COMPARATIVE ASSESSMENT OF LAND SUITABILITY EVALUATION BASED ON LAND MAPPING UNITS AND AGROECOLOGICAL ZONES: A CASE STUDY OF MOROGORO RURAL DISTRICT, TANZANIA

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (SOIL SCIENCE AND LAND MANAGEMENT) OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2003

ABSTRACT

A study was conducted in Morogoro rural District to compare land evaluation based on land mapping units (LMUs) and Agro ecological zones (AEZs) as a land unit criterion for land suitability classification and evaluates their effectiveness for land evaluation at district level in Tanzania. The study comprised of Agro economic survey using semi-structured questionnaires, compilation of land resource and Agro economic databases, and physical and Agro economic land suitability evaluation of LMUs and AEZs for maize, paddy and sesame as the main land utilization types (LUTs) using Automated Land Evaluation System (ALES). The results showed that parts of land units Va1 (50%), Va2 (50%), AEZ IX (50%), MO21 (35%), AEZ V (35%), AEZ VI (35%), Pe3 (30%), AEZ III (20%) and AEZ VII (5%) are moderately suitable for maize production. The rest are either marginally or currently not suitable for maize production. Parts of land units Va1 (50%) and AEZ VII (45%) are highly suitable for paddy production. While land unit Va2 and, parts of the land units Pe1 (55%) and AEZ IV (75%) are moderately suitable for paddy production. The rest are either marginally or currently not suitable for paddy production. Also the results indicates that parts of land units AEZ IX (50%), AEZ V (35%), Pe3 (30%), AEZ VI (5%) and AEZ VII (5%) are moderately suitable for sesame production. The rest are either marginally or currently not suitable for sesame cultivation. The major limiting factors for production of these LUTs are erosion hazards, oxygen availability to root zones, rooting condition, moisture availability, nutrient availability and nutrient retention. The study also revealed that there is positive correlation between ALES predictions and farmers' reported yields and gross margins with correlation ranging from 0.3 to 0.7 and 0.2 to 0.8 for yields and gross margins respectively. Predictions of yields and gross margins by ALES were better ($P<0.05$) when AEZs were used as a land unit criterion for land suitability evaluation than when were based on LMUs. The study has demonstrated that land suitability evaluations using Agroecological zones criteria as a unit for land evaluation is much better and more effective ($P< 0.5$) than LMUs criterion particularly when working on small scale surveys for land use planning at District level. Similar studies should be carried out elsewhere in Tanzania in areas with similar environmental conditions to verfy the applicability of AEZs as an evaluation land unit in land evaluation in favour of the LMUs. Further research to assess on-farm land evaluation methodologies taking into consideration climatic variability over a long time is also recommended.

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ACKNOWLEDGEMENT

I am greatly indebted to many individuals and institutions for their support and encouragement throughout the study. Special gratitude goes to the Norwegian Agency for Development Co-operation NORAD for the sponsorship.

My sincere appreciation is due to my supervisors Dr. A.K. Kaaya and Mr. D.N. Kimaro for their dedication, tireless technical support, constructive criticisms and invaluable guidance throughout the study.

My appreciation is also extended to Dr Kilasara the Head Department of soil science, SUA, Morogoro for kind assistance and co-operation he rendered to me. My heart-felt thanks go to the staff Department of soil science. SUA, for according me the intellectual and human environment within which I have been privileged to conduct my studies.

The study would have been impossible to be completed without the co-operation of the Mvuha, Matombo, Duthumi, Mkuyuni and Ngerengere Division Leaderships and farmers to them I say "Asante Sana". My heart-felt thanks also go to my course mates for their assistances and co-operation rendered to me.

The Ministry of Agriculture and Food security is also thanked for granting me a study leave.

Finally I am indebted to my sons Geophrey, Kellyvin and Jonathan, my wife Joyce, and my parents for their insurable perseverance towards the company denied to them by my study.

Above all, I thank GOD for keeping me alive, safe, stable and healthy for my whole stay in SUA, Amen.

DEDICATION

This dissertation is dedicated to my parents and my family, particularly my mother, the late Salome Joseph who toiled for my primary and secondary education and aroused in me the love for education. May the Almighty Father rest her soul in eternal peace. AMEN.

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LIST OF SYMBOLS AND ABBREVIATION

AEZs	Agro ecological zones
ALES	Automated Land Evaluation System
FAO	Food and Agriculture Organisation of United Nations
GDP	Gross Domestic Product
GM	Gross margin
IIASA	International Institute for Applied System Analysis
ILACO	International Land Development Consultants
Kg/ha	Kilogram per hectare
LCs	Land characteristics
LECS	Land Evaluation Computer System
LMU	Land mapping units
LURs	Land use requirements
LUs	Land units
LUTs	Land utilization types
LQs	Land qualities
m.a.s.l	Meters above sea level
Max	Maximum
Min	Minimum
No.Observ	Number of observations
PRA	Participatory Rural Appraisal
QUEFTS	Quantitative Evaluation for the Fertility of Tropical Soil
SHLIR	Smallholder low input rainfed crop

St dev.	Standard deviation
SUA	Sokoine University of Agriculture
t/ha	Tonnes per hectare
Tsh/ha	Tanzania shillings per hectare
URT	United Republic of Tanzania
WRB	World Reference Base

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background and justification

Tanzania is largely an agricultural country. The agricultural sector in Tanzania contributes 65% of the country's export earnings and 48 % of its GDP (United Republic of Tanzania (URT), 2000). In addition it provides 38.3% of employment (United Republic of Tanzania (URT), 2000).

Despite being an agricultural country, the country faces frequent and intermittent food shortages due to low crop production (URT, 1988). Some of the important factors contributing to low crop production in Tanzania include lack of information suitable to different agro ecological zones, insufficient research, inadequate land use planning and cropping in marginal areas (Kimaro, 1989). Low food production in Tanzania is also caused by declining of soil fertility (Eele *et al.*, 1992); land degradation (Mawenya, 1994) and unreliable rainfall (URT, 2000).

The need to increase crop production in Tanzania is a prerequisite in order to supply adequate quantities of food to the growing population (URT, 1992). Increased crop production can be achieved and sustained to a large extent through proper land use planning (Temple, 1972; Kileo, 2000). Appropriate land use planning is, therefore, needed to ensure increased and sustainable food production for the present population as well as conservation of the environment for future generations (FAO, 1989). However, formulation of appropriate land use plans requires knowledge of the potential and constraints of the various agro-ecological zones for a set of relevant crop and livestock species (Temple and Rapp, 1972; Mwango, 2000; Kileo, 2000). Various measures to improve and speed up the process of land use planning in Tanzania have been proposed by many scientists (Mushi, 1983; Kaaya, 1989; Kileo, 2000) through the results of land evaluations which include assessing the potential and constraints of the land and land management for various land utilization types (De Pauw, 1982; Samki, 1989; Kaaya *et al.*, 1994, Magoggo and Meliyo, 1994; Mwango, 2000). Land evaluation studies have been carried out in Tanzania using different approaches and criteria. For example, a land evaluation study for general purpose by Msanya (1980) on the soils of a toposequence on metasedimentary rocks of the Morogoro region, Tanzania was based on soil unit approach. Similar approach was also followed by Kaaya *et at.* (1994) while working on the soils of SUA farm in Morogoro, Tanzania. Samki (1989) used land unit approach to assess the potentials and constraints for the production of sisal, .citrus, groundnuts and maize on the coastal areas of Tanga region in Tanzania. Land mapping unit approach was widely used in Kilosa District (Kimaro, 1989), in Mbulu District (Magoggo and Meliyo, 1994) and Mgeta area, in the Uluguru mountains, Tanzania (Mwango, 2000). At present only limited studies have been carried out to assess the applicability and adaptability of these approaches and therefore lack of enough appropriate land evaluation methodology for extrapolation to other areas.

According to Rossiter (1996) land evaluation based on both socio economic and physical resource is an important tool for attaining sound land use planning for various agro ecological zones (AEZs). Agro ecological zones are natural physical regions, which are sufficiently large to be mapped, and are sufficiently uniform in climate, physiography, and soil pattern normally compiled and used for generalized descriptions and evaluation of the agricultural potential and constraints (De Pauw, 1984). The AEZ approach was first applied in a global study of land resources for populations of the future (FAO/IIASA, 1994), which focused on the determination of ecological potential of land resources for food production and the appropriate policies for their management. Subsequently, the AEZ methodology has been extended, refined and utilized in national and sub national assessments of land productivity and population supporting capacity in various countries such as Bangladesh, China, Mozambique, Nigeria, the Philippines, Thailand and Kenya (FAO/IIASA, 1994). Example, Kenya has adopted AEZ approach in land evaluation at the District levels for the determination of land use potentials of land resources for policy formulation and development planning (FAO, 1984). For Tanzania, AEZ approach for land evaluation has never been tested. However, the establishment and compilation of AEZs for generalized descriptions and evaluation of the agricultural potential and constraints have been attempted at the scales of 1:2 000 000 for Tanzania at the beginning of the 1980s (Samki, 1989). Example, the establishment and compilation of AEZs land resource database of Tanzania for agricultural development planning was established by Samki and Dewan (1981), De Pauw (1982, 1983, 1984), Munisi (2001). According to De Pauw (1984) Tanzania is divided into 63 AEZs based on climate, physiography, soil, vegetation/land use and Tsetse occurrence. Most of the land evaluations that have been carried out in Tanzania however, are mainly based on soil units or land mapping units (Kimaro, 1989; Kimaro and Msanya, 1999; Kileo, 2000).

Munisi (2001) recommended carrying out land suitability evaluation based on agro ecological zones rather than land mapping units, which has been used in Tanzania for a long time now. One of the reported advantages of using AEZ is that an agro-ecological zone represents more homogeneous ecological conditions for a set of land use type than the land-mapping unit (Dent and Young, 1981; De Pauw, 1984). However, no study has been done to compare the usefulness of these two approaches. There is, therefore, a need to evaluate the usefulness of these land evaluation approaches in order to come up with a better approach for land suitability assessment in Tanzania.

1.2 Overall objective

This study is therefore aimed at comparing the results of land suitability evaluation based on land mapping units (LMUs) and agro ecological zones (AEZs) in Morogoro Rural District, and evaluates their effectiveness in order to provide useful recommendations for a better land evaluation approach to be used at the district level in Tanzania.

1.3 Specific objectives

The specific objectives of the study were:

1. To carry out physical and agro economic land suitability evaluation based on AEZ.
2. To carry out physical and agro economic land suitability evaluation based on LMU.
3. To carry out comparative analysis of the results of the two approaches (AEZ and LMU).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Basic concepts and definitions on Land Evaluation

Land evaluation is the assessment of land performance when used for specified purposes (FAO. 1983). According to FAO (1976) land evaluation is the process of collating and interpreting basic inventories of land form (physiography). soil. vegetation, climate, socio-economic factors and other aspects of land in order to identify and make a comparison of promising land use alternatives in terms applicable to the objectives of the evaluation. As such it provides a rational basis for taking land-use decions based on analysis of relations between land use and land, giving estimates of required inputs and projected outputs (FAO, 1983). In land evaluation exercise, the land use planner matches land areas termed land units (LUs) with land uses, termed land utilization types (LUTs), determining the relative suitability of each area for each land use (FAO, 1976; FAO, 1983). Therefore in land evaluation the suitability is assessed, classified and presented separately for each kind of use (FAO, 1983).

The principle aim of land evaluation is to select the optimum land use for each defined land unit taking into account both physical and socio-economic considerations and conservation of environmental resources for future use (FAO, 1983). However, it has been noted that land unit for suitability assessment is either based on soil unit (Kaaya *et al.*, 1994), land mapping unit (Mwango, 2000) and or Agroecological zone (FAO, 1984; FAO/IIASA, 1994). In Tanzania the usefulness of these units for land evaluation has not been studied neither evaluated. Therefore, the following sections review the different land units that have been used as unit for land evaluation and identify their respective usefulness and limitations. Principles of land evaluation, types of land evaluation, land evaluation systems, and studies on land evaluation approaches and criteria carried out in Tanzania are also reviewed.

2.2 Land evaluation in Tanzania

2.2.1 Principles of land evaluation used

Land evaluations for various land utilization types such as Smallholder low inputs rainfed Maize and Paddy in Tanzania have been computed by, determining the actual land characteristics for the land, combining these land characteristics values into land qualities, matching the land qualities with land use requirements, and finally combining these land qualities into composite suitability classes.

Land evaluations in Tanzania have been carried out based on the following six principles stipulated in guideline of land evaluation for rainfed agriculture (FAO, 1983). a) Land suitability should be assessed and classified with respect to specified kind of use, b) Evaluation requires a comparison of the outputs (benefits) obtained and the inputs needed on different types of land, c) Evaluation is made in terms relevant to the physical, economic and social context of the area concerned (country or region), d) Evaluation involves comparison of more than one kind of use, i.e. Land evaluation should involve the comparison between alternatives, e) In land evaluation a multidisciplinary approach is required, f) Suitability refers to use on a sustained basis.

2.2.2 Types of Land Evaluation carried out in Tanzania

According to FAO (1983) there are two major types of land evaluation. qualitative land evaluation and quantitative land evaluation. A qualitative land evaluation is one in which the results are expressed in qualitative terms only. without specific estimates of outputs. inputs. or costs and returns (FAO. 1983). A quantitative land evaluation is one in which the results are expressed in numerical terms which permit comparison between suitabilities of different kinds of use (FAO. 1983). Quantitative land evaluation can either be quantitative physical or economic land evaluation (Dent and Young, 1981).

In Tanzania both qualitative and quantitative land evaluation have been carried out. Kaaya (1989) carried qualitative land evaluation of central parts of SUA farm, Morogoro for rainfed crops using soil units approach. Kimaro and Kips (1991) carried both qualitative and quantitative land evaluation for smallholder low input rainfed maize production in Kilosa District using land mapping units (LMUs) approach. Magoggo and Meliyo (1994) carried qualitative land evaluation for smallholder rainfed agriculture in Mbulu District using LMUs approach. Also Mwango (2000) and Kileo (2000) carried both qualitative and quantitative land evaluation for smallholder low inputs rainfed crops of Mgeta areas and Wami plains in Morogoro rural District, respectively using LMUs.

2.2.3 Land evaluation systems used in Tanzania

Land evaluation systems commonly used in Tanzania are categorized into two groups known as the conventional land evaluation systems and computerized land evaluation systems. The assessments of the potentials and constraints of the land in different land units in Tanzania previously have been carried out using the conventional systems based on LMU (Mushi, 1983) and Soil units (Kaaya, 1989). These systems are quite tedious and time consuming, because they involved manual procedure of matching land use requirements (optimal conditions) with actual condition of the land. For this reason some investors and land use planners were forced to do without adequate land evaluation studies. Recently computerized land evaluation systems such as ALES, LECS and QUEFTS have been adopted in Tanzania (Kimaro, 1989; Kimaro and Kips, 1991; Magoggo and Meliyo, 1994; Kimaro and Msanya, 1999; Mwango, 2000 and Kileo, 2000). These systems have been developed to facilitate the interpretation of land and soil resources information for quick land suitability evaluation. These systems have been developed following FAO (1976) Framework for land evaluation. The following sections review convention systems, computerized land evaluation systems and soil fertility capability classification system.

2.2.3.1 Conventional systems

Tanzania has adopted FAO methodology (FAO, 1976) as a conventional or local standard land evaluation system for evaluating land for various land uses. The FAO methodology comprises four categories in a decreasing generalization, namely land suitability orders, land suitability classes, land suitability subclasses and land suitability units (FAO, 1976; Dent and Young, 1981). Land suitability order indicates whether the land is suitable or not suitable for specified kind of use. Land suitability classes indicate degrees of suitability within orders. Land suitability sub classes reflect kinds of limitations or main kinds of improvement measures required within classes, and land suitability units reflect minor differences in required management within subclasses (FAO, 1976; Dent and Young, 1981). In Tanzania, the first three categories (order, classes and subclasses) are used.

2.2.3.2 Computerized Land Evaluation systems

Most of these systems are purely physical in nature and they assess suitability for various lands uses and often predict yields for specific crop under defined conditions of land, soil and climate data (Elbersen, 1989). The computerized land evaluation systems, which have been applied in Tanzania, include: Land Evaluation Computer System (LECS), that was proposed by Wood and Dent (1983), Automated Land Evaluation system (ALES) which was developed by Rossiter and Van Wambeke (1989) and Quantitative Evaluation for the Fertility of Tropical soils (QUEFTS) developed by Janssen *et al.* (1986). According to Elbersen (1989), LECS and ALES are capable of incorporating the results of farming systems analysis so as to arrive at a complete agro-economic suitability assessment and are both developed within the FAO framework for land evaluation. In Tanzania LECS and ALES have been tested and applied in different ways and scales by Kimaro, 1989; Kimaro and Kips, 1991; Kimaro and Msanya, 1999; Kileo, 2000 and Mwango, 2000.

2.2.3.3 Soil fertility capability classification system

Soil fertility capability classification of Sanchez and Buol (1985) has been a great step forward in semi-quantitative land evaluation. This is technical soil classification system that focuses quantitatively on the physical and chemical properties of the soil that are important to fertility management. The system is applicable to upland and wet rice crops, pasture, forestry and Agroforestry under high- or- low-input system. The system does not rank soil, but rather it states the soil properties important to management decisions, which will differ by crop type and management system. Also the system provides management statements for the classified soils and lists the general adaptability of various crops. There is little information about applicability of this system in Tanzania.

2.3 Land units for land evaluation

2.3.1 General overview

Land units are areas of land with specific land characteristics and land qualities (FAO, 1980, FAO, 1983). Therefore land units can be described in terms of their characteristics, their qualities or both (FAO, 1980). A land characteristic is a fairly simple attribute of a land that can be measured or estimated. A land quality, on the other hand, is a complex attribute of a land that usually reflects the interaction of many land characteristics (Dent and Young, 1981).

The basic aim of defining land units is that they should be of maximum relevance to the range of land uses envisaged by evaluation. Ideally they should approximate to land management units with uniform suitabilities for particular kinds of use, similar response to land improvement practices and similar management requirement. In practice, such ideals have to be compromised according to limitations imposed by mapping, particularly in low to medium intensities of survey (Dent and Young, 1981).

It is noted from other literature (FAO, 1983), the term land unit does not refer to any single kind of mapped area, described in a specific way: it is a term of convenience to cover any unit of land used for land evaluation. Therefore, any area of land, no matter how its boundaries are defined, can be regarded as a land unit for purposes of land evaluation, provided that the characteristics of the land enclosed can be adequately described (FAO, 1980). But, land evaluation can be performed more easily and its findings are likely to be more valuable if the land units on which it is based have been defined and mapped for the purpose, using available and especially collected data (FAO, 1983).

An enormous number of characteristics is required to describe a single piece of land adequately (Dent and Young, 1981). Comparatively few of these characteristics are especially important in relation to a particular kind of land use. Thus there is often a surprising amount of choice in deciding where boundaries should be drawn. A judgement therefore has to be made on where the most significant changes occur (FAO, 1983). However, the overall aim of establishing land units for land evaluation is to enclose areas that are as nearly homogeneous as possible to meet the required objectives (FAO, 1980).

In practice, land units are often defined by superimposing maps of different themes of the land such as climate, soil, vegetation and landform, and then drawing boundaries that best reflects the most important distinctions in the separate map (FAO, 1980).

The intensity of the study, the scale of the mapping and the degree of details desired. is important in determining which land characteristics should be used to define the boundaries of a land unit (FAO, 1983). For example, in an overview of a large region, differences in climate will largely determine these boundaries because differences in other factors, such as soils, are likely to be too localized to be investigated and mapped individually on such a small scale. Information on the nature and influence of these other factors, which may well change with climate, can be included in the description of the land units but will not determine their boundaries. In contrast, if the evaluation is focussed on a small area, even minor differences in soils may be represented by separate land units whilst macro climate will be assumed to be uniform across the area and will not, therefore, affect the land boundaries. Knowledge of local climate will be just as important for practical interpretation of the soil differences but, in a detailed study, climatic information is generalized and confined to the land unit description. At intermediate scales (around 1:250 000) landform is likely to be decisive in locating boundaries, with both soils and climate contributing only to the description (FAO, 1980).

Examples of land units employed in land evaluation are: major climates, length of growing periods, and agroclimatic zones (De Pauw, 1984; FAO, 1983); soil series, soil phases, soil variants, soil types and soil associations (Dent and Young, 1981); land systems and land facets (Dent and Young, 1981; FAO, 1983); soil landscapes and special purpose units (Dent and Young, 1981); Physiographic units (Magoggo and Meliyo, 1994); land mapping units (Kileo, 2000); and Agroecological zones (Dent and Young, 1981; FAO, 1984; FAO/IIASA, 1994).

However, a common practice in land evaluations for rainfed agriculture is to employ two kinds of land units at different stages. Agroclimatic zones are employed for initial selection of crops for consideration. The major part of the evaluation is then based on more detailed land units, based on some combination of landforms and soils (FAO, 1983).

In practices there is variation in the definition and interpretation of land units used in land evaluation between survey organizations. The following section reviews the types of land units employed in the various land evaluation.

2.3.2 Types of land units used for land evaluation

2.3.2.1 Soil mapping units

A soil survey for land evaluation attempts to delineate soil areas that behave differently or will respond differently to some specified management. Where the limiting value for soil characteristics have been established experimentally, the soil can then be grouped on an *ad hoc* basis according to similarities and differences in the key characteristics, and a map can be produced that is of high predictive value for the specified purpose.

According to Dent and Young (1981), soil-mapping units are real soil areas, and the soil individual, whether a taxonomic unit or a mapping unit, is a matter of personal judgement. The judgement is guided by the following principles and constraints:

a) The soil-mapping units should be as homogeneous as possible. This is not necessarily the same as distinguishing soils with uniform characteristics, but the variation within a mapping unit is kept within defined limits and the kind of variation should be consistent within all mapping units given the same name.

b) The grouping of soil units should be of practical value.

c) It must be possible to map the soil units consistently.

d) The mapping must be accomplished in reasonable time and with only such equipment as can be used in the field. This means that the soil characteristics used in mapping must be, in the main, visible and tactile properties such as colour and texture.

e) Relatively stable soil properties, such as texture and lithology, should be used to define taxonomic units, rather than properties, which may change rapidly according to management, such as soil structure or top soil organic matter.

According to Dent and Young (1981) and FAO (1983) soil mapping units include, soil series, soil phases, soil variants and soil associations.

Soil series is a group of soils developed from particular type of parent material and having genetic horizons that, except for texture of the surface layer, are similar in differentiating characteristics and in arrangement in the profile (National Cooperative Soil Survey (NCSS), 1972; FAO, 1983). It is divided into soil phases because of differences in slope, stoniness, thickness, or some other characteristics that affect its management but not its behaviour in natural landscape (NCSS, 1972; Dent and Young, 1981)). This soil-mapping unit is a simple mapping unit and normally used in detailed soil survey for land evaluation.

Soil phases is a simple land units which is a subdivision of a soil series or other unit in the classification system made because of differences in the soil that affect its management but do not affect its classification in the natural landscape (Dent and Young, 1981). Soil phases are most useful soil mapping units in planning the management of farms and fields; therefore they are used in detailed soil survey for land evaluation (National Cooperative Soil survey, 1972). Soil phases are sometimes appropriate soil mapping units for special purpose land resource survey and land evaluation (Dent and Young, 1981).

Soil variant is a simple land unit, and it is defined as a soil having properties sufficiently different from those of other known soils to justify a new series name. but occurring in such a limited geographic area that creation of a new series is not justified (National Cooperative Soil survey, 1972). Soil variant used for detailed soil survey and land evaluation.

Soil association is a compound land unit, and it is defined as a group of geographically associated soils, each of which is confined to a particular land facet of landscape and which occur in a predictable pattern (Dent and Young, 1981). This soil mapping unit is useful to people who want a general idea of the soils in a country, or who want to know the location of large tract that are suitable for a certain kind of land use. It is not a suitable for planning the management of a farm or field, or for selecting the exact location of a road, building, or similar structure. because the soils in any soil association ordinarily differ in the slope, depth, stoniness drainage and other characteristics that affect their management (National Cooperative Soil survey. 1972).

Soil landscape can be defined as an association of soils described and delineated by means of landforms (Dent and Young. 1981). Therefore. it is a compound land unit. based on landscape but defined in terms of soil. This soil-mapping unit is used if it is desired to carryout a survey at reconnaissance scale but specifically directed at soil.

Compound soil mapping units including. soil associations. soil complex and soil landscape in most cases referred to be land mapping units (FAO. 1983).

Further more, literature revealed that. in general purpose surveys. soils are mapped according to their morphology on the hypothesis that soils. which look alike and similar in characteristics. will behave similarly and those that appear different will respond differently in many circumstances. Soil units are therefore mapped as if they were discrete three-dimensional individuals by inserting boundaries where the rate of change of their morphology with distance is greatest. In practice this has to be done largely according to their surface expression. inserting boundaries at changes in slope. vegetation or surface soil characteristics. In general soil survey many useful predictions about soil behaviour and response to management are made on the basis of morphological characteristics and related accessory properties. because soil morphology is related to the soil-forming factors of climate, parent materials. topography. drainage, vegetation and the age of the landform.

2.3.2.2 Land mapping units (LMUs)

A land-mapping unit is a mapped area of land with specified characteristics (FAO. 1983). It is generally defined and mapped by natural resource surveys. and forms a basis for land evaluation (Dent and Young. 1981). Any kind of area. which possesses a degree of homogeneity in physical characteristics. may be employed as a land-mapping unit (Dent and Young. 1981).

According to Dent and Young (1981) some of soil units such as soil associations. soil series or phases: geomorphological units of various kind. soil-landform associations (soil landscape/physiographic unit) are termed as land mapping units and employed for the land suitability evaluation.

According to FAO (1983) the following guidelines are used in defining the LMUs for land evaluations:

a) Land mapping units should be as homogeneous as possible;

b) Grouping should have practical value. in relation to the proposed land use;

c) Units should be defined as simply as possible and based on properties. which are readily observable in the field with the use of remote sensing techniques;

d) Units should be defined according to relatively stable properties of the soil and land surface, which are unlikely to change rapidly in response to management practices.

According to Munisi (2001) the combination of landform. parent materials and soil types form land-mapping units. The author revealed that all LMUs are compound-mapping units, i.e., they consist of landscape unit with two or more soil units. The proportion of each constituent soil unit of a land-mapping unit is known, and each constituent of a land-mapping unit is a homogeneous unit and entered in land evaluation systems. Land evaluation based on land mapping units have been carried out by many soil scientists in Tanzania (Kimaro, 1989; Kileo, 2000; Mwango, 2000).

Land system is a land-mapping unit, and defined as an area with a recurring (repeating) pattern of topography (landforms), soil and vegetation, and with relatively uniform climate (Dent and Young, 1981; FAO, 1983). It is therefore, an area with a recurring pattern of genetically linked land facets (Dent and Young, 1981). According to FAO (1983) land facet is a subdivision of a land system, and defined as an area of the land within which, for most practical purposes, environmental conditions are uniform (climate, landform, soil and vegetation characteristics). The land facets within each land system are numbered and given connotative title, e.g., 1: Flood plains, 2: Ridge crests, 3: Gently slopping valley sides (Dent and Young, 1981). Land systems and land facets are principal land units that used in land evaluation, and are commonly referred to as land mapping units (Dent and Young, 1981; FAO, 1983).

2.3.2.3 Agro ecological Zones (AEZs)

Agro ecological zone (AEZ) is a natural physical region, which is sufficiently uniform in climate, physiography, and soil pattern for generalized descriptions and evaluation of the agricultural potential and constraints (De Pauw, 1984). It is therefore a fairly homogeneous land area in terms of climate, physiography, soil patterns and vegetation/land use. According to Baijukya and Folmer (1999) agro ecological zone is a geographical land unit in that physical conditions for crop and livestock production differ more between than within zones. According to Dent and Young (1981) agro ecological zones refer to broad climatic regions suitable for certain crops or farming systems as widely recognized within the country.

The AEZ approach was first applied in a global study of land resources for Populations of the Future (FAO/IIASA, 1994). which focused on the determination of ecological potential of land resources for food production and the appropriate policies for their management. Subsequently, the AEZ methodology has been extended, refined and utilized in national and sub national assessments of land productivity and population supporting capacity in various countries such as Bangladesh, China, Mozambique, Nigeria, the Philippines, Thailand and Kenya (FAO/IIASA, 1994). The AEZ approach is widely used in Kenya as national methodology for the determination of land use potential of individual Districts for policy formulation and development planning (FAO. 1984). To enhance the AEZ methodology for national and sub-national application, FAO, with the concurrence of the Kenya Government and IIASA's participation, undertook an AEZ case study of Kenya (FAO/IIASA, 1994) to assess the food crop and livestock production potential based on the following principles (FAO/IIASA, 1994):

a) An inter-disciplinary approach, based on inputs from crop ecologists, pedologists, agronomists, climologists, livestock specialists, nutritionists, and economists;

b) Land evaluation is only meaningful in relation to specific land uses;

b) Land evaluation is only meaningful in relation to specific land uses;

c) Land suitability refers to use on a sustained basis, i.e., the envisaged use of land must take account of degradation. Soil regeneration is assumed to be achieved by means of fallowing land, appropriate crop rotations and soil conservation measures;

d) Evaluation of production potential with specified levels of inputs;

e) Different kinds of use must be considered in the context of meeting national or regional food crop-mix and products demand;

f) Different kinds of livestock feed resources must be considered in the context of meeting seasonal and spatial feed requirements;

g) Land use patterns must be constructed so as to optimize land productivity in relation to political and social objectives taking into account physical, socio-economic and technological constraints.

