CHAPTER 1

INTRODUCTION

Land Evaluation is a process of estimating the potential of land for alternative kinds of use (Dent and Young, 1981) or as the prediction of land performance when the land is used for specified purposes (Diepen, 1991, Rossiter and Van Wambeke, 1997). According to (FAO, 1976) it is the process of assessing the performance of land when the land is used for specified purposes. Land evaluation is, therefore, a key tool for land use planning both for individual land users such as farmers, or by groups of land users such as co-operatives or villages or by society as a whole as represented by governments. In this definition, 'land' is much more than 'soil', 'topography', 'climate', 'political density', and in fact is an integrated geographic concept , both physical and human. 'Reasonably stable' attributes include variable but non- cyclic attributes that can be presented by time series, in particular, the weather (Rossiter, 2001).

Land evaluation is considered to be an interface between land resources surveys and land use planning and management. Conducting a land evaluation involves the integration of a number of factors including soil properties, the ways in which soils react to various farming methods, climatic variables, topography, geology and geomorphology and social and technical consideration (Peder, 1986). It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be of value in planning, the range of land uses considered has to be limited to those which are relevant within the physical, economic and social context of the area considered. The results of a land evaluation are a prediction of the use potential of land for several actual or proposed land-use systems. In other words, it predicts how each land area would behave if it were used according to each of these systems (Rossiter and Van Wambeke, 1997). The results of a land evaluation, therefore, serve as a guide for strategic land use decisions. The results of a land evaluation exercise, therefore, serves as a basis for decision making by land use planners and other decision makers who have an influence on land use in a given region (Rossiter,2001).

In Zambia, land evaluation for the agricultural use is conducted after an area has been surveyed to determine the nature of the land resources. This is usually done by the Soil Survey Unit of the Zambia Agricultural Research Institute (ZARI). The products of such surveys are a Soil Survey Report, which contains an evaluation of the suitability of land for various uses. These reports are intended to provide information to land users and land use planners. Very few land users ever read these reports, other than technical experts in the Ministry of Agriculture and Livestock (MAL) who prepared the reports and occasionally a few visiting consultants. The low usage of the reports among other factors is attributed to the highly technical language used in these reports (Woode, 1981).

Despite the difficulties faced in making the land evaluation reports read by land users and land use planners in Zambia, land evaluation still remains an important tool for proper land use planning. It has been successfully employed in the establishment of a number of successful large scale farming enterprises in the country. There are officially three main land evaluation methods used to assess the suitability of land for agricultural use in Zambia. They are: (i) the Land Capability System of the former Land Use Branch of the Ministry of Agriculture, now referred to as the Technical Services Branch, (ii) the Zambia Land Evaluation System of the Soil Survey Unit of the Zambia Agriculture Research Institute (ZARI) and (iii) the Zambia Semi-Quantified Land Evaluation System for non-irrigated or agriculture.

The Zambia Semi-Quantified Land Evaluation System for non irrigated agriculture, also referred to as the Land Evaluation System of Zambia (Veldkamp, 1987) was developed to address the major shortcomings of the preceding two systems which were their in ability to provide quantitative estimates of expected crop yields on various land units. The system was designed to indicate or predict how crop production is affected by adverse land conditions. Data used to develop this system for predicting crop production given specific land conditions were gathered from international literature and Zambian sources. According to Veldkamp (1987), the system, however, needed local testing and verification or validation to revise or fine tune it. The major advantage of this new system is that it incorporates all the factors used in the other two systems, and in addition had the capacity of predicting crop yields unlike its predecessors.

Unfortunately, since its development in 1987, there is only one report of an attempt to locally test or validate the Zambia Land Evaluation System. This was carried out by Chinene (1991), who tested the system using a number of crops in four locations in Zambia. There has been no other similar study since, and the system appears to have been abandoned even in the department that developed it at the Zambia Agricultural Research Institute (ZARI). Considering the merits of the system, a need was felt to try and assess the yield predicting capacity of the Zambia Semi-Quantified Land Evaluation System for maize production some 11 to 12 years after its development. This study was conducted to try and assess the yield predicting capacity of the Zambia Semi- Quantified Land Evaluation System for maize production for rain fed condition under small holder farming conditions with moderate levels of management.

1.1 STATEMENT OF THE PROBLEM

The semi-detailed semi-quantified land evaluation system was developed in 1987 to assist agricultural staff involved in the evaluation of land for non-irrigated agricultural production to be able to make predictions of likely yields of specific crops in locations within Zambia, given information on the biophysical conditions of the area and land management capacity of the farmer or land user. The system was designed to improve on the earlier qualitative systems of land evaluation that were only able to provide qualitative assessments of the land for crop production using terms such as, highly suitable, moderately suitable or unsuitable with no quantitative information about expected crop yields under specified management levels. The new system was, therefore, an improvement in that it allowed the land user to be able to predict the performance of land quantitatively using crop yield. This performance of the land could, therefore, be easily assessed quantitatively. Before being adopted for use in the field, the semi-detailed semi-quantified land evaluation system needed to be validated.

The first attempt to validate the system was by Chinene (1991). He carried out a study to assess the yield predicting capacity of the Zambia Land Evaluation System as he called it, using a number of crops in four different locations within Zambia. Results of his study showed that there were significant differences between predicted yields by the system and actual yields that were obtained by farmers. However, strong correlations were observed between the predicted and actual yields. Since that study there has been no other documented study to further validate the system. Despite the great efforts that went into the development of the system, the system seems to have been abandoned even by Staff at the Soil Survey Unit of the Zambia Agricultural Research Institute (ZARI), where the Zambia Semi-Quantified Land Evaluation System was developed. However, considering the relative merits of the system, it was decided to revisit the system with a view of finding out how well it worked in predicting maize yields under small holder farmer's conditions in Agro-Ecological Zone II where maize is mainly grown in Zambia.

1.2 Justification

There is a gap in the Zambian Semi-Quantified Land Evaluation System in Zambia as the one that is currently in use has not been validated since the mid 1980s. The system needed local testing and verification to revise and fine tune it as a tool for predicting yield for various crops given soil and climatic conditions under given levels of management by farmers.

1.3 Objective

The main objective of the study was to validate the yield predicting capacity of the Zambia Semi-Quantified Land Evaluation System for non-irrigated agriculture for maize production under small holder farmers' conditions in Agro-Ecological Region II of Zambia.

1.4 Hypothesis

The hypothesis that was tested in the study was:

There are no significant differences between maize yields predicted for small holder farmers on different soil types by the Zambia Semi- Quantified Land Evaluation System and actual yields obtained by small holder farmers following recommended agronomic practices on the different soil types in Magobbo Settlement Scheme of Mazabuka district in the Southern Province of Zambia.

CHAPTER 2

LITERATURE REVIEW

Land evaluation aims at assessing the suitability of land for specified uses (Landon, 1991). The main purpose of land evaluation is to inform the process of allocation of land uses to land areas by individuals, collectives, or governments. As such it is a tool for strategic decision making. A complementary purpose of land evaluation is to describe the limitations to land use, so that appropriate management methods are taken based on them (Rossiter and Van Wambake, 1997). The results of a land evaluation exercise may be quantitative or qualitative or may have a combination of both (Dent and Young 1981). Qualitative interpretations are useful in providing general information on the relative suitability of land for various uses. Quantitative assessments on the other hand, provide both relative assessments, and are further amenable to quantitative analysis which is very important in making in or carrying out economic analyses.

In qualitative land evaluation, the suitability of land for alternative purposes is expressed in qualitative terms, such as highly, moderately, or marginally suitable, or not suitable for a specified use. Qualitative evaluation is employed mainly at a reconnaissance scale, or as a preliminary to more detailed investigations. Qualitative evaluations are based mainly on the physical productive potential of the land, and are commonly employed in reconnaissance studies, aimed at a general appraisal of large areas (FAO, 1976).

Qualitative land evaluation may be as simple as narrative statements of land suitability for particular uses, or may group the land in a subjective way into smaller number of categories or suitability classes. This assumes a thorough knowledge of the optimum land conditions and of the consequences of the deviations from the optimum. These relatively simple systems of land evaluation depend largely on experience and initiative judgement and are, therefore, real empirical systems. No quantitative expressions of either inputs or outputs are normally given

(Van Diepen, 1991). The results of qualitative evaluation remain valid for many years, or until a major new technology is introduced.

