	8	6.912	6.126
	9	6.912	6.148
	10	6.912	6.17
ES 5	PT1	6.957	5.95
	2	6.957	5.972
	3	6.957	5.994
	4	6.957	6.016
	5	6.957	6.038
	6	6.957	6.06
	7	6.957	6.082
	8	6.957	6.104
	9	6.957	6.126
	10	6.957	6.148
	11	6.957	6.17
ES 6	PT 1	7.002	5.972
	2	7.002	5.994
	3	7.002	6.016
	4	7.002	6.038
	5	7.002	6.06
	6	7.002	6.082
	7	7.002	6.104
	8	7.002	6.126
	9	7.002	6.148
	10	7.002	6.17
ES 7	PT1	7.047	5.928
	2	7.047	5.95
	3	7.047	5.972
	4	7.047	5.994
	5	7.047	6.016
	6	7.047	6.038
	7	7.047	6.06
	8	7.047	6.082
	9	7.047	6.104
	10	7.047	6.126
	11	7.047	6.148
	12	7.047	6.17
ES 8	PT1	7.092	5.84
	2	7.092	5.862
	3	7.092	5.884
	4	7.092	5.906
	5	7.092	5.928
	6	7.092	5.95
	7	7.092	5.972
	8	7.092	5.994
	9	7.092	6.016
	10	7.092	6.038
	11	7.092	6.06
	12	7.092	6.082
	13	7.092	6.104
	14	7.092	6.126
	15	7.092	6.148
	16	7.092	6.17
ES 9	PT 1	7.137	5.862
	2	7.137	5.884

		3	7.137	5.906
		4	7.137	5.928
		5	7.137	5.95
		6	7.137	5.972
		7	7.137	5.994
		8	7.137	6.016
		9	7.137	6.038
		10	7.137	6.06
		11	7.137	6.082
		12	7.137	6.104
		13	7.137	6.126
ES 10	PT 1		7.182	5.884
		2	7.182	5.906

		3	7.182	5.928
		4	7.182	5.95
		5	7.182	5.972
		6	7.182	5.994
		7	7.182	6.016
		8	7.182	6.038
		9	7.182	6.06
		10	7.182	6.082
ES 11	PT 1		11	5.884
		2	7.227	5.906
		3	7.227	5.928

Appendix 2: RRIN auger Points

POINT	N	E
A1	07.20516	005.99861
A3	07.20472	005.99872
A4	07.20459	005.99836
A5	07.20441	005.99793
A6	07.20446	005.99750
A7- A10	No record	
A11 last becon	07.20378	005.99608
B1	07.20354	005.99618
B2	07.20324	005.99634
B3- B5 no record		
B6	07.20215	005.99731
B7	07.20210	005.99772
B8	07.20192	005.99803
B9		
C1	07.20078	005.99924
D1	07.20482	005.99649
D2	07.20453	005.99660
E1	07.20239	005.99488
E2	07.20255	005.99522
E3	07.20228	005.99554
E4	07.20240	005.99586
E5	07.20249	005.99622
E6	07.20271	005.99649
E7	07.20191	005.99664
Profile 1	07.20074	005.99594
Profile 2	07.20437	005.99671
Profile 3	07.20240	005.99622

Appendix 3: FDALR Pro FORMA Sheets

Soil mapping Unit	CP 6
Classification	Lithic Haplustalfs

1) Site Description

Location	3 Kilometers to Auchi on the road from Sobe – Ogbe; right hand side
Physiographic position	Upper slope
Topography	Gently undulating
Slope;	3 – 5 percent
Drainage	Well drained
Vegetation and land uae:	Secondary forest fallow
Parent material	Coastal plain terrace
Date of Examination	November 22, 1983

2) Profile Description:

Depth (cm)	Horizon	Description
0 -10	Ap	Brown (10YR 4/3) sandy clay loam; moderate medium subangular blocky; firm moist; strong cementation; many interstitial and tubular pores; lateritic concretions; many fine roots; abrupt wavy boundary
10 – 46	A2	Strong brown (7.5YR 4/6) gravelly sandy clay Loam;; strong cementation; common fine interstitial and tubular pores; lateritic concretions; common coarse roots
46 -	R	Rock material

Appendix 4

Soil mapping Unit	CP 2
Classification	Typic Paleustalfs

1) Site Description

Location	About 4 Kilometers from Ebele village
Physiographic position	Top slope
Topography	Gently undulating landscape
Slope;	3 %
Drainage	Well drained
Vegetation and land uae:	Secondary forest fallow
Parent material	Colluvium derived from false bedded sandstone
Date of Examination	November 17, 1983

2) Profile Description:

Depth (cm)	Horizon	Description
0 -8	Ap	Very gray (10YR 4/1) loam; very weak , fine sub angular blocky structure; soft, very friable, slightly sticky and slightly plastic; many fine woody roots and many fine to medium interstitial pores; clear smooth boundary
8 – 54	Ec	Dark brown (10 YR 3/3) gravelly sandy Loam; weak, medium sub angular blocky structure; slightly hard dry, non –plastic wet; many medium woody roots and many medium interstitial pores; common coarse hard angular ferruginous and manganious concretions (35%); clear smooth boundary.
54 - 96	B+C1	Strong brown (7.5 YR 5/6) gravelly sandy clay Loam; moderate, medium sub angular blocky structure; slightly hard dry, friable moist; moderately sticky and moderately plastic wet; common medium woody roots and common coarse very hard angular ferruginous and manganious concretions (60%); clear smooth boundary.