Based on those principles, AEZs were compiled using computerized procedures, and the determination of land use potentials of land resources in each of the 41 Districts in Kenya was done, and the preparation of scenarios for optimal District land resources allocation as a tool in policy formulation and development planning was performed (FAO/IIASA, 1994).

In Tanzania AEZs was established with the main objective offering a condensed inventory of the agricultural potential or constraints for agricultural development (De Pauw, 1984). The Agro ecological zones compiled in Tanzania (De Pauw, 1984) were based on climate, physiography, soil, vegetation/land use and Tsetse occurrence database, which are the main physical factors that influence potential and constraints for crop and livestock production.

The main climatic factors specified by the AEZs map are the temperature regime and the growing period. The moisture availability has been assessed by means of the growing period concept. Finally, the AEZs so compiled provides a brief description of the physiography in each zone in terms of general drainage conditions (upland or low lands, watershedding or water receiving), relief, altitude and occurrence, if any, of significant land degradation or soil erosion. This information can be used for a broad interpretation of suitability for crops with specific drainage or temperature requirements. The main land units that occur in AEZs are specified so that, if necessary, can be referred to the legend of the map.

2.4 Land units' criteria used for land evaluation in Tanzania

2.4.1 Land evaluation based on soil mapping units

Land evaluation based on soil mapping units have been carried out by few soil scientists in Tanzania. For example, Kaaya *et al.* (1994) carried out physical land suitability classification of part of Sokoine University of agriculture farm using conventional land evaluation system based on soil units. Land evaluation of each soil unit for each land utilization type in this study was carried out using FAO framework for land evaluation method (FAO, 1976)

2.4.2 Land evaluation based on land mapping units

Land evaluation based on land mapping units have been carried out by many soil scientists in Tanzania. For example, Mushi (1983) employed convention system of land evaluation to carry out qualitative land suitability assessment of Mtibwa sugar estate for optimum sugar cane production based on LMUs. This land evaluation was carried out using FAO framework for land evaluation method, the parametric method developed for humid tropics and the Index of productivity rating developed by FAO. The results matched fairly closely with observations of sugar performance in the fields. Kimaro (1989) carried out land suitability assessment for rain fed maize production in Kilosa area using ALES based on LMU approach. The results were in same range as farmer' reported yields. Physical and economical land suitability assessment for smallholder low input maize was also carried out in Kilosa district using LMU approach (Kimaro and Kips, 1991). The results were positively correlated with farmers' reported yields and gross margins. Magoggo and Meliyo (1994) employed physiographic units, which are similar to land mapping units, in Mbulu District for physical land suitability assessment for low input small holder rainfed agriculture, medium to high input, mechanized agriculture, afforestation and extensive grazing.

LMU approach was further used by Kileo (2000) for physical and economic land suitability evaluation for smallholder low input rainfed maize and rice, and extensive grazing, in Wami plain, Morogoro Rural District and Mwango (2000) for physical and economic land evaluation for low input rainfed arabica coffee, cabbage and round potatoes in Mgeta areas, Morogoro Rural District. Their results were in the same range as farmer reported yields and gross margins. Munisi (2001) also used LMU approach at a scale of 1:250 000 for physical land evaluation of smallholder low input rainfed maize, paddy and citrus in Eastern Morogoro Rural District, Tanzania.

2.4.3 Land evaluation based on Agro ecological zones (AEZs)

Information regarding the use of AEZ approach for land evaluation in Tanzania is limited. The establishment and compilation of AEZs for generalized descriptions and evaluation of the agricultural potential and constraints at the scales of 1:2 000 000 started at the beginning of the 1980s (Samki, 1989). For example, the establishment and compilation of AEZs land resource database of Tanzania for agricultural development planning was initiated by Samki and Dewan (1981) and later modified by De Pauw (1984). Munisi (2001) also worked with AEZs within Morogoro Rural District.

According to De Pauw (1984) Tanzania is divided into 63 AEZs at the scales of 1:2 000 000 based on climate, physiography, soil, vegetation/land use and Tsetse occurrence. Literature reveals that, no land evaluation was carried out using these broad AEZs as a land units for suitability assessment, but land evaluations has been carried out based on land mapping units (LMUs) or soil units within these AEZs.

Munisi (2001) established nine AEZs in the Eastern parts of Morogoro Rural District, Tanzania at the scale of 1:250 000 based on landscape/landforms, elevation, length of growing period, climate and soils. At the scale of 1:2 000 000 (De Pauw,

1984) this area was divided into three AEZs. According to Munisi (2001) the computerized compilation procedure of AEZs was done as follows:

a) The different map layers were combined digitally to produce the digital thematic maps for elevation, temperature, rainfall, length of growing period and physiography/soil for the Eastern parts of Morogoro Rural District;

b) The digital thematic maps for elevation, temperature, rainfall and length of growing period were combined by intersection to produce agroclimatic zones of the Eastern parts of Morogoro Rural District;

c) Agroclimatic zones were intersected with physiography/soil layer to form agroecological zones of the Eastern parts of Morogoro Rural District.

Further more, it noted that Munisi (2001) developed and compiled more detailed AEZs and LMUs at a scale of 1:250 000 for Eastern part of Morogoro rural District, and he carried out a land evaluation based on LMUs only. In addition to that, it is observed that Munisi (2001) recommend the use of AEZs as land units for land suitability assessment at District level without any reason.

2.5 Comparative studies on the types of land units used for land evaluation in Tanzania

The comparative assessment studies on land evaluation approaches and criteria in Tanzania are essential, since the qualities of the results of land evaluation needed for proper land use planning are highly affected by land evaluation approaches and criteria being used to get such results.

At present, in Tanzania, an attempt to study and compare the criteria of land unit used for land evaluation has not been done. Therefore, the usefulness of different land units used for land evaluation has neither been studied nor evaluated. Despite that, in view of the characteristics of each land unit and objectives of intended land evaluation, the following observations have been made (Dent and Young, 1981):

a) Soil mapping units such as soil series, soil types, soil phases, soil variant and compound mapping units such as soil associations and soil complex are more appropriate land units for land evaluation in detailed soil survey than small scale surveys. Criteria is more useful in the evaluation of small areas,

b) Soil mapping units termed as soil phases and soil series are more appropriate for special purpose surveys,

c) Land mapping units such as soil landscape, land system and land facets are more appropriate for use at scales of 1:250 000 or less. These land units are more useful in the evaluation of the area of intermediate size,

d) Land units such as Agro ecological zones are more appropriate for reconnaissance land resources surveys. They are also useful in the evaluation of large areas.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location

The study was conducted in the eastern part of Morogoro Rural District in Tanzania covering an area of approximate 503 100 ha. The study area was purposely selected on the basis of having well established AEZs and LMUs at the scale of 1:250 000 (Munisi, 2001), ease communication and favourable agro-ecological conditions for data collection to meet the specific objectives of the study. The study area is located between latitudes 6°45'S and 7°30'S and between longitudes 37°40' E and 38°15'E, and is divided into four topograghic levels. These include areas with elevation below 200 m.a.s.l. which comprise mainly valleys, the plains (200 m to 400 m.a.s.l.), the piedmonts (400 m to 600 m.a.s.l.) while areas with elevation above 600 m.a.s.l. comprised the mountains.

3.1.2 Climate

The area experiences bimodal rainfall pattern characterised by short rainy season (*vuli*) and long rains (*masika*). Short rains occur in October through December and long rain starts in February to the end of May. The mean annual rainfall in the area varies from around 900 mm in the plains to about 2500 mm in the mountains. This amount is sufficient for rainfed agriculture (Sharma, 1986; Munisi, 2001).

The distribution of temperature over study area shows a clear trend with altitude where in mountains temperatures are cooler than in the plains. The lowest temperatures are found within the highest elevation where the mean annual temperature is between 13.3°C and 16.3°C. The highest temperature (above 25.3°C) is found in the plains.

3.1.3 Physiography, soils and hydrology

The study area is highly dissected with complex steep slopes and narrow valleys in between. The study area comprised the mountains which are strongly dissected with complex steep slopes and V-shaped valleys; dissected piedmonts with gentle to moderate slopes; undulating to rolling peneplains with isolated hills, and floodplains and watershed valleys. Piedmonts and peneplains are results of colluviation and severe erosion while valleys resulted from deposition of materials from higher landscapes areas (Westerberg, 1999).

The mountains have complex of rock outcrops and shallow to moderately deep, well- to excessively drained soils. The piedmonts have complex of moderate to deep well drained soils. The peneplains have association of deep to very deep well and imperfectly drained soils whereas the valleys have a complex of deep to very deep, imperfectly to poorly drained soils (Munisi, 2001).

The soils in the study area are mostly sandy clays to sandy clay loams and are well drained except on the valleys where they are imperfectly to poorly drained. These soils are classified according to FAO-WRB system of classification (FAO, 1998) into Ferralsols, Luvisols, Regosols, Cambisols, Lixisols, Phaeozems, Acrisols and Fluvisols (Munisi, 2001).

The area is drained by rivers Ngerengere, Kiziwa, Mvuha and Mgeta. The area forms the major part of the watershed for the Great Ruvu River that drains in to the Indian Ocean.

3.1.5 Geology.

The dominant rocks in the study area are metasediments of Precambrian age, mainly comprised of pyroxene granulites. In some areas there are pockets underlain by crystalline limestones and dolomite and a complex of sandstones, shales and calcareous sediments of Karroo epoch (Sampson and Wright, 1964).

3.1.6 Vegetation and land use

The mountainous parts are dominated by tropical rain forest and grassland (Msanya, 1980). The major land uses in the area include cultivation of maize, rice, sesame, citrus and beans. The plains are dominated with bushland and grassland, but some crops such as maize, millet, sorghum and cassava are also cultivated (Munisi, 2001).

3.2 Pre-field work

3.2.1 Collection of materials and relevant data

The following materials and data were collected for the study. Agroecological zones map at the of scale 1:250 000 of eastern part of Morogoro rural district, Tanzania (Munisi; 2001), Physiography and soil map at the scale of 1:250 000 of eastern part of Morogoro rural district, Tanzania (Munisi, 2001). Data on land mapping units (LMUs) and agroecological zones (AEZs) developed by Munisi (2001) for the study area formed the basis for subsequent land evaluation and comparative analysis of the two approaches to be tested in this study.

Salient site features including, landforms, elevation, geology and soils of both LMUs and AEZs selected for this study are presented in Table 1a and 1b.

Table 1a: Salient site features, landforms, soils and elevation ranges of the LMUs

LMU	Landform	Elevation (m)
MO 21	Moderately dissected ridges with V shaped valleys, with banded pyroxene granulite. Dominated with Luvisols soil units	500-800
MO 22	Moderately dissected ridges with V shaped valleys, with crystalline limestone and dolomite. Dominated with Phaeozems and Lixisols soil units.	500-800
Pi 2	Level to gently sloping undissected foothills, with colluvium derived from crystalline limestone. Dominated with Cambisols soil units.	400-500
Pe 1	Undulating to rolling with many dissected hills, with migmatite and gneiss. Dominated with Cambisols s soil units.	200-400
Pe 3	Undulating to rolling with isolated hills, with Siltstones, sandstones and limestones. Dominated with Phaeozems soil units.	200-400
Va 1	Watershed valleys with complex stream networks, with sandstone, shales, calcareous gneiss and Karroo sediments. Dominated with Regosols and Phaeozems soil units.	<200
Va 2	Floodplains and backswamps, with Alluvio-colluvium of diverse origin. Dominated with Fluvisols and Phaeozems soil units.	<200

Source: Munisi (2001)

Table 1b: Salient site features, landforms, length of growing period and elevation ranges of the AEZs

AEZ	Landform	Elevation (m)
II	Mountains, with LGP 210-240 days and clay soils. Dominated with Luvisols and Lixisols soil unit.	500-800
III	Piedmonts, with LGP 210-240 days and clay soils. Dominated with Acrisols. Ferralsols. Cambisols. Phaeozems and Lixisols soil units.	400-500
IV	Valley, with LGP 210-240 days and loamy soils. Dominated with Fluvisols, Phaeozems, Lixisols and Cambisols soil units.	100-200
V	Peneplains, with LGP 210-240 days and, loamy and sandy soils. Dominated with Lixisols, Cambisols, Regosols and Phaeozems soil units.	200-400
VI	Peneplains, with LGP 150-180 days and loamy soils. Dominated with Regosols. Cambisols and Phaeozems soil units.	100-200
VII	Watershed valley, with LGP 210-240 days and loamy soils. Dominated with Regosols and Phaeozems soil units.	100-200
IX	Peneplains, with LGP 150-180 days and loamy soils. Dominated with Phaeozems soil units.	<200

Source: Munisi (2001)

3.2.2 Development of Questionnaire for Agro-economic survey

Semi-structured questionnaires were modified from Mwango (2000). Kileo (2000) and Munisi (2001) for field survey to collect agro-economic data for screening by ALES. The data collected included, production packages, yields and prices, capital and labour, land tenure, farm size and farming systems. The data were also used to define in detail the present land utilization types. The format for the Questionnaires is presented in Appendix 1. Detailed data were collected using PRA as supplementary information so as to have a better description and understanding of the study area.

3.3 Fieldwork

3.3.1 Reconnaissance survey

A reconnaissance survey was carried out to obtain birds eye view of the study area with respect to communication network and pre-testing of the questionnaire.

Reconnaissance survey was also done to check the relevance of the land mapping and agro-ecological zones units established by Munisi (2001) with respect to the collected agro economic data. The LMU and AEZ maps developed by Munisi (2001) were used as a base for field survey.

3.3.2 Agro-economic survey

A purposely-sampling technique was employed where out of 11 LMUs and 9 AEZs, 7 LMUs and AEZs were selected due to their easy accessibility and completeness of the required data to meet the specific objectives of the study.

Semi-structured questionnaires were administered together with PRA to collect agro-economic data. Information related to the LUTs as practiced in the study area were compiled. These information included data related to the type of produce, yields and prices, capital and labour intensity; yields and prices; farm size and status of farm, level of management, cultural practices, marketing facilities and level of technology. Information about existence of other farm services such as credicts and extension services were also documented. A total of 170 farmers (male and female) were interviewed.

3.4 Post fieldwork.

3.4.1 Compilation of land resources database for physical land evaluation

Table 2a and 2b summarize the land resource database (modified from Munisi 2001) of the surveyed LMUs and AEZs. The compiled database comprised of climatic, physiography and soil resources. The climatic resource database included rainfall, temperature and length of growing period. Physiography and soil resources database included elevation and slope, soil physical properties and soil chemical properties. The land resources database formed the basis for entry in the physical model of the ALES programme. The land resources database codes are presented in Appendices 3 and 4 for the surveyed LMUs and AEZs respectively.

Table 2a: Land resources database of the surveyed LMUs for screening by ALES

LC LMU (Alt M)	LMU Sub unit (%)	Area (ha)	Tem. (°C)	GPR (mm)	MAR (mm)	LGP (Day	Slop (%)	Surf textu	Sub text	Flood (Day)	Soil depth (Cm)	Drainage (Class)	Soil pH	CEC (Cm(+)/kg)	OC (%)	N (%)	Avail P (mg/kg)	BS (%)
Mountains(MO) (>500).																		
MO 21	Rhodic Luvisols (40)	8 525	22.0	793	1 244	213	40.0	SC	SCL	<1	70	SED	6.3	17.0	2.5	0.30	9	100
	Profondic Luvisols (60)	12 788	22.0	793	1 244	213	42.0	SC	C	<1	100	WD	6.4	13.0	2.2	0.20	13	100
MO 22	Chromic Phaeozems 35	8 652	23.0	967	1 954	244	2.0	SCL	SC	<1	>110	WD	6.0	8.0	2.1	0.20	32	72
	Profondic Lixisols (65)	16 067	23.0	967	1 954	244	24.0	CL	C	<1	>80	WD	6.2	15.0	1.2	0.06	14	51
Piedmonts (Pi) (400-500)																		
Pi 2	Sodic Cambisols (60)	13 613	26.3	596	1 071	183	6.0	SL	SCL	<1	25	SED	5.8	13.0	1.5	0.20	13	100
	Orthidystric Cambisols (40)	9 075	26.3	596	1 071	183	2.5	S	LS	<1	150	SED	6.1	5.0	0.6	0.10	8	49
Peneplains(Pe) (200-400)																		
Pe 1	Ferralic Cambisols (55)	19 835	26.3	512	941	213	6.0	LS	LS	<1	90	WD	6.5	6.0	0.4	0.04	3	91
	Ferralic Cambisols (45)	16 228	26.3	512	941	213	2.0	LS	SCL	<1	>38	ED	5.5	2.0	0.7	0.07	32	46
Pe 3	Haplic Phaeozems (70)	16 713	27.0	628	1 068	213	0.5	CL	C	<5	117	WD	7.6	37.0	2.0	0.20	3	100
	Chromic Phaeozems (30)	7 163	27.0	628	1 068	213	5.0	SL	SCL	<1	25	ED	5.8	13.0	1.5	0.20	13	100
Valleys (Va) <200																		
Va 1	Eutric Regosols (50)	45 813	27.0	694	1 278	229	0.5	SC	C	<15	135	PD	7.1	45.0	2.8	0.30	40	100
	Luvic Phaeozems (50)	45 813	27.0	694	1 278	229	2.0	SCL	SC	<5	98	WD	6.8	12.0	0.6	0.10	3	100
Va 2	Gleyic Fluvisols (50)	28 750	27.5	705	1 119	213	1.0	CL	L	<15	134	PD	6.9	25.0	1.5	0.13	27	94
	Pachic Phaeozems (50)	28 750	27.5	705	1 119	213	1.5	SCL	SC	<15	120	ID	7.1	21.0	1.5	0.30	15	83

GPR=Growing period rainfall, MAR=Mean annual rainfall, LGP=Length of growing period, WD=Well drained, SED=Somewhat excessively drained, ID=Imperfectly drained, PD=Poorly drained, C=Clay, SL=Sandy loam, LS=Loamy sand, SCL=Sandy clay loam, SC=Sandy clay, L=Loam

Source: Munisi (2001)

Table 2b: Land resources database of the surveyed AEZs for screening by ALES

AEZ (Alt m)	AEZ Sub unit (%)	Area (ha)	Tem (°C)	GPR (mm)	MAR (mm)	LGP (Days)	Slop (%)	Surf textu	Sub textu	Flood (Day)	Soil depth (cm)	Draina (Class)	Soil pH	CEC (Cm(+)/kg)	OC (%)	N (%)	Avail P (mg/kg)	BS (%)
AEZII	Rhodic Luvisols (20)	8 556	21.0	821	1 400	223	40.0	SC	SCL	<1	70	SED	6.3	17	2.5	0.30	9	100
(500-800)	Profondic Luvisols (30)	12 833	21.0	821	1 400	223	42.0	SC	C	<1	100	WD	6.4	13	2.2	0.20	13	100
	Profondic Lixisols) (50)	21 390	21.0	821	1 400	223	36.0	SCL	C	<1	<100	WD	5.8	25	2.4	0.30	6	25
AEZIII	Profondic Acrisols (10)	7 827	24.0	783	1 502	218	5.0	SCL	C	<1	150	WD	5.6	18	2.1	0.21	4	71
(400-500)	Rhodic Ferralsols (15)	11 739	24.0	783	1 502	218	21.0	C	C	<1	90	WD	6.1	6	1.3	0.12	8	100
	Sodic Cambisols (15)	11 739	24.0	783	1 502	218	6.0	SL	SCL	<1	25	SED	5.8	13	1.5	0.20	13	100
	Orthidystric Cambisols (20)	15 652	24.0	783	1 502	218	2.5	S	LS	<1	150	SED	6.1	5	0.6	0.10	8	49
	Chromic Phaeozems (20)	15 652	24.0	783	1 502	218	2.0	SCL	SC	<1	>110	WD	6.0	8	2.1	0.20	32	72
	Profondic Lixisols (20)	15 652	24.0	783	1 502	218	24.0	CL	C	<1	>80	WD	6.2	15	1.2	0.06	14	51
AEZ IV	Gleyic Fluvisols (35)	22 236	26.0	750	1 315	221	1.0	CL	L	<15	134	PD	6.9	25	1.5	0.13	27	94
(100-200)	Pachic Phaeozems (35)	22 236	26.0	750	1 315	221	1.5	SCL	SC	<15	120	ID	7.1	21	1.5	0.30	15	83
	Profondic Lixisols (5)	2 891	26.0	750	1 315	221	2.0	SL	SCL	<1	110	WD	6.2	13	1.5	0.20	3	76
	Fluvic Cambisols (5)	2 891	26.0	750	1 315	221	1.0	SL	L	<1	150	SED	7.0	12	1.1	0.13	23	100
	Eutric Cambisols (5)	2 891	26.0	750	1 315	221	0.5	SL	SCL	<15	103	ID	7.6	16	1.2	0.13	3	52
	Gleyic Cambisols (5)	2 891	26.0	750	1 315	221	0.5	CL	C	<15	105	ID	6.6	20	2.1	0.22	38	100
	Chromic Phaeozems (5)	2 891	26.0	750	1 315	221	2.0	SCL	SC	<1	>110	WD	6.0	8	2.1	0.20	32	72
	Profondic Lixisols (5)	2 891	26.0	750	1 315	221	24.0	CL	C	<1	>80	WD	6.2	15	1.2	0.06	14	51

GPR=Growing period rainfall, MAR=Mean annual rainfall, LGP=Length of growing period, WD=Well drained, SED=Somewhat excessively drained, ID=Imperfectly drained, PD=Poorly drained, C=Clay, SL=Sandy loam, LS=Loamy sand, SCL=Sandy clay loam, SC=Sandy clay, L=Loam

Source: Munisi (2001)

Table 2b: Continued

AEZ (Alt m)	AEZ Sub unit (%)	Area (ha)	Tem (°C)	GPR (mm)	MAR (mm)	LGP (Days)	Slop (%)	Surf textu	Sub textu	Flood (Day)	Soil depth (cm)	Draina (Class)	Soil pH	CEC (Cm(+)/kg)	OC (%)	N (%)	Avail P (mg/kg)	BS (%)
AEZ V	Profondic Lixisols (25)	34 212	26.6	611	1 096	218	2.0	SL	SCL	<1	110	WD	6.2	13	1.5	0.20	3	76
(200-400)	Fluvic Cambisols (25)	34 212	26.6	611	1 096	218	1.0	SL	L	<1	150	SED	7.0	12	1.1	0.13	23	100
	Ferralic Cambisols (15)	20 527	26.6	611	1 096	218	6.0	LS	LS	<1	90	WD	6.5	6	0.4	0.04	3	91
	Ferralic Cambisols (15)	20 527	26.6	611	1 096	218	2.0	LS	SCL	<1	>38	ED	5.5	2	0.7	0.07	32	46
	Eutric Regosols (10)	13 685	26.6	611	1 096	218	0.5	SC	C	<15	135	PD	7.1	45	2.8	0.30	40	100
	Luvic Phaeozems (10)	13 685	26.6	611	1 096	218	2.0	SCL	SC	<5	98	WD	6.8	12	0.6	0.10	3	100
AEZ VI	Eutric Regosols (50)	14 891	26.8	666	1 458	213	0.5	SL	SCL	<15	103	ID	7.6	16	1.2	0.22	3	52
(100-200)	Gleyic Cambisols (30)	8 935	26.8	666	1 458	213	0.5	CL	C	<15	105	ID	6.6	20	2.1	0.13	38	100
	Chromic Phaeozems (5)	1 489	26.8	666	1 458	213	5.0	SL	SCL	<1	25	ED	5.8	13	1.5	0.20	13	100
	Haplic Phaeozems (15)	4 467	26.8	666	1 458	213	0.5	CL	C	<5	117	WD	7.6	37	2.0	0.20	3	100
AEZ.VII	Eutric Regosols (45)	28 699	26.8	661	1 173	221	0.5	SC	C	<15	135	PD	7.1	45	2.8	0.30	40	100
(100-200)	Luvic Phaeozems (45)	28 699	26.8	661	1 173	221	2.0	SCL	SC	<5	98	WD	6.8	12	0.6	0.10	3	100
	Chromic Phaeozems (5)	3 189	26.8	661	1 173	221	5.0	SL	SCL	<1	25	ED	5.8	13	1.5	0.20	13	100
	Haplic Phaeozems (5)	3 189	26.8	661	1 173	221	0.5	CL	C	<5	117	WD	7.6	37	2.0	0.20	3	100
AEZ IX	Haplic Phaeozems (50)	7 760	26.8	628	1 068	213	0.5	CL	C	<5	117	WD	7.6	37	2.0	0.20	3	100
(<200)	Chromic Phaeozems (50)	7 760	26.8	628	1 068	213	5.0	SL	SCL	<1	25	ED	5.8	13	1.5	0.20	13	100

GPR=Growing period rainfall, MAR=Mean annual rainfall, LGP=Length of growing period, WD=Well drained, SED=Somewhat excessively drained, ID=Imperfectly drained, PD=Poorly drained, C=Clay, SL=Sandy loam, LS=Loamy sand, SCL=Sandy clay loam, SC=Sandy clay, L=Loam
Source: Munisi (2001)

3.4.2 Compilation of agro economic database for economic land evaluation

Agroeconomic database corresponding to LMUs and AEZs for the studied LUTs are presented in Tables 3a, 3b and 3c for LMUs and Tables 4a, 4b and 4c for AEZs. The compiled agro-economic database comprised information related to outputs, prices, labour cost and cost of material inputs. This database formed the basis for entry in the agroeconomic model of the ALES programme.

Table 3a: Agro-economic database on smallholder low input rainfed maize for the surveyed LMUs

Economic parameter	Unit	Mean	Stdev	Min	Max	No.obs
Yield	Kg/ha	2.4	1.1	0.8	4.5	72
Returns	Tsh/ha	369 514	184 272	75 000	810 000	72
Annual cost						
Plough	Tsh/ha	33 854	12 483	10 000	50 000	72
Planting	Tsh/ha	13 750	4 452	7 500	25 000	72
Weeding	Tsh/ha	33 125	5 013	25 000	40 000	72
Rodent control	Tsh/ha	8 528	11 624	0	37 500	72
Harvesting	Tsh/ha	10 500	6 911	2 500	25 000	72
Transport	Tsh/ha	4 274	2 660	1 000	10 000	72
Processing	Tsh/ha	8 042	4 963	2 250	20 000	72
Total labour cost	Tsh/ha	112 073	48 106	48 250	207 500	
Material input cost						
Seeds	Tsh/ha	13 000	6 114	7 500	25 000	72
Total cost	Tsh/ha	125 073	54 220	55 750	232 500	
Gross margins	Tsh/ha	244 441	130 052	19 250	577 500	

Table 3b: Agro-economic database on smallholder low input rainfed paddy for the surveyed LMUs

Economic parameter	Unit	Mean	Stdev	Min	Max	No.obse
Yield	Kg/ha	3.1	1.7	0.5	6.3	72
Returns	Tsh/ha	476 042	276 419	70 000	1 080 000	72
Annual cost						
Plough	Tsh/ha	35 729	9 601	15 000	50 000	72
Planting	Tsh/ha	24 340	11 154	7 500	37 500	72
Weeding	Tsh/ha	35 903	7 274	20 000	50 000	72
Rodent control	Tsh/ha	23 819	12 414	0	37 500	72
Harvesting	Tsh/ha	17 535	11 230	3 750	37 500	72
Transport	Tsh/ha	12 271	14 337	750	52 500	72
Processing	Tsh/ha	14 299	12 230	750	37 500	72
Sub total labour cost	Tsh/ha	163 896	78 240	47 750	302 500	
Material input cost						
Seeds	Tsh/ha	15 483	7 364	7 000	28 125	72
Total cost	Tsh/ha	179 379	85 604	54 750	330 625	
Gross margins	Tsh/ha	296 663	190 815	15 250	749 375	

Table 3c: Agro-economic database on smallholder low input rainfed sesame for the surveyed LMUs

Economic parameter	Unit	Mean	Stdev	Min	Max	No.obse
Yield	Kg/ha	0.6	0.3	0.1	1.5	72
Returns	Tsh/ha	152 292	74 163	15 000	360 000	72
Annual cost						
Plough	Tsh/ha	24 340	11 408	10 000	50 000	72
Planting	Tsh/ha	10 764	2 855	5 000	15 000	72
Weeding	Tsh/ha	24 514	5 819	15 000	35 000	72
Rodent control	Tsh/ha	0	0	0	0	72
Harvesting	Tsh/ha	9 934	9 169	500	30 000	72
Transport	Tsh/ha	1 435	1 294	125	5 000	72
Processing	Tsh/ha	4 233	3 453	250	15 000	72
Sub total labour cost	Tsh/ha	75 220	33 998	30 875	150 000	
Material input cost						
Seeds	Tsh/ha	4 472	1 765	2 250	6 250	72
Total cost	Tsh/ha	79 692	35 763	33 125	156 250	
Gross margins	Tsh/ha	72 600	38 400	-18 125	203 750	

Table 4a: Agro-economic database on smallholder low input rainfed maize for the surveyed AEZs

Economic parameter	Unit	Mean	Stdev	Min	Max	No.observ
Yield	Kg/ha	2.4	1.0	0.8	4.5	163
Returns	Tsh/ha	372 843	176 422	75 000	810 000	163
Annual cost						
Plough	Tsh/ha	34 534	11 186	10 000	50 000	163
Planting	Tsh/ha	12 843	4 032	7 500	25 000	163
Weeding	Tsh/ha	32 206	5 887	25 000	40 000	163
Rodent control	Tsh/ha	6 020	10 487	0	37 500	163
Harvesting	Tsh/ha	9 657	6 086	2 500	25 000	163
Transport	Tsh/ha	3 929	2 385	1 000	10 000	163
Processing	Tsh/ha	7 765	4 362	2 250	20 000	163
Sub total labour cost	Tsh/ha	106 954	44 425	48 250	207 500	
Material input cost						
Seeds	Tsh/ha	12 485	5 268	7 500	25 000	163
Total cost	Tsh/ha	119 439	49 693	55 750	232 500	
Gross margins	Tsh/ha	253 404	126 729	19 250	577 500	

Table 4b: Agro-economic database on smallholder low input rainfed paddy for the surveyed AEZs

Economic parameter	Unit	Mean	Stdev	Min	Max	No.observ
Yield	Kg/ha	2.7	1.6	0.5	6.3	163
Returns	Tsh/ha	450 147	251 705	70 000	1 080 000	163
Annual cost						
Plough	Tsh/ha	35 760	8 782	15 000	50 000	163
Planting	Tsh/ha	24 044	11 176	7 500	37 500	163
Weeding	Tsh/ha	36 618	6 221	20 000	50 000	163
Rodent control	Tsh/ha	21 078	11 261	0	37 500	163
Harvesting	Tsh/ha	14 485	10 730	3 750	37 500	163
Transport	Tsh/ha	9 681	12 850	750	52 500	163
Processing	Tsh/ha	11 113	11 592	750	37 500	163
Sub total labour cost	Tsh/ha	152 779	72 612	47 750	302 500	
Material input cost						
Seeds	Tsh/ha	16 493	7 616	7 000	28 125	163
Total cost	Tsh/ha	169 272	80 228	54 750	330 625	
Gross margins	Tsh/ha	280 875	171 477	15 250	749 375	

Table 4c: Agro-economic database on smallholder low input rainfed sesame for the surveyed AEZs

Economic parameter	Unit	Mean	Stdev	Min	Max	No.observ
Yield	Kg/ha	0.5	0.3	0.1	1.5	163
Returns	Tsh/ha	156 814	77 561	15 000	360 000	163
Annual cost						
Plough	Tsh/ha	24 289	11 009	10 000	50 000	163
Planting	Tsh/ha	10 539	2 414	5 000	15 000	163
Weeding	Tsh/ha	24 167	5 066	15 000	35 000	163
Rodent control	Tsh/ha	0	0	0	0	163
Harvesting	Tsh/ha	7 456	8 601	500	30 000	163
Transport	Tsh/ha	1 109	1 199	125	5 000	163
Processing	Tsh/ha	3 179	3 328	250	15 000	163
Sub total labour cost	Tsh/ha	70 739	31 617	30 875	150 000	
Material input cost						
Seeds	Tsh/ha	4 995	1 688	2 250	6 250	163
Total cost	Tsh/ha	75 734	33 305	33 125	156 250	
Gross margins	Tsh/ha	81 080	44 256	-18 125	203 750	

3.5 Land evaluation

The Automated land evaluation system (ALES) was applied in this study. The system basically follows the procedures laid down in the FAO framework for Land Evaluation (FAO, 1976). Firstly the land utilization types (LUTs) were described. Data on land resources were coded using land characteristics specification dictionary into a digital database file. This step was followed by the comparison of the optimal environmental requirements of the LUTs with the actual conditions of the land; a process referred to as matching. The matching process in this study was done in the Automated Land Evaluation System (ALES) model (Rossiter and Van Wambeke, 1989; 1994). The tracts of the land being used for suitability assessment in this study are land mapping units and agro-ecological zones.

