Guidelines on Land Evaluation for Rainfed Agriculture in Mozambique

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GUIDELINES ON LAND EVALUATION
FOR RAINFED AGRICULTURE
IN MOZAMBIQUE
(Basement Complex)

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'The greatest obstacles to progress are lack of imagination about the earth and its infinitely varied wealth of resources; lack of organized, coherent accessible knowledge concerning many of the key factors; and a widespread failure to seek out, learn and apply even such knowledge and experience, already fairly substantial, as now exists.

It is particularly serious handicap that the main practical requirement and opportunity for a concentrated point of knowledge required in land evaluation, happens to coincide, in terms of organized studies, with a no-man's land between climatology, soils, ecology, geography and agronomy'. Adapted from Nicholson (1970).
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1 INTRODUCTION

1.1 Background and Objectives

Mozambique needs to increase its agricultural production in order to feed a growing urban and rural population and to produce raw materials for local industry and export in sufficient quantities to sustain a healthy economy.

Increased agricultural production can be achieved by more intensive use of the land and by bringing additional land into cultivation both of which imply substantial changes in land utilization. Even more profound changes in agricultural land use are brought about by the re-settlement of the dispersed population into Aldeias Comunais (communal villages), a corner-stone of Mozambique's policy for rural areas.

The sound planning of changes in land use requires a thorough knowledge of the natural resources, and a reliable estimate of what they are capable of producing, so that reliable predictions and recommendations can be made. In addition to production potential, the conservation of soil and water resources for use by future generations requires consideration in planning land development.

A solid basis for agricultural land use planning consists of adequate land resources survey, followed by the suitability assessment of the land for specified uses (land evaluation). Mozambique's Government agency responsible to carry out such studies is the Land and Water Department of the National Agronomic Research Institute (INIA). The Department prepares terms of reference and also controls surveys commissioned to foreign consulting companies.

The nature and quality of previous land evaluation studies of the Department have varied considerably merely because of educational background and experience of the technicians involved. Foreign companies usually imported their national land evaluation system. Further unnecessary time has been lost where technicians developed their own evaluation system for a specific area, whereas already considerable experience in similar areas had been obtained by the Department.

In view of the above, it was felt that guidelines for land suitability assessment needed to be written, which would ensure consistency and compatibility of results of evaluations. In particular it was recommended that such guidelines should include a comprehensive set of land quality ratings in order to capitalize on previously gained experience. In addition, the guidelines should be designed according to the principles of the FAO Framework for Land Evaluation (FAO, 1976).
The Head of the Land and Water Department requested the author to write such land evaluation guidelines and consequently this activity has been included in his job description.

It is in the above context that the present guidelines have been written. Other guidelines intended to standardize working methods within the Department concern for instance thematic map preparation (Spiers, 1984), Reporting and typography of reports (Voortman and Spiers, 1985) and fieldwork (Van Wambcke et al 1985).

1.2 Scope and Use of the Guidelines

Rainfed arable farming is by far the dominant type of land utilization in Mozambique. The present guidelines aim to assist in the land suitability assessment for this kind of land use.

The presented land quality ratings (chap.7), are based on literature and on experience of the author, obtained from semi-detailed and reconnaissance land resources surveys of Basement Complex areas in Mozambique. The Basement Complex constitutes about 60% of the land surface of the country and its extent is depicted in Fig. 1.1. The presented ratings may be valid under other circumstances but this requires confirmation.

The guidelines concern the first stage of a two-stage approach towards land evaluation (cf.FAO, 1976). It relates the physical properties of the land with the ecological and agronomic requirements of crops and with the type of land management. This first stage of land evaluation can be followed by economic land evaluation in a second stage, depending on the objectives and detail of the study. This second stage of social and economic analysis has not been considered in the present report.

The above choice is determined by the present staffing of the Department, where the vast majority of staff is specialized in land resource survey and evaluation. In addition it was considered that first-stage land evaluation results have a relatively long time validity, whereas economic evaluations are short-lived due to changes in costs and prices. Moreover, the two-stage approach is much more straightforward than the parallel approach (cf. FAO, 1976), with activities and responsibilities being clearly defined.

The above does not preclude the land resource surveyor to use social and economic data as much as possible if available. In addition, the principles of land evaluation (cf. Chap. 2,3) still require the first-stage evaluation to be made in terms relevant to the economical and social context of the area concerned.

The presented evaluation system is partly quantitative and partly qualitative. Firstly climatic factors are evaluated quantitatively resulting in climatic yield potential which sets the upper limit to crop production. The degree to which the climatic potential can be attained is determined by edaphic factors, which are evaluated in a qualitative manner.

