# LAND EVALUATION OF MANGOCHI PROJECT AREA IN MALAWI FOR GRAZING BY APPLICATION OF AUTOMATED LAND EVALUATION SYSTEM (ALES)

By

ISAAC REUBEN MSUKU (MALAWI)

SOILS DIVISON



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INSTITUTE FOR AEROSPACE SURVEY AND EARTH SCIENCES

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# Land Evaluation of Mangochi Project Area in Malawi for Grazing by Application of Automated Land Evaluation System

by

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The Thesis is presented in partial fulfilment of the requirements for the degree of Master of Science in Soil Survey using Aerial Photographs and other Remote Sensing techniques at the International Institute of Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands and submitted to an Examination Committee, comprizing;

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## S U M M A R Y

The objective of this study is to test the applicability of Automated Land Evaluation System (ALES) on assessing the physical suitability of Mangochi area in Malawi for grazing and to determine whether the area is overstocked or understocked and come up with recommendations on how to improve the livestock industry.

The study area had been surveyed in 1988 by FAO and a soil map exists at the scale of 1:250,000. However, data on vegetation is lacking and were collected during fieldwork between March and May, 1990.

ALES was used to evaluate the area for grazing based on erosion hazards, grazing capacity and accessibility models. ILWIS was employed to incorporate distance to source of water. The results by ALES were compared with those obtained by manual application of land evaluation procedures.

The results of the investigations are as follows;

- Mangochi area is overstocked by animals. The overstocking is worse for the eastern lakeshore area than the western lakeshore area.
- Most of Mangochi low lying area is moderately suitable (S2) for grazing mainly due to low crude protein content of the forage as well as long distances from grazing areas to source of water. The hilly areas are not suitable because of erosion hazards and accessibility problems.

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# CHAPTER 1. INTRODUCTION.

## 1.1 Background Information

Malawi is facing many challenges in raising the standard of living of its population by means of social and economic development. The population of Malawi is over 8.0 million (1987 cencus) and it is growing at the rate of 3.5% per year which is one of the highest in Africa. The total land area is 9.4 million hectares of which 3.5 million hectares is arable. Each year more than 3 million hectares is under cultivation and about 1.2 million hectares is under fallow. The balance is under forest or used for grazing (Dzowela,1985). The high population growth rates and small holdings is the concern of the Malawi government.

Systematic land use planning is therefore required to assure not only the improvement of the present population but also the conservation of the environment for the future generations. Any successful development programme requires a comprehensive inventory of human, economic and physical resources, an appraisal of the present situation, an analysis of the cultural and physical problems in resource development, and an estimate of resource potentials in spatial terms. These are the basic elements of land evaluation; the results of land evaluation provide information on which decisions for future land use can be taken so that a permanent ecological balance can be achieved.

In Malawi land for agricultural purposes is assessed according to the FAO's framework for land evaluation (1976) methodology. However methods based on manual evaluation involve repeative calculations and making conversion tables, and are thus tidious if many alternatives are being considered. Manual procedures, both for construction of matching tables or similar devices , and for calculation of suitability, are time consuming and prone to error. Because of the above problems many agricultural projects in Malawi are being implemented without sufficient land evaluation data. In many cases land evaluation is done for rainfed crops (maize and tobacco) and there is little or no data on the potential or suitability of the range lands for grazing.

To overcome the planning problem due to lack of data, the government of Malawi in cooperation with UNDP and FAO initiated in 1986 a Land Resource Evaluation Project. The aim of the project is to make an inventory of the land resources of the country and carry out an evaluation of them. Under this project Automated Land Evaluation Systems (ALES; Rossiter and Van Wambeke 1989) is being used in evaluating the land. However ALES is a new computer program which has not been tested under Malawi farming systems or land use practices.

## 1.2 The Objectives of Study:

The objective of this study is to test the applicability of ALES on assessing the physical suitability of land for grazing for the main livestock types found in Mangochi Project Area, MALAWI. The main livestock types are cattle ( Malawi Zebu, Bos Indicus), goats and sheep. The results obtained by using ALES will be compared with those obtained by assessing suitability manually.

It is also intended to look at the present livestock populations of Mangochi survey area and find out whether the land is overstocked or understocked and come up with recommendations on how best the land can be utilized and improved for grazing.

# CHAPTER 2: LITERATURE REVIEW.

## 2.1 Objective of Land Evaluation.

The objective of land evaluation is to assess the suitability of different tracks of land for specified alternative forms of rural land use (FAO, 1976). It is the process by which land qualities are matched with the requirements of a land use. The results of a land evaluation provide for the planner a basis for decisions regarding changes in land use.

## 2.2 Principles and Procedures of Land Evaluation.

There are six basic principles (FAO, 1976) which are fundamental in the approach and methods employed in land evaluations:-

a. land suitability is assessed and classified with respect to a specified kind of use.

b. evaluation requires a comparison of the benefits obtained and the inputs needed by different types of land.

c. evaluation is made interms relevant to the physical, economic, and social context of the study area.

d. a multi-disciplinary approach is required.

e. suitability refers to use on a sustained basis, therefore environmental degradation is taken into account when assessing suitabilities.

f. evaluation involves comparisons of more than a single kind of use.

Two different land evaluation approaches can be distinguished with respect to the time sequence in which the physical and social-economic studies are carried out (FAO, 1976).

a. a two stage land evaluation approach. This consists of a first stage which is mainly concerned with physical land evaluation, later followed by a second stage consisting of economic and social analysis.

b. a parallel approach; the physical evaluation proceeds concurrently with socio-economic analysis.

In practice the difference between the two approaches is not clear cut, and a combination of these approaches is possible; for example a two stage approach at reconnaissance level followed by a parallel approach at semi detailed and detailed scales.

2.3 Basic Concepts of Land Evaluation.

Certain concepts and definitions are needed as a basis for land evaluation. These concern the land quality, land characterristics, diagnostic creteria and land use requirements.

Land Quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use, eg, temperature regime, moisture availability, drainage, nutrients etc. Whilst a land characteristic is defined as an attribute of land that can be measured or estimated (FAO, 1976), eg.slope, mean monthly temperature, soil drainage class, soil depth,etc.

Land use requirement is a set of conditions needed by a particular land use. Land use requirements and land qualities express the same thing but from different view points.

Diagnostic creteria are used for the rating or estimation of land qualities in land evaluation. In some cases, a land quality can be satisfactory described on the basis of a single land characteristics, whilst in others, a combination of characteristics is used.

In land evaluation it is possible to use any of the following as a basis for assessment of land siutability ( FAO 1984, Huizing 1987);

a. Land Qualities.

The advantage of the use of land quality are that the evaluation is directly related to specific requirements of land use; this enables development of simulation models to explain land/land use relationships. Land qualities take account of interactions between environmental factors. The total number of the land qualities is considerably less than the number of land characteristics. The main disadvantage is the complexity involved in converting characteristics into qualities and in the selection of diagnostic characteristics for assessment of the qualities.

b. Land Characteristics.

The advantage of using land characteristics is that evaluation procedures are simple and direct, permitting a direct comparizon between the characteristics observed and the suitability rating. Disadvantages are the very large number of characteristics, the fact that it is often not clear what is the effect on the land use and the failure to take account of the interactions.

c. A mixture of Land Quality and Land Characteristics.

The advantage of this approach is that it combines the good elements of both systems.

As discussed, if the above approaches are done manually it can be tidious, time comsuming and prone to error. Hence, scientists started to develop automated procedures as an answer to the above problems. One notable automated procedure that has been developed and which is the subject of this investigation is Automated Land Evaluation System ( ALES). Automated Land Evaluation System (ALES) was developed by D.G. Rossiter, M. Tolomeo and A.R. Van Wambeke of Cornel University and is designed to carry out land evaluation according to principles of the Framework for Land Evaluation ( FAO, 1976).

2.4 Types of Land Suitability Classification.

In Framework for Land Evaluation (FAO, 1976) only four kinds of suitability classifications are recognised. Choice are whether its qualitative or quantitative and current or potential suitability. According to the way in which the results are expressed, two types of land evaluation can be distinguished (FAO1984; H.Huizing 1987).

2.4.1 Qualitative Land Suitability Classification.

It is the one in which the results are expressed in qualitative terms only without specific estimates of outputs, inputs or costs on returns. The limit in between land suitability classes are defined in qualitative terms only.

2.4.2 Quantitative Land Suitability Classification.

It is the one in which the results are expressed in numerical terms which allow comparison between suitabilities for different types of land use. There are two types of quantitative evaluation;physical and economic. A quantitative physical evaluation is one which provides quantitative estimates of the benefits crop yields. The definition of the limits between land suitability classes include crop yield estimates for specified inputs and management. An economic land suitability classification, is one in which the results are expressed, at leased in part, in economic or financial terms. The essential feature is the use of monetary values for costs of inputs and prices of output.

Based on the presentation of the land use requirements, in the Giudelines for Rainfed Agriculture (FAO, 1984) two types of land evaluation can be recognized;

a) suitability rating:- every land quality is given a factor rating that indicates suitability of the land quality for a specific use. The factor ratings are expressed by means of a set of critical values, which determine the limits between classes. Normally suitability ratings distinguish 5 classes ( class 1 is highly suitable and class 5 is unsuitable).

b) Use of degree of limitation for rating suitability:- every relevant land quality is given a rating according to its effects on specific use. The rating is given according to the degree of limitation.

## CHAPTER 3. LAND EVALUATION FOR GRAZING.

In this study grazing refers to the land utilization in which animal feed comes from both grazing land ( rangelands) and cultivated lands. This is so because in Malawi due to population pressure rangelands cannot be separated from cultivated lands.

According to FAO 1976, land evaluation is the assessment of land performance for a specific use by matching the land qualities with the land use requirements with due consideration to both physical environment and social-economic factors. The principles and the techniques of the framework for land evaluation (1976) are to be adopted in assessing the land qualities of the mapping units identified in the study area for grazing by means of a computer program (ALES).

### 3.1 Land Use Requirements for Grazing.

The requirements for grazing are considered under three groups. The first deals with animal requirements and these are the requirements that affect the welfare of the animals directly. The second group concerns the management requirements and these relate to the technology of management systems while the final group looks at the conservation requirements for the avoidance of soil erosion or degradation so that sustained production can be maintained.

Most of the management and conservation requirements are directly related to the production of primary production. Hence, these requirements are the same as those outlined in the guidelines for land evaluation for rainfed agriculture (FAO,1984).

a. <u>Animal Requirements</u>.

Actual production of forage is the most important requirements that falls in this sphere. The weight of dry matter of plant materials required by a cow per day varies between 2 and 3% of body weight. In case of a tropical livestock unit (TLU) which is equivalent to cattle weighing 250kg, its dry matter requirement is 6.25kg per day.

The nutritive value of forage which is viewed in terms of the amount of phosphorus and crude protein content of the plant tissue is another factor that affects the animal directly. According to FAO,(1988) voluntary intake of grass by beef cattle and sheep is deppressed if crude protein is below 7% of dry matter. For Malawi Zebu cattle a level of 3.8% crude protein is sufficient for maintenance (FAO,1988; Munthali, 1986).

Another factor that affects animals directly is drinking water. There are many factors that influence the drinking water requirements of an animal. Among these is the daily temperature, the higher the temperature the more water the animal requires to fight against desiccation. The amount of water contained in its feed is known to affect the quantity of water needed. For example during the rainy season when the grass is green and with high moisture contents the animals drink less water than during the dry season when the forage contains less water.

Another important factor that affects the animal directly is the toxicity of some of the elements contained in animal feed. The maximum tolerable levels of aluminium and manganese for cattle for example is 1000ppm in both cases (NAS, 1985).

b. <u>Management Requirements</u>.

Soil fertility is variable depending on whether the forage is of grasses or cereals. Usually, medium to heavy type of soil textural classes are ideal for the growth of most fodder crops.

c. <u>Conservation Requirements.</u>

The conservation requirements of grazing land depends on such factors like the stocking rate, the topography of the area, rainfall intensity, land cover and soil types. The stocking rate is the actual number of animals, expressed in either animal units or animal unit months on a specified area at a specific time (FAO,1988). The more the number of animals per unit area, the greater is the tendancy for soil deterioration resulting from mashing and trampling actions on the soils by animals. The second factor deals with topographic features slope length and slope % and these factors are known to influence erosion. Rainfall intensity affects erosivity while soil types influence erodability.

3.2 Land Qualities and Land Characteristics.

FAO (1976) defines a land quality as a complex attribute of land which acts in a manner distinct from other land qualities in its influence on the suitability of land for a specified kind of use; while a land characteristic is an attribute of land that can be measured or estimated. The selection of land qualities depends on the land utilization types. FAO (1988) and Siderius (1984) lists a number of relevant land qualities for grazing. Out of these, those selected for this study are forage availability, nutritive value, erosion hazard, accessibility, drinking water availability and biological hazards. Table 1 shows the relationship between the various land qualities and the land characteristics.

Not all of these land qualities and land characteristics were used in the evaluation models. The quality of water was found to be alright and it was difficult to measure the quantity of water. For climatic hazards it is not necessary because the breeds of livestock being evaluated are local and well adapted to the climate. Climatic factors become important when one considers introducing exotic breeds. Flooding, thickets and stoniness are not a problem for the study area. There are poisonous plants, tsetse flies and tickborn diseases in the area but are not serious enough to affect production and the problems are evenly distributed throughout the area.

Table 1. Land Qualities and Land Characteristics ( source; FAO,1988

| Land Qualities | Land Characteristics |
|---|---|
| Grazing capacity | -forage yield (kg/ha)<br>-% crude protein<br>-% phosphorus |
| Water availability | - quality of water *<br>- distance to water<br>- quantity of water * |
| Erosion hazard | - % land cover<br>- % slope<br>- slope length<br>- rainfall<br>- soil depth<br>- soil texture |
| accessibity | - slope<br>- stonniness *<br>- flooding *<br>- thickets * |
| Biological hazards | -tsetse flies<br>- poisonous plants *<br>- tickborn diseases * |
| Climatic hazards | - temperature *<br>- rainfall *<br>- humidity * |

note: land characteristic with * were not relevant for the area

# CHAPTER 4: GENERAL DESCRIPTION OF THE STUDY AREA

## 4.1 Location.

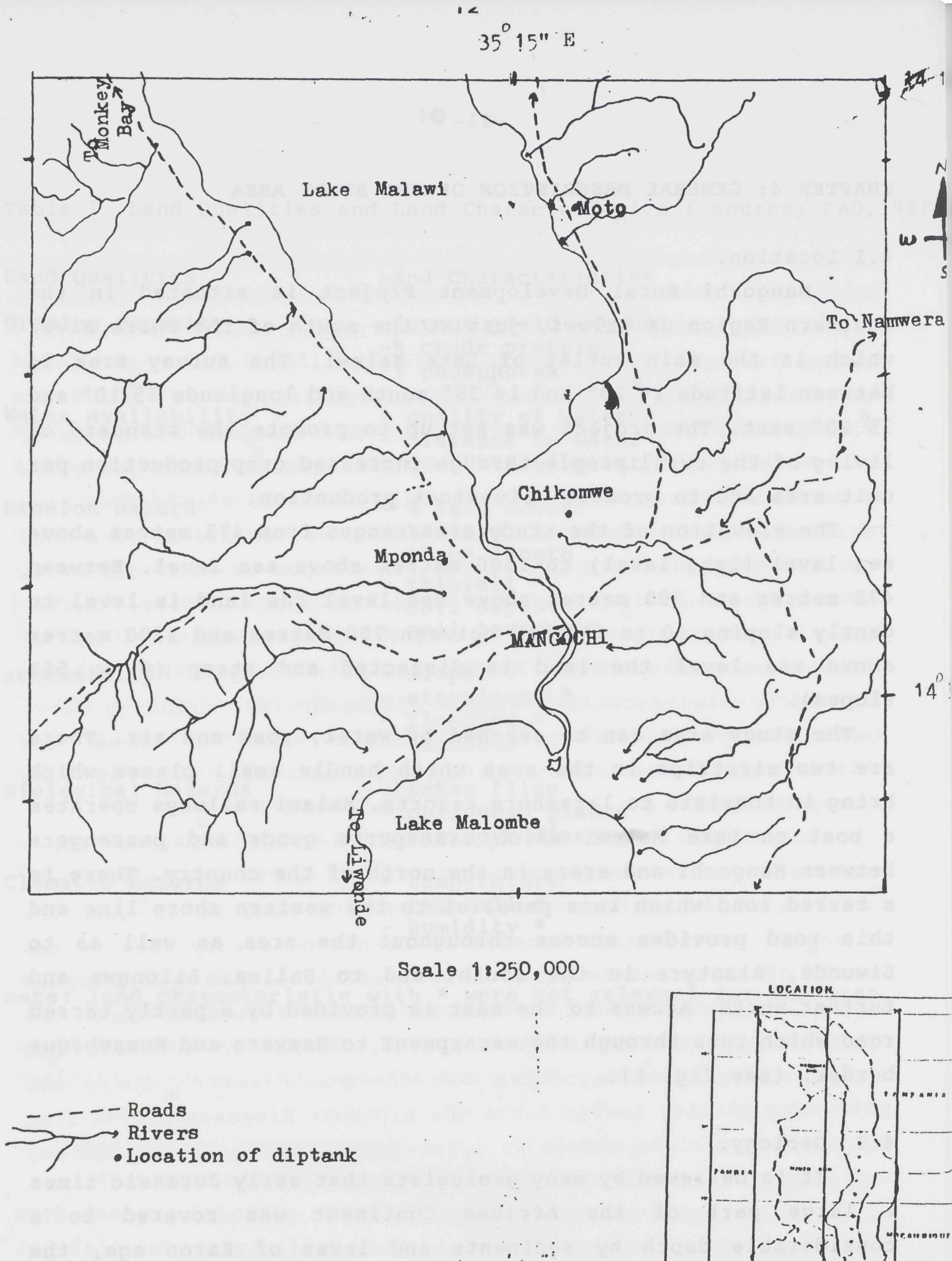
Mangochi Rural Development Project is situated in the Southern Region of Malawi, just at the mouth of the Shire River which is the main outlet of Lake Malawi. The survey area is between latitude 14° 20" and 14° 35" south and longitude 35° 10" and 35° 20" east. The project was set up to promote the standard of living of the rural people through increased crop production per unit area and to promote livestock production.

The elevation of the study area ranges from 472 metres above sea level (lake level) to 1300 metres above sea level. Between 472 metres and 700 metres above sea level the land is level to gently sloping (0 to 6%) and between 700 metres and 1300 metres above sea level the land is dissected and steep (6 to 55% slopes).

The study area can be reached by water, road and air. There are two airstrips in the area which handle small planes which bring in tourists to lakeshore resorts. Malawi railways operates a boat on Lake Malawi which transports goods and passengers between Mangochi and areas in the north of the country. There is a tarred road which runs parallel to the western shore line and this road provides access throughout the area as well as to Liwonde, Blantyre in the south; and to Salima, Lilongwe and further north. Access to the east is provided by a partly tarred road which runs through the escarpment to Namwera and Mosambique border. (see fig. 1).

## 4.2 Geology.

It is believed by many geologists that early Jurassic times a large part of the African Continent was covered to a considerable depth by sediments and lavas of Karoo age, the surface of which had, at that time, been peneplaned to a



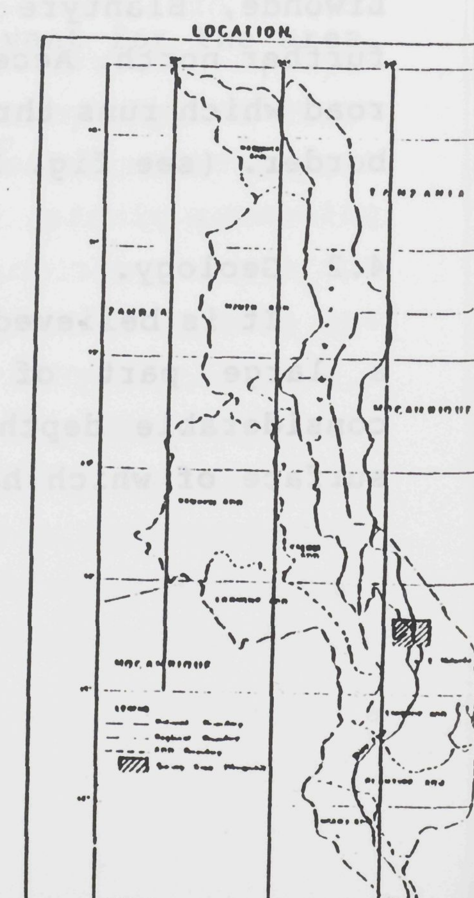



Fig.1. Location map of the study area.

remarkable smooth surface (Pike, 1965). Round about mid Jurassic times , fractures along the present line of the rift valley in which the survey area is located were initiated, which were however influenced by older fractures.