3.5.1 Description of the land Utilization types (LUTs)

Three major land utilization types (LUTs) namely smallholder low input rainfed maize, smallholder low input rainfed paddy and smallholder low input rainfed sesame described by Munisi (2001) were elaborated and tested for their physical and economic suitability for the surveyed LMUs and AEZs. The LUTs were described in the field with emphasis on farming systems, produce (varieties grown), labour input, farm size, land tenure, yields and prices of the produce as reported by farmers. Table 5 presents the summary of the attributes for the three selected LUTs, which were also used as a database for entry into the ALES land utilization type model.

Table 5: Description of land utilization types (LUTs) for Eastern part of Morogoro Rural District

LUTs	Produce	Cropping characteristics	Labour	Level of technology	Farm size range (ha)	Land tenure	Yield range (t/ha)
Smallholder low input rainfed Maize	Local varieties	Monoculture and intercropping systems	Hired and family	Low: Handtools, No fertilizer application; No chemical application to control Pests and Disease; little Extension services; Local unimproved storage facilities	0.2-2.0	Customary	0.8-4.5
Smallholder low input rainfed Paddy	Local varieties	Monoculture and intercropping systems	Hired and family	Low: Handtools, No fertilizer application; No chemical application to control Pests and Disease; little Extension services; Local unimproved storage facilities	0.2-2.0	Customary	0.5-6.3
Smallholder low input rainfed Sesame	Local varieties	Monoculture and intercropping systems	Hired and family	Low: Handtools, No fertilizer application; No chemical application to control Pests and Disease; little Extension services; Local unimproved storage facilities	0.1-1.2	Customary	0.1-1.5

3.5.2. Rating of land use requirements (LURs)

Land suitability in this study was assessed on the basis of those land use requirements (LURs) that were considered diagnostic for the identified LUTs. In the study area the land qualities that were taken into consideration are: moisture availability, moisture retention, oxygen availability to roots, rooting condition, nutrient availability, nutrient retention capacity, erosion hazard and temperature regime. LURs are composed of certain land characteristics (LCs). Appendix 5a, 5b and 5c summarize the land use requirements for maize, paddy and sesame respectively as adopted from Munisi (2001).

Using land characteristic specifications and land use requirements, the expert models in the form of decision trees for each specific land utilization type was constructed in ALES program. These are structured representations of the reasoning processes (expert knowledge system) needed to reach decisions. The land characteristic specifications used in ALES model construction are presented in appendix 2. Class limit sets in the decision trees for the selected LUTs was mainly based on literature sources and information obtained from PRA and field observations. Rating of the LURs was done using severity levels as follows: (1) no limitation, (2) moderate limitation, (3) severe limitation and (4) very severe limitation. An example of part of decision making tree is presented in Appendix 6.

3.5.3.Types of Land suitability classification.

Land suitability classification take into account a sustainable use of the lands basing on the environmental resources (physical suitability) and socio-economic factors

(Agro-economic suitability) (FAO, 1976, Kimaro and Kips, 1991, Rossiter, 1996) were performed in this study.

3.5.3.1 Physical suitability classification.

Physical suitability ratings of the land based on LMUs and AEZs were determined using decision trees severity levels constructed as described on section 3.3.2. The rating followed the Liebig's law of minimum (Rossiter and Van Wambeke, 1989), by which the most limiting LUR determines the suitability class. Four physical suitability classes were defined as (1) god potential, (2) moderate potential, (3) poor potential and (4) very poor potential. As apart of the physical evaluation ALES was instructed to predict yields on the basis of the limiting yield factors. Predictions were made by multiplying the chosen yield factors with the optimum attainable yield. The yield factors that used were derived from the proposed FAO suitability classes i.e. 80 – 100% S1, 40 – 80 %S2, 20 – 40 % S3, and 0 – 20 % N of the optimum yield (FAO, 1984). The ALES yield factors were class 1 = 1, class 2 = 0.8, class 3 = 0.4 and class 4 = 0.2. These factors were used to predict the final physical suitability class with its associated yield.

3.5.3.2 Agro-economic suitability classification

ALES program was used to compute the economic evaluation after the physical evaluation. The economic evaluation was carried out using the predicted yields arrived at the physical evaluation. The results of economic evaluation are the predicted gross margins for each LMU/AEZ for a specific LUT. In the economic evaluation the FAO suitability classes were used as follows: S1 (highly suitable), S2 (moderate suitable), S3 (marginally suitable), N1 (economically not suitable) and N2 is reserved for physically unsuitable land. Agro-economic suitability class limits used in this study were the gross margins. ALES requires the evaluator to set the Agro-economic suitability class limits. These class limits are gross margins based on the maximum attainable yields. The same factors were used for setting the class limits as for the physical evaluation.

3.6 Data analysis

Microsoft Excel computer program was adopted for statistical analysis. Linear regression analysis was used to assess the relationship between the ALES predicted and actual farmers' reported yields/gross margins for both LMUs and AEZs.

This was done by plotting the predicted yields/Gross margins representing the values of the dependent variable (Y) against actual farmers' reported yields/Gross margins, representing the value of the independent variable (X). The following Linear equation was applied:

$Y = aX + b$

Where: X= Independent Variable (reported)

Y= Dependent Variable (predicted)

a & b= constants indicating the relation between X and Y.

3.7 Comparison of LMUand AEZ suitability evaluations

The correlation coefficients r (X, Y) of the predicted yields/Gross margins for land evaluations based on LMU and AEZ approach were compared. The land evaluation approach that showed a better correlation coefficient was considered to be more efficient than the one having relatively poor correlation coefficient for a given LUT.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Socio-economic setting of the study area.

The socio-economic survey results in study area indicate that the size of one household ranges from 4-8 persons. Most of the households include man, wife, children and other relatives. Production is mainly subsistence and labour intensities are high, which are mainly family or hired. Both annual and perennial crops are produced but the annual crops are dominant. The family income depends solely on selling agricultural products, but in some parts of Ngerengere Division, credit facilities are provided to farmers groups by National Microfinance Bank. Several types of crops are sold to earn money to satisfy other needs such as kerosene, salt and clothes. The crops, which in most cases are sold to meet these needs, are cassava, banana, rice and sesame. The level of know-how and technology employed is very low. Hand tools which include hoe, machete (panga), bush axe, sickle and knife are commonly used. In addition, the local cultivars are commonly grown with no fertilizers and chemical application, and no conservation measures. Agricultural management practices depend mainly on traditional knowledge and experience of the environment due to inadequate agricultural advisory services provided by the Government. The land tenure system is customary and the land use is mostly permanent with average farm size ranging from 0.1 to 2 ha.

4.2 The Agro-economic database

The results of Agro-economic database for the selected LMUs and AEZs are presented in two categories: farmers' reported yields and Gross margins on one hand (sections 4.2.1 and 4.2.2) and their corresponding ALES predictions (sections 4.3.1 and 4.3 2).

4.2.1 Farmers reported yield

Farmers' reported yields for the tested LUTs are presented in Tables 6a, 6b and 6c for the studied LMUs and Tables 7a, 7b and 7c for the studied AEZs.

The Agro-economic database indicate that the maize yields in the study area range from 0.8 t ha^{-1} to 4.5 t ha^{-1} with an average of 2.4t ha^{-1} and standard deviation of 1.1 t ha^{-1} and 1.0 t ha^{-1} for LMUs and AEZs, respectively. Paddy yields range from 0.5 t/ha to 6.3 t ha^{-1} with an average of 3.1 t ha^{-1} and 2.7 t ha^{-1} per LMU and AEZ respectively, and with standard deviation of 1.7 t ha^{-1} and 1.6 t ha^{-1} per LMUs and AEZs respectively. According to URT (1995) the potential yields of maize ranges from 4 to 8 t ha^{-1}, and 8 t ha^{-1} for paddy production. Sesame yields range between 0.1 t ha^{-1} and 1.5 t ha^{-1} with an average of 0.6 t ha^{-1} per LMUs and 0.5 t ha^{-1} per AEZ, and with standard deviation of 0.3 t ha^{-1} for both land units. This indicates that, the study area produce slightly to the lower limit of maize potential yields and below the lower limit of the paddy potential yields.

Generally, the results of the Agro-economic survey carried out on the basis of AEZs are more homogeneous results than the Agro-economic survey carried out on the basis of LMUs as shown by the standard deviations of maize and paddy production based on the AEZs and LMUs, respectively.

Table 6a: Farmers' reported yield for smallholder low input rainfed maize based on LMUs

LMU Altitude (m)	LMU Subunit Area (%)	Area (ha)	Aver-age (t/ha)	STD (t/ha)	Mini-mum (t/ha)	Maxi-mum (t/ha)	No. Obs.
Mountains (>500)							
MO 21		21 313	1.4	0.8	0.8	2.5	10
	Rhpodic Luvisols (40)	8 525	1.2	0.8	0.8	2.0	5
	Profondic Luvisols (60)	12 788	1.6	0.8	1.0	2.5	5
MO 22		24 719	3.7	0.9	2.0	4.5	12
	Chromic Phaeozems (35)	8 652	3.8	0.7	2.0	4.5	5
	Profondic Lixisols (65)	16 067	3.6	1.0	2.5	4.2	7
Piedmonts (Pi) (400-500)							
Pi 2		22 688	2.0	0.8	1.3	3.0	10
	Sodic Cambisols (60)	13 613	2.2	0.7	1.5	3.0	5
	Orthidystric Cambisols (40)	9 075	1.8	1.0	1.3	2.7	5
Peneplains (Pe) (200-400)							
Pe 1		36 063	2.3	0.6	1.5	3.0	10
	Ferralic Cambisols (55)	19 835	2.1	0.7	1.5	2.8	5
	Ferralic Cambisols (45)	16 228	2.5	0.6	1.7	3.0	5
Pe 3		23 875	2.7	1.0	1.0	3.8	10
	Haplic Phaeozems (70)	16 713	2.3	1.2	1.0	3.3	5
	Chromic Phaeozems (30)	7 163	3.1	1.2	1.9	3.8	5
Valleys (Va) (<200)							
Va 1		91 625	2.3	0.9	1.5	3.8	10
	Eutric Regosols (50)	45 813	2.3	1.0	2.3	3.8	5
	Luvic Phaeozems (50)	45 813	2.3	0.9	1.5	3.1	5
Va 2		57 500	1.7	0.7	0.8	2.5	10
	Gleyic Fluvisols (50)	28 750	1.7	0.8	0.9	2.5	5
	Pachic Phaeozems (50)	28 750	1.6	0.8	0.8	2.3	5

Table 6b: Farmers' reported yield for smallholder low input rainfed paddy based on LMUs

LMU Altitude (m)	LMU Subunit Area (%)	Area (ha)	Average (t/ha)	STD (t/ha)	Minimum (t/ha)	Maximum (t/ha)	No. Obs.
Mountains(MO) (>500)							
MO 21		21 313	1.0	0.4	0.5	1.3	10
	Rhpodic Luvisols (40)	8 525	0.9	0.4	0.5	1.2	5
	Profondic Luvisols (60)	1 2788	1.1	0.3	0.6	1.3	5
MO 22		24 719	2.7	1.5	1.0	5.0	12
	Chromic Phaeozems (35)	8 652	2.9	2.0	1.0	5.0	5
	Profondic Lixisols (65)	16 067	2.5	1.4	1.0	3.7	7
Piedmonts (Pi) (400-500)							
Pi 2		22 688	4.7	1.0	3.8	6.3	10
	Sodic Cambisols (60)	13 613	4.8	1.2	4.5	6.3	5
	Orthidystric Cambisols (40)	9 075	4.6	0.7	3.8	5.5	5
Peneplains (Pe) (200-400)							
Pe 1		36 063	3.8	1.0	2.5	5.0	10
	Ferralic Cambisols (55)	19 835	3.9	1.0	2.9	5.0	5
	Ferralic Cambisols (45)	16 228	3.7	1.2	2.5	4.8	5
Pe 3		23 875	1.2	0.3	0.8	1.5	10
	Haplic Phaeozems (70)	16 713	1.3	0.3	1.0	1.5	5
	Chromic Phaeozems (30)	7 163	1.1	0.3	0.8	1.4	5
Valleys (Va) (<200)							
Va 1		91 625	4.8	0.7	4.0	6.3	10
	Eutric Regosols (50)	45 813	5.1	0.7	4.0	5.3	5
	Luvic Phaeozems (50)	45 813	4.5	1.2	4.2	6.3	5
Va 2		57 500	2.4	0.5	1.8	3.0	10
	Gleyic Fluvisols (50)	28 750	2.3	0.5	1.8	2.7	5
	Pachic Phaeozems (50)	28 750	2.5	0.6	1.9	3.0	5

Table 6c: Farmers' reported yield for smallholder low input rainfed sesame based on LMUs

LMU Altitude (m)	LMU Subunit Area (%)	Area (ha)	Average (t/ha)	STD (t/ha)	Minimum (t/ha)	Maximum (t/ha)	No. Obs.
Mountain(MO) (>500)							
MO 21		21 313	0.4	0.2	0.3	0.8	10
	Rhpodic Luvisols (40)	8 525	0.4	0.1	0.3	0.7	5
	Profondic Luvisols (60)	12 788	0.4	0.4	0.3	0.8	5
MO 22		24 719	0.6	0.2	0.5	1.0	12
	Chromic Phaeozems (35)	8 652	0.5	0.2	0.4	0.8	5
	Profondic Lixisols (65)	16 067	0.7	0.3	0.6	1.0	7
Piedmonts (Pi) (400-500)							
Pi 2		22 688	0.8	0.2	0.5	1.0	10
	Sodic Cambisols (60)	13 613	0.7	0.2	0.5	1.0	5
	Orthidystric Cambisols (40)	9 075	0.9	0.3	0.6	1.0	5
Peneplains (Pe) (200-400)							
Pe 1		36 063	0.4	0.3	0.1	0.8	10
	Ferralic Cambisols (55)	19 835	0.4	0.3	0.1	0.8	5
	Ferralic Cambisols (45)	16 228	0.4	0.2	0.2	0.6	5
Pe 3		23 875	0.9	0.4	0.5	1.5	10
	Haplic Phaeozems (70)	16 713	0.8	0.3	0.5	1.2	5
	Chromic Phaeozems (30)	7 163	1.0	0.5	0.5	1.5	5
Valley (Va) (<200)							
Va 1		91 625	0.3	0.1	0.1	0.5	10
	Eutric Regosols (50)	45 813	0.2	0.1	0.1	0.4	5
	Luvic Phaeozems (50)	45 813	0.4	0.1	0.3	0.5	5
Va 2		57 500	1.0	0.2	0.8	1.3	10
	Gleyic Fluvisols (50)	28 750	0.9	0.1	0.8	1.2	5
	Pachic Phaeozems (50)	28 750	1.1	0.2	0.9	1.3	5

Table 7a: Farmers' reported yield for smallholder low input rainfed maize based on AEZs

AEZ (Altitude m)	AEZ Subunit (Area %)	Area (ha)	Average (t/ha)	STD (t/ha)	Minimum (t/ha)	Maximum (t/ha)	No. Obs
AEZ II		42 779	1.4	0.8	0.8	2.5	17
(500-800)	Rhodic Luvisols (20)	8 556	0.9	0.2	0.8	2.4	5
	Profondic Luvisols (30)	12 833	2.5	0	2.5	2.5	5
	Profondic Lixisols (60)	21 390	0.8	0	0.8	0.8	7
AEZ III		78 261	3.0	1.2	1.3	4.5	22
(400-500)	Profondic Acrisols (10)	7 827	3.7	0.8	2.3	3.8	5
	Rhodic Ferralsols (15)	11 739	2.4	1.2	1.3	3.8	5
	Sodic Cambisols (15)	11 739	2.7	1.0	2.1	3.9	5
	Orthidystric Cambisols (20)	15 652	3.4	1.2	2.2	4.5	5
	Chromic Phaeozems (20)	15 652	4.5	0	4.5	4.5	5
	Profondic Lixisols (20)	15 652	1.3	0	1.3	1.3	7
AEZ IV		57 818	1.7	0.7	0.8	2.5	42
(100-200)	Gleyic Fluvisols (35)	22 236	1.2	0.2	1.1	1.4	5
	Pachic Phaeozems (35)	22 236	2.4	0.5	1.5	2.5	5
	Profondic Lixisols (5)	2 891	1.3	0.8	0.8	2.4	7
	Fluvic Cambisols (5)	2 891	2.3	0.7	1.2	2.4	5
	Eutric Regosols (5)	2 891	1.1	0.6	0.9	2.1	5
	Gleyic Cambisols (5)	2 891	2.5	0	2.5	2.5	5
	Chromic Phaeozems (5)	2 891	2.0	0.7	1.3	2.4	5
	Profondic Lixisols (5)	2 891	0.8	0	0.8	0.8	5
AEZ V		136 848	2.3	0.7	1.5	3.8	32
(200-400)	Profondic Lixisols (25)	34 212	2	0.8	1.7	3.3	7
	Fluvic Cambisols (25)	34 212	3.8	0	3.8	3.8	5
	Ferralic Cambisols (15)	20 527	1.6	0.2	1.5	2.1	5
	Ferralic Cambisols (15)	20 527	2.2	0.7	1.5	3.1	5
	Eutric Regosols (10)	13 685	2.7	1.0	1.6	3.8	5
	Luvic Phaeozems (10)	13 685	1.5	0	1.5	1.5	5
AEZ VI		29 782	2.7	1.0	1.0	3.8	20
(100-200)	Eutric Regosols (50)	14 891	2.6	1.0	1.2	3.3	5
	Gleyic Cambisols (30)	8 935	3.4	0.8	2.3	3.8	5
	Chromic Phaeozems (5)	1 489	3.8	0	3.8	3.8	5
	Haplic Phaeozems (15)	4 467	1.0	0	1.0	1.0	5
AEZ VII		63 776	2.5	0.9	1.0	3.8	20
(100-200)	Eutric Regosols (45)	28 699	2.6	1.0	1.5	3.6	5
	Luvic Phaeozems (45)	28 699	1.0	0	1.0	1.0	5
	Chromic Phaeozems (5)	3 189	3.8	0	3.8	3.8	5
	Haplic Phaeozems (5)	3 189	2.6	1.0	1.6	3.8	5
AEZ IX		15 519	2.7	1.0	1.0	3.8	10
(<200)	Haplic Phaeozems (50)	7 760	1.6	0.7	1.0	3.5	5
	Chromic Phaeozems (50)	7 760	3.8	0	3.8	3.8	5

Table 7b: Farmers' reported yield for smallholder low input rainfed paddy based on AEZs

AEZ (Altitude m)	AEZ Subunit (Area %)	Area (ha)	Average (t/ha)	STD (t/ha)	Minimum (t/ha)	Maximum (t/ha)	No. Obs.
AEZ II		42 779	1.0	0.4	0.5	1.3	17
(500-800)	Rhodic Luvisols (20)	8 556	1.1	0.3	0.8	1.2	5
	Profondic Luvisols (30)	12 833	1.1	0.6	0.5	1.3	5
	Profondic Lixisols (60)	21 390	0.8	0.4	0.6	1.2	7
AEZ III		78 261	2.0	0.8	0.8	6.0	22
(400-500)	Profondic Acrisols (10)	7 827	2.0	0.8	2.2	2.9	5
	Rhodic Ferralsols (15)	11 739	0.8	0	0.8	0.8	5
	Sodic Cambisols (15)	11 739	1.2	0.6	0.8	2.5	5
	Orthidystric Cambisols (20)	15 652	5.0	1.7	3.1	6.0	5
	Chromic Phaeozems (20)	15 652	1.0	1.0	2.0	2.8	5
	Profondic Lixisols (20)	15 652	2.0	0.8	1.5	3.0	7
AEZ IV		57 818	4.8	0.5	3.8	6.3	42
(100-200)	Gleyic Fluvisols (35)	22 236	5.1	0.3	4.0	5.3	5
	Pachic Phaeozems (35)	22 236	5.0	0.5	4.0	5.6	5
	Profondic Lixisols (5)	2 891	4.5	0.4	3.8	5.3	7
	Fluvic Cambisols (5)	2 891	4.5	0.3	3.9	6.3	5
	Eutric Regosols (5)	2 891	4.6	0.5	3.8	5.7	5
	Gleyic Cambisols (5)	2 891	5.1	0.3	4.1	6.0	5
	Chromic Phaeozems (5)	2 891	4.6	0.5	4.2	5.8	5
	Profondic Lixisols (5)	2 891	5.0	0.7	4.6	6.1	5
AEZ V		136 848	3.3	1.3	1.0	5.0	32
(200-400)	Profondic Lixisols (25)	34 212	3.0	1.2	2.3	4.6	7
	Fluvic Cambisols (25)	34 212	3.0	1.0	2.0	4.5	5
	Ferralic Cambisols (15)	20 527	3.3	1.2	2.8	5.0	5
	Ferralic Cambisols (15)	20 527	3.6	1.3	2.3	4.6	5
	Eutric Regosols (10)	13 685	3.8	1.2	1.0	5.0	5
	Luvic Phaeozems (10)	13 685	3.1	1.3	1.8	4.5	5
AEZ VI		29 782	1.2	0.3	0.8	1.5	20
(100-200)	Eutric Regosols (50)	14 891	1.2	0.2	1.0	1.4	5
	Gleyic Cambisols (30)	8 935	1.3	0.2	1.0	1.5	5
	Chromic Phaeozems (5)	1 489	1.1	0.3	0.8	1.3	5
	Haplic Phaeozems (15)	4 467	1.2	0.3	0.9	1.4	5
AEZ VII		63 776	2.4	1.3	0.8	5.0	20
(100-200)	Eutric Regosols (45)	28 699	3.1	1.2	2.4	5.0	5
	Luvic Phaeozems (45)	28 699	1.6	1.0	0.8	3.0	5
	Chromic Phaeozems (5)	3 189	3.8	1.2	1.0	2.4	5
	Haplic Phaeozems (5)	3 189	1.1	0.4	0.9	1.8	5
AEZ IX		15 519	1.2	0.3	0.8	1.5	10
(<200)	Haplic Phaeozems (50)	7 760	1.2	0.4	0.8	1.5	5
	Chromic Phaeozems (50)	7 760	1.2	0.3	0.9	1.4	5

Table 7c: Farmers' reported yield for smallholder low input rainfed sesame based on AEZs

AEZ (Altitude m)	AEZ SUBUNIT (Area %)	Area (ha)	Aver-age (t/ha)	STD (t/ha)	Mini-mum (t/ha)	Maxi-mum (t/ha)	No. Obs
AEZ II		42 779	0.5	0.3	0.3	0.8	17
(500-800)	Rhodic Luvisols (20)	8 556	0.5	0.1	0.4	0.6	5
	Profondic Luvisols (30)	12 833	0.3	0.0	0.3	0.3	5
	Profondic Lixisols (60)	21390	0.7	0.3	0.5	0.7	7
AEZ III		78 261	0.4	0.3	0.1	1.0	22
(400-500)	Profondic Acrisols (10)	7 827	0.3	0.4	0.2	0.9	5
	Rhodic Ferralsols (15)	11 739	0.1	0.0	0.1	0.1	5
	Sodic Cambisols (15)	11 739	0.3	0.1	0.2	1.0	5
	Orthidystric Cambisols (20)	15 652	0.4	0.3	0.2	0.8	5
	Chromic Phaeozems (20)	15 652	1.0	0.0	1.0	1.0	5
	Profondic Lixisols (20)	15 652	0.3	0.4	0.1	0.6	7
AEZ IV		57 818	1.0	0.2	0.8	1.3	42
(100-200)	Gleyic Fluvisols (35)	22 236	0.8	0.0	0.8	0.8	5
	Pachic Phaeozems (35)	22 236	1.1	0.1	0.9	1.2	5
	Profondic Lixisols (5)	2 891	1.0	0.3	0.8	1.2	7
	Fluvic Cambisols (5)	2 891	1.3	0.0	1.3	1.3	5
	Eutric Regosols (5)	2 891	1.1	0.1	1.0	1.3	5
	Gleyic Cambisols (5)	2 891	0.9	0.1	0.8	1.1	5
	Chromic Phaeozems (5)	2 891	1.0	0.2	0.9	1.2	5
	Profondic Lixisols (5)	2 891	0.8	0.0	0.8	0.8	5
AEZ V		13 6848	0.5	0.3	0.1	1.0	32
(200-400)	Profondic Lixisols (25)	34 212	0.5	0.3	0.1	0.8	7
	Fluvic Cambisols (25)	34 212	1.0	0.0	1.0	1.0	5
	Ferralic Cambisols (15)	20 527	0.1	0.0	0.1	0.1	5
	Ferralic Cambisols (15)	20 527	0.4	0.3	0.1	0.6	5
	Eutric Regosols (10)	13 685	0.7	0.3	0.5	1.0	5
	Luvic Phaeozems (10)	13 685	0.3	0.3	0.2	0.7	5
AEZ VI		29 782	0.4	0.2	0.3	0.8	20
(100-200)	Eutric Regosols (50)	14 891	0.4	0.2	0.3	0.6	5
	Gleyic Cambisols (30)	8 935	0.4	0.1	0.3	0.7	5
	Chromic Phaeozems (5)	1 489	0.5	0.3	0.4	0.8	5
	Haplic Phaeozems (15)	4 467	0.3	0.0	0.3	0.3	5
AEZ VII		63 776	0.4	0.2	0.1	0.8	20
(100-200)	Eutric Regosols (45)	28 699	0.4	0.2	0.1	0.5	5
	Luvic Phaeozems (45)	28 699	0.3	0.1	0.1	0.4	5
	Chromic Phaeozems (5)	3 189	0.6	0.2	0.3	0.8	5
	Haplic Phaeozems (5)	3 189	0.3	0.2	0.2	0.6	5
AEZ IX		15 519	0.9	0.2	0.5	1.5	10
(<200)	Haplic Phaeozems (50)	7 760	0.8	0.1	0.6	1.2	5
	Chromic Phaeozems (50)	7 760	1.0	0.4	0.7	1.5	5

4.2.2 Farmers' reported Gross margins (GM)

Tables 8a, 8b and 8c summarize the farmers' reported Gross margins for the surveyed LMUs, while Tables 9a, 9b and 9c present the Gross margins of the surveyed AEZs.

