LAND EVALUATION STUDIES OF SOME SELECTED SOILS IN IKOLE SOUTH-WESTERN NIGERIA

BY

GBAJA CHRISTIANAH OLUWASOLA

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ABSTRACT

Sustainable use of soils requires in-depth knowledge of the formation, genesis and properties of soil. It is in view of this that some soils derived from granitic parent rock in Ikole, South-western Nigeria covering 33.7 hectares of land where mapped at a scale of 1:50,000 using a combination of convectional and remote sensing methods of soil survey. The objective was to generate detailed information on the properties of the soil for their sustainable agricultural use and management. Seven soils located on seven land use types were identified and classified. Four of the soils (IK1, IK2, IK3 and IK5) were classified as Typic Plinthudult while IK4 was classified as Kandic Plinthaquult and IK6 was classified as Plinthic Kandiudult and IK7 as Fluvaquentic Epiaquept. Using the FAO/UNESCO, the soils (IK1, IK2, IK3 and IK5) were classified as Dystric Lixisol while IK4 was classified Ferric Lixisol, IK6 as Plinthudult Lixisol while IK7 was classified as Fluvic Cambisol. The USDA/FAO framework and land capability classification, land suitability classification and land fertility classification were used to evaluate the soils. Soil IK1, IK2, IK5 and IK6 belong to class III while IK3, IK4 and IK7 belong to class IV in the land capability classification due to soil fertility, physical soil characteristics and wetness limitation of the soil. The soils were evaluated for their suitability for the production of cassava *(Manihot esculentus),* Oil palm *(Elaeis guinnensis)*, cashew *(Anacardium occidentale)*, maize *(Zea mays) and* banana *(Musa acuminata)*. All the soil types are highly suitable for cashew production and moderately suitable for cassava, oil palm, maize and banana production except soils IK4 and IK7 that are not suitable due to wetness problem. The potentials of these soils will increase from moderately suitable (S2) to highly suitable (S1) with proper fertility management. Appropriate sustainable soil management recommendations have been made.

CERTIFICATION

I certify that this work was carried out by **GBAJA CHRISTIANAH OLUWASOLA** in the Department of Soil Science and Land Resources Management, Federal University Oye-Ekiti, Ekiti State.

.... 11/10/2016 ....

Professor A.S. FASINA **Date**

Project Supervisor

B.Sc. Agric. (Hons), Ibadan

M.Sc, Ph.D (Agronomy),

Ibadan

Professor (Pedology)

Head of Department,

Soil Science and Land Resources Management,

Federal University Oye-Ekiti.

DEDICATION

I dedicate this project work to Almighty God who is the ultimate being, giver of life, knowledge, wisdom and strength.

I also dedicate it to my parents and siblings for their support and encouragement throughout my career in the University.

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CHAPTER ONE

INTRODUCTION

Land evaluation is an applied classification system that assesses the capacity of the soil for its optimal use, that is, to derive maximum benefits with minimum degradation. This can be defined, according to van Diepen *et al.* (1991), as "any method to explain or predict the use and potential of land". Land evaluation is based on the idea that this response is a function of these properties, and, hence, knowing these, one can predict the behaviour of the soil under a given use. From the study of such properties, different degrees of suitability of the soil can be inferred for each end proposed. These degrees are reflected on maps of use capacity or suitability, on which the corresponding recommendations are made for the rational planning of soil use. As land evaluation is intended to offer practical results that can be plotted on territorial maps, such endeavours cannot be limited to the analysis of the physical medium of the earth, but rather must be complemented by the corresponding socio-economic studies that enable cost benefit analyses of the profitability of the land use. Thus, land evaluation enables predictions on the biophysical and economic behaviour of land for current and potential uses.

The term land evaluation has been used to describe many concepts and analytical procedures. Most frequently its main objective is to appraise the potential of land for alternative kinds of land use by a systematic comparison of the requirements of this land use with the resources offered by the land (Dent and Young, 1981). Land evaluation was intended to optimize particularly the productive function of the land and to obtain other important land information at the same time (Hurni, 2000).

The process of assessing land to meet the user's need is called land evaluation and serves as the basis for proper land use planning (FAO, 1984). Land evaluation is soil survey interpretation. For areas that have potential to be put to any productive use, there will be need for such areas to be covered by a good soil survey. Information from such survey should however be accompanied by some technical guidance on the most appropriate productive uses to which the land can be put and provide information on the nature of the properties of the soil in any study area thereby establishing some background information upon which several other studies can be carried out.

It is the function of land evaluation to bring about understanding between land and the uses it is put, and to present planners with comparison of the most promising kinds of land use. Land evaluation is concerned with the assessment of land performance when used for specified purpose. It involves the execution and interpretation of basic surveys of climate, soils, vegetation, and other aspects of land in terms of the requirements of alternative forms of land use. The land uses considered have to be limited to those which are relevant within the physical, economic and social context of the area under consideration while the comparisons must incorporate economic consideration. In view of this, Beek (1978) regards land evaluation as the process of assessment of land use performance, 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 land uses in connection with specific land uses in terms applicable to objectives of the land evaluation.

Information on the soils of the study area is not available; as a result of this, it will be very difficult to develop a sustainable management system for the soils of this area. There is need to assess the potentials of these soils to be able to meet the user's need and this serves as the basis for proper land use planning.

The research output from this study will contribute to the database required for the precise characterization, classification, evaluation and understanding of the soil resources of the study area. Lands have been utilized intensively for all purposes at the expense of its suitability and capability thereby resulting in land degradation and altering of the natural ecological conservatory balances in the landscape (Senjobi, 2007). In view of this, it is mandatory to carryout land suitability in order to ensure that the study area is suitable and capable of sustaining long term production of the selected crops. Land evaluation studies using optimum and suitable methods has been the major concern for the sustainable planning and management of most of the cultivation areas and agricultural lands.

The general objective of this study is to carry out land evaluation studies on some selected soils at Ikole-Ekiti South-Western Nigeria. This is with the view to identify the potentials of these soils for various land use activities, identify limitations/constraints to crop production on these soils and also provide management strategies.

The specific objectives of this study are to:

i. characterize and classify the soils from seven land use types within Federal University Oye-Ekiti, Ikole campus.

ii. evaluate the potentials of the soils.

iii. produce a soil capability and suitability maps for the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1. Soil Survey and its Relevance

Soil surveys provide information needed for land management and land use planning. A well executed soil survey provides an adequate and accurate information on the kinds of soils, extent of distribution, properties and potentials to meaningful agricultural sector is imperative, especially in finding effective solution to problems of poor agricultural productivity in Nigeria.

Soil survey is an exercise whose objective is to make predictions of land use for agricultural, engineering and other purposes. These predictions are conventionally presented in terms of crop suitability or land capability classes must be based on sound interpretation of soil data (kellogg, 1961). The basic objective of soil surveys is the same for all kinds of land, although the number of mapping units, their composition, and the detail of mapping vary with the complexity of the soil patterns and the specific needs of the users. Thus, a soil survey is matched to the soils and the soil edge about soils and serves practical purposes. They satisfy a need for soil information about specific geographic areas for state, country and community land use plans. These plans include resource conservation plans for farms and ranches, development of reclamation projects, forest management, engineering projects as well as other purposes.

Soil survey ultimately leads to evaluation of the quality of different mapping units for specific types of land use (Deckers *et al.,* 2006). Soil surveys are always conducted with a certain purpose in mind which will be reflected upon in the map legend and in the explanatory notes. Soil data are only part of the information which is needed for land evaluation.

The results of soil surveys are published to provide the public with the soil information it needs to make sound decisions about land use and management and to provide a permanent record of what has been learnt about soils. The survey is the key element in planning both agricultural and non agricultural uses.

Soil survey information is becoming increasingly available for agricultural planning in general and crop production in particular. Naidu *et al.,* (1988) described an approach soil survey to crop yield prediction. They observed significant differences in grain yield of wheat of different soil series along with variations in soil physico-chemical properties.

2.2 Land Evaluation

Land evaluation is the process of estimating the potential of the land for alternative kinds of uses (Dent and Young, 1981). These include productive uses such as arable farming, livestock production, and forestry together with uses that provide services and other benefits.

Land evaluation can either be qualitative or quantitative. It is qualitative when the suitability of land for alternative purposes is expressed in qualitative terms (i.e. highly, moderately, or marginally suitable or not suitable for a specified use. Quantitative physical evaluation on the other hand provides quantitative estimates of the production or other benefits to be expected e.g. crop yields.

The evaluation of land is normally carried out to determine their suitability for specific uses. The information obtained can be used for a more realistic land use recommendation and present constraints (FAO, 1995; Abdulkadir, 1998; Braimoh, 2000). It also enables management guidelines in order to promote a suitable use of soil and environmental resources. The present shortage of good land for food production as caused by competing demand for other land uses such as industrialization, grazing, fuel wood, cash crop and their degradation as caused by unsuitable land use practices (FAO, 1983 and Raji, 1999) called for a reliable land evaluation.

The purpose of land evaluation is to predict the inputs, outputs, and other favourable as well as adverse effects resulting from the action of the most pertinent types of land use that can be identified in connection with the land that is evaluated.

Thus, land evaluation is vital in answering the following questions:

i. what is the present land use and what consequence can be encountered in the future if the present practice remain unchanged?

ii. What are the possible improvement in management practices within the present use?

iii. What other uses of land are physically, economically and socially relevant?

iv. Which of these uses offer possibilities of sustained production or other benefits which is not detrimental to human environment?

v. What inputs are necessary to bring about the desired production and minimize the adverse effects? What are the benefits of each form of use?

If the introduction of each new use involves significant change in the land itself, for example irrigation schemes then the following questions will be answered:

i. What are the necessary feasible changes and how can they be brought about?

ii. What are the necessary inputs to implement the changes? (FAO, 1981).

Land evaluation can be performed directly or indirectly. The direct evaluation starts from field tests (experimental stations, random agricultural sampling in the field) or from yield production provided by individual farmers and cooperatives, or else from agricultural statistics. These data are usually local, spotty, and sometimes not reliable and are generally difficult to extrapolate. Therefore, the evaluation is normally conducted indirectly on the basis of the soil properties, assuming that yield of a given soil depends on its properties and its level of management. The evaluations made in this manner should be validated finally with real yield data. In an indirect evaluation, it is evident that to define a degree of suitability, it does not suffice to choose only one property, but rather it requires a group of properties, possibly the more the better. The properties to choose will depend on the proposed use of the soil. The values of these evaluation parameters can be derived from disparate sources which include remote sensing, maps, literature and directly from the field and or laboratory with sharply differing degrees of precision.

In addition, these evaluation characteristics can be combined in many ways in various assessment systems used in soil evaluation, so that even for the same use, the results for a given soil can differ markedly, depending on the evaluation system chosen. Therefore, we propose that it is useful to define in a general manner the properties that most influence soils as well as their degree of suitability. It has been recognized that the quality of land suitability assessment and hence, the reliability of land use decisions depend largely on the quality of soil information used to derive them (FAO, 1976; Ghaffri *et al.,* 2000; Bouma, 2001; Mermut and Eswaram, 2001; Bogaert and D'Or, 2002; Salehi, *et al.,* 2003).

2.3 Basic concepts of Land evaluation

This study makes use of some basic terminologies used in land evaluation which needs to be well understood. These definitions are updated from those in FAO, (1976; 1983; 1984; 1985).

2.3.1 Soil and Land

Land is an area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal population, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man (FAO, 1976). The major component of land is the soil which is formed on the land together with all its physical, chemical and biological inclusions.

The concept of soil is not as wide and all embracing as the concept of land. In application of the interpretation of soil survey data, land is usually used instead of soil. The fitness of soils for land use cannot be assessed in isolation from other aspects of the environment, and hence it is land which is employed as the basis for suitability evaluation. The soil is a three dimensional body occupying the uppermost part of the earth's crust and having properties differing of the underlying rock materials as a result of interaction between climate, living organisms (including man's activities), parent materials, and the relief over a period of time and which is distinguished from other soils in terms of differences in internal characteristics and or slope complexity, micro topography, stoniness and rockiness of its surface (FAO, 1976).

2.3 Land use Requirement

It is defined as the assessment of quality of the land for specific land use demands. It is a condition of the land necessary for successful and sustained implementation of a specific land utilization type. Therefore, land use requirement changes with land utilization type.

2.2.3 Land use

Land use is the human management and modification of natural environment into built environment such as fields, pastures and settlements. It is also the total arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO, 2010). The purpose for which a tract of land is used constitutes its land-use (Annon, 2005).

2.2.4 Land characteristics

Land characteristics is an attribute of the land which can be measured or estimated and can be used for distinguishing between land units of differing suitabilities employed as means of describing land qualities (FAO, 1976).Examples include soil texture, organic matter content, salinity, alkalinity, acidity and toxicity.

2.2.5 Land quality

Land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use (FAO, 1976). Land qualities may be expressed in a positive or negative way. Examples are moisture availability, erosion resistance, flooding hazard, nutritive value of pastures, accessibility. Where data are available, aggregate land qualities may also be employed, e.g. crop yields, mean annual increments of timber species. A land quality is not necessarily restricted in its influence to one kind of use. The same quality may affect both arable use and animal product.

A land quality is relevant to a given type of land use if it influences either the level of inputs required, or the magnitude of benefits obtained, or both. For example, capacity to retain fertilizers is a land quality relevant to most forms of agriculture, and one which influences both fertilizer inputs and crop yield. Land qualities can sometimes be estimated or measured directly, but are frequently described by means of land characteristics. Qualities or characteristics employed to determine limits of land suitability classes or subclasses are known as diagnostic criteria.

2.2.6 Land use planning

Land-use planning is the term used for a branch of urban planning encompassing various disciplines which seek to order and regulate land use in an efficient and ethical way, thus preventing land-use conflicts. Governments use land-use planning to manage the development of land within their jurisdictions. Therefore, the governmental unit can plan for the needs of the community while safeguarding natural resources. It is therefore systematic assessment of land and water potential, alternatives for land use, and economic and social conditions in order to select and adopt the best land-use options. A land-use plan provides a vision for the future possibilities of development in neighborhoods, districts, cities, or any defined planning area.

2.2.7 Land Utilization type (LUT)

Land utilization type according to FAO, (1983) is defined as a kind of land use stated in more detail according to a set of technical specifications in a given physical, economic and social setting.

Land utilization type (LUT) according to FAO, (1976) refers to any kind of land use described or defined in a degree of detail greater than that of a major kind of land use, which in turn corresponds to a major subdivision of rural land use, such as rain-fed agriculture, irrigated agriculture, grassland, forestry or recreation.

Land utilization according to Sys (1985) defined the crop produced or crop rotation in addition to management systems of the crops. LUT therefore includes the kinds of crop, the succession of crops in a rotation or farming system with precision on the type of management.

Attributes of land utilization types include data or assumptions on:

- Produce, including goods (e.g. crops, livestock timber), services (e.g. recreational facilities) or other benefits (e.g. wildlife conservation).
- Market orientation, including whether towards subsistence or commercial production.
- Capital intensity
- Labour intensity
- Power sources (e.g. man's labour, draught animals machinery using fuels)
- Technical knowledge and attitudes of land users
-Technology employed (e.g. implements and machinery, fertilizers, livestock breeds, farm transport, methods of timber felling)
- Infrastructure requirements (e.g. sawmills, tat factories, agricultural advisory services)
- Size and configuration of land holdings, including whether consolidated or fragmented.
- Land tenure, the legal or customary manner in which rights to land are held, by individuals or groups
- Income levels, expressed per capital, per unit of production (e.g. farm) or per unit area.
- Management practices on different areas within one land utilization type are not necessarily the same. For example, the land utilization type may consist of mixed farming,

with part of the land under arable use and part allocated to grazing. Such differences may arise from variation in the land, from the requirements of the management system or both.

2.4 Matching land use with land qualities

This is the matching of the land characteristics/qualities with established FAO land use requirement standards.

2.5 Land evaluation efforts in Nigeria

Previous efforts at understanding land evaluation studies in Nigeria have been fairly documented in Nigeria and other countries of the world (Adesemuyi, 2014; Babalola *et al.*, 2011, Fasina, 1999; Fasina *et al.*, 2006; Fasina *et al.*, 2008; Fasina and Adeyanju 2007; Fasina *et al.*, 2015 Oluwatosin and Ogunlade 1998; Ogunkunle *et al.*, 1994). To date, in land evaluation projects, production has been valued over all other concerns, but the time has arrived to concede the importance of environmental and human-health issues, as well as sustainability (FAO, 2001). It would be useful to provide the degree of uncertainty in these studies, and thereby reinforce the credibility of the use recommendations (Rossiter, 1996).

Fasina and Adeyanju (2007) carried out studies comparing three land evaluation systems in evaluating the predictive value of some selected soils in Ado-Ekiti, Ekiti state. The systems which include land capability classification, Fertility capability classification and land suitability classification. They compared the accuracy of the three systems on seven major soil types in the humid forest zone. They discovered there was a significant difference between land suitability classification and fertility capability classification ($r=0.52$: $P<0.05$) while others did not correlate.

Babalola *et al.*, (2011) carried out land evaluation studies on two wetland soils at Ado-Ekiti, Ekiti state and Kabba, Kogi state. They evaluated the soils using fertility capability classification which tested the influence of local and improved management practices on rice yield on the field. The soils at Kabba were classified as presently not suitable (N1) for rice production and Ado-Ekiti as permanently not suitable (N2) because of the limitations of the soils chemical properties. The potential of these.soils can increase to moderately suitable (S2) for rice production with proper soil fertility management. They estimated the economic analysis of rice production at the two locations showed that the cost benefit ratio was positive at both locations but the best return will be obtained at Kabba with gross margin of N532,775/ha.

Fagbami and Akamigbo (1986) carried out series of studies on the soils of Benue State and their capabilities. They discovered the soils to be highly to moderately suitable for most agricultural land use qualitatively.

Fasina, (2008) carried out a detailed survey of land in Asu River Basin to evaluate the soil suitability for irrigation Agriculture. He worked on four major soil types which are Ihuibe 1, Ihuibe 2, Ameta 1 and Ameta 2. The soil textures vary from loam, sandy clay loam, clay loam and loamy sand respectively. The soils were classified under irrigation classes, Ihuibe1 and 2 are moderately suitable while Ameta 1 was classified highly suitable (S1) and Ameta 2 currently not suitable. In his study, he considered the use of drip or localized irrigation. He therefore, recommended that sustainable use of the area for irrigation agriculture, drip irrigation should be used.

2.6 Land evaluation Methods

Some methods use qualitative criteria while others use quantitative. The qualitative systems are normally used in examinations aimed at a general evaluation of broad zones. The quantitative methods are used more often in detailed studies and thus need more information on the soils, both to construct the evaluation system as well as to apply it, but they are more objective and the results are therefore more reliable. Other methods begin with qualitative data which are weighted to reach a final numerical result.