A quantitative physical evaluation is one which provides quantitative estimates of the production or other benefits to be expected such as crop yields. To do this, it is necessary to specify the inputs also in quantitative form such as the tonnes of fertiliser used. Economic considerations are taken into account as part of the background information such as the general level of wages for labour and the likely labour intensities which are essential in making approximations of costs and prices needed to decide appropriate levels of inputs on which to base the estimates (Dent and Young, 1981). Physical land evaluations are mostly carried out as the basis for quantitative economic land evaluations. These indicate the degree of suitability for a land use, without respect to economic conditions (Rossiter, 1994). It tends to concentrate on risks or hazards or absolute limitations of undertaking a given land utilization type on a given land area. Where economic evaluations are needed, detailed quantitative physical evaluations are necessary, so that the results can be reinterpreted using other economic assumptions.

There are three main land evaluation systems used in Zambia. These are (i) the Land Capability System of the former Land Use Branch of the Ministry of Agriculture, now referred to as the Technical Services Branch, (ii) the Land Evaluation System of the Soil Survey Unit of the ZARI and (iii) the Zambia Semi-Quantified Land Evaluation System for non-irrigated agriculture.

2.1 The land Capability Classification System

The Land Capability Classification System was developed in the early 1970s and was designed to indicate the relative suitability of land for rain - fed, medium to large scale commercial farming of mainly maize, and tobacco, and to a lesser extent soya beans, sunflower, and groundnuts, on land cultivated using either tractors or ox-drawn implements, where farmers had access to adequate inputs of fertilizers, pesticides, and weed control, and other relevant technical services to prevent land degradation (Anonymous, 1977). This system places greater emphasis on soil physical properties than the chemical status of the soil, on the assumption that physical factors such as soil texture, gravel content, depth to limiting layer, and permeability of the soil are much more difficult to alter compared to chemical conditions of the soils for which amendments are easier to obtain. The Land Capability Classification is still widely used, despite its many limitations. Some of the weakness of the system is its reliance on physical properties of the soil alone as the major criterion for assessing suitability of the land and its emphasis on only two major crops, namely maize and tobacco at one level of management (Kalima and Veldkamp, 1985).

2.2 The Land Evaluation System based on the FAO Framework for Land Evaluation

The FAO Framework developed from earlier land capability approaches that emphasize relatively permanent limitations to land use. In this system, the overall land suitability of a specified land area for a specific land use is evaluated from a set of independent land qualities, which may each limit the land-use potential (Rossiter and Van Wambeke, 1997). Land suitability, on the other hand, is assessed and classified with respect to specified kinds of use as opposed to a single scale of 'goodness' of land (Rossiter, 1994). There are two kinds of suitability in the FAO System, namely, physical and economic; while Automated Land Evaluation System (ALES) can evaluate for both (Rossiter and Van Wambake, 1997).

2.3 The Automated Land Evaluation System (ALES)

The Automated Land Evaluation System (ALES), is a computer programme that allows evaluators to build expert systems to evaluate land according to the method of the FAO Framework of Land Evaluation and it is intended for use in project or regional scale land evaluation .The entities evaluated by the system are map units which can be defined either broadly or narrowly. Broadly as in reconnaissance surveys and general feasibility studies and narrowly as in detailed resource surveys and farm scale planning. There is no fixed list of land use requirements by which land is uses are evaluated and no fixed list of land characteristics from which land qualities are inferred as these lists are determined by the evaluators themselves (Rossiter and Van Wambake,1997).

The Land Evaluation System of the Soil Survey Unit of ZARI is based on the FAO Framework for Land Evaluation (1976) Guidelines for Land Evaluation (Kalima and Veldkamp, 1985). It involves matching the requirements of various land uses in terms of measureable properties of the land with the actual properties of the land. The land use requirements include, climatic factors, physical and chemical conditions of the land, management level of the farmers and access to land conservation technologies to prevent land degradation. The final product of the evaluation is a qualitative assessment of the suitability of the land for a specified use, with an indication of the limiting factors to the use of the land for and intended purpose.

2.4 The Zambia Semi- quantified land evaluation System

The Zambia Semi- Quantified Land Evaluation System is a model developed for rain-fed agriculture to predict yield for various crops and involves fifteen steps to execute as described by Veldkamp (1987). The first stage requires the selection of the crops whose suitability is to be evaluated. This requires a description of the season in which the crops are to be grown and the level of inputs that will be used in its production. The evaluator then selects the relevant land qualities to be used from the 78 sub- qualities which are grouped into 21 qualities, 6 of which deal with climate and the other 15 with soil. A Land Quality (LQ) is a complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use (Rossiter, 1994). Soil derived land qualities are qualities that can be measured or estimated through soil survey and laboratory techniques. (Siderius, 1992). After selection of relevant sub-qualities and land characteristics required for the evaluation is done, the relevant land characteristics are then assessed and a rating of the suitability of the land at a given input level is made. An assessment of whether the limiting characteristics are permanent or variable is also made and a determination of the nature of the most limiting factor is made. Based on the overall suitability rating of an area for a given crop, the expected sustainable yield of the crop is estimated based on the reference yield of the variety of a crop to be grown. Above all, the area where the crop is grown has to be classified in terms of the Agro- Ecological Zone and Sub- Zone for effective selection and rating of various climatic and soil sub-qualities.

The Zambia Semi- Quantified Land Evaluation System differs from the other land evaluation systems because it incorporates physical and chemical properties of the soil, climatic conditions of the location and the farmers' ability to manage the land for crop production. The system further includes a method of predicting yields from information on the soil, climatic conditions and farmers' levels of management based on a reference potential yield of the crop cultivated. The output of this system is a qualitative suitability classification of the land and a quantitative prediction of crop yield, whereas the other systems were basically qualitative.

The only published attempt was by Chinene (1991) when he made comparisons between expected and actual yields. In the study, he observed that the range of actual yields was wider than expected. He attributed this to among other things, variation in management practices by the farmers. Despite this, strong correlations were observed between the actual yields and expected yields, although there were significant differences between the predicted and observed yields. A study was therefore conducted in the Magobbo area of Mazabuka District in Southern Province, to assess how well the Zambia Semi-Quantified System of Land Evaluation could predict maize crop yields grown by small scale farmers under different soil conditions.

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of Study Site

Magobbo Settlement Scheme is 12km North West of Mazabuka on farm number 125(a) in Chief Naluama's area. It is located between Nakambala Sugar Estate and Nanga. The settlement is served by an all weather gravel road which links it with Mazabuka to the South and joins the Great North Road near Munali Hills to the North. The scheme has 73 farms in total covering an area of approximately 1,800 ha.

3.1.1 Location of study site

The study was conducted in Magobbo Settlement Scheme, an area in Mazabuka District of the Southern Province of Zambia. Magobbo settlement is located between longitudes 27^{o}53' and 27^{o} 55' East and latitudes 15^{o} 49' and 15^{o} 51' South with an average elevation of about 1015 m above sea level. The scheme is located North- East of Mazabuka District. There is a rail line and a major hydro-electricity power line passing to the South West of the settlement.

3.1.2 Geology and Geomorphology

Magobbo settlement together with most flat areas of Mazabuka District is part of the Central African Plateau. It is part of the degraded Central African Plateau being level to gently undulating where the drainage density is low (Dalal-Clayton 1985). The area is traversed by networks of streams and rivers and dambos. Mazabuka District is underlain by rocks belonging to the Mazabuka Group which comprises five main rock formations, namely; the Nega-Nega formation of quartzite and quartz, Muscovite –schists, the Chifumpu limestone, Muzuma calc-silicate formation and the Kaleya limestone formation (Anonymous, 1998; Sokotela and Sichinga, 2007) reported that the Magobbo area is underlain by calc-silicate rocks.

3.1.3 Climate

The climatic conditions in Magobbo are similar to those that prevail over much of Zambia, characterized by a tropical continental climate characterized by three main seasons. There is a cool dry season from May to July, a hot dry season from August to Mid October and a hot wet season from end of October to April. The nearest Meteorological stations to the study area are at the National Irrigation Research Station (NIRS), Zambia Agricultural Research Institute (ZARI) of the Ministry of Agriculture and Livestock (MAL) at Nanga located about 4 kilometres North East of the study site. There is also a Meteorological Station at Nakambala Sugar Estates in Mazabuka District about 13 km South East of Magobbo.