Further peneplanation took place before the beginning of Cretaceous times, followed by uplifting , fracturing and tilting. Following upon cycles of uplifts and erosion came further fracturing and down-warping; and it is thought that the intervening part of the rift between the northern and southern sections occurred at about the same time (prehistoric Lake Malawi).

During the Miocene widespread peneplaination took place again due to changes in climatic conditions (dry to very wet conditions). The softer rocks were base levelled and remnants of the late Jurassic and Cretaceous peneplains were preserved on areas underlain by resistant rocks, such as the harder syenetic and granitic intrusions and the harder quartzites and gneisses; Mulanje, Zomba and Dedza mountains are remnants of the old peneplain.

The Miocene uplift, of some 1000 t0 1100 metres, led to the erosion of the greater part of the Cretaceous sediments from the inland valleys and coastal plains. This infilling of the Lake Malawi trough was probably removed by the ancient Shire River that had by this time established itself within the main valley. This uplift, like that of the late Jurassic, was accompanied or followed by interminent fracturing and tilting of the surface, generally following older lines of weakness, but rather than to those of the early Cretaceous, are tentatively ascribed the subsidence stages of part of the floor of the Malawi rift from a level of the northern lake littoral (472 to 600 metres) to maximum of 200 metres below sea level, thus forming the basin now occupied by the present Lake Malawi. Together with the subsidence of Lake Malawi floor, contemporary movements were taking place in the southern area ( Mangochi to Lower Shire Valley) where the upper shire rift floor was lowered by about 100 metres along Makongwe scarp with local warping to form Lake Malombe and diversion of the Shire River from the east to its present position (Pike, 1965).

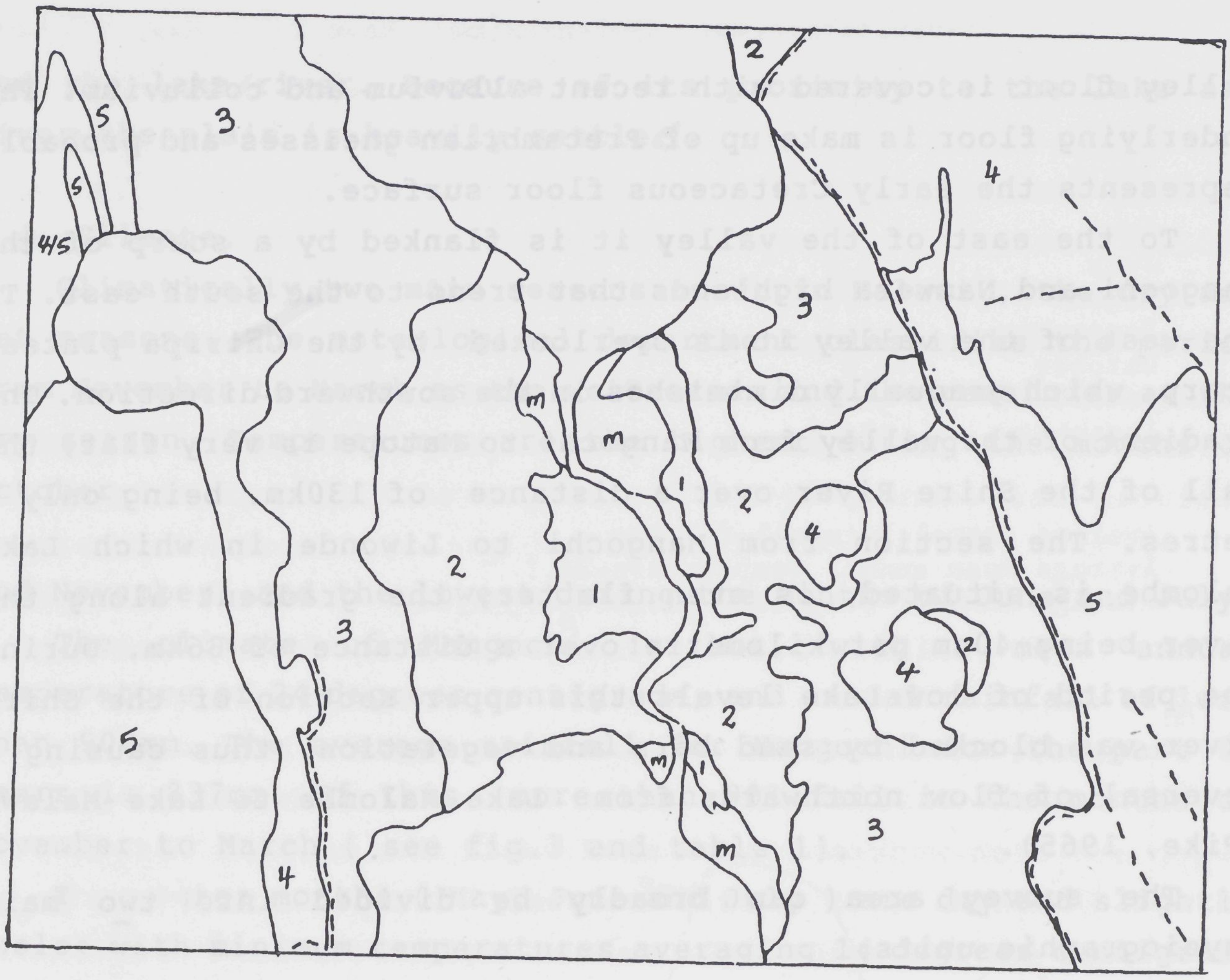
The most widespread system of rocks in Malawi are various gneisses, schists, metamorphised sediments and igneous intrusions of preCambrian age. The subdivision of these rocks is broadly divided into two systems; the Mozambique System which underly much of Southern Malawi and it is composed of schists, migmatites, gneisses, granulites, and dolomitic marbles together with intrusions of syenites and associated rocks. The second system called Mafingi occurs in isolated areas in the Central and Northern areas, and is made up of quartzites, phyllites and micaeous schist, clearly of sedimentary origin ( Pike, 1965).

According to Bloomfield, 1965 the rocks of the hilly areas of the study area consist of biotite and hornblende gneisses with bands of marble and calc-silicate granulites, and intrusions of granite and syenite. The lakeshore plain is composed of colluvial and alluvial deposits of various textures derived from the mountains/hills. The beach ridges and probably the lower footslopes have material deposited by the retreating lake. see figure 2.

## 4.3 Physiography.

The survey area is located in the Upper Shire Valley which is part of the Great Rift Valley. The Upper Shire Valley is a wide, flat valley extending from the southern limit of Lake Malawi along the course of the Shire River as far as Matope at the head of Murchison cataracts. At the northern end, a few kilometers from the outlet from Lake Malawi, the valley floor has been downwarped to form a basin now occupied by Lake Malombe. This northern part of the valley which covers the survey area, probably as far south as Liwonde, formed the bed of Lake Malawi during the late Pleistocene or early recent times and much of the

Fig.2: GEOLOGY OF MANGOCHI AREA(Source; Geological Map of Malawi)




Scale 1:250,000

| FORMATION | DESCRIPTION |
|---|---|
| Tertiary-Recent | (m) Marshes<br>(1) Lacustrine sands,spits,bars and beaches<br>(2) River alluvium,lacustrine deposits and dambo soils<br>(3) Residual deposits and colluvium. |
| Precambrian-Lower Palaeozoic | (4) Charnorkitic granulite and gneiss;Quartzo-feldspathi granulite and gneisses locally with biotite.<br>(5) Biotite gneiss with garnet strongly contorted into small folds. |

------ Faults

valley floor is covered with recent alluvium and colluvium. The underlying floor is make up of Precambrian gneisses and probably represents the early Cretaceous floor surface.

To the east of the valley it is flanked by a scarp of the Mangochi and Namwera highlands that trend to the south east. To the west of the valley it is overlooked by the Chiripa plateau scarp, which gradually diminishes in the southward direction. The gradient of the valley from Mangochi to Matope is very flat, the fall of the Shire River over a distance of 130km. being only 7 metres. The section from Mangochi to Liwonde in which Lake Malombe is situated, is even flatter, the gradient along the river being 40cm per kilometre over a distance of 36km. During the period of low Lake levels this upper section of the Shire River was blocked by sand bars and vegetation, thus causing a reversal of flow northwards from Lake Malombe to Lake Malawi (Pike, 1965).

The survey area can broadly be divided into three main physiographic units;

4.3.1 The Dissected Plateaux/ Hilly Land.

This area is found on both sides of lake Malawi. Lake Malawi occupies part of the Rift Valley which cuts through the middle of the study area. The hilly land can further be divided into the hills, incisions and the escarpment. The hills and the escarpment are not cultivated or settled but are left to natural vegetation. Livestock are allowed to graze in some areas.

4.3.2 The Piedmont.

The piedmont comprises of alluvial fans, glacis and some isolated hills. The alluvial fans and glacis are heavily settled and cultivated and are also used for grazing. The hills are not cultivated but left to natural vegetation.

4.3.2 The Lakeshore Plain.

The lakeshore plain is a narrow zone between the piedmont and the lake/river. Because of its proximity to the lake and river the plain is heavily settled.

4.4 Climate.

Climatically two main seasons occur in Malawi , the dry and wet seasons. The meteological department classifies the period from November to March as the wet season and the remainder as the dry season. Temperatures are the highest during the months of October

and November, and the lowest during the months of June and July.

The climate of Mangochi is hot, with a mean annual temperature of 24 degrees centigrade, and annual rainfall of less than 900mm. The average rainfall for Mangochi for the past 30 years is 837mm. Of this more than 90% fall in the months of November to March ( see fig.3 and table 1).

The winter months ( May, June and July ) are dry and slightly cooler with minimum temperatures averaging 14 degrees centigrade in July. The highest temperatures occur in October and November, before the start of the rainy season, when temperatures of 32 degrees centigrade are commonly recorded.

The length of the growing period ranges from 135 to 150 days. However it should be pointed out that rainfall in Mangochi is unreliable. Dry spells longer than two weeks are common during the growing season and if they occur they have detrimental effects on crop production.

The rainy season begins towards the end of November and ends early April. Between mid December and mid March rainfall exceeds evapo-transpiration and this humid period lasts 99 days. Between March and mid November evopotranspiration is higher than rainfall and the period between end April and mid November is the dry season.

Table 2: Climatological data for Mangochi Meteological Station (1958 to 1988)

| Month | Precipitation(mm) | ET-Penman(mm) | Mean T(°C) | Max. T(°C) | Min. T(° |
|---|---|---|---|---|---|
| January | 197.1 | 139.9 | 25.6 | 30.2 | 21.5 |
| February | 198.8 | 118.2 | 25.5 | 30.0 | 21.3 |
| March | 133.8 | 129.3 | 25.2 | 30.1 | 21.0 |
| April | 38.5 | 113.2 | 24.2 | 29.5 | 19.6 |
| May | 5.8 | 98.5 | 22.1 | 27.3 | 16.5 |
| June | 4.5 | 83.4 | 20.2 | 26.5 | 14.3 |
| July | 3.9 | 97.3 | 20.1 | 26.2 | 14.1 |
| August | 1.7 | 119.9 | 21.7 | 28.2 | 15.1 |
| September | 5.4 | 151.9 | 24.5 | 30.3 | 17.2 |
| October | 13.8 | 178.5 | 27.0 | 32.5 | 20.7 |
| November | 59.4 | 166.5 | 27.5 | 31.1 | 20.5 |
| December | 174.6 | 140.2 | 26.2 | 29.8 | 21.0 |

Average annual rainfall=837.5mm
Average mean annual temperature=24.1 °C
Average annual evapotranspiration=1532.8mm

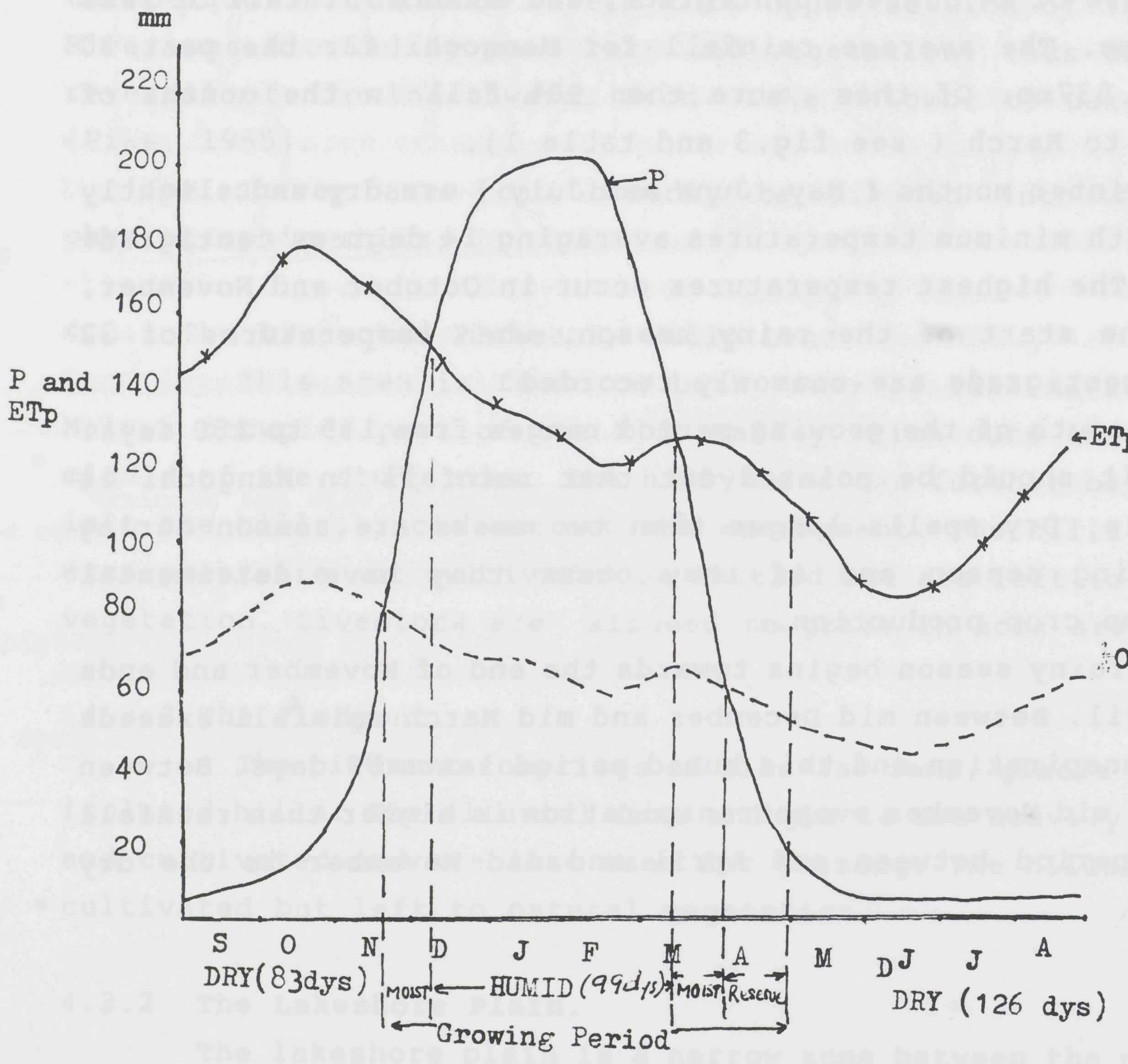



Fig.3: Rainfall(P) and potential evapotranspiration (ETp) diagram for Mangochi

4.5 Hydrology.

All rivers in the area of study drain into Lake Malawi and Lake Malombe, and the lakes are drained by the Shire River which is a branch of Zambezi River in Mozambique. On the eastern shore some rivers are perennial and this has encouraged people to settle all over the plain. On the western side most of the rivers dry up soon after the rainy season. As a result much of the plain is not settled; most people have settled close to the lakes. Where drinking water is a problem the government has provided people with boreholes.

4.6 Present Land Use and Population Distribution.

4.6.1 Crop Production.

The main crops grown by the small holder farmers with holding sizes between 1 and 10 hectares are maize, cotton, beans, groundnuts, sorghum and rice. Tobacco and cashew nuts are grown by commercial farmers on large estates. More than 80% of the cultivated land is under maize crop. However the maize is normally interplanted with one or several of the crops mentioned above. Cotton, tobacco and rice are normally planted on pure stands. 99% of the farmers grow maize as a food crop. Tobacco, cashewnuts and cotton are grown as cash crops.

4.6.2 Livestock Production.

The main livestock of the area are cattle, goats and sheep. All the three livestock types are kept mainly for meat production for sell and for home consumption. Though the Malawi Zebu is not dairy breed farmers do milk their cows and sell the milk locally. There are 920 farmers who own a total of 10237 head of cattle in the study area. These cattle are served by three diptanks located at Mponda, Chikomwe and Moto villages. Diptanks are places where animals take a bath against ticks. For many farmers livestock farming is secondary to crop production; i.e all livestock farmers engage in crop production.

4.6.3 Population Distribution.

Some of the factors that affect human population distibution
are water availability and the suitability of the land for crop production. These factors seem to play a big role in the distribution of population in Mangochi. For most of the villages the only reliable source of water are the two lakes. This situation is very true for villages on the western shore where rivers dry up soon after the rainy season. As a result most villages are on the beach ridges close to the lake. On the eastern shore the villages are scattered all over the plain because most big rivers from the Namizimu and Mangochi Forest Reserves are perennial. Because livestock are housed near homes the distribution of cattle is linked to distribution of villages.

The population of the study area is 35,392 farm families and a farm family is compost of 4 members; this gives a total of 138,568 people in the area. The total survey area is 560 square kilometres (56,000 ha) and this gives a population density of 247 persons per square kilometre or 1.6 hectares per farm family.

# CHAPTER 5. RESEARCH METHODOLOGY.

The survey was carried out to collect data for assessing the physical suitability of the study area for grazing by using ALES. Therefore the data collected had to be relevant to the land utilization type to be evaluated and that the data had to be in a form required by ALES.

## 5.1 Preparation for Fieldwork.

The material available for fieldwork included the following;

- topographic maps of Mangochi Project area at the scale of 1:50,000.
- a soil map of the study area at the scale of 1:250,000.
- aerial photographs of the study area taken in 1982. The scale of the photographs is approximately 1:40,000.
- climatic data of the study area.
- materials for soil and vegetation surveys were also available.

Two months before the commencement of fieldwork photo-interpretation work started of the survey area to map land use and land cover. The land cover/land use map was superimpossed on the soil map. In most cases the land cover boundaries were the same as the soil boundaries except for two areas which had to be verified in the field. On the basis of the land cover and soil map a sample area for detailed surveys was selected. The sample area covers all the different land covers and soils.

## 5.2 Fieldwork.

### 5.2.1 Survey Methodology.

The first week was spent on the reconnaissance survey of the study area in order to identify the various units (land cover and soils) that appear on the photographs. The entire study area was visited in three days and the last three days were spent on visiting the sample area with the aim of establishing areas where vegetation and soilss would be studied and sampled.

5.2.2 Collection of vegetation and soil data.

Since the study area was to be assessed for its suitability for grazing, obviously it is necessary to collect vegetation samples and determine their nutritive value. Several square sample plots of 50cm x 50cm were chosen at rondom in each mapping unit. This was done by throwing a pointed peg for the direction and where it fell it was tossed again for direction. Then ten steps were taken in the direction indicated by the peg. Normally 3 to 4 samples were taken in each mapping unit. Soil mini pits were dug and described in the area where vegetation samples were taken.

Vegetation cover for each strata for the mapping units was estimated according to combined cover and abundance scale ( Zonnoved et al, 1974; Zonneveld, 1988). Before cutting the grass the species within the sample plot and those outside the sample plot but within the mapping units were identified. Those vegetation species not identified in the field were collected and sent for identification at the National Herbarium.

In the evenings the vegetation samples were sorted so that grasses were separated from herbs, and different grass species were also separated to determine the dominant grasses in the mapping unit. The samples in their separated form were taken for laboratory analysis. At the laboratory the samples were oven dried and reweighed. Then finally the seperated samples were combined as they were taken in the field and analysed.
Soil samples were also sent for analysis. The vegetation data was recorded on ITC releve sheets and soils data were also recorded on ITC soil description cards.