96 – 136	B+ C2	Strong brown (7.5 YR 5/6) gravelly sandy clay Loam; moderate, medium sub angular blocky structure; slightly hard dry, friable moist; moderately sticky and moderately plastic wet; common medium woody roots and common coarse very hard angular ferruginous and manganious concretions (60%); clear smooth boundary.
136 – 192	Cc	Reddish Yellow (7.5 YR 6/8) loamy sand; weak fine, granular blocky; loose; non- sticky and non –plastic; few medium woody roots and common coarse very hard angular ferruginous and manganious concretions (60%); clear smooth boundary.

Appendix 5 Owan East LGA Profiles Pro FORMA Sheets

PEDON 1

Soil Series

Taxonomic Class	Ruptic –Ultic Dystrudept / Haplic Petroplinthic Cambisol (Skeletic Densic)
Parent Material	Sedimentary
Bearing	0-3 %
Physiographic Position	Plain
Drainage	Well drained
Vegetation / Landuse	Secondary vegetation/ Residential
Presence of Biological activities	Nil
Depth to water table	> 139m
Elevation	134m
Latitude	06. 57 40.7
Longitude	006 02 13.7
Described by & date	Obazuaye Esohe 2018

Horizon	Depth (cm)	Description
Ap	0 – 26	Sand; pH 6.9, pale brown colour (10YR$^{6}/_{3}$) Granular, mixed few roots, firm, wavy clear boundary ‘‘‘‘‘
Bt1	26 -85	Sandy clay loam; pH 5.8, grayish brown (10YR$^{5}/_{2}$) platy, firm, presence of concretion, broken diffuse
Bt2	85 – 139	Sandy clay loam; pH 4.7,dark red (10R 3/6), platy, extremely stony, no roots, extremely firm

Appendix 6

PEDON 2

Soil Series

Taxonomic Class	Rhodic kandiudalf / Vertic Lixisol (Rhodic, Siltic)
Parent Material	Sedimentary
Bearing	2 - 5%
Physiographic Position	Plain
Drainage	Poorly drained
Vegetation / Landuse	Fallow
Presence of biological activities	Nil
Depth to water table	> 180cm
Elevation	159m
Latitude	07.00187
Longitude	006.17037
Described by & date	Obazuaye Esohe in 2018

Horizon	Depth (cm)	Description
Ap	0 -16	Black brown (10YR 2/1); Sand; Loose; blocky; many mixed root ; clear smooth boundary; pH 6.4
AB	16 -42	Reddish brown (2.5YR 4/4) ; Loamy sand; loose,platy; many mixed roots; diffuse smooth boundary; pH 5.8
Bt1	42 -92	Reddish brown (2.5YR 4/4) ; Silty loam, firm; platy, few fine roots; diffuse wavy boundary; pH 5.3
Bt2	92 – 180	Red (2.5YR 4/8); Silty loam, firm; platy, pH 4.7

Appendix 7

PEDON 3

Soil Series

Taxonomic Class	Aquic Kandiudults / Gleyic Vetic Lixisol (Clayic, Oxyaquic)
Parent Material	Coastal Plain Sand
Bearing	8 -12%
Physiographic Position	Plain
Drainage	Fairly well drained
Vegetation / Landuse	Arable farmimg
Presence of biological activities	crab burrows
Depth to water table	> 180cm
Elevation	113.8m
Latitude	06.91207
Longitude	006.05384
Described by & date	Obazuaye Esohe in 2018

Horizon	Depth (cm)	Description
A1	0 -30	Black brown (10YR 2/1); sandy clay; extremely firm; sub angular blocky; many coarse root size; clear wavy boundary; pH 6.30
AB	30 -70	Light gray (10YR 7/1) ; sandy clay; abundance of mottles; extremely firm; few fine roots; sub angular blocky; clear wavy boundary; pH 6.0
Bt1	70 – 120	Light gray (10YR7/1) ; clay, abundance of mottles; extremely firm; sub angular blocky, diffuse wavy boundary; pH 5.7
Bt2	127 – 180	Light gray (10YR7/1) ; clay, abundance of mottles; extremely firm; sub angular blocky, pH 4.8

Appendix 8

PEDON 4

Soil Series

Taxonomic Class	Mollic Udarent / Ferralic Rubic Arenosol (Hyperochric, Dystric)
Parent Material	Basement Complex
Bearing	2 -5%
Physiographic Position	Depression
Drainage	Well drained
Vegetation / Landuse	Faming
Presence of biological activities	Nil
Depth to water table	> 180cm
Elevation	258m
Latitude	07. 03 15.7
Longitude	006. 03 24.2
Described by & date	Obazuaye Esohe in 2018

Horizon	Depth (cm)	Description
Ap	0 -11	Dark reddish brown (5YR 3 /1); Sand ; crumb;loose many mixed root ; smooth clear boundary; pH 6.8
AB	11 -67	Yellowish red (5YR 4 /6) ; sand; sub angular blocky ; friable; few roots; smooth clear boundary; pH 6.6
B1	67 - 124	Yellowish red (5YR 4 /6); loamy sand, sub angular blocky; friable; few coarse root ; smooth clear boundary; pH 4.5
B2	124 - 180	Yellowish red (5YR 4/6) ; loamy sand; sub angular blocky, friable; few coarse roots; pH 4.4