The Agro-economic database generated from Agro-economic survey indicates that in the study area Gross margins for maize range from -19750 Tsh/ha to 649250 Tsh/ha with an average of 244440 Tsh/ha and 253405 Tsh/ha per LMU and AEZ respectively, and with standard deviation of 130050 Tsh/ha and 126730 Tsh/ha per LMUs and AEZs respectively. GM for Paddy range from -16500 Tsh/ha to 752250 Tsh/ha with an average of 296665 Tsh/ha and 280875 Tsh/ha per LMU and AEZ respectively, and with standard deviation of 190815 Tsh/ha to 171475 Tsh/ha for LMUs and AEZs respectively. GM for Sesame range between -60750 Tsh/ha and 297250/ha with an average of 72600 Tsh/ha and 81080 Tsh/ha per LMU and AEZ respectively, and with standard deviation of 38400 Tsh/ha and 44256 per LMU and AEZ respectively.

Generally the data generated from Agro-economic survey carried out on the basis of AEZs gave lower standard deviations than those based on LMUs. This indicates that the reported GM on the basis of AEZs are more homogeneous than those obtained on the basis of LMUs.

Table 8a: Farmers' reported Gross Margin for smallholder low input rainfed maize based on LMUs

LMU Altitude (m)	LMU Subunit Area (%)	Area (ha)	Average (Tshs/ha)	STD (Tshs/ha)	Minimum (Tshs/ha)	Maximum (Tshs/ha)	No. Obs.
Mountains (MO) (>500)							
MO 21		21 313	132 185	62 730	62 500	216 250	10
	Rhpodic Luvisols (40)	8 525	113 300	59 700	62 500	173 000	5
	Profondic Luvisols (60)	12 788	151 070	72 945	78 125	216 250	5
MO 22		24 719	394 285	119 085	242 500	605 000	12
	Chromic Phaeozems (35)	8 652	404 939	162 439	242 500	605 000	5
	Profondic Lixisols (65)	16 067	372 970	191 694	303 125	564 664	7
Piedmonts (Pi) (400-500)							
Pi 2		22 688	192 300	182 600	-19 750	429 000	10
	Sodic Cambisols (60)	13 613	211 530	159 775	51 755	429 000	5
	Orthidystric Cambisols(40)	9 075	173 070	228 250	-19 750	401 320	5
Peneplains (Pe) (200-400)							
Pe 1		36 063	221 200	74 105	112 500	316 000	10
	Ferralic Cambisols (55)	19 835	201 965	86 455	112 500	294 930	5
	Ferralic Cambisols (45)	16 228	230 815	74 105	127 500	316 000	5
Pe 3		23 875	228 450	123 695	34 250	348 000	10
	Haplic Phaeozems 70	16 713	186 145	148 435	34 250	334 580	5
	Chromic Phaeozems (30)	7 163	262 295	148 435	113 860	348 000	5
Valleys (Va) (<200)							
Va 1		91 625	367 850	175 125	197 750	649 250	10
	Eutric Regosols (50)	45 813	367 850	281 400	303 215	649 250	5
	Luvic Phaeozems (50)	45 813	383 845	175 125	197 750	558 970	5
Va 2		57 500	92 425	71 685	-2 750	192 500	10
	Gleyic Fluvisols (50)	28 750	92 425	71 685	20 740	192 500	5
	Pachic Phaeozems (50)	28 750	86 990	71 685	-2 750	158 675	5

Table 8b: Farmers' reported Gross Margin for smallholder low input rainfed paddy based on LMUs

LMU Altitude (m)	LMU Subunit Area (%)	Area (ha)	Average (Tshs/ha)	STD (Tshs/ha)	Minimum (Tshs/ha)	Maximum (Tshs/ha)	No. Obs.
Mountain(MO) (>500)							
MO 21		21 313	50 500	35 616	10 500	79 250	10
	Rhpodic Luvisols (40)	8 525	45 450	35 616	10 500	73 155	5
	Profondic Luvisols (60)	12 788	55 550	26 712	12 600	79 250	5
MO 22		24 719	301 300	39 000	257 500	736 50	12
	Chromic Phaeozems (35)	8 652	323 618	39 000	257 500	736 250	5
	Profondic Lixisols (65)	16 067	278 980	12 000	267 190	544 825	7
Piedmonts (Pi) (400-500)							
Pi 2		22 688	193 500	150 120	48 000	409 500	10
	Sodic Cambisols (60)	13 613	198 595	143 595	55 000	409 500	5
	Orthidystric Cambisols(40)	9 075	188 410	140 410	48 000	393 120	5
Peneplains (Pe) (200-400)							
Pe 1		36 063	542 450	110 865	388 750	656 250	10
	Ferralic Cambisols (55)	19 835	553 990	102 260	460 360	656 250	5
	Ferralic Cambisols (45)	16 228	530 910	142 160	388 750	572 915	5
Pe 3		23 875	213 825	76 915	86 000	298 125	10
	Haplic Phaeozems 70	16 713	231 645	66 480	107 500	298 125	5
	Chromic Phaeozems (30)	7 163	196 005	82 245	86 000	278 250	5
Valleys (Va) (<200)							
Va 1		91 625	519 285	12 210	271 945	752 500	10
	Eutric Regosols (50)	45 813	507 490	125 565	284 615	633 055	5
	Luvic Phaeozems (50)	45 813	530 105	222 395	239 980	752 500	5
Va 2		57 500	117 500	75 765	-16 500	168 500	10
	Gleyic Fluvisols (50)	28 750	112 605	75 765	-16 500	151 650	5
	Pachic Phaeozems (50)	28 750	122 395	90 920	31 475	168 500	5

Table 8c: Farmers' reported Gross Margin for smallholder low input rainfed sesame based on LMUs

LMU Altitude (m)	LMU Subunit Area (%)	Area (ha)	Average (Tshs/ha)	STD (Tshs ha)	Minimum (Tshs ha)	Maximum (Tshs ha)	No. Obs.
Mountain(MO) (>500)							
MO 21		21 313	178 500	987 620	57 250	297 250	10
	Rhpodic Luvisols (40)	8 525	158 670	101 420	57 250	237 800	5
	Profondic Luvisols (60)	12 788	198 500	98 750	57 250	297 250	5
MO 22		24 719	53 036	30 726	42 500	101 250	12
	Chromic Phaeozems (35)	8 652	53 036	10 536	42 500	101 250	5
	Profondic Lixisols (65)	16 067	53 036	22 900	42 500	75 940	7
Piedmonts (Pi) (400-500)							
Pi 2		22 688	-24 550	36 665	-60 750	35 000	10
	Sodic Cambisols (60)	13 613	-24 085	36 665	-60 750	35 000	5
	Orthidystric Cambisols(40)	9 075	-20 000	55 000	-50 625	35 000	5
Peneplains (Pe) (200-400)							
Pe 1		36 063	60 500	27 595	34 750	112 000	10
	Ferralic Cambisols (55)	19 835	52 940	18 190	34 750	112 000	5
	Ferralic Cambisols (45)	16 28	68 065	26 365	41 700	112 000	5
Pe 3		23 875	11 7525	96 575	50 500	261 000	10
	Haplic Phaeozems 70	16 713	11 7525	67 025	50 500	228 375	5
	Chromic Phaeozems (30)	7 163	11 7525	143 475	50 500	261 000	5
Valleys (Va) (<200)							
Va 1		91 625	69 250	51 935	-7 125	129 750	10
	Eutric Regosols (50)	45 813	46 170	51 935	-7 125	103 800	5
	Luvic Phaeozems (50)	45 813	92 35	51 935	40 400	129 750	5
Va 2		57 500	82 940	26 500	61 400	134 000	10
	Gleyic Fluvisols (50)	28 750	74 645	13 245	61 400	123 695	5
	Pachic Phaeozems (50)	28 750	71 235	2 160	69 075	134 000	5

Table 9a: Farmers' reported Gross Margin for smallholder low input rainfed maize based on AEZs

AEZ (Altit. m)	AEZ SUBUNIT (Area %)	AREA (ha)	Average (Tshs/ha)	STDev (Tshs/ha)	Minimum (Tshs/ha)	Maximum (Tshs/ha)	No. Obs.
AEZ II		42 779	132 188	62 732	62 500	216 250	17
(500-800)	Rhodic Luvisols (20)	8 556	103 862	33 549	70 313	207 600	5
	Profondic Luvisols (30)	12 833	160 514	55 736	78 125	216 250	5
	Profondic Lixisols (60)	21 390	132 188	49 462	62 500	181 650	7
AEZ III		78 261	92 425	71 685	-2 750	192 500	22
(400-500)	Profondic Acrisols (10)	7 827	65 240	42 569	59 500	107 800	5
	Rhodic Ferralsols (15)	11 739	10 8735	83 765	85 300	192 500	5
	Sodic Cambisols (15)	11 739	97 860	92 375	-2 750	184 800	5
	Orthidystric Cambisols (20)	15 652	76 115	101 940	62 350	184 800	5
	Chromic Phaeozems (20)	15 652	119 610	85 585	68 500	161 700	5
	Profondic Lixisols (20)	15 652	108 735	72 890	94 850	192 500	7
AEZ IV		57 818	310 125	166 085	-19 750	605 000	42
(100-200)	Gleyic Fluvisols (35)	22 236	320 460	190 430	130 030	510 890	5
	Pachic Phaeozems (35)	22 236	258 440	278 190	19 750	510 890	5
	Profondic Lixisols (5)	2 891	310 125	214 210	95 915	524 335	7
	Fluvic Cambisols (5)	2 891	351 475	253 525	97 950	605 000	5
	Eutric Regosols (5)	2 891	372 150	232 850	139 300	605 000	5
	Gleyic Cambisols (5)	2 891	248 100	222 455	-19 750	470 555	5
	Chromic Phaeozems (5)	2 891	310 125	214 210	184 800	510 890	5
	Profondic Lixisols (5)	2 891	310 125	214 210	115 500	470 555	5
AEZ V		136 848	294 525	143 671	117 750	649 250	32
(200-400)	Profondic Lixisols (25)	34 212	307 330	254 900	133 450	562 300	7
	Fluvic Cambisols (25)	34 212	371 360	259 100	172 700	630 460	5
	Ferralic Cambisols (15)	20 527	210 300	147 530	117 750	357 830	5
	Ferralic Cambisols (15)	20 527	294 525	233 700	117 750	528 225	5
	Eutric Regosols (10)	13 685	345 780	301 720	125 600	649 250	5
	Luvic Phaeozems (10)	13 685	231 25	110 290	133 450	340 790	5
AEZ VI		29 782	228 450	123 93	34 250	348 000	20
(100-200)	Eutric Regosols (50)	14 891	194 605	153 505	41 100	302 210	5
	Gleyic Cambisols (30)	8 935	262 294	85 705	78 775	348 000	5
	Chromic Phaeozems (5)	1 489	270 755	68 090	85 625	338 845	5
	Haplic Phaeozems (15)	4 467	186 145	116 065	34 250	302 210	5
AEZ VII		63 776	298 150	149 395	38 000	644 500	20
(100-200)	Eutric Regosols (45)	28 699	322 000	265 000	57 000	610 580	5
	Luvic Phaeozems (45)	28 699	202 740	272 155	38 000	474 895	5
	Chromic Phaeozems (5)	3 189	357 780	269 760	87 400	627 540	5
	Haplic Phaeozems (5)	3 189	310 075	249 270	60 800	644 500	5
AEZ IX		15 519	228 450	123 693	34 250	348 000	10
<200	Haplic Phaeozems (50)	7 760	203 065	136 060	34 250	320 525	5
	Chromic Phaeozems (50)	7 760	253 830	86 585	78 775	348 000	5

Table 9b: Farmers' reported Gross Margin for smallholder low input rainfed paddy based on AEZs

AEZ (Altit. m)	AEZ SUBUNIT (Area %)	AREA (ha)	Average (Tshs/ha)	STDev (Tshs/ha)	Minim-um (Tshs/ha)	Maxim-um (Tshs/ha)	No. Obs
AEZ II		42 779	50 500	35 616	10 500	79 250	17
(500-800)	Rhodic Luvisols (20)	8 556	55 550	38 750	16 800	73 153	5
	Profondic Luvisols (30)	12 833	55 550	45 050	10 500	79 250	5
	Profondic Lixisols (60)	21 390	40 400	32 753	12 600	73 153	7
AEZ III		78 261	11 7500	97 779	-16 500	168 500	22
(400-500)	Profondic Acrisols (10)	7 827	127 290	37 170	96 880	162 885	5
	Rhodic Ferralsols (15)	11 739	107 710	60 995	98 880	168 500	5
	Sodic Cambisols (15)	11 739	102 810	137 175	-16 500	140 420	5
	Orthidystric Cambisols (20)	15 652	122 400	38 540	90 850	134 800	5
	Chromic Phaeozems (20)	15 652	137 090	15 180	122 400	157 270	5
	Profondic Lixisols (20)	15 652	107 710	60 970	95 820	168 500	7
AEZ IV		57 818	528 938	75 766	388 750	752 500	42
(100-200)	Gleyic Fluvisols (35)	22 236	506 900	35 595	409 210	633 055	5
	Pachic Phaeozems (35)	22 236	5289 40	36 310	409 210	668 890	5
	Profondic Lixisols (5)	2 891	495 880	124 210	388 750	633 055	7
	Fluvic Cambisols (5)	2 891	573 960	31 990	398 980	752 500	5
	Eutric Regosols (5)	2 891	528 940	34 870	388 750	680 835	5
	Gleyic Cambisols (5)	2 891	562 700	31 410	419 440	716 670	5
	Chromic Phaeozems (5)	2 891	528 940	130 940	409 210	673 750	5
	Profondic Lixisols (5)	2 891	528 940	120 190	409 210	743 500	5
AEZ V		136 848	247 400	178 621	39 500	673 750	32
(200-400)	Profondic Lixisols (25)	34 212	262 395	171 545	90 850	619 850	7
	Fluvic Cambisols (25)	34 212	224 910	145 910	79 000	606 375	5
	Ferralic Cambisols (15)	20 527	284 885	174 285	110 600	673 750	5
	Ferralic Cambisols (15)	20 527	269 890	179 040	90 850	619 850	5
	Eutric Regosols (10)	13 685	209 915	170 415	39 500	539 000	5
	Luvic Phaeozems (10)	13 685	232 410	161 310	71 100	606 375	5
AEZ VI		29 782	213 825	76 914	86 000	298 125	20
(100-200)	Eutric Regosols (50)	14 891	213 825	64 425	107 500	278 250	5
	Gleyic Cambisols (30)	8 935	231 645	66 480	107 500	298 125	5
	Chromic Phaeozems (5)	1 489	196 005	62 370	86 000	258 375	5
	Haplic Phaeozems (15)	4 467	213 825	64 425	96 750	278 250	5
AEZ VII		63 776	257 563	160 217	61 000	695 625	20
(100-200)	Eutric Regosols (45)	28 699	463 610	232 015	183 000	695 625	5
	Luvic Phaeozems (45)	28 699	231 805	185 570	61 000	417 375	5
	Chromic Phaeozems (5)	3 189	151 540	179 360	76 250	333 900	5
	Haplic Phaeozems (5)	3 189	180 295	111 670	68 625	250 425	5
AEZ IX		15 519	213 825	76 914	86 000	298 125	10
(<200)	Haplic Phaeozems (50)	7 760	213 825	81 300	86 000	298 125	5
	Chromic Phaeozems (50)	7 760	213 000	65 250	96 750	278 250	5

Table 9c: Farmers' reported Gross Margin for smallholder low input rainfed sesame based on AEZs

AEZ (Altitude m)	AEZ SUBUNIT (Area %)	AREA (ha)	Average (Tshs/ha)	STD (Tshs/ha)	Minimum (Tshs/ha)	Maximum (Tshs/ha)	No. Obs
AEZ II		42 779	82 940	26 500	61 400	134 000	17
(500-800)	Rhodic Luvisols (20)	8 556	74 650	38 735	61 400	113 385	5
	Profondic Luvisols (30)	12 833	91 230	22 160	69 075	134 000	5
	Profondic Lixisols (60)	21 390	82 945	38 735	61 400	123 695	7
AEZ III		78 261	20 708	41 022	-60 750	88 750	22
(400-500)	Profondic Acrisols (10)	7 827	24 850	55 025	16 000	79 875	5
	Rhodic Ferralsols (15)	11 739	16 570	72 330	-60 750	71 000	5
	Sodic Cambisols (15)	11 739	24 850	63 900	20 050	88 750	5
	Orthidystric Cambisols (20)	15 652	20 710	50 000	15 500	71 000	5
	Chromic Phaeozems (20)	15 652	24 850	63 900	225 000	88 750	5
	Profondic Lixisols (20)	15 652	8 040	45 210	-37 170	53 250	7
AEZ IV		57 818	117 525	96 574	50 500	261 000	42
(100-200)	Gleyic Fluvisols (35)	22 236	117 525	78 225	50 500	195 50	5
	Pachic Phaeozems (35)	22 236	117 525	67 025	50 500	228 375	5
	Profondic Lixisols (5)	2 891	146 910	62 736	84 170	261 000	7
	Fluvic Cambisols (5)	2 891	117 525	67 025	50 500	261 000	5
	Eutric Regosols (5)	2 891	110 175	42 770	76 750	228 375	5
	Gleyic Cambisols (5)	2 891	117 525	51 480	76 750	237 800	5
	Chromic Phaeozems (5)	2 891	117 525	47 190	61 400	223 575	5
	Profondic Lixisols (5)	2 891	102 900	88 200	69 075	190 740	5
AEZ V		136 848	64 875	26 797	1 875	108 000	32
(200-400)	Profondic Lixisols (25)	34 212	51 900	50 025	1 875	86 400	7
	Fluvic Cambisols (25)	34 212	64 875	61 125	3 750	75 600	5
	Ferralic Cambisols (15)	20 527	64 875	59 250	5 625	97 200	5
	Ferralic Cambisols (15)	20 527	51 900	50 025	1 875	64 800	5
	Eutric Regosols (10)	13 685	90825	81450	9375	108 000	5
	Luvic Phaeozems (10)	13 685	51 900	48 150	3 750	75 600	5
AEZ VI		29 782	178 500	97 620	57 250	297 250	20
(100-200)	Eutric Regosols (50)	14 891	158 670	89 970	68 700	237 800	5
	Gleyic Cambisols (30)	8 935	17 8500	98 930	117 250	277 430	5
	Chromic Phaeozems (5)	1 489	198 330	98 920	140 150	297 250	5
	Haplic Phaeozems (15)	4 467	198 330	68 300	131 210	261 000	5
AEZ VII		63 776	93 390	68 953	-7 125	261 000	20
(100-200)	Eutric Regosols (45)	28 699	70 040	77 165	-7 125	163 125	5
	Luvic Phaeozems (45)	28 699	70 040	77 165	-7 125	130 500	5
	Chromic Phaeozems (5)	3 189	140 080	79 620	60 460	261 000	5
	Haplic Phaeozems (5)	3 189	93 390	42 207	51 181	195 750	5
AEZ IX		15 519	117 525	96 574	50 500	261 000	10
(<200)	Haplic Phaeozems (50)	7 760	117 525	67 025	50 500	195 750	5
	Chromic Phaeozems (50)	7 760	116 500	66 000	50 500	261 000	5

4.3 Land suitability classification

4.3.1 Physical land suitability classification

4.3.1.1 Physical land suitability classification for the studied LMUs

Tables 10a, 10b and 10c show summaries of results of physical land suitability classification and predicted yields for the tested LUTs in the selected LMUs.

Table 10a shows that some parts of land mapping units MO22 (35%), Pe3 (30%), Va1 (50%) and Va2 (50%) had maize yield predictions of 2.64 t ha^{-1}. These areas are moderately suitable (S2) for maize production due to moderate limitations of moisture availability, nutrient availability, nutrient retention, rooting conditions, oxygen availability and erosion hazards. Land mapping unit Pi2 and parts of land mapping units Pe 1 (55%), Pe3 (70%), Va1 (50%) and Va2 (50%) had maize yield prediction of 1.32 t ha^{-1}, and are classified as marginally suitable (S3) for maize production due to severe limitations of nutrient availability, rooting condition, nutrient retention, and oxygen availability. The rest of the area including land mapping units MO21 and parts of land mapping units MO22 (65%) and Pe1 (55%) had zero yield predictions, and they were physically classified as not suitable (N) for maize production due to very severe limitations of erosion hazards, nutrient retention and nutrient availability.

Table 10a: Physical land suitability classification and predicted yields of the studied LMUs for smallholder low input rainfed maize

LMU (Altitudes m)	LMU Subunit (%)	Area (ha)	Suitability Class[§]	Predicted Yield (t/ha)
Mountains (MO) (>500)				
MO 21		21 313	N	0.00
	Rhpodic Luvisols (40)	8 525	Ner	0.00
	Profondic Luvisols (60)	12 788	Ner	0.00
MO 22		24 719	N & S2	0.92
	Chromic Phaeozems (35)	8 652	S2m/na/nr/rc	2.64
	Profondic Lixisols (65)	16 067	Ner	0.00
Piedmonts (Pi) (400-500)				
Pi 2		22 688	S3	1.32
	Sodic Cambisols (60)	13 613	S3rc	1.32
	Orthidystric Cambisols (40)	9 075	S3na/nr	1.32
Peneplains (Pe) (200-400)				
Pe 1		36 063	N &S3	0.59
	Ferralic Cambisols (55)	19 835	Nna	0.00
	Ferralic Cambisols (45)	16 228	S3na/nr/rc	1.32
Pe 3		23 875	S3 & S2	1.72
	Haplic Phaeozems (70)	16 713	S3na	1.32
	Chromic Phaeozems (30)	7 163	S2er/na/nr/rc	2.64
Valleys (Va) (<200)				
Va 1		91 625	S2 & S3	1.98
	Eutric Regosols (50)	45 813	S2o/rc	2.64
	Luvic Phaeozems (50)	45 813	S3na	1.32
Va 2		57 500	S2 & S3	1.98
	Gleyic Fluvisols (50)	28 750	S3o	1.32
	Pachic Phaeozems (50)	28 750	S2na/nr/o/rc	2.64

[§] Suitability classes: S1 = Highly suitable, S2 = Moderately suitable, S3 = Marginally suitable, N = Not suitable,

Limitations: er = Erosion hazards, m = moisture availability, na = nutrient availability, nr = nutrient retention, rc = rooting conditions, o = oxygen availability, tr = temperature regime

Table 10b shows that some parts of LMU Va1 (50%) had 4.0 t ha^{-1} of rainfed paddy yield prediction. These areas were classified as highly suitable (S1) for paddy production. Land mapping unit Va2 and some parts of land mapping unit Pe1 (55%) had 3.2 t ha^{-1} paddy yields prediction. These areas were classified as moderately suitable (S2) for paddy production due to moderate limitations of nutrient availability, nutrient retention, rooting condition, erosion hazards and oxygen availability. About 45% of LMU Pe1 had 1.6 t ha^{-1} paddy yield predictions, and the area classified as marginally suitable (S3) for this LUT due to severe limitation of nutrient retention. The remaining parts of land mapping units MO21, MO22, Pi2, and Pe3 had zero yields prediction for paddy. These areas were classified as physically not suitable (N) for paddy cultivation due to very severe limitations of erosion hazards, oxygen availability, nutrient availability and nutrient retention.

Table 10c indicates that about 30% of LMU Pe3 had 0.8 t ha^{-1} yield predictions for sesame. This area was classified as moderately suitable (S2) for sesame production due to moderate limitations of nutrient availability and nutrient retention. Land mapping units MO21, MO22, Pi2 and some parts of Pe1 (45%), Pe3 (70%), Va1 (50%) and Va2 (50%) had 0.4 t ha^{-1} yield predictions for sesame. These areas were classified as marginally suitable (S3) for this LUT due to severe limitations of erosion hazards, nutrient availability, rooting conditions, nutrient retention and oxygen availability to root zones. The remaining parts of LMUs Va1 (50%) and Va2 (50%) had zero yield predictions for sesame, and they were classified as not suitable (N) for sesame production due to very severe limitation of oxygen availability in the root zones.

Table 10b: Physical land suitability classification and predicted yields of the studied LMUs for smallholder low input rainfed paddy

LMU (Altitudes m)	LMU Subunit (%)	Area (ha)	Suitability Class[$]	Predicted Yield (t/ha)
Mountains (MO) (>500)				
MO 21		21 313	N	0.00
	Rhpodic Luvisols (40)	8 525	Ner/o	0.00
	Profondic Luvisols (60)	12 788	Ner/o	0.00
MO 22		24 719	N	0.00
	Chromic Phaeozems (35)	8 652	No	0.00
	Profondic Lixisols (65)	16 067	Ner/o	0.00
Piedmonts (Pi) (400-500)				
Pi 2		22 688	N	0.00
	Sodic Cambisols (60)	13 613	Ner/o	0.00
	Orthidystric Cambisols (40)	9 075	No	0.00
Peneplains (Pe) (200-400)				
Pe 1		36 063	S3 & S2	2.19
	Ferralic Cambisols (55)	19 835	S2nr/o	3.20
	Ferralic Cambisols (45)	16 228	S3 nr	1.60
Pe 3		23 875	N	0.00
	Haplic Phaeozems (70)	16 713	No	0.00
	Chromic Phaeozems (30)	7 163	No	0.00
Valleys (Va) (<200)				
Va 1		91 625	S1 & N	2.00
	Eutric Regosols (50)	45 813	S1	4.00
	Luvic Phaeozems (50)	45 813	Nna/o	0.00
Va 2		57 500	S2	3.20
	Gleyic Fluvisols (50)	28 750	S2er/na/rc	3.20
	Pachic Phaeozems (50)	28 750	S2na/nr/rc	3.20

[$] Suitability classes: S1 = Highly suitable, S2 = Moderately suitable, S3 = Marginally suitable, N = Not suitable,

Limitations: er = Erosion hazards, m = moisture availability, na = nutrient availability, nr = nutrient retention, rc = rooting conditions, o = oxygen availability, tr = temperature regime

Table 10c: Physical land suitability classification and predicted yields of the studied LMUs for smallholder low input rainfed sesame

LMU (Altitudes m)	LMU Subunit (%)	Area (ha)	Suitability Class[§]	Predicted Yield (t/ha)
Mountains (MO) (>500)				
MO 21		21 313	S3	0.40
	Rhpodic Luvisols (40)	8 525	S3er/na	0.40
	Profondic Luvisols (60)	12 788	S3er	0.40
MO 22		24 719	S3	0.40
	Chromic Phaeozems (35)	8 652	S3nr	0.40
	Profondic Lixisols (65)	16 067	S3er/na	0.40
Piedmonts (Pi) (400-500)				
Pi 2		22 688	S3	0.40
	Sodic Cambisols (60)	13 613	S3rc	0.40
	Orthidystric Cambisols (40)	9 075	S3na/nr	0.40
Peneplains (Pe) (200-400)				
Pe 1		36 063	N & S3	0.18
	Ferralic Cambisols (55)	19 835	Nna	0.00
	Ferralic Cambisols (45)	16 228	S3na/nr/rc	0.40
Pe 3		23 875	S3 & S2	0.52
	Haplic Phaeozems (70)	16 713	S3na	0.40
	Chromic Phaeozems (30)	7 163	S2na/nr	0.80
Valleys (Va) (<200)				
Va 1		91 625	S3 & N	0.20
	Eutric Regosols (50)	45 813	No	0.00
	Luvic Phaeozems (50)	45 813	S3na	0.40
Va 2		57 500	S3 & N	0.20
	Gleyic Fluvisols (50)	28 750	No	0.00
	Pachic Phaeozems (50)	28 750	S3o	0.40

[§] Suitability classes: S1 = Highly suitable, S2 = Moderately suitable, S3 = Marginally suitable, N = Not suitable,

Limitations: er = Erosion hazards, m = moisture availability, na = nutrient availability, nr = nutrient retention, rc = rooting conditions, o = oxygen availability, tr = temperature regime

4.3.1.2 Physical land suitability classification for the surveyed AEZs

Tables Table 11a, 11b and 11c show summaries of results of physical land suitability classification and predicted yields for the tested LUTs in the selected AEZs.

Table 11a shows that in the study area some parts of agro-ecological zones III (20%), IV (50%), V (35%), VI (35%), VII (5%) and AEZ IX (50%) had maize yields predictions of 2.8 t ha^{-1}. These areas were classified as moderately suitable (S2) for maize production due to moderate limitations of nutrient availability, nutrient retention, rooting conditions, oxygen availability, moisture availability and erosion hazards. Areas covering parts of AEZ III (45%), AEZ IV (45%), AEZ V (40%), AEZ VI (65%), AEZ VII (50%) and AEZ IX (50%) gave maize yield prediction of 1.4 t ha^{-1} and they were classified as marginally suitable (S3) for maize production due to severe limitations of nutrient availability, rooting condition, nutrient retention, and oxygen availability. The remaining AEZs i.e AEZ II and parts of AEZ III (35%), AEZ IV (5%), AEZ V (25%) and AEZ VII (45%) had zero yield prediction for maize, and they were therefore classified as physically not suitable (N) for this LUT due to very severe limitations of erosion hazards, nutrient retention and nutrient availability.