5.2.3 Land use data.

Part of the landuse data was observed in the field during soil and vegetation surveys and accordingly noted. In addition farmers, agriculture staff and some local party leaders were interviewed by using a questionaire, a copy of which is given in appendix 1,2,3.

5.3 Post fieldwork.

This was a period of data analysis, building of land use models for grazing as required by ALES; use of ILWIS to import results of land evaluation by ALES and preparation of a conversion tables for use by manual approach.

5.4 Reliability of the survey method.

The grazing land utilization type is complex in nature. Unlike annual crops, animals require food through out the year. Animals eat grasses which are mostly annuals, which means they are only green for a few months per year. This means that for the rest of the year, animals feed on dry grasses which have low nutritive value.

In Mangochi traditional grazing areas ie dambos, are grazed throughout the year. However this survey was done at the end of the rainy season which means that the samples from the grazing areas are not true yield figures because they exclude amounts consumed during the rainy season. For other mapping units i.e cropped lands, the forage yields can be said to be reliable because at the time of the survey animals had not been allowed to graze. In case of Mangochi and Malawi in general I would suggest that areas to be sampled should be fenced off for one year and then samples taken a few months before the start of the rainy season. Such an approach would give realistic results. Areas near the homes are overgrazed as they are preferred because of their proximity to the homes.

The other problem is the variability of nutrients with seasons, in particular, crude protein. According to Freites et al, 1970, crude protein of forage crops is the highest during the middle of the growing season and lowest during the dry season (

see figure.4). Therefore, samples taken at the end of the rainy season cannot be used in assessing suitablity for grazing because they tend to overestimate the potential of the land. Land evaluation for grazing should be based on land qualities measured during a period when most factors for livestock production are limiting. In a country which has a distinct one rainy season and one dry season , the best period for taking vegetation samples for analysis would be 4 to 3 months before the beginning of the rainy season. In Mangochi this period would be between July and September. If an animal is able to survive during this period when feed and water supplies are inadequate, then it can survive throughout the years. Therefore it is my belief that April is not the right month for taking vegetation samples for analysis of nutrients because from figure 4 it is likely that forage in April has higher nutritive value than in August.

The other problem which was discovered in the field was the importance of distance to water or grazing areas. Unfortunately the mapping units of the survey area were based on physiography, soils and vegetation , and these units were found to be insufficient to be used for land evaluation for grazing. The use of drinking water as a creterion pauses some difficulties. Touber (1983) observed that the use of distance to drinking water causes sub-division of mapping units in different suitability ratings. In the study area it was found imperative to sub-divide the mapping units interms of distance to water because without doing so most of the areas would be rated highly suitable when in actual fact they are not suitable due to lack of water within reach. Because of the above problems the land will initially be evaluated by ALES based on mapping units which were based on physiography, soils and vegetation , and on mapping units based on the subdivision of the above mapping units on the basis of distance to water by using ILWIS.

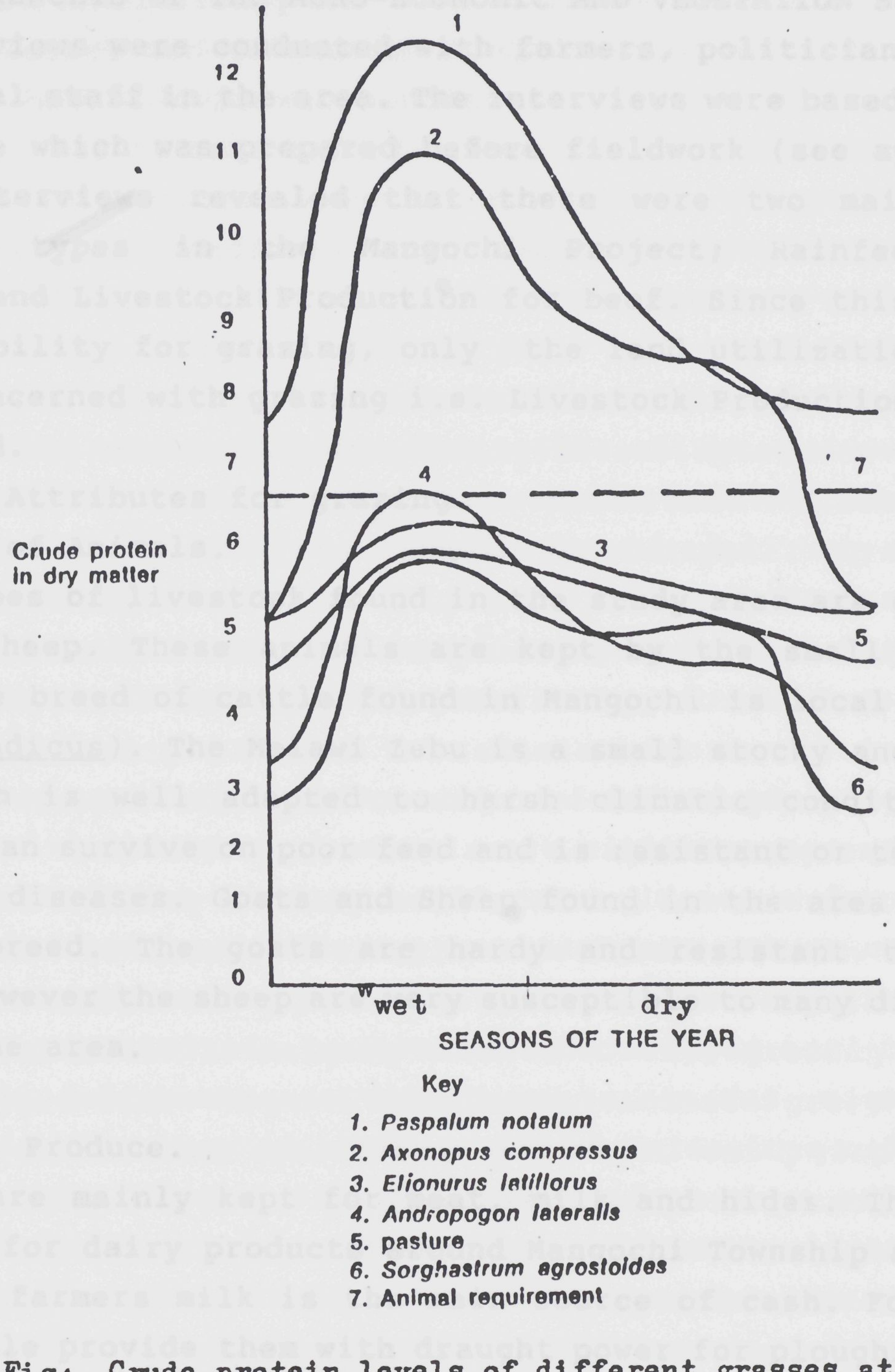



Fig4 Crude protein levels of different grasses at different seasons.

( Source; Freits 1970)

# CHAPTER 6. RESULTS OF THE AGRO-ECONOMIC AND VEGETATION SURVEYS.

Interviews were conducted with farmers, politicians and agricultural staff in the area. The interviews were based on the questionaire which was prepared before fieldwork (see appendix 1). The interviews revealed that there were two main land utilization types in the Mangochi Project; Rainfed Crop Production and Livestock Production for beef. Since this study is on suitability for grazing, only the land utilization type directly concerned with grazing i.e. Livestock Production, will be described.

## 6.1 The Key Attributes for grazing.

### 6.1.1 Types of Animals.

The types of livestock found in the study area are cattle, goats and sheep. These animals are kept by the small holder farmers. The breed of cattle found in Mangochi is local Malawi Zebu (Bos indicus). The Malawi Zebu is a small stocky and hardy animal which is well adapted to harsh climatic condition of Malawi. It can survive on poor feed and is resistant or tolerant to tickborn diseases. Goats and Sheep found in the area are of the local breed. The goats are hardy and resistant to many diseases. However the sheep are very susceptible to many diseases common in the area.

### 6.1.2 Animal Produce.

Cattle are mainly kept for meat, milk and hides. There is high demand for dairy products around Mangochi Township and for many cattle farmers milk is the main source of cash. For some farmers cattle provide them with draught power for ploughing and pulling farmcarts.

Sheep and goats mainly provide meat and hides. They are not milked.

### 6.1. Land Use Rights and Land Tenure.

Three types of land tenure systems are found in the study area; private land, communal land and public land. Private land is land which an individual or a company has leased from the government. No other person can use such leased land unless with permission from the owner. Public land is the land which is under government control such as game reserves, forest reserves, airports etc. These areas with government approval can be utilized by the local people after fullfiling certain conditions. Communal land is that land which belongs to the community and vested in the Traditional Authority of the area. Every member of the community can use the land provided he has permission from the chief. The chief can, at anytime, forbid an individual from use of a particular land.

Livestock farmers operate under the communal system. The areas used for grazing belong to the entire community. This is also true with cropped lands; as soon as the individual has harvested his crops animals are free to graze in the fields because as long as the land has no crops, it reverts back to the community temporarily.

Communal ownership of land is quite a problem for livestock expansion in the Mangochi Project. This kind of land ownership has resulted in overgrazing of some of the dambos and has also resulted into conflicts between peoples of different interests. For example, tobacco or vegetable farmers would like to use the dambos for production of their seedlings while livestock farmers would like to use the same piece of land for grazing. In most cases the livestock farmer loses because livestock is secondary in importance to crop production.

6.1.4 Rights to the animals and produce.

Only the owners have the rights to the animals and the produce. However under customery law the herd belongs to the family and each family has a family head. All the rights to the animals and produce are vested in him.

6.1.5 Mobility and grazing pattern.

Livestock farmers in Mangochi practice what is known as sedentary pastoralism which implies that herds are taken out daily by the herders from the village kraals to the communal grazingland. Before the animals are taken out they are first milked in the morning. The animals will graze upto around 15.00 hours and then they are milked again before returning them to the village via a water point.

There are two grazing seasons in the country; rainy season grazing and dry season grazing. During the rainy season animals graze in the dambos as the upland areas are under cultivation. The animals are in dambos from November to end April. During this period the herdboys are constantly with the animals to prevent them from going into cropped lands. Feed and water supply is plentiful during the rainy season and animals therefore put on weight.

Dry season grazing is from May to end October or early November. During this period animals are allowed to graze on the crop residues and when the crop residues have been exhausted they go back to the dambos. In the dry season feed is of low quality and in short supply, and as a result animals lose weight. The dry season grazing period can be divided into two; grazing on the cropped lands and grazing in the dambos. Animals graze in the cropped lands from May to end of August or early September. Towards the end of August, farmers start preparing crop ridges in readiness for the rainy season, as a result, animals are no longer allowed on the fields. So from September to November animals return to the dambos which may not have enough grass.

6.1.6 Labour intensity.

Livestock rearing does not require a lot of labour input. The animals are kept mainly for beef production on some form of extensive grazing. There is no supplementary feeding and the only labour needed is to take the animals for grazing and back. The kraal is repaired once in a year or two and does not need much labour. Herders are paid Mk1.00 per month per adult animal.

6.1.7 Market orientation.

It is surprising to note that farmers in the survey area are responding to market forces. In the past cattle prices were fixed by the government and these prices tended to be very low. These low prices discouraged farmers from selling their animals (bulls) and as a result the herds kept on expanding. Since the liberalization of the cattle market in 1987, prices of the cattle has gone up and farmers are encouraged to sell their bulls because of the high returns. Farmers have now realised that there is bussiness in livestock production and as a result only productive animals are kept and the none productive are sold away.

6.1.8 Technical know-how.

Most of the farmers interviewed are illiterate and know very little about animal husbandry practices. The herd boys are normally young boys who have very little or no knowledge of animal husbandry. However Mangochi project is organising training courses for livestock owners on dairy farming, beef production and disease control. With such courses it is hoped that the technical know-how of the farmers will be improved.

6.1.9 Yield and production.

The main products are beef and milk. An average cow gives 5 litres of milk per day and the lactation period varies from 4 to 5 months. On average a cow gives between 600 and 800 litres per lactation period.

For beef cattle (by law, only bulls are sold) it takes 3 to 4 years for a bull to be ready for slaughter. The average weight of the animal at slaughter is more than 250kg. The slow growth rate is due shortage of feed, however, some farmers who have been attracted by high prices are engaged in some form of stall feeding their bulls with crop residues and such bulls are ready for slaughter in less than 3 years.

In the study area cattle normally calf between May and November. According to Koning, (1977), who was working with the local herd, found that females were more fertile in September and that calvings were concentrated in June. Farmers indicated that most animals calf in June and July. Normally a cow gives a calf every year.

6.1.10. Management Specification.

Disease control:- Cattle farmers register their cattle with the nearest vetenary station or diptank station. A diptank is provided for cattle within a radius of 10km if cattle exceed 1000 in number. Cattle within a diptank are dipped once a week as a means of controlling tickbone diseases. The dip is provided free of charge by the government. However, treatment of sick animals when sick attracts a charge. The farmer must pay before the animal is treated.

Animal Husbandry:- Selection in rural smallholder herds for breeding stock is not being practiced intensively. To reduce indiscriminate mating and in breeding, farmers in Mangochi are persuaded to castrate their inferior looking males and sell or slaughter any stock with obvious defects. Farmers are also encouraged to exchange bulls from different herds.

## 6.2.0. VEGETATION AND SOILS OF THE AREA.

### 6.2.1 Vegetation .

Physiography (elevation), soils distribution pattern, human and livestock influences are the main factors for vegetation distribution in the study area. Cultivation and wood cutting has resulted in certain tree and grass species in certain areas being replaced. Grazing is mainly restricted to the wetlands and overgrazing has resulted into soil erosion and the disappearance of palatable species of grasses.

Differences in topography (elevation) and soil properties have influenced the composition of vegetation in different areas. The vegetation of the area between about 600 and 1000 metres above sea level is dominated by Brachystegia species, while the area between the lake (472 metres) and about 600 metres above sea level is dominated by Adansonia-Sclerocarya-Cordya community on the well drained soils, grasses ( Digitaria-Urochloa community) on the poorly drained soils, Hyhaene-Sterculia community on the sands and Acacia albida on the alluvial fans.

a. Vegetation of the different mapping units.

On the alluvial fans over lacustrine (mapping unit A1e-1/A1m-1) and various footslopes ( A1e-1/A1f-9, A2e-2 and A2f-3/A2e-3) the vegetation type is the wooded and bushed grasslands. The dominant tree species are Adansoinia digitata (boabac), Sclerocarya caffra, Commiphora mollis and Cordyla africana africana. Where the land is not cultivated, the tree/shrub cover is moderately dense and there are many shrubs becoming thickets in places. The common grasses found in these mapping units are Urochloa mosambicensis, Digitaria milanjiana , Rhynchelytrum repens , Echinochloa pyramidalis and Eragrotis arenicola . These areas are between 472 metres and 600 metres above sea level. They are cultivated and sparsely settled.

However, the vegetation of the alluvial fans, (mapping unit A1f-9), is dominated by Acacia albida which forms a canopy cover of more than 30%. The vegetation type is Acacia woodlands. Other trees commonly occurring are Kigeria pinnata, Acacia xanthophloea and Adasonia digitata. The dominant grasses found in the area are Pennisetum polystachya, Circhinis trilocularis, Eragrotis arenicola, and Echinochloa pyramidalis. These areas are heavily cultivated and are below 600 metres above sea level.

The beach ridges, (mapping unit A1a1), have a characteristic dense palm tree ( Hyhaene crinita) vegetation with scattered Sterculia africana. Most of this area is settled and cultivated. However where the land is undisturbed , Adansonia digitata, palm trees, Sterculia africana and many other species, often with dense undergrowth are found forming a wooded bushland. The dominant grasses on beach ridges are the Digitaria milanjiana and Urochloa mosambicensis.

On the poorly drained soils, (mapping units A1g-4/A1m-1), the vegetation type is bushed grassland with some Acacia sp. scrub in some places. On the imperfectly drained soils, (mapping unit A1m-1) the vegetation type is wooded grassland dominated by Colophospernum mopane. The dominant grasses of these areas are Urochloa mosambicensis, Digitaria milanjiana and Echinochloa pyramidalis. The poorly drained soils are used for grazing throughout the year.

The vegetation type of the hilly areas, (mapping units X2e-7/A2f-3, X3p, X4p and X5p/R), is forest woodland. The dominant trees being the Brachystegia species and the grasses being the Hypehrrenia species. Much of the area is protected forest reserve with scattered cultivations in areas which are outside the protected areas.

b. Forage yield, percent crude protein and percent phosphorus.

The forage yield, % crude protein and % phosphorus of the vegetation for each mapping unit is as indicated in Table.3. As explained in chapter 5 the big differences in forage yields is probably due to differences in land use. Mapping unit A1g-4/A1m-1 is grazed throughout the year while the rest are seasonally grazed or not grazed at all.

Table 3. Forage yield and dominant grasses of the mapping units.

| Mapping unit | forage yield (kg/ha) | % crude protein | % phos. | Dominant grasses | Vegetation type | Land use |
|---|---|---|---|---|---|---|
| A1a-1 | 3020 | 5.8 | 0.28 | Digitaria milanjiana<br>Urochloa mosambicensis | wooded bushland | villages and grazing |
| A1g-4/A1m-1 | 1200 | 6.77 | 0.26 | Digitaria milanjiana<br>Urochloa mosambicensis<br>Echinochloa pyramidalis | bushed grassland | grazing |
| A1m-1 | 5370 | 4.07 | 0.22 | Digitaria milanjiana<br>Cassia mimosoides<br>Brachiaria sp.<br>Urochloa mosambicensis | wooded grassland | grazing |
| A1e-1/A1m-1 | 5690 | 5.92 | 0.26 | Maize stover<br>Digitaria milanjiana<br>Urochloa mosambicensis<br>Eragrotis arenicola<br>Echinochloa pyramidalis | wooded and bushed grassland | cultivation and grazing |
| A1f-9 | 4960 | 6.5 | 0.29 | Maize stover<br>Digitaria milanjiana<br>Pennisetum polystachya<br>Eragrotis arenicola | Acacia woodland | cultivation and grazing |
| A1e-1/A1f-9 | 4200 | 6.10 | 0.26 | Maize stover<br>Digitaria milanjiana<br>Urochloa mosambicensis<br>Eragrotis arenicola<br>Echinochloa pyramidalis | wooded and bushed grassland | cultivation and grazing |
| A2f-3/A2e-3 | 4186 | 6.27 | 0.26 | as above | " | " |
| A2e-2 | 5080 | 7.94 | 0.25 | as above | " | " |
| X2e-7/A2f-3 | 2400 | 5.40 | 0.25 | Maize stover<br>Indingofera sp.<br>Pannicum maximum<br>Hyperrhenia sp. | wooded bushland | cultivation |
| X3p | 2050 | 6.50 | 0.27 | as above | wooded bushland | grazing |
| X4p | 3500 | 5.46 | 0.26 | Pannicum maximum<br>Hyperrhenia sp. | Brachystegia woodland | forest |
| X5p/R | 3920 | 5.75 | 0.25 | Pannicum maximum<br>Hyperrhenia sp. | Brachystegia woodland | forest |

6.2.2. Physiography and Soils.

The soil map of the study area was available. The map at the scale of 1:250,000 was prepared by the FAO Land Resource Evaluation Project in April, 1990. Since the soil map was available, in this study more emphasis was put on collection of vegetation data. However, soils were described and samples taken from the places where vegetation samples were collected.

The soil map of the study area is based on parent material, dominant slope, and main soil characteristics. According to Venema (1988), the mapping unit symbols are made up of a maximum of four elements[1]. The description of the physiography and soils is based on the soil map mentioned above. In the study area the following units occur ( appendix 7 ).

6.2.2.1 The Basement Complex (on Gneiss and Schist).

The areas covered by the basement complex material were mapped into three units; mapping unit X3p, X4p and X5p/R. These mapping units occur in the hilly areas and their slopes varies from 6 to 13% in unit X3p, 13 to 25% in unit X4p and 25 to 55% in unit X5p/R. The mapping units consist of relatively young soils. The soils have developed in situ from intermediate metarmorphic rocks (mainly schist and gneiss). These soils are shallow to moderately

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[1] Capital letter indicates parent material; A stands for Alluvial, Colluvial and Lacustrine materials; and X stands for intermediate igneous or metermorphic rocks. At second level the numbers 1 to 5 stand for slopes 0 t0 2% (1), 2 to 6 (2), 6 t0 13% (3), 13 to 25% (4) and 25 to 55% (5). At third level the lower case letters indicate dominant soil characteristics i.e arenic (a), fluvic (f), gleyic (g), mopanic (m), calcaric (c), fersialic-dystric (d), fersialic-eutric (e), ferralic-dystric (r) and ferralic-eutric (x). At the fourth level a serial number seperated by hyphen indicates complex units or associations.

deep, well drained sandy loam/sandy clay loam over gravely sandy clay loam to sandy clay. The deeper soils are found on the lower slopes and are cultivated in some places; the shallow soils are found on the ridges and are mostly left to natural vegetation. The dominant soils are the Eutric Cambisols which are found in association with Eutric Leptosols.