This report on purpose is entitled 'guidelines' and not 'manual'. The rating scheme presented in Chapter 7 should not be followed blindly as if it were a cookery book. This would under-estimate the-
Fig 11 Extent of Basement Complex in Mozambique
importance of local experience and the creativity of the land evaluator involved. However, deviations from the present guidelines judged to be relevant by the land evaluator, should be accompanied by well founded arguments and/or field experience (e.g. crop yields).

1.3 **Arrangement of the Report**

The guidelines on rainfed land evaluation (sensu stricto) are presented in Chapters 7 and 8: 'Land qualities and their assessment' and 'Land suitability assessment'. The land evaluation system elaborated for Basement Complex areas of Mozambique is explained herein.

In the preceding chapters general aspects on land, land resources survey and land evaluation are summarized. These chapters are partly drawn from existing literature. With the choice of texts and the additions by the author, it is intended to provide a concise text relevant to the conditions of Mozambique. Throughout chapters 2-4 ample use has been made of quotations from the following publications:


In order to avoid excessive citations in the text, these publications where quoted are indicated with (1) and (2) respectively.
2 OBJECTIVES AND PROCEDURES OF LAND EVALUATION

2.1 The Need for Land Evaluation

'Land evaluation is the assessment of land performance when used for specified purposes. As such it provides a rational basis for taking land use decisions based on analysis of relations between land use and land, giving estimates of required inputs and projected outputs.

The need for optimum use of land has never been greater than at present. Rapid population growth and urban expansion make land available for agriculture a relatively scarce commodity. The increasing demand for intensification of existing cultivation and opening up of new areas of land can only be satisfied, without damage to the environment, if land is classified according to its suitability for different kinds of use: (2)

2.2 Objectives of Land Evaluation

'The principal objective of land evaluation is to select the optimum land use for each type of land, taking into account both physical and socio-economic considerations and the conservation of environmental resources for future use'.

Detailed objectives vary considerably according to the purpose and scale of the land evaluation. Every evaluation, however, should address itself to the following questions, the answers to which should be included in the results of the evaluation:

- How is the land currently managed, and what will happen if present practices remain unchanged?
- What improvements in management practices, within the present use, are possible?
- What other uses of land are physically possible and economically and socially relevant?
- Which of these uses offer possibilities of sustained production or other outputs?
- What adverse effects, physical, economic or social, are associated with each use?
- What recurrent inputs are necessary to bring about the desired production and minimize the adverse effects?
- What are the outputs (products, services and other benefits) of each form of use?

If the introduction of a new use involves significant change in the land itself, as for example in conservation or drainage schemes, then the following additional questions should be answered:

- What changes in the condition of the land are feasible and necessary, and how can they be brought about?
- What non-recurrent inputs are necessary to implement these changes?
The evaluation process does not in itself determine the land use changes that are to be carried out, but provides data on the basis of which such decisions can be taken. To be effective in this role, the output from an evaluation normally gives information on two or more potential forms of use for each area of land, including the consequences, beneficial and adverse, of each (2).

2.3 Principles of Land Evaluation

The framework for land evaluation (FAO, 1976) was formulated specifically to satisfy the objectives stated above. The 'Framework' is dynamic in concept and aims to predict the effects of changes in land use through an understanding of the relationships, both ecological and socio-economic, which exist between a given tract of land and its use. It therefore has an advantage over systems of land capability or suitability classification which are based on static, mainly physical factors. The 'Framework' is based on six principles (2).

i Land suitability is assessed and classified with respect to specified kinds of use

The concept of land suitability is only meaningful in terms of specific kinds of land use, each with its own requirements for climate and soil. For example, land very suitable for rice is often not suited to maize. Land use may be defined in broad terms (e.g. rainfed agriculture) or more specifically (e.g. a tobacco-maize rotation under improved traditional management).

ii Evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land

Any kind of land use requires inputs, varying from labour only to fertilizer, fuel, machinery, etc. Suitability for each use is assessed by comparing the required inputs with the goods produced or other benefits obtained. It is very often the case that the difference between the best land for a given crop and less good land lies not so much in the yields obtained as in the inputs needed to achieve a satisfactory yield.

iii A multi-disciplinary approach is required

In addition to specialists in land evaluation itself, the disciplines most likely to be needed in an evaluation study for rainfed agriculture are:

- soil survey, soil conservation, agroclimatology, agronomy, economics. However, land evaluation requires more than the sum of the mentioned fields and indeed is rather an inter-disciplinary than multidisciplinary activity. The land evaluator or team leader should have a sufficiently wide background of knowledge to overview the fields of the different specialists and to ensure interdisciplinarity. It is further useful that the team members are trained or have systematized experience in more than one speciality and/or include in the
team, members specialized in interdisciplinary sciences like land ecology, farming systems, etc. Where no team is available, a single land evaluator should attempt to achieve a interdisciplinary approach, or at least avoid undue bias towards the methods of one discipline (e.g. soil science or economics).

iv Evaluation is made in terms relevant to the physical, economic and social context of the area concerned

Land which is suitable for a given crop in one region will not always be suitable in another, because of differences in labour costs, capital availability, levels of technical knowledge possessed by the farmers, local export markets, systems of land tenure which are socially and politically acceptable. The assumptions in the respect which underly the evaluation may differ from one region to another. Many of these factors are often implicitly assumed; to avoid misunderstanding and to assist in comparisons between different areas, such assumptions should be explicitly stated.

v Suitability refers to use on a sustained basis

'The aspect of environmental degradation is taken into account when assessing suitability. There might, for example, be forms of land use which appeared to be highly profitable in the short run but were likely to lead to soil erosion, progressive pasture degradation, or adverse changes in river regimes downstream. Such consequences would outweigh the short-term profitability and cause the land to be classed as not suitable for such purposes' (1).

vi Evaluation involves comparison of more than a single kind of use

'This comparison could be, for example, between agriculture and forestry, between two or more different farming systems, or between individual crops. Often it will include comparing the existing uses with possible changes, either to new kinds of use or modifications to the existing uses. Occasionally a proposed form of use will be compared with non-use, i.e. leaving the land in its unaltered state, but the principle of comparison remains. Evaluation is only reliable if benefits and inputs from any given kind of use can be compared with at least one, and usually several different alternatives. If only one use is considered there is the danger that, whilst the land may indeed be suitable for that use, some other and more beneficial use may be ignored' (1).

The present guidelines intend to translate the above concepts into a practical system of land evaluation for rainfed crop production. Prior to carrying out land evaluation, however, it is necessary to understand how it related to other stages in the overall process of rural development planning.
2.4 The Role of Land Evaluation in Rural Development Planning

"In the cycle of rural development planning illustrated in Figure 2.1, land evaluation forges a link between the basic surveys of resources and the taking of decisions on land use planning and management. The outcome of decisions following land evaluation may be project implementations. Alternatively, the evaluation may have indicated a need for redefinition of objectives and the carrying out of more detailed surveys and evaluation, as indicated by the feedback loop. A typical sequence would comprise a reconnaissance survey and land evaluation resulting in project identification in terms of areas and land use types, followed by more detailed surveys and evaluation resulting in project implementation (or rejection) in these areas.

There is no sharp boundary between land evaluation and the taking of decisions on land use planning, development and management. The land evaluation procedure does not of itself take such decisions. It can and should, however, make recommendations. The main objective of land evaluation is to put at the disposal of the user, whether farmer, planner, government official or politician, relevant information about land resources that is necessary for planning, development and management decisions. The end result of a land evaluation survey is thus a number of clear recommendations, with alternatives, on appropriate types of land use, together with their consequences'.(2)

2.5 Outline of Land Evaluation Procedures

'Used in its broadest sense, the process of land evaluation includes the basic land resource surveys (e.g. soil survey, analysis of climatic records) which form one of its major sources of data. In a narrower sense, evaluation is the interpretation of this collected data in terms of resources and limitations for land use. The difference is mainly a semantic one; whichever view is taken, land evaluation is most certainly not a 'desk exercise' but requires a considerable amount of field survey and data collection activities'.(2)

Figure 2.2 depicts the full process of a land resources survey and land evaluation study. Any study starts with 'initial consultations', which consist of discussions between those commissioning the survey and those responsible for its execution. Initial consultations are called for when the need for change in land use is felt at the decision making level, based on policy objectives and existing (broad) knowledge of socio-economic and eco-physical conditions of the country and its regions. During initial consultation the study area is delineated, the most adequate type of survey defined, the timing of survey and reporting are determined. The land utilization types which require evaluation are defined in a general matter.