Appendix 9

PEDON 5

Soil Series	
Taxonomic Class	Ruptic – Alfic Eutrudept / Haplic Petroplinthic Cambisol (Skeletic Eutric)
Parent Material	Sedimentary
Bearing	28 – 32%
Physiographic Position	Plain
Drainage	Moderately drained
Vegetation / Landuse	Savannah Vegetation / Fallow
Presence of biological activities	Nil
Depth to water table	> 120cm
Elevation	332m
Latitude	07. 11 43.8
Longitude	006 .01 10.3
Described by & date	Obazuaye Esohe in 2018

Horizon	Depth (cm)	Description
Ap	0 -17	Black (5YR 2.5 /1); Sand ; crumbs; loose; many mixed root ; very stony; smooth clear boundary; pH 7.1
Bt1	17 - 58	Dark reddish brown (5YR 3 /2) ; loamy sand ; crumbs ; loose; many mixed roots; very stony; wavy diffuse boundary; pH 6.7
Bt2	58 -88	Dark reddish brown (5YR 3 /3); sandy loam, sub angular blocky; friable; few fine root ;very stony; clear wavy boundary; pH 6.3
Bt3	88 -120	Dark reddish brown (5YR 3/4) ; Sandy clay loam; platy, firm; very stony; pH 6.2

Appendix 10

PEDON 6

Soil Series	
Taxonomic Class	Arenic Eutrudept / Haplic Pisoplinthic Cambisol (Chromic, Calcaric)
Parent Material	Basement
Bearing	38 – 56%
Physiograsphic Position	Depression
Drainage	Well Drained
Vegetation / Landuse	Secondary vegetation
Presence of biological activities	Nil
Depth to water table	> 180cm
Elevation	320m
Latitude	07. 11 35.6
Longitude	006 .00 44.7
Described by & date	Obazuaye Esohe in 2018

Horizon	Depth (cm)	Description
Ap	0 -12	Very dark grayish brown (10YR 3 /2); Sand ; crumb; loose; many mixed root ; very stonny; diffuse clear boundary; pH 7.4
Bt1	12 - 36	Dark grayish brown (10YR 4 /2) ; loamy sand ; granular; loose ; many mixed roots; very stonny; wavy diffuse boundary; pH 7.1
B	36 -72	Gray (7.5YR 5 /1); loamy sand, blocky; firm; few mixed root ; stonny; clear smooth boundary; pH 6.8
Bt21	72 -109	Weak red (2.5YR 5/2) ; Sandy loam; blocky, firm ; few fine roots; diffuse smooth boundary; pH 6.5
Bt22	109 – 145	Dark gray (7.5YR 4/1) ; Sandy loam ,sub angular blocky; firm; few fine roots; wavy diffuse boundary; pH 6.4

Bt23	145 – 180	Dark gray (7.5YR 4/ 1) ; sandy clay loam; sub angular blocky firm; pH 5.8

Appendix 11.: Land suitability requirements for rubber cultivation by Sys (1985) as modified by (Orimoloye and Akinbola 2013)

Land characteristics	Suitability classes

	S_1	S_2	S_3	N_1	N_2
CLIMATE (c)					
Annual rainfall (mm)	> 2,400	1500 -2000	1250 – 1500	-	<1250
Length of dry season (months)	1 -2	3 -4	5	>5	-
Mean annual max temperature (OC)	29	25 -29	22 -25	-	<22
Mean annual min temperature (OC)	>20	16 -20	14 -16	12 -14	<12
Relative Humidity (%)	>75	65 -75	60 -65	-	<65
Permanent Soil limitations (s)					
Effective soil depth (cm)	200	150 -200	100 – 150	50 -100	50 or less
Texture	SC,CL,SCL	LC,FINE SC	Coarse SCL,CL,SL	LS	S
Gravel (%) 0 -15cm	<3 -10	10 -35	35 -60	60-90	>90
Slope gradient (%)	0 -3	3 -8	8 -20	20 -35	>35
Altitude (m)	<200	200 -500	500 -600	600 -800	>800
Subsoil Ph	5 -6	4.5 -5	4 – 4.5	6.5 -7	7.0
ECEC (cmol/ kg)	> 10	5 -10	<5	-	-
Base saturation (%)	>45	30 -45	15 -30	<15	-
Available P(Bray P1) mg/kg	>15	10 -15	5 -10	<3	-
Organic Carbon (%)	>1.2	0.8 1.2	<0.8	-	-
Wetness (w)					
Drainage	Well drained	Well drained s	Mod –imperfect	Poorly drained	Very poorly drained
Depth to water table (cm)	>200	150 -200	100 -150	50 -100	>50

Appendix 12: Land suitability requirements for Oil Palm cultivation Sys (1985) as modified by (Senjobi and Ogunkunle, 2010)

Land characteristics	Suitability classes				
	S_1	S_2	S_3	N_1	N_2
CLIMATE (c)					
Annual rainfall (mm)	> 2000	1700 -2000	1450 – 1700	1300-1250	<1250
Length of dry season (months)	1 -2	2 -3	3 -4	-	>5
Mean annual max temperature (OC)	29	25 -29	22 -25	-	<22
Mean annual min temperature (OC)	>20	16 -20	14 -16	12 -14	<12
Relative Humidity (%)	>75	65 -75	60 -65	-	<65
Permanent Soil limitations (s)					
Effective soil depth (cm)	>100	>75	>50	-	<50
Texture	SC,L,S CL	SCL	SCL- LS	Any	C,Cs, Any
Coarse Fragment (Vol %)	<15	<35	<55	Any	
Topography (t)					
Slope gradient (%)	0 -8	8 -16	16 -30	>30	>30
Soil fertility (f)					
ECEC (cmol/ kg clay)	> 16	<10	<10	<5	<5
Base saturation (%)	>35	20 -15	15 -10	<10	<10
Available P(Bray P1) mg/kg	>15	10 -15	5 -10	<3	-
Organic Carbon (%, 0 - 15)	>1.5	<0.8	<0.5	0.2	Any
Wetness (w)					
Drainage	Some what poorly drained	Mod,Well drained	Mod – well	Poorly drained	Very poor, not drainable
Depth to water table (cm)	>200	150 -200	-	-	-