6.2.2.2 The Alluvial, Colluvial and Lacustrine Areas.

The areas covered by the alluvium, colluvium and lacustrine materials were mapped into the following physiographic units;

a. Alluvial Fans over Lacustrine Sediments (Ale-1/Alm-1).

This area has dominant slopes ranging from 0 to 2%. The soils have developed from relatively old alluvial/colluvial material covering most of the plain. The soils range in texture from sandy loam to sandy clay, but the dominant soil type is a very deep, well drained and permeable sandy loam topsoil merging into sandy clay loam subsoil. The origin of the alluvium/colluvium are the surrounding hilly areas. These soils are heavily cultivated during the rainy season and livestock graze on crop residues in the dry season. The dominant soils are the Haplic Luvisols.

b. Beach Ridges (Ala-1).

The beach ridges are covered by lacustrine material rich in sand. The sand was probably deposited by the retreating lake or by sand bars on the Shire River. On the beach ridges the soils are very deep, well drained sand/loamy sand throughout the profile. The beach ridges are favoured for settlement as the area is near the lake and river and are well drained. The dominant soils are the Cambic Arenosols.

c. The Lower and Upper Footslopes ( Alg-4/Alm-1; Alm-1).

Between mapping units Ale-1/Alm-1 and Ala-1 are footslopes covered with colluvium of clayey material. On the basis of drainage conditions the area has been divided into the Lower Footslopes (A1g-4/A1m-1) which are poorly drained and the Upper Footslopes (A1m1) which are imperfectly drained. On the Lower Footslopes the soils are poorly drained, deep, sandy clay over clay with many distinct mottles. Soils on the Upper footslopes are deep, imperfectly drained, sandy clay loam over sandy clay. The subsoil contains calcium carbonate nodules/concretions and the profile shows distinct mottling and with small black concretions. The poorly and imperfectly drained soils are not being cultivated but the land is used for grazing. The dominant soils on the Lower Footslopes are the Eutric Gleysols and Eutric Planosols (Mopanosols). On the Upper Footslopes the dominant soils are Eutric Planosols found in association with the Stagnic Luvisols.

d. <u>Footslopes and Dissected Footslopes (A1e-1/A1f-9, A2f-3/A2e 3, A2e-2).</u>

These are the various Footslopes which are found between the hills and those Alluvial Fans over Lacustrine (A1e-1/A1m-1). The footslopes have been sub divided on the basis of slope and degree of dissection. Mapping unit A2f-3/A2e-3 has dissected footslopes with slopes of 2 to 6%; mapping unit A2e-2 has slopes of 2 to 6% but it is not dissected and A1e-1/A1f-9 has slopes of 0 to 2%.

Soils of the mapping units A2f-3/A2e-3 and A2e-2 are well drained, deep, permeable sandy loam to sandy clay loam topsoil over sandy clay loam to sandy clay sub soil. The dominant soils are the Haplic Luvisols. The soils of mapping unit A1e-1/A1f-9 are well drained, deep, sandy loam to sandy clay loam over sandy clay loam and sandy clay.

The dominant soils are the Eutric Fluvisols and Haplic Luvisols.

e. <u>Alluvial Fans (A1f-9).</u>

The soils of the Alluvial Fans have formed from various alluvial materials which had been deposited recently. The profiles show marked stratification with variations in texture from sand to silty clay. These soils show very little profile development and are subject to high water tables during the rainy season. These soils cover mapping unit A1f-9 and are heavily cultivated.

f. Basement Complex and Colluvial Area (X2e-7/A2f-3).

This mapping unit is covered by colluvium and basement complex. The hills are composed of gneiss and schist and the plains (glacis) between the hills are covered by colluvium. The dominant soils are deep, well drained, dark brown to dark reddish brown clay loam and sandy clay over clay. Haplic Luvisols are the dominant soils of the unit (see soil map).

6.3 The Grazing Capacity of the Area.

Before carrying out an evaluation of land it is important to appraise the present situation with regards to the land utilization type to be evaluated. This is done in order to find out whether the resources in the area are being over exploited or under exploited. Whichever is the case, information is needed by the planners. For the grazing land utilization type, one of the ways of looking at the present situation is to look at the total grazing capacity of the lands used for grazing against the total livestock populations.

The grazing capacity is defined (FAO,1988) as the maximum possible stocking that a rangeland can support on a sustained basis. Grazing capacity can be calculated from the following formula (adapted from Thalem, 1979; Esselink et.al 1988) as quoted by FAO, 1988.

$$G = \frac{SC}{R} * X$$

where G= grazing capacity in tropical livestock units per unit area (TLU/ha).

SC= is the standing crop in weight per unit area (KgDm/ha).

R= Animal requirement of dry matter per day (KgDm/day/TLU).

X = is the lowest value of either g or (1-l) or p

where g= the grazing efficiency

l= is the forage loss factor due to trampling.

p= is the proper use factor.

The formulae assumes that energy is the limiting factor for animal maintenance and production and the forage is assumed to have enough crude protein and minerals per kg of dry matter.

- a Tropical Livestock Unit (TLU) is equivalent to an adult bull or cow weighing 250kg.

- an animal (grazer) eats forage equivalent to between 2% and 3% of its body weight. In case of a TLU this is equal to 6.25kg/day.

- according to Msisya, (1986) the grazing efficiency of natural grasslands in Malawi is between 40% and 50%.

6.3.1 Livestock population and the present stocking rates.

The population of cattle and other livestock in the study area is as follows;

Table 4. Livestock population by diptank as at December 1989.

| | Mponda | Chikomwe | Moto | Total |
|---|---|---|---|---|
| Bulls | 315 | 502 | 87 | 904 |
| cows | 2594 | 3246 | 1148 | 6988 |
| calves | 799 | 903 | 643 | 2345 |
| Total | 3708 | 4651 | 1878 | 10237 |
| goats | 409 | 1439 | 486 | 2334 |
| sheep | 417 | 759 | 2419 | 3595 |

In order to find stocking rates and grazing capacities the total livestock was converted into TLUs. According to FAO (1988), a calf is equal to 0.25 of the TLU; a weaner is 0.50 of TLU and a 1.5 to 2 year heifer/bull is 0.75. Since the above data for cattle does not classify the calves, therefore, they are treated as weaners for the calculation of grazing capacity. Hence, the figures for calves were converted into TLU by a factor of 0.50; and those of goats and sheep were converted by a factor of 0.20. The total livestock population (TLUs) were then compared with the total grazing areas to arrive at the present stocking rates.

Table 5: Present stocking rates.

| Dip Tank | Grazing Area(ha) | Livestock Pop (TLU) | Stocking rate |
|---|---|---|---|
| Mponda | 3984 | 3473 | 1.15ha/TLU |
| Chikomwe | 5488 | 4640 | 1.18ha/TLU |
| Moto | 1088 | 2138 | 0.51 ha/TLU |
| Mangochi | 10560 | 10251 | 1.03ha/TLU |

The figures in table 5 indicate that Mangochi area has a high livestock population density. Note that the grazing area refers to the areas which are purely used for grazing only and will remain so for a long time.

6.3.2 The Grazing Capacity of Mangochi Area.

The data in Table 5 does not tell much about the actual situatation in Mangochi because the grazing capacity of the areas was not taken into consideration. Tables 6 and 6a show the grazing capacities of different mapping units used for grazing for the entire survey area and also per diptank. The following assumptions were made when computing grazing capacities;

- a 250 kg animal requires 6.25kg/day of dry matter.
- the grazing efficiency was estimated at 40%.
- two grazing periods were used; 244 days ( April to November) and 365 days (one year).

For example; Mapping Unit Ala1 = 1248 ha

Forage yield = 3020kg/ha

For 244 days.

$$\text{Grazing capacity} = \frac{3020\text{kg/ha} * 40 * 1248 \text{ ha}}{6.25\text{kg/day} * 100 * 244 \text{ days}}$$

$$= 989 \text{ TLUs or } 1.26 \text{ ha/TLU}$$

Table 6. Grazing capacities by mapping unit

| Mapping Unit | Area | Forage Yield | Considering the period April to November(244dys) | | Considering a 1 year period | |
|---|---|---|---|---|---|---|
| | (ha) | (Kg/ha) | Grazing Capacity (TLUs/244days) | Stocking rate (ha/TLU) | Grazing Capacity (TLUs/year) | Stocking (ha/TLU) |
| Ala-1 | 1248 | 3020 | 989 | 1.26 | 661 | 1.89 |
| Alg-4/Alm-1 | 4704 | 1200 | 1480 | 3.18 | 990 | 4.75 |
| Alm-1 | 3600 | 5370 | 5071 | 0.71 | 3390 | 1.06 |
| X3pl | 1008 | 2050 | 542 | 1.86 | 362 | 2.78 |
| Mangochi | 10552 | | 8082 | 1.31 | 5403 | 1.96 |

Table 6a: Grazing Capacity by Diptank

1. Mponda diptank

| Mapping Unit | Area | Forage Yield | Considering the period April to November(244dys) | | Considering a 1 year period | |
|---|---|---|---|---|---|---|
| | (ha) | (Kg/ha) | Grazing Capacity (TLUs/244days) | Stocking rate (ha/TLU) | Grazing Capacity (TLUs/year) | Stocking (ha/TLU) |
| Ala-1 | 1248 | 3020 | 989 | 1.26 | 661 | 1.89 |
| Alg-4/Alm-1 | 1408 | 2906 | 1073 | 1.3 | 717 | 1.96 |
| Alm-1 | 1328 | 6750 | 2351 | 0.57 | 1572 | 0.85 |
| total | 3984 | | 4413 | 0.90 | 2950 | 1.35 |

2. Chikomwe diptank

| | | | | | | |
|---|---|---|---|---|---|---|
| Alg-4/Alm-1 | 2384 | 1240 | 775 | 3.08 | 518 | 4.60 |
| Alm-1 | 2096 | 3060 | 1682 | 1.25 | 1125 | 1.86 |
| X3pl | 1008 | 2050 | 542 | 1.86 | 362 | 2.78 |
| total | 5488 | | 2999 | 1.83 | 2005 | 2.74 |

3. Moto diptank

| | | | | | | |
|---|---|---|---|---|---|---|
| Alg-4/Alm-1 | 912 | 1200 | 287 | 3.17 | 192 | 4.76 |
| Alm-1 | 176 | 5370 | 248 | 0.71 | 165 | 1.06 |
| Total | 1088 | | 535 | 2.03 | 357 | 3.04 |

Data in table 6 is giving a clear picture about the situation in the Mangochi Area. If we consider that forage yields as measured during the survey were to be available to the animals for the entire year then there is enough forage for only 5403 TLUs; this means that 4848 TLUs in the area are in excess of the grazing capacity of the area. If the forage will be available to the animals for 244 days ie from April to end November then there is enough forage for 8082 TLUs, leaving a balance of 2169. In both situations Mangochi grazing lands are overstocked. While the data in table 6 gives an overall situation in Mangochi area, it is not being specific enough.

Table 6a shows the situation by diptank. Since the samples were taken in April it is assumed that the forage will be available for 244 days. Mponda diptank has enough forage for the livestock it has and in fact it can support more, about 940 Tropical Livestock Units. Chikomwe and Moto diptanks are seriously overstocked, even if the forage is available for 244 days. The overstocking problem of Chikomwe and Moto diptanks has been known by the agricultural staff for a longtime but solving the problem is difficult bacause farmers take pride in the number of cattle they have and not the quality. Though Mponda has room for extra animals it is not possible for animals from Chikomwe which is on the other side of Shire River to graze in Mponda.

6.3.3 The importance of the cultivated lands and crop residues.

From the above figures on grazing capacities it is evident that the traditional grazing areas of Mangochi are over stocked; ie there are more animals than the grazing areas can support them. The apparent shortage of feed is overcome by allowing animals to graze on the crop residues for three to four months ( May to August) so that the pressure on the grazing lands is some-how relieved. The cultivated lands and their crop residues play a very important role as source of feed during the dry season. If the animals are not allowed to graze on the crop residues then Mangochi area would not be able to support the present livestock populations. With the population pressure, one wonders how long the farmers will allow animals to graze on their fields. Unfortunately for the study area, cultivated lands are far from cattle kraals and as a result, they are not fully being utilized. Apart from long distance some farmers start preparing their fields very early so that their fields are available to the animals for a very short period.

The other problem for the study area is that cattle are concentrated just around a few villages and near the dip tanks. This means that a large number of cattle graze in an area nearest to the village where the cattle live. This uneven concentration of cattle is reflected in the forage yields of different grazing areas. For example, mapping unit A1m-1 has higher forage yields than mapping units A1a-1 and A1g-4/A1m-1 probably for the following reasons:-

a. A1m-1 is far from the villages so that the herdboys are reluctant to go there when grass is plentiful near home.

b. A1m-1 is slightly better drained than A1g-4/A1m-1 and that it is found between the cultivated lands and the grazing areas. In some places these areas are cultivated. As a result during the rainy season herdboys are afraid to take animals there for fear of animals going into cultivated fields. This is so because sometimes herdboys simply leave the animals to wander around while they are involved in other activities.

c. The other reason is probably due to differences in the palatability of the grasses. From table 3 it can be seen that the crude protein levels of forage from mapping unit A1m-1 is low and as such it is not preferred by the livestock.

# CHAPTER 7: APPLICATION OF AUTOMATED LAND EVALUATION SYSTEM (ALES).

## 7.1 Introduction to Automated Land Evaluation System.

ALES is a computer program that allows the land evaluator to build an expert system to evaluate the land according to the FAO methodology. This system was developed by D.G.Rossiter, M.Tolomeo and A.R. Van Wambeke from Cornel University, USA.

Understanding the basic vocabulary used in ALES is necesary before discussing the system.

### a. Severity Level.

The degree to which a land quality limits a land use is called a severity level. A severity level is the degree of limitation or restriction that a land quality imposes on a land use. The number of severity levels is determined by the precision needed in the evaluation. Severity level 1 is considered optimal (no limitation to land use).

### b. Land Use Requirements.

These are sets of conditions needed by a particular land use. The degree up to which a land use requirement is fulfilled is also reported as a severity level. The ALES program does not make use of the term "land quality" but instead it uses "land use requirements". This is so because the model building is from the point of the user.

Land use requirements and land qualities actually express the same thing but from different points of view. Land qualities are what the land offers; land use requirements describe what a given land use needs. If the land can offer 70% of what it requires, then the land use's needs are 70% fulfilled.

### c Land Utilization Types.

Land utilization types are the land uses to be compared in land evaluation. Depending on the purpose of the evaluation, they can be general e.g. "improved pasture" or they can be specific e.g certain cropping sequences. In both cases, a specified context, both in terms of farming practices and socio-economic conditions is required.

d Decision Trees.

The evaluator builds models to evaluate land for certain uses. These models take the form decision trees. Decision trees are constructed by the evaluator and are used to store expert information in a form usable by the ALES program.

7.2 The Components of ALES.

ALES as an expert system does not provide knowledge or data. It allows the user to record and manipulate them. For this purpose it has the following four components: (a) the knowledge base,(b) the data base, (c) the inference mechanism and (d)a component with explanation facility.

a. The Knowledge Base

The evaluator is free to build up a model that relates to the land and land use requirements. Each evaluation model consists of a set of proposed Land Utilization Types (LUT'S),a set of outputs, and a set of land characteristics. The requirements of each land use are specified by defining severity levels of limitations. These severity levels are used in decision trees that spell out the different combinations of characteristics that pertain to the same severity level. For a certain land use, the production cost are specified together with "added production costs" for improvement of limitations. The system allows for types of land use in general or specified. Two types of land evaluation models can be constructed in ALES;

(i). Physical Evaluation Models.

In this model, parametric and multiplication approaches are used. Physical suitability is assessed by judging how well the land use requirements are met. Each land utilization type will usually have several land use requirements (land qualities), and each land use requirement can be expected to present a severity level. Physical suitability results are derived by multiplication of all land use requirements.

Physical suitability classes are established using a decision tree. The procedure is to use a parametric approach to produce the proportional yield decision tree. A multiplication process of several land use requirements results in the proportional yield. In most cases, four levels of suitability are used S1 (suitable), S2 (moderately suitable), S3 (marginary suitable) and N(not suitable).

(ii). Economic Evaluation Models.

In economic evaluation models the value of the inputs needed for a land use is compared with the value of the outputs received. ALES classifies the gross margin/profit from a land use into economic classes, using these classes to evaluate economic feasibility of the land.

Predicted Returns.

The predicted return is the sum of the returns for each land utilization type. Some land utilization types may produce more than one product through crop rotations. The calculation uses the following formula:

S1 yields * yield proportion * output price * rotation fraction.

Predicted Costs.

The predicted cost for a land utilization type is the sum of the S1 cost plus any additional cost. The S1 cost is the same for all land mapping units under the land utilization type, with the additional cost varying for each land unit. The calculation of S1 cost is computed as:

S1 annual cost + (S1 capital amount * S1 interest rate).

The additional cost is computed as the sum of the additional costs associated with each land use requirement that is limited. Each of this is expressed as:

Added annual cost + ( added capital amounts * interest rate).

All this information is supplied by the evaluator. Added costs are always associated with improving the limitation for a specific LUT.

Economic Classes.

The difference between returns and costs results in the gross margin for the land use. The gross margins are then placed in economic suitability classes. Based on the economic conditions in the area the evaluator enters lower limits in the class ranges for the economic feasibility classes. There are limits needed for the classes: S1(suitable), S2(moderately suitable), S3 (marginary suitable). Land which is lower than the S3 at starting point is rated N1 (economically unsuitable).

b. The Data Base.

Data from the natural resource survey can be directly entered via keyboard or imported from other database programs. When the needed data are lacking the system provides a facility to generate them via decision trees from other land characteristics (e.g. drainage class from texture and slope). The format of the data can be controlled by the user and either discrete or continuous land characteristics can be handled. Class limits have to be set in order to accommodate the format in which the data is available on the one hand and the format in which it is required on the other hand.

c. Inference Mechanism.

Once a model is built up and land data are entered, the model user can run the evaluation so that ALES determines the physical and economic suitability of each mapping unit for each LUT. ALES computes these in two stages, first the physical and then the economic. The computation proceeds by transversing decision trees,and querying the data base for values of land characteristics as necessary. In the physical evaluation the matching between land qualities and land use requirements is performed according to the models built. Economic suitability is determined on the basis of predicted gross margin per hectare per year. The results of the evaluation are displayed as an evaluation matrix.

d. The Explanation Facility.

While viewing the results, the user can request an explanation of any evaluation result how the system has arrived at that decision. Explanations follow a backward chain, from the predicted returns and costs, to the severity levels of land qualities, and then to the values of the land characteristics. An explanation screen shows the actual path traversed in decision trees. Editing of data during the process is possible to improve the results and bring them closer to observed values. In this way the user can fine tune his system.

7.3 Model Building Procedures for Land Evaluation for Grazing Purposes.

Models are created in the form of decision trees and assigned severity levels. Decision trees are land quality models in which land charecteristics are related to land use requirements. For the study area the following models have been found to be relevant to the grazing land utilization types; erosion hazard model, grazing capacity model and accessibility model. A model for water availability would be dealt with outside the ALES framework.

7.3.1 Erosion Hazard Model.

The problem of soil erosion is one of the consequences that can arise from overgrazing of the grazing areas. This in turn has a great influence on soil fertility and then impart a detrimental effect on plant and pasture management.

The erosion model to be used is based on the Soil Loss Estimation Model for Southern Africa (SLEMSA; Elwell, 1980) which was designed for Zimbabwe conditions and has slightly been modified to suit Malawi conditions. SLEMSA is used for this study because climatic, soil and crop conditions in Malawi are reasonably similar to the conditions in most parts of Zimbabwe.

The original SLEMSA model has been developed and extensively tested in Zimbabwe, and consists of the three submodels (K, X & C ) as follows:

-K: Mean annual soil loss (t/ha/yr) from a standard tilled field (bare soil, 4.5% slope, 30m long). K is a function of rainfall energy (E) and soil erodability (Erod).

-X: The ratio of soil loss from a plot length of L metres and slope percent s, to that lost from the standard plot.