2.7 Land Evaluation systems

There are various land evaluation methods which originated from different countries of the world. Examples of these are land capability classification (LCC) of the USDA (Klingebiel and Montgomery 1961); land suitability evaluation (LSE, 1976) by FAO, Wong (1974) for Malaysia, Mackney (1974) for United Kingdom and Fertility Capability classification (FCC) by Buol *et al.,* (1982).

1. Land Capability Classification (LCC) as modified by USDA (Klingebiel and Montgomery 1961)
2. Land Suitability Evaluation (LSE): (FAO 1976),
3. Fertility Capability Classification (FCC) (Buol *et al*; 1975).
4. Irrigation Capability classification by USBR system (1953)
5. Parametric System by Burnham (1981)

2.7.1 LAND CAPABILITY CLASSIFICATION (LCC)

This is the grouping of land units primarily for agricultural purposes in terms of their capacity to support crop production, especially arable crops (Klingebiel and Montgomery, 1961). It was originally developed for use in the USA for farm planning but has been widely adapted and applied all over the world (Wong, 1974). LCC is normally produced after the soil survey of the land of interest, thus it derives all its data from the survey. The principles are: (i) the criteria used in assessing a land unit are physical land properties made available after the soil survey; (ii) the seriousness of the limitation is a function of the severity with which crop growth is inhibited; (iii) the capability of land unit for soil conservation. Classes I-IV are arable while V-VIII are non arable. The capability classes are defined on the basis of conservation problems such as: e – erosion, w – excess water, s – root zone limitation, and c – climatic limitation. Subclasses provide information so as to the kind of conservation involved while class and sub-class together provide the map user with the information about the kind of problem involved as well as the degree of limitation. A capability unit is a subdivision of subclasses on the basis of potential productivity. Thus, all soils within a capability unit can be used for the same crop and require similar conservation treatment and other management practices and have comparable productivity potential. In practice, however, separation into capability units is not common because the real extent of each is often below normal management farm/plot size (Ogunkunle, 1987).

Conventionally land capability classification uses eight classes (I - VIII), each comprising land units that have the same relative degree of hazard or limitation. The constraints become progressively greater from low to higher capability classes

Class I: The soils in Class I present very little limitations constraining the use. They are level or nearly level with deep soils and well drained. The workability, water retention capacity and natural fertility is good. Crop yields are good in comparison with other sites in the area, but it is necessary to conserve the natural fertility and productivity by using simple methods of management.

Class II: The soils in Class II present slight limitations, which reduce the choice of crops, or require some moderate conservation practices. They correspond to level soils with slight slopes, deep to moderate deep soils, good permeability and drainage, favourable textures that vary more between clayey and sandy than class I. Common constraints are: slightly sloping and a micro relief slightly profound; less deep soil than in Class I; not favourable structure and texture characteristics; and wet conditions, which can be drained.

Class III: The soils in Class III present moderate constraints reducing the choice of crops. The topography varies between level and moderately sloping which severely constrains irrigation. The soil permeability varies from slow to fast. Common constraints are: topography moderately sloping; less deep soil than in Class II; unfavourable structure and texture; low water holding capacity; and wet soil conditions that impede root development. Moderate conservation practices are necessary.

Class IV: The soils in Class IV present severe constraints, which limit the choice of crops. These soils require careful agricultural practices, conservation measures and are more difficult to use and maintain than Class III. Common constraints are: very shallow soils; dissected and sloping topography; low water holding capacity; and poor drainage.

Class V: The soils in Class V are level and present none or low erosion risks. However, other severe limitations are not practicable to remove such as, excessive wetness, stony and/or rocky, frequent inundations and prolonged salinity. Soils are suited for pasture or forestry.

Class VI: The soils in Class VI are inadequate for cultivation and should be used for pasture and forest. Constraints cannot be eliminated, e.g. too steep, high erodibility, effects from old erosion features, high amounts of stones, shallow soil, excessive wetness, low water holding capacity and salinisation.

Class VII: The soils in Class VII are not adequate for cultivation and should be used for pasture and forestry.

Class VIII: The soils in Class VIII have no value for agriculture, livestock or forest, and should be kept in the natural state for recreation, wild life, or as protection of hydrological sites.

2.7.2 LAND SUITABILITY EVALUATION (LSE)

The concept and principle embodied in the framework for Land Evaluation (FAO, 1976) have been developed for appraisal of dry land crops. According to the framework, differences occur in the degree of suitability and these are determined by the relationship between benefit and required inputs. By definition, land suitability evaluation is the grouping of land unit with similar performance into classes according to cost – benefit relationships of a selected land use (FAO, 1976). It is described in terms of orders, classes, sub-classes, and units. The categories of orders are suitable (S), and Not Suitable (N). The following classes indicate the degree of suitability within an order:

S1 = highly suitable

S2 = moderately suitable

S3 = marginally suitable

N1 = temporarily not suitable

N2 = permanently not suitable

Subclasses denote limitations within a class. The suitability class indicates the type of limitations (e.g. moisture deficiency, erosion hazard) or main kinds of improvement measures required within the classes. These are indicated by lower-case letters placed after the class symbol, e.g. S2m, S2e. The subclasses have been identified and defined by the

FAO (1976). Suitability units are sub divisions of subclasses differing in detailed aspects of their production, characteristics, and management requirements. They are numbered successively e.g. S2w1, S2w2, for the common case of land evaluation for specific crops under rain-fed agriculture. Land suitability units are subdivisions of a subclass. They differ in production and minor management requirements.

2.7.3 FERTILITY CAPABILITY CLASSIFICATION (FCC)

The Fertility Capability Soil Classification (FCC) was developed by Buol, Sanchez and co-workers (Buol, 1972; Buol *et al,* 1975, Sanchez *et al,* 1982) as a technical system for grouping soils according to the kind of problems they present for agronomic management of their chemical and physical properties. The system emphasizes quantifiable topsoil parameters as well as subsoil properties directly relevant to plant growth and yield performance.

The FCC System (quoted from Sanchez et al 1982) the system consists of three categorical levels: type (topsoil texture), substrata type (subsoil texture), and 15 modifiers, including several changes from the original version (Buol *et al*, 1975) making the following, in effect the second approximation. The classes within each categorical level are defined below. Class designations from the three categorical levels are combined to form an FCC-unit. The FCC systems simplify information about the soil profile and analysis of its soil for the benefits of those who are not familiar with soil classification system (Chu, 1960). It appears to be a suitable framework for agronomic-soil taxonomy, one which is acceptable both to the pedologists and agronomists. One of the most obvious advantages of FCC is that it can be used to describe nutrient deficiencies, toxicities, and physiological disorders. In spite of its attractiveness, FCC has some limitations which may affect its acceptance (Ogunkunle and Babalola, 1986). The capability unit designation cannot be easily interpreted at a glance (i.e. high, low, suitable, or not suitable).

2.7.4 IRRIGATION CAPABILITY CLASSIFICATION

The system was designed by the United States Department of Interior Bureau Reclamation, the USBR system (1953) and modifications of it are widely used for irrigation suitability evaluation. Unlike every other system are based on the economics of land development although physical features are used as a basis for the economic rating. Depending on the nature and scale of the surveys, such systems can have varying degree of quantitative assessment built into both the physical and the economic criteria used. The limitations or hazards become progressively greater from Class 1 to Class 6. Land in Class 1 to Class 4 is suitable for irrigation. Class 5R is temporarily irrigable, undergoing reclamation. Class 5 is a non-irrigable provisional class.

Class 1 - irrigable: Land in this class is excellent for irrigated agriculture with no significant limitations. Class 1 land is capable of producing a sustained and a relatively high yield of a wide range of climatically adapted crops. The soils are of a medium texture, well drained, and hold adequate available moisture. Harmful accumulations of soluble salts are absent. Class 1 land is level to nearly level. This class is suitable for irrigation by gravity and sprinkler methods.

Class 2 - irrigable: Land in this class is good irrigation land with moderate limitations. A narrower range of crops or slightly more input to development and management may be required for Class 2 land than for Class 1. The limitations of Class 2 land are less acceptable than those of Class 1. They can be maintained or possibly improved with proper management. The soils in this class may have low hydraulic conductivity due to fine texture or adverse structure. The available water holding capacity may be lower as reflected by the coarser texture or limited soil depth. Salinity levels may be low to moderate. Class 2 land may be level to gently sloping or undulating to hummocky. Land in this class is suitable for irrigation by gravity and sprinkler methods or by sprinkler methods only.

Class 3 - irrigable: Land in this class is fair for irrigation. Limitations of this land under irrigation are moderately severe. The deficiencies may be due to either a serious single factor or a combination of several limitations in soil and/or topographic features. The soils may be inferior because of excess salinity, sodicity, very low hydraulic conductivity, or low water holding capacity. Subsurface or surface drainage may be restricted. The range of crops that could consequently be grown may be restricted. A greater management input, such as light, frequent irrigations or more intensive soil conservation and improvement practices, may be required than for Class 2 land. Class 3 land may be level to hummocky. Land in this class is suitable for. irrigation by gravity and sprinkler methods or by sprinkler methods only.

Class 4 - irrigable (restricted or special use): Land in this class has severe limitations for irrigation and requires special crop, soil, and water management practices. Limitations of Class 4 land may include moderate to strong slopes or small irregularly shaped fields. Class 4 land is suitable for irrigation with a special irrigation system design to minimize runoff and water erosion and prevent prolonged surface ponding.

Class 5R - temporarily irrigable (undergoing reclamation): Land undergoing reclamation after the implementation of an appropriate improvement, such as drainage or canal lining. Class 5R land shall be added to the assessment roll as acres subject to a terminable agreement, for the purpose of promoting reclamation. Class 5R land shall be reviewed after the land has undergone reclamation for five irrigation seasons, after which the land shall be upgraded to an irrigable class (Class 1, 2, 3, or 4) if it meets the requirements, or remain as Class 5R for an additional 5 years. If significant improvement has not been achieved within a 10-year period to upgrade the land to an irrigable class, then the land shall be rated Land Class 6, non-irrigable, and the terminable water agreement shall be discontinued. Land in this class is suitable for irrigation by gravity and sprinkler methods or by sprinkler methods only.

Class 5 –non-irrigable (pending): Land in this class is considered not suitable for irrigation under existing conditions, but has sufficient potential to warrant segregation for additional investigation or improvement. The limitations of Class 5 may include one, or more, of the following: poor drainability, a high water table, very poor soil structure, and excess salinity.

***Class 6* – non-irrigable:** This class may consist of steep, rough-broken, or badly eroded land, or land having soils of very poor structure, very coarse texture, excess salinity and/or sodicity, poor drainage, shallow soils over gravel or bedrock, or other deficiencies not feasible to improve. Class 6 land may also include Land Classes 1 to 5 which cannot be separated out due to small size, the intensity of the investigation, or the purpose of the project.

2.7.5 PARAMETRIC SYSTEM

Mathematical formulae are applied so that the final result is expressed in numerical terms. These can be additive (Index = A + B + C + D + ...) or with a multiplicative scheme (Index = A x B x C x D x...), the latter offering better results for following the minimum law. The additive systems give an evaluation that is usually correct from the theoretic standpoint but can give evaluations that are not realistic in as much as they do not represent the serious consequences implicit in a highly limiting soil factor. It is generally accepted that the parametric methods are, according to McRae and Burnham (1981): simple, objective, quantitative, reliable, easy to understand and apply, even by the non-specialist, and easy to modify and adapt to new uses. Their main disadvantage is precisely that their objectivity and precision are illusory. Their formulation is difficult and, if they are not well applied; their results can be completely erroneous. The scheme is too artificial and the relationship between the soil properties and the result of the evaluation is poorly defined. The results from this type of system, perhaps more than any other, need careful validation by values for soils under practical use. Some systems pursue agricultural ends while others seek exclusively engineering uses (such as the support and placements for structures, roads, septic tanks, etc). Within the systems for agricultural uses, some, called land capability, evaluate the capacity of the soil for general use (crops, pasture, forestry), while others, called land suitability, evaluate the suitability of the soil for specific uses, such as a specific crop (e.g., wheat, potato) and with a particular kind of soil management. The classifications of land capability define the degrees of capacity in generally vague terms, focusing fundamentally on the limitations for the general use. Land suitability provides more practical results but need more data both for the land as well as for concrete specifications for each type of crop. An important compilation of data on the optimal and marginal conditions of many crops is provided for the tropical and subtropical regions by Sys *et al.* (1993).

The Land Class is defined as a "category of land having similar physical and economic attributes which affect the suitability of land for irrigation" (McRae and Burnham, 1981). The USBR system establishes six classes to evaluate the suitability of the soils for irrigation. The parameter used and its ranges are reproduced in the corresponding tables. To facilitate the reading of the evaluation maps on each cartographic unit, a formula is written in which all the representative data are reflected.

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY SITE CHARACTERISTICS

The location of the study area is Ikole Local Government in Ekiti State, Nigeria. The soil mapping field is the whole Federal University Oye-Ekiti, Ikole campus. The GPS statement for the study location (seven land uses) are as follows: *Cashew* (N 07° 48.196` , E 005° 29.796), *Gmelina* (N 07° 48.268, E 005° 29.756), *Fisheries* (N 07° 48.306, E005°29.566), *Oil palm* (N 07°48.404, E 005°29.506), *Banana* (N 07°48.456, E 005°29.508), *Lowland* (N07°48.405, E 005°29.414) and *Fallow* (N 07°48.357, E 005°29.722). The total area coverage is 33.7 hectares. The survey area falls within the rain forest zone.

3.2 CLIMATE

The area experiences a tropical climate with distinct wet and dry season. Rain starts in March and ends in November. The two seasons which are the dry Season (November – February) and rainy Season (early March – mid November) are quite distinct and they are very important to the agricultural pursuits of the people. The mean annual rainfall is 200mm.

3.3 GEOLOGY

Generally, Ekiti State is underlain by metamorphic rocks of the basement complex, the great majority of which are very ancient in age. The survey area falls within the rainforest zone. The geology is basically rock of the basement complex rocks especially granite gneisses. These basement complex rocks show great variations in grain size and in mineral composition (Smyth and Montgomery, 1962). The rocks are quartz, gneisses and schist consisting essentially of quartz with small amount of micaeous minerals.

3.4 SOIL SAMPLING

Profile soil sampling was done after the soil profile has been located, dug and described. Soil samples were collected from each identified soil horizons from seven land uses. Seven (7) locations of different land use types and soil types were identified within the study area. Samples were collected for land evaluation studies from different land use types which include Cashew, Gmelina, Fisheries, Oil palm, Banana, Lowland and Fallow land.

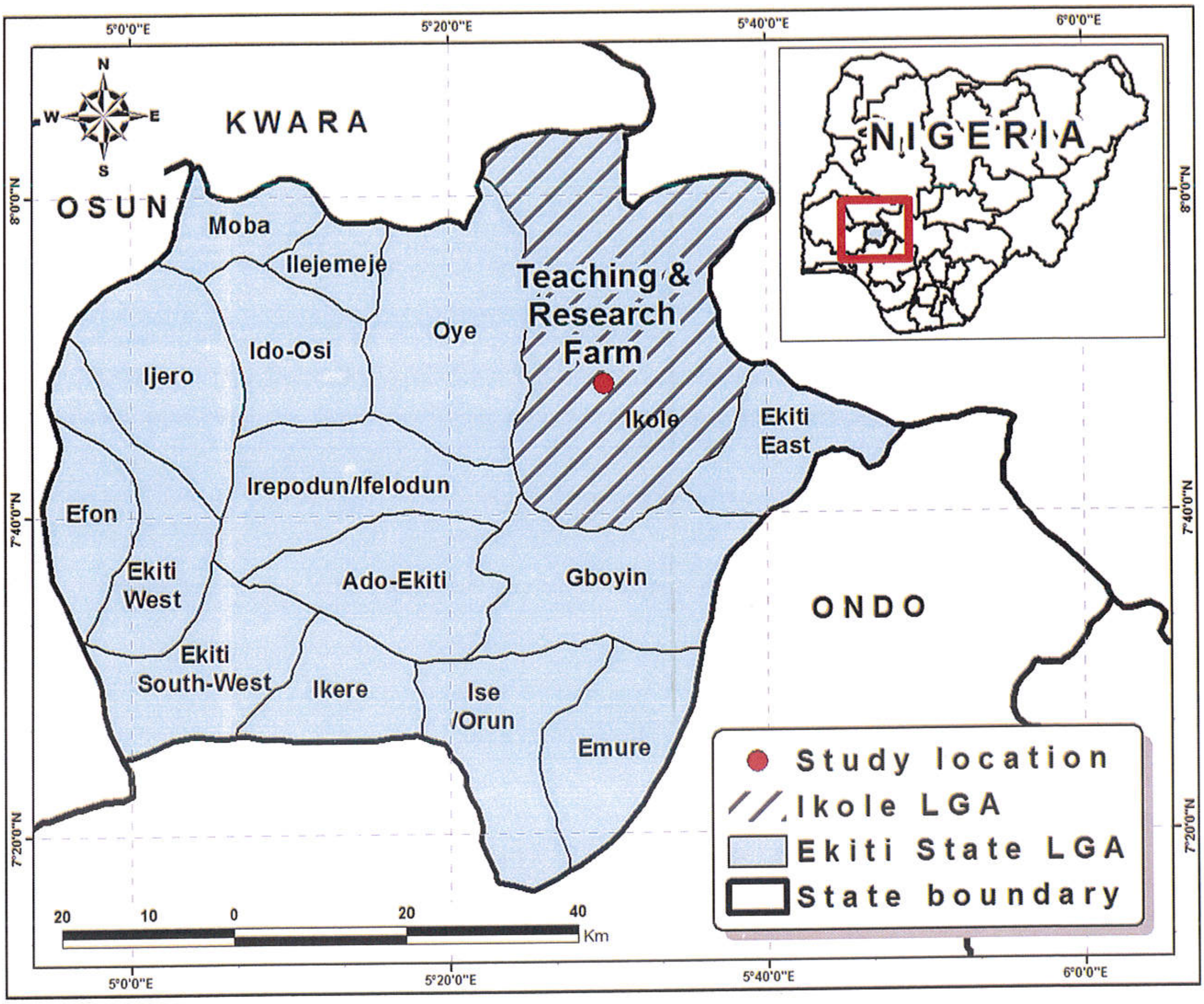

Plate 1: map showing the description of the study area

Key: LGA- local Government Area

3.5 METHODOLOGY

A combination of the conventional method of soil survey (free survey) and remote sensing was used in this study. The coordinates (latitude, longitude and elevation) of the different land use was taken by using Global Positioning System (GPS). The coordinates were loaded into the Geographic Information System (GIS). Digital data on landform model using the ASTER 30meter resolution Digital elevation model (DEM) projected to Universal Transverse Mercator (UTM), World Geodetic System (WGS) 84. The digital landscape data used was from the vegetation and land use project of Forestry Management Valuation and Coordinating Unit (FORMECU) of the Federal Ministry of Environment. Digital geologic data was however derived from the geologic maps of the Federal Geological Survey of Nigeria. Provisional photo-soil maps were obtained when the land use and geology vector GIS layers were loaded into Arc. The GIS 10 and the spatial proximity function intersect was used to spatially merge the three into one layer. This way every single polygon has defined the land-use geology and landform data. A new composite class mapping units were then produced.