Appendix 13.: Land suitability requirements for cocao cultivation by Sys (1985) as modified by Fasina *et al*, 2007)

Land characteristics	Suitability classes				
	S_1	**S_2**	**S_3**	**N_1**	**N_2**
CLIMATE (c)					
Annual rainfall (mm)	1600 - 2500	1400 -1600	1200 – 1400	-	<1200
Length of dry season (months)	<2	<3	<4	-	>5
Mean annual temperature (OC)	23 -32	22 -35	22 -38	-	<22
Relative Humidity (%)	40 -65	35 -75	60 -65	-	<65
Permanent Soil limitations (s)					
Effective soil depth (cm)	>100	>75	>50	-	<50
Texture	SC,L,SCL	SCL	SCL- LS	Any	C,Cs, Any
Topography (t)					
Slope gradient (%)	0 -8	8 -16	16 -30	>30	>30
Soil fertility (f)					
CEC (cmol/ kg clay)	> 16	<10	<10	<5	<5
Base saturation (%)	>35	20 -15	15 -10	<10	<10
Organic Carbon (%)	>1.5	<0.8	<0.5	0.2	Any
Wetness (w)					
Drainage	Some what poorly drained	Mod,Well drained	Mod – well	Poorly drained	Very poor, not drainable
Depth to water table (cm)	>200	150 -200	-	-	-

Appendix 14: Requirement for the cultivation of maize

Parameters	**Suitability class**				
	S_1 (highly suitable)	**S_2 (moderately suitable)**	**S_3 (marginally suitable)**	**N_1 (currently not suitable)**	**N_2 (permanently not suitable)**
CLIMATE					
Altitude (m)	≤ 2,000	2,000 - 2,200	2,200-2,300	-	>2,300
Annual rainfall (mm)	≥1,000	1000 - 900	<900	-	-
LANDSCAPE					
Slope gradient (%)	≤6	6-13	13-25	25-55	>55
Soil					
Flooding	No risk	-	-		Any risk
Drainage	Excessive to moderate	Imperfect	Poor	Very poor	-
Clay (%) & Structure	20-60, > 60 blocky	≤20, >60 vertic	-	-	Organic soils
Coarse Fragment (Vol %)	<15	<35	<55	Any	
Depth(m)	≥0.75	0.75 – 0.50	<0.50	-	-
SBC($cmolkg^{-1}$)	>5.0	5.0 – 3.5	3.5 – 2.0	≤2.0	-

Source: Verdoodt and Van Ranst (2003)

Appendix 15**: Requirements for the cultivation of cassava**

Parameters	**Suitability class**				
	S_1 (Highly suitable)	**S_2 (Moderately suitable)**	**S_3 (Marginally suitable)**	**N_1 (Currently not suitable)**	**N_2 (Permanently not suitable)**
CLIMATE					
Altitude (m)	≤ ,1500	1,500 – 1,700	1,700 – 1,900	-	>1,900
Annual temperature (ºC)	≥21	21-28	18-17	-	<17
Annual rainfall (mm)	≥1,000	<1,000	-	-	-
Length of dry days	1 – 5	<6	<7	-	Any
LANDSCAPE					
Slope gradient (%)	≤6	6-13	13-25	25-55	>55
Soil wetness (w)					
Flooding	No risk	-	-		Any risk
Drainage	Excessive to well	Moderate	imperfect	Poor to very poor	
Soil Physical Characteristics (s)					
Clay(%)& structure	≤35, 35 – 60 blocky	35 – 60 vertic, >60 blocky	60 vertic	-	Organic soils
Coarse Fragment	<3 (S1)	<15(S2)	<35(S3)	<35 (N1)	any (S2)
Depth(m)	≥1.00	1.00 - 0.75	0.75 - 0.50	-	<0.50
SBC($cmolkg^{-1}$)	>2.0	≤2.0	-	-	-

Source: Verdoodt and Van Ranst (2003)

Appendix 16

RRIN PEDON 1

Soil Series

Taxonomic Class	Typic Kandiudalf / Nitic Lixisol (Hypereutric, maganiferric)
Parent Material	Basement complex
Bearing	0 -2%
Physiographic Position	Valley Bottom
Drainage	Poorly drained
Vegetation / Landuse	Arable farmimg
Presence of biological activities	Nil
Depth to water table	> 160cm
Elevation	
Latitude	07.20074
Longitude	005.79594/ 005.99594
Described by & date	Obazuaye Esohe in 2014

Horizon	Depth (cm)	Description
Ap	0 - 13	Grayish brown (10YR 5/2); loamy sand; friable; sub angular blocky; many coarse root ; diffuse wavy boundary; pH 6.7
A12	13 - 33	Brown (10YR 5/3) ; loamy sand; firm; many coarse roots; sub angular blocky; clear wavy boundary; pH 6.8
Bt1	33 – 62	Brown (10YR5/3) ; sandy loam, few mottles; many coarse root; firm; sub angular blocky, clear wavy boundary; pH 6.4
2Bt1	62 - 105	Very dark grayish brown (10YR3/2) ; sandy loam, coarse few root; firm; sub angular blocky, clear wavy boundary; pH 6.4
2Bt2	105 -140	Very dark grayish brown (10YR3/2) ; sandy loam ; coarse few root; firm; sub angular blocky, diffuse wavy boundary; pH 6.4