The rainfall distribution pattern is unimodal and highly erratic. Mazabuka receives an annual rainfall varying from about 400 to 1100 mm with an average annual rainfall of about 700 mm for the 32 year period of 1965- 1997. Most of this rain falls during the rainy season between November and March. According to the Agro-Ecological Sub-Zones Map of Zambia extracted from the Zambia Semi-Quantified Land Evaluation Manual (Veldkamp, 1987), Mazabuka District including Magobbo settlement occur in Agro Ecological Zone II, sub region IIa and sub-zone 9. The current rainfall figures for Mazabuka indicate that it should be in region I, while the boundaries of the Agro-Ecological zone map in Veldkamp report (1987) shows that Mazabuka is in region II. For the purpose of this study, therefore, Magobbo settlement was taken to be occurring in Agro-ecological Sub-Zone IIa (Anonymous, Ministry of Agriculture and Livestock, National Agricultural Policy, 2004-2015).

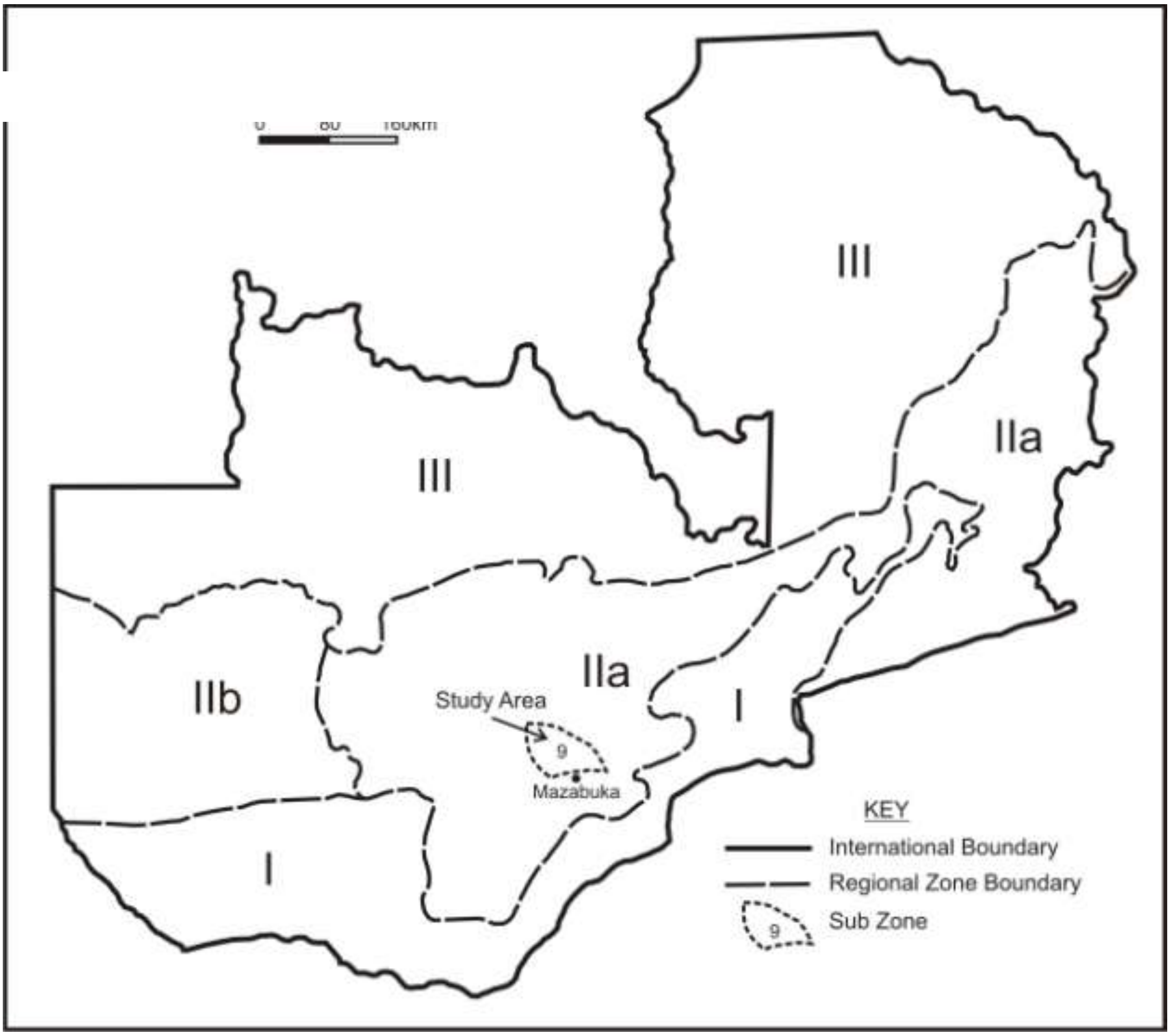

Figure 1. Agro-Ecological Zone Map of Zambia. (Source: Veldkamp (1987).

3.1.4 Soils and Topography

Topography in Magobbo area is generally flat, with slopes of not more than 2%. In very wet years, flooding affects most areas, especially in the lower position of the landscape, such as those represented by mapping units two and three. Three main mapping units were identified in the study area by Sokotela and Sichinga (2007). The major land mapping units and description of soils in the study area are shown in figure 1 below.

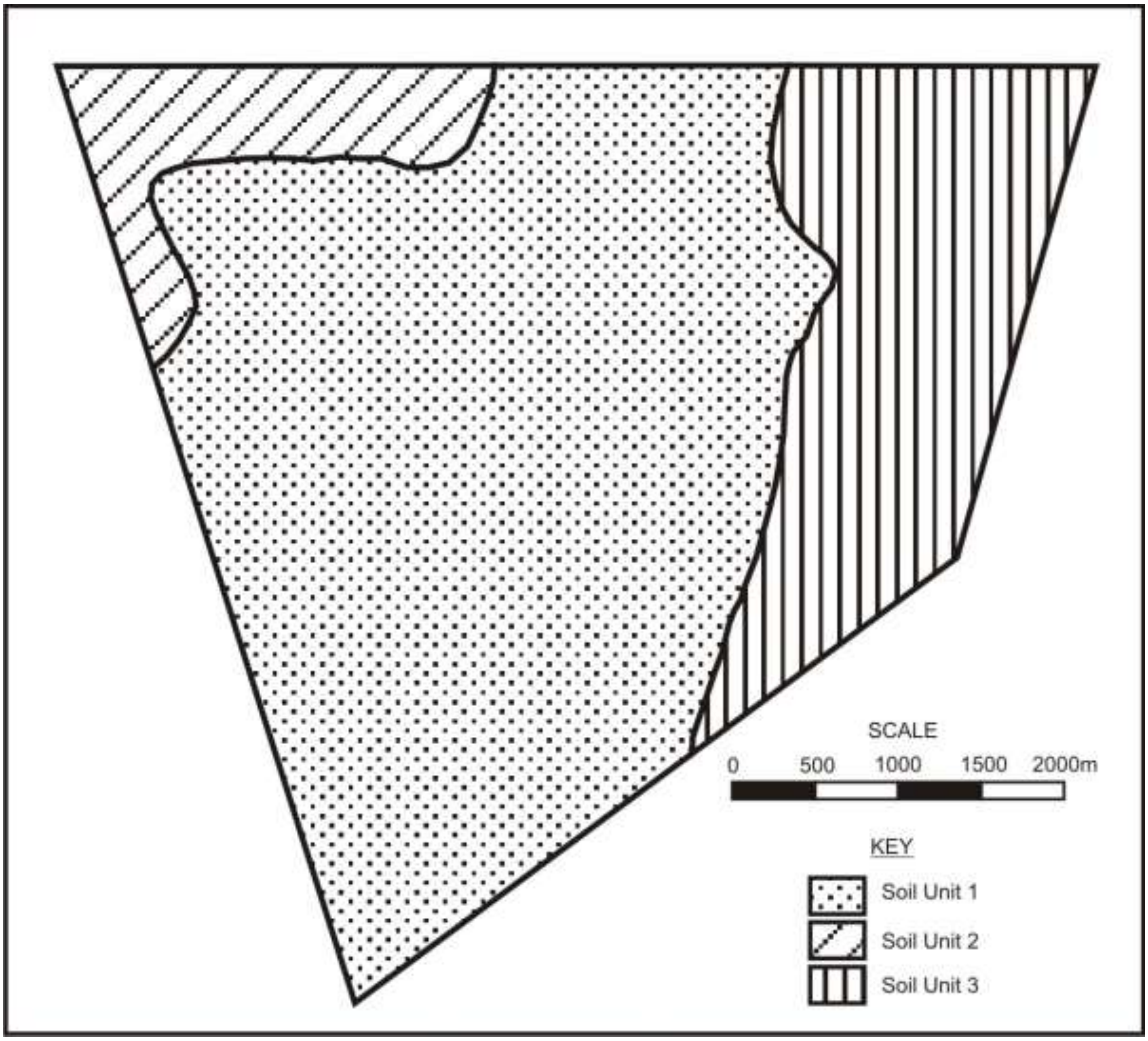

Figure 2. Major land mapping units and soils in Magobbo (Source: Sokotela and Sichinga, 2007).