The provisional soil photomaps were then taken to the field for free detailed soil survey within the selected mapping units (seven land use types). The result was then used to extrapolate the whole study area. After the mapping exercise, soils with similar characteristics were grouped together as the mapping units. Seven soil types were identified. Seven profile pits were located and dug to represent each of the soils identified on the field.

The profile pits were described according to the FAO handbook "Guidelines for soil profile description" with properties which include presence of mottles, colour, texture, consistence, presence or absence of concretions, stoniness, and depth to ground water table. Soil samples were taken from the horizons in each profile pit. The soils were classified using the criteria set by Soil Taxonomy (Soil Survey Staff 1996) and Smyth and Montgomery (1962).

3.6 LABORATORY ANALYSIS

The samples were air-dried and crushed to pass through a 2mm sieve, and analysed for the following parameters:

3.6.1 Soil pH (water)

This was determined in water (1:1 soil to water ratio) using a pH meter. Soil pH was measured by pH meter with glass electrode (Richards, 1954).

Apparatus

- Glass electrode
- 50ml beakers
- A glass rod

Reagent

- Distilled water

Procedure

Soil pH in H_2O (1:1 soil to water ratio)

20g of air-dried sample was weighed into a 50ml beaker. 20ml of distilled water was added and allowed to stand for 30minutes with occasional stirring using a clean glass rod. After the 30minutes equilibriation time, the electrode of the pH meter was inserted into the partly settled suspension and the pH was measured without any further stirring.

3.6.2 Organic carbon

The organic carbon was determined using potassium dichromate method (Walkley and Black, 1934).

3.6.3 Effective Cation Exchange capacity (ECEC)

This was the sum of 1N NH_4OAc (pH 7.0) exchangeable cations and exchangeable acidity.

3.6.4 Total N

This was determined using macro-kjedahl method (Black, 1965). Total nitrogen was determined by the regular Macro-Kjeldahl technique (Bremmer, and Mulvaney, 1982). One gram of soil was weighed into a digesting tube into which 20ml of concentrated sulphuric acid was added and digested for two hours. The content of the tube was then emptied into a 250ml volumetric flask and filled to mark. This was distilled after which 10ml of the distillate was titrated with 0.01m H_2SO_4 to the end point. Potassium sulphate (K_2SO_4) was used as the catalyst.

3.6.5 Exchangeable acidity

The soils were extracted with 1N KCl and titrated on radiometer autotitrator (IITA, 1985).

3.6.6 Exchangeable cations

Exchangeable K, Na, Ca, and Mg were extracted with 1N NH4OAc (pH 7.0) K and Na in the filtered extracts were determined with a flame photometer while Ca and Mg were determined with Atomic Absorption Spectrophotometer (AAS, Model Buck 200).

3.6.7 Available P (Bray-I-P)

Soils were extracted with 1.0N NH4F and 0.5N HCl, (Bray and Kurtz, 1945) and was colorimetrically determined using Technicon Auto Analyser II.

3.6.8 Organic Matter

Walkey-Black (1934) wet oxidation method was used.

Apparatus

- 50ml burette
- 250ml conical flasks
- 10ml pipette
- 50ml graduated cylinders

Reagents

- $K_2Cr_2O_7$ -49.04g of potassium dichromate were dissolved in distilled water and diluted to one litre.
- Concentrated H_2SO_4
- O- phenanthroline ferrous complex
- Concentrated H_3PO_4 (orthophosphoric acid)
- 0.5N Fe 804-196.1g ferrous ammonium sulphate.
- Fe $(NH4)_2$ $(SO_4)_3$. $6H_2O$ was dissolved in 800ml distilled water. 20ml of conc. H_2SO_4 was added, shaken vigorously and made up to a litre with distilled water.

Procedure

About 25g of soil was ground to pass through a sieve. 0.5g was accurately weighed into a 250ml conical flask. 10ml of $1.0NK_2Cr_2O_7$ was added using a pipette and swirled to mix. Using a 50ml graduated cylinder 20ml of concentrated H_2SO_4 was rapidly added, by directing the steam into the suspension. The flask was immediately swirled gently until reagents were mixed, then more vigorously for a total of 1minute. The flask was allowed to stand for 30minutes. After this time 200ml of water, 10ml of conc. H_2SO_4 and 3 to 4 drops of O-phenathroline indicator was added. The mixture was titrated to a wine red endpoint with 0.5N $FeSO_4$ (colour changed from blue to dark green as the end point was approached).

3.6.9 Base saturation (BS)

Base saturation was calculated for both ECEC and CEC (NH4OAc) from the formula:

$$\% \text{ Base Saturation} = \frac{\text{Total exchangeable bases X 100}}{\text{CEC}}$$

3.6.10 Particle size analyses

Bouyoucos (1951) hydrometer method was used.

Apparatus:

- Mechanical stirrer
- Bouyoucos hydrometer
- Thermometer
- Cylinder, 1L capacity

Reagents

- 5% calgon (sodium hexametaphosphate)
- Water

Procedure

50g (2mm) of soil sample was weighed into a dispersion cup. The cup was filled half full with water and 10ml of 5% calgon solution was added. The dispersion cup was then placed on a mechanical stirrer and the suspension was stirred for 10minutes. The suspension was transferred to a sedimentation cylinder, through a 72 mesh sieve placed on a funnel and filled to the lower mark with water while the hydrometer was in suspension. The sieve was oven dried at 105°C for 24hrs, cooled and the weight of soil particles (coarse sand) retained was determined. The hydrometer was removed and suspension was shaken vigorously and placed on a desk hydrometer and temperature reading was then recorded at 40seconds and 2hours.

For each degree above 20°C, 0.3 was added to the hydrometer reading to get the corrected hydrometer reading.

Calculations

$$\%\text{silt} + \text{clay} = \frac{\text{30secs reading } \pm(0.3 \text{ x b}) \text{ X } 100}{\text{weight of sample}}$$

Where b is the temperature difference between that of the soil suspension and 20°C. It assumes a positive value when temperature of the suspension is higher than 20°C and a negative value when the temperature of the suspension is less than 20°C.

$$\%\ \text{clay} = \frac{\text{corrected 2hr reading}}{\text{weight of sample}}$$

$$\%\ \text{silt} = \%\ \text{silt} + \text{clay} - \%\ \text{clay}$$

$$\%\ \text{coarse sand} = \frac{\text{weight of coarse sand X } 100}{\text{weight of sample}}$$

$$\%\ \text{fine sand} = 100 - \%\ \text{silt} \times \text{clay} + \text{coarse sand}$$

3.6.11 Bulk Density

Bulk density was determined by oven-drying the undisturbed soil samples collected in 100cm3 –metal cylinders to constant weight at 1050C and dividing the dry weight of the sample by total volume of the sample.

$$\text{Bulk density (gcm-3)} = \frac{\text{weight of oven dry soil (g)}}{\text{volume of soil}}$$

3.6.12 Soil Texture

The soil texture was determined by international pipette method (Piper 1966) and textural classes were determined by using USDA textural triangle.

3.6.13 Soil Colour

Soil colour was determined using Munsell colour chart.

3.7 Soil Classification

The soils identified were classified using Smyth and Montgomery (1962), Moss (1957), FAO/UNESCO (2014) and USDA (2014) classification systems.

3.8 LAND EVALUATION

The potentials of these soils for agricultural production were assessed using the following land evaluation methods:

1. Land capability classification (LCC) as modified by USDA (Klingebiel and Montgomery 1961)
2. Land suitability classification (LSE) (FAO, 1976)
3. Fertility Capability classification (FCC) (Buol *et al;* 1975)
4. Irrigation Capability classification by USBR

3.8.1 LAND CAPABILITY CLASSIFICATION

The land capability used is a modified form of USDA (Klingebiel and Montgomery 1961) method as suggested by Young, (1967) (Table 1). The classification is based on physical soil and land properties with CEC as the chemical property involved. Using the conversion table (table 1), soil limitations in terms of these properties were used to place the soils into different classes ranging from classes I-IV for arable and V-VIII as non-arable. Most limiting soil property determines the land capability classification to which the land will be put.

3.8.2 LAND SUITABILITY EVALUATION

The suitability of the soils was assessed for crops (cassava, oil palm, cashew, maize and banana) commonly grown in the Ikole area following the method of Sys, (1985). The detailed land and soil requirement for each of the crops is given tables 2 - 6. The mapping units were placed in suitability classes by matching the Land use requirements, with the characteristics of the mapping unit .The suitability class of a mapping unit was indicated by its most limiting characteristics.

3.8.3 FERTILITY CAPABILITY CLASSIFICATION (FCC)

The FCC used here is mainly based on the modified and revised version developed by Buol *et al;* (1982). The System consists of three levels which are Type, substratum type and modifiers. The criteria for the FCC are given in Appendix 17. Results from the soil profiles at the seven land uses were used to determine the FCC classes. The FCC unit lists the type and substratum type in capital letters and the modifiers in lower case letters.

Type: S= sandy topsoils: Loamy sands and sands (USDA definition); L= loamy topsoils : > 35% clay.

Substratum: S= sandy soils: texture as in type; L = loamy subsoils: texture as in type; C = clayey subsoils: texture as in type; G = Gravel.

Modifiers: h= acidic reaction, e= low cation exchange capacity (CEC), K= deficient K, I = high P-fixation by iron.

3.8.4 IRRIGATION CAPABILITY CLASSIFICATION

Soil survey for irrigation suitability assessment was carried out to check the effect of irrigation on the different land use. This supplied the basic information on crop requirements, suitable irrigation method, drainage requirements and other soil improvement techniques.

The land class indicated the general capability of land for irrigation use in its present state. Land classes are based upon the rating and assessment of soil and topographic features that affect the suitability of land for irrigation. The limitations or hazards become progressively greater from Class 1 to Class 6.

Table 1: Land Capability Classification System

Limitations	I	II	III	IV	V	VI	VII	VIII
Slope Angle (Degree)	1	3	5	10	18	35	Any	Any
Rock outcrops And Boulders	0	1	2	5	10	25	Any	Any
Wetness class	Nil	Nil	Slightly	Slightly	Mod.	Mod.	Severe	Severe
Soil Effective Depth (cm)	150	100	30	30	20	20	0	0
Texture	SL-C	SL-C	LS-C	LS-C	LS-Hc	LS-Hc	Any	Any
Available W.C	25	20	10	10	5	2	0	0
CEC (Meq/100g) Clay	20	15	5	5	5	2	0	0

Source: Modified USDA System as suggested by Young (1967)

Key: LS- Loamy Sand, C= Clay, Hc = Heavy Clay, SL = Sandy Loam
e = Erosion, w = Available water, s = effective soil depth /soil fertility, t = topography
b = Land Suitability Evaluation

Table 2: Land and soil requirements suitability classes for cassava (Modified from Sys, 1985)

Land qualities	100 S11	95 S12	85 S2	60 S3	40 N1	25 N2
<u>Climate ©</u>						
Annual rainfall (mm)	1400-1800	1000-1400	600-1000	500-600	-	<500
		1800-2400	>2400			
Mean temp. (°C)	26-20	26-30	>30			
		20-18	18-16	16-12	-	<12
Length of dry season	3-4	4-5	5-6	6-7	-	>7
		1-3	<1			
<u>Topography (t)</u>						
Slope (%)	0-4	4-8	8-16	16-30	30-50	>50
<u>Wetness (w)</u>						
Drainage	Good	-	Moderate	imperfect	Poor Drainable	Poor,non drainable, Very poor
<u>Soil physical properties</u>					-	
Texture/structure	L,SCL	SL,C-60S,SICsC, SICL CL,SIL,SC C+60S,Ifs LS,LCS,fs	C+60s,Ifs, LS,LCS.fs	C+60V,s, Cs		
Volume of coarse fragments (s)	No <3	<3 <15	<15 <35	<35 <55	- -	>35 >55
(d)	>125	>100	>75	>50	-	<50
Soil depth (cm)						
<u>0Soil fertility (f)</u>						
CEC (meq/100g clay)	>16	Any	<20			
Base saturation (%)	>35	35-20	<0.8			
Organic matter (%) 0-15cm	>1.5	0.8-1.5				

Table 3: Land and soil requirements for suitability classes for Oil palm (Modified from Sys, 1985)

Land qualities	100 S1	95 S12	85 S2	60 S3	40 N1	25 N2
Climate ©						
Annual	>2000	1700-	1450-	1250-	-	<1250
rainfall (mm)	<1	2000	1700	1450	-	>4
Mean annual	>25	1-2	2-3	3-4	-	<18
temp ° C		22-25	20-22	18-20		
Relative	>75				-	<60
humidity (%)		70-75	65-70	60-65		
Topography	0-4	4-8	8-16	16-30	>30	-
Slope (%)						
Wetness (w)						
Flooding	FO	FO	F1	F2	-	F3
Drainage	Imperfect	Mod. well	Mod. Well	Poor seric	Poor, drainable	Poor, v-poor, not drainable
Soil physical properties						
Texture	CL,SCL,L	CL,SCL,L	SCL	SCL-LFS	Any	C,Cs,massive
Structure	Blocky	Blocky				single gra
Coarse						
fragments (vol	3-10	10-15	15-35	35-55	-	55
%)	.100	90-100	50-90	25-50	-	<25
0-10cm						
Depth (cm)						
Fertility (f)	S					
Cation	<10	8-10	6-8			
Exchange	<35	20-35	<20	<6	-	-
Capacity	5.5-6	5.5-6	5.5-6	-	-	-
(meq/100g)	>1.2	1.2-0.8	<0.8	6.5-7	4,4>7	<4,>7
Base				-	0	-
saturation (%)					-	
pH						
Organic						
carbon (%), 0-						
15cm						

Table 4: Land and soil requirements for suitability classes for cashew (Sys, 1985)

Land qualities	100	95	85	60	40	25
	S11	S12	S2	S3	N1	N2
Climate (c) :						
Annual rainfall (mm)	1600-2000	1200-1600	800-1200	500-800	-	<500
		2000-3000	3000-3800	+3800		
Length dry season (months)	2-3	<2	4-5	5-6	-	>6
Mean annual temp. °C	>18	-	10-18	4-10	-	<4
Topography (t):						
Slope (%)	0-4	4-8	8-16	16-30	30-50	50
Wetness (W):						
Drainage	good	moderate	imperfect flunctuating ground water	imperfect permanent high ground water	poor drainable	poor and very poor
Soil physical properties (s):	C-OS, SIC, CO	C+ 60S, C-60V	C + 60V	S, CS	-	Cm
	SICL, CL, SII	L,SCL,SL	LCS,fS			
Texture	SC	Lfs, LS				
Coarse fragments (Vol %): 0-10cm	<3	<15	<35	<55	-	<55
Soil Depth (cm)	>100	100-75	75-50	50-25	-	<25
Fertility (f) :						
Cation exchange capacity (Cmol/kg)	any					
Base saturation (%)	>35	20-35	<20			
Organic carbon (g/kg), 0-15cm	>1.5	0.8-1.5	<0.8			

Table 5: Land requirements for Maize

Land qualities	S11	S12	S2	S3	N1	N2
Climate (c) :						
Annual rainfall	850-1250	850-750	750-600	600-500	-	<500
(mm)		1250-1600	1600-1800	>1800		
	150-220	220-270	270-325	325-345	-	>345
Lenght growing		130-150	110-130	90-110	-	<90
season (months)	22-26	22-18	18-16	16-14	-	<14
Mean annual temp		26-32	32+			
(oC)	50-80	50-42		36-30	26-30	<30
		>80				
Relative humidity	0-2	2-4	4-8	8-16	-	>16
(%)	0-4	4-8	8-16	16-30		>50
Developmental	FO	-	-	F1		F2+
stage	Good	Moderate	Imperfect	Poor	Poor	Poor and
<u>Topography (t)</u>	Imperfect	Moderate	Good	seric	drainable	very poor not
Slope (%)						drainable
<u>Wetness (w)</u>	C-	C+60S, C-	C+60V, SL	LCS,fs		
Flooding	60S,SICS,CO,	60V	LFs, LS			Cm,s,cs
Drainage (4)	SICL,CL	SC, L, S				
(5)	Si,SIL	CL.,	15-35	35-55		
<u>Soil physical</u>		3-15	50-75	20-50		
<u>properties</u>	3<3	75-100	<16(-)	<16(+)		>55
Texture	>100	16-24	20-35	<20		<20
Structure		35-50	0.8-1.2	<0.8		
Coarse fragments	>24	1.2-2	0.5-0.8	<0.5		
(vol%) 0 + 10cm)	>50	0.8-1.2	>0.4			
Depth	>2	0.4-0.8	20-35	<20		
	>1.5	35-50	0.8- 1.2	< 8		
<u>Fertility (f)</u>	<0.8	1.2 -2	0.5-0.8	<0.5		
CEC (cmol kg^{-1}	>50	0.8-1.2	>0.4			
Clay)	>2	0.4-0.8				
	>1.2					
Organic matter (%0)	>0.8					
(6)						
(0-15cm)						
(7)						
(8)						
Base saturation (%)						
Organic carbon						
(g/Kg), 0-15cm						

Source: modified from Sys 1985

Table 6: Land and soil requirements for suitability classes for plantain/banana (Modified from Sys, 1985)

Land qualities	100 S11	95 S12	85 S2	60 S3	40 N1	25 N2
Climate ©					-	
Annual rainfall (mm)	>1800	1250–1800	1250-1500	1000-1250		<1000
Length of dry season (months)	<1	<3	<4	<6	-	>6
Mean annual temp (°C)	>22	22-18	18-16	16-14	-	<14
Topography (t)						
Slope (%)	0-4	4-8	8-16	16-30	30-50	>50
Wetness (w)						
Drainage	Good	Moderate	Imperfect	Poor seric	Poor drainable	Very poor
Soil physical characteristics Texture/structure	C-60s, SiCs,Co,Sic L,SiL	C+60s, C-60vL,SC	C + 60v, SCL	SL, Ffs, LS	-	Cm, Cv, Lcs, fs, S
Vol. of coarse fragments	<3	<15	<35	<55		>55
Soil depth (cm)	>100	75-100	50-75	25-50	-	<25
Fertility (f)						
CEC (Meq/100 clay)	>24	16-24	<16 (-)	<16 (+)		
Base saturation (%)	>50	35-50	20-35	-20		
Organic matter (%) 0-15cm	>24	1.5-2.4	0.8-1.5	<0.8		

Table 7: Modified USBR land suitability class specifications by Esu, 1998

Land characteristics	Class 1- irrigable	Class 2 – irrigable	Class 3 – irrigable
Soil			
Topsoil texture (0-30cm)	Porous fine sandy loams to fine sandy clay loams	Fine sand to loamy fine sand	Fine sand to loamy fine sand
Subsoil texture (30-80cm)	As topsoils	Porous fine sandy loams to fine sandy clay loams	Fine sand to loamy fine sand
Effective depth	>150cm	>150cm	>150cm
Available water capacity	>150mm m^{-1} soil	150-120mm m^{-1} soil	120-90mm m^{-1}
Infiltration (IR) after 4 hours	0.7-5.0cm h^{-1}	5.0-12.0cm h^{-1}	12.0-15.0cm h^{-1}
Topography			
Slopes	<0.5°	<0.5°	0.5° to 1°
Leveling requirements	<350m^3 ha^{-1}	350-750 m^3 ha^{-1}	750-1000m^3 ha^{-1}
Vegetation cover	moderate to low clearing costs	Moderate clearing costs	Moderate to high clearing costs
Drainage			
Ground water table	Normally ≥ 10m	7-10m	5-7m
Drainage	No immediate farm drainage required; profiles well drained	No immediate farm drainage required; profiles well drained	Minor farm drainage required in places. Good to moderate profile drainage.