-C: The ratio of soil loss from a cropped plot, to that from the bare fallow.

The annual soil loss Z (in t/ha/yr) is calculated by multiplication of K, C, and X. Therefore, $Z = K * C * X$.

In figure 5, the framework of SLEMSA is given with various sub models. In the following sections how these sub-models are used in Mangochi area, will be described.

(a) <u>Calculation of K.</u>

K ( climate and soil factor) is a function of mean seasonal rainfall energy (E) and soil erodability (Erod).

E is derived from the mean annual rainfall (p-an). The mean annual rainfall for Mangochi is 850mm. In the SLEMSA model a geographic subdivision has been made on the basis of the occurrence or absence of significant amounts of light rain during winter

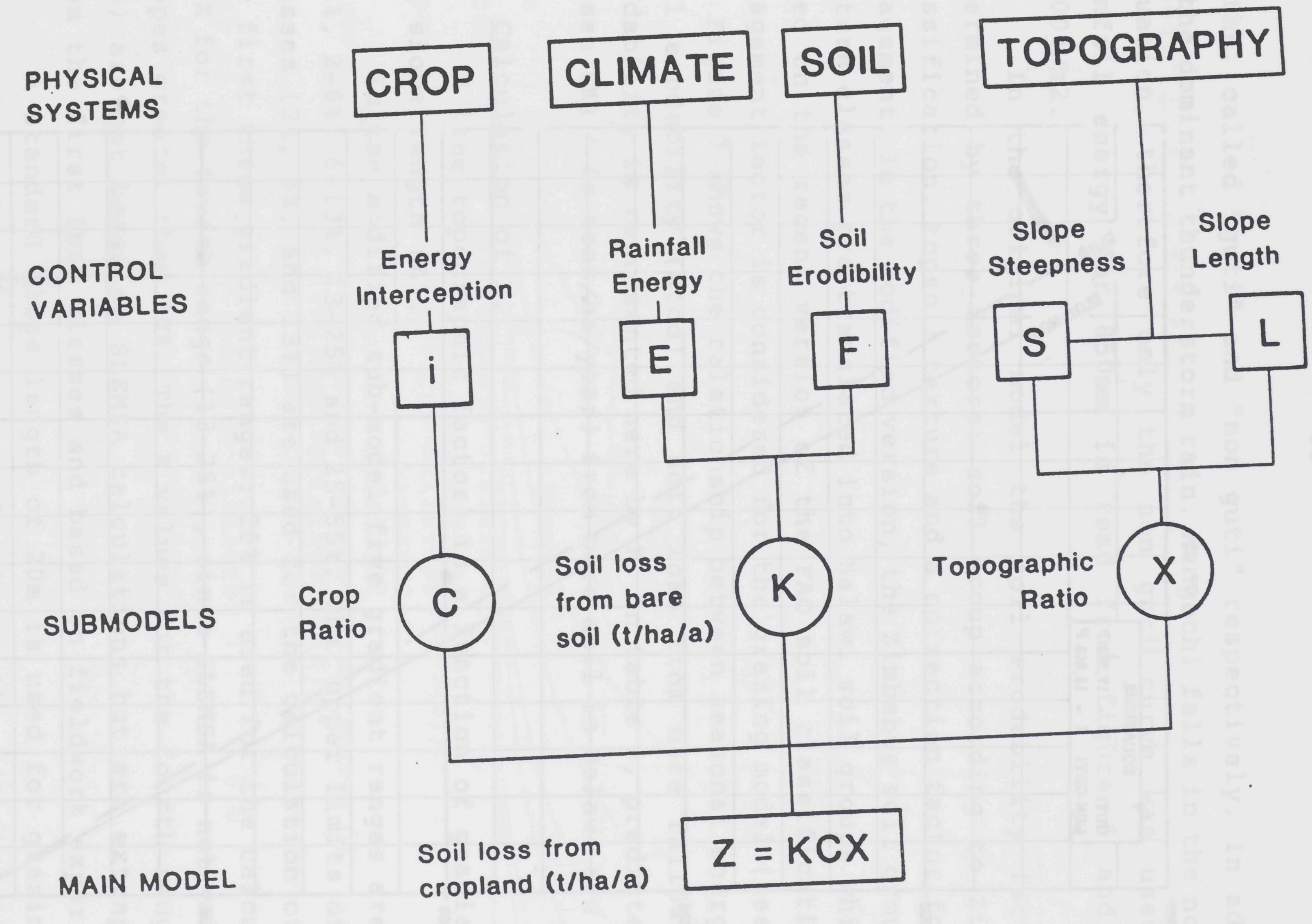



Figure 5 The SLEMSA framework.

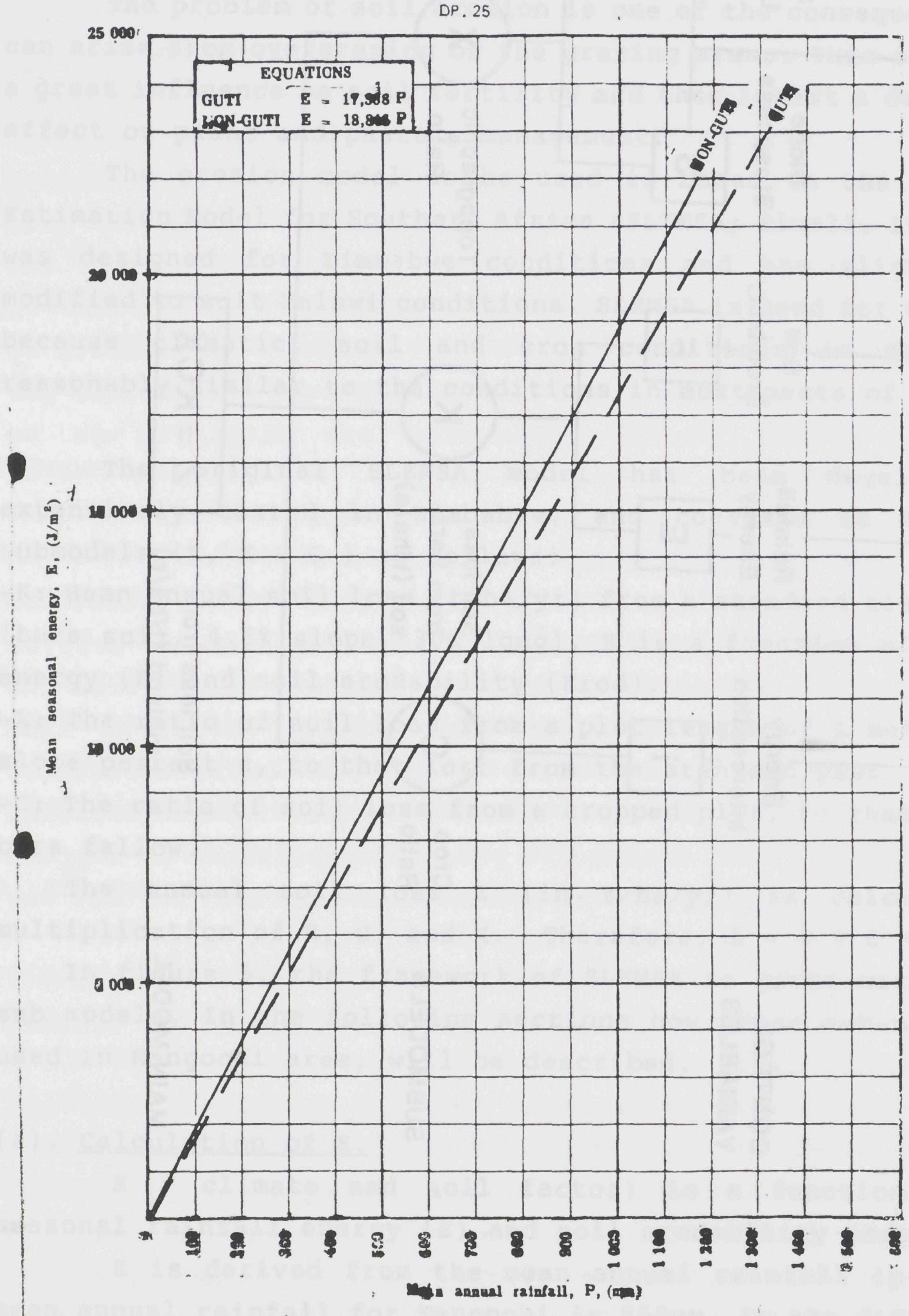



Fig.6 SELECTION of E from MEAN ANNUAL RAINFALL

months, called "guti" and "non guti" respectively, in addition to the dominant thunderstorm rain. Mangochi falls in the non guti situation, therefore only the non guti curve was used. The rainfall energy for 850mm is read from figure 6 and gives 16500j/m2.

In the original model the soil erodability factor is determined by three factors: soil group according to Zimbabwe classification, topsoil texture and a correction factor for soil management. In the modified version, the Zimbabwe soil groups and texture classes are translated into Malawi soil groups which are based on the recent version of the FAO soil classification. No management factor is considered for the grazing model (see table 7). Figure 7 shows the relationship between seasonal energy (E), soil erodability (Erod) and soil loss from bare fallow (K); Erodability is represented here by F. In table 8, predicted soil losses (K) ( in tons/ha/year) from bare soil in Malawi are given.

(b) <u>Calculation of X.</u>

X (the topographic factor) is a function of gradient (S) and slope length (L).

In the modified sub-model five gradient ranges are used: 0-2%, 2-6%, 6-13%, 13-25% and 25-55%. The upper limits of slope classes (2%, 6%, and 13%) are used for the calculation of X for the first three gradient ranges; 20% is used for the calculation of X for the fourth range (13-25%), since SLEMSA is not valid for slopes greater than 20%. The X values for the fourth range (25-55%) are not based on SLEMSA calculations but are extrapolated from the first four classes and based on fieldwork experience.

A standard slope length of 20m is used for grazing. The short slope lengths are used since the construction of cultivation ridges of one metre apart is common practice in Mangochi, and ridges are assumed to reduce slope length drastically. Figure 8 shows the relationship between slope length (L), slope gradient (S) and soil loss (X). In table 9, the topographic factor (X) for various slope classes are given.

Table 6. Soil erodability factor values for all soil types.

| soil erodability factor (Er. f) | soil types (Malawi) |
|---|---|
| 3.5 | salic<br>mopanic (planosols)<br>vertic |
| 4.5 | lithic<br>paralithic<br>fluvic<br>gleyic<br>arenic<br>calcaric<br>ferralic dystric,with coarse topsoil texture<br>ferralic-eutric, with coarse topsoil texture<br>fersialic- dystric, with coarse topsoil texture<br>fersialic eutric |
| 6.5 | ferralic-dystric, with medium to fine topsoil texture<br>ferralic-eutric, with medium to fine topsoil texture<br>fersialic dystric, with medium to fine topsoil texture |

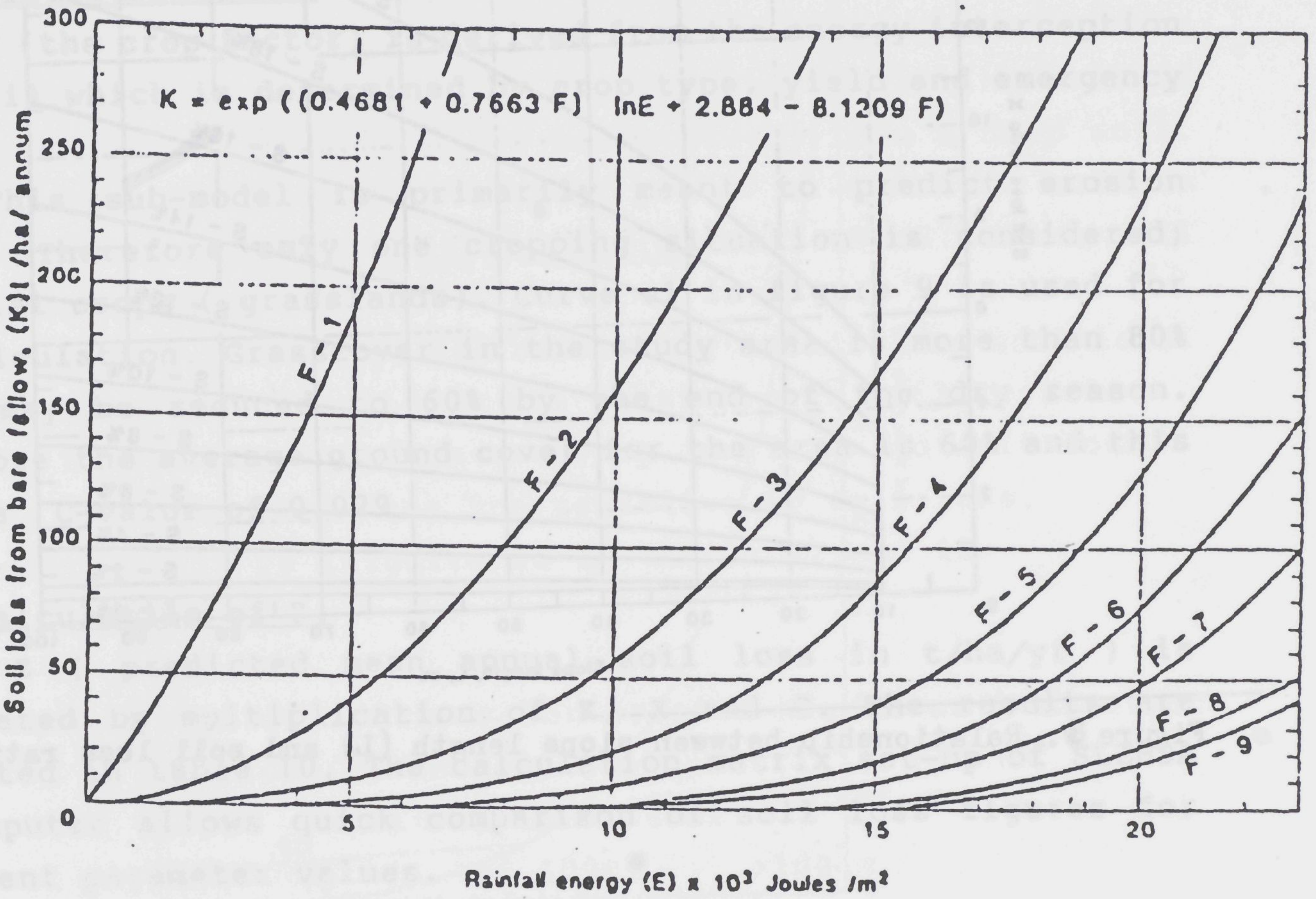



Figure 7. The Relationship between mean ~~s~~seasonal energy (E), soil erodability(F) and soil loss from bare ~~s~~ fallow (K).

Table 8. Predicted Soil Loss from Bare Soil in ~~Mxmx~~ Mangochi

| Rainfall Energy (joules/m ) | Soil Erodability factor | Soil Loss (ton/ha/yr) |
|---|---|---|
| 16500 | 3.5 | 170 |
| 16500 | 4.5 | 90 |
| 16500 | 6.5 | 24 |

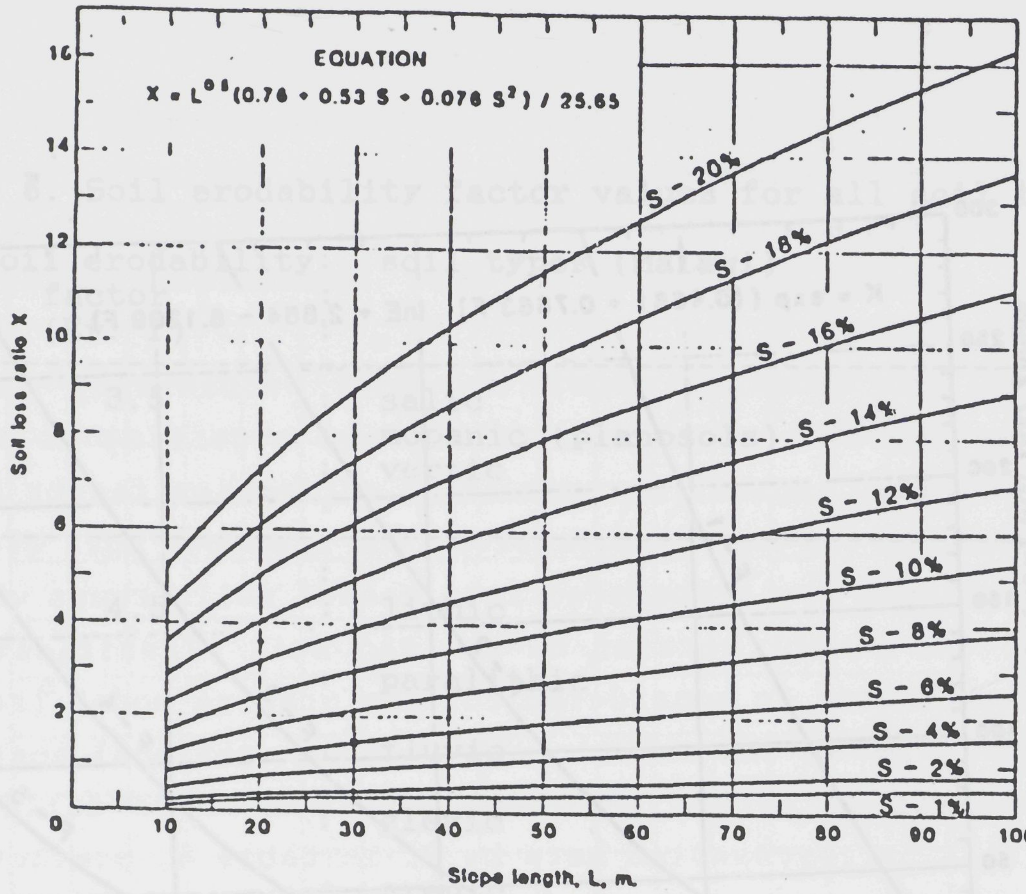



Figure 8. Relationship betwwen slope length (L) and soil loss ratio (X).

Table 9. X values of different slope classes.

| Gradient Class (%) | X values for slope length of 20 metres |
|---|---|
| 0 to 2 | 0 to 0.4 |
| 2 to 6 | 0.4 to 1.2 |
| 6 to 13 | 1.2 to 3.6 |
| 13 to 25 | 3.6 to 7.3 |

(c) Calculation of C.

C (the crop factor) is derived from the energy interception factor(i) which is determined by crop type, yield and emergency date.

This sub-model is primarily meant to predict erosion hazard. Therefore only one cropping situation is considered; perennial crops ( grasslands). Curve c1 in figure 9 is used for the calculation. Grasscover in the study area is more than 80% which may be reduced to 60% by the end of the dry season. Therefore the average ground cover for the area is 60% and this gives a C-value of 0.029.

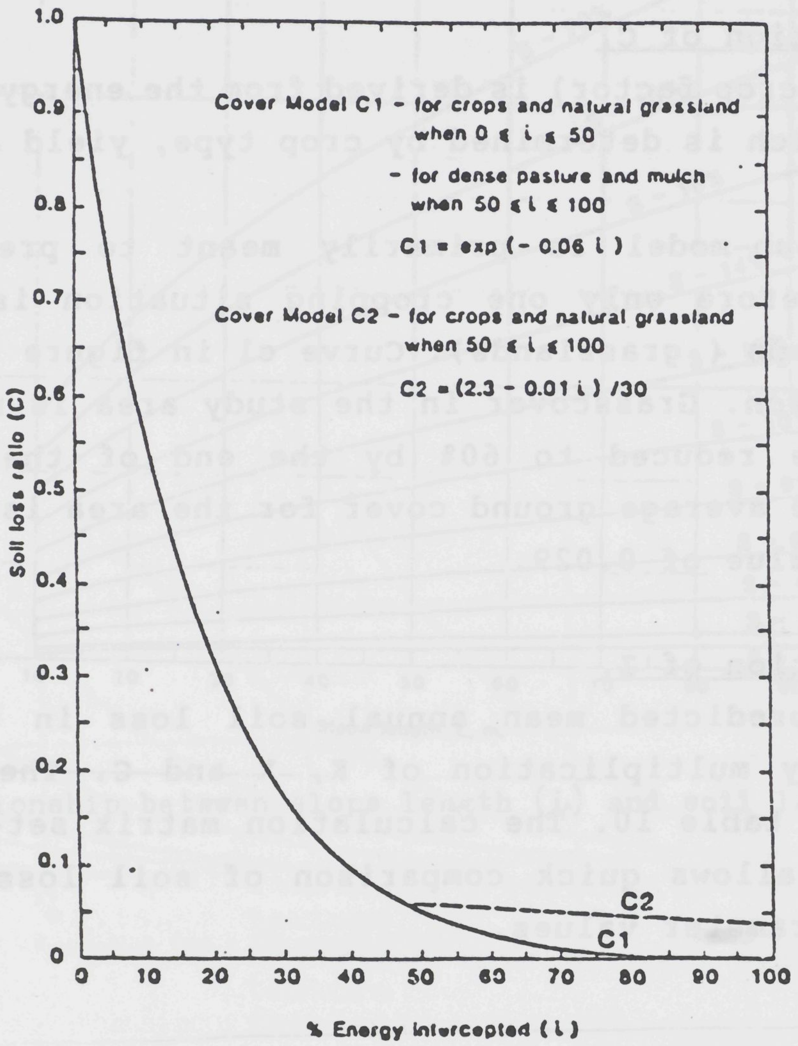
(d) Calculation of Z.