After a quick perusal of available data and for instance satellite imagery, it may appear that some of the underlying assumptions during the above discussions prove (partially) incorrect and a second round of consultations may be necessary to adjust the objectives of the study.
Figure 2.1 Generalized sequence of activities in rural development planning
Source: FAO, 1983
Policy Objectives

Knowledge of economic and social conditions

recognition of the need for change

Knowledge of eco-physical conditions

initial consultations; define objectives and study area, type of study, time frame and broad land utilization types

National Spatial Planning

socio-economic and agro economic surveys
- employment
- population
- markets
- services

survey and mapping of land resources and land use

agro-climatic zones
present land use
land units

relevant land utilization types; detailed definition

land use requirements

land qualities and land characteristics

Matching

Present and potential land suitability of each land utilization type for each land unit

Regional Spatial Planning

Spatial distribution of socio-economic aspects

Spatial distribution of present land use

Study phase

study of spatial relationships and comparison of development alternatives

decision-making and implementation

Monitoring

Continuous dialogue between planners regional officers and the surveyors; adjustment of the objectives of the study whenever necessary

Fig. 2.2. Outline of the systematic process of land resource survey and land evaluation

Source: Adapted from Voortman, 1979 and De Vos t.N.C. 1978
Thereafter field studies of the various data required can commence. During the survey, the land utilization types will be further detailed, in an iterative manner, based on results from socio-economic and agro-economic analysis as well as from present land use and the agro-climatic characteristics of the area under study. Once these land utilization types have been determined in detail, the land use requirements of the same can be determined.

These land use requirements are to be compared with the land qualities which in the mean time have been determined through the survey and mapping of land resources. The process of comparison is called 'matching' and leads to the suitability classification of each land unit for each land utilization type. From the ecological land suitability classification the most productive land use can be determined.

However, the ecologically best adapted land use is not always selected for a development plan. Compatibilization has to take place with other sectors of development, the socio-economic conditions in and outside the region, the constraints of present land occupation and also development plans existing for other regions. This phase of regional spatial planning should be executed by planners assisted by politicians, decision-makers and the land evaluators themselves.
3 DIFFERENT KINDS OF LAND EVALUATION

In Chapter 1 the kind of land evaluation described in this report has been introduced: ecological, partly quantitative and partly qualitative. The land evaluation studies presently executed by the Land and Water Department can be further classified in various manners depending on the chosen guiding principle:

- general purpose or special purpose land evaluation
- level of detail
- current suitability or potential suitability assessment

These aspects are described below.

3.1 General Purpose and Special Purpose Land Evaluation

'A general purpose land evaluation assesses the suitability of an area for all relevant forms of use. These include both existing uses and new ones, for example the introduction of new crops. Evaluation may be made in terms of major kinds of land use, but usually it is better to amplify these at least to a limited degree into individual crops under broadly defined management levels. By no means all the kinds of use will be given at the start of the survey, since one of the aims of a general-purpose evaluation is to identify, investigate and describe potential new uses.

In a special-purpose land evaluation the kinds of land use to be considered are restricted and at least partly stated in the objectives. This situation usually applies in evaluation carried out at the project level and may also apply at regional scales. Examples at the reconnaissance level are surveys to locate the most suitable areas for rainfed agriculture itself, to be potential arable land, or for the development of certain crops'.(2) At a more detailed level the objective may for instance involve the definition of appropriate cropping patterns depending on the degree of salinity of the soils in a well defined area. Before commencement of the study, salinity is already defined as a major constraint to crop production.

Table 3.1 presents a subdivision of surveys based on their purpose, which also bears an influence on the way of reporting.

3.2 Level of Detail

A subdivision of land resource surveys according to their level of detail is presented in Table 3.2. The level of detail of the land resource survey generally sets the limit to the detail and reliability of the land evaluation, and consequently sets the limits for what purposes the study is adequate.

3.3 Current and Potential Land Suitability Classification

'A classification of current suitability refers to the suitability for a defined use of land in its present condition, without major improvements. A current suitability classification may refer
<table>
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<th>Objectives</th>
<th>Sampling Approach</th>
<th>Level of Detail</th>
<th>Utilization</th>
<th>Documentation</th>
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<tr>
<td>General purpose</td>
<td>Most or all units identified by aerial photo or</td>
<td>National</td>
<td>Regional Planning</td>
<td>Report with general maps on resources and land</td>
</tr>
<tr>
<td></td>
<td>satellite image interpretation (systematic)</td>
<td>Exploratory</td>
<td>(multi-sectoral)</td>
<td>suitability</td>
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<tr>
<td></td>
<td></td>
<td>Reconnaissance</td>
<td></td>
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<td></td>
<td></td>
<td>Semi-detailed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special purpose</td>
<td>Most or all units identified by aerial photo-</td>
<td>(Reconnaissance)</td>
<td>Local planning</td>
<td>Report with general and applied maps</td>
</tr>
<tr>
<td></td>
<td>interpretation (systematic)</td>
<td>Semi-detailed</td>
<td>(mainly in the agricultural</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Detailed</td>
<td>sector)</td>
<td></td>
</tr>
<tr>
<td>Special purpose</td>
<td>Some of the units identified by aerial photo or</td>
<td>Exploratory</td>
<td>Quick identification of</td>
<td>Brief report with (sketch) maps on natural zones</td>
</tr>
<tr>
<td></td>
<td>satellite image interpretation (non-systematic)</td>
<td></td>
<td>promising areas</td>
<td>and estimated land suitability</td>
</tr>
<tr>
<td>Special purpose</td>
<td>Some of the units identified by aerial photo-</td>
<td>Site evaluation</td>
<td>Problem solving</td>
<td>Brief report with sketch map or oral communication</td>
</tr>
<tr>
<td></td>
<td>interpretation (non-systematic)</td>
<td>1/</td>
<td>Site selection</td>
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Table 3.1. Characteristics of different survey types.