Class 4: Restricted irrigable or special use

Includes lands with coarse soils (fine and medium sands, loamy fine sands) to depth; high IR rates of >15.0cm h^{-1}; low AWC values; slopes between 1° and 3° ; land leveling requirements > 1000 m^3 ha^{-1}; GWT levels within 5m of the surface; poorly drained profiles. These soils are considered suitable only for overhead or drip irrigation systems, although small basin irrigation may be possible on a small scale.

Class 5: Provisionally non –irrigable

Includes land underlain by laterite within 150cm of the soil surface; additional economicand engineering studies are required to determine whether drainage is required or is practical.

Class 6: Non-irrigable

Includes lands with excessive topographic, flooding or drainage problems which are considered to be non-correctable at an economic rate.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Morphological properties of the soils

Cashew (IK1): It is deep, well drained, with sandy clay loam texture on top and they occupy the crest of the landscape with dominant gradient of 2%. Soil colour ranged from dark brown (7.5YR 3/4, dry) on top coming down to yellowish red (5YR 4/6, dry) with clay subsoil. The soils have moderate coarse sub angular blocky structure throughout the profile. Bulk density values ranged from 1.56gcm^{-3} to 1.13gcm^{-3} in the subsoil. Soil pH ranged from 4.77 to 4.42 in the subsoil indicating very strong acid to strongly acid. Soils of this unit have low inherent natural fertility. This is because they are low in organic matter; total nitrogen and available phosphorus. Many reddish prominent mottles were encountered also from 40cm downwards.

Gmelina (IK2): It occupies undulating middle slope positions of the landscape with dominant gradient of 2-3%. It is deep, well drained. Soil colour ranged from reddish brown (2.5YF 4/3, dry) on top coming down to sandy loam with yellowish red (5YR 5/8, dry). The soil unit has presence of roots, stones and few iron-manganese concretions. The soil pH move from weakly acidic (5.2) coming down to acidic (4.86). Many coarse reddish mottles encountered at 80cm in the soil profile. They are so low in their inherent fertility status. They have low cation exchange capacities; Ca, Mg, K, N and P. Bulk density ranges from 1.39gcm^{-3} to 2.26gcm^{-3}.

Fallow (IK3): It occupies the upper slope of the landscape with dominant gradient of 2%. The soil is deep, well drained with a granitic parent material. Soil colour ranged from dark grayish brown (2.5Y 4/2, dry) with sandy clay loam on top coming down to sandy clay in brownish yellow colour (10YR 6/8, dry) in the subsoil. Soils are weakly acidic (5.96) on top coming down to acidic (4.27) in the subsoil. The soil has many coarse prominent reddish mottles from the surface to the subsoil and Structural aggregates are moderate. The soils are low in cation exchange capacity, total nitrogen, organic matter and basic cation (Ca, Mg and K). However, high value of available phosphorus was obtained on the surface (29.57ppm) while low values were obtained for the rest of the profile. The soils are low in their inherent fertility status. At 45 – 59cm there is evidence of stone lines with heavy concretions which reduces penetrability of roots.

Fisheries (IK4): It occupies the middle to lower slope portion of the landscape with dominant gradient of 2-4%. It is deep, imperfectly drained with dark yellowish brown (10YR 4/4, dry) coming down to olive yellow (2.5Y 6/8, dry). They possess a texture of sandy clay loam throughout the profile. The soil pH ranges from acidic 4.87 to strongly acidic 3.9. The soil mapping unit was low in their inherent fertility status. They have low cation exchange capacities, Ca, Mg, K, N, P and organic matter. Bulk density ranged from1.54gcm^{-3} to 2.2gcm^{-3} in the sub-soil. There was an evidence of saprolites encountered at 130cm in the soil profile. Many iron-manganese concretions encountered at 49cm and 118cm respectively in the soil profile.

Oil palm (IK5): It occupies slightly undulating middle slope position of the landscape with dominant gradient of 3% with a granitic parent material. They were deep and well drained. Soil colour ranged from Brown (10YR5/3, dry) with sandy clay loam on top coming down to yellowish red (5YR 5/8, dry) in the subsoil. The soils have moderate, medium sub-angular blocky throughout the profile. The soils pH ranges is acidic (5 - 5.73). Many Iron-manganese concretions encountered from a depth of 43cm down the soil profile. Many coarse, prominent reddish mottles also encountered within the soil profile.

Banana (IK6): It occupies slightly undulating lower slope positions of the landscape with dominant gradient of 3 – 4%. The soil is deep, well drained and developed on granitic parent material. Soil ranged from dark grayish brown (10YR4/2, dry) with sandy clay loam on top coming down to light yellowish brown (2.5YF 5/4, dry) sandy clay. The soils have moderate coarse sub-angular blocky structure on the surface coming down to strong medium sub-angular blocky structure in the subsoil. The soil pH is acidic (4.69 to 4.22). The soil mapping unit was low in their inherent fertility status. They have low cation exchange capacity, K, Mg, and total Nitrogen. Few yellowish mottles encountered between 104cm to 150cm in the soil profile.

Lowland (IK7): It is not deep, poorly drained. It ranged from dark grayish brown (10YR 4/2, dry) colour with coming down to grayish (10YR5/1, dry). . The soil has a sandy clay loam texture throughout the soil profile. The soil unit occupies the narrow flood plain valley which experiences seasonal flooding and water logging. The soils are weakly structured and there is evidence of stratification with weak horizon differentiation on the field. Stratification of parent materials is not uncommon in soils having alluvial origin such as the one encountered in this soil mapping unit. Soil pH ranged from 5.03 to 4.21 in the subsoil indicating strong acid to strongly acidic soil. Soils of this in it have moderately low inorganic matter and were highly weathered. Structural aggregates are moderate coarse sub-angular blocky with slightly sticky consistence. Many dominant yellowish red and reddish mottles encountered at 48cm and 80cm in the soil profile. Water table was encountered at 80cm.

4.2 Physico-chemical characteristics of soils of the study sites

Generally the texture of the soils at the surfaces varies from sandy clay loam to clay/sandy clay in the subsoil. This indicates that erosion and run-off has removed the Ap horizon (i.e. sand) as a result of the undulating topography which make the soil easily detached under the impact of rain-drops or running water.

The silt/clay ratio ranged from 0.16 – 1.27. Van Wambeke, (1962) reported that "old" parent materials usually have a silt/clay ratio below 0.15 while silt/clay ratios above 0.15 are indicative of "young" parent materials. Results of this study shows that all the soils have silt/clay ratio above 0.15 indicating that the soil are relatively young with high degree of weathering potential. Silt/clay ratios are relatively higher in the surface horizon and decrease with increase depth in the land use. According to Young, (1976), the low silt to clay ratio is an indication of low weathering intensity as a ratio of <0.15 indicates low to moderate while a ratio of >0.15 indicates high intensity. Therefore, the decrease in silt/clay ratio with depth indicates that the soils in the sub-soils horizons are more weathered than surface horizons.

The bulk density values range from 1.33 – 1.64gcm^{-3} in the Ap horizon and 1.13 – 2.26gcm^{-3} in the subsurface horizon. The differences occur as a result of differences in mineralogy, clay content and structural development. Plants perform best in bulk densities below 1.4 and 1.6gcm^{-3} for clay and sandy soil respectively (Miller and Donahue, 1990). The Ap horizon bulk density of most of the soils are greater than 1.4gcm^{-3} (cashew plantation – 1.56gcm^{-3}, oil palm – 1.55gcm^{-3}, Fallow – 1.43gcm^{-3}, banana – 1.45gcm^{-3} and fisheries – 1.64gcm^{-3}). There is need to carefully manage the soils to avoid compaction which may pose resistance to root penetration or growth. Tarawali *et al.*, (2001) and Odunze, (2006) reported that bulk density can inhibit root growth due to high bulk density because of soil resistance to root penetration, poor aeration, slow movement of nutrients and water build up of toxic gases and root exudates. With reference to the bulk density obtained in this study, Gmelina and Lowland landuse looks fairly favourable for crop production while others must be managed carefully.

Porosity values range from 38.11% – 49.81% on the surface of all the soils. Maniyunda and Malgwi (2011) reported similar values in the soil of Zaria, Kaduna State. Fetter (1998) and Rien and Sposito (1991) recommended that soils having porosity of over 50% and 45% – 50% of volume are good agricultural soils. The values of porosity recorded for soils in this study (except for Fisheries – 38.11%) shows that they are good agricultural soils.

Exchangeable bases K, Na, Ca, Mg values range from 0.08-0.38, 0.14-0.48, 2-7.1 and 1-3.4meq/100kg respectively. It was observed that the exchangeable bases in most cases decreased with depth. Calcium is the most abundant exchangeable cation with magnesium next in abundance in all the profiles (Table 13).The low to medium range of exchangeable bases indicate low basic nutrient status of the soils. Similar results of exchangeable bases were reported by Shobayo *et al.,* 2013. Appropriate use of chemical fertilizers will ameliorate the deficiency of the exchangeable bases for continuous and intensive sustainable crop production.

Available phosphorus is very low in some of the land use (Gmelina, cashew, Fisheries, lowland and oil palm) they range from 0.78mg/kg - 7.16mg/kg on the surface compared with the critical level of 20mg/kg (Tanaka and Yoshida, 1970). This low values is typically of most tropical soils. These soils will therefore require a lot of P fertilization. Soils in Banana and Fallow are high in phosphorus on the soil surface.

The pH of the surface soils ranges from 4.69 (acidic) to 5.96 (weakly acidic). Soil pH was observed to have no definite regularity with increasing depth. Similar trends have been observed and reported by Sharu *et al.,* (2013) and Fasina *et al.,* (2007). According to Landon (1991) a pH range of 5.5 – 7.0 is the preferred range for most crops. Factors suggested to be responsible to the acidic nature of the soils may include heavy rainfall, the acidic nature of the parent rocks and the acidic precipitation around the study area. Annual rainfall around the study area is about 1700-1800mm and most of this fall within five to seven months in the year. This distribution of rainfall is considered adequate for leaching and colloid translocation.

Organic matter decreased irregularly and became very low in the subsoil. High values were obtained on the surface for Gmelina – 4.03%, Banana – 4.99%, Oil palm – 4.29% and lowland – 3.86% while for cashew (1.92%), Fallow (2.77%), Fisheries (2.25%) low values were obtained. The low organic matter might be due to high temperature and relative humidity which favour rapid mineralization of organic matter (Fasina *et al.,* 2006, Fasina, 1999). The low organic matter content recorded on the average for most of the soils cannot sustain crop production program. Soil organic matter content can be increased through effective crop residue management, establishment of legume cover crops will enhance organic matter accumulation by providing the nitrogen needed for decomposition of freshly added organic materials.

Exchangeable sodium percentage (ESP) in most of the soil surface is low except Fisheries (11.76). ESP of 15 is recognized as a limit above which the soils are characterized as sodic (Richards, 1954). This limit, though tentative, has been increasingly found useful because many soils show a sharp deterioration in physical properties around or above this ESP

(Abrol *et al.*, 1978; Acharya and Abrol, 1978; Varallyay, 1977; Gardner *et al.*, 1959), although for some soils a lower ESP (6) has been suggested as a limiting value (Northcote and Skene, 1972).

The total nitrogen values range from very low to low (0.02% – 0.25%). Similar results of very low to low N values have been reported by Fasina *et al.,* (2006) on granitic soils in Nigeria. The values decreased down the profile in all land use except Gmelina (0.02-0.13) with very little increase and this could be attributed to the influence of continuous cultivation, a common practice on Nigerian soils caused by crop residues removal (Noma *et al.,* 2011). The variation in quantity maybe associated with leaching coupled with intermittent flooding and drying which favour nitrogen loss through nitrification-denitrification process (Wong *et al.,* 1991). Effective management of these soils is the application of nitrogenous fertilizer.

CEC values ranges from Low to medium (3.44cmol/kg to 25.93cmol/kg). This indicates that the soils have low potentials for retaining plant nutrients, hence the necessity for adequate soil management. Similar findings were reported by Fạsina *et al.,* (2015). The low to medium CEC of the soils could be attributed to the nature of clay minerals (kaolinite) (Hassan *et al.,* 2011, Lakubu *et al.,* 2011).

Base saturation by ECEC range from very low to medium with most values ranging between 14% - 96%, thus reflecting the relatively high acidity level of the soils. The base saturation has high values at the surface across all land use which decreases with increasing depth except lowland which increases with soil depth (41%-89%). Minimal level of acid forming fertilizers should be used to prevent further acidification of the soil. Most of the high values were recorded on the soil surface values of base saturation and decrease down the depth in most cases.

4.2 LAND CAPABILITY CLASSIFICATION

Soils in Cashew (IK1), Gmelina (IK3), Oil palm (IK5) and Banana (IK6) land use belong to Class III. This Class is moderately good with fertility and soil depth as limitation for crop production. But the land can be used for cultivated crops regularly in a good rotation, if ploughed on the contour on sloping fields. The use of organic materials, crop and plant residues can be used to correct this limitation. Soils in fallow (IK2), fisheries (IK 4), and lowland (IK 7) belong to Class IV_{fs}, IV_{fsw}, and IV_{fsw} respectively. This class of land is fairly good, but its use for cropping is limited by natural features such as slope, erosion, adverse soil wetness. Its best use is for pastures or forestry, but some of it may be cultivated occasionally with proper management. Fertility as a limitation can be removed because it is not a permanent characteristic unlike effective soil depth.

Table 8: Summary of Capability Classification of the soils

Capability	Sites	Limitation	Recommendation
III	Cashew (IK 1)	Fertility	Appropriate fertilizer application
III	Gmelina (IK 2)	Fertility, effective soil depth	Appropriate fertilizer application Plant shallow rooted crops
IV	Fallow (IK 3)	Fertility, effective soil depth, rock outcrop	Appropriate fertilizer application Plant shallow rooted crops
IV	Fisheries (IK 4)	Fertility, effective soil depth, wetness	Appropriate fertilizer application Plant shallow rooted crops Plant water resistant crops like rice
III	Oil palm (IK 5)	Fertility, effective soil depth	Appropriate fertilizer application Plant shallow rooted crops
III	Banana (IK 6)	Fertility	Appropriate fertilizer application
IV	Lowland (IK 7)	Fertility, effective soil depth, wetness	Plant shallow rooted crops Plant water resistant crops like lowland rice or cultivation of dry season vegetable

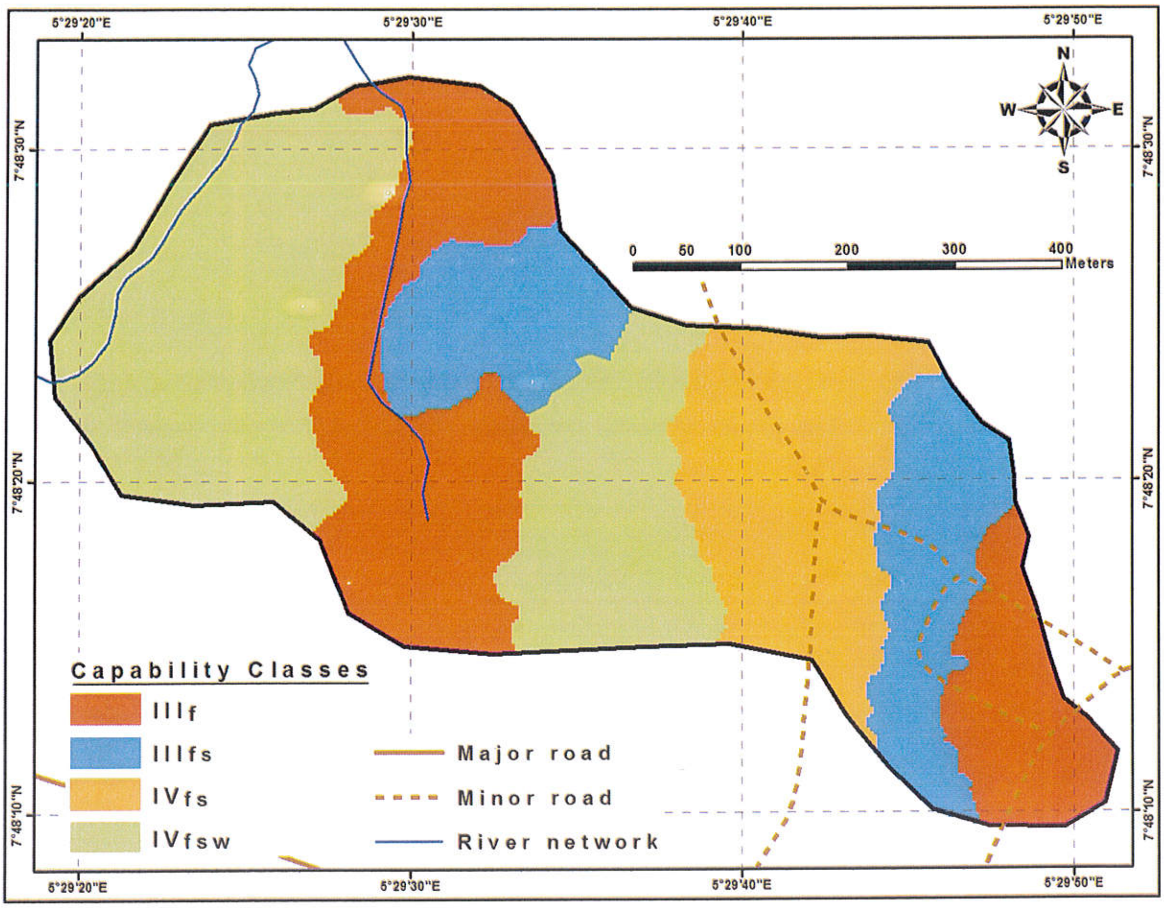

Plate 2: Land capability classification map of the study site

Capability	Area (Hectare)
IIIf	9.40396686
IIIfs	6.11757007
IVfs	5.66208522
IVfsw	12.50208428

4.3 LAND SUITABILITY EVALUATION

4.3.1 Cassava (IK1)

The matching of Land Characteristics used for suitability of the land use for cassava *(Manihot esculentus)* production in the study area with Land and soil requirements for suitability of cassava (Table 2) resulted in the suitability classes of the soil mapping units. Cashew, Gmelina, Fallow, Oil palm and Banana sites are moderately (S2) suitable for cassava production because of the limitation of fertility while fisheries is marginally (S3) and lowland is temporarily not suitable due to poor drainage status. Necessary soil amendments can be made to increase the suitability of the land thereby improving productivity.