Table 11a: Physical land suitability classification and predicted yields of the studied AEZs for smallholder low input rainfed maize

AEZ (Altitudes m)	AEZ Subunit (%)	Area (ha)	Suitability Class[$]	ALES Predicted yield (t/ha)
AEZ II		42 779	N	0.00
(500-800)	Rhodic Luvisols (20)	85 56	Ner	0.00
	Profondic Luvisols (30)	12 833	Ner	0.00
	Profondic Lixisols (60)	21 390	Ner	0.00
AEZ III		78 261	S2, S3 & N	1.19
(400-500)	Profondic Acrisols (10)	7 827	S3na/rc	1.40
	Rhodic Ferralsols (15)	11 739	Nnr	0.00
	Sodic Cambisols (15)	11 739	S3rc	1.40
	OrthidystricCambisols (20)	15 652	S3na/nr	1.40
	Chromic Phaeozems (20)	15 652	S2na/rc	2.80
	Profondic Lixisols (20)	15 652	Ner	0.00
AEZ IV		57 818	S2, S3 & N	2.03
(100-200)	Gleyic Fluvisols (35)	22 236	S3o	1.40
	Pachic Phaeozems (35)	22 236	S2na/nr/o/rc	2.80
	Profondic Lixisols (5)	2 891	S3na	1.40
	Fluvic Cambisols (5)	2 891	S2er/na/nr/rc	2.80
	Eutric Regosols (5)	2 891	S3na	1.40
	Gleyic Cambisols (5)	2 891	S2nr/o.rc	2.80
	Chromic Phaeozems (5)	2 891	S2na/nr/rc	2.80
	Profondic Lixisols (5)	2 891	Ner	0.00
AEZ V		136 848	S2, S3 & N	1.54
(200-400)	Profondic Lixisols (25)	34 212	S3na	1.40
	Fluvic Cambisols (25)	34 212	S2er/na/nr/rc	2.80
	Ferralic Cambisols (15)	20 527	Nna	0.00
	Ferralic Cambisols (15)	20 527	S3na/nr/rc	1.40
	Eutric Regosols (10)	13 685	S2rc	2.80
	Luvic Phaeozems (10)	13 685	Nna	0.00
AEZ VI		29 782	S3 & S2	1.89
(100-200)	Eutric Regosols (50)	14 891	S3na	1.40
	Gleyic Cambisols (30)	8 935	S2m/nr/o/rc	2.80
	Chromic Phaeozems (5)	1 489	S2er/na/nr/rc	2.80
	Haplic Phaeozems (15)	4 467	S3na	1.40
AEZ VII		63 776	S3, N & S2	0.84
(100-200)	Eutric Regosols (45)	28 699	S3rc	1.40
	Luvic Phaeozems (45)	28 699	Nna	0.00
	Chromic Phaeozems (5)	3 189	S2er/na/nr/rc	2.80
	Haplic Phaeozems (5)	3 189	S3na	1.40
AEZ IX		15 519	S2 & S3	2.10
(<200)	Haplic Phaeozems (50)	7 760	S3na	1.40
	Chromic Phaeozems (50)	7 760	S2er/na/nr/rc	2.80

[$] Suitability classes: S1 = Highly suitable, S2 = Moderately suitable, S3 = Marginally suitable, N = Not suitable,

Limitations: er = Erosion hazards, m = moisture availability, na = nutrient availability, nr = nutrient retention, rc = rooting conditions, o = oxygen availability, tr = temperature regime

Table 11b shows that some parts of AEZ VII (45%) had 3.4 t ha^{-1} paddy yield prediction, and it was classified as highly suitable (S1) for paddy production. AEZ IV (75%) had 2.72 t ha^{-1} paddy yield prediction, and it was classified as moderately suitable (S2) for this LUT due to moderate limitations of erosion hazards. nutrient availability, nutrient retention, rooting condition and oxygen availability. About 5% of AEZ IV and 80% of AEZ VI had 1.36 t ha^{-1} paddy yield predictions. and they were classified as marginally suitable (S3) for this LUT due to severe limitation of nutrient retention. The remaining AEZ II, AEZ III, AEZ V, AEZ IX and parts of AEZ IV (20%), AEZ VI (20%) and AEZ VII (55%) had zero yields prediction for paddy. These areas were classified as not physically suitable (N) for paddy cultivation due to very severe limitations of erosion hazards, oxygen availability, nutrient retention and nutrient availability.

Table 11c shows that about 5% of AEZ IV, 35% of AEZ V, 5% of AEZ VI, 5% of AEZ VII and 50% of AEZ IX had 0.8 t ha^{-1} yield prediction for sesame. These LMUs were classified as moderately suitable (S2) for sesame production due to moderate limitations of nutrient availability and nutrient retention. Some parts of AEZ III (65%), AEZ IV (55%), AEZ V (40%), AEZ VI (95%), AEZ VII (5%) and AEZ IX (50%) had 0.4 t ha^{-1} sesame yield predictions, and they were classified as marginally suitable (S3) for this LUT due to severe limitations of erosion hazards, nutrient availability, nutrient retention, rooting conditions, and oxygen availability to root zones. The remaining AEZ II and parts of AEZ III (35%), AEZ IV (40%), AEZ V (35%) and AEZ VII (45%) had zero yield predictions for sesame, and they were classified as not suitable (N) for sesame production due to very severe limitation of erosion hazards, nutrient retention, oxygen availability to root zones and nutrient availability.

Table 11b: Physical land suitability classification and predicted yields of the studied AEZs for smallholder low input rainfed paddy

AEZ (Altitudes m)	AEZ Subunit (%)	Area (ha)	Suitability Class[§]	ALES Predicted yield (t/ha)
AEZ II		42 779	N	0.00
(500-800)	Rhodic Luvisols (20)	8 556	Ner/o	0.00
	Profondic Luvisols (30)	12 833	Ner	0.00
	Profondic Lixisols (60)	21 390	Ner/o	0.00
AEZ III		78 261	N	0.00
(400-500)	Profondic Acrisols (10)	7 827	No	0.00
	Rhodic Ferralsols (15)	11 739	Ner/nr/o	0.00
	Sodic Cambisols (15)	11 739	Ner/o	0.00
	OrthidystricCambisols (20)	15 652	No	0.00
	Chromic Phaeozems (20)	15 652	No	0.00
	Profondic Lixisols (20)	15 652	Ner/o	0.00
AEZ IV		57 818	S2 & N	2.11
(100-200)	Gleyic Fluvisols (35)	22 236	S2er/na/rc	2.72
	Pachic Phaeozems (35)	22 236	S2na/nr/o/rc	2.72
	Profondic Lixisols (5)	2 891	No	0.00
	Fluvic Cambisols (5)	2 891	No	0.00
	Eutric Regosols (5)	2 891	S3nr	1.36
	Gleyic Cambisols (5)	2 891	S2nr/o	2.72
	Chromic Phaeozems (5)	2 891	No	0.00
	Profondic Lixisols (5)	2 891	Ner/o	0.00
AEZ V		136 848	N	0.00
(200-400)	Profondic Lixisols (25)	34 212	No	0.00
	Fluvic Cambisols (25)	34 212	No	0.00
	Ferralic Cambisols (15)	20 527	Nna/o	0.00
	Ferralic Cambisols (15)	20 527	Ner/o	0.00
	Eutric Regosols (10)	13 685	No	0.00
	Luvic Phaeozems (10)	13 685	Nna/o	0.00
AEZ VI		29 782	S3 & N	1.09
(100-200)	Eutric Regosols (50)	14 891	S3nr	1.36
	Gleyic Cambisols (30)	8 935	S3nr	1.36
	Chromic Phaeozems (5)	1 489	No	0.00
	Haplic Phaeozems (15)	4 467	No	0.00
AEZ VII		63 776	S1& N	1.53
(100-200)	Eutric Regosols (45)	28 699	S1	3.40
	Luvic Phaeozems (45)	28 699	Nna/o	0.00
	Chromic Phaeozems (5)	3 189	No	0.00
	Haplic Phaeozems (5)	3 189	No	0.00
AEZ IX		15 519	N	0.00
(<200)	Haplic Phaeozems (50)	7 760	No	0.00
	Chromic Phaeozems (50)	7 760	No	0.00

[§] Suitability classes: S1 = Highly suitable,
S2 = Moderately suitable,
S3 = Marginally suitable,
N = Not suitable,
Limitations: er = Erosion hazards, m = moisture availability, na = nutrient availability, nr = nutrient retention, rc = rooting conditions, o = oxygen availability, tr = temperature regime

Table 11c: Physical land suitability classification and predicted yields of the studied AEZs for smallholder low input rainfed sesame

AEZ (Altitudes m)	AEZ Subunit (%)	Area (ha)	Suitability Class[§]	ALES Predicted yield (t/ha)
AEZ II		42 779	N	0.00
(500-800)	Rhodic Luvisols (20)	8 556	Ner	0.00
	Profondic Luvisols (30)	12 833	Ner	0.00
	Profondic Lixisols (60)	21 390	Ner	0.00
AEZ III		78 261	S3 & N	0.26
(400-500)	Profondic Acrisols (10)	7 827	S3 na	0.40
	Rhodic Ferralsols (15)	11 739	N nr	0.00
	Sodic Cambisols (15)	11 739	S3rc	0.40
	OrthidystricCambisols (20)	15 652	S3na/nr	0.40
	Chromic Phaeozems (20)	15 652	S3nr	0.40
	Profondic Lixisols (20)	15 652	Ner	0.00
AEZ IV		57 818	N, S3 & S2	0.26
(100-200)	Gleyic Fluvisols (35)	22 236	N o	0.00
	Pachic Phaeozems (35)	22 236	S3o	0.40
	Profondic Lixisols (5)	2 891	S3na	0.40
	Fluvic Cambisols (5)	2 891	2na/nr	0.80
	Eutric Regosols (5)	2 891	S3 na/o	0.40
	Gleyic Cambisols (5)	2 891	S3 o	0.40
	Chromic Phaeozems (5)	2 891	3 nr	0.40
	Profondic Lixisols (5)	2 891	N er	0.00
AEZ V		136 848	S2, S3 & N	0.44
(200-400)	Profondic Lixisols (25)	34 212	S3na	0.40
	Fluvic Cambisols (25)	34 212	S2na/nr	0.80
	Ferralic Cambisols (15)	20 527	Nna	0.00
	Ferralic Cambisols (15)	20 527	S3na/nr/rc	0.40
	Eutric Regosols (10)	13 685	S2nr	0.80
	Luvic Phaeozems (10)	13 685	Nna	0.00
AEZ VI		29 782	S3 & S2	0.42
(100-200)	Eutric Regosols (50)	14 891	S3na/o	0.40
	Gleyic Cambisols (30)	8 935	S3o	0.40
	Chromic Phaeozems (5)	1 489	S2na/nr	0.80
	Haplic Phaeozems (15)	4 467	S3na	0.40
AEZ VII		63 776	N, S3 & S2	0.06
(100-200)	Eutric Regosols (45)	28 699	No	0.00
	Luvic Phaeozems (45)	28 699	Nna	0.00
	Chromic Phaeozems (5)	3 189	S2na/nr	0.80
	Haplic Phaeozems (5)	3 189	S3na	0.40
AEZ IX		15 519	S2 & S3	0.60
(<200)	Haplic Phaeozems (50)	7 760	S3na	0.40
	Chromic Phaeozems (50)	7 760	S3na/nr	0.80

[§] Suitability classes: S1 = Highly suitable,
S2 = Moderately suitable,
S3 = Marginally suitable,
N = Not suitable,
Limitations: er = Erosion hazards, m = moisture availability, na = nutrient availability, nr = nutrient retention, rc = rooting conditions, o = oxygen availability, tr = temperature regime

4.3.2 Agro-economic land suitability classification

4.3.2.1 Agro-economic land suitability classification of the studied LMUs

The results of Agro-economic land suitability classification and predicted Gross Margins based of the studied LMUs for the selected LUTs are summarized in Tables 12a, 12b and 12c.

Table 12a shows that some parts of land mapping units MO22 (35%), Pe3 (30%), Va1 (50%) and Va2 (50%) had 293 090 Tshs ha^{-1} Gross margins (GM) predictions for maize, and therefore they were classified as agro economically moderately suitable (S2) for maize production due to moderate economic limitations. Land mapping unit Pi2 and parts of Pe 1 (45%), Pe3 (70%), Va1 (50%) and Va2 (50%) had 78 945 Tshs ha^{-1} GM predictions for maize, and were classified as agro-economically marginally suitable (S3) for maize production due to severe economic limitations. The rest of the area including land mapping unit MO21 and parts of MO22 (65%) and Pe1 (55%) had zero GM prediction for maize, and were classified as agro-economically not suitable (N) for this LUT due to very severe physical factors related to characteristics of the environment.

Table 12a: Agro-economic land suitability classification and predicted Gross margins of the studied LMUs for smallholder low input rainfed maize

LMU (Altitudes m)	LMU Subunit (%)	Area (ha)	Suitability Class[§]	Predicted GM (Tshs/ha)
Mountains (MO) (>500)				
MO 21		21 313	N1	0
	Rhpodic Luvisols (40)	8 525	N2	0
	Profondic Luvisols (60)	12 788	N2	0
MO 22		24 719	S3	102 580
	Chromic Phaeozems (35)	8 652	S2	293 090
	Profondic Lixisols (65)	16 067	N2	0
Piedmonts (Pi) (400-500)				
Pi 2		22 688	S3	78 945
	Sodic Cambisols (60)	13 613	S3	78 945
	Orthidystric Cambisols (40)	9 075	S3	78 945
Peneplains (Pe) (200-400)				
Pe 1		36 063	N1	35 525
	Ferralic Cambisols (55)	19 835	N2	0
	Ferralic Cambisols (45)	16 228	S3	78 945
Pe 3		23 875	S3	143 190
	Haplic Phaeozems (70)	16 713	S3	78 945
	Chromic Phaeozems (30)	7 163	S2	293 090
Valleys (Va) (<200)				
Va 1		91 625	S2	186 015
	Eutric Regosols (50)	45 813	S2	293 090
	Luvic Phaeozems (50)	45 813	S3	78 9459
Va 2		57 500	S2	186 015
	Gleyic Fluvisols (50)	28 750	S3	78 945
	Pachic Phaeozems (50)	28 750	S2	293 090

[§] Suitability classes: S1 = Highly suitable
S2 = Moderately suitable
S3 = Marginally suitable
N1 = Not suitable, due to agro-economic factors
N2 = Not suitable due to physical factors

Table 12b shows that some parts of LMU Va1 (50%) had 447 520 Tshs ha^{-1} GM predictions for paddy, and they are classified as agro-economically highly suitable (S1) for paddy production. Land mapping unit Va2 and some parts of land mapping unit Pe1 (55%) had 319 015 Tshs ha^{-1} GM predictions for paddy, and they were classified as moderately suitable (S2) for this LUT due to moderate economic limitations. About 45% of LMU Pe1 had 62 010 Tshs ha^{-1} GM predictions, and it was classified as agro-economically not suitable (N1) for this LUT due to very severe economic limitations. The remaining LMUs MO21, MO22, Pi2, Pe3 and parts of land mapping unit Va1 (50%) had 0 Tshs GM prediction for paddy, and were therefore classified as Agro-economically not suitable (N2) because they are physically not suitable for paddy cultivation.

Table 12c indicates that about 30% of LMU Pe3 had 104 780 Tshs ha^{-1} GM prediction for sesame, and it was classified as moderately suitable (S2) for sesame production due to moderate economical limitations. Land mapping units MO21, MO22, Pi2 and some parts of Pe1 (45%), Pe3 (70%), Va1 (50%) and Va2 (50%) had 7 490 Tshs ha^{-1} GM predictions for sesame, and they were classified as agro-economically not suitable (N1) for this LUT due to very severe economic limitations imposed by severe physical limitations. The remaining parts of LMUs Va1 (50%) and Va2 (50%) had zero GM predictions for sesame, and they were classified as agro-economically not suitable (N2) for sesame production due to very severe physical limitations.

Table 12b: Agro-economicl land suitability classification and predicted Gross margins of the studied LMUs for smallholder low input rainfed paddy

LMU (Altitudes m)	LMU Subunit (%)	Area (ha)	Suitability Class[§]	Predicted GM (Tshs/ha)
Mountains (MO) (>500)				
MO 21		21 313	N 1	0
	Rhpodic Luvisols (40)	8 525	N 2	0
	Profondic Luvisols (60)	12 788	N 2	0
MO 22		24 719	N 1	0
	Chromic Phaeozems (35)	8 652	N 2	0
	Profondic Lixisols (65)	16 067	N 2	0
Piedmonts (Pi) (400-500)				
Pi 2		22 688	N 1	0
	Sodic Cambisols (60)	13 613	N 2	0
	Orthidystric Cambisols (40)	9 075	N 2	0
Peneplains (Pe) (200-400)				
Pe 1		36 063	S 3	151 960
	Ferralic Cambisols (55)	19 835	S 2	319 015
	Ferralic Cambisols (45)	16 228	N 1	62 010
Pe 3		23 875	N 1	0
	Haplic Phaeozems (70)	16 713	N 2	0
	Chromic Phaeozems (30)	7 163	N 2	0
Valleys (Va) (<200)				
Va 1		91 625	S 2	223 760
	Eutric Regosols (50)	45 813	S 1	447 520
	Luvic Phaeozems (50)	45 813	N 2	0
Va 2		57 500	S 2	319 015
	Gleyic Fluvisols (50)	28 750	S 2	319 015
	Pachic Phaeozems (50)	28 750	S 2	319 015

[§] Suitability classes: S1 = Highly suitable
S2 = Moderately suitable
S3 = Marginally suitable
N1 = Not suitable, due to agro-economic factors
N2 = Not suitable due to physical factors

Table 12c: Agro-economic land suitability classification and predicted Gross margins of the studied LMUs for smallholder low input rainfed sesame

LMU (Altitudes m)	LMU Subunit (%)	Area (ha)	Suitability Class[§]	Predicted GM (Tshs/ha)
Mountains (MO) (>500)				
MO 21		21 313	N 1	7 490
	Rhpodic Luvisols (40)	8 525	N 2	7 490
	Profondic Luvisols (60)	12 788	N 2	7 490
MO 22		24 719	N 1	7 490
	Chromic Phaeozems (35)	8 652	N 1	7 490
	Profondic Lixisols (65)	16 067	N 1	7 490
Piedmonts (Pi) (400-500)				
Pi 2		22 688	N 1	7 490
	Sodic Cambisols (60)	13 613	N 1	7 490
	Orthidystric Cambisols (40)	9 075	N 1	7 490
Peneplains (Pe) (200-400)				
Pe 1		36 063	N 1	3 370
	Ferralic Cambisols (55)	19 835	N 2	0
	Ferralic Cambisols (45)	16 228	N 1	7 490
Pe 3		23 875	S 3	36 675
	Haplic Phaeozems (70)	16 713	N 1	7 490
	Chromic Phaeozems (30)	7 163	S 2	104 780
Valleys (Va) (<200)				
Va 1		91 625	N 1	3 745
	Eutric Regosols (50)	45 813	N 2	0
	Luvic Phaeozems (50)	45 813	N 1	7 490
Va 2		57 500	N 1	3 745
	Gleyic Fluvisols (50)	28 750	N 2	0
	Pachic Phaeozems (50)	28 750	N 1	7 490

[§] Suitability classes: S1 = Highly suitable
S2 = Moderately suitable
S3 = Marginally suitable
N1 = Not suitable, due to agro-economic factors
N2 = Not suitable due to physical factors

4.3.2.2 Agro-economic land suitability classification for the surveyed AEZs

The results of land suitability evaluation of the studied AEZs for the selected LUTs are summarized in Tables 13a, 13b and 13c.

Table 13a shows that some parts of agro-ecological zones (AEZ) III (20%), AEZ IV (50%), AEZ V (35%), AEZ VI (35%), AEZ VII (5%) and AEZ (50%) had GM predictions of 321 510 Tshs ha^{-1} for maize and they were therefore classified as agro-economically moderately suitable (S2) for maize production due to moderate economic limitations. Areas covering parts of AEZ III (45%), AEZ IV (45%), AEZ V (40%), AEZ VI (65%), AEZ VII (50%) and AEZ IX (50%) had 96 655 Tshs ha^{-1} GM predictions for maize, and they were classified as marginally suitable (S3) for maize production due to severe economic limitations. The remaining AEZs including AEZ II and parts of AEZ III (35%), AEZ IV (5%), AEZ V (25%) and AEZ (45%) had zero GM prediction for maize, and they were classified as agro-economically not suitable (N2) for this LUT due to very severe physical and economic limitations.

Table 13a: Agro-economic land suitability classification and predicted Gross margins of the studied AEZs for smallholder low input rainfed maize

AEZ (Altitudes m)	AEZ Subunit (%)	Area (ha)	Suitability Class§	Predicted GM (Tshs/ha)
AEZ II		42 779	N1	0
(500-800)	Rhodic Luvisols (20)	8 556	N2	0
	Profondic Luvisols (30)	12 833	N2	0
	Profondic Lixisols (60)	21 390	N2	0
AEZ III		78 261	S3	107 800
(400-500)	Profondic Acrisols (10)	7 827	S3	96 655
	Rhodic Ferralsols (15)	11 739	N2	0
	Sodic Cambisols (15)	11 739	S3	96 655
	OrthidystricCambisols (20)	15 652	S3	96 655
	Chromic Phaeozems (20)	15 652	S2	321 510
	Profondic Lixisols (20)	15 652	N2	0
AEZ IV		57 818	S2	208 114
(100-200)	Gleyic Fluvisols (35)	22 236	S3	96 655
	Pachic Phaeozems (35)	22 236	S2	321 510
	Profondic Lixisols (5)	2 891	S3	96 655
	Fluvic Cambisols (5)	2 891	S2	321 510
	Eutric Regosols (5)	2 891	S3	96 655
	Gleyic Cambisols (5)	2 891	S2	321 510
	Chromic Phaeozems (5)	2 891	S2	321 510
	Profondic Lixisols (5)	2 891	N1	0
AEZ V		136 848	S3	151 190
(200-400)	Profondic Lixisols (25)	34 212	S3	96 655
	Fluvic Cambisols (25)	34 212	S2	321 510
	Ferralic Cambisols (15)	20 527	N2	0
	Ferralic Cambisols (15)	20 527	S3	96 655
	Eutric Regosols (10)	13 685	S2	321 510
	Luvic Phaeozems (10)	13 685	N2	0
AEZ VI		29 782	S2	175 355
(100-200)	Eutric Regosols (50)	14 891	S3	96 655
	Gleyic Cambisols (30)	8 935	S2	321 510
	Chromic Phaeozems (5)	1 489	S2	321 510
	Haplic Phaeozems (15)	4 467	S3	96 655
AEZ VII		63 776	N1	64 405
(100-200)	Eutric Regosols (45)	28 699	S3	96 655
	Luvic Phaeozems (45)	28 699	N2	0
	Chromic Phaeozems (5)	3 189	S2	321 510
	Haplic Phaeozems (5)	3 189	S3	96 655
AEZ IX		15 519	S2	209 080
(<200)	Haplic Phaeozems (50)	7 760	S3	96 655
	Chromic Phaeozems (50)	7 760	S2	321 510

§ Suitability classes: S1 = Highly suitable
S2 = Moderately suitable
S3 = Marginally suitable
N1 = Not suitable, due to agro-economic factors
N2 = Not suitable due to physical factors

Table 13b show that some parts of AEZ VII (45%) had 437 180 Tshs ha^{-1} GM predictions for paddy. These areas were classified as agro economically highly suitable (S1) for paddy production. Some parts of AEZ IV (75%) had 317 045 Tshs ha^{-1} GM prediction for paddy, and they were therefore classified as moderately suitable (S2) for this LUT due to moderate economic limitations. About 5% of AEZ IV and 80% of AEZ VI had 76 770 Tshs ha^{-1} GM predictions for paddy. These areas were classified as agro-economically not suitable (N1) for this LUT due to very severe economic limitations. The remaining AEZ II, AEZ III, AEZ V, AEZ IX and Parts of AEZ IV (20%), AEZ VI (20%) and AEZ VII (55%) had zero GM prediction for paddy, and they were therefore classified as agro-economically not suitable (N2) for paddy cultivation due to very severe limitations of physical environmental factors.

Table 13c show that about 5% of AEZ IV, 35% of AEZ V, 5% of AEZ VI, 5% of AEZ VII and 50% of AEZ IX had 143 770 Tshs ha^{-1} GM predictions for sesame. These areas were classified as moderately suitable (S2) for sesame production due to moderate economic limitations. Other areas including parts of AEZ III (65%), AEZ IV (55%), AEZ V (40%), AEZ VI (95%), AEZ VII (5%) and AEZ IX (50%) had 28 485 Tshs ha^{-1} GM predictions for sesame and they were classified as agro-economically not suitable (N1) for this LUT due to very severe economic limitations. The remaining AEZ II and parts of AEZ III (35%), AEZ IV (40%), AEZ V (35%) and AEZ VII (45%) had zero GM predictions for sesame, and they were therefore classified as Agro-economically not suitable (N2) for sesame production due to very severe economic and physical limitations of the environmental factors.

Table 13b: Agro-economic land suitability classification and predicted Gross margins of the studied AEZs for smallholder low input rainfed paddy

AEZ (Altitudes m)	AEZ Subunit (%)	Area (ha)	Suitability Class[§]	Predicted GM (Tshs/ha)
AEZ II		42 779	N1	0
(500-800)	Rhodic Luvisols (20)	85 56	N2	0
	Profondic Luvisols (30)	12 833	N2	0
	Profondic Lixisols (60)	21390	N2	0
AEZ III		78 261	N1	0
(400-500)	Profondic Acrisols (10)	7 827	N2	0
	Rhodic Ferralsols (15)	11 739	N2	0
	Sodic Cambisols (15)	11 739	N2	0
	OrthidystricCambisols (20)	15 652	N2	0
	Chromic Phaeozems (20)	15 652	N2	0
	Profondic Lixisols (20)	15 652	N2	0
AEZ IV		57 818	S2	241 620
(100-200)	Gleyic Fluvisols (35)	22 236	S2	317 045
	Pachic Phaeozems (35)	22 236	S2	317 045
	Profondic Lixisols (5)	2 891	N2	0
	Fluvic Cambisols (5)	2 891	N2	0
	Eutric Regosols (5)	2 891	N1	76 770
	Gleyic Cambisols (5)	2 891	S2	317 045
	Chromic Phaeozems (5)	2 891	N2	0
	Profondic Lixisols (5)	2 891	N2	0
AEZ V		136 848	N1	0
(200-400)	Profondic Lixisols (25)	34 212	N2	0
	Fluvic Cambisols (25)	34 212	N2	0
	Ferralic Cambisols (15)	20 527	N2	0
	Ferralic Cambisols (15)	20 527	N2	0
	Eutric Regosols (10)	13 685	N2	0
	Luvic Phaeozems (10)	13 685	N2	0
AEZ VI		29 782	N1	61 415
(100-200)	Eutric Regosols (50)	14 891	N1	76 770
	Gleyic Cambisols (30)	8 935	N1	76 770
	Chromic Phaeozems (5)	1 489	N2	0
	Haplic Phaeozems (15)	4 467	N2	0
AEZ VII		63 776	S2	196 730
(100-200)	Eutric Regosols (45)	28 699	S1	437 180
	Luvic Phaeozems (45)	28 699	N2	0
	Chromic Phaeozems (5)	3 189	N2	0
	Haplic Phaeozems (5)	3 189	N2	0
AEZ IX		15 519	N1	0
(<200)	Haplic Phaeozems (50)	7 760	N2	0
	Chromic Phaeozems (50)	7 760	N2	0

[§] Suitability classes: S1 = Highly suitable
S2 = Moderately suitable
S3 = Marginally suitable
N1 = Not suitable, due to agro-economic factors
N2 = Not suitable due to physical factors

Table 13c: Agro-economic land suitability classification and predicted Gross margins of the studied AEZs for smallholder low input rainfed sesame

AEZ (Altitudes m)	AEZ Subunit (%)	Area (ha)	Suitability Class[§]	Predicted GM (Tshs/ha)
AEZ II		42 779	N1	0
(500-800)	Rhodic Luvisols (20)	8 556	N2	0
	Profondic Luvisols (30)	12 833	N2	0
	Profondic Lixisols (60)	21390	N2	0
AEZ III		78 261	N1	18 515
(400-500)	Profondic Acrisols (10)	7 827	N1	28 485
	Rhodic Ferralsols (15)	11 739	N2	0
	Sodic Cambisols (15)	11 739	N1	28 485
	OrthidystricCambisols (20)	15 652	N1	28 485
	Chromic Phaeozems (20)	15 652	N1	28 485
	Profondic Lixisols (20)	15 652	N2	0
AEZ IV		57 818	N1	22 855
(100-200)	Gleyic Fluvisols (35)	22 236	N2	0
	Pachic Phaeozems (35)	22 236	N1	28 485
	Profondic Lixisols (5)	2 891	N1	28 485
	Fluvic Cambisols (5)	2 891	S2	143 770
	Eutric Regosols (5)	2 891	N1	28 485
	Gleyic Cambisols (5)	2 891	N1	28 485
	Chromic Phaeozems (5)	2 891	N1	28 485
	Profondic Lixisols (5)	2 891	N2	0
AEZ V		136 848	S3	61 715
(200-400)	Profondic Lixisols (25)	34 212	N1	28 485
	Fluvic Cambisols (25)	34 212	S2	143 770
	Ferralic Cambisols (15)	20 527	N2	0
	Ferralic Cambisols (15)	20 527	N1	28 485
	Eutric Regosols (10)	13 685	S2	143 770
	Luvic Phaeozems (10)	13 685	N2	0
AEZ VI		29 782	N1	34 250
(100-200)	Eutric Regosols (50)	14 891	N1	28 485
	Gleyic Cambisols (30)	8 935	N1	28 485
	Chromic Phaeozems (5)	1 489	S2	143 770
	Haplic Phaeozems (15)	4 467	N1	28 485
AEZ VII		63 776	N1	8 615
(100-200)	Eutric Regosols (45)	28 699	N2	0
	Luvic Phaeozems (45)	28 699	N2	0
	Chromic Phaeozems (5)	3 189	S2	143 770
	Haplic Phaeozems (5)	3 189	N1	28 485
AEZ IX		15 519	S2	86 130
(<200)	Haplic Phaeozems (50)	7 760	N1	28 485
	Chromic Phaeozems (50)	7 760	S2	143 770

[§] Suitability classes: S1 = Highly suitable
S2 = Moderately suitable
S3 = Marginally suitable
N1 = Not suitable, due to agro-economic factors
N2 = Not suitable due to physical factors

4.4 Comparison assessment

4.4.1 Comparison of predicted and farmers' reported yields for the studied LMUs

Tables 14a and 14b show the comparison of ALES predicted and farmers' reported yields for the studied LMUs.