The major soils in mapping unit 1 belong to Nakambala Soil Series, which is classified as a Ferric Luvisols in the FAO Legend (FAO, 1988) and as Typic Kanhaplustalf in Soil Taxonomy (Soil Survey Staff 1992). In mapping unit 2, the dominant soils belong to Mwembeshi Soil Series which is classified as a Calcaric Phaeozem according to the FAO Legend (FAO, 1988) and as an Udic Haplustoll in Soil Taxonomy (Soil Survey Staff, 1992). Mapping unit 3 is dominated by soils belonging to Cheta Soil Series, classified as Chromic Vertisol (FAO, 1988) and Udic Chromustert in Soil Taxonomy (Soil Survey Staff, 1992). Profile Descriptions for the dominant soils in mapping units 1, 2, and 3 are presented in Appendices 1, 2, and 3 respectively.

Table 1. Major Soil Properties and Classification of Major Soils in the Three Land Mapping Units

Mapping unit	Physiographic position	Description of soil in mapping unit	Classification of soil
1	Upland area to middle slopes on nearly level gently sloping land	Deep moderately drained dark yellowish brown sandy clay loam top soil , with mottling from 60-80cm	Nakambala soil series Ferric Luvisol (FAO, 1988). Typic kanhaplustalf (USDA, 1992) *
2	Middle to lower slopes of very gently sloping plateau	Deep, imperfectly drained, very dark grayish brown to dark brown sandy clay loam top soil over yellowish brown to olive brown clay sub soil with mottles from 50-100 cm depth in the soil profile.	Mwembeshi Soil Series Calcaric Phaeozem (FAO, 1988) Udic Haplustoll (USDA, 1992).
3	Lower slopes of very gently sloping plateau	Deep, poorly drained dark gray sandy clay loam to clay top soils over sandy clay to clay sub soil with frequent depressions due to sink holes. Calcium carbonates occur on the surface and increases with depth in some instances.	Cheta Soil Series Chromic Vertisol (FAO, 1988) Udic Chromustert (USDA, 1992). *

(Source: Soil Survey Staff, 1992).

3.1.5 Water Resources

The Kafue River runs through the Kafue Flats, which is a flood plain. The upstream end of the flood plain to the West lies below the Itezhi Tezhi Dam, which controls water supply to the Kafue Gorge Power station to the eastern end. The flood regime is, therefore, no longer natural but controlled by the Zambia Electricity Supply Corporation (ZESCO). The Corporation aims to simulate a natural flooding regime in order to maintain the natural habitat of the flats. Control of the flood levels and the flow to the Gorge is controlled by a modern computerised system that accounts for all the upstream water levels and the downstream demands from ItezhiTezhi Dam. Therefore the water regime is well understood and monitored so that availability for irrigation should be entirely predictable.

3.1.6 Socio-Economic Environment

Magobbo settlement scheme is one of the sixteen schemes in Mazabuka Districts that was established by government with the aim of settling farmers. The settlement is 12km North West of Mazabuka on farm number 125(A) in Chief Naluama's area. It is located between Nakambala Sugar Estate and Nanga. The settlement is served by an all weather gravel road which links it with Mazabuka to the South and joins the Great North Road near Munali Hills to the North. The main electricity power line and the railway line that links the South to the North of the country pass through the settlement. A few farmers have access to electricity. There is a railway siding or substation at Lubombo located about a kilometre South of Magobbo for easy marketing of produce and farm input acquisition.

There are about 73 small farm holdings ranging from 4 to 32 ha in size. The total area of land held by small holder farmers is about 940 ha with an average area of 12.5 ha per farmer, while the total area of the whole settlement is about 1800 ha. The average household size per small holding is 9 people. The estimated population of the settlement at the time of the survey was about 900 people.

Agriculture is the major economic activity in this settlement. At the time of the study, most of the small holder farmers were engaged in rearing cattle for beef, a few were engaged in rearing dairy cattle. Besides rearing cattle, many farmers also kept goats, and free range poultry. A few farmers had donkeys that were mainly used for draft power for cultivation and transport .A few farmers were involved in fish farming while some had also established citrus orchards. The dominant or main crop grown by most farmers is maize. Maize is grown under rain fed conditions during the wet season. Because of the relatively high production of maize in the area compared to other crops, the government constructed a maize storage shed for farmers to use to store the harvested maize crop before marketing it to other areas. Vegetables are also grown by all farmers, though on a much smaller scale compared to maize. The settlement is served by one extension officer based at the Agricultural Research Station at Nanga who is the chief advisor to small holder farmers on matters relating to agriculture.

3.2 Selection of Farmers for the Study

An area in Magobbo Settlement Scheme in Mazabuka District was selected as a study area. The area had been surveyed, and mapped at a semi-detailed survey level by Sokotela and Sichinga, (2007). Three major land mapping units were identified during this survey. A number of farmers occupying the mapped area were small holder farmers growing maize who were beneficiaries of the Farmer Input Support Program (FISP) provided by the Ministry of Agriculture and Livestock. Farmers under this programme follow the agronomic practices recommended by the Ministry of Agriculture and Livestock for smallholder farmers who receive 5 kg maize seed and two bags of fertiliser per lima as a pack for maize cultivation.

Other crops were not supported at the time of the study as they were grown only by a handful of farmers. Incorporating other crops in study was, therefore, difficult because of this phenomenon. The fertiliser component comprises two bags of fertiliser, (top and basal dressing). The farmers' level of management of the land and the crop corresponds to the moderate level of management described by Veldkamp (1987) in the Zambian Semi-Quantified Land Evaluation System.

For the purpose of this study, farmers included in the study were those who were cultivating maize in the area surveyed and mapped by Sokotela and Sichinga (2007), who were growing maize following Ministry of Agriculture and Livestock recommendations and who were beneficiaries of the FISP. Farmers under the FISP received maize seed and fertilizers at rates recommended by the Ministry of Agriculture and Livestock. The selection of the farmers was done with assistance of the local agricultural extension officer operating in the settlement. Veldkamp (1987) defined farmers with moderate input levels as those who are able to spend between 10 to 100 US $ or a current equivalent of 50,000 to 500, 000 ZK on agricultural inputs per hectare per year. These are typically smallholders with some access to agriculture extension services, who do buy some fertilizer, new seed every year, may have oxen, or can hire labour at peak periods. Each of the farmers selected to participate in the study was asked to allocate one Lima (0.25 hectares) of their maize field for growing maize under the project. A total of 30 farmers were selected for the project. These were distributed over three land mapping units identified during the survey by Sokotela and Sichinga (2007). The largest category of farmers were from the Nakambala Soil Series as it had 80% of the soils mapped and hence with the largest proportion of the farmers. The Mwembeshi and Cheta Soil Series only had 3 and 4 farmers each. The Mwembeshi and Cheta Soils often get flooded in the rainy season and have been mostly reserved as grazing areas.

3.3 Management of Trial Sites

One Lima (0.25 ha) plots were demarcated on each of the thirty (30) farmer's fields for cultivating maize following Ministry of Agriculture and Livestock recommendations for small holder farmers with a moderate level of management. The one Lima plot was cultivated using the traditional hand hoe. The fertilizers rates used were an equivalent of 200 kg Compound D fertilizer (10% N: 20 % P_2O_5: 10 % K_2O) per hectare as basal dressing applied at the time of planting, and 200 kg Urea (46% N) per hectare applied about 4 to 5 weeks after germination. The maize variety MM 603 was used as the test crop for all farmers who participated in the project. According to Mc Phillips (1987) the yield potential for MM 603 is 7,000 kg/ ha. The normal agronomic practices such as weeding were carried out by farmers as they do on their own fields following recommendations by farmers. Weeding was mainly done by hand, using family labour. No pesticides were used to control pests. The supervision of the management of the fields was left to the Agriculture Extension Officer in charge of the Camp where the scheme lies. This management was from farmer selection, land preparation, planting weeding up to harvest time.

3.4 Collection of Maize Yield data

At the time of harvesting, each farmer collected the maize cobs from the one Lima trial plot. The maize was left to dry and then shelled. The grain was weighed and recorded as kilograms of grain per Lima. This was then converted to the expected grain yield per hectare by multiplying it by a factor of four. The yield data collected from the different land mapping units were aggregated to get an estimate of the mean yield per mapping unit, which was compared with the yield estimates obtained using calculations based on yields predicted by the Zambian Semi-Quantified Land Evaluation System.