2Bt3	140 -160	Brown (10YR4/3) ; sandy clay loam, firm; sub angular blocky, pH 6.3

Appendix 17

RRIN PEDON 2

Soil Series	
Taxonomic Class	Ruptic-Alfic Dystrudept / Haplic Ferallic Cambisol (Skeletic, Dystric)
Parent Material	Basement complex
Bearing	8 - 13%
Physiographic Position	Middle slope / Hill crest
Drainage	Very poorly drained
Vegetation / Landuse	Secondary / fallow
Presence of biological activities	Nil
Depth to water table	> 115cm
Elevation	
Latitude	07.20437
Longitude	005.99671
Described by & date	Obazuaye Esohe in 2014

Horizon	Depth (cm)	Description
Ap	0 -17	Reddish brown (5YR 4/4); sandy clay loam; firm; crumb; many mixed coarse root ; clear wavy boundary; pH 6.20
AB1	17 - 45	Yellowish red (5YR 4/6) ; clayey; firm; coarse many roots; crumb; presence of gravels; clear wavy boundary; pH 6.2
AB2	45 -78	Yellowish red (5YR4/6) ; clayey, extremely firm; few fine root; angular blocky, stony; clear wavy boundary; pH 6.2
Bt	78 - 115	Dark red (2.5YR3/6) ; sandy loam, few roots; stony friable; blocky, pH 5.5

Appendix 18

RRIN PEDON 3

Soil Series	
Taxonomic Class	Ruptic-Alfic Eutrudept / Haplic Ferallic Cambisol (Densic, Eutric)
Parent Material	Basement complex
Bearing	5 -7%
Physiographic Position	Middle slope
Drainage	Fairly drained
Vegetation / Landuse	Fallow
Presence of biological activities	Nil
Depth to water table	> 120cm
Elevation	
Latitude	07.20240
Longitude	005.99622
Described by & date	Obazuaye Esohe in 2014

Horizon	Depth (cm)	Description
Ap	0 -12	Dark yellowish brown (10YR 3/4); sandy loam; friable; blocky; many mixed root ; clear wavy boundary; pH 6.7
A12	12 -35	Dark yellowish brown (10YR 3/4) ; sandy loam; friable ;coarse many roots; few stones; blocky; diffuse wavy boundary; pH 6.8
AC1	35 - 65	Dark yellowish brown (10YR3/4) ; sandy clay loam, firm; course few root; angular blocky, diffuse smooth boundary; pH 6.8
AC2	65 - 90	Yellowish brown (10YR5/4) ; sandy clay loam, presence of mottles; firm; very few root; angular blocky, clear smooth boundary; pH 6.5
C	90 -120	Brown (10YR4/3) ; sandy clay loam, presence of mottles; firm; medium root; platy, pH 5.2

Appendix 19

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
pH	Pedon1	3	5.8000	1.10000	.63509	3.0674	8.5326	4.70	6.90
	Pedon2	4	5.5500	.72342	.36171	4.3989	6.7011	4.70	6.40
	Pedon3	4	5.7000	.64807	.32404	4.6688	6.7312	4.80	6.30
	Pedon4	4	5.5750	1.30224	.65112	3.5028	7.6472	4.40	6.80
	Pedon5	4	6.5750	.41130	.20565	5.9205	7.2295	6.20	7.10
	Pedon6	6	6.6667	.56451	.23046	6.0743	7.2591	5.80	7.40
	Total	25	6.0400	.87560	.17512	5.6786	6.4014	4.40	7.40
EC	Pedon1	3	43.3333	25.92939	14.97034	-21.0788	107.7455	25.00	73.00
	Pedon2	4	100.0250	73.35145	36.67573	-16.6935	216.7435	44.10	208.00
	Pedon3	4	452.5000	174.19625	87.09812	175.3149	729.6851	243.00	650.00
	Pedon4	4	138.5000	106.60050	53.30025	-31.1252	308.1252	72.00	296.00
	Pedon5	4	122.5000	83.78345	41.89173	-10.8182	255.8182	67.00	247.00
	Pedon6	6	168.1667	93.38612	38.12472	70.1639	266.1694	56.00	284.00
	Total	25	175.7240	158.95665	31.79133	110.1099	241.3381	25.00	650.00
OC	Pedon1	3	.6433	.31390	.18123	-.1364	1.4231	.29	.89
	Pedon2	4	.6250	.54286	.27143	-.2388	1.4888	.16	1.41
	Pedon3	4	.8400	.78115	.39058	-.4030	2.0830	.32	2.00
	Pedon4	4	.7650	.91784	.45892	-.6955	2.2255	.11	2.11
	Pedon5	4	.9675	.81680	.40840	-.3322	2.2672	.26	2.14
	Pedon6	6	.9283	1.21873	.49754	-.3506	2.2073	.10	3.36
	Total	25	.8116	.79797	.15959	.4822	1.1410	.10	3.36
N	Pedon1	3	.0427	.02515	.01452	-.0198	.1051	.01	.06
	Pedon2	4	.0483	.05012	.02506	-.0315	.1280	.01	.12
	Pedon3	4	.3070	.54939	.27470	-.5672	1.1812	.02	1.13
	Pedon4	4	.0500	.05771	.02885	-.0418	.1418	.01	.13
	Pedon5	4	.0965	.11286	.05643	-.0831	.2761	.02	.26
	Pedon6	6	.0650	.07847	.03204	-.0174	.1474	.01	.22
	Total	25	.1010	.22385	.04477	.0086	.1934	.01	1.13
P	Pedon1	3	1.6900	.82964	.47899	-.3709	3.7509	.75	2.32