Regression analysis (Tables 14a and 14b) shows that there are positive correlations between ALES yield predictions and farmers' reported yields. However, the relationship between the predicted and farmers' reported yields are not significant ($P<0.05$). Also the results shows that ALES could only explain about 30-40% of the yield variations within LMUs and LMU subunits. According to Kimaro and Kips (1991) more than 60% of the yield variation has to be explained by ALES. It is likely that the remaining (60-70%) unaccounted yield variations are due to incomplete or incorrect information obtain from the farmers, assumptions made during model building, the suggested optimum yield factors, land use requirements that were considered diagnostic for the selected LUTs. Based on the obtained correlation coefficients, there is a stronger relationship between predicted yields and the farmers' reported yields within LMU subunits than within LMUs. This could be explained by the fact that the LMU subunits are more homogeneous than the LMUs.

Further more, the results revealed that the probability values and correlation coefficients of subunits within LMUs are better than those of LMUs. This could be attributed to the fact that subdivisions of LMUs into more homogeneous units have increased the predictive values of these units. However, since soil maps at scales of ≤

1:250 000 are less reliable, LMU must be used instead of LMU subunits (National Cooperative Soil survey, 1972; Dent and Young, 1981). LMU subunits are better used as land evaluation units at larger scales (Dent and Young, 1981).

Table 14a: Comparison of predicted and farmer's reported yields within LMUs

LUT	Linear regression	Coefficient of determination (R^2)	Correlation Coefficient R (X, Y)	Probability value P (0.05)	No. of Obser
Maize	Y=0.317x+0.486	0.100	0.317	0.489	7
Paddy	Y=0.268x+0.270	0.092	0.303	0.509	7
Sesame	Y=0.164+0.226	0.113	0.334	0.460	7

Table14b: Comparison of predicted and farmer's reported yields within LMU subunits

LUT	Linear regression	Coefficient of determination (R2)	Correlation Coefficient R (X, Y)	Probability value P (0.05)	No. of Obser
Maize	Y=0.407x+0.388	0.089	0.298	0.302	14
Paddy	Y=0.323x+0.137	0.093	0.305	0.290	14
Sesame	Y=0.300x+0.154	0.153	0.391	0.167	14

4.4.2 Comparison of predicted and farmers' reported Gross margins within LMUs

Table 14c and 14d shows the comparison of Gross Margins predicted using ALES and farmers' reported gross margins for LMUs and LMU subunits, respectively.

The results show that ALES predicted and the actual farmers' reported Gross margins are positively correlated but not significant ($P<0.05$). Regression analysis show that ALES can only explain 23-28% of the GM variation for maize, 27-29 % of the GM variation for paddy and 21-28% of the GM variation for sesame. Generally, the results show that ALES could explain about 20-30% of the Gross margins variations basing on LMUs and LMU subunits. According to Kimaro and Kips (1991) more than 60% of the variations have to be explained by ALES. It is likely that the remaining (70-80%) unaccounted GM variations are due to incomplete or incorrect information obtains from the farmers and assigned costs and prices.

The probability values subunits within LMUs are better than those of LMUs indicating the homogeneity within LMU subunits.

Table 14c: Comparison of predicted GM and farmer's reported GM within LMUs

LUT	Linear regression	Coefficient of determination (R2)	Correlation Coefficient R (X, Y)	Probability value P (0.05)	No. of Observ
Maize	Y=0.151x+69570	0.055	0.235	0.612	7
Paddy	Y=0.201x+43560	0.083	0.288	0.530	7
Sesame	Y=0.074x+2780	0.077	0.277	0.548	7

Table 14d: Comparison of predicted GM and farmer's reported GM within LMU subunits

LUT	Linear regression	Coefficient of determination (R2)	Correlation Coefficient R (X, Y)	Probability value P (0.05)	No. of Obser
Maize	Y=0.305x+46970	0.080	0.282	0.328	14
Paddy	Y=0.242x+37740	0.072	0.268	0.354	14
Sesame	Y=0.094x+5690	0.046	0.214	0.463	14

4.4.3 Comparison of predicted and farmers' reported yields for the studied AEZs

Tables 15a and 15b show the comparison of ALES predicted and farmers' reported yields for the studied AEZs.

The results show that ALES predicted and the actual farmers' reported yields are positively correlated but their relationship is not significant ($P<0.05$). The relationship for maize and sesame is significantly correlated ($P<0.05$) within AEZs subunits. This implies that ALES yield predictions within AEZ subunits are better than those obtained within AEZs. Regression analysis indicates that ALES predictions can only explain 42-67% of yield variations for maize, 37-59 % of yield variations for paddy and 39-47% of yield variations for sesame for the studied AEZs. Generally, the results show that ALES could explain about 37-67% of the yield variations observed in both the AEZs and subunits within AEZ.

The probability values and correlation coefficients of maize and sesame predictions for the studied subunits of AEZs are better than those of AEZs. This suggests that the subunits of AEZs are better land evaluation unit's criteria for larger scale survey than AEZs criteria.

Table 15a: Comparison of ALES predicted and farmers' reported yields within AEZ

LUT	Linear regression	Coefficient of determination (R^2)	Correlation Coefficient R (X, Y)	Probability value P (0.05)	No. of Observ
Maize	Y=0.549x+0.093	0.175	0.419	0.350	7
Paddy	Y=0.381x-0.190	0.348	0.589	0.164	7
Sesame	Y=0.321x+0.100	0.149	0.386	0.393	7

Table 15b: Comparison of ALES predicted and farmer's reported yields within AEZ subunits

LUT	Linear regression	Coefficient of determination (R2)	Correlation Coefficient R (X, Y)	Probability value P (0.05)	No. of Obser
Maize	Y=0.7x-0.123	0.443	0.665	0.000024	33
Paddy	Y=0.233x-0.163	0.138	0.372	0.033000	33
Sesame	Y=0.405x+0.095	0.219	0.468	0.006000	33

4.4.4 Comparison of ALES predicted and farmers' reported GM for the studied AEZs

Tables 15c and 15d show the results of the comparison between ALES predicted and farmers' reported Gross margins for the selected LUTs in the studied AEZs.

The results show that ALES predictions and the actual farmers' reported GM are positively correlated both in AEZ and in their subunits. The relationship is significantly correlated ($P<0.05$) for AEZ subunits and not significant for AEZs.

Regression analysis show that 44 - 47% of GM variation for maize. 55-80 % of GM variation for paddy and 34 - 36% of GM variation for sesame can be explained. Generally. ALES could explain about 34-80% of the GM variations within AEZs and AEZ subunits.

Table 15c: Comparison of predicted and farmers reported GMs for the selected LUTs within AEZs

LUT	Linear regression	Coefficient of determination (R^2)	Correlation Coefficient R (X, Y)	Probability value P (>0.05)	No. of Observ
Maize	Y=0.429x+33565	0.221	0.470	0.288	7
Paddy	Y=0.554x-57650	0.640	0.800	0.031	7
Sesame	Y=0.222x+11705	0.127	0.357	0.432	7

Table 15d: Comparison of predicted and farmers reported GMs for the selected LUTs within AEZs subunits

LUT	Linear regression	Coefficient of determination (R2)	Correlation Coefficient R (X, Y)	Probability value P (>0.05)	No. of Obser
Maize	Y=0.625x-2095	0.199	0.446	0.009	33
Paddy	Y=0.375x-52235	0.302	0.550	0.001	33
Sesame	Y=0.354x+7670	0.119	0.344	0.050	33

4.5 Comparative assessment based on LMUs and AEZs

4.5.1 Comparison of predicted and farmers' reported yields based on LMUs and AEZs.

Table 16 shows the comparison of ALES predicted and farmers' reported yields from the studied LMUs and AEZs using correlation coefficients.

Table 16: Correlation coefficients of predicted yields and farmers' reported yields of the selected LUTs from the studied LMUs and the AEZs

LUTs	LMUs	AEZs
Maize	0.317	0.419
Paddy	0.303	0.589
Sesame	0.334	0.386

Figures 1a and 1b, 1c and 1d, and 1e and 1f show the relationship between predicted and the farmers' reported yields based on LMUs and AEZs for the studied LUTs.

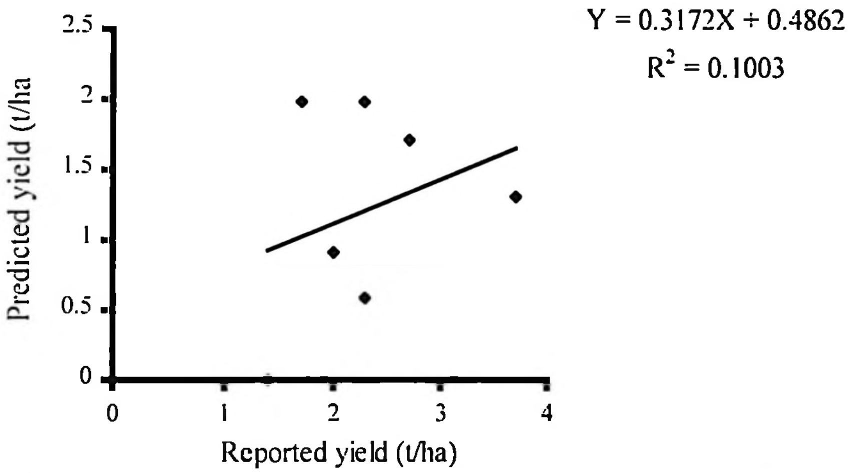

Figure 1a: Relationship between predicted and farmers' reported maize yields based on LMUs

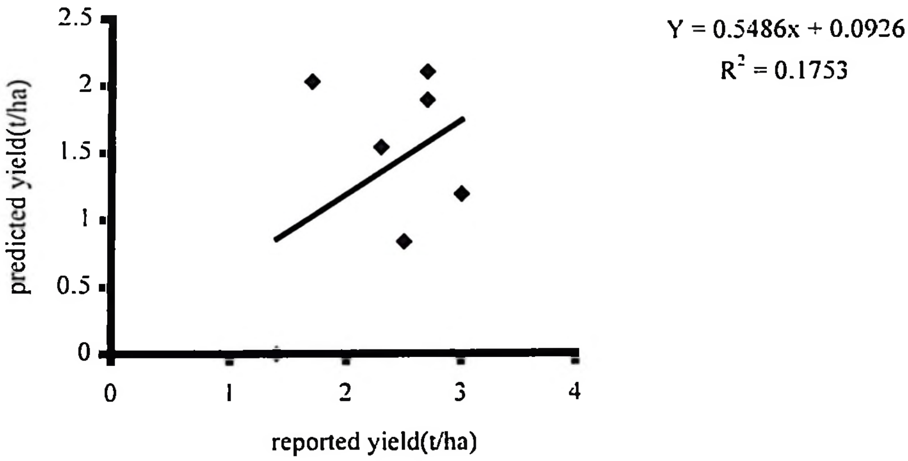

Figure 1b: Relationship between maize predicted and farmers' reported yield based on AEZs

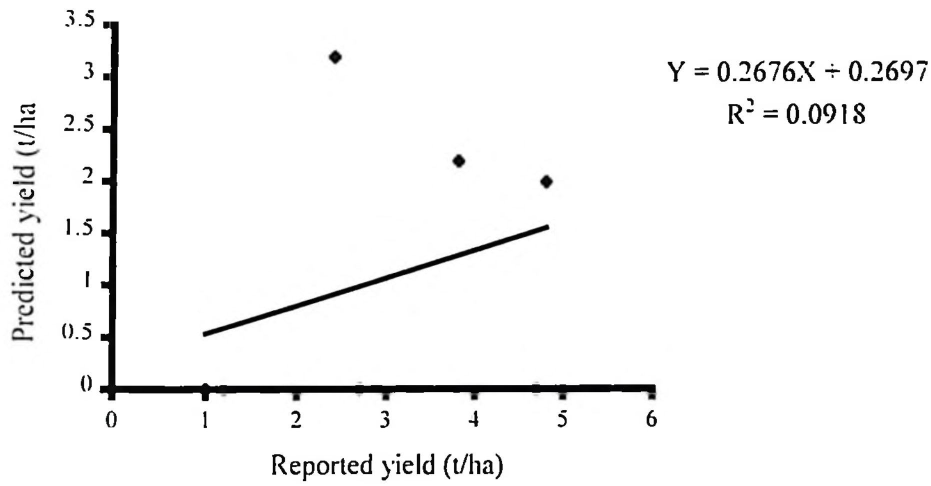

Figure 1c: Relationship between predicted and farmers' reported paddy yields based on LMUs

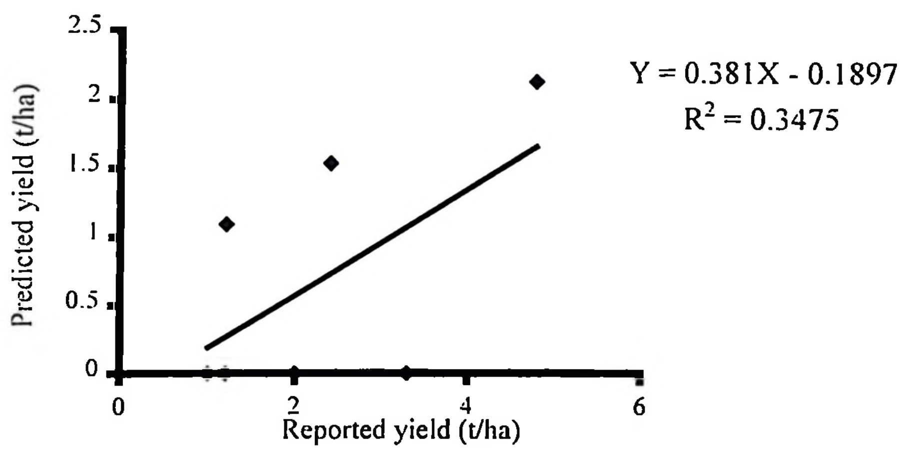

Figure 1d: Relationship between predicted and farmers' reported paddy yields based on AEZs

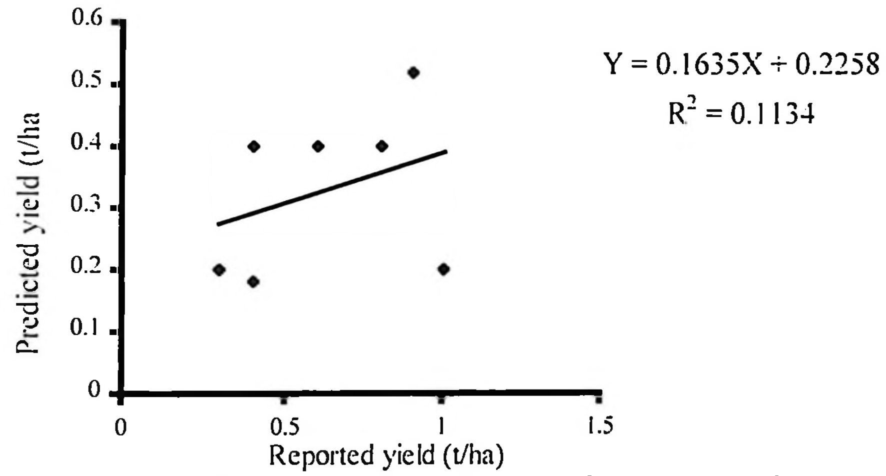

Figure 1e: Relationship between predicted and farmers' reported sesame yields based on LMUs

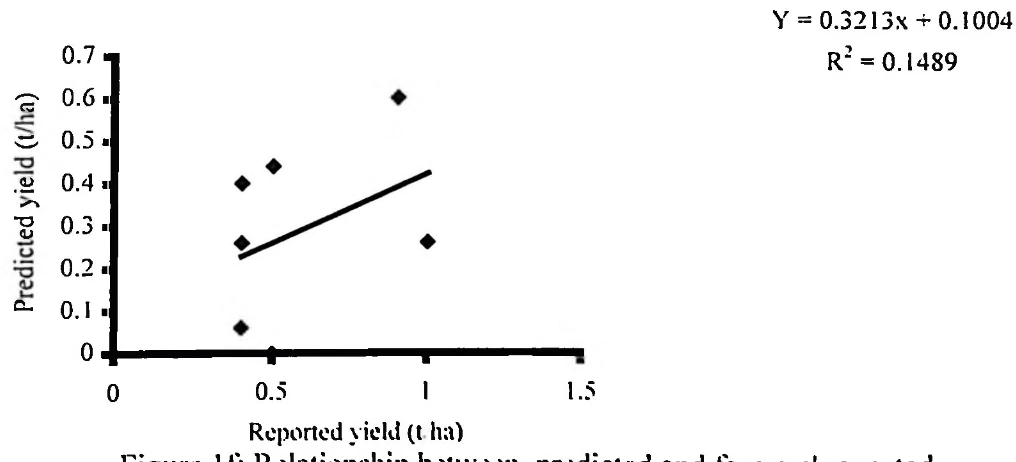

Figure 1f: Relationship between predicted and farmers' reported Sesame yield based on AEZs

Table 16 shows that the correlation coefficients of predicted yields and farmers' reported yields were statistically poor for both land units, but higher (P< 0.05) in AEZs than in LMUs for the selected land utilization types. Also, Figures 1a to 1f show that there are higher slopes and coefficients of determination in AEZs than in LMUs. Therefore, predictions of yields by ALES were better (P< 0.05) when AEZs were used as a land unit criterion for land suitability assessment than when based on LMUs criteria. This indicates that AEZs criteria as a land unit for land evaluation of small-scale surveys is bettered suited than LMUs criteria.

Further more it noted that, the use of AEZs as a units for land suitability evaluation is much more practical and useful than the use of LMUs because, the reported yields based on AEZs were more homogeneous and representative than those based on LMUs as indicated by lower standard deviations in the studied LUTs based on AEZs.

4.5.2 Comparison of predicted and farmers' reported yields between LMU subunits and AEZ subunits.

Table 17 shows the comparison of ALES predicted and farmers' reported yields of the studied LMU subunits and AEZ subunits for the selected LUTs.

Table 17: Correlation coefficients of predicted yields and farmers' reported yields of the selected LUTs from the studied subunits of LMUs and the AEZs

LUT	LMU subunit	AEZ subunit
Maize	0.298	0.665
Paddy	0.305	0.372
Sesame	0.391	0.468

Figures 2a and 2b, 2c and 2d, and 2e and 2f show the relationship between predicted and farmers' reported yields of the selected LUTs on the studied subunits of LMUs and AEZs.

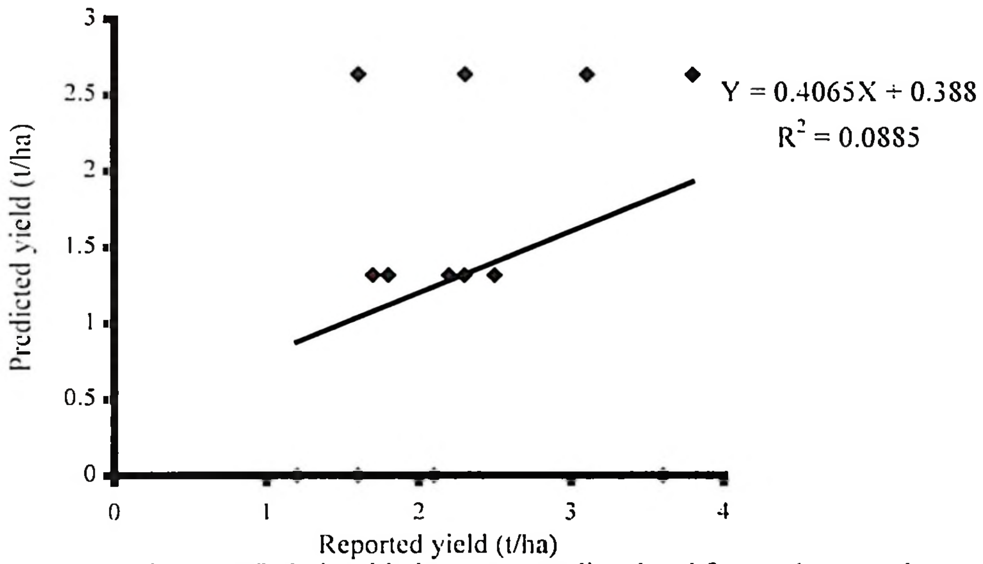

Figure 2a:Relationship between predicted and farmers' reported maize yield based on LMU subunits

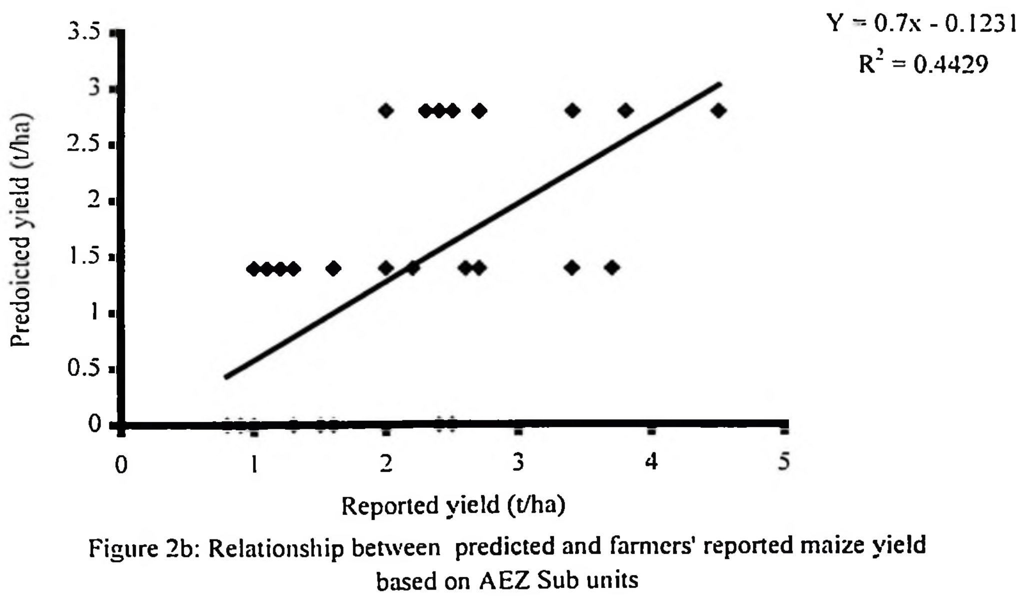

Figure 2b: Relationship between predicted and farmers' reported maize yield based on AEZ Sub units

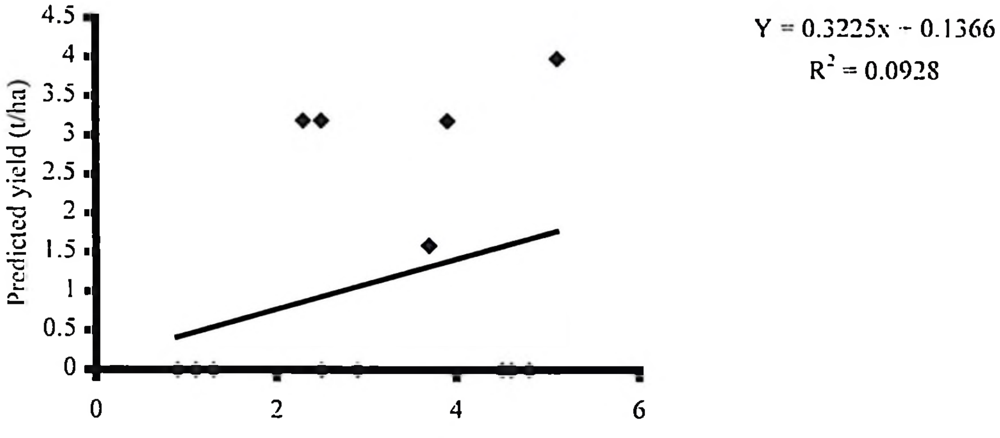

Figure 2c: Relationship between predicted and farmers' reported paddy yield based on LMU Subunits

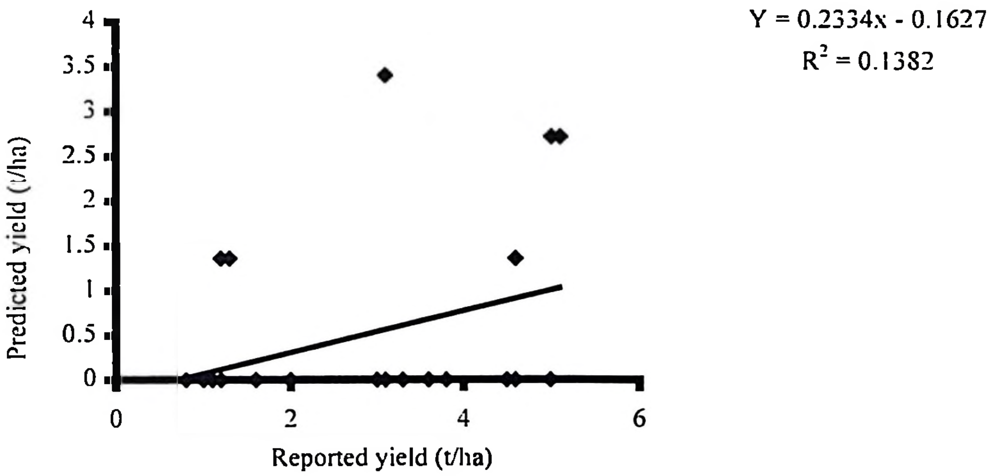

Figure 2d: Relationship between predicted and farmers' reported paddy yield based on AEZ subunits

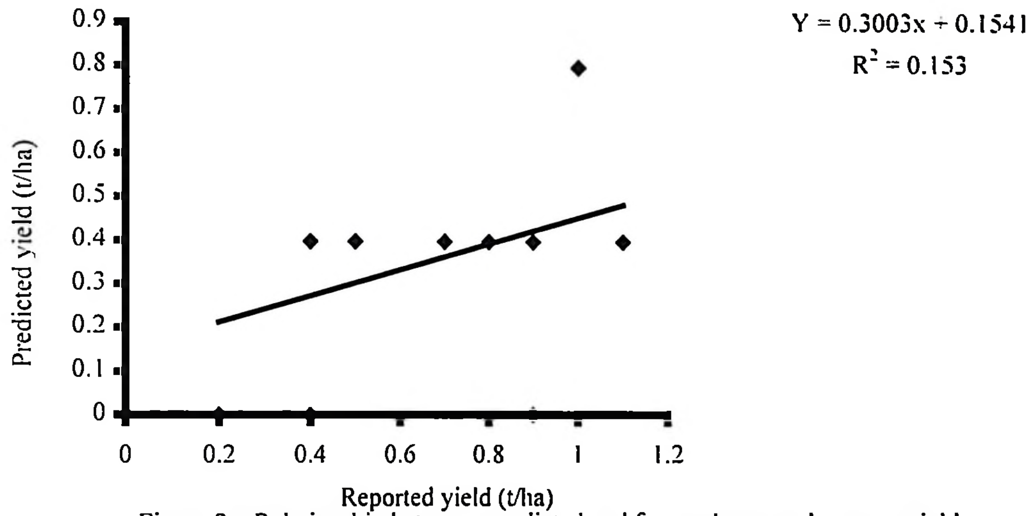

Figure 2e: Relationship between predicted and farmers' reported sesame yield based on LMU Subunits

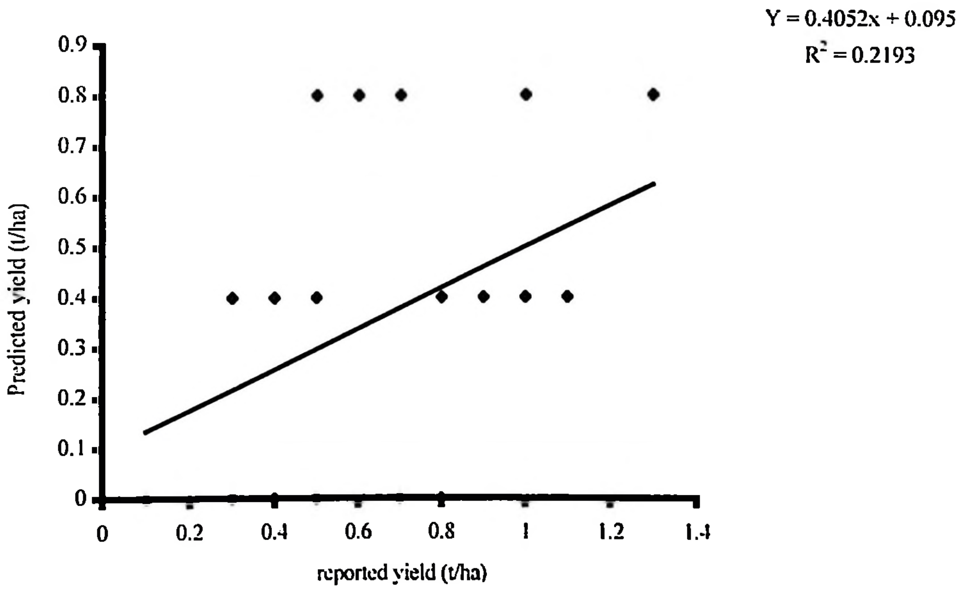

Figure 2f: Relationship between predicted and farmers' reported sesame yield based on AEZ subunits

Although not significant (P< 0.05), Table 17 shows that the correlation coefficients of predicted and farmers' reported yields in the AEZs subunits are higher than those in the LMU subunits for all the selected land utilization types. In addition, Figures 2a to 2f show that AEZ subunits have higher coefficients of determination than that of LMU subunits. This implies that yield variations are explained better in AEZ subunits than in LMU subunits

These results show further that using AEZ as a land unit for land evaluation is much better than LMUs criterion particularly when working on small scale surveys.