Z ( predicted mean annual soil loss in t/ha/yr ) is calculated by multiplication of K, X and C. The results are presented in table 10. The calculation matrix set-up of SLEMSA on computer allows quick comparison of soil loss figures for different parameter values.

Table 10. Predicted Soil Loss for Mangochi (ton/ha/yr).
: perennials and pastures
: C value of 0.029
: annual precipitation (850 mm)

| Slope Class(%) | X Values | E. Factor | K (ton/ha/yr) | Z (predicted soil loss) (ton/ha/yr) |
|---|---|---|---|---|
| 0 to 2 | 0.4 | 3.5 | 170 | 2 |
| 2 to 6 | 1.2 | 3.5 | 170 | 6 |
| 0 to 2 | 0.4 | 4.5 | 90 | 1 |
| 2 to 6 | 1.2 | 4.5 | 90 | 3 |
| 6 to 13 | 3.6 | 4.5 | 90 | 9 |
| 13 to 25 | 7.3 | 4.5 | 90 | 19 |
| 25 to 55 | - | 4.5 | 90 | 40' |
| 0 to 2 | 0.4 | 6.5 | 24 | 1 |
| 2 to 6 | 1.2 | 6.5 | 24 | 1 |
| 6 to 13 | 3.6 | 6.5 | 24 | 3 |
| 13 to 25 | 7.3 | 6.5 | 24 | 5 |
| 25 to 55 | - | 6.5 | 24 | 23' |

' figures estimated.




| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C2 | | | | | | 0.060 | 0.057 | 0.053 | 0.050 | 0.047 | 0.043 |
| C1 | 1.0 | 0.55 | 0.30 | 0.17 | 0.09 | 0.050 | 0.029 | 0.015 | 0.008 | 0.005 | 0.002 |

Figure 9. Relationship between energy interception and the soil loss ratio.

(e) Interpretation of results.

The tolerance to a decline in productivity of the eroding soil is being considered. It is assumed that a shallow soil is in greater danger of losing its productivity than a deep soil. On a shallow soil it takes a shorter period to erode the soil to the bedrock than a deeper soil. Therefore four different soil depths are considered:

- soils deeper than 100cm are reasonably tolerant to soil loss.
- soils between 50 and 100cm are sensitive to soil loss.
- soils between 30 and 50cm are very sensitive to soil loss.
- soils less than 30cm are too sensitive to soil loss.

This relationship is illustrated in tables 11 and 12.

Table.11. Suitability ratings for erosion hazard as a function of soil loss(Z) and Soil depth.

| | soil depth classes | | |
|---|---|---|---|
| | 30-50cm | 50-100cm | >100cm |
| s1 | 0-5t/ha/yr | 0-5t/ha/yr | 0-7t/ha/y |
| s2 | 6-8 " | 6-11 " | 8-22 " |
| s3 | 9-10 " | 11-16 " | 23-32 " |
| n | >10 " | >16 " | >32 " |

Table 12. Suitability ratings for the study area.

| Soil Depth (cm) | E. factor | SLOPE CLASSES (%) 0-2 | 2-6 | 6-13 | 13-25 | 25-55 |
|---|---|---|---|---|---|---|
| 30-50 | 4.5 | s1 | s1 | s3 | n | n |
| 50-100 | 3.5 | s1 | s1 | | | |
| | 4.5 | s1 | s1 | s2 | n | n |
| | 6.5 | s1 | s1 | s1 | s2 | n |
| 100++ | 3.5 | s1 | s1 | | | |
| | 4.5 | s1 | s1 | s2 | s3 | n |
| | 6.5 | s1 | s1 | s1 | s1 | s3 |

(f) <u>Severity Level Decision Tree for Erosion Hazard.</u>

The decision tree for erosion hazard is constructed on the basis of the above information. Rainfall, slope length and crop cover are constant for the area and therefore they are not included in the decision tree (see preceeding pages).

Slope is considered to have greater influence on the rate of erosion and therefore it is considered first in the decision tree. Any land above 55% slope is cosidered to have severe erosion problems, therefore it is not suitable. However for other slope categories, other factors need to be considered before the decision is made.

The next factor to be entered in the decision tree is soil depth. Very shallow soils (less than 30cm) are very sensitive to soil erosion, therefore soils <30cm. are not suitable for grazing. However for the other soil depths a decision cannot be made without considering texture of the soil; in this case soil erodability. By including soil erodability the decision tree is complete and possible combinations are considered. See figure 10.

irmg (Grazing; Mangochi)

Fig 10 Decision Trees for erosion hazards.

DtId Type                                   Where Used

**Fig. 10: Decision Tree for Erosion Hazards.**

```
1    Severity Level                     gr,eh
  > sl (slope)
   1 (level) [0-2 %] > sd (soil depth)
      vs (very shallow) [0-30  : 2 (slight)
      sh (shallow) [30-50 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : ?
         4.5 (4.5) [3.5-4.5 0]... : 1 (nil)
         6.5 (6.5) [4.5-6.5 0]... : ?
         ?....................... : ?
      md (moderately deep) [50-100 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : 1 (nil)
         4.5 (4.5) [3.5-4.5 0]... : 1 (nil)
         6.5 (6.5) [4.5-6.5 0]... : 1 (nil)
         ?....................... : ?
      dp (deep) [100-1000 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : 1 (nil)
         4.5 (4.5) [3.5-4.5 0]... : 1 (nil)
         6.5 (6.5) [4.5-6.5 0]... : 1 (nil)
         ?....................... : ?
      ?.......................... : ?
   2 (gently sloping) [2-6 %] > sd (soil depth)
      vs (very shallow) [0-30  : 3 (moderate)
      sh (shallow) [30-50 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : ?
         4.5 (4.5) [3.5-4.5 0]... : 1 (nil)
         6.5 (6.5) [4.5-6.5 0]... : ?
         ?....................... : ?
      md (moderately deep) [50-100 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : 1 (nil)
         4.5 (4.5) [3.5-4.5 0]... : 1 (nil)
         6.5 (6.5) [4.5-6.5 0]... : 1 (nil)
         ?....................... : ?
      dp (deep) [100-1000 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : 1 (nil)
         4.5 (4.5) [3.5-4.5 0]... : 1 (nil)
         6.5 (6.5) [4.5-6.5 0]... : 1 (nil)
         ?....................... : ?

      ?.......................... : ?
   3 (sloping) [6-13 %] > sd (soil depth)
      vs (very shallow) [0-30  : 4 (severe)
      sh (shallow) [30-50 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : ?
         4.5 (4.5) [3.5-4.5 0]... : 3 (moderate)
         6.5 (6.5) [4.5-6.5 0]... : ?
         ?....................... : ?
      md (moderately deep) [50-100 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : ?
         4.5 (4.5) [3.5-4.5 0]... : 2 (slight)
         6.5 (6.5) [4.5-6.5 0]... : 1 (nil)
         ?....................... : ?
      dp (deep) [100-1000 cm] > ef (erodability factor)
         3.5 (3.5) [0-3.5 0]..... : ?
         4.5 (4.5) [3.5-4.5 0]... : 2 (slight)
         6.5 (6.5) [4.5-6.5 0]... : 1 (nil)
         ?....................... : ?
      ?.......................... : ?
```

```
irmg (Grazing; Mangochi)
                                 Decision Trees
DtId Type                                  Where Used
--------------------------------------------------------------------------------
-----------------------------------------------------------------
1    Severity Level                        gr,eh
(continued)
  4 (moderately steep) [13-25 %] > sd (soil depth)
    vs (very shallow) [0-30  : 4 (severe)
    sh (shallow) [30-50 cm] > ef (erodability factor)
       3.5 (3.5) [0-3.5 0]..... : ?
       4.5 (4.5) [3.5-4.5 0]... : 4 (severe)
       6.5 (6.5) [4.5-6.5 0]... : ?
       ?....................... : ?
    md (moderately deep) [50-100 cm] > ef (erodability factor)
       3.5 (3.5) [0-3.5 0]..... : ?
       4.5 (4.5) [3.5-4.5 0]... : 4 (severe)
       6.5 (6.5) [4.5-6.5 0]... : 2 (slight)
       ?....................... : ?
    dp (deep) [100-1000 cm] > ef (erodability factor)
       3.5 (3.5) [0-3.5 0]..... : ?
       4.5 (4.5) [3.5-4.5 0]... : 3 (moderate)
       6.5 (6.5) [4.5-6.5 0]... : 1 (nil)
       ?....................... : ?
    ?....................... : ?
  5 (steep) [25-55 %] > sd (soil depth)
    vs (very shallow) [0-30  : 4 (severe)
    sh (shallow) [30-50 cm]. : =1
    md (moderately deep) [50 : =1
    dp (deep) [100-1000 cm] > ef (erodability factor)
       3.5 (3.5) [0-3.5 0]..... : ?
       4.5 (4.5) [3.5-4.5 0]... : 4 (severe)
       6.5 (6.5) [4.5-6.5 0]... : 3 (moderate)
       ?....................... : ?
    ?....................... : ?
  6 (very steep) [55-100 % : 4 (severe)
  ?....................... : ?
```

7.3.2 Grazing Capacity Model.

In order to support the metabolic processes and promote production, animals must have regular supplies of nutrients. These nutrients may broadly be defined as carbohydrates, protein, minerals and vitamins. Under extensive systems of animal husbandry, the animal may not be able to obtain an adequate diet throughout the year because of the seasonal variation in the quantity or composition of the herbage.

In order to predict animal performance it is necessary to measure the quantity of feed and its nutrient content and animal requirements. Therefore, the grazing capacity model is based on three factors; dry matter forage yield per hactare, % crude protein of dry matter and % phosphorus of dry matter.

(a) <u>Forage Dry Matter Yield.</u>

The forage yields have been based on the stocking rates of animals. The following stocking rates have been used; 0-2ha. per Tropical Livestock unit (TLU), 2-5 ha/TLU, 5-10h/TLU and >10ha/TLU. A TLU requires 6.25 kg of dry matter per day and the grazing efficiency is estimated at 40%. In order to achieve the above stocking rates the following minimum forage yields are required; >2800kg/ha for 0-2ha/TLU, 1200 -2800kg/ha for 2-5ha/TLU, 600-1200kg/ha for 5-10ha/TLU and <600kg/ha for >10ha/TLU. The results are rated as follows;

<u>Table 13</u>. Forage Yield Rating.

| Forage Yield | Rating |
|---|---|
| >2800kg/ha | high yield |
| 1200-2800 | medium yield |
| 600-1200 | low yield |
| <600 | very low yield |

(b) Crude Protein.

Forage uptake by animals is reduced when crude protein levels fall below 7% of dry matter. When crude protein levels are higher than 7% the beef cattle put on weight. Malawi Zebu requires at least forage to have >3.8% crude protein of dry matter of forage for maintenance (FAO, 1988 and Munthali 1986). On the basis of minimum crude protein requirements for maintenance and growth, the following ratings are used ;

Table 14. Crude Protein Rating.

| Crude protein | Rating |
|---|---|
| >7% | high |
| 5-7% | medium |
| 3.8-5% | low |
| <3.8% | very low |

(c) Phosphorus.

According to FAO, (1989) the phosphorus requirements for most categories of livestock is when fodder has more than 0.25% phosphorus. When the fodder has less than 0.1% phosphorus is considered to be inadequate. The following ratings are used ;

Table 15. Phosphorus Rating.

| Phosphorus | Rating |
|---|---|
| >.25% | high |
| .15-.25% | medium |
| .1-.15% | low |
| <.1% | Very low |

(d) Interpretation of the Results.

By using the above information a severity level decision tree for grazing capacity was constructed.

The most important parameter in the grazing capacity model is forage yield. This is because animals will eat as long as the stomach is empty and feed is available. Therefore forage yield is the first parameter to be considered in the decision tree. A forage yield of <600 kg/ha gives a stocking rate of more than 10ha per animal; this means the animal will spend most of its energy wandering around in search of food. Therefore any land with forage yields of <600kg/ha cannot be suitable for grazing. So in the decision tree <600kg has severe limitation.

However the grazing capacity of the other forage yields cannot be decided straight away because they depend on other factors such as crude protein and phosphorus. Therefore crude protein is considered. It has been decided that forage with crude protein of <3.8% of dry matter is not adequate for maintenance of animals, therefore any forage with <3.8% has severe limitations. However a decision for the other levels of crude protein in combination with forage yield cannot be decided unless phosphorous levels are considered.

The third branch in the decision tree to be entered is therefore that of % phosphorous. When this is entered a full decision tree for grazing capacity is completed by looking at possible combinations. See figure.11. for the decision tree constructed for grazing capacity.

```
irmg (Grazing; Mangochi)
                              Decision Trees
DtId Type                                        Where Used
```

**Fig. 11 : Decision Tree for Grazing Capacity.**

```
----------------------------------------------------------------------
2     Severity Level                             gr,gc
 > fy (forage yield)
   a (v.low) [0-600 kg/ha]. : 4 (v.low)
   b (low) [600-1200 kg/ha] > cp (crude protein)
      v.l (very low) [0-3.8 %] : 4 (v.low)
      l (low) [3.8-5 %] > ph (phosphorus)
         v.l (very low) [0-.1 %]. : 4 (v.low)
         l (low) [.1-.15 %]...... : 3 (low)
         med (medium) [.15-.25 %] : =2
         high (high) [.25-2 %]... : =2
         ?....................... : ?
      med (medium) [5-7 %] > ph (phosphorus)
         v.l (very low) [0-.1 %]. : 4 (v.low)
         l (low) [.1-.15 %]...... : 3 (low)
         med (medium) [.15-.25 %] : 2 (medium)
         high (high) [.25-2 %]... : =3
         ?....................... : ?
      h (high) [7-30 %] > ph (phosphorus)
         v.l (very low) [0-.1 %]. : 4 (v.low)
         l (low) [.1-.15 %]...... : 3 (low)
         med (medium) [.15-.25 %] : 2 (medium)
         high (high) [.25-2 %]... : =3
         ?....................... : ?
      ?.......................... : ?
   c (medium) [1200-2800 kg/ha] > cp (crude protein)
      v.l (very low) [0-3.8 %] : 4 (v.low)
      l (low) [3.8-5 %] > ph (phosphorus)
         v.l (very low) [0-.1 %]. : 4 (v.low)
         l (low) [.1-.15 %]...... : 3 (low)
         med (medium) [.15-.25 %] : =2
         high (high) [.25-2 %]... : =2
         ?....................... : ?
      med (medium) [5-7 %] > ph (phosphorus)
         v.l (very low) [0-.1 %]. : 4 (v.low)
         l (low) [.1-.15 %]...... : 3 (low)
         med (medium) [.15-.25 %] : 2 (medium)
         high (high) [.25-2 %]... : 2 (medium)
         ?....................... : ?
      h (high) [7-30 %] > ph (phosphorus)
         v.l (very low) [0-.1 %]. : 3 (low)
         l (low) [.1-.15 %]...... : =1
         med (medium) [.15-.25 %] : 2 (medium)
         high (high) [.25-2 %]... : 1 (high)
         ?....................... : ?
      ?.......................... : ?
   d (high) [2800-15000 kg/ha] > cp (crude protein)
      v.l (very low) [0-3.8 %] : 4 (v.low)
      l (low) [3.8-5 %] > ph (phosphorus)
         v.l (very low) [0-.1 %]. : 3 (low)
         l (low) [.1-.15 %]...... : =1
         med (medium) [.15-.25 %] : =1
         high (high) [.25-2 %]... : =1
         ?....................... : ?
      med (medium) [5-7 %] > ph (phosphorus)
         v.l (very low) [0-.1 %]. : 3 (low)
         l (low) [.1-.15 %]...... : 2 (medium)
```

```
irmg (Grazing; Mangochi)
                                Decision Trees
DtId Type                                  Where Used
------------------------------------------------------------------------

2    Severity Level                        gr,gc
(continued)
        med (medium) [.15-.25 %] : =2
        high (high) [.25-2 %] : =2
        ?........................ : ?
     h (high) [7-30 %] > ph (phosphorus)
        v.l (very low) [0-.1 %] : 3 (low)
        l (low) [.1-.15 %]...... : 2 (medium)
        med (medium) [.15-.25 %] : 1 (high)
        high (high) [.25-2 %] : =3
        ?........................ : ?
     ?........................ : ?
```

### 7.3.3 Accessability Model.

There are many factors that would affect the accessibility of an area to animals. These factors are flooding and ponding, stonniness, slope and vegetation density. In the study area flooding and ponding were found to be insignificant; there is some flooding and some areas are poorly drained but these conditions are not extensive. Stonniness and vegetation densities are of little significance in the area. In many places the thickets have been cleared for fuelwood or for cultivation. The only factor that would affect the accessibility of the land to animals is slope. Therefore the following slope categories were used;

Table.16

| Slope | Rating |
|---|---|
| 0-6% | no problem of accessibility |
| 6-13% | slight problems |
| 13-25% | moderate problems |
| >25% | severe problems |

Using the above ratings a severity level decision tree for accessiblity was constructed (see figure 12).

Fig. 12: Decision Tree for Accessibility.

```
4      Severity Level                          gr,acc
  > sl (slope)
    1 (level) [0-2 %]....... : 1 (no problems)
    2 (gently sloping) [2-6  : =1
    3 (sloping) [6-13 %].... : 2 (slight problems)
    4 (moderately steep) [13 : 3 (moderate problem)
    5 (steep) [25-55 %]..... : 4 (severe problem)
    6 (very steep) [55-100 % : =5
    ?....................... : ?
```

(a) Interpretation of the Results.

In the decision tree land which has slopes of more than 25% has severe limitation and therefore not suitable for grazing. Animals find it difficult to climb slopes greater than 25% and it is even worse if the animal is in calf or young or very old. However land with slope less than 6% pause no problems to animals; animals move without problems and therefore the land is highly accessible to animals.

7.4 Physical Suitability of the Study Area.

After building the severity level decision trees for the models on erosion hazards, grazing capacity and accessibility a physical suitability decision tree was contructed based on the above models. In building the physical suitability decision tree the first factor considered is grazing capacity because feed is important for the livehood of the animal, this is followed by erosion hazards and the third branch of the decision tree is accessibility. In figure 13, the physical suitability decision tree is given shows how evaluation decisions are made.

After building physical suitability decision tree for grazing, inputing of mapping unit data of the study area was done and a physical suitability evaluation was computed. The mapping unit data is in the appendix 4 and was derived from table 2 and the soil map. In ALES when entering mapping unit data one has to specify whether the mapping unit is homogeneous or compound. If the mapping unit is compound the components of the unit must be homogeneous units which have been mapped in the study area. In this study area the components of the compound units were not mapped seperately so that all mapping units were entered as homogeneous units.