	Pedon2	4	4.4875	1.98817	.99409	1.3239	7.6511	2.91	7.33
	Pedon3	4	4.2575	3.91125	1.95563	-1.9662	10.4812	2.12	10.12
	Pedon4	4	.9875	.40111	.20056	.3492	1.6258	.40	1.28
	Pedon5	4	6.4675	4.75988	2.37994	-1.1065	14.0415	.27	11.16
	Pedon6	6	.9550	.88331	.36061	.0280	1.8820	.12	2.62
	Total	25	3.0240	3.17003	.63401	1.7155	4.3325	.12	11.16
Ca	Pedon1	3	3.8167	2.90528	1.67736	-3.4004	11.0338	1.23	6.96
	Pedon2	4	2.2900	.95631	.47816	.7683	3.8117	1.44	3.56
	Pedon3	4	2.3400	.69244	.34622	1.2382	3.4418	1.52	3.12
	Pedon4	4	4.2200	3.37986	1.68993	-1.1581	9.5981	.96	8.32
	Pedon5	4	6.1800	4.61990	2.30995	-1.1713	13.5313	3.28	13.04
	Pedon6	6	12.3533	2.04344	.83423	10.2089	14.4978	9.28	15.44
	Total	25	5.8276	4.64323	.92865	3.9110	7.7442	.96	15.44
Mg	Pedon1	3	.7833	.34530	.19936	-.0744	1.6411	.40	1.07
	Pedon2	4	.6450	.26752	.13376	.2193	1.0707	.32	.96
	Pedon3	4	.8000	.25298	.12649	.3974	1.2026	.48	1.04
	Pedon4	4	1.2800	.67567	.33784	.2049	2.3551	.64	2.16
	Pedon5	4	3.3200	.79061	.39531	2.0620	4.5780	2.72	4.48
	Pedon6	6	3.3667	1.45995	.59602	1.8345	4.8988	1.84	5.20
	Total	25	1.8692	1.47075	.29415	1.2621	2.4763	.32	5.20
Na	Pedon1	3	.2333	.14468	.08353	-.1261	.5927	.14	.40
	Pedon2	4	.3450	.01291	.00645	.3245	.3655	.33	.36
	Pedon3	4	.4075	.05188	.02594	.3249	.4901	.36	.47
	Pedon4	4	.2150	.05066	.02533	.1344	.2956	.17	.28
	Pedon5	4	.3700	.09309	.04655	.2219	.5181	.28	.46
	Pedon6	6	.1967	.03615	.01476	.1587	.2346	.16	.26
	Total	25	.2892	.10567	.02113	.2456	.3328	.14	.47
K	Pedon1	3	.2333	.14468	.08353	-.1261	.5927	.14	.40
	Pedon2	4	.0675	.03862	.01931	.0060	.1290	.03	.12
	Pedon3	4	.1375	.12339	.06169	-.0588	.3338	.05	.32
	Pedon4	4	.1325	.10404	.05202	-.0331	.2981	.05	.28
	Pedon5	4	.2525	.14863	.07432	.0160	.4890	.11	.44
	Pedon6	6	.1550	.07817	.03191	.0730	.2370	.06	.26
	Total	25	.1596	.11385	.02277	.1126	.2066	.03	.44
ECEC	Pedon1	3	5.8167	3.13698	1.81114	-1.9760	13.6094	3.06	9.23
	Pedon2	4	3.6475	1.34093	.67046	1.5138	5.7812	2.32	5.40
	Pedon3	4	4.0100	1.21403	.60701	2.0782	5.9418	2.61	5.45