4.5.3 Comparison of predicted and farmers' reported Gross margins based on LMUs and AEZs

Table 18 shows correlation coefficients of predicted and farmers' reported GM within LMUs and AEZs.

Table 18: Correlation coefficients of predicted and farmers' reported Gross margins within LMU and AEZ

LUT	LMUs	AEZs
Maize	0.235	0.470
Paddy	0.288	0.800
Sesame	0.277	0.357

Figures 3a and 3b, 3c and 3d, and 3e and 3f show the relationship of predicted and farmers' reported GM of the selected LUTs within LMUs and AEZs.

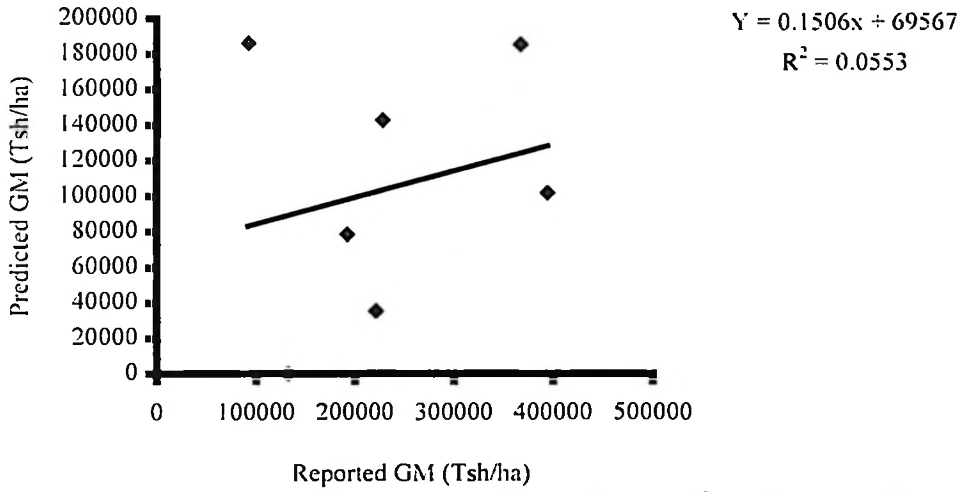

Figure 3 a): relationship between maize predicted and farmers' reported GM based on LMUs

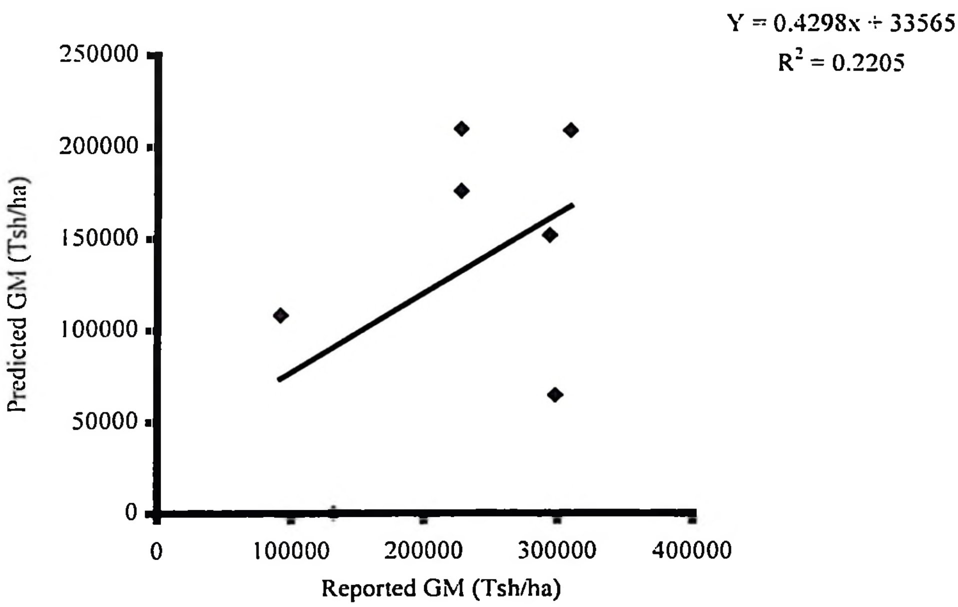

Figure 3b: Relationship between maize predicted and farmers' reported GM based on AEZs

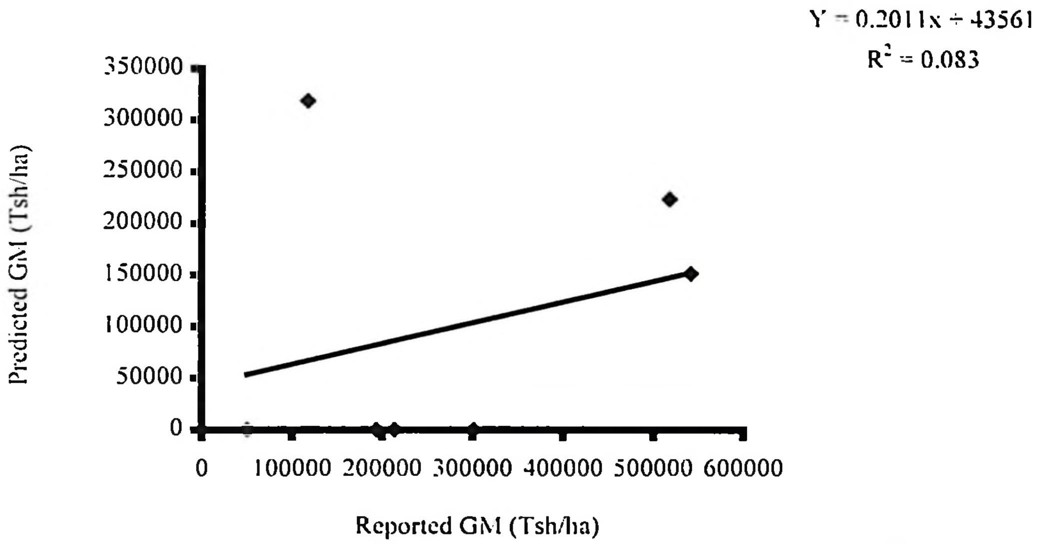

Figure 3 c) Relationship between paddy predicted and farmers' reported GM based on LMUs

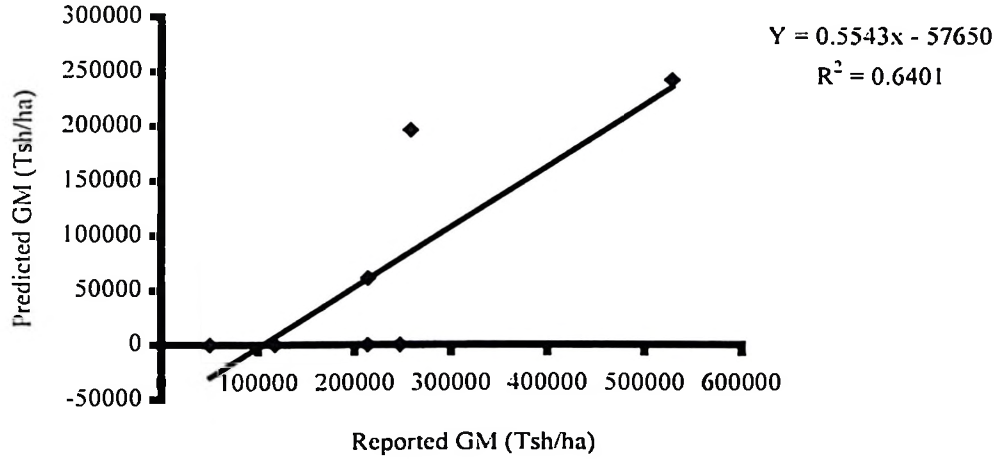

Figure 3d: Relationship between Paddy predicted and farmers' reported GM based on AEZs

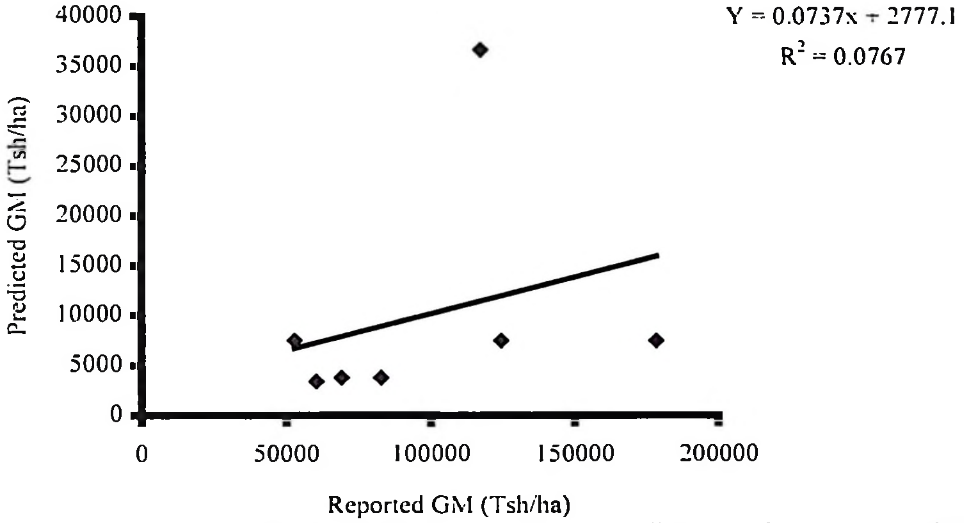

Figure 3 e): Relationship between Sesame predicted and farmers' reported GM based on LMUs

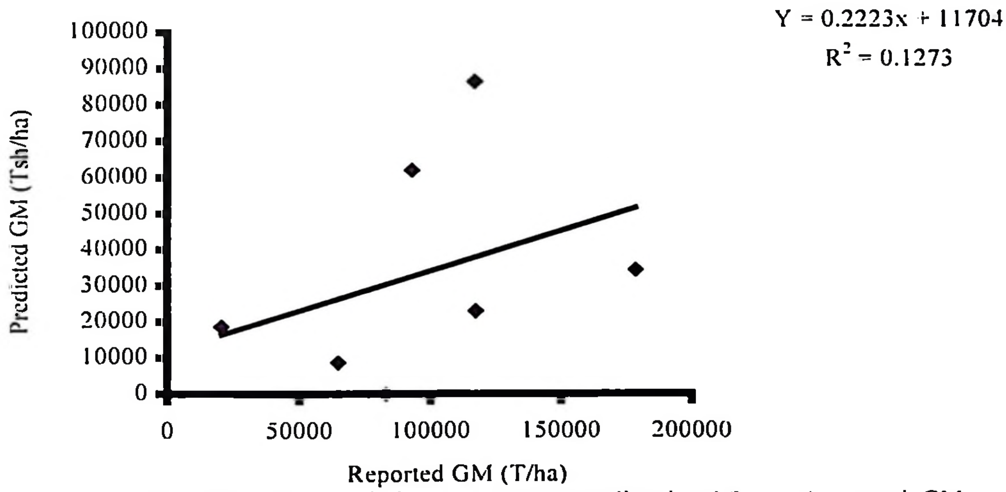

Figure 3f: Relationship between sesame predicted and farmers' reported GM based on AEZs

Table 18 shows that the correlation coefficients of the predicted and farmers' reported GM are higher in the AEZs than in the LMUs for the selected land utilization types. In addition, Figures 3a to 3f show that AEZs have higher slopes and coefficients of determination than that of LMUs. This implies that Gross margins variations are explained better in AEZs than in LMUs. These results show similar pattern as those discussed on sections 4.5.1 and 4.5.2.

4.5.4 Comparison of predicted and farmers' reported Gross margins (GM) based on LMU subunits and AEZs subunits

Table 19 shows correlation coefficients of predicted and farmers' reported GM within LMUs subunits and AEZs subunits.

Table 19 shows that the correlation coefficients of the predicted and farmers' reported Gross margins (GMs) although not significantly different ($P<0.05$); they are higher in the AEZ subunits than in the LMU subunits for the selected land utilization types (maize and sesame). In addition, Figures 4a to 4f show that AEZ subunits have higher slopes and coefficients of determination than that of LMU subunits. Similar patterns were also observed on sections 4.5.1, 4.5.2 and 4.5.3. This implies that Gross margins variations are explained better in AEZs subunits than in LMUs subunits, therefore AEZs are more effective land units for land suitability evaluation at a scale of 1:250 00 for land use planning. However, there is absolute lack of predictability of GMs in this study. This could be due to incomplete and /or incorrect information that might have been provided by the farmers.

Figures 4a and 4b, 4c and 4d, and 4e and 4f show the relationship of predicted and farmers' reported Gross margins of the selected LUTs within LMUs subunits and AEZs subunits.

Table 19: Correlation coefficients of predicted and farmers' reported GMs within LMU subunits and AEZ subunits

LUT	LMU	AEZ
Maize	0.282	0.446
Paddy	0.268	0.550
Sesame	0.214	0.344

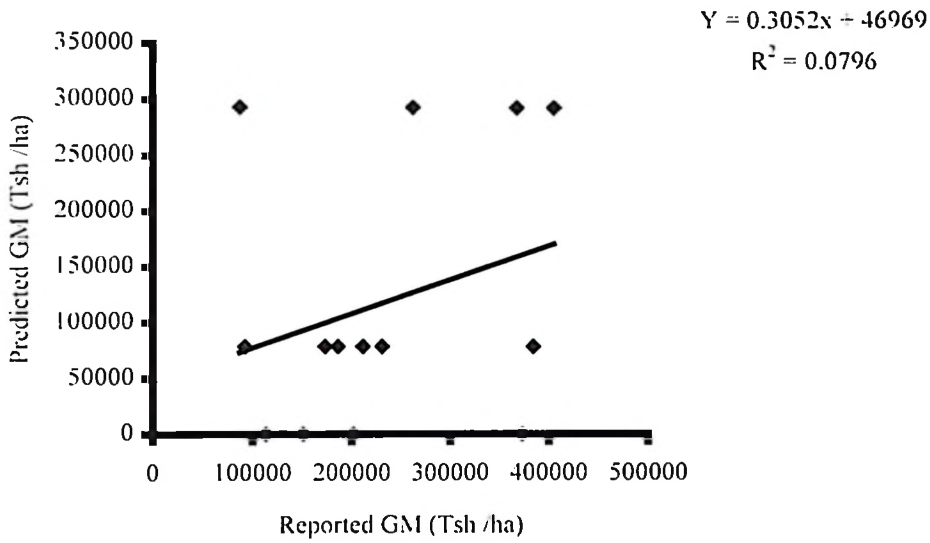

Figure 4a: Relationship between maize predicted and farmers' reported GM based on LMU subunits

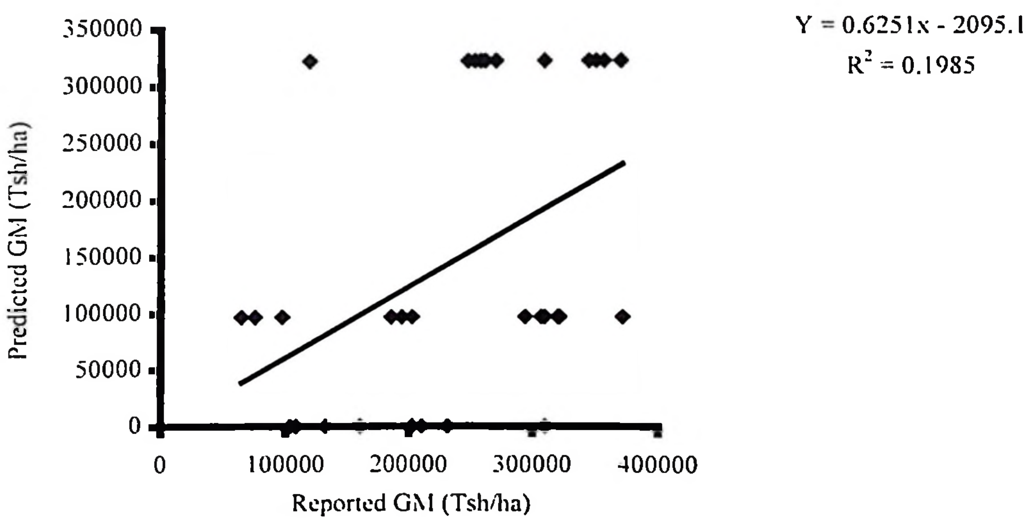

Figure 4b:Relationship between maize predicted and farmers' reported GM based on AEZ Subunits

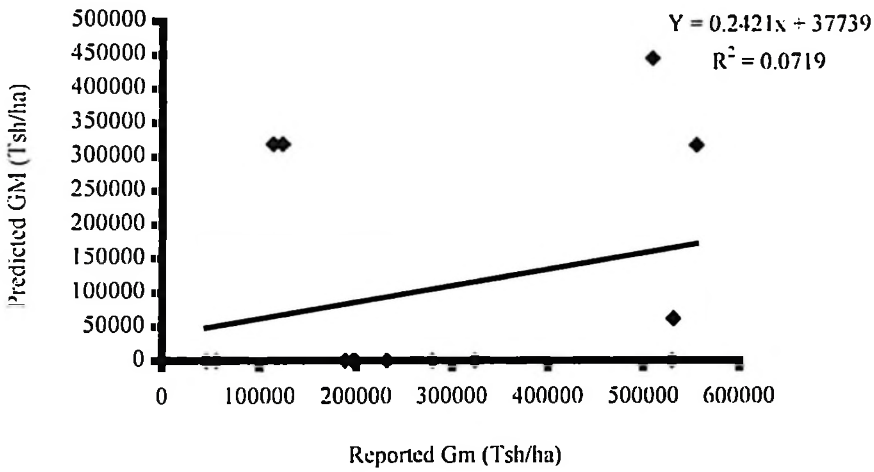

Figure 4c: Relationship between paddy predicted and farmers' reported GM based on LMU Subunits

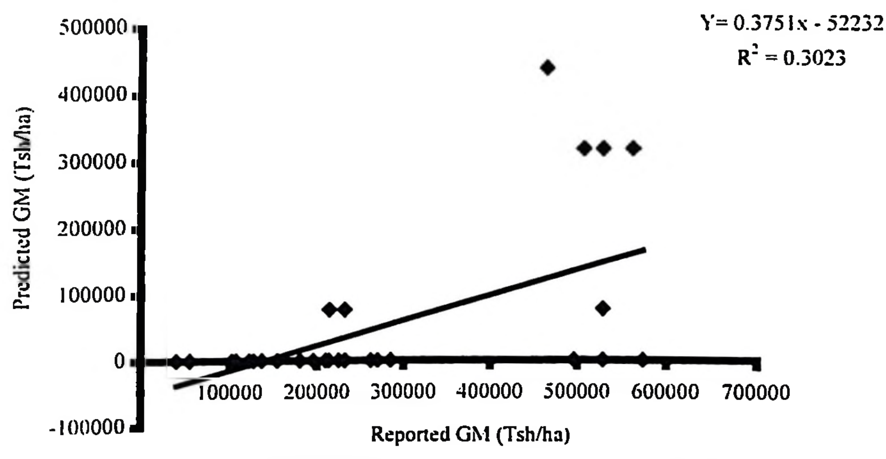

Figure 4d: Relationship between paddy predicted and farmers reported GM based on AEZ Subunits

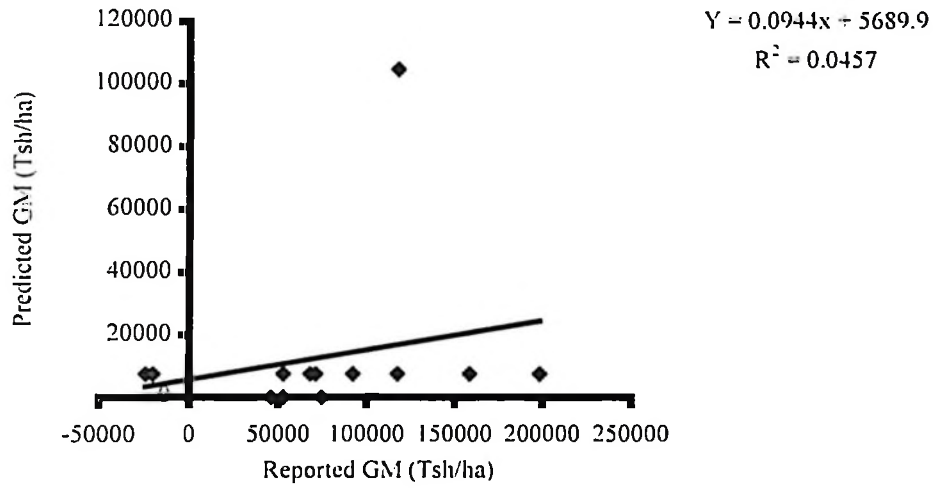

Figure 4e: Relationship between sesame predicted and farmers reported GM based on LMU Subunits

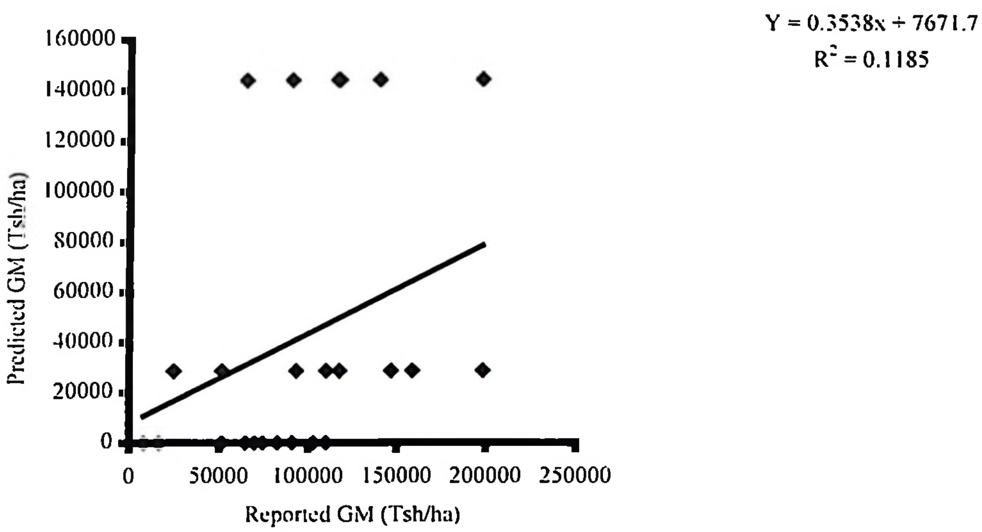

Figure 4f: Relationship between sesame predicted and farmers' reported GM based on AEZ Subunits

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This study has revealed that the study area produces 0.8 to 4.5 tonnes per hectare maize, 0.5 to 6.3 tonnes per hectare paddy and 0.1 to 1.5 tonnes per hectare sesame. and these are below the yield optimum levels.

The reported yields and Gross margins based on AEZs are more representative than those based on LMUs. Therefore the results of land suitability obtained using this criterion can better be extrapolated to other areas with similar agro-ecological characteristics.

Land suitability evaluation revealed that different land units could be classified as follows: Parts of land units Va1 (50%), Va2 (50%), AEZ IX (50%), MO21 (35%), AEZ V (35%), AEZ VI (35%), Pe3 (30%), AEZ III (20%) and AEZ VII (5%) are moderately suitable for maize production. While land unit Pi2 and parts of land units AEZ VI (65%), Pe1 (55%), Va1 (50%), Va2 (50%), AEZ VII (50%), AEZ IX (50%), AEZ III (45%), AEZ IV (45%) and AEZ V (40%) are marginally suitable for maize production. The rest of the area including land units MO21 and AEZ II, and parts of land units MO22 (65%), Pe1 (55%), AEZ VII (45%), AEZ III (35%), AEZ V (25%) and AEZ IV (5%) are currently not suitable for maize production. The major limiting factors are erosion hazards, rooting condition, oxygen availability, moisture availability, nutrient availability and nutrient retention.

The parts of land units Va1 (50%) and AEZ VII (45%) are highly suitable for paddy production. Land unit Va2 and, parts of the land units Pe1 (55%) and AEZ IV (75%) are moderately suitable for paddy production. While the parts of land units AEZ VI (80%), Pe1 (45%) and AEZ IV (5%) are marginally suitable for paddy production. The remaining land units MO21, MO22, Pi2 Pe3, AEZ II, AEZ III, AEZ V, AEZ IX and parts of AEZ VII (55%), Va1 (50%), AEZ IV (20%) and AEZ VI (20%) are currently not suitable for paddy production. The major limiting factors are erosion hazards, oxygen availability to root zones, rooting condition, nutrient availability and nutrient retention.

The parts of land units AEZ IX (50%), AEZ V (35%). Pe3 (30%), AEZ VI (5%) and AEZ VII (5%) are moderately suitable for sesame production. Land units MO21, MO22, Pi2 and some parts of land units AEZ VI (95%), Pe3 (70%), AEZ III (65%), AEZ IV (55%), AEZ IX (50%), Va1 (50%), Va2 (50%), Pe1 (45%), AEZ V (40%) and AEZ VII (5%) are marginally suitable for sesame production. The rest of the areas including the parts of land units Va1 (50%), Va2 (50%), AEZ VII (45%), AEZ IV (40%), AEZ III (35%) and AEZ V (35%) are currently not suitable for sesame cultivation. The major limitations are oxygen availability, erosion hazards, rooting condition, nutrient availability and nutrient retention.

There is positive correlation between ALES yields and gross margins predictions and farmers' reported yields and Gross margins. However correlation values are low ranging from 0.3 to 0.7 and 0.2 to 0.8 for yields and gross margins respectively. This could be due to incomplete or incorrect information provided by farmers about yields, returns and costs and assumptions made in ALES (such as most limiting land use requirements to determine the suitability class, limiting yield factors to determine yields and predicted yields, assigned returns and costs to determine the Gross margins) during model building.

Predictions of yields and Gross margins by ALEs were better when Agro-ecological zones (AEZs) were used as a land unit criterion for land suitability assessment than when based on land mapping units (LMUs) criteria.

The results demonstrated that using AEZs criteria as a unit for land evaluation is much better than LMUs criterion particularly when working on small scale surveys for land use planning at district level.

5.2 RECOMMENDATIONS

It is recommended that more similar studies should be carried out elsewhere in Tanzania in areas with similar environmental conditions to verify the applicability of AEZs as an evaluation land unit in land evaluation in favour of the LMUs. The uses of various land evaluation procedures including soil fertility capability classification (Sanchez and Buol, 1985) may improve the results.

Furthermore it is recommended that more similar studies should be carried out based on on-farm assessment methodologies, which will take into account variability of climate across the years. Since the farmer's reported yields are not reliable, the study should involve field monitoring of yields on farmer's fields for at least three consecutive years. The studies should involve collection of sufficient data to allow for mechanistic modelling which may assist to explain how the system works in the study area.

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APPENDICES

Appendix 1. Questionnaires for Agro-economic survey

General information

Questionnaire number ....

Name of enumerator ....

Name of respondent ....

Date:...

Agro-ecological zone (Munisi, 2001) ....

Land mapping unit (Munisi, 2001) ....

Landform ....

Soil type ....

Village ....

Ward: ....

District: ....

Region: ....

GPS Coordinates ....

Section A: Farmer's background

(a) Sex ....

(b) Age (years) ....

(c) Marital status: ....

d) What is your belief (religion)? ....

(e) What is your ethnic group (tribe)?..

Section B: Farmer's socio-economic status.

(a) What is your highest level of education? ....

(b) What is your social position (occupation)?...

(c) What is the major source of your income?..

(d) What is your average monthly income?..

Section C: Land acquisition and use

a) Since when have you been residing at this village? ....

b) How did you acquire your farmland? ....

c) What is the size of your farm? ....ha or...........................acres.

d) How far is the farm(s) from home?

i) Around homestead ....km or .... m

ii) Away from the homestead ....km or .... m.

e) Do you keep livestock? If yes mention them with their breed.

....

....

....

....

....

....

....

....

f) Crops informarion?