3.5 Method of Land Evaluation

As already alluded to, results of survey and mapping of the soils were provided by Sokotela and Sichinga (2007). The assessment of the land mapping units identified by Sokotela and Sichinga (2007) for maize production under small holder farming conditions was carried out following the procedure described in the Zambian Land Evaluation System described by Veldkamp (1987).

3.6 Land Evaluation using the Zambia Semi-Quantified Land Evaluation System

The procedure used in evaluating the land using the Zambia Semi-Quantified Land Evaluation system has been described by Veldkamp (1987) and involves about 15 steps. The first stage requires the selection of the crop whose suitability is to be evaluated. This requires a description of the season in which the crop is grown and the level of inputs that will be used in its production. The evaluator then selects the relevant land qualities to be used to evaluate the suitability of the crop for the area in question. The relevant land characteristics are then determined and a rating of the suitability of the land at a given input level is made. An assessment of whether the limiting characteristics are permanent or variable is also made and a determination of the nature of the most limiting factor is made. Based on the overall suitability rating of an area for a given crop, the expected sustainable yield of the crop is estimated based on the reference yield of the variety or cultivar considered.

To assess the suitability of maize on the three land mapping units identified by Sokotela and Sichinga, the Zambia Semi-Quantified Land Evaluation System outlined by Veldkamp (1987) was applied. Out of the twenty-one (21) land qualities that Veldkamp (1987) identifies, seventeen (17) were found to be relevant for assessing the suitability of growing maize in Magobbo. These land qualities that were selected included accessibility of the area in the rainy season, rainfall excess hazard, rainfall deficit hazard, wind hazard, biological degradation hazard, chemical degradation hazard, nutrient reserve, levels of potassium, and calcium, vernalization requirement, high temperature hazard, low monthly temperatures, low or high mean temperatures, low radiation hazard, solar radiation and flooding hazard.

An assessment of the suitability of each of the three land mapping units for growing maize at moderate levels of inputs was made and the final rating for each unit was determined. The final ratings of each land mapping unit were then used to estimate the sustainable yield of maize expected assuming that (i) one used the reference yield of maize given by Veldkamp (1987) of 5000 kg per hectare and (ii) one used the reported reference yield of the maize variety MM603 that was actually used by the farmers in Magobbo. For the larger land mapping unit that had the highest number of farmers, farmers were further subdivided into two groups based on their level of actual management of the crop that season namely, those that managed their crop well according to recommended practices and those that did not follow recommended practices.

3.7 Statistical Analysis

To find out whether there were statistically significant differences between the maize yields obtained by farmers in the three land mapping units and the maize yields predicted for the three land mapping units using the model of the Zambia Semi Quantified Land Evaluation System, a t-test were used at 0.05 level of significance. The statistical analyses were carried out using the Statistical Software SAS Version 9.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Rating of Land qualities in mapping units for maize production.

To determine the suitability of the three mapping units for maize production, seventeen (17) sub qualities that were found to be relevant for maize production in the Semi-quantified land evaluation system were selected. The 17 land qualities include some related to climatic conditions and others related to soil conditions. The climate related land qualities included accessibility in rainy season, rainfall excess, rainfall deficit, wind hazard, vernalization requirement, high temperature hazard, low monthly temperature, low or high mean temperature, low radiation and flooding hazards. The soil related land qualities included biological degradation, chemical degradation hazard, nutrient reserve, potassium, calcium, soil pH, drainage or soil aeration hazard and flooding hazard were assessed.

The properties of each of the three mapping units with respect to each of the 17 land qualities were compared with the requirements for maize productions for the same qualities. A rating was then made for each land quality in each mapping unit. Results of these ratings are presented in Table 2 below.

Table 2. Rating of sub qualities for maize production for the three land mapping units.

Land sub quality	Code	Land quality ratings of the three mapping units		
		Unit 1	Unit 2	Unit 3
Accessibility	AC	1a	1a	1a
Rainfall- excess	BE	1a	1a	1a
Rainfall deficit	BM	1a	1a	1a
Wind hazard	CV	1a	1a	1a
Biological degradation hazard	DB	1a	1a	1a
Chemical degradation hazard	DC	1a	1a	1a
Nutrient Reserve	NA	1a	1a	1a
Potassium	K	1a	1a	1a
Calcium	NT	1a	1a	1a
Soil pH	pH	1a	1a	1a
Drainage or soil aeration hazard	WO	1	2	3
Vernalization requirement	TC	1a	1a	1a
High temperature hazard	TH	1a	1a	1a
Low monthly temperature	TL	1a	1a	1a
Low or high mean temperature	TT	1a	1a	1a
Low radiation hazard	UR	1a	1a	1a
Flooding hazard	FL	2	3	4

In the Zambia Semi-Quantified Land Evaluation System, each land quality may form a constraint. The severity of such a constraint is expressed by five constraint classes namely 1a, none, 1b slight, 2 moderate, 3 severe and 4 very severe. The suitability class, therefore, is formed on the basis of the severity of the constraints (Veldkamp, 1987).

4.2 Suitability Rating of Land mapping Units

From the ratings of the 17 land sub-qualities presented in Table 2 the final suitability rating for reach mapping unit was determined. The final suitability rating of a mapping unit was determined by the lowest rating of the sub-qualities in that mapping unit. For the three mapping units the sub quality that had the lowest rating was the flooding hazard, indicating that the greatest limitation to the use of the three mapping units for maize production was the flooding hazard. Most of the other land qualities were non- limiting for maize production, other than the limited drainage in mapping units 2 and 3 that were likely to adversely affect aeration of roots. Results of the final rating of the three land mapping units are presented in Table 3.

Table 3. Final Suitability Ratings of Mapping Units for maize production

Land Mapping Unit	Suitability Class	Suitability Interpretation
1	II	Moderately Suitable
2	III	Marginally Suitable
3	IV	Marginally Suitable

(Moderately suitable)= Land having limitations that in aggregate are moderately severe for sustained application of the defined use.

(Marginally suitable)= Land having limitations that in aggregate are severe for sustained application of the defined use and will reduce productivity or benefits.

Results in Table 3 show that land mapping unit 1 falls in Suitability Class II which indicates that the land in this unit is moderately suitable for maize production. ,Land mapping unit 2 falls in Suitability class III, which is marginally suitable for maize production while land mapping unit 3 falls in Suitability Class IV which is also marginally suitable for maize production though more severely affected than mapping unit 2.

4.3 Prediction of sustainable maize yields using the Zambia Semi -Quantified Land Evaluation System

To determine the expected yields under small holder farmer conditions with moderate levels of management data in Table 4 were used. This yield gives the percent yield of the potential yield of a crop one can expect to obtain under different levels of management for land with different suitability ratings. In this study, since the three mapping units fell in suitability classes II and III and while the farmers had moderate levels of management, the predicted yields were those falling under the column with moderate levels of management for land suitability classes of II and III.

Table 4. Expected sustainable yield levels under different levels of management

Land Suitability Class	Expected % of Potential yield under different management levels			
	LOW	MODERATE	HIGH	VERY
Class 1	38	63	88	125
Class II	19	**31**	44	63
Class III and IV	9	**16**	22	31

(Source, Veldkamp,1987).

Based on Table 4, the expected maize yields for farmers with moderate levels of management on land with a suitability rating of II is 31 % of the potential yield of the maize variety grown by the farmer, while the expected yield for farmers growing a maize crop on land with a suitability rating of class III would be 16 % of the potential yield for the maize variety grown by the farmer.

The reference potential yield for maize presented in the Zambia Semi Quantified Land Evaluation System is 5000 kg/ha (Appendix 4). Based on this reference potential yield and using expected percent yields from Table 4, the expected or predicted yields of maize for each of the land mapping units were calculated. However, the actual potential yield of the maize variety used by farmers in Magobbo in the 2008/2009 season is MM 603 which has a yield potential of 7000 kg/ha (Mc Phillips, 1987). Therefore, the predicted yields for the maize crop for the different mapping units were also calculated using the expected percent yields presented in Table 4. Results of the expected or predicted maize yield using the Zambia Semi-Quantified Land Evaluation System for reference potential yields of 5000 kg/ha and 7000 kg/ ha are presented in Table 5.

Table 5. Predicted maize yields for the three land mapping units, based on reference or potential maize yields of 5000 kg ha and 7000 kg/ha.