	Pedon4	4	6.3975	3.85300	1.92650	.2665	12.5285	2.82	11.24
	Pedon5	4	10.4475	5.45281	2.72641	1.7709	19.1241	6.89	18.52
	Pedon6	6	16.3550	3.43287	1.40146	12.7524	19.9576	11.74	21.36
	Total	25	8.5436	5.85091	1.17018	6.1285	10.9587	2.32	21.36
Clay	Pedon1	3	17.6667	10.28462	5.93783	-7.8817	43.2151	5.80	24.00
	Pedon2	4	14.1000	6.64580	3.32290	3.5250	24.6750	6.40	19.80
	Pedon3	4	45.5500	6.56582	3.28291	35.1023	55.9977	39.80	52.10
	Pedon4	4	8.4000	3.46506	1.73253	2.8863	13.9137	4.30	11.70
	Pedon5	4	14.4250	7.33002	3.66501	2.7613	26.0887	4.30	21.30
	Pedon6	6	15.5000	7.26719	2.96682	7.8736	23.1264	5.30	26.10
	Total	25	19.0360	13.63552	2.72710	13.4075	24.6645	4.30	52.10
Silt	Pedon1	3	4.7667	1.11505	.64377	1.9967	7.5366	3.50	5.60
	Pedon2	4	30.0750	31.73929	15.86964	-20.4293	80.5793	1.90	60.00
	Pedon3	4	9.5250	1.01776	.50888	7.9055	11.1445	8.00	10.10
	Pedon4	4	2.0250	1.05000	.52500	.3542	3.6958	1.10	3.50
	Pedon5	4	2.3750	1.37689	.68845	.1841	4.5659	1.00	4.00
	Pedon6	6	2.6333	1.55392	.63439	1.0026	4.2641	1.10	5.50
	Total	25	8.2440	15.10985	3.02197	2.0070	14.4810	1.00	60.00
Sand	Pedon1	3	77.5667	11.37556	6.56768	49.3082	105.8251	70.80	90.70
	Pedon2	4	55.8250	38.14170	19.07085	-4.8670	116.5170	20.50	90.20
	Pedon3	4	44.9250	5.91854	2.95927	35.5073	54.3427	39.70	50.10
	Pedon4	4	89.5750	2.49583	1.24791	85.6036	93.5464	87.20	92.20
	Pedon5	4	83.2000	6.02771	3.01386	73.6086	92.7914	77.70	91.70
	Pedon6	6	81.8667	5.85275	2.38937	75.7246	88.0087	72.80	89.20
	Total	25	72.7200	21.80153	4.36031	63.7208	81.7192	20.50	92.20
Fe	Pedon1	3	50.3567	13.71556	7.91868	16.2853	84.4280	36.57	64.00
	Pedon2	4	.4525	.19085	.09543	.1488	.7562	.27	.72
	Pedon3	4	1.6225	1.04459	.52229	-.0397	3.2847	.63	3.09
	Pedon4	4	23.3900	1.77979	.88990	20.5580	26.2220	21.70	25.46
	Pedon5	4	70.4050	7.51988	3.75994	58.4392	82.3708	64.59	81.35
	Pedon6	6	93.2433	41.30314	16.86194	49.8983	136.5883	40.93	160.80
	Total	25	43.7604	42.33530	8.46706	26.2852	61.2356	.27	160.80
Zn	Pedon1	3	1.5867	.46544	.26872	.4305	2.7429	1.05	1.88
	Pedon2	4	8.6325	1.43321	.71661	6.3519	10.9131	7.06	10.20
	Pedon3	4	17.2525	7.55879	3.77939	5.2248	29.2802	9.42	26.68
	Pedon4	4	2.9550	2.05625	1.02813	-.3170	6.2270	1.26	5.75
	Pedon5	4	5.1900	2.53163	1.26581	1.1616	9.2184	3.50	8.89

	Pedon6	6	10.0017	2.69774	1.10135	7.1706	12.8328	6.38	14.65
	Total	25	8.0356	6.02471	1.20494	5.5487	10.5225	1.05	26.68
Cu	Pedon1	3	.1933	.24090	.13908	-.4051	.7918	.03	.47
	Pedon2	4	.8150	.26006	.13003	.4012	1.2288	.52	1.14
	Pedon3	4	1.1325	.24717	.12358	.7392	1.5258	.85	1.41
	Pedon4	4	.8000	1.20019	.60010	-1.1098	2.7098	.05	2.57
	Pedon5	4	1.9075	2.33797	1.16898	-1.8127	5.6277	.34	5.37
	Pedon6	6	5.9933	6.99614	2.85616	-1.3487	13.3353	.14	17.58
	Total	25	2.2064	4.00406	.80081	.5536	3.8592	.03	17.58
Mn	Pedon1	3	6.9200	4.72089	2.72561	-4.8073	18.6473	1.56	10.46
	Pedon2	4	.0000	.00000	.00000	.0000	.0000	.00	.00
	Pedon3	4	1.0850	1.25668	.62834	-.9147	3.0847	.00	2.29
	Pedon4	4	14.4100	21.42224	10.71112	-19.6776	48.4976	.67	45.89
	Pedon5	4	37.6325	16.19803	8.09902	11.8578	63.4072	25.44	61.50
	Pedon6	6	16.5983	14.26931	5.82542	1.6236	31.5731	6.09	42.30
	Total	25	13.3144	17.19523	3.43905	6.2166	20.4122	.00	61.50
Gravel	Pedon1	3	49.5533	37.32110	21.54735	-43.1574	142.2641	7.09	77.15
	Pedon2	4	.1600	.32000	.16000	-.3492	.6692	.00	.64
	Pedon3	4	26.0825	10.35495	5.17747	9.6055	42.5595	13.19	35.27
	Pedon4	4	.2300	.46000	.23000	-.5020	.9620	.00	.92
	Pedon5	4	60.5150	3.78879	1.89440	54.4862	66.5438	56.89	65.60
	Pedon6	6	26.0283	32.44142	13.24415	-8.0168	60.0735	.00	74.56
	Total	25	26.1112	28.98992	5.79798	14.1447	38.0777	.00	77.15
Ksat	Pedon1	3	10.7947	5.15032	2.97354	-1.9994	23.5888	7.39	16.72
	Pedon2	4	3.3000	1.80555	.90277	.4270	6.1730	1.50	5.80
	Pedon3	4	9.6750	18.55018	9.27509	-19.8425	39.1925	.30	37.50
	Pedon4	4	12.0120	5.54027	2.77014	3.1962	20.8278	5.63	18.13
	Pedon5	4	1.4960	1.82056	.91028	-1.4009	4.3929	.00	3.70
	Pedon6	6	4.8781	8.06252	3.29151	-3.5830	13.3392	.07	21.12
	Total	25	6.7034	8.88646	1.77729	3.0352	10.3715	.00	37.50
BD	Pedon1	3	1.8227	.53965	.31157	.4821	3.1632	1.37	2.42
	Pedon2	4	1.6250	.05000	.02500	1.5454	1.7046	1.60	1.70
	Pedon3	4	1.5250	.17078	.08539	1.2532	1.7968	1.30	1.70
	Pedon4	4	1.5810	.13251	.06626	1.3701	1.7918	1.49	1.77
	Pedon5	4	1.3894	.93457	.46728	-.0977	2.8765	.00	1.99
	Pedon6	6	1.7329	.30344	.12388	1.4145	2.0513	1.21	2.11