Crop	Main Use
1. Maize	
2. Rice	
3. Sesame	
4. Citrus	
5. Beans	
6. Bananas	
7. Others (specify)	

Section D: Service related, political and cultural information

a). Do you have access to the following services?

i) Crop seeds Yes/ No

ii) Livetock dip or spray Yes/No

iii) Farm implements (eg. Tractor, harrow) Yes/No

iv) Vertinary services Yes/ No

v) Fertiliser Yes/ No

How does the above situation affect farming activities? ....

b). Do you get advice in the following activities?

Crop husbandry. Yes No Source

Livestock husbandry Yes No Source

Other (specify) .... Yes No Source ....

c) How frequent do you get extension services? Per week/month/year (specify)

Do you think the visits are adequate? Yes/ No

How do village or Ward government leaders promote farming activities in this area?

....

Section E: Farm characteristics

(a) What is the main soil constraint?

Water logging

Weed

Stoniness

Pests

Other (specify)

(b) Is this plot permanently used for this crop? Yes/No

(c) What is the estimated yield per plot?.............kg/plot.

Section F: Gender roles

i). Resource Analysis

Between man and woman, who has access to the following resources?

Resource	Man	Women
Land		
Capital		
Credit		

Section G: Crop information

Crop	Where is the best place to grow this crop/	Total area per crop (m^2)	Cop production system: Monoculture, Mixed, Intercropping, Agroforestry	Residues after harvesting: removed, Left, Burnt, others.	Yield (kg/m^2, bag/m^2)	Amount of yield that is used for home consumption	Amount of yield that is sold on farm or market	Price obtained on farm or market per unit (Tsh/,kg/bag)
Maize								
Paddy								
Sesame								

Total benefit: (T. Shillings)

What is the most important crop to you? ....

Why? ....

Section H: Specific information per crop

Crop: ....

1. Management level: Input. Low/Medium/High.

2. Initial package:

i) Seeds: Local/Improved

Do you use improved seed? Yes/No:

Where do you get? ....

Material required:..............kg price (per kg):............... TShs

Cost of transport .... TShs

Total cost: ....TShs.

ii) Planting/Replanting

When: ....

How: ....

Material used: ....

Own labour required: ....mandays cost per manday:.............TShs

Hired labour required:..........mandays cost per manday:.............TShs

Total cost of labour:..................Cost of transport ....TShs

Total cost: ....TShs.

iii) Pesticide /Herbicides

Do you apply: Yes/ No:

Type: ....

When: ....

Material required: ....Price (per kg) ....TShs

Own labour required: ....mandays cost per manday: ....TShs

Hired labour required:............mandays cost per manday: .... TShs

Total cost of labour:..................Cost of transport .... TShs

Total cost: ....TShs.

Are you aware of any impact of this on the environment? ....

Have already noticed this? ....

3 Production package

i) Land preparation

Do you practice: Yes/No:

When: ....

How: Manual/Animal traction/Tractor/Others (specify):

Own labour required:........mandays cost per manday: ....TShs

Hired labour required:........mandays cost per manday: ....TShs

Total cost of labour:..............TShs

Total cost: .... TShs.

ii) Weeding

Do you practice: Yes/No:

When: ....

How: ....

Material used: ....

Own labour required: ....mandays cost per manday: ....TShs

Hired labour required:...........mandays cost per manday: ....TShs

Total cost of labour:…………………. TShs

Total cost: …………………………… TShs.

iii) Pruning/thinning:

Do you practice: Yes/No:

When: ……… days or ………..weeks after planting

How: ……………………………………

Material used: ……………………………………

Own labour required:……….mandays cost per manday: ………TShs

Hired labour required:……….mandays. cost per manday: ……….. TShs

Total cost of labour: ………………..TShs

Total cost: ………………………TShs.

iv) Rodent control

Do you practice: Yes/No:

When: ……….. days or …………….. weeks after planting

How: ……………………………………

Material used: ……………… cost of material used …………………

Own labour required: …………mandays cost per manday: …….TShs

Hired labour required:…………mandays, cost per manday: ……..TShs

Total cost of labour: …………………TShs

Total cost:……………………………TShs.

4. Soil Conservation

Have you ever-experienced erosion in any of your plots? ....

What kind of erosion? ....

Do you practice soil conservation: Yes/No:

Why? ....

When: ....

Type: ....

How: ....

Material used: ....Cost? ....

Own labour required: ....mandays cost per manday: .... TShs

Hired labour required:...........mandays cost per manday: .... TShs

Total cost of labour: ....TShs

Total cost: ....TShs.

5. Land improvement activities:

Fertiliser:

Do you practice: Yes/No:

When: ....

How: manual: ....

Kind of fertiliser: N/ P/ K/ Manure/ Lime

Material used: ....

Own labour required:.........mandays cost per manday:............TShs

Hired labour required:..........mandays cost per manday: ....TShs

Total cost of labour:..............Cost of transport. ....TShs

Fertilizers costs

	Quantity (kg)	Price /kg (Tshs)	Total cost (TShs)
N:			
P:			
K:			

Total cost:............TShs.

6) Other farm characteristics

How far is from farm to market:.......m or ....km

Do you have credit? Yes/No.

If Yes; Purpose: ....

Conditions: ....

Sources: Bank/ Co-operative/Family/Middleman:

Where do you get your firewood? ....km Cost? ....TShs

Where do you get your water? ....km Cost? ....TShs

7. Harvesting/ Post-harvesting

(i) Harvesting

When: ....

How: ....

Material used: ....

Own labour required:......... mandays cost per manday: ....TShs

Hired labour required: .... mandays cost per manday: ....TShs

Total cost of labour: .... TShs

Transport: ....Cost of Transport: ....TShs

Total cost: ....TShs.

(ii) Post-harvesting (shelling, threshing, winnowing, grading, packing)

Do you practice: Yes/No:

When: ....

How: ....

Material used ....

Own labour required: ....mandays cost per manday: ....TShs

Hired labour required:.............mandays cost per manday: .... TShs

Total cost of labour: ....TShs

Transport: .... Cost of Transport: ....TShs

Total cost: TShs.

(iii) Prospects:

Are the yields improving (+) or declining (-)?......................................

What are the causes of this trend? ....

What are your future expectations?

(i) To use improved seeds

(ii) To change cropping system

(iii) Other (specify)...

Appendix 2: Land Characteristics specification (Land attribute table dictionary) for the study area

LC Id		LC Name	Classes Units (Upper Limit)	Unit
Code	class	Class Name		
sl		**Dominant slope classes**		%
1	1	Flat to nearly level	0-1.0	
2	2	Very gently slopping	1.0-2.0	
3	3	Gently slopping	2.0-5.0	
4	4	Slopping	5.0-10	
5	5	Strongly slopping	10-15	
6	6	Moderately steep	15-30	
7	7	Steep	30-60	
8	8	Very steep	>60	
T-GP		**Mean annual temperature**		oC
1	1	Very cool	10-15	
2	2	Cool	15-17.5	
3	3	Moderately cool	17.5-20	
4	4	Moderately warm	20-22.5	
5	5	Warm	22.5-25	
6	6	Very warm	25-27.5	
7	7	Extremely warm	>27.5	
Tex-p		**Average soil texture throughout profile**		class
1	1	Clay (C)		
2	2	Sandy clay (SC)		
3	3	Silty clay (SiC)		
4	4	Clay loam (CL)		
5	5	Sandy clay loam (SCL)		
6	6	Silty loam(SiL)		
7	7	Silty clay loam (SiCL)		
8	8	Sandy loam (SL)		
9	9	Sand (S)		
10	10	Loamy sand (LS)		
11	11	Loam (L)		
12	12	Silt (Si)		
Tex-t		**Average soil texture within 0-30 cm**		class
1	1	Clay (C)		
2	2	Sandy clay (SC)		
3	3	Silty clay (SiC)		
4	4	Clay loam (CL)		
5	5	Sandy clay loam (SCL)		
6	6	Silty loam (SiL)		
7	7	Silty clay loam (SiCL)		
8	8	Sandy loam (SL)		
9	9	Sand (S)		
10	10	Loamy sand (LS)		
11	11	Loam (L)		
12	12	Silt (Si)		

Appendix 2: Continued

Dr		**Soil drainage class**		
1	1	Excessively drained		
2	2	Somewhat excessively drained		
3	3	Well drained		
4	4	Somewhat poorly (imperfectly) drained		
5	5	Poorly drained		
6	6	Very poorly drained		
FL		**Duration of flooding**		days
1	1	Less than 1 day		
2	2	1-5 days		
3	3	5-15 days		
4	4	15-30 days		
5	5	30-90 days		
6	6	90-180 days		
7	7	180-365 days		
LGP		**Reference length of growing period**		days
1	1	Short	150-180	
2	2	Medium	180-210	
3	3	Long	210-240	
4	4	Very long	240-270	
5	5	Extremely long	270-300	
6	6	Almost continuous	300-365	
Sd		**Effective soil depth**		cm
1	1	**Very shallow**	<20	
2	2	Shallow	20-40	
3	3	Moderately deep	40-80	
4	4	Deep	80-120	
5	5	Very deep	>120	
Sd-T		**Topsoil thickness**		cm
1	1	Thin	<10	
2	2	Thick	10-20	
3	3	Very thick	>20	
P-gp		**Rainfall 4 months before end of growing period**		mm/m
1	1	Very low	0-200	
2	2	Low	200-400	
3	3	Moderate	400-600	
4	4	High	600-800	
5	5	Very high	800-1000	
6	6	Extremely high	1000-1100	
P-an		**Mean annual precipitation**		mm
1	1	Very low	100-250	
2	2	Low	250-500	
3	3	Moderate	500-750	
4	4	High	750-1500	
5	5	Very high	1500-2000	
6	6	Extremely high	>2000	

Appendix 2: Continued

pH-t		**Soil reaction pH (H2O) within 0-30 cm**		
1	1	Very strongly acid	0-5.0	
2	2	Strongly acid	5.1-5.5	
3	3	Moderately acid	5.6-6.0	
4	4	Slightly acid	6.1-6.5	
5	5	Neutral	6.6-7.5	
6	6	Mildly alkaline	7.6-8.0	
7	7	Moderate alkaline	>8.0	
pH-s		**Soil reaction pH (H2O)**		
1	1	Very strongly acid	0-5.0	
2	2	Strongly acid	5.1-5.5	
3	3	Medium	5.6-6.0	
4	4	Slightly acid	6.1-6.5	
5	5	Neutral	6.6-7.3	
6	6	Mildly alkaline	7.4-7.8	
7	7	Moderate alkaline	7.9-8.4	
CEC		**Cation exchange capacity within 0-30 cm**		
1		Very low	<6.0	
2		Low	6.0-12.0	
3		**Medium**	12.1-25.0	
4		High	25.0-40.0	
5		Very high	>40.0	
N		**Nitrogen content within 0-30 cm**		**cmol (+)/kg**
1		Very low	<0.10	
2		Low	0.10-0.20	
3		Medium	0.21-0.50	
4		High	>0.50	
P-Av		**Available phosphorus within 0-30 cm**		**%**
		Low	<7.0	
		Medium	7-20	
		High	>20	
K-cl		**Potassium within 0-30cm (clay soils)**		**mg K/kg soil**
1	1	Very low	<0.2	
2	2	Low	0.2-0.4	
3	3	Medium	0.41-1.2	
4	4	High	1.21-2.0	
5	5	Very high	>2.0	
K-loa		**Potassium within 0-30cm (loam soils)**		**mg K/kg soil**
1	1	Very low	<0.13	
2	2	Low	0.13-0.25	
3	3	Medium	0.26-0.8	
4	4	High	0.81-1.35	
5	5	Very high	>1.35	

Appendix 2: Continued

K-sa		**Potassium within 0-30cm (sandy soils)**		mg K kg soil
1	1	Very low	<0.05	
2	2	Low	0.05-0.1	
3	3	Medium	0.11-0.4	
4	4	High	0.41-0.70	
5	5	Very high	>0.7	
OC		**Organic carbon content within 0-30cm**		%
1	1	Very low	<0.6	
2	2	Low	0.6-1.25	
3	3	Medium	1.26-2.50	
	4	High	2.51-3.50	
5	5	Very high	>3.50	
ESP		**Soil sodicity**		%
1	1	Non-sodic	<6	
2	2	Slightly sodic	6-10	
3	3	Moderately sodic	11-15	
4	4	Strongly sodic	16-25	
5	5	Very strongly sodic	26-35	
6	6	Extremely sodic	>35	
BS		**Base saturation**		%
1	1	Very low	<20	
2	2	Low	20-40	
3	3	Medium	41-60	
4	4	High	61-80	
5	5	Very high	>80	

Appendix 3: Land resource database coding of surveyed LMUs for screening by ALES

LC LMU (Alt M)	LMU Sub unit (%)	Area (ha)	Tem. (°C)	GPR (mm)	MAR (mm)	LGP (Day	Slop (%)	Surf textu	Sub text	Flood (Days)	Soil depth (cm)	Drainage (Class)	Soil pH	CEC (cmo(+)/kg)	OC (%)	N (%)	Avail P (mg/kg)	BS (%)
Mountains(MO) (>500).																		
MO 21	Rhodic Luvisols (40)	8 525	4	4	4	3	7	2	5	1	3	2	4	4	3	2	2	5
	Profondic Luvisols (60)	12 788	4	4	4	3	7	2	1	1	4	3	4	3	3	2	2	5
MO 22	Chromic Phaeozems 35	8 652	4	5	5	4	2	5	2	1	4	3	3	2	3	2	3	4
	Profondic Lixisols (65)	16 067	4	5	5	4	7	2	1	1	4	3	4	3	2	1	2	3
Piedmonts (Pi) (400-500)																		
Pi 2	Sodic Cambisols (60)	13 613	5	4	4	2	4	8	5	1	2	2	3	3	3	2	3	5
	Orthidystric Cambisols (40)	9 075	5	4	4	2	3	9	10	1	5	2	4	1	1	2	2	3
Peneplains(Pe) (200-400)																		
Pe 1	Ferralic Cambisols (55)	19 835	5	4	3	3	3	10	5	1	4	3	4	2	1	1	1	5
	Ferralic Cambisols (45)	16 228	5	4	3	3	4	10	10	1	2	1	2	1	2	1	3	3
Pe 3	Haplic Phaeozems (70)	16 713	5	4	4	3	1	4	1	2	4	3	6	4	3	2	1	5
	Chromic Phaeozems (30)	7 163	5	4	4	3	3	8	5	1	4	1	3	3	3	2	3	5
Valleys (Va) <200																		
Va 1	Eutric Regosols (50)	45 813	5	4	4	3	1	2	1	2	5	5	5	5	4	3	3	5
	Luvic Phaeozems (50)	45 813	5	4	4	3	2	5	2	2	4	3	5	3	2	2	1	5
Va 2	Gleyic Fluvisols (50)	28 750	5	4	4	3	2	4	11	3	5	5	5	4	3	2	3	5
	Pachic Phaeozems (50)	28 750	5	4	4	3	1	5	2	1	4	4	5	3	3	3	2	5

GPR=Growing period rainfall, MAR=Mean annual rainfall, LGP=Length of growing period.

Appendix 4: Land resource database coding of surveyed AEZs for screening by ALES

AEZ (Alt m)	AEZ Sub unit (%)	Area (ha)	Tem (°C)	GPR (mm)	MAR (mm)	LGP (Days)	Slop (%)	Surf textu	Sub textu	Flood (Day)	Soil depth (cm)	Draina (Class)	Soil pH	CEC (cmo(+)/kg)	OC (%)	N (%)	Avail P (mg/kg)	BS (%)
AEZII	Rhodic Luvisols (20)	8 556	4	5	5	3	7	2	5	1	3	2	4	4	3	2	2	5
(500-800)	Profondic Luvisols (30)	12 833	4	5	5	3	7	2	1	1	4	4	4	3	3	2	2	5
	Profondic Lixisols) (50)	21 390	4	5	5	3	7	5	1	1	4	3	3	4	3	3	1	2
AEZIII	Profondic Acrisols (10)	7 827	4	4	4	3	3	5	1	1	5	3	3	2	2	2	2	3
(400-500)	Rhodic Ferralsols (15)	11 739	4	4	4	3	6	1	1	1	4	3	4	1	3	2	2	1
	Sodic Cambisols (15)	11 739	4	4	4	3	4	8	5	1	2	1	3	3	3	2	3	5
	Orthidystric Cambisols (20)	15 652	4	4	4	3	3	9	10	1	5	2	4	1	1	2	2	3
	Chromic Phaeozems (20)	15 652	4	4	4	3	2	5	2	1	4	3	3	2	3	2	3	4
	Profondic Lixisols (20)	15 652	4	4	4	3	7	2	1	1	4	3	4	3	2	1	2	3
AEZ IV	Gleyic Fluvisols (35)	22 236	5	4	4	3	2	4	11	3	5	5	5	4	3	2	3	5
(100-200)	Pachic Phaeozems (35)	22 236	5	4	4	3	1	5	2	1	4	4	5	3	3	3	2	5
	Profondic Lixisols (5)	2 891	5	4	4	3	2	8	5	1	4	3	4	3	3	2	1	4
	Fluvic Cambisols (5)	2 891	5	4	4	3	1	8	11	1	4	2	5	2	2	2	3	5
	Eutric Cambisols (5)	2 891	5	4	4	3	1	8	5	3	4	4	6	3	2	2	1	3
	Gleyic Cambisols (5)	2 891	5	4	4	3	1	4	1	3	4	4	5	3	3	3	3	5
	Chromic Phaeozems (5)	2 891	5	4	4	3	2	5	2	1	4	3	3	2	3	2	3	4
	Profondic Lixisols (5)	2 891	5	4	4	3	7	2	1	1	4	3	4	3	2	1	2	3
AEZ V	Profondic Lixisols (25)	34 212	5	4	4	3	2	8	5	1	4	3	4	3	3	2	1	4
(200-400)	Fluvic Cambisols (25)	34 212	5	4	4	3	1	8	11	1	5	2	5	2	2	2	3	5
	Ferralic Cambisols (15)	20 527	5	4	4	3	3	10	5	1	4	3	4	2	1	1	1	5
	Ferralic Cambisols (15)	20 527	5	4	4	3	4	10	10	1	2	1	2	1	2	1	3	3
	Eutric Regosols (10)	13 685	5	4	4	3	1	2	1	2	4	3	5	5	4	3	3	5
	Luvic Phaeozems (10)	13 685	5	4	4	3	2	5	2	2	4	3	5	3	1	1	1	5

GPR=Growing period rainfall, MAR=Mean annual rainfall, LGP=Length of growing period.

Appendix 4: Continued

AEZ (Alt m)	AEZ Sub unit (%)	Area (ha)	Tem (°C)	GPR (mm)	MAR (mm)	LGP (Days)	Slop (%)	Surf textu	Sub textu	Flooding (Day)	Soil depth (cm)	Draina (Class)	Soil pH	CEC (cmo(+)/kg)	OC (%)	N (%)	Avail P (mg/kg)	BS (%)
AEZ VI (100-200)	Eutric Regosols (50)	14891	5	4	4	3	1	8	5	3	4	4	6	3	2	2	1	3
	Gleyic Cambisols (30)	8935	5	4	4	3	1	4	1	3	4	4	5	3	3	3	3	5
	Chromic Phaeozems (5)	1489	5	4	4	3	3	8	5	1	4	1	3	3	3	2	3	5
	Haplic Phaeozems (15)	4467	5	4	4	3	1	4	1	2	4	3	6	4	3	2	1	5
AEZ.VII (100-200)	Eutric Regosols (45)	28699	5	4	4	3	1	2	1	2	5	5	5	5	4	3	3	5
	Luvic Phaeozems (45)	28699	5	4	4	3	2	5	2	2	4	3	5	3	1	1	1	5
	Chromic Phaeozems (5)	3189	5	4	4	3	3	8	5	1	4	1	3	3	3	2	3	5
	Haplic Phaeozems (5)	3189	5	4	4	3	1	4	1	2	4	3	6	4	3	2	1	5
AEZ IX (<200)	Haplic Phaeozems (50)	7760	5	4	4	3	1	4	1	2	4	3	6	4	3	2	1	5
	Chromic Phaeozems (50)	7760	5	4	4	3	3	8	5	1	4	1	3	3	3	2	3	5

GPR=Growing period rainfall, MAR=Mean annual rainfall, LGP=Length of growing period.

Appendix 5a: Land use requirements (LURs) for rainfed maize (*Zea mays*) production

Land quality	Diagnostic factor	Unit	Factor rating			
			Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Moisture availability	Total rainfall in growing period	mm	800 - 600	600 - 400	400 - 250	<250
Temperature regime	Mean temp in growing period	°C	24 – 18 24 – 32	18 – 16 32 - 35	16 – 14 35 - 40	<14 >40
Oxygen availability to root	Soil drainage	Drainage class	Well	Moderately well	Imperfect	Poor, very poor
	Flooding	days	<1	1 - 5	15 - 30	>30
Rooting condition	Effective depth	cm	>120	75 - 120	30 - 75	<30
	Profile texture	class	SiC, SiCl, Si, CL, SC, L, SCL	SL, LfS, LS	FS, S, LcS	Cm, Si, CM, cS
Nutrient availability	Soil reaction	pH	6.6 – 5.8 6.6 – 7.8	5.8 – 5.5 7.8 – 8.2	5.5 – 5.2 8.2 – 8.5	<5.2 >8.5
	Top soil OC	%	>2.0	1.0 – 2.0	0.5 – 1.0	<0.5
	Top soil N content	%	>0.2	0.1 – 0.2	0.02 – 0.1	<0.02
	Top soil available P	mg/kg	>40	40 - 10	10 - 5	<5
Nutrient retention capacity	Base saturation	%	>80	40 - 80	20 - 40	<20
	Top soil CEC	cmol(+)/kg	>25	25 - 13	13 - 6	<6
Erosion hazard	Slope angle	%	0 – 5	5 - 10	10 - 15	>15
	Surface texture	class	SiC, SiCl, Si, CL, SC, L, SCL	SL, LfS, LS	FS, S, LcS	Cm, Si, CM, cS

C=Clay, SL=Sandy loam, LS=Loamy sand, SCL=Sandy clay loam, SC=Sandy clay, L=Loam SiCL=Silty clay loam, SiL=Silty loam, Si=Silt,

Appendix 5b: Land use requirements (LURs) for rainfed rice (Oryza sativa) production

Land quality	Diagnostic factor	Unit	Factor rating			
			Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Moisture availability	Total rainfall in growing period	mm	700 - 600	600 – 300 700 - 800	300 – 200 800 - 900	<200 <900
Temperature regime	Mean temp in growing period	°C	34 – 24 31 – 36	24 – 18 >36	18 – 10	<18
Oxygen availability to root	Soil drainage	Drainage class	Very poor to poor	Imperfect	Moderate	Well
Rooting condition	Effective depth	cm	>75	75 - 50	50 - 25	<25
	Profile texture	class	C, SiCl, CL,	SC, SiCL, SiL	SL, L, SCL	S, LS
Nutrient availability	Soil reaction	pH	6.5 – 5.5 6.5 – 8.2	5.5 – 5.0 8.2 – 8.5	5.0 – 4.5 8.5 – 8.8	<4.5 >8.8
	Top soil OC	%	2.0- 4.0	1.0 – 2.0	0.5 – 1.0	<0.5 >5.0
	Top soil N content	%	>0.2	0.1 – 0.2	0.05 – 0.1	<0.05
	Top soil available P	mg/kg	>40	40 - 20	20 - 10	<10
Nutrient retention	Base saturation	%	>75	75 - 50	50 - 30	<30
	Top soil CEC	cmol(+)/kg	>25	25 - 13	13 - 6	<6
Erosion hazard	Slope angle	%	< 1	1 - 2	2 - 4	>4

C=Clay, SL=Sandy loam, LS=Loamy sand, SCL=Sandy clay loam, SC=Sandy clay, L=Loam, SiCL=Silty clay loam, SiL=Silty loam

Appendix 5c: Land use requirements (LURs) for rainfed sesame (sesamum indicum) production

Land quality	Diagnostic factor	Unit	Factor rating			
			Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Moisture availability	Total rainfall in growing period	mm	800 – 600	600 – 400 800 - 900	400 – 200 900 - 1000	<200 >1000
Temperature regime	Mean temp in growing period	°C	25 – 28 25 – 20	28 – 3o 20 - 18	16 – 14 18 - 16	<14 >16
Oxygen availability to root	Soil drainage	Drainage class	Well, excessively, somewhat well drain	Moderately well	Imperfect	Poor, very poor
Rooting condition	Effective depth	cm	>100 - 75	75 - 50	50 – 30	<30
	Profile texture	class	SiCs, SCl, Si, CL, SC, L, SiL, SiCL	LS, Cs	C, S,	Cm, SiCM,
Nutrient availability	Soil reaction	pH	6.3 – 5.8 6.3 – 7.0	5.8 – 5.5 7.0 – 7.5	5.5 – 5.2 7.5 – 8.2	<5.2 >8.2
	Top soil OC	%	>1.2	1.2 – 0.8	0.8 – 0.6	<0.6
	Top soil N content	%	>0.2	0.2 – 0.1	0.1 –0.02	<0.02
	Top soil available P	mg/kg	>40	40 - 20	20 - 10	<10
Nutrient retention capacity	Base saturation	%	>80	80 - 50	50 - 35	<35
	Top soil CEC	cmol(+)/kg	>24	24 - 16	16 - 9	<9
Erosion hazard	Slope angle	%	0 – 10	10 - 15	15 - 30	>30
	Surface texture	Class	SiC, SiCl, Si, CL, SC, L, SCL	SL, LfS, LS	FS, S, LcS	Cm, Si, CM, cS

C=Clay, SL=Sandy loam, LS=Loamy sand, SCL=Sandy clay loam, SC=Sandy clay, L=Loam SiCL=Silty clay loam, SiL=Silty loam, Si=Silt,

Appendix 6: Part of ALES decision tree for SHLIR maize

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AEZ (Land evaluation of eastern Morogoro rural AEZ approach)       Decision Tree
DLId Type                                 Where Used'
--------------------------------------------------------------------------------
1     Severity Level                      SHLIRM.er
 > sla (Slope angle)
   1 (Flat to nearly level) [0-1 %] > stext (Surface soil texture)
     1 (cLAY) > lgp (Length of growing period)
       1 (Short) [150-180 Days] : 3 (Severe limitatio)
       2 (Medium) [180-210 Days : 3 (Severe limitatio)
       3 (Long) [210-240 Days]. : 2 (Moderate limitat)
       4 (Very long) [240-270 D : ?
       5 (Extremely long) [270- : ?
       6 (Almostly continuous)  : ?
       ?........................ : ?
     2 (Sandy clay)........... : 1 (No limitation)
     3 (Silty clay).......... : 1 (No limitation)
     4 (Clay loam)........... : 1 (No limitation)
     5 (Sandy clay loam)..... : 1 (No limitation)
     6 (Silty loam).......... : 1 (No limitation)
     7 (Silty clay loam)..... : 1 (No limitation)
     8 (Sandy loam).......... : 2 (Moderate limitat)
     9 (Sandy )............... : 2 (Moderate limitat)
     10 (Loamy sand)......... : 2 (Moderate limitat)
     11 (Loam)............... : 1 (No limitation)
     12 (Silt)............... : 2 (Moderate limitat)
     ?....................... : ?
   2 (Very gently slopping) [1-2 %] > stext (Surface soil texture)
     1 (cLAY)................ : 2 (Moderate limitat)
     2 (Sandy clay).......... : 1 (No limitation)
     3 (Silty clay).......... : 1 (No limitation)
     4 (Clay loam)........... : 1 (No limitation)
     5 (Sandy clay loam)..... : 1 (No limitation)
     6 (Silty loam).......... : 1 (No limitation)
     7 (Silty clay loam)..... : 1 (No limitation)
     8 (Sandy loam).......... : 2 (Moderate limitat)
     9 (Sandy )............... : 2 (Moderate limitat)
     10 (Loamy sand)......... : 2 (Moderate limitat)
     11 (Loam)............... : 1 (No limitation)
     12 (Silt)............... : 2 (Moderate limitat)
     ?....................... : ?
   3 (Gently slopping) [2-5 %] > stext (Surface soil texture)
     1 (cLAY)................ : 2 (Moderate limitat)
     2 (Sandy clay).......... : 1 (No limitation)
     3 (Silty clay).......... : 1 (No limitation)
     4 (Clay loam)........... : 1 (No limitation)
     5 (Sandy clay loam)..... : 1 (No limitation)
     6 (Silty loam).......... : 1 (No limitation)
     7 (Silty clay loam)..... : 1 (No limitation)
     8 (Sandy loam).......... : 2 (Moderate limitat)
     9 (Sandy )............... : 2 (Moderate limitat)
     10 (Loamy sand)......... : 2 (Moderate limitat)
     11 (Loam)............... : 1 (No limitation)
     12 (Silt)............... : 2 (Moderate limitat)
     ?....................... : ?
   4 (Slopping) [5-10 %] > stext (Surface soil texture)
     1 (cLAY)................ : 2 (Moderate limitat)
     2 (Sandy clay).......... : 2 (Moderate limitat)
     3 (Silty clay).......... : 2 (Moderate limitat)
     4 (Clay loam)........... : 2 (Moderate limitat)
     5 (Sandy clay loam)..... : 2 (Moderate limitat)
     6 (Silty loam).......... : 2 (Moderate limitat)
     7 (Silty clay loam)..... : 2 (Moderate limitat)
     8 (Sandy loam).......... : 2 (Moderate limitat)
     9 (Sandy )............... : 3 (Severe limitatio)
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