4.3.2 Oil palm (IK2)

The suitability of the soils for oil palm *(Elaeis guinnensis)* production is shown in table 3. Fallow, Oil palm, Gmelina, Cashew and Banana are moderately suitable (S2) while Fisheries and Lowland sites are marginally suitable (S3) and temporarily not suitable (N1) respectively due to fertility and wetness as limitation.

4.3.3 Cashew (IK3)

The suitability of the soils for cashew *(Anacardium occidentale)* production is shown in table 4. Gmelina, Cashew, Fallow, Oil palm and Banana sites are highly suitable for cashew production. Fisheries site is marginally suitable (S3) and Lowland site is temporarily not suitable (N1) because of the poor drainage status of the sites.

4.3.4 Maize (IK4)

The suitability of the soils for maize *(zea mays)* production is shown in table 5. However, depth and low soil fertility levels had limited the suitability of Gmelina, Banana, Cashew, Fallow, Oil palm and Fisheries land use into moderately suitable (S2) for maize production. The drainage status of lowland reduced its suitability for maize cultivation to temporarily not suitable (N1).

4.3.5 Banana

The suitability of the soils for Banana *(Musa acuminata)* production is shown in table 6. The major limitation in the soils (Gmelina, Banana, Cashew, Fallow, Fisheries and Oil palm) is the physical soil characteristics and fertility which makes the land to be placed into moderately suitable (S2) for Banana production. The imperfect drainage status of lowland has reduced its productivity to temporarily not suitable (N1).

Table 9: Summary of Land Suitability Evaluation of Ikole soils

Sites	Cassava	Oil palm	Cashew	Maize	Banana
Cashew (IK1)	S2f	S2f	S1	S2f	S2f
Gmelina (IK2)	S2f	S2f	S1	S2f	S2f
Fallow (IK3)	S2f	S2f	S1	S2f	S2f
Fisheries (IK4)	S3w	S3wf	S3w	S2wf	S2wf
Oil palm (IK5)	S2s	S2s	S1	S2f	S2f
Banana (IK6)	S2s	S2f	S1	S2f	S2f
Lowland (IK7)	N1w	N1ws	N1ws	N1wfs	N1wfs

See attached soil suitability maps in Appendix 6-10.

4.4 FERTILTY CAPABILITY CLASSIFICATION (FCC)

The result FCC (Table 10) classified the different land use as follows; Cashew and Banana as SSek, Gmelina, Oil palm, Fallow, Fisheries and Lowland sites as SSeh, SSh, SSghk, SSegk and SSgh respectively. Low CEC indicates that the soils have low potentials for retaining nutrients, hence the necessity for adequate management like application of fertilizer. The result shows that different land use in the study site can have different FCC. It therefore confirms the extent of soil variability in terms of the chemical properties of different land use. This has great implication for crop production and soil management. The implication of this is that each soil will be managed separately based on the condition modifier identified on the field.

Table 10: Fertility Capability Classification of soils in the seven land use types

Sites	Type	Substrata type	------Modifiers-------					
			E	G	H	I	B	K
Cashew (IK 1)	S	S	+	-	-	-	-	+
Gmelina (IK 2)	S	S	+	-	+	-	-	-
Fallow (IK 3)	S	S	-	-	+	-	-	+
Fisheries (IK 4)	S	S	+	+	-	-	-	+
Oilpalm (IK 5)	S	S	-	-	+	-	-	-
Banana (IK 6)	S	S	+	+	-	-	-	+
Lowland (IK 7)	S	S	-	+	+	-	-	-

Key: S: sandy topsoil and subsoil

e: Low CEC

g: gleyic condition, mottles

h: acidity

i: high P-fixation

b: basic reaction

k: Low in reserve K

4.5 IRRIGATION SUITABILITY CLASSIFICATION

The result of the suitability of the soils for irrigation class is shown in table 11. All the soils are placed as restricted or special use soils (class 4) except lowland which is placed as non-irrigable (class 6) because of its drainage problem which considered the land to be non-correctable at an economic rate. However, the restricted irrigable soils are considered only for drip irrigation systems because of the limitations of texture, effective depth and slope. None of the land use was considered irrigable.

Table 11: Irrigation suitability classification

Land characteristics	Cashew	Gmelina	Fisheries	Oil palm	Banana	Fallow	Lowland
Top soil texture (0-30cm)	Medium Coarse (class 4)	Medium Coarse (class 4)	Medium Coarse (class 4)	Medium Coarse (class 4)	Medium Coarse (class 4)	Medium Coarse (class 4)	Medium Coarse (class 4)
Subsoil Texture (30-80)	Class 4	Class 4	Class 4	Class 4	Class 4	Class 4	Class 4
Effective depth (150cm)	150cm (class 1)	130cm (Class 4)	130cm (Class 4)	140cm (Class 4)	150cm (class 1)	120cm (Class 4)	80cm (Class 4)
Ground water Table	-	-	-	-	-	-	Class 1
Drainage	Class 1	Class 1	Class 4	Class 1	Class 1	Class 1	Class 6
Total suitability	Class 4	Class 4	Class 4	Class 4	Class 4	Class 4	Class 6

4.6 SOIL CLASSIFICATION

4.6.1 Cashew (IK1)

Soils of this unit were characterized by the presence of argillic horizon. The soil was classified at suborder level as Udult because of Udic moisture regime. They are therefore classified as Great group. Plinthudult have plinthites within 150cm of the surface. At subgroup level they are classified as Typic Plinthudult and as Dystric Lixisol (World Reference Base, 2014).

4.6.2 Gmelina (IK2)

The soils in this land use were also classified as Typic Plinthudult (USDA, 2014) and Dystric Lixisol (FAO/UNESCO, 2014).

4.6.3 Fallow (IK3)

The soils in this land use have the same characteristics as that of IK1 and IK2, they are also classified as Typic Plinthudult (USDA, 2014) and Dystric Lixisol (FAO, 2014).

4.6.4 Fisheries (IK4)

Soils of this unit were classified as order Ultisol that is, soil with low base saturation and argillic horizon. It was classified at suborder level as Aquilt (have acquic conditions for some time in normal years or artificial drainage) in one or more horizons within 50cm of the mineral soil surface. At Great group level, the soils were classified as Plinthaquilt (Aquilts that have one or more horizons within 150cm of the mineral soils surface) in which plinthite either forms a continuous phase or constitute one-half or more of the volume. At subgroup level the soil was classified as Kandic Plinthaquilt (USDA, 2014) and as Ferric Lixisol (FAO, 2014).

4.6.5 Oil palm (IK5)

The soils in this land use possess similar characteristics like those of soils in IK1, IK2 and IK3, so it was classified as Typic Plinthudult (USDA, 2014) and Dystric Lixisol (FAO/UNESCO, 2014).

4.6.6 Banana (IK6)

The soils here were classified as Ultisol at order level and suborder Udult. At Great group level it was classified as Kandiudult that is, the soil possess Kandic horizon with irregular decrease in organic carbon with increase in depth. At subgroup level it was classified as Plinthic Kandiudult (USDA, 2014) (having 5% or more (by volume) plinthite or more horizons within 150cm of the mineral surface) and as Plinthic Lixisol (FAO/UNESCO, 2014)

4.6.7 Lowland (IK7)

They soils here are recognized on the field by weak evidence of horizonation with the presence of Cambic B horizon evidence of stratification which was observed on the field soils are developed from hill wish deposits. The soils are therefore characterized by altered horizon. These soils were classified as order Inceptisol and suborder Aquept that is aquic conditions for some time in normal year and as Great group Epiaquept and as subgroup Fluvaquentic. Epiaquept which is an irregular decrease in organic carbon content between 25cm and with a depth of 125cm below the mineral soil surface. The soil was also classified as Fluvic Cambisol (FAO/UNESCO, 2014).

Table 12: Soil Classification according to USDA Soil Taxonomy (Soil Survey Staff 2014) and the WRB System (FAO – ISRIC – ISSS, 2014)

Land use	USDA system	WRB system
Cashew IK1	Typic Plinthudult	Dystric Lixisol
Gmelina IK2	Typic Plinthudult	Dystric Lixisol
Fallow IK3	Typic Plinthudult	Dystric Lixisol
Fisheries IK4	Kandic Plinthaquult	Ferric Lixisol
Oil palm IK5	Typic Plinthudult	Dystric Lixisol
Banana IK6	Plinthic Kandiudult	Plinthic Lixisol
Lowland IK7	Fluvaquentic Epiaquept	Fluvia Cambisol

Key: USDA- United State Department of Agriculture

WRB - World Reference Base

LCC - Land Capability Classification

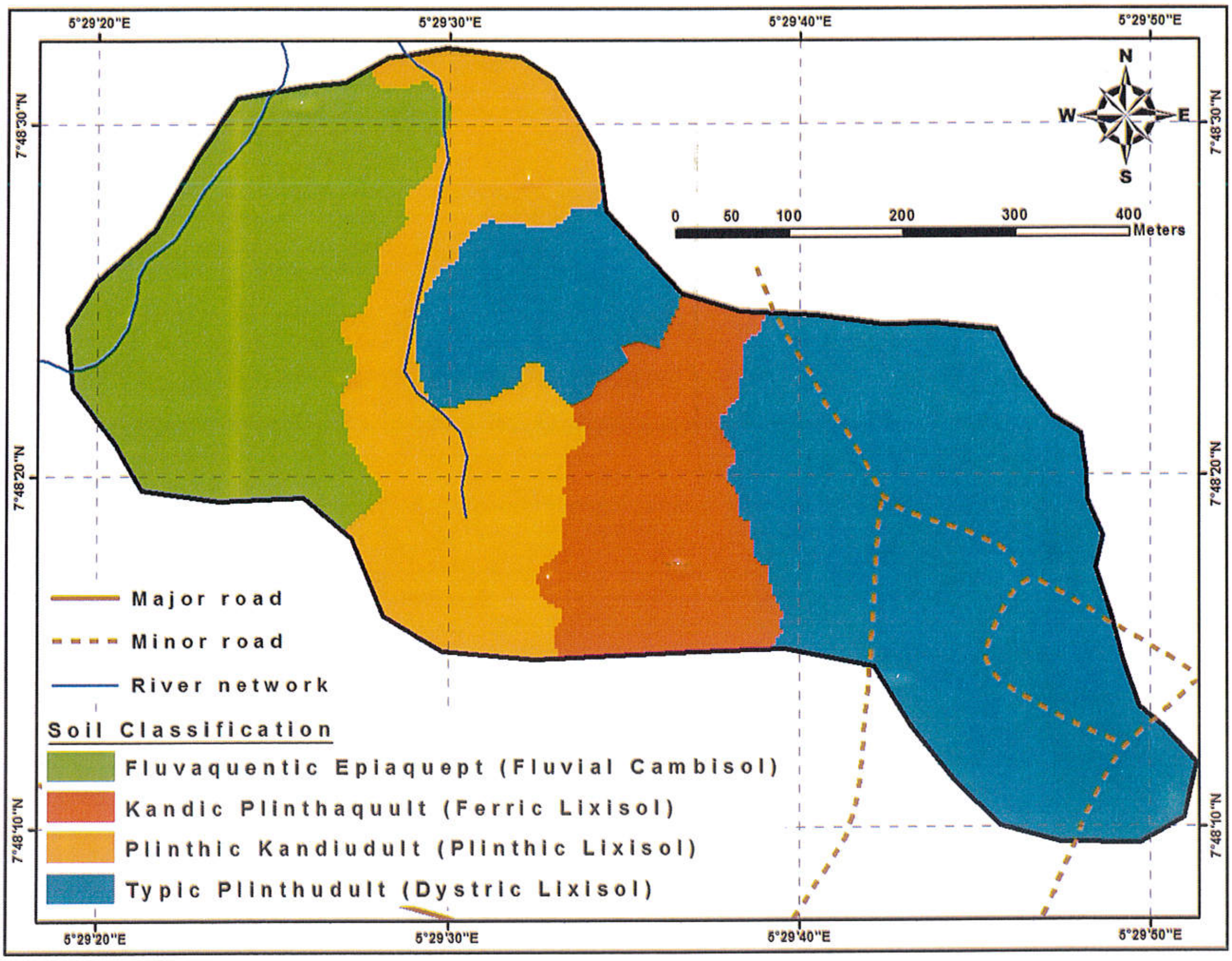

Plate 3: Soil classification map of the study site

Soil Classification	Area (Hectare)
Fluvaquentic Epiaquept	8.002992117
Kandic Plinthaquult	4.499092161
Plinthic Kandiudult	6.790345765
Typic Plinthudult	14.39327639

Table 13: Chemical Properties of Soils in Ikole

Land use Types with Depths	K	Na	Ca	Mg	P (mg/kg)	pH (H_2O)	OC (%)	OM (%)	Exch. Acidity (cmol/kg)	N (%)	CEC (cmol/kg)	BS (%)
Gmelina 0-12cm	0.26	0.18	4.7	2	0.78	5.2	2.34	4.03	0.3	0.02	7.44	95.96
Gmelina 12-23	0.08	0.19	2.4	1.1	0.23	3.27	1.47	2.54	8.4	0.13	12.17	30.98
Gmelina 23-43	0.09	0.15	2.8	1.2	8.87	4.47	0.82	1.42	11.5	0.07	15.74	26.93
Gmelina 43-80	0.11	0.19	3.7	1.3	1.32	4.47	0.65	1.12	9.05	0.06	14.35	36.93
Gmelina 80 below	0.05	0.23	3.5	1.4	0.32	4.86	0.3	0.53	10.5	0.03	15.68	33.04
Banana 0-38	0.15	0.14	4.6	2.2	24.5	4.7	2.89	4.99	1.5	0.25	8.59	82.54
Banana 38-64cm	0.05	0.2	4.6	2	0.47	4.75	1.24	2.15	3.1	0.11	9.95	68.84
Banana 64-104	0.06	0.23	1.9	1.6	0.16	4.89	0.38	0.66	3.05	0.03	6.84	55.41
Banana 104-150	0.12	0.2	3.9	1.4	0.47	4.22	1.05	1.82	6.75	0.09	12.37	45.43
Cashew 0-16	0.08	0.17	3.6	1.3	7.16	4.77	1.11	1.92	1.35	0.16	6.5	79.23
Cashew 16-40	0.07	0.21	2.4	1	0.16	5.24	1.03	1.78	22.35	0.09	25.93	14.19
Cashew 40-63	0.09	0.2	3	1.1	0.93	4.8	1.11	1.92	4.35	0.12	8.74	60.87
Cashew 63-88	0.05	0.18	3.6	1.4	3.19	4.85	0.48	0.83	10.09	0.03	15.32	34.14
Cashew 88-150	0.16	0.22	1.8	0.8	0.16	4.42	0.59	1.02	0.75	0.06	3.73	79.89
Fallow Land 0-24	0.17	0.16	2.8	1.2	29.57	5.96	1.61	2.77	6	0.14	10.33	41.92
Fallow Land 24-45	0.05	0.16	3.4	1.2	0.16	5.52	0.52	0.89	5.3	0.04	10.11	42.83
Fallow Land 45-59	0.07	0.22	1.9	0.8	0.62	4.22	0.65	1.12	0.45	0.05	3.44	86.72
Fallow Land 59-79	0.07	0.16	3.7	1.2	0.47	5.81	0.34	0.59	8.25	0.12	13.38	38.34
Fallow Land 79-112	0.05	0.18	2.6	1.2	0.86	4.27	0.46	0.79	4.25	0.04	8.53	47.25
Fisheries 0-23	0.1	0.48	2	1	4.12	4.87	1.3	2.25	0.5	0.11	4.08	87.74
Fisheries 23-49	0.06	0.2	2	1	0.31	3.97	0.57	0.99	8.1	0.04	11.36	27.69
Fisheries 49-99	0.04	0.21	1.8	0.7	0.46	4.39	0.38	0.66	1.5	0.03	4.25	64.71
Fisheries 99-118	0.05	0.19	2.6	1.2	0.47	4.82	0.34	0.59	7.4	0.04	11.44	35.31
Fisheries 118 below	0.07	0.27	3.9	1.5	3.03	3.9	0.36	0.63	0.75	0.03	6.49	88.44
Low Land 0-6	0.38	0.25	5.1	2.2	2.41	5.03	2.24	3.86	11.45	0.19	19.38	40.92
Low Land 6-48	0.23	0.21	4.5	2	1.56	4.21	0.5	0.86	1.45	0.04	8.39	82.72
Low Land 48-70	0.11	0.26	2.2	1	1.4	3.95	0.59	1.02	0.4	0.05	3.97	89.92
Low Land 70-80	0.08	0.2	2.5	1.1	0.16	4.97	0.34	0.59	7	0.03	10.88	35.66
Oil Palm 0-25	0.27	0.21	7.1	3.4	5.52	5	2.49	4.29	8.35	0.22	19.33	56.80
Oil Palm 25-43	0.1	0.15	3.9	1.4	1.4	4.93	0.44	0.76	3.7	0.04	9.25	60
Oil Palm 43-95	0.07	0.17	3.9	2	4.36	5.26	0.57	0.99	11.4	0.05	17.54	35.01
Oil Palm 95-140	0.09	0.15	3.8	12	0.16	5.73	0.15	0.26	6.7	0.02	11.94	43.90