Land mapping Unit	Reference Potential Yield of Maize	
	5000 kg/ha	7000 kg/ha
1	1500	2170
2	800	1120
3	800	1120

4.4 Actual Maize yields obtained by farmers

The actual maize yields obtained by farmers in Magobbo from 1 lima (0.25 ha) fields were obtained and converted to equivalent yields per hectare assuming that the level of management of a 1 lima field would not be significantly different from that of a 1 ha field are presented in Appendix 5. Table 6 presents the mean yields of maize per hectare per farmer in each of the three mapping units.

Table 6: Average maize yields obtained by farmers in the different mapping units in Magobbo area

Land mapping Unit	Number of farmers	Maize Yield (kg/ha)
1	23	1627
2	3	1367
3	4	1511

Land mapping unit 1 had the most extensive area and highest number of farmers. Some farmers in this unit did not strictly adhere to the recommendations given by the Ministry of Agriculture and Livestock such as timely weeding, and their management was, therefore, lower than expected. Farmers who followed recommended practices obtained higher yields than those who did not. Therefore, in this land mapping unit, farmers were separated into two groups representing those who followed recommended practices and those who did not. The average maize yields obtained by farmers from the three mapping units after making a subdivision of farmers in land mapping unit 1 into those with good management and those with poor management are presented in Table 7.

Table 7. Average actual maize yields obtained by farmers in the different mapping units in Magobbo area reflecting differences in management in mapping unit 1

Land mapping Unit	Management	Number of farmers	Maize Yield (kg/ha
1	Good	13	2057
1	Poor	10	1150
2	Good	3	1367
3	Good	4	1511

Farmers who followed recommended practices in mapping unit 1 had yields of about 2000 kg /ha while those who did not follow recommended practices had yields of about 1200 kg/ha which was quite a significant difference. Those in mapping unit 2 obtained about 1400 kg/ha while those in mapping unit 3 had about 1500 kg/ ha which are quite comparable to the national average of about 1500 kg/ ha for small holder farmers (Anonymous,2010).

4.5 Comparison of predicted maize yields with actual yields obtained by farmers.

Table 8. Comparison of predicted maize yields and actual yields obtained by farmers using a reference potential yield of maize of 5000 kg/ha.

Land Mapping Unit	Suitability Class	Expected maize Yield(kg/ha)	Actual maize Yield(kg/ha)	Sign t-Test at α=0.05
1	II	1500	1627	Non sign
2	III	800	1367	Sign
3	III	800	1511	Sign
Percentage of successful predictions				33.3 %

The data in table 8 above show that predicted average yields as a percentage of potential yield in different land mapping units at 5000 kg/ha as suggested by Veldkamp(1987). The percentage of successful predictions is 33% in the three land mapping units without considering management aspects at farmer level.

When the Zambia Semi-Quantified Land Evaluation System is used to predict maize yield based on 5000 kg/ ha which was used in the system, the model is only able to make 33 % correct predictions. The failure rate in the predictability of yield when one uses 5000 kg/ha as reference yield is not acceptable for the system. Therefore, the use of 5000 kg as reference yield is a major source of error in the prediction of yield because the potential yield that was used was much higher than the reference yield given in the system. Therefore, using the 5000 kg/ ha as reference yield is likely to lead to very unrealistic predictions when used for maize varieties with a potential yield that is much higher than 5000 kg/ ha

To verify whether the poor yield prediction of the Zambia Semi-Quantified Land Evaluation System for maize yields in Magobbo was due to using a reference yield of 5000 kg/ ha when the actual potential yield of the maize grown was 7000 kg/ha, a comparison was made of the predicted and actual yields using a reference potential yield of 7000 kg/ha. Results of these comparisons are presented in Table 9.

Table 9. Comparison of predicted maize yields and actual yields obtained by farmers using a reference potential yield of maize of 7000 kg/ha.

Land Mapping Unit	Suitability Class	Expected maize Yield(kg/ha)	Actual maize Yield(kg/ha)	Sign T-Test at α=0.05
1	II	2170	1627	Sign
2	III	1120	1367	ns
3	III	1120	1511	ns
Percentage of successful predictions				66.7 %

Results in Table 9 show that using the actual potential yield of the maize variety grown by farmers instead of using the reference yield given in the model , increased the yield predicting capacity of the model from 33.3 to 66.7 % . Correcting the reference yield input for the potential yield in the model thus doubled the models’ yield predicting capacity. It also confirms that the use of 5000 kg/ha as the reference yield may have contributed to the poor prediction of maize yields in results presented in Table 8.

As earlier alluded to, the levels of management by farmers in land mapping unit 1 differed significantly. Due to this difference in levels of management, the farmers were segregated into two groups as the differences in levels of management affected the yield of maize obtained by farmers. For this reason, a further comparison of yields taking into account differences in management by the farmers in land mapping unit 1 and assuming potential yields of 5000 and 7000 kg/ ha was made. Results of this analysis are presented in Table 10.

Table 10. Comparison of predicted and actual maize yields of farmers using potential yields of 5000 and 7000 kg/ha with segregation of farmers in mapping unit 1 according to levels of management.

Map Unit	Actual Yield (kg/ha)	Predicted yield and significance at 5000 kg/ha potential yield		Predicted yield and significance at 7000 kg/ha potential yield	
		Predicted yield (kg/ha)	Significance at 0.05	Predicted yield (kg/ha)	Significance at 0.05
1 (Well managed)	2018	1500	Sign	2170	Non sign
1 (Poorly managed)	1150	1500	Sign	2170	Sign
2	1367	800	Sign	1120	Non sign
3	1511	800	Sign	1120	Non Sign
Percent successful predictions		NA	0 %	NA	75 %

Results show that when the influence of management in mapping unit 1 was taken into account, the yield prediction by the Zambia Semi-Quantified Land Evaluation System when the potential yield of maize was assumed to be 5000 kg/ha was 0 %, indicating that system completely failed to make correct predictions when the levels of management were taken into account and a potential yield of maize of 5000 kg/ha was used. This confirms the importance of using correct input parameters such as the potential yield of the crop for making reliable predictions of actual yields. The failure by the system to predict yields correctly when a reference yield of 5,000 kg/ ha was used is due to the fact that potential yields of the new crop varieties that farmers are using are much higher than those that existed in the late 1980s when the model was developed. It is, therefore, necessary to make corrections for such input parameters that may have changed over time, if the Zambia Semi-Quantified Land Evaluation System is to be used to make reliable predictions.

A further observation of the results in Table 10 is that when farmer's levels of management in land mapping unit 1 were taken into account and corrections for the potential yield of maize were made, the rate of successful yield predictions by the system increased to 75 % which is reasonably good. This increase in the ability of the system to predict maize yield can thus be attributed to correcting some of the input parameters, namely using the actual potential yield of the crop grown by farmers and by accounting for discrepancies between the actual and assumed management levels employed by the farmers. These findings are similar to those by (Chinene, 1991) in the land evaluation system for rain fed agriculture which he developed for Zambia for use in reconnaissance and semi- detailed. The evaluation system works with 74 sub-qualities, 40 crops and four input levels. His findings were such that the range of actual yields was wider than expected when comparisons were made between expected and actual yields because of variation in management levels between farmers.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The Zambia Semi Quantified Land Evaluation System was tested to find out how well it predicted maize yields under smallholder farming conditions in Magobbo area following recommended practices by the Ministry of Agriculture and Livestock. When yields were predicted using a reference potential yield of 5000 kg/ha, the system made 33 % correct predictions. Upon correcting the potential yield from the assumed 5000 kg/ha given in the manual for the method, to the actual potential yield of the maize variety grown of 7000 kg/ha, the yield predicting capacity of the system increased from 33.3 to 66.7 %. A further refinement of the input into the system by taking into account the actual management levels by farmers in land mapping unit 1, which had the largest number of farmers, the predicting capacity of the system decreased to 0% at 5000 kg/ha while that of 7000 kg/ha increased to 75 % which is good. Results of this study have demonstrated that the Zambia Semi Quantified Land Evaluation System is able to make good predictions of maize yields for small scale farmers, provided correct input parameters such as the potential yield of the crop and accurate assessments of the management levels are used in the system.

5.2 RECOMMENDATIONS

This study was conducted in Agro-ecological zone II of Zambia. The validation results contained in this report, therefore ,only apply to region II, There is need ,therefore, for this system to be tested in other Agro- Ecological zones namely I and III. For effective use of the system, there is also need to use the correct input values of parameters such the actual potential yield for a particular crop being investigated instead of relying on the values that are in the tables in the manual that was originally prepared in 1987. Furthermore, to obtain reliable estimates of crop yields using the Zambia Semi- Quantified Land Evaluation System requires that that the management levels of farmer are in line with recommended agronomic practices assumed in the system. An immediate recommendation is that input parameters on potential yields of crops presented in Appendix 4 be updated to reflect changes in potential crop yields that have occurred since the Zambia Semi-Quantified Land Evaluation System was developed in 1987.