	Total	25	1.6139	.42153	.08431	1.4399	1.7879	.00	2.42

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Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
pH	Pedon1	3	5.8000	1.10000	.63509	3.0674	8.5326	4.70	6.90
	Pedon2	4	5.5500	.72342	.36171	4.3989	6.7011	4.70	6.40
	Pedon3	4	5.7000	.64807	.32404	4.6688	6.7312	4.80	6.30
	Pedon4	4	5.5750	1.30224	.65112	3.5028	7.6472	4.40	6.80
	Pedon5	4	6.5750	.41130	.20565	5.9205	7.2295	6.20	7.10
	Pedon6	6	6.6667	.56451	.23046	6.0743	7.2591	5.80	7.40
	Total	25	6.0400	.87560	.17512	5.6786	6.4014	4.40	7.40

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	5.962	5	1.192	1.821	.157
	Within Groups	12.438	19	.655		
	Total	18.400	24	0.766		

Multiple Comparisons

LSD

Dependent Variable	(I) Pedon	(J) Pedon	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
pH	Pedon1	Pedon2	.25000	.61796	.690	-1.0434	1.5434
		Pedon3	.10000	.61796	.873	-1.1934	1.3934
		Pedon4	.22500	.61796	.720	-1.0684	1.5184
		Pedon5	-.77500	.61796	.225	-2.0684	.5184
		Pedon6	-.86667	.57212	.146	-2.0641	.3308
	Pedon2	Pedon1	-.25000	.61796	.690	-1.5434	1.0434
		Pedon3	-.15000	.57212	.796	-1.3475	1.0475
		Pedon4	-.02500	.57212	.966	-1.2225	1.1725
		Pedon5	-1.02500	.57212	.089	-2.2225	.1725
		Pedon6	-1.11667*	.52227	.046	-2.2098	-.0235
	Pedon3	Pedon1	-.10000	.61796	.873	-1.3934	1.1934
		Pedon2	.15000	.57212	.796	-1.0475	1.3475
		Pedon4	.12500	.57212	.829	-1.0725	1.3225
		Pedon5	-.87500	.57212	.143	-2.0725	.3225
		Pedon6	-.96667	.52227	.080	-2.0598	.1265
	Pedon4	Pedon1	-.22500	.61796	.720	-1.5184	1.0684
		Pedon2	.02500	.57212	.966	-1.1725	1.2225
		Pedon3	-.12500	.57212	.829	-1.3225	1.0725
		Pedon5	-1.00000	.57212	.097	-2.1975	.1975
		Pedon6	-1.09167	.52227	.050	-2.1848	.0015

	Pedon5	Pedon1	.77500	.61796	.225	-.5184	2.0684
		Pedon2	1.02500	.57212	.089	-.1725	2.2225
		Pedon3	.87500	.57212	.143	-.3225	2.0725
		Pedon4	1.00000	.57212	.097	-.1975	2.1975
		Pedon6	-.09167	.52227	.863	-1.1848	1.0015
	Pedon6	Pedon1	.86667	.57212	.146	-.3308	2.0641
		Pedon2	1.11667*	.52227	.046	.0235	2.2098
		Pedon3	.96667	.52227	.080	-.1265	2.0598
		Pedon4	1.09167	.52227	.050	-.0015	2.1848
		Pedon5	.09167	.52227	.863	-1.0015	1.1848

Owan East LGA – 2019.

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
pH	Pedon1	3	5.8000	1.10000	.63509	3.0674	8.5326	4.70	6.90
	Pedon2	4	5.5500	.72342	.36171	4.3989	6.7011	4.70	6.40
	Pedon3	4	5.7000	.64807	.32404	4.6688	6.7312	4.80	6.30
	Pedon4	4	5.5750	1.30224	.65112	3.5028	7.6472	4.40	6.80
	Pedon5	4	6.5750	.41130	.20565	5.9205	7.2295	6.20	7.10
	Pedon6	6	6.6667	.56451	.23046	6.0743	7.2591	5.80	7.40
	Total	25	6.0400	.87560	.17512	5.6786	6.4014	4.40	7.40

ANOVA

	Sum of Squares	Df	Mean Square	F	Sig.

pH	Between Groups	5.962	5	1.192	1.821	.157
	Within Groups	12.438	19	.655		
	Total	18.400	24	0.766		

Owan East LGA – 2019.

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
pH	pedon1	2	5.3500	.77782	.55000	-1.6384	12.3384
	Pedon2	6	5.2833	.56006	.22864	4.6956	5.8711
	Total	8	5.3000	.55806	.19730	4.8335	5.7665

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	.007	1	.007	.018	.897
	Within Groups	2.173	6	.362		
	Total	2.180	7	0.311		

PARAMETERS:

1. C V = Std / mean = .55806 / 5.3000 X 100 = 10.5 %
2. Variance ratio test = 0.018 NS
3. Relative variance = 0.362 / 0.311 = 1.16
4. 1 – R V = 1- 1.16 = -0.16.
5. Pi = 0.007-0.362 / 0.007+0.362(3) = -0.32