Table 14: Soil Physical Properties of Selected Land Use Types in Ikole

LAND USE	HORIZONS (cm)	BULK DENSITY (g/cm^3)	POROSITY (%)	MOISTURE CONTENT (%)	GPS	SAND (%)	SILT (%)	CLAY (%)
CASHEW	0 – 16	1.56	41.13	13.66	N 07° 48.196	52.8	16	31.2
	16 – 14	1.65	37.74	21.73	E 005° 29.796	44.8	10	45.2
	40 – 63	1.49	43.77	22.94		36.8	12	51.2
	63 – 88	1.40	47.17	25.03		40.8	12	47.2
	88 - 150	1.13	57.36	27.27		32.8	16	51.2
GMELINA	0 – 12	1.39	47.55	10.48	N 07° 48.268	60.8	16	23.2
	12 – 23	1.86	29.81	22.64	E 005° 29.756	60.8	22	17.2
	23 – 43	1.87	29.43	17.80		56.8	12	31.2
	43 – 80	2.16	18.49	18.53		44.8	9	47.2
	80 below	2.26	14.72	22.47		42.8	10	47.2
FISHERIES	0 – 23	1.64	38.11	18.09	N 07° 48.306	64.8	10	25.2
	23 – 49	2.01	24.15	21.14	E005°29.566	60.8	8	31.2
	49 – 99	2.14	19.25	12.04		60.8	16	23.2
	99 – 118	2.07	21.89	22.32		48	16	36.2
	118 below	2.20	16.98	10.92		56.8	12	31.2
OIL PALM	0 – 25	1.55	41.51	22.52	N 07°48.404	60.8	16	23.2
	25 – 43	2.07	21.89	16.69	E 005°29.506	56.8	12	31.2
	43 – 95	1.89	28.68	19.16		52.8	16	31.2
	95 – 120	1.8	32.08	25.33		44.8	8	47.2
BANANA	0 – 38	1.45	45.28	24.60	N 07°48.456	60.8	12	27.2
	38 – 64	1.87	29.43	15.79	E 005°29.508	60.8	12	27.2
	64 – 104	2.05	22.64	17.59		64.8	8	27.2
	104 – 150	1.75	33.96	22.63		48.8	12	39.2
LOWLAND	0 – 6	1.33	49.81	31.16	N07°48.405	56.8	20	23.2
	6 – 48	1.73	34.71	14.39	E 005°29.414	60.8	12	27.2
	48 – 70	1.84	30.57	18.01		64.8	10	25.2
	70 – 80	2.12	20.00	16.89		68.8	10	21.2
	0 – 24	1.43	46.04	15.15	N 07°48.357	68.8	8	23.2
FALLOW	24 – 45	1.77	33.21	23.45	E 005°29.722	48.8	8	43.2
	45 – 59	2.26	14.72	13.70		44.8	12	43.2
	59 – 79	1.57	40.75	32.11		40.8	8	51.2
	79 -120	1.54	41.89	35.16		48.8	10	41.2

Table 15: Morphological Properties of Soils in Ikole

Gmelina

Horizon	Depth (cm)	Colour (dry)	Texture	Structure	Consistence	Concretions	Drain.
A1	0 – 12	2.5YR4/3	SCL	Mcsab	SL-st	Ffe-Mn	Well drain
A11	12 – 23	7.5YR4/2	SL	Wccr	Ns	Ffe-Mn	"
B21t	23 – 43	10YR5/6	SCL	Mcsab	SL-st	Ffe-Mn	"
B22t	43 – 80	7.5YR6/8	C	Mcsab	Vst	Ffe-Mn	"
B23t	118 – 130	5YR5/8	C	Mcsab	Vst	-	"

Banana

Horizon	Depth (cm)	Colour (dry)	Texture	Structure	Consistence	Inclusive Concretions	Drain
A1	0 – 23	10YR4/2	SCL	Mcsab	SL-st	Ffe-Mn	Well
B21t	38 – 64	10YR6/4	SCL	Mcsab	SL-st	MFe-Mn	"
B21t	64 – 104	10YR7/4	SCL	Mcsab	SL-st	-	"
B22t	104 – 150	2.5YR6/4	C	Mcsab	Vst	MFe-Mn	"

Cashew

Horizon	Depth (cm)	Colour (dry)	Texture	Structure	Consistence	Concretions	Drain
A1	0 – 16	7.5YR ¾	SCL	Mcsab	SL-st	A	Well drain
B21t	16 – 40	7.5YR5/6	SC	Mcsab	Vst	MFe-Mn	"
B22t	40 – 63	7.5YR5/8	C	Mcsab	Vst	Mfe-Mn	"
B23t	63 – 88	7.5YR5/8	C	Mcsab	Vst	Ffe-Mn	"
B24t	88 – 150	5YR4/6	C	Mcsab	Vst	-	"

Fallow land

Horizon	Depth (cm)	Colour (dry)	Texture	Structure	Consistence	Concretions	Drain.
A1	0 – 24	10YR4/2	SCL	Mcsab	SL-st	MFe-Mn	Well drain
B21t	24 – 45	10YR7/6	C	Mcsab	Vst	MFe-Mn	"
B22t	45 – 59	10YR7/6	C	Mcsab	Vst	Mfe-Mn	"
B23t	59 – 79	10YR6/8	C	Mcsab	Vst	MFe-Mn	"
B24t	79 – 120	10YR6/8	SC	Mcsab	Vst	MFe-Mn	"

Highly concretional from the top to the subsoil with evidence of structures at 45 – 59cm

Fisheries

Horizon	Depth (cm)	Colour (dry)	Texture	Structure	Consistence	Concretions	Draina
A1	0 – 23	10YR4/4	SCL	Mcsab	SL-st	-	Imperf well dr
B21t	23 – 49	10YR5/4	SCL	Mcsab	SL-st	MFe-Mn	"
A11	49 – 99	10YR7/4	SCL	Mcsab	SL-st	-	"
B22t	99 – 118	2.5YR7/6	SC	Mcsab	Vst	MFe-Mn	"
B23t	118 – 130	2.5YR6/8	SCL	Mcsab	SL-st	-	"

Evidence of saprolites

Lowland

Horizon	Depth (cm)	Colour (dry)	Texture	Structure	Consistence	Concretions	Drain
A1	0 – 6	10YR4/2	SCL	Mcsab	SL-st	-	Poor
B21t	6 – 48	10YR5/1	SCL	Mcsab	SL-st	-	Poor
B21t	48 – 70	10YR4/3	SCL	Mcsab	SL-st	-	Poor
B21t	70 – 80	10YR5/1	SCL	Mcsab	SL-st	-	Poor

Oil palm

Horizon	Depth (cm)	Colour (dry)	Texture	Structure	Consistence	Concretions	Drain
A1	0 – 25	10YR5/3	SCL	Mcsab	SL-st	-	Well
B21t	25 – 43	7.5YR4/2	SCL	Mcsab	SL-st	Ffe-Mn	"
B21t	43 – 95	2.5YR7/4	SCL	Mcsab	SL-st	Mfe-Mn	"
B22t	95 – 140	5YR5/8	C	Mcsab	Vst	MFe-Mn	"

Key:

Structure: Mcsab = Medium coarse subangular blocky;
Wccr = Weak, coarse, crumb

Texture: LS = Loamy sand; SL = Sandy loam; SCL = Sandy clay loam; SC = Sandy clay; CL = Clay loam; S = Sand

Consistence: SL-St = Slightly sticky; Ns = non-sticky; Vst = Very sticky

Roots: Mfw = Many fibrous and woody; ff = few fibrous; Mf = many fibrous; Ff = few fibrous; Ffw; few fibrous and woo

SUMMARY AND CONCLUSION

Land evaluation studies were carried out on seven land use types at Federal University Oye-Ekiti, Ikole campus. The soils were identified, mapped, characterized and classified and their potentials were evaluated using the following land evaluation methods below:

i. Land Capability Classification

ii. Land Suitability Evaluation

iii. Fertility Capability Classification

iv. Irrigation Suitability Evaluation

From the results obtained from the study, the following summary and conclusion can be made:

a. The soils are strongly acidic (3.27) to weakly acidic (5.96).

b. The soils are highly weathered and have low inherent natural fertility with low exchange basic cations, organic carbon, cation exchange capacity and total nitrogen.

c. The location of the soils has tremendous influence on the properties of the soils in terms of erosion, leaching, degradation. This is because the area where the soils are located has undulating and rolling topography.

d. Four of the soils (IK1, IK2, IK3 and IK5) were classified as Typic Plinthudult (Dystric lixisol) while IK4 was classified as Kandic Plinthaquult (Ferric lixisol), IK6 classified as Plinthic Kandiudult (Plinthic Lixisol) and IK7 as Fluvaquentic Epiaquept (Fluvia Cambisol).

e. The results of the Land capability classification placed IK1, IK2, IK5 and IK6 in land capability class III while IK3, IK4 and IK7 belong to capability class IV. The major limitations identified on the field that placed the soils in capability III and IV are soil fertility, effective soil depth and wetness.

f. The soils were assessed by testing the suitability of the soils on five different crops (cassava, oil palm, cashew, maize and banana). The suitability of the crops for the land use types ranged from highly suitable to marginally suitable (S1- S3) except lowland site which is temporarily not suitable (N1) for all the crops.

g. All the soils (IK1, IK2, IK3, IK4, IK5 and IK6) were classified as restricted irrigable except IK7 that was classified as non-irrigable due to its drainage problem.

h. The application of lime to the soil will correct its acidic nature, especially in the subsurface layers which support the roots of most of the arable and tree crops. Low organic matter has to be increased through planting of leguminous plants as well as the use of organic fertilizers. The application of appropriate chemical fertilizers will correct the problem of the deficiency exchangeable bases by these soils. Therefore, the use of Ammonium sulphate fertilizer must be avoided in order to prevent erosion, leaching and an increase in the level of acidity of the soil. These is the need to encourage post-harvest incorporation of plant residue into the soil instead of the usual burning of crop residue minimum tillage is recommended because of the concretionary nature of most of the soils (IK1, IK2, IK3,IK4, IK5 and IK6).

i. Based on this research work, the suitability and capability classes have helped to know the use to which the different soils can be put to; I therefore recommend the need to apply effective soil management strategies to achieve sustainable productivity in the different land use types.

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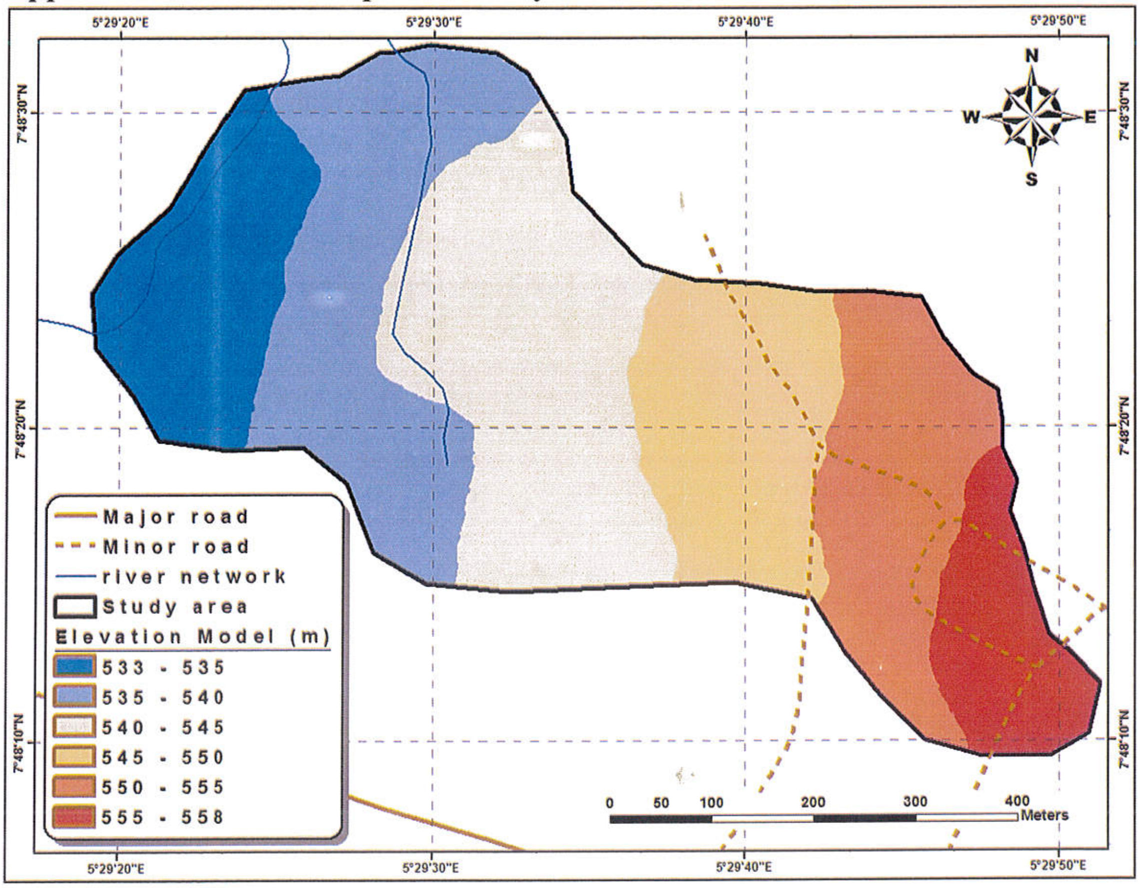
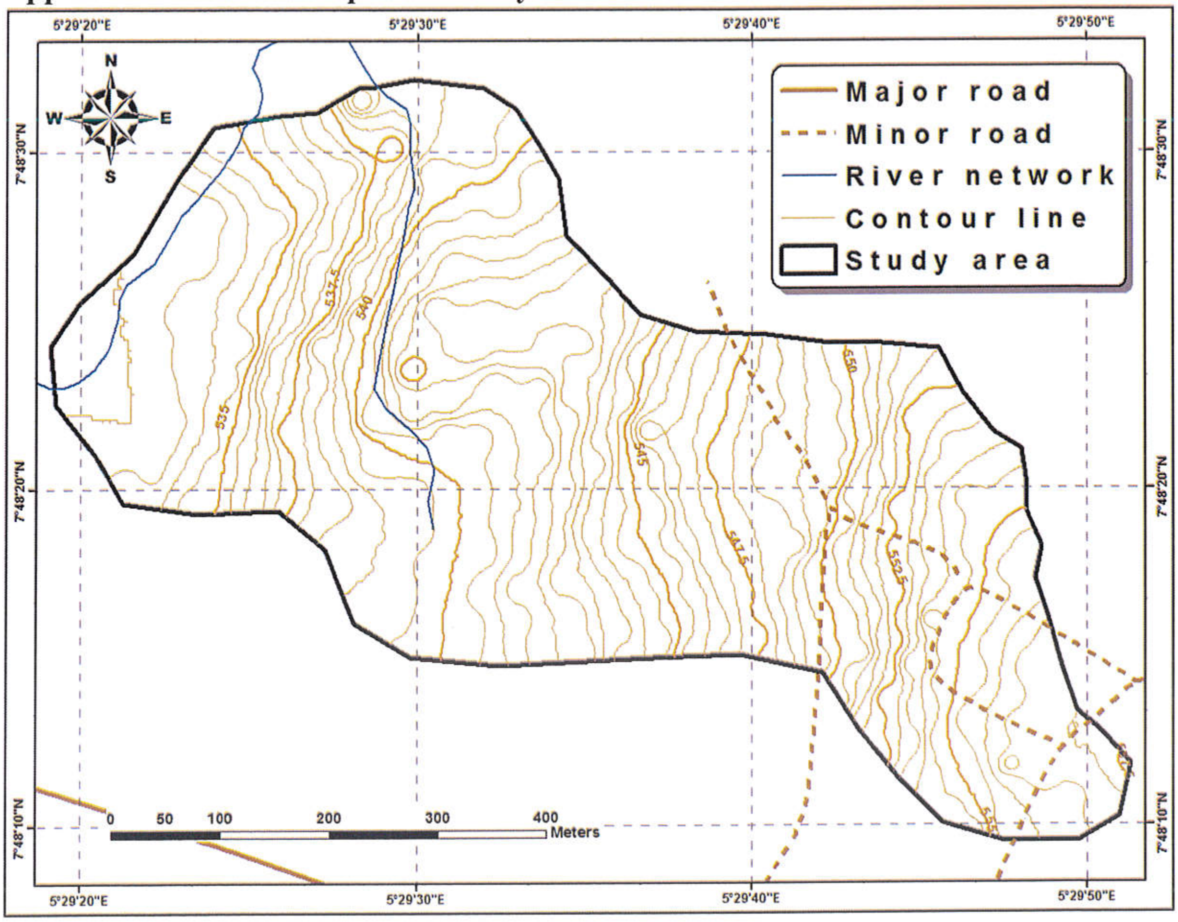
APPENDICES

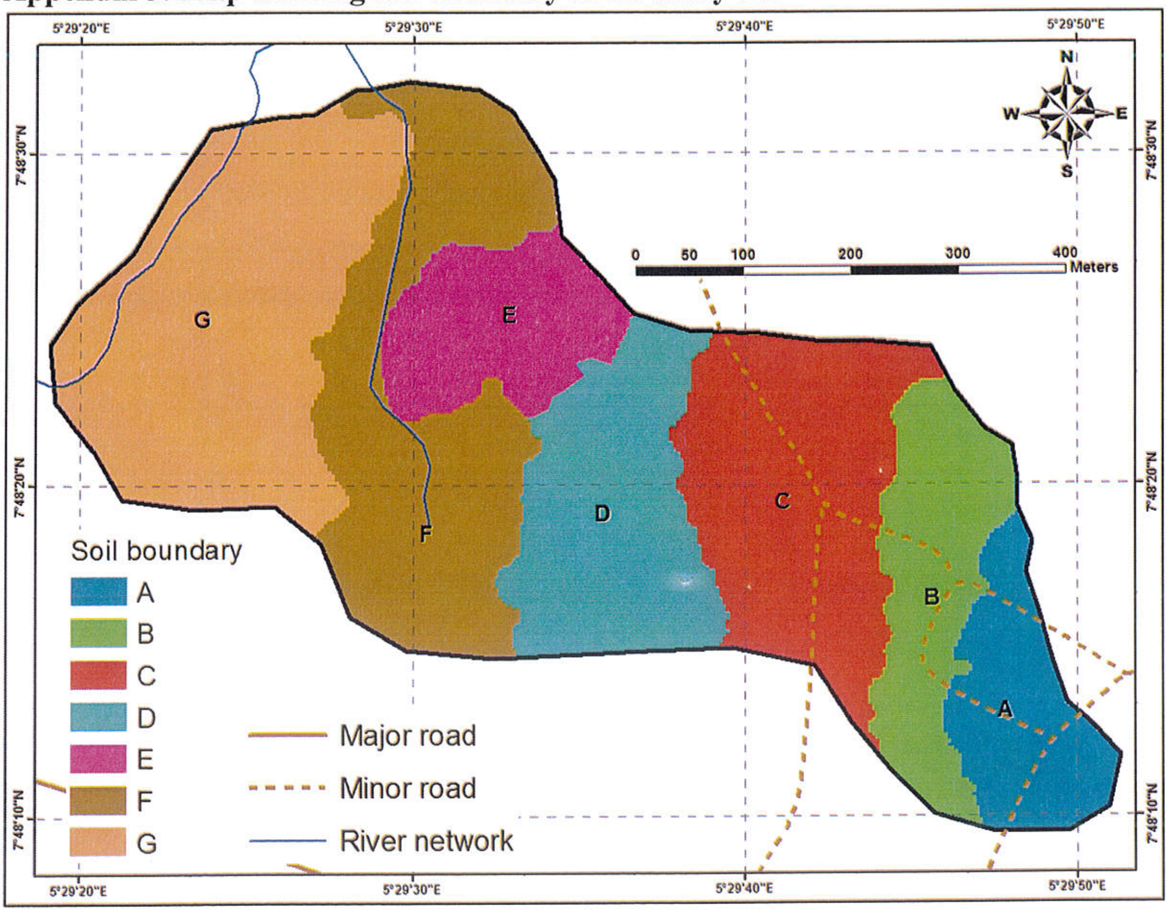
Appendix 1: Elevation map of the study site