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7.0 APPENDICES

Appendix 1.0 Soil profile Descriptions for major soil in Land mapping unit 1. .

Profile number: 1

Zambian Soil Name: Nakambala Soil Series

Classification: FAO: Ferric Luvisol (FAO, 1988)

USDA: Typic kanhaplustalf (USDA, 1992).

Date: 10 February 2007

Author(s): Stalin Sichinga

Location: Magobbo, Mazabuka

Longitude: 35 L595963E

Latitude: UTM 8248756N

Altitude: 1021m

SITE DESCRIPTION

Vegetation type: Cleared grass land with *hyperhania*

Land Use: Cropland

Crops: Maize

Input level: Medium

Land form: Degraded Central African Plateau

Land Element: Interfluve

Micro relief (<50cm) Type: Tussocks

Slope: 0-1%

Slops type: Simple

Slope Class: 0-2%

Slope side position on slope: Upland to middle slopes on nearly level gently sloping land.

GENERAL INFORMATION

Drainage: Moderately well drained

Moisture condition in the soil: Wet

Depth of ground water table: 1.8m

Presence of surface stones or rock outcrop: none

Incidence of flooding: No floods

Source of Data: Local information

Water Erosion: Slightly eroded land

Shrink-Swell potential: Low

SOIL PROFILE DESCRIPTION

Horizon	Depth	Description
A	0-10	Very dark grayish brown (10YR3/2) moist; sandy clay loam; strong, medium, crumb primary structure, firm (moist), slightly sticky and plastic (wet), few, worm holes, partly filled with excreta/nest material medium, irregular, in local concentration, many fine random roots, highly porous, many fine inped and exped tubular pores, clear and smooth boundary.
BA	10-28	Dark brown (10YR3/3) moist; sandy clay loam; common fine faint diffuse, both interior/exterior of peds mottles, strong sub angular

blocky medium primary structure, strong sub angular blocky, medium secondary structure, firm (moist), slightly sticky and plastic (wet); few moderately thick prominent common manganese coats in both horizontal and vertical ped faces; few medium irregular worm holes partly filled with excreta/nest material in local concentration; common fine random roots; moderately porous, many fine inped and exped tubular pores, few medium inped and exped tubular pores, clear and smooth boundary.

Btgz1	28-43	Dark brown (10YR4/3) moist; clay loam; common fine distinct clear mottles in both interior and exterior of peds, strong fine sub angular blocky primary structure; strong fine sub angular blocky secondary structure; firm (moist), sticky and plastic (wet); common moderately thick prominent common manganese coats in both horizontal and vertical ped faces both random and tubular, few medium irregular worm holes partly filled with excreta/nest material in local concentration; common random fine roots; moderately porous, common fine both inped and exped pores; gradual and smooth boundary.
Btgz2	43-100	Dark yellowish brown (10YR4/4) moist; clay loam; common fine distinct clear mottles in both interior and exterior of peds, strong fine sub angular blocky primary structure; strong fine sub angular blocky secondary structure; firm (moist), sticky and plastic (wet); few coarse

medium random roots; slightly porous common fine both inped and exped pores; gradual and smooth boundary

Btgz3 100-137 Yellowish brown (10YR5/4) moist; clay loam; common fine distinct clear mottles in both interior and exterior of peds, strong fine sub angular blocky primary structure; strong fine sub angular blocky secondary structure; sticky and plastic (wet); few medium oblique roots; common fine both inped and exped pores;

Appendix 1.1. Soil Analytical Data for Nakambala Soil Series

Lab No	Your Ref	pH $CaCl_2$	Na Cmol/ kg soil	P ppm	K Cmol/ kg soil	Ca Cmol/ kg soil	Mg Cmol/ kg soil
2007/289	0 -10	5.3	<0.01	5	0.72	4.0	1.6
2007/290	10 - 28	4.9	<0.01	2	0.43	4.5	2.0
2007/291	28 - 43	4.9	<0.01	3	0.26	4.6	1.8
2007/292	43 - 100	5.6	0.09	3	0.26	6.6	3.1
2007/293	100 - 137	6.1	0.13	2	0.18	6.9	3.3
	Critical level	**4.5**		**15**	**0.15**		

Appendix 2.0 Soil profile Descriptions for major soil in Land mapping unit 2.

Profile No.

Authors Sichinga Stalin & Rabson Mwenda

Mapping Unit: 2.1

Date of Description: 12.02.2007.

Location: Magobbo

Province/ District:Southern/Mazabuka Longitude:27 50.

Land Form: Degraded Central African Plateau. Latitude: 15 50.

Land Element: Interfluve UTM Grid: 35L 595 664, 8247 767

Slope: 0 - 2 %

Descriptive: **Magobbo area NE of Mazabuka**

Slope Type: Simple. Elevation: 1029 m a.s.l.

Slope Length: 100m. Surface Runoff: Medium.

Slope Position: Middle slope Internal Drainage: Medium.

Soil Erosion: not appreciable Drainage Class: moderately

Parent Material: *calcareous-feldspathic sandstone* . Seepage: none.

Vegetation: Munga woodland Ground water table: not found

Plant Species: grass species dominancy Incidence of Flooding: incidental to heavy rains

Density: medium to dense Meso relief: Termite hills

Land Use: Small scale cultivation Micro relief: Stool mounds

Farming System: Small scale maize production/ fishing Agro-ecological Zone: 5.

Crops: Maize, Groundnuts, Cotton, Sugarcane etc

2. SOIL CLASSIFICATION **USDA Soil Taxonomy**: Udic Haplustoll (USDA, 1992).

FAO: Calcaric Phaeozem(FAO,1988).

Zambia Soil Series: Mwembeshi Soil Series.

3. **SOIL PROFILE DESCRIPTION.**

Horizon	Depth (cm)	Description
Ad	0 - 25	**Very dark gray** (10YR 3/1); moderately drained, sandy clay loam, with a coarse sized, strong grade crumb structure, having friable, slightly-sticky and plastic wet and moist consistence. Has common medium and coarse sized spherical and irregular shaped partly filled nest termite holes in local concentrations. There are many fine sized, randomly oriented, and common medium size oblique oriented roots. The horizon is moderately porous with many fine sized inped tubular, and few medium sized inped and exped pores. Has a clear and smooth horizon boundary.
BA	25 - 45	**Dark yellowish brown (**10YR 3/4); sandy clay, having common medium sized faint dark brown (7.5YR 4/4) interior and exterior of ped mottles. Has moderate grade course sized subangular blocky structure that breaks into fine sized strong grade subangular blocky structure. Soils have firm moist, sticky and plastic wet consistence. Have common medium and coarse sized spherical and irregular shaped partly filled termite holes throughout the horizon. There are common fine sized, randomly oriented, and few medium size horizontally oriented roots. The horizon is moderately porous

with many fine sized inped tubular, and few medium sized inped and exped pores. Has a diffuse and smooth horizon boundary.

Btg1 45 - 79 **Dark yellowish brown** (10YR 4/4); sandy clay having many coarse sized distinct dark red (2.5YR 3/6) interior and exterior of ped mottles. Has strong grade coarse sized subangular blocky which breaks into moderate grade fine sized subangular blocky structure. Soils have firm moist, sticky and plastic wet consistence.

Shows few fine sized faint clay skins on both horizontal and vertical ped faces. There are few medium sized irregular shaped dark red (2.5YR 3/6) clay nodules throughout the horizon. Have common medium and coarse sized spherical and irregular shaped partly filled termite holes throughout the horizon. There are few fine sized, randomly oriented, and common coarse size oblique oriented roots. The horizon is moderately porous with many fine sized inped tubular, and few medium sized inped and exped pores. Has a gardual and smooth horizon boundary.

Btg2 79 - 120 **Yellowish brown** (10YR 5/4); sandy clay soil with having many coarse sized distinct yellowish red (5YR 5/8) interior and exterior of ped mottles. Has weak grade medium sized sub angular blocky structure that breaks into weak grade fine sized sub angular blocky structure. Soils have firm moist, sticky and plastic wet consistence. Shows few fine sized faint clay skins on both horizontal and vertical ped faces. Contains few medium sized irregular shaped yellowish red (5YR 5/8) clay nodules throughout the horizon. Has a common medium and coarse sized spherical and irregular shaped partly filled termite hole throughout the horizon. There are few fine sized, randomly oriented roots. The horizon is moderately porous with many fine sized inped tubular, and few medium sized inped and exped pores. Has a gradual and smooth horizon boundary.