The physical suitability sub class decision tree and the physical suitability results of the study area are as shown in figures 13 and 14.

```
irmg (Grazing; Mangochi)
                            Decision Trees
DtId Type                            Where Used
-----------------------------------------------
Fig. 13: Physical Suitability Decision Tree.
5    Physical Subclass               gr
 > gc (grazing capacity)
   1 (high) > eh (erosion hazard)
      1 (nil) > acc (accessibility)
         1 (no problems)......... : 1
         2 (slight problems)..... : 2acc
         3 (moderate problem).... : 3acc
         4 (severe problem)...... : 4acc
         ?....................... : ?
      2 (slight) > acc (accessibility)
         1 (no problems)......... : 2eh
         2 (slight problems)..... : 2acc/eh
         3 (moderate problem).... : 3acc
         4 (severe problem)...... : 4acc
         ?....................... : ?
      3 (moderate) > acc (accessibility)
         1 (no problems)......... : 3eh
         2 (slight problems)..... : 3eh
         3 (moderate problem).... : 3acc/eh
         4 (severe problem)...... : 4acc
         ?....................... : ?
      4 (severe)............... : 4eh
      ?........................ : ?
   2 (medium) > eh (erosion hazard)
      1 (nil) > acc (accessibility)
         1 (no problems)......... : 2gc
         2 (slight problems)..... : 2gc/acc
         3 (moderate problem).... : 3acc
         4 (severe problem)...... : 4acc
         ?....................... : ?
      2 (slight) >acc (accessibility)
         1 (no problems)......... : 2gc/eh
         2 (slight problems)..... : 2gc/acc/eh
         3 (moderate problem).... : 3acc
         4 (severe problem)...... : 4acc
         ?....................... : ?
      3 (moderate) > acc (accessibility)
         1 (no problems)......... : 3eh
         2 (slight problems)..... : 3eh
         3 (moderate problem).... : 3acc/eh
         4 (severe problem)...... : 4acc
         ?....................... : ?
      4 (severe)............... : 4eh
      ?........................ : ?
   3 (low) > eh (erosion hazard)
      1 (nil) > acc (accessibility)
         1 (no problems)......... : 3gc
         2 (slight problems)..... : =1
         3 (moderate problem).... : 3gc/acc
         4 (severe problem)...... : 4acc
         ?....................... : ?
      2 (slight) > acc (accessibility)
         1 (no problems)......... : 3gc
         2 (slight problems)..... : =1
         3 (moderate problem).... : 3gc/acc
         4 (severe problem)...... : 4acc
```

```
irmg (Grazing; Mangochi)
DtId Type                                    Where Used
--------------------------------------------------------------------------------
5    Physical Subclass                       gr
(continued)
         ?.......................... : ?
      3 (moderate) > acc (accessibility)
         1 (no problems)............ : 3gc/eh
         2 (slight problems)........ : =1
         3 (moderate problem)....... : 3gc/acc/eh
         4 (severe problem)......... : 4acc
         ?.......................... : ?
      4 (severe).................... : 4eh
      ?............................. : ?
   4 (v.low)........................ : 4gc
   ?................................ : ?
```

**Fig. 14$ Suitability Results by ALES.**

```
irmg (Grazing; Mangochi)
LUT: gr (grazing by livestock)
-----------------------------------------------------------------------
1             A2e-2          (Footslopes)

2gc           A1a-1          (Beach Ridges)
              A1e-1/A1f-9    (Footslopes)
              A1e-1/A1m-1    (Alluvial Fans over Lacustrine)
              A1f-9          (Alluvial Fans)
              A1g-4/A1m-1    (Lower Footslopes)
              A1m-1          (Upper Footslopes)
              A2f-3/A2e-3    (Dissected Footslopes)
              X2e-7/A2f-3    (Dissected Footslopes)

2gc/acc/eh    X3p            (Hilly Land)

4eh           X4p            (Hilly Land)
              X5p/R          (Escarpment)

?             R              (Rock Outcrops)
              m              (marshes)
```

# CHAPTER 8. APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM.

ALES evaluates the mapping units and assumes that within the mapping units all the properties are homogeneous. However in land evaluation for grazing one of the land qualities to be considered is distance to source of water during the dry season. The land quality water availability affects a mapping unit differently depending upon where you are within the mapping unit with respect to the source of water. Therefore, in order to consider distance to water as a land quality the Intergrated Land and Watershade Information System (ILWIS) was employed.

Intergrated Land and Watershade Information System (ILWIS) has capability to combine conventional Geographical Information System (GIS) procedures with image processing and rational data base. The system uses both vector and raster graphics for data storage. One of the most important facilities of ILWIS is modelling i.e the preparation of scenarios indicating the various actions, to assist decision makers in evaluating produced development plans.

## 8.1 Data Input in ILWIS.

A geographical entity is usually defined by two types of data i.e geometric and non-geometric. Non-geometric data relate recorded information ( usually descriptive) to a geometric entity. The geometric data on the otherhand, relates to the geometric location of that entity. The transformation of these geometric data into format compatible with digital computers requires the use of a digitizing procedure.

### a. Digitization and Rasterization.

Digitization is a sequence of tasks for encoding the position identifiers of spatially oriented data. In its narrowest form, digitizing can be viewed as determing X and Y coordinate values to describe the location of points, lines or areas as these are depicted on the maps. Whilst rasterization is the transformation of data structure from vector format to raster. The raster data consists of a matrix of cells of uniform size, each one referenced by a unique position index. It contains a number or code representing the type of value of the attribute being mapped, which can be ordinal ( vector or scalar) or nominal.

The soil map of the study area was digitized. After polygonization the polygons were identified as mapping units. Then the polygons were rasterized and a soil map was prepared (see figure 15).

b) <u>Distance to water source map.</u>

Water is as important as food for the life of animals. Animals obtain water in their food, from their food by metabolism and from open water. The need to drink depends on the amount of water present in the food and this varies seasonally; on environmental conditions in particular high temperatures that affect the loss of water from the body.

According to FAO,(1989) in hot and arid regions animals should not be allowed to walk a total distance of 10 km. per day in search of food or water. Walking involves the expenditure of energy and reduces grazing time. In the study area water is not a problem during the rainy season ( end November to early April), however, after the rainy season it becomes scarce. For the study area the following classes for the distance to source of water were used:-

Table 17. Distance to source of water.

| | |
|---|---|
| 0 to 2km | no problems |
| 2 to 4km | slight problems |
| 4 to 6km | moderate problems |
| > 6km | severe problem |

In order to incorporate distance to water in evaluating land for grazing, a map showing perennial streams and lakes as sources of water was digitized and rasterized. Then the distance to water source map was computed using the programme called Distance in ILWIS. The output is a raster map showing various distances to the


Fig 15. Soil Map Of Mangochi Project Area.


Fig.16:SUITABILITY OF MANGOCHI AREA FOR GRAZING BY ALES

water sources.(see fig 16).

c. Importation of ALES results into ILWIS.

The physical land evaluation results by ALES based on grazing capacity, erosion hazards and accessibility models was imported into ILWIS in the tabular database of the soil map and a suitability map was produced using map calculation procedures (see fig.17).

8.2 Computation of Final Suitability.

To compute the final suitability, a two dimensional table was craeted. In the table one axis represents distance classes to water source and the axis represents physical suitability results by ALES. Using the map calculation procedure in ILWIS, the final suitability computed by this 2-dimensional table.

The final suitability map of the study area is presented in figure 18. As expected the results show that some mapping units fall under more than one suitability level; this is so because the further the area is from water source the less suitable it becomes for grazing. This problem was observed by Touber,(1983) that by including distance to source of water causes sub division of mapping units into different suitability classes. In the study area the mapping unit most affected is Ale-1/Alm-1. This mapping unit is a wide plain, in some places it is more than 10km. wide. However, the only reliable source for this unit is the lake. As a result, the suitability of the land varies with distance from the lake.


Fig 17. Distance to source of water map.

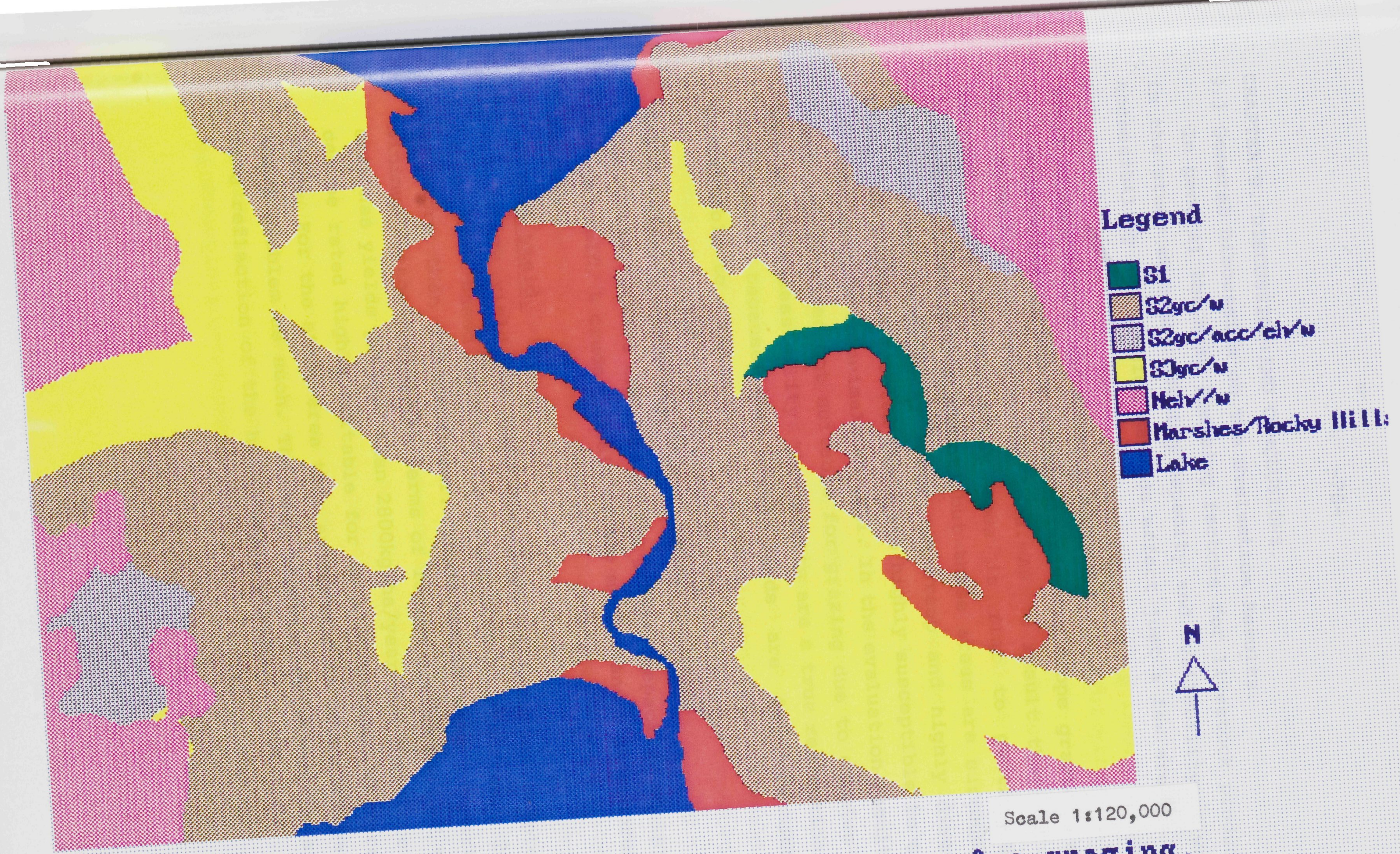



Fig 18. Overall Suitability of Mangochi area for grazing.

# CHAPTER 9. DISCUSSION AND CONCLUSIONS.

## 9.1 General Discussion on the Evaluation Results.

In general the main limiting factors for livestock production in the study area are grazing capacity and availability of water. Accessibility and erosion hazards affect just a few areas.

### 9.1.1 Accessibility and Erosion Hazards.

Accessibility and erosion hazards use slope gradient as the main parameter in rating the land. As a result they are inter related. Much of the study area is flat to gently sloping (lakeshore plain and piedmont) but these areas are surrounded by hilly lands. These hilly areas are steep and highly dissected. Steep and highly dissected lands are highly susceptible to erosion and inaccessible to animals as well. In the evaluation results land above 13% is rated not suitable for grazing due to erosion and to some extent accessibility. The results are a true reflection of the study area because the steep lands are in accessible and susceptible to erosion.

### 9.1.2 Grazing Capacity.

Three factors are used in the grazing capacity models; namely forage yield, % crude protein of dry matter and % phosphorus of dry matter.

<u>Forage yield.</u>

Forage yield has been discussed in previous chapters. The rating were based on stocking rates of 0-2ha/TLU/year, 2-5, 5-10 and more than 10ha/TLU/year. These rates were converted into minimum forage yields. In terms of forage yields most of the study area has yields greater than 2800kg/ha/year and therefore the area can be rated highly suitable for grazing interms of forage yield alone. For the study area this assessment is true. Forage yield is not a problem as such. The high stocking rates of the study area is a reflection of the high forage yields.

% Crude Protein.

The variability of crude protein levels with seasons has been discussed under 5.4. Of all the samples taken only those from A2e-2 had crude protein levels more than 7%, the rest had less than 7%. As has already been discussed crude protein levels less than 7% retards animal growth rates and if it is less than 3.8% the animal actually loses weight. The low crude protein levels may be due to low soil fertility , the genetic potential of the grasses and management of the grazing areas. The high crude protein levels in samples from A2e-2 mapping unit may be due to the inclusion of legumes in the farming system. This area is cultivated and leguminous crops are common in the mixtures such as cowpeas, pigeon peas and groundnuts. In this sample cowpeas were included. As a result A2e-2 is highly suitable for grazing while the rest of low lying area is moderately suitable due to insufficient crude protein levels in the forage.

Mapping unit A1m-1 is marginally suitable because it has the lowest crude protein levels. This area is composed of unpalatable grass species.

% Phosphorus.

Phosphorus is not limiting in the study area. All samples from the study area had more than 0.2% phosphorus which is more than the animal requires. So the area is highly suitable interms of phosporus.

The low productivity of the livestock in Mangochi is a reflection of a diet low in crude protein. Due to lack of crude protein animal growth rate is retarded and milk production is low.

9.1.3. Availablity of water.

During the rainy season ( from end November to early April) water is readily available throughout the area. However immediately after the rainy season these sources of water dry up especially on the western shoreline. As a result these areas are sparsely settled and cultivated and are hardly used for grazing. Mapping units A1e-1/A1m-1 and A2e-7/A2f-3 on the western shore line has high potential for grazing and rainfed agriculture but due to lack of water during the dry season and distance from the villages which are located along the lake, this area is sparsely cultivated and not grazed at all.

9.1.4 Recommendations.

After evaluating the land and identifying problems that affect the productivity of the land utilization type, it is important to see how such problems can be solved. A land evaluation without solutions is useless. Below are some of the recommendations;

a. Introduction of Legumes in Grazing Lands.

Nitrogen ( crude protein ) is the main nutrient limiting the productivity of the grasslands and therefore of the animals. Nitrogen application to the grazing lands would result into increased forage yield and nitrogen content of the forage. However application of nitrogen fertilizers is not economic under communal land ownership. The cheaper way of adding nitrogen to grazing areas is through the use of nodulated legumes which fix nitrogen and they themselves are palatable feed with higher crude protein content.

b. Controlled Feeding of the Crop Residues.

The way the crop residues are used in the study area is quite wastefull. The crop residues are left in the fields and for those fields near homes the crop residues are grazed by animals. The rest of the crop residues rot in the field or are burnt as a way of field preparation. On the other hand maize bran which is an end product after processing maize grain into maize flour is simply thrown away. It is being suggested here that farmers should be encouraged to stock pile crop residues and feed the crop residues to the animals as supplement during the dry season.

c. Improving Livestock Husbandry.

Farmers should be encouraged to have animal outputs concentrated in the seasons when fodder is plentiful. Thus it should be planned that young ones are born just before the beginning of the rainy season, so that the mother is not hungry during suckling. The final fattening of animals should be done during the rainy season. The size of the herds should be adjusted to seasonal variations in relation to fodder growth. Therefore, the herd is stocked up during the rainy season and reduced for the dry season. All births and purchases should be therefore planned for just before the start of the rainy season, and all slaughterings and sales should take place at the beginning of the rainy season.

d. Growing Multipurpose Crops and Multiple Land Use:

Under present conditions and even in the future maize production is likely to retain its prominent position because of its interchangeable role as food and cash crop. Overall production from maize fields could be increased by intercropping with grain or forage legume. Similarly, in choosing grain legume crops, the fodder value of the stover should be taken into account. Because of the widespread protein deficiency, both in humans and livestock, as much emphasis as possible should be placed on pulses.

There is always a considerable area of land within the cultivated field that is wasted. This could be sown with forage plants to offer considerable scope for increased production. Such areas like bunds and marker ridges can be planted to fodder crops or leguminous trees.

e. Provision of water.

If boreholes can be drilled in the mapping units A1e-1/A1m-1 and A2e-7/A2f-3, provided there is ground water these areas would open up to settlements and thus people will bring in their animals.

9.2 Comparizon between the evaluation results obtained by manual procedures with those received from ALES.

9.2.1 Land Evaluation by Manual Approach.

The land unit data of the study area was used to evaluate the land manualy by using FAO's framework for land evaluation (1976) with the aim of comparing the results with those obtained by using ALES. To evaluate the land the land qualities and land characteristics for grazing land utilization type must be defined and rated. The land qualities and the land characteristics selected are those on table 1. Those chosen for manual land evaluation are grazing capacity, erosion hazards and accessibility. The rest of the other land qualities and land characteristics in table 1 are not relevant for the study area.

On the basis of the requirements of the grazing land utilization type which are defined in terms of rated land qualities, a conversion table was constructed (Table 18). The evaluation results are as indicated in Table 19.

Table 18 Conversion table for grazing.

| Land Quality | Land Characteristics | Suitability Ratings | | | |
|---|---|---|---|---|---|
| | | S1 | S2 | S3 | N |
| Grazing Capacity | Forage Yield(kg/ha) | >2800 | 1200-2800 | 600-1200 | <600 |
| | % Crude Protein | >7 | 5-7 | 3.8-5 | <3.8 |
| | % Phosphorus | >0.25 | .15-.25 | .1-.15 | <.1 |
| Erosion Hazard | % slope | 0-2 | 2-6 | 6-13 | >13 |
| | Soil texture | L and finer | sl-scl | s-sl | |
| | Soil Depth (cm) | >100 | 50-100 | 30-50 | <30 |
| Accessibility | Slope | 0-6 | 6-13 | 13-25 | >25 |

Table 19 SUITABILITY RESULTS BY MANUAL APPLICATION

| Mapping Unit | Suitability | Limitation |
|---|---|---|
| A1a1 | S2 | crude protein |
| A1g4/A1m1 | S2 | forage yield and crude protein |
| A1m1 | S3 | crude protein |
| A1e1/A1f9 | S2 | crude protein |
| A2e2 | S1 | |
| A2e7/A2f3 | S2 | crude protein |
| A1e1/A1m1 | S2 | crude protein |
| A1f9 | S2 | crude protein |
| X3p | S2 | crude protein and erosion hazards |
| X4p | N | erosion hazards |
| X5p/R | N | erosion hazards and accessibility |
| R | | |

9.2.2 Comparing ALES and Manual Results.

The results obtained by using both means are almost the same in terms of suitability ratings but differ interms of limitations. For ALES limitations are given as a general land use requirement, e.g grazing capacity. In this case grazing capacity does not mean anything because grazing capacity is measured by three factors namely; forage yield, % crude protein and % phosphorus. However it is possible to know the actual limitation through the explaination facility in ALES. With manual application limitations are indicated by land quality or land characteristics.

The other difference is that with ALES one is able to look at different combinations possible while in manual application one is limited to few combinations. With ALES interactions of land characteristics are simple to visualize.

The problem of time consuming and tidiousness of going through a large volume of data sets in the manual approach is still a problem. In ALES, it takes a long time in the begining to build models but once the models have been built and transferred into decision trees, large volume of data can be processed.

The other difference is the relationship between the actual field data and the data used for evaluating land. In manual application this relationship is very close because the conversion tables which are rated land qualities are compared directly with the land characteristics of the mapping units. In such a case adjustment of the suitability rating of a mapping unit is well understood. However with ALES the relationship is not so clear. Evaluation results are based on decision trees and mapping unit data entered. The mapping unit data entered is general in nature and the results are also general in nature and not specific to the mapping unit.

9.3 Advantages and Limitations of ALES.

9.3.1 Advantages

a. Transferability of Models.

The main problem with the conventional methods of land evaluation was the need for construction of conversion tables each time one does a land evaluation of an area after data collection. With ALES such problems are history. With ALES it is possible to come up with land use models for a district or region and these models can be updated easily. For example it is possible to have land use requirement models for different ecological regions of Malawi and that each time one does a survey, all he has to do is pick the model which fits his survey area and then input land unit data.

b. Usability of the Land Unit Data:

Land evaluation is done after a soil survey or resource survey. During surveys a lot of data is collected. However when it comes to land evaluation a lot of data is not used because with manual application many combinations are not possible or difficult to visualize. However with ALES most of the data collected can be used in building land use requirement models. It is also possible to import data from already existing models such as SLEMSA and USLE.

9.3.2 Some limitations.

a. Compound Mapping Unit.