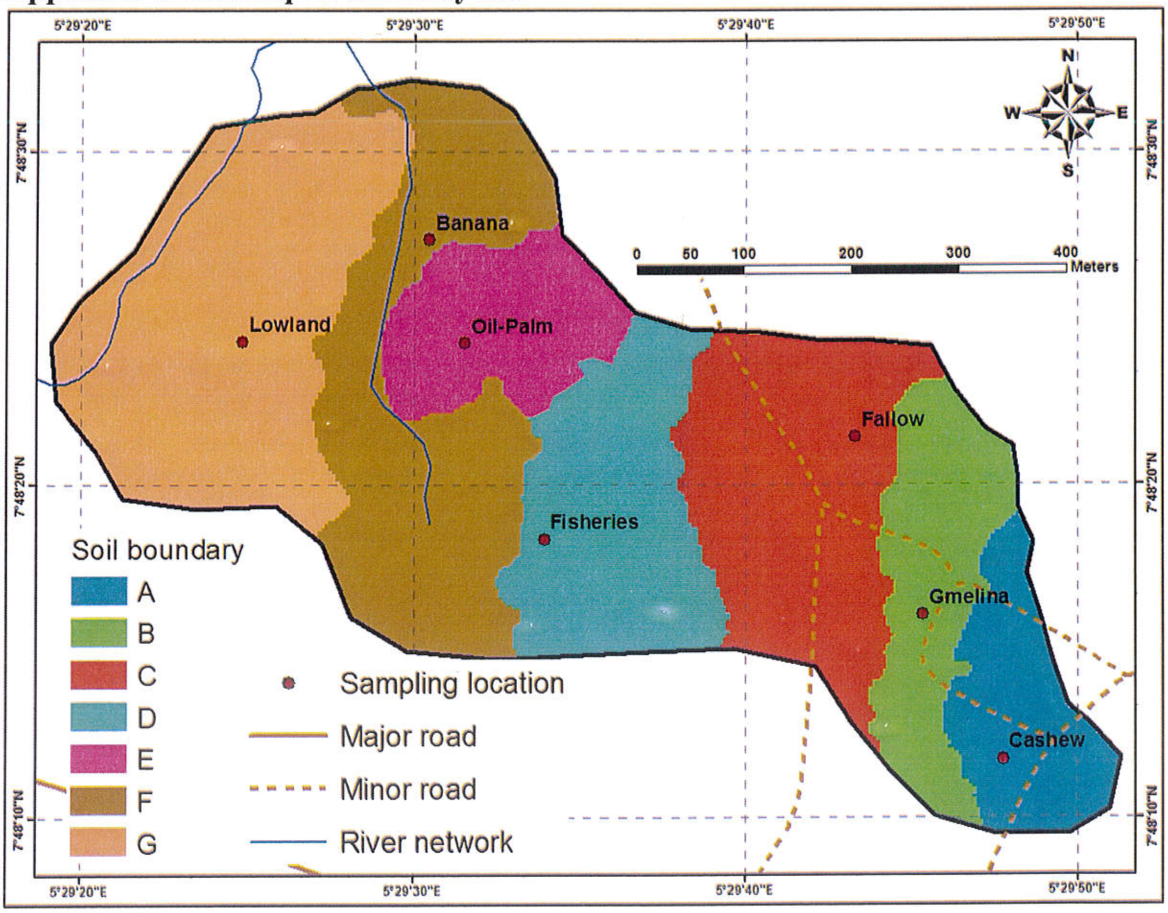
Appendix 2: Contour map of the study site



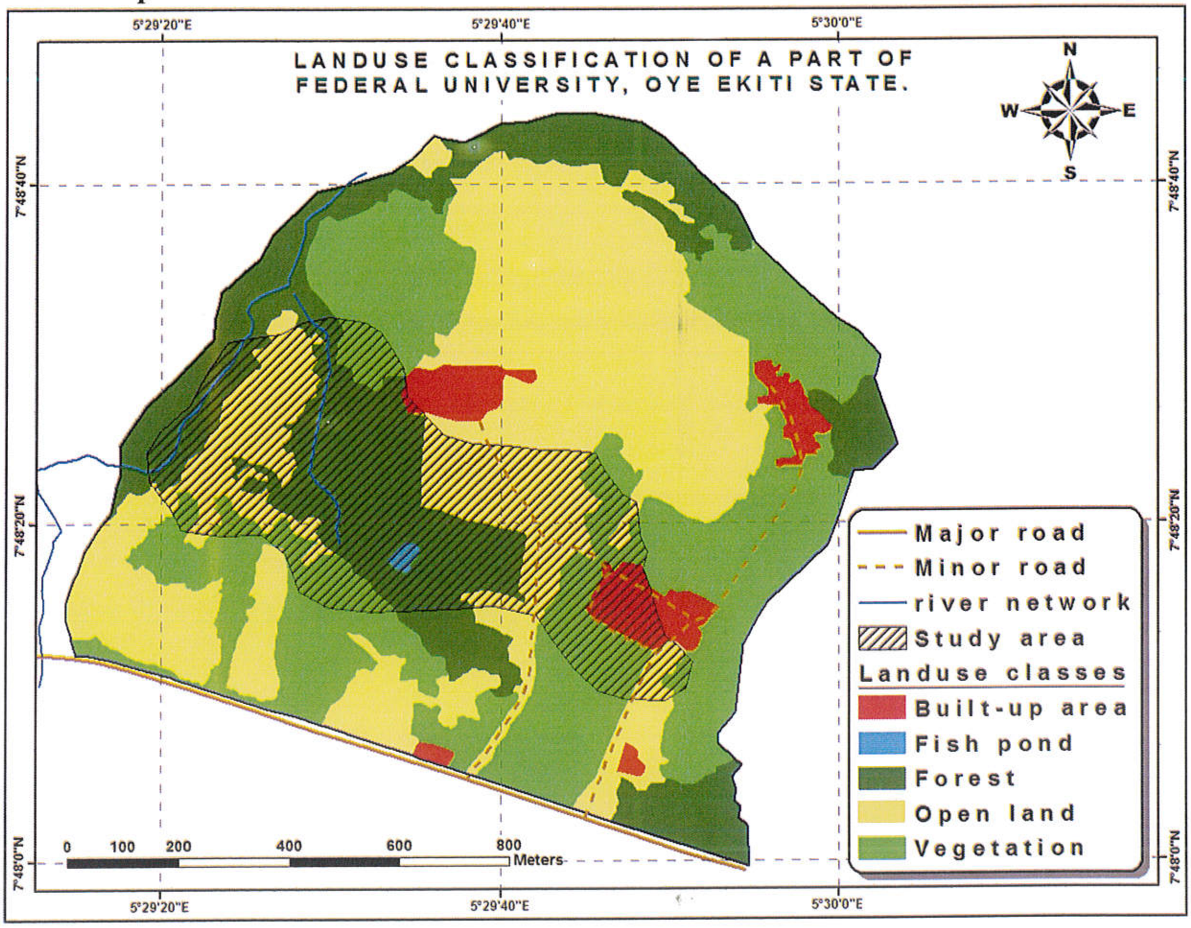
Appendix 3: Map showing soil boundary of the study site



Appendix 4: Soil map of the study site



Appendix 5: Land use classification of a part of Federal University Oye-Ekiti, Ikole campus



WHOLE LANDUSE

Landuse	Area (Hectare)
Built-up area	5.484379356
Fish pond	0.196065997
Forest	30.22875722
Open land	50.27679459
Vegetation	42.08138815

a

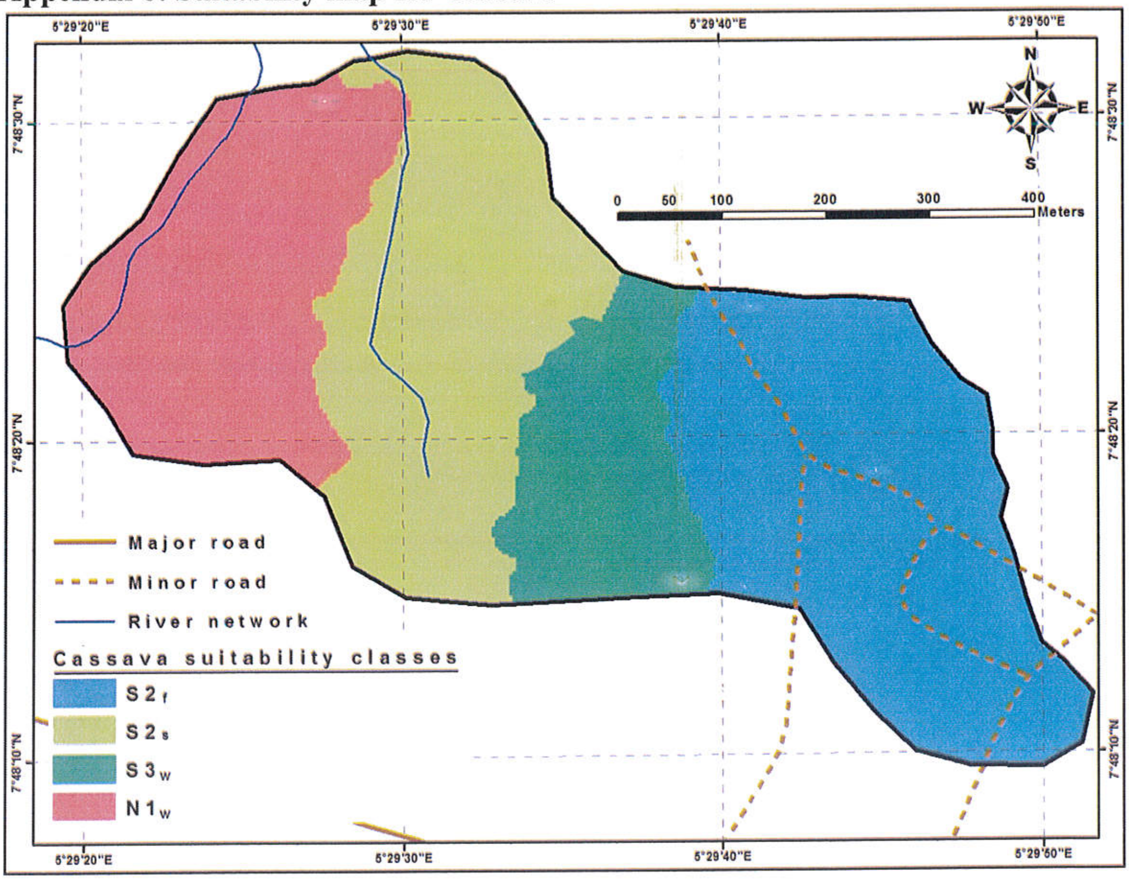
STUDY AREA LANDUSE.

Landuse	Area (Hectare)
Built-up area	1.488508377
Fish pond	0.196065997
Forest	13.31049915
Open land	11.68790419
Vegetation	6.995846189