Btg3 120 - 140 Yellowish brown (10YR 5/6); sandy clay soil with having common medium sized distinct yellowish red (5YR 5/8) interior and exterior of ped mottles. Has weak grade medium sized subangular blocky structure that breaks into weak grade fine sized subangular blocky structure. Soils have friable moist, sticky and plastic wet consistence. Have common medium and coarse sized spherical and irregular shaped partly filled termite holes throughout the horizon. There are few fine sized, randomly oriented roots. The horizon is moderately porous with many fine sized inped tubular, and few medium sized inped and exped pores.

Appendix 2.1 Soil Analytical data for Mwembeshi Soil Series

Lab No	Your Ref	pH $CaCl_2$	Na Cmol/ kg soil	P ppm	K Cmol/ kg soil	Ca me%	Mg Cmol/kg soil
2007/294	0 - 25	5.8	<0.01	5	0.79	5.8	1.5
2007/295	25 – 45	5.8	0.04	3	0.41	5.8	3.1
2007/296	45 – 79	6.4	<0.01	4	0.49	6.4	2.0
2007/297	79 – 120	6.1	<0.01	3	0.36	6.1	1.9
2007/298	120 - 140	5.6	0.04	7	0.31	5.6	1.9
	Critical level	**4.5**		**15**	**0.15**		

Appendix 3.0 Soil profile Descriptions for major soil in Land mapping unit 3

Profile No: 3

Zambian Soil Name:	Cheta Soil Series
Classification:	(i) FAO: Chromic Vertisol (FAO, 1988).
	(ii) USDA Soil Taxonomy: Udic Chromustert (USDA 1992).
Date:	5 February 2006
Author(s):I	S. B. Sokotela, A. Mambo, Stalin Sichinga, and G. K. Siulemba
Location:	Magobbo Settlement, Mazabuka District, Southern Province

SITE DESCRIPTION

Vegetation type:	Termitariar
Land Use:	Natural grazing
Farming System	Peasant farming
Input Level:	High
Parent Material:	Not identified
Other unconsolidated:	Alluvial
Land form:	Degraded Central African Plateau
Land Element:	Plain

Mesorelief (>50cm) type: Pinnacle type termite mound, 3m base diameter, 2.5m Height, 80m distance between features.

Micro relief (<50cm) Type:	Gilgai
Slope:	1%
Slops type:	Simple
Slope Class:	0-2%
Slope side position on slope:	Lower slope

Aspect:	North

SOIL MOISTURE AND DRAINAGE

Surface Runoff:	Ponded
Internal Soil Drainage:	Very slow
Soil Drainage Class:	Poorly drained
Seepage:	Present Seasonally
Incidence of flooding:	Floods common
Ground water:	20cm depth of water table at the date of the observation. Measured in profile, 20cm minimum expected depth of water table, 2m maximum expected depth of water table
Water Erosion:	No appreciable erosion
Gully Modifier:	Not observed
Wind Erosion:	No Wind erosion
Stoniness:	Non-Stony
Rockiness:	Non-rocky
Salinity:	Non saline
Sodicity:	Non sodic
Shrink-Swell potential:	High

Soil Profile Description.

Horizon	Depth (cm)	Description
Ah	0–8 cm	Dark gray (2.5Y4/0) moist; matrix features, moist, clay loam, fine, fine; common, medium, distinct, clear, rusty root channels (10YR4/6); few, fine, faint, diffuse, exterior of peds (10YR4/6); sub angular blocky, moderate, medium primary

structure; sub angular blocky, weak, very fine secondary structure; friable (moist), sticky (wet), plastic; other insect holes, unfilled, few, medium, tubular, in local concentrations; many, fine, vertical roots; many, medium, vertical roots; moderately porous; many, fine, inped, tubular pores; few, medium, inped, tubular pores; clear and smooth boundary.

AB 8–22 cm Dark gray (2.5Y4/0) moist; matrix features, moist, clay, fine, fine; common, medium, distinct, clear, rusty root channels (10YR4/6); few, fine, faint, diffuse, exterior of peds (10YR4/6); sub angular blocky, strong, medium primary structure; friable (moist), sticky (wet), plastic (wet); many, prominent, thick, both horizontal and vertical ped faces, clay skins (10YR4/6); few, unfilled, medium, irregular, other insect holes, in local concentration; common, fine, vertical roots; common, medium, vertical roots; slightly porous; few, fine, inped, tubular pores; few; clear and smooth boundary.

Bt 22–78 cm Gray (2.5Y5/0) moist; matrix features, moist, clay, fine; columnar, strong, very coarse primary structure; friable (moist), sticky (wet), plastic (wet); many, thick, prominent, clay skins, both horizontal and vertical ped faces, (10YR4/6); few, fine, vertical roots; common, medium, vertical roots; slightly porous; few, fine, inped, tubular pores; few, medium, inped, tubular pores; clear and smooth boundary.

Bt/Cg 78-100 Submerged under water.

Table 13. Soils chemical data for Cheta soil series.

Depth (cm)	Ca cmol/.kg soil	Mg cmol./kg soil	K cmol/.kg soil	Na cmol/.kg soil	Org.C (%)	Total N (%)	pH	P (ppm)	CEC Cmol/.kgclay
0–8	10.4	5.4	0.44	0.66	2.61	0.19	5.8	7	26.9
8–22	9.2	5.2	0.08	0.27	0.66	0.05	6.1	8	29.5
22–78	10.2	5.7	0.12	0.88	0.43	0.03	7.1	9	12.3

Appendix 4. Reference potential crop yields per hectare of various crops.

Crop	Yield (kg/ha)	Crop	Yield (kg/ha)
Alfalfa	20,000	Orange, sweet	20,000
Avocado	25,000	papaya	20,000
Banana	30,000	Pea, pigeon	1,600
Barley	2,000	pineapple	30,000
Bean ,common(dry)	1,200	Potato, sweet	10,000
Cabbage	25,000	Potato, white	25,000
Cassava	25,000	pumpkin	10,000
Castor bean	1,500	rape	40,000
cashew	1,500	Rice, dry land	2,500
Coffee arabica	1,200	Rice, paddy	5,000
Cotton	1,500	sorghum	3,000
Cowpea	1,200	Soya bean	1,600
Rhode Grass,	20,000	Sun flower	1,500
Groundnuts (unshelled)	2,000	Tea	1,700
Grass star	20,000	Sugarcane	100,000
Kenaf	1,500	Tobacco	1,200
Maize	5,000	Tomato	1,200
mango	15,000	Water melon	20,000
Millet, bulrush	2,000	Wheat, rain fed	2,500
Millet, finger	2,000		
Onion	10,000		

(Source, Veldkamp, 1987).

Appendix 5. Names of farmers in the different mapping units and actual maize yields obtained in kg/ha.

S/N	Mapping Unit	Name	Farm	Maize Yield (kg/lima)	Maize Yield (kg/ ha)
1	1	Peter Makumbi	72	525	2,100
2	1	Simwakaka Friday	14	431.25	1,725
3	1	Henry Simwakaka	14	318.75	1,275
4	1	Simon Mutinta	14	431.25	1,725
5	1	George Muchindu	15	193.75	775
6	1	Milambo Edward	07	431.25	1,725
7	1	Hangombe Severino	29	287.5	1,150
8	1	Ngoma George	29	437.5	1,750
9	1	Malambo cyprianol	53B	625	2,500
10	1	Mulopa Obert	08	625	2,500
11	1	Kakoma situmbeko	51	475	1,900
12	1	Ebby Musantakwela	52B	512.5	2,050
13	1	Felix Nalumino	23	256.25	1,025
14	1	Muleya Gellard	65	387.5	1,550
15	1	Ngandu Alfred	27	581.25	2,325
16	1	Mweemba Goodson	49	312.5	1,250
17	1	Clement Hanyulu	68	575	2,300
18	1	Chifwa Edward	48	325	1,300
19	1	Obert Hameenda	06	343.75	1,375
20	1	Magaya Rabion	47	562.5	2,250
21	1	Lena Siabwanda	50	225	900
22	1	Kakoma Situmbeko	51	475	1,900
23	1	Angerston Chuubo	53	225	900
24	2	Face Moonga	19 A	356.25	1,425
25	2	Rodger Mweene	21	368.875	1,437.5
26	2	Ask Nalonda	18	300	1,200
27	3	Moonga Blescol	26 B	448.75	1,795
28	3	Katowa Peter	25B	387.5	1,550
29	3	Robby Moonga	26 A	400	1,600
30	3	Peter Ngandu	25	275	1,100