The whole idea of indicating a mapping unit whether it is homogeneous or compound is good but evaluating a compound mapping unit causes a lot of problems. There are two problems;

i). When entering data for a compound unit the components must be homogeneous units in the area of survey and must have been mapped as mapping units. If the above condition is not fulfilled ALES does not accept the mapping unit. This condition is difficult to fulfil.

ii). Assuming that the components of a compound unit are homogeneous areas within the study area, when entering land unit data, the data for the compound unit is not entered but ALES uses the data of the homogeneous units.

The above approach works very well when one evaluates land based on a soil survey and that land is evaluated for crops based on soil properties and the components of compound units are mapped. However for grazing this question of land being homogeneous or compound was found to be irrelevant and confusing because though the mapping unit may be homogeneous in terms of soils it is not homogeneous in terms of natural vegetation, the most important parameter in evaluating land for grazing. Therefore in defining mapping units for grazing if one defines a mapping unit as compound the mapping unit information is taken from homogeneous units. I think for vegetation this is wrong because the natural vegetation of an area is not as a result of soil properties alone but as a result of several interactions, ie climate, soils, grazing regime, cultivations, bushfires, etc.

b. Decision Trees.

The procedure of making decision trees is time consuming and requires inputs from different specialists. The trees are unnecessarily long since most combinations may not occur in your area of study or they are too theoretical. In this respect, ALES is as tidious and time consuming as the manual approach.

9.4 Overall Conclusions.

a). Mangochi area is moderately suitable for grazing due to low crude protein levels of the forage dry matter and also due to distance to water .

b). At present Mangochi area is overstocked. The right stocking rate or carrying capacity of the grazing areas of Mangochi is probably 2ha/ TLU on the higher side and 5ha/TLU on the lower side. If both yield and crude protein levels can be improved the grazing capacity can be increased and so would be the growth rates and milk production.

c). ALES can be an important tool in land suitability assessment. It allows a very quick land evaluation once land use requirement models have been entered. However the results by ALES should not be taken as final as they give a general overview of the situation. The results should be compared with the actual field data and models should be adjusted accordingly or it should be followed by a detailed investigation at a later stage.

d). Once the land use requirement models have been constructed and tested they form an evaluation system that can be used for any dataset provided the data is presented in a form required by ALES. This is a very useful aspect for Malawi. At the ministry of agriculture headquarters there is a lot of soil data from different regions and districts in the country and with ALES this data can easily be analysed.

e) Large datasets for land use types which were troublesome in the past because they had to be dealt with manually can be handled now without difficult.

f) The evaluation results by ALES are just as good as those done manually but the speed of processing is certainly faster.

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# A P P E N D I X 1 . The Questionaire

Appendix 1.

GENERAL FARM SURVEY

Observation Number: Date:

Name of Farmer and Age: Marital Status:

E.P.A.: Village:

Mapping Unit: Dominant Soil:

CROPS

| Farm Size | Crops | Area | Yield | Land Tenure |
| --- | --- | --- | --- | --- |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

LIVESTOCK

| Type | Cattle | Goat | sheep | pig |
| --- | --- | --- | --- | --- |
| Numbers | | | | |
| Function | | | | |
| Products | | | | |

Appendix 1.

2

Grazing Pattern

Where do animals graze a) Rainy Season

b) Dry Season

When is feed supply sufficient and when is it in short supply?

How far are the grazing areas? ______

How are feed shortages overcome? ______

Who owns the grazing areas? ______

Which areas are not grazed but have potential? ______

If some, what is the reason? ______

Name the grasses, herbs and shrubs preferred by:-

a) cattle ______

b) goats ______

c) sheep ______

In which landscape are they found? ______

CREDIT AND INPUTS

What kinds of inputs are required for production of livestock?

a) cattle ______

b) goats ______

c) sheep ______

Appendix 1.



How are the inputs obtained?
a) on credit
b) cash
c) free

What is the cost of each input? ______

Do you receive extension advice? ______

PRODUCTION

How long does the animal take to reach mature age?
a) cattle ______
b) goat ______
c) sheep ______

How much do they weigh when mature? ______

Any desease epidemics?

WATER AVAILABILITY

What is the source of water for cattle? ______

Is the source of water perennial? ______

If not, then how long(months) is water available? ______

MARKETING

At what age are animals sold?
a) cattle
b) goat
c) sheep

Where are they sold and at what price?

How far are the livestock markets?

Appendix 1.



GENERAL QUESTIONS( FARMERS AND AGRICULTURAL STAFF)

Total number of livestock in the section/EPA by type?

What is the off take?

What do you consider to be the major problems that hinder livestock production ?

How can these problems be solved?

What is the percentage of livestock farmers of the total population?

# APPENDIX 2. ITC Relevee sheets

**Appendix 2.**

## ITC RELEVÉ DATA SHEET

ITC Vegetation and Agricultural Land Use Sırvey

| | | | |
|---|---|---|---|
| PHOTO No. (run, type etc.) | Area, Country, etc. | DATE / / day month year | No. |
| PRELIMINARY LEGEND SYMBOL: | SIZE SAMPLE $m^2$ | ALTITUDE IN m: | |
| PRELIMINARY LANDUNIT NAME: | OBSERVER(S): | | |

**FINAL CLASSIFICATION (not for fielduse)**

| | |
|---|---|
| FINAL MAP SYMBOL | |
| LANDFORM - (HYDROLOGY) | SYMBOL |
| SOIL | SYMBOL |
| VEGETATION form | SYMBOL |
| compositon | SYMBOL |
| LAND USE | SYMBOL |

**TERRAIN DATA**

| | |
|---|---|
| SITE/ELEMENT | MAPPING UNIT |
| ROCK LITHOLOGY: | ROCK LITHOLOGY/GEOLOGICAL FORMATION |
| LANDFORM/TOPOGRAPHIC POSITION WITHIN MAPPING UNIT | LANDFORM |
| SLOPE TYPE<br>straight, concave, convex,irregular | RELIEF TYPE<br>- Very flat<br>- Almost flat ( < 2%)<br>- Undulating (3 - 7%)<br>- Rolling (8 -13%)<br>- Hilly (14-20%)<br>- Steeply dissected (21-55%)<br>- Mountaineous (> 55%) |
| SLOPE : LENGTH: / EXPOSURE N.NE.E.SE.S.SW.W.NW. | RELIEF INTENSITY |
| MICRO-MESORELIEF | |

**SOIL AND WATER DATA**

| EROSION | | | SOIL DRAINAGE | | WATER SOURCE | RUNOFF | | FLOODING/PONDING | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TYPE | RATE | AREA AFFECTED | | | | | | DEPTH | AGENT | FREQUENCY | DURATION |
| none<br>sheet<br>rill<br>gully<br>eolic | very low<br>low<br>moderate<br>strong<br>severe | <25%<br>20-50%<br>50-75%<br>>75% | excessive<br>somewhat excessive<br>well | mod.well<br>imperfect<br>poor<br>very poor | rain<br>run-on<br>aquifer<br>irrigation | very rapid<br>rapid<br>medium | slow<br>very slow | | none<br>rain<br>run-on<br>river<br>lake<br>sea | ...per<br>.....years<br>month<br>week | days<br>weeks<br>months |

| HORIZON symbol | DEPTH cm | TEXTURE | COLOUR | PH | HCL | MOTTLING | CONSISTENCE | SURFACE SEAL | SURFACE STONINESS/ ROCK OUTCROPS (%) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | effective soil depth (cm) .... | groundwater depth (cm) ..... |

PRELIMINARY SOIL CLASSIFICATION

**LAND COVER/USE DATA (semi-)natural or planted**

| SAMPLE PLOT | | | | SITE/ELEMENT | MAPPING UNIT |
|---|---|---|---|---|---|
| STRATA | HEIGHT | COVER % | DOMINANT SPECIES (for details p.t.o.) | general cover/use type (if complex, estimate % cover of each type) | general cover/use type (if comple , estimate % cover of each type) |
| trees | | | | | |
| shrubs | | | | | |
| herbs | | | | | |
| total real cover % | | | | | |

PRELIMINARY COVER CLASSIFICATION:
form:
composition:

LAND USE
type:
field size/shape:

| (repeat number here) No. | LIST OF SPECIES | OBSERVATIONS/INTERVIEWS ON VEGETATION, CROPS, ANIMALS AND MANAGEMENT ASPECTS (SAMPLE SIZE) |
|---|---|---|

(SEMI-)NATURAL VEGETATION

- burning
- fuel wood collection
- range condition
- grazing traces
- fences
- watering points
- dropping/footmarks/tracks

CROPS

- planting distance
- stage
- height
- crop condition

<u>Timing</u>

- date of planting
- date of harvesting
- rotation

<u>Mechanisation</u>

<u>Input use</u>

- fertilizer
- pesticides

<u>Yield</u>

(expected) yield in year of survey

- normal yield range

ANIMALS

- type/breed
- number
- estimated body weight
- age/sex
- condition

| SAMPLE SIZE: | TOTAL NO. OF TAXA: | |
|---|---|---|

| Fresh WEIGHT DATA g/m2 | | | | | | dry |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | a. $\frac{1 \to n}{n}$ | c sub.sample |
| 6 | 7 | 8 | 9 | 10 | b. sub.sample | c/b.a=g/m2 |

A P P E N D I X 3. List of vegetation species of Mangochi Area.

**Appendix 3.**

List of vegetation of Mangochi Area

Trees
Acacia albida
Acacia polyacantha
Colophospernum mopane
Pericopsis angolensis
Markhamia acuminata
Kirkia acuminata
Pretocarpus angolensis
Annona species
Adasonia digitata
Lonchocarpus capassa
Poliostigma thonningii
Diplorhynchus condylocarpon
Tamarindus indica

Herbs
Triumfetta rhomboidea
Eclipta prostrata
Crotalaria ochroleuca
Ceratotheca sesamoides
Caesalpinia decapetala
Bidens pilosa
Trichodesma zeylanicum
Solanum panduriforme
Sida acuta
Mucuna pruriens

Grasses
Chloris gayana
Cynodon dactylon
Pennisetum purpureum
Eleusine indica
Rottboellia exaltata
Sporobolus pyramidalis
Setaria palustris
Echinochloa pyramidalis
Urochloa mossambicensis
Eragrotis castellaneana
Eragrotis aspera
Rhynchelytrum repens
Cloestachne sorghoides
Echinochloa colonum
Panicum species
Pennisetum polystachyon
Digitaria milanjiana
Eragrotis ciliaris

APPENDIX 4. Mapping Unit data of the study area.

```
irmg (Grazing; Mangochi)                              Appendix 4.
LMU ID      LMU Name
    LC code       data
------------------------------------------------------------------------
A1a-1       Beach Ridges
    cp            med (medium)  [5-7]
    ef            4.5 (4.5)  [3.5-4.5]
    fy            d (high)  [2800-15000]
    ph            high (high)  [.25-2]
    sd            dp (deep)  [100-1000]
    sl            1 (level)  [0-2]

A1e-1/A1f-  Footslopes
    cp            med (medium)  [5-7]
    ef            6.5 (6.5)  [4.5-6.5]
    fy            d (high)  [2800-15000]
    ph            high (high)  [.25-2]
    sd            dp (deep)  [100-1000]
    sl            1 (level)  [0-2]

A1e-1/A1m-  Alluvial Fans over Lacustrine
    cp            med (medium)  [5-7]
    ef            6.5 (6.5)  [4.5-6.5]
    fy            d (high)  [2800-15000]
    ph            high (high)  [.25-2]
    sd            dp (deep)  [100-1000]
    sl            1 (level)  [0-2]

A1f-9       Alluvial Fans
    cp            med (medium)  [5-7]
    ef            6.5 (6.5)  [4.5-6.5]
    fy            d (high)  [2800-15000]
    ph            high (high)  [.25-2]
    sd            dp (deep)  [100-1000]
    sl            1 (level)  [0-2]

A1g-4/A1m-  Lower Footslopes
    cp            med (medium)  [5-7]
    ef            6.5 (6.5)  [4.5-6.5]
    fy            c (medium)  [1200-2800]
    ph            high (high)  [.25-2]
    sd            dp (deep)  [100-1000]
    sl            1 (level)  [0-2]

A1m-1       Upper Footslopes
    cp            med (medium)  [5-7]
    ef            6.5 (6.5)  [4.5-6.5]
    fy            d (high)  [2800-15000]
    ph            med (medium)  [.15-.25]
    sd            dp (deep)  [100-1000]
    sl            1 (level)  [0-2]
```

irmg (Grazing; Mangochi) **Appendix 4**

| LMU ID | LMU Name | |
|---|---|---|
| LC code | | data |
| A2e-2 | Footslopes | |
| cp | | h (high) [7-30] |
| ef | | 6.5 (6.5) [4.5-6.5] |
| fy | | d (high) [2800-15000] |
| ph | | high (high) [.25-2] |
| sd | | dp (deep) [100-1000] |
| sl | | 2 (gently sloping) [2-6] |
| A2f-3/A2e- | Dissected Footslopes | |
| cp | | med (medium) [5-7] |
| ef | | 6.5 (6.5) [4.5-6.5] |
| fy | | d (high) [2800-15000] |
| ph | | high (high) [.25-2] |
| sd | | dp (deep) [100-1000] |
| sl | | 2 (gently sloping) [2-6] |
| R | Rock Outcrops | |
| X2e-7/A2f- | Dissected Footslopes | |
| cp | | med (medium) [5-7] |
| ef | | 6.5 (6.5) [4.5-6.5] |
| fy | | c (medium) [1200-2800] |
| ph | | high (high) [.25-2] |
| sd | | dp (deep) [100-1000] |
| sl | | 2 (gently sloping) [2-6] |
| X3p | Hilly Land | |
| cp | | med (medium) [5-7] |
| ef | | 4.5 (4.5) [3.5-4.5] |
| fy | | c (medium) [1200-2800] |
| ph | | high (high) [.25-2] |
| sd | | md (moderately deep) [50-100] |
| sl | | 3 (sloping) [6-13] |
| X4p | Hilly Land | |
| cp | | med (medium) [5-7] |
| ef | | 4.5 (4.5) [3.5-4.5] |
| fy | | d (high) [2800-15000] |
| ph | | high (high) [.25-2] |
| sd | | md (moderately deep) [50-100] |
| sl | | 4 (moderately steep) [13-25] |
| X5p/R | Escarpment | |
| cp | | med (medium) [5-7] |
| ef | | 4.5 (4.5) [3.5-4.5] |
| fy | | d (high) [2800-15000] |
| ph | | high (high) [.25-2] |
| sd | | md (moderately deep) [50-100] |
| sl | | 5 (steep) [25-55] |
| m | marshes | |

Appendix 5: Land characteristics description.

**Appendix 5.** irmg (Grazing; Mangochi)

Land Characteristics

| LC Id | | LC Name | Classes | Units | Infer from |
|---|---|---|---|---|---|
| | Class Code | Class Name | Upper limit | | |
| cp | | crude protein | 4 | % | |
| 1 | v.l | very low | 3.8 | | |
| 2 | l | low | 5 | | |
| 3 | med | medium | 7 | | |
| 4 | h | high | 30 | | |
| dr | | soil drainage | 5 | 0 | |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| dw | | distance to water | 4 | km | |
| 1 | v.s | very short | 2 | | |
| 2 | s | short | 4 | | |
| 3 | m | medium | 6 | | |
| 4 | l | long | 20 | | |
| ef | | erodability factor | 3 | 0 | |
| 1 | 3.5 | 3.5 | 3.5 | | |
| 2 | 4.5 | 4.5 | 4.5 | | |
| 3 | 6.5 | 6.5 | 6.5 | | |
| fy | | forage yield | 4 | kg/ha | |
| 1 | a | v.low | 600 | | |
| 2 | b | low | 1200 | | |
| 3 | c | medium | 2800 | | |
| 4 | d | high | 15000 | | |
| ph | | phosphorus | 4 | % | |
| 1 | v.l | very low | .1 | | |
| 2 | l | low | .15 | | |
| 3 | med | medium | .25 | | |
| 4 | high | high | 2 | | |
| qw | | quantity of water | 3 | months | |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| sd | | soil depth | 4 | cm | |
| 1 | vs | very shallow | 30 | | |
| 2 | sh | shallow | 50 | | |
| 3 | md | moderately deep | 100 | | |
| 4 | dp | deep | 1000 | | |
| sl | | slope | 6 | % | |
| 1 | 1 | level | 2 | | |
| 2 | 2 | gently sloping | 6 | | |
| 3 | 3 | sloping | 13 | | |
| 4 | 4 | moderately steep | 25 | | |
| 5 | 5 | steep | 55 | | |
| 6 | 6 | very steep | 100 | | |

Appendix 6: Compuation diagram for Physical Suitability

Appendixx 6: Computation Diagram for Physical Suitability.

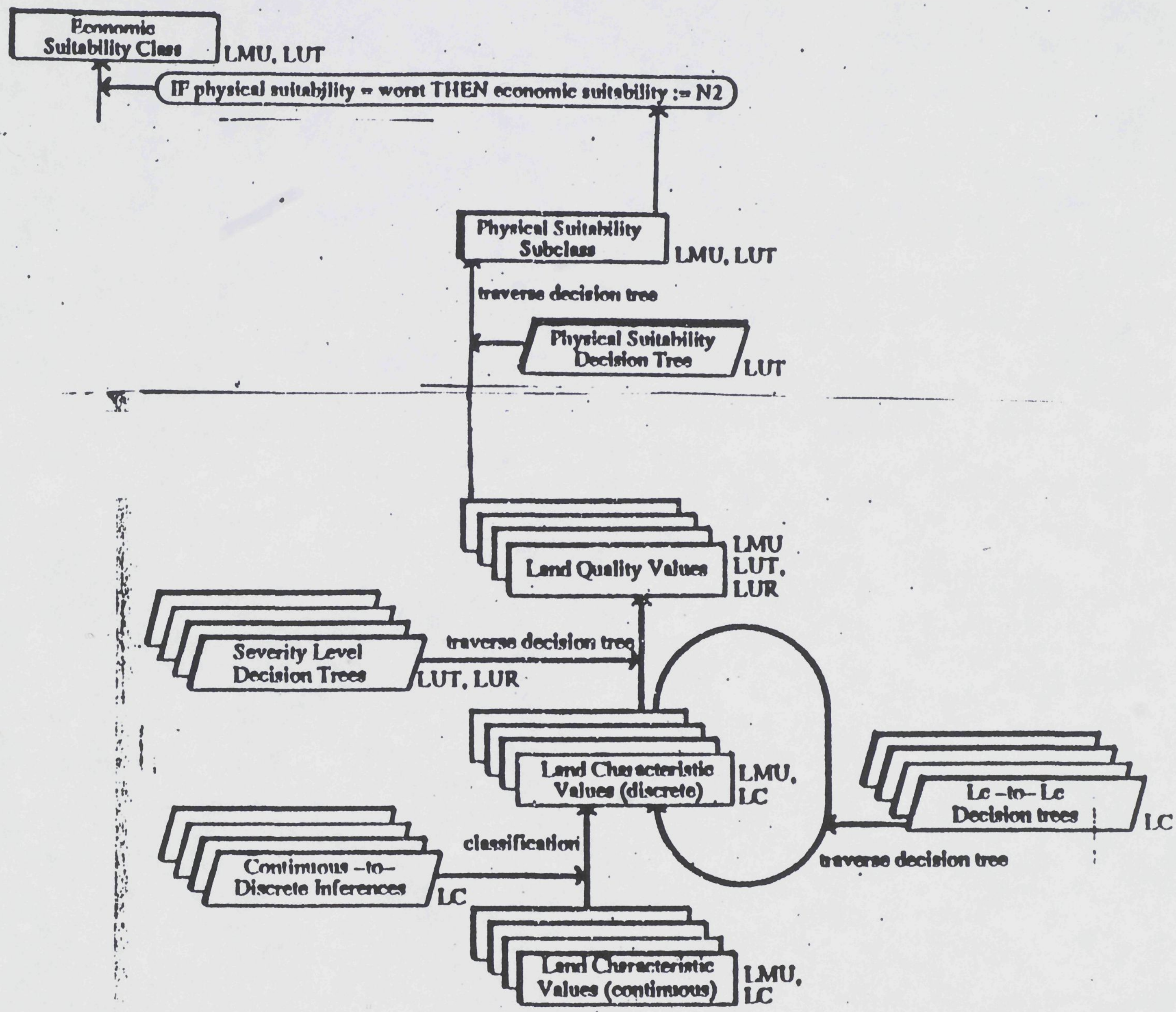


**Figure A : Computation of land quality valuesa** and Physical Suitabilit;