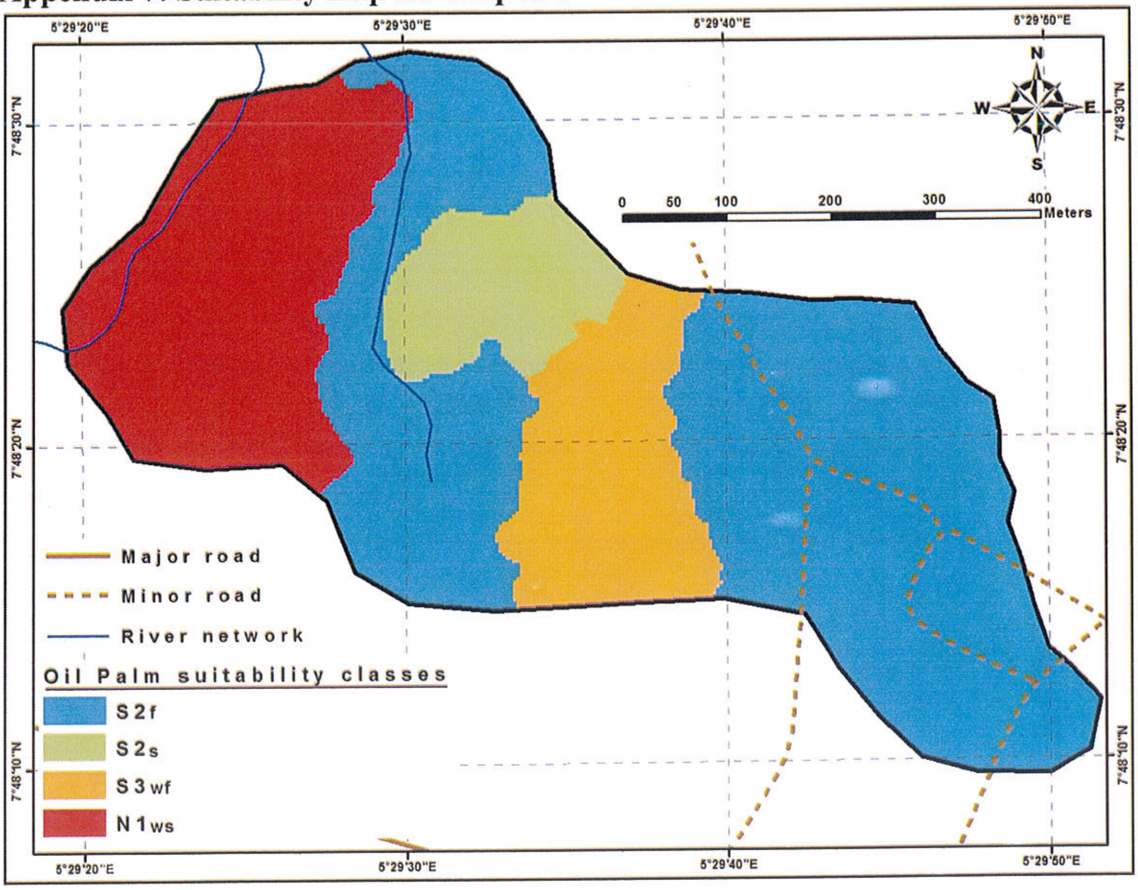
b

Key: a and b shows hectares of the whole land use and study area

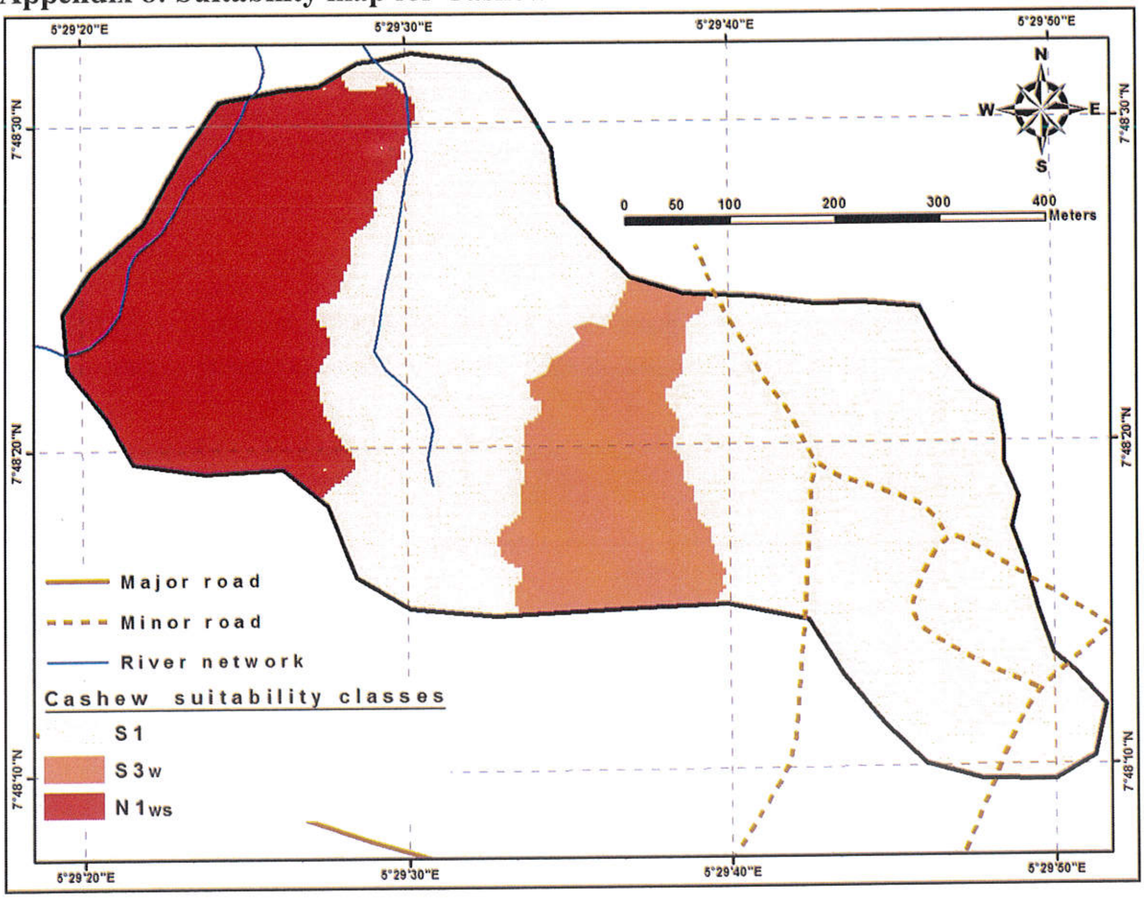
Appendix 6: Suitability map for Cassava



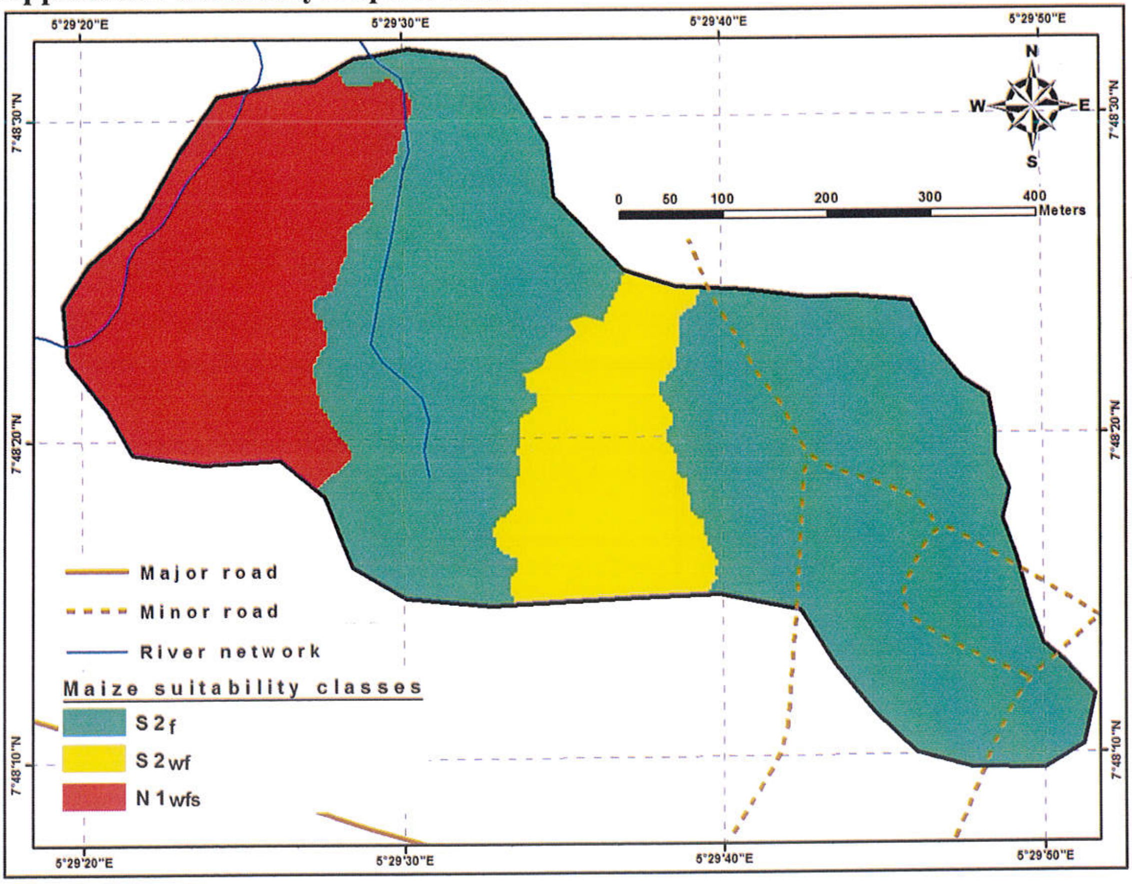
Appendix 7: Suitability map for Oil palm



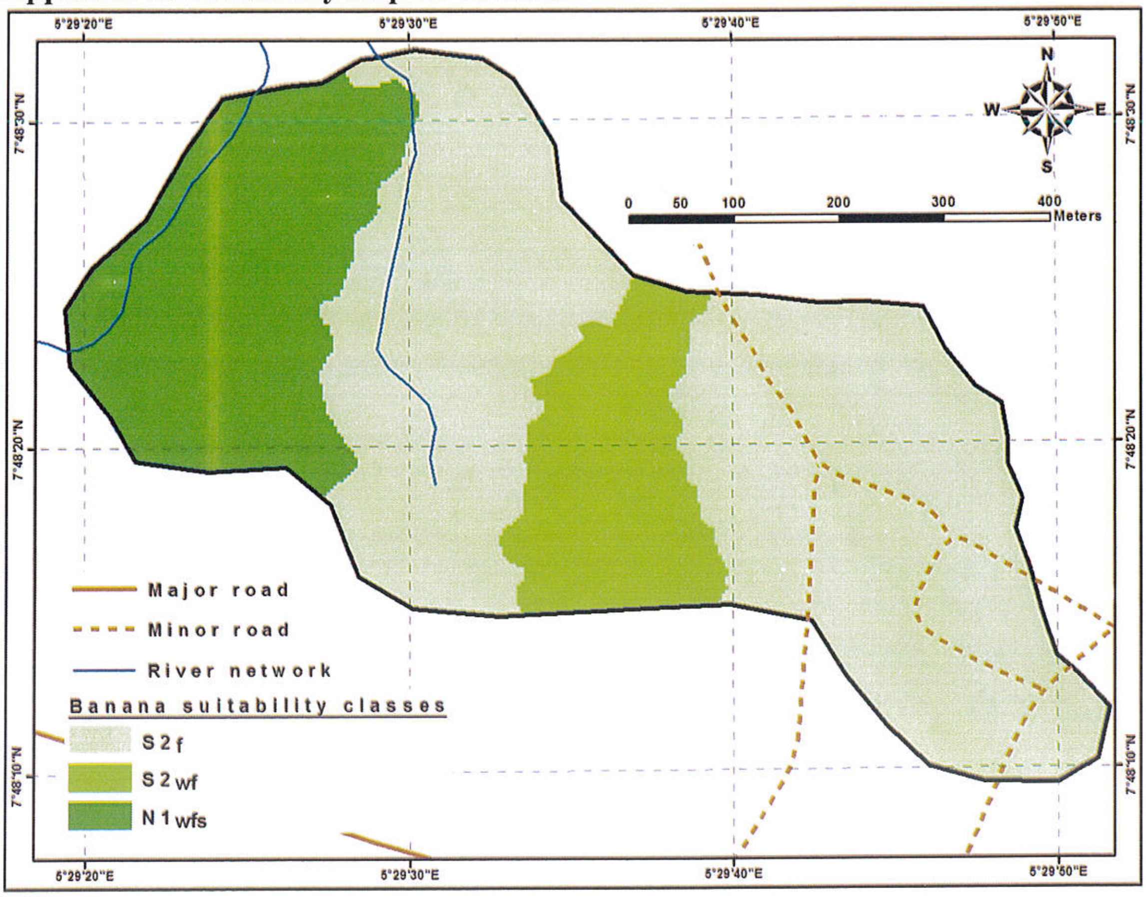
Appendix 8: Suitability map for Cashew



Appendix 9: Suitability map for Maize



Appendix 10: Suitability map for Banana



Appendix 11: Land Capability Classification of the study sites

	Cashew	Gmelina	Fallow	Fisheries	Oil palm	Banana	Low land
Slope	2% (II)	2-3% (II)	2% (II)	2-4% (II)	3% (II)	3-4% (II)	Valley bottom
Rock outcrop	Nil (I)	Nil (I)	5% (IV)	Nil (I)	Nil (I)	Nil (I)	Nil (I)
Wetness	well drained (I)	well drained (I)	well drained (I)	Imperfectly drained (III)	well drained (I)	well drained (I)	Poor drained (IV)
Soil depth	150 (I)	130 (II)	120 (II)	130(III)	140 (II)	150 (I)	80 (III)
Texture	SCl (I)	SCl (I)	SCl (I)	SCl (I)	SCl (I)	SCl (I)	SCl (I)
Available W.C.	13.66 (III)	10.48 (III)	23.45 (II)	18.09 (III)	22.52 (II)	24.60 (II)	31.16 (I)
CEC	6.5 (III)	7.44 (III)	10.33 (III)	4.08 (IV)	19.33 (II)	8.59 (III)	19.38 (II)II
Total Capability	III_f	III_{fs}	IV_{fs}	IV_{fws}	III_{fs}	III_f	IV_{fws}

KEY: f: fertility
w:wetness
s: soil depth

Appendix 12: Suitability classes for Cassava

Land use	Climate (mm)	Length of Dry season	Slope (0-4%)	Drainage (good)	Texture/ Structure (SCL)	Coarse fragment	Soil depth (>125)	CEC (meq/100) (>16)	BS (%) (>35)	OM (>1.5)	Tot Suitability
Cashew	1700-1800 (S1)	S1	2 (S1)	Well drained (S1)	SCL (S1)	S2	150 (S1)	6.5 (S12)	79.23 (S1)	1.92 (S1)	S2f
Gmelina	1700-1800 (S1)	S1	2-3 (S1)	Well drained (S1)	SCL (S1)	S2	130 (S1)	7.44 (S12)	95.96 (S1)	4.03 (S1)	S2f
Fallow	1700-1800 (S1)	S1	2 (S1)	Well drained (S1)	SCL (S1)	S2	120 (S12)	10.33 (S12)	41.92 (S1)	2.77 (S1)	S2f
Fisheries	1700-1800 (S1)	S1	2-4 (S1)	Imperfect (S3)	SCL (S1)	S2	130 (S1)	4.08 (S12)	87.74 (S1)	2.25(S1)	S3w
Oilpalm	1700-1800 (S1)	S1	3 (S1)	Well drained (S1)	SCL (S1)	S2	140 (S1)	19.33 (S1)	56.80 (S1)	4.29 (S1)	S2
Banana	1700-1800 (S1)	S1	3-4 (S1)	Well drained (S1)	SCL (S1)	S2	150 (S1)	8.59 (S12)	82.50 (S1)	4.99 (S1)	S2
Lowland	1700-1800 (S1)	N1	Valley bottom (N1)	Poorly drained (N1)	SCL (S1)	S2	80 (N2)	19.38 (S1)	40.90 (S1)	3.86 (S1)	N1

Appendix 13: Suitability classes for Oil palm

ıd use	Rainfall (mm) (>2000)	Length of dry season	Slope (0-4%)	Texture	Drainage (good/imperfect)	Coarse fragment (%)	Soil depth (.100)	CEC (meq/kg) (<10)	BS (%) (>35)	OC (>1.2)	Total suitability
;hew	S12	S2	2 (S1)	SCL (S1)	Well drained (S1)	S12	150 (S1)	6.5 (S2)	79.23 (S1)	1.11 (S2)	S2f
ıelina	S12	S2	2-3 (S1)	SCL (S1)	Well drained (S1)	S12	130 (S1)	7.44 (S2)	95.96 (S1)	2.34 (S1)	S2f
low	S12	S2	2 (S1)	SCL (S1)	Well drained (S1)	S12	120 (S1)	10.33 (S1)	41.92 (S1)	1.61 (S1)	S2f
heries	S12	S2	2-4 (S1)	SCL (S1)	Imperfectly (S1)	S12	130 (S1)	4.08 (S3)	87.74 (S1)	1.3 (S1)	S3f
palm	S12	S2	3 (S1)	SCL (S1)	Well drained (S1)	S12	140 (S1)	19.33 (S1)	56.80 (S1)	2.49 (S1)	S2
ıana	S12	S2	3-4 (S1)	SCL (S1)	Well drained (S1)	S12	150 (S1)	8.59 (S2)	82.50 (S1)	2.89 (S1)	S2f
wland	S12	N1	Valley bottom (N1)	SCL (S1)	Poorly drained (N1)	S12	80 (S2)	19.38 (S1)	40.90 (S1)	2.24 (S1)	N1ws

Appendix 14: Suitability classes for Cashew

and use	Rain fall (mm)	Length of dry season	Slope (0-4%)	Drainage (good)	Texture (SCL)	Coarse fragment (%)	Soil depth (>100)	CEC (meq/kg) (Any)	BS (%)	Organic matter (%) (>1.5)	Total suitability
ashew	S1	S12	2 (S1)	Well drained (S1)	SCL (S1)	S12	150 (S1)	6.5 (S1)	79.23 (S1)	1.92 (S1)	S1
melina	S1	S12	2-3 (S1)	Well drained (S1)	SCL (S1)	S12	130 (S1)	7.44 (S1)	95.96 (S1)	4.03 (S1)	S1
allow	S1	S12	2 (S1)	Well drained (S1)	SCL (S1)	S12	120 (S1)	10.33 (S1)	41.92 (S1)	2.77 (S1)	S1
isheries	S1	S12	2-4 (S1)	Imperfectly (S3)	SCL (S1)	S12	130 (S1)	4.08 (S1)	87.74 (S1)	2.25 (S1)	S3w
ilpalm	S1	S12	3 (S1)	Well drained (S1)	SCL (S1)	S12	140 (S1)	19.33 (S1)	56.80 (S1)	4.29 (S1)	S1
anana	S1	S12	3-4 (S1)	Well drained (S1)	SCL (S1)	S12	150 (S1)	8.59 (S1)	82.50 (S1)	4.99 (S1)	S1
owland	S1	N1	(N1)	Poorly drained (N1)	SCL (S1)	S12	80 (N1)	19.38 (S1)	40.90 (S1)	3.86 (S1)	N1ws

Appendix 15: Suitability classes for Maize

Land use	Rainfall (mm) (850-1250)	Length of grow season	Slope (%) (0-2)	Drainage (good)	Texture (SICL, CL)	Soil depth (cm) (>100)	CEC (meq/kg) (>24)	BS (%) (>50)	OC (%) (>2)	Total suitability
Cashew	S2	S2	2 (S1)	Well drained (S1)	S1	150 (S1)	6.5 (S2)	79.23 (S1)	1.11(S2)	S2f
Gmelina	S2	S2	2-3 (S12)	Well drained (S1)	S1	130 (S1)	7.44 (S2)	95.96 (S1)	2.34 (S1)	S2f
Fallow	S2	S2	2 (S1)	Well drained (S1)	S1	120 (S1)	10.33 (S2)	41.92 (S12)	1.61(S12)	S2f
Fisheries	S2	S2	2-4 (S12)	Imperfectly (S2)	S1	130 (S1)	4.08 (S2)	87.74 (S1)	1.3 (S12)	S2f
Oil palm	S2	S2	3 (S12)	Well drained (S1)	S1	140 (S1)	19.33 (S12)	56.80 (S1)	2.49 (S1)	S2f
Banana	S2	S2	3-4 (S12)	Well drained (S1)	S1	150 (S1)	8.59 (S2)	82.50 (S1)	2.89 (S1)	S2f
Lowland	S2	S2	Valley bottom (S2)	Poorly (N1)	S1	80 (S12)	19.38 (S12)	40.90 (S12)	2.24 (S1)	N1wfs

Appendix 16: Suitability classes for Banana

	Rainfall (mm)	Length of dry season	Slope (0-4%)	Drainage (good)	Texture/ Structure	Soil depth (>100)	CEC (meq/kg) (>24)	BS (%) (>50)	OM (%) (>24)	Total Suitability
Cashew	S12	S12	2 (S1)	Well drained (S1)	S1	150 (S1)	6.5 (S2)	79.23 (S1)	1.92 (S2)	S2f
Gmelina	S12	S12	2-3 (S1)	Well drained (S1)	S1	130 (S1)	7.44 (S2)	95.96 (S1)	4.03 (S2)	S2f
Fallow	S12	S12	2 (S1)	Well drained (S1)	S1	120 (S1)	10.33 (S2)	41.92 (S12)	2.77 (S2)	S2f
Fisheries	S12	S12	2-4 (S1)	Imperfectly (S2)	S1	130 (S1)	4.08 (S2)	87.74 (S1)	2.25 (S2)	S2f
Oil palm	S12	S12	3 (S1)	Well drained (S1)	S1	140 (S1)	19.33 (S12)	56.80 (S1)	4.29 (S2)	S2f
Banana	S12	S12	3-4 (S1)	Well drained (S1)	S1	150 (S1)	8.59 (S2)	82.54 (S1)	4.99 (S2)	S2f
Lowland	S12	N1	Valley bottom (N1)	Poorly (N1)	S1	80 (S12)	19.38 (S12)	40.92 (S12)	3.86 (S2)	N1wfs

Appendix 17: The Fertility Capability System

Type (Texture of ploughed-layer or surface 20cm, which is shallower)

S= sandy top soils: loamy sands and sands (by USDA definition)

L= loamy top soils :< 35% clay but not loamy sand or sand

C= clayey top soils :> 35% clay.

O= organic soils : <20% O.M to a depth of 50cm or more.

Substrata type (Texture of sub soils)

S= sandy subsoil: texture as in type

L= loamy subsoil:

C= clayey subsoil:

R= rock or other hard root-restricting layer.

Modifiers

g = (gley) = soil or mottles <2 chroma within 60cm of the soil surface and below all Al horizons, or soil saturated with water for 60 days in most years.

d = (dry) ustic, aridic or xeric soil moisture regimes (subsoils dry >90 cumulative days per year within 20 to 60cm depth.

k = (low in reserves): <10% weatherable minerals in silt and sand fraction within 50cm of the soil surface, or exchangeable K < 0.20cm/kg or K <2% of S bases; if bases <10 cmol/kg.

e = (low action exchange capacity): applies only to plough layer or surface 20cm, whichever is shallower; CEC <4 cmol/kg soil by S bases + KCL-extractable Al (ECEC), or CEC < 7 cmol/kg soil by S cation at pH 7, or CEC <10 cmol/kg soil by S cations + Al+H at pH 8.2.

a = (aluminium toxicity): > 60% Al saturation of the ECEC within 50cm of the soil surface, or >67% acidity saturation of CEC by S cations at pH 8.2 within 50cm, except in organic soils where pH must be less than 4.7.

h = (acid) = 10 – 60% Al-saturation of the ECEC within 50cm of the soil surface, or pH in 1:1 H20 between 5.0 and 6.0.

b = (basic reaction): free CaCO3 within 50cm of the soil surface (effervescence with HCl), or pH > 7.3.

i = (high P, fixation by iron): % free Fe2O3% clay > 0.15 and more than 35% clay; or hues of 7.5YR or redder and granular structure. This modifier is used only in clay © types; it applies only to plough-layer or surface 20cm lof soil surface, whichever is shallower.

X = (x-ray amorphous):pH > 10 in 1N NaF, or positive to field NaF test, or other indirect evidences of allophone dominance in the clay fraction.

v = (vertisol): very sticky plastic clay: 35% clay and 50 & of 2:1 expanding clays, or severe topsoil shrinking and swelling.

s = (salinity): > 4mmhos/cm of electrical conductivity of saturated extract at 25°C within 1cm of the soil surface.

n = (natric): > 15% Na-saturation of CEC within 50cm of the soil surface.

c = (cat clay):pH in 1:1 H20 is < 3.5 after drying and jarosite mottles with hues of 2.5Y or yellower and chromas 6 or more are present within 60cm of the soil surface.

g = (gravel):one prime(') denotes