1/ Site evaluation apart from land resources implies the consideration of the social and economic environment necessary for proper assessment.
<table>
<thead>
<tr>
<th>Survey Type</th>
<th>Extent</th>
<th>Type of Land Evaluation</th>
<th>Objectives/Possibilities</th>
<th>Land Resource 1/ Information</th>
<th>Progress 2/ ( \text{ha/ha/year} )</th>
<th>Map Scale</th>
<th>Remote Sensing Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploratory</td>
<td>National</td>
<td>Qualitative ecological</td>
<td>Identification of areas with high potential; elimination of areas where more detailed surveys are not justified</td>
<td>- altitude</td>
<td>3/</td>
<td>1:500 000</td>
<td>Satellite imagery photo-mosaics</td>
</tr>
<tr>
<td></td>
<td>Regional</td>
<td>Qualitative ecological</td>
<td>IDentification of areas with high potential; elimination of areas where more detailed surveys are not justified</td>
<td>- rainfall</td>
<td></td>
<td>1:2 000 000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regional</td>
<td>General ecological</td>
<td>Location of most promising zones and determination of broadly defined land utilization types, ecologically suitable and socio-economically relevant. Identification of planning problems and development alternatives</td>
<td>- altitude</td>
<td>10 000</td>
<td>1:100 000</td>
<td>Satellite imagery photo-mosaics</td>
</tr>
<tr>
<td></td>
<td>Regional</td>
<td>General ecological</td>
<td>Location of most promising zones and determination of broadly defined land utilization types, ecologically suitable and socio-economically relevant. Identification of planning problems and development alternatives</td>
<td>- rainfall</td>
<td>25 000</td>
<td>1:250 000</td>
<td>Small scale aerial photo-mosaics</td>
</tr>
<tr>
<td></td>
<td>Regional</td>
<td>General ecological</td>
<td>Location of most promising zones and determination of broadly defined land utilization types, ecologically suitable and socio-economically relevant. Identification of planning problems and development alternatives</td>
<td>- agro-climatic zones</td>
<td></td>
<td></td>
<td>Medium scale aerial photos (1:10 000-1:50 000)</td>
</tr>
<tr>
<td>Semi-Detailed</td>
<td>Regional</td>
<td>Quantitative ecological including input-output relations of land utilization types; full economic appraisal for feasibility studies</td>
<td>Detailed determination of best adapted land utilization types; location of farm blocks; feasibility studies of large projects</td>
<td>- altitude</td>
<td>1 000</td>
<td>1:50 000</td>
<td>Medium scale aerial photos (1:30 000-1:50 000)</td>
</tr>
<tr>
<td></td>
<td>Regional</td>
<td>Quantitative ecological</td>
<td>Detailed determination of best adapted land utilization types; location of farm blocks; feasibility studies of large projects</td>
<td>- rainfall</td>
<td>2 500</td>
<td>1:100 000</td>
<td>Medium scale aerial photos (1:30 000-1:50 000)</td>
</tr>
<tr>
<td>Detailed</td>
<td>Local</td>
<td>Quantitative ecological and economic appraisal</td>
<td>Detailed definition of ecological and economic constraints/possibilities for land management and improvement; farm and project planning; irrigation surveys</td>
<td>- (altitude)</td>
<td>100</td>
<td>larger than 1:25 000</td>
<td>Large scale aerial photos (1:5 000-1:25 000)</td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>Quantitative ecological and economic appraisal</td>
<td>Detailed definition of ecological and economic constraints/possibilities for land management and improvement; farm and project planning; irrigation surveys</td>
<td>- (rainfall)</td>
<td>250</td>
<td>1:10 000</td>
<td>Irrigation</td>
</tr>
</tbody>
</table>

1/ For definition of 'landscape' and 'land unit' see chapter 5.2
2/ Rate of progress assumes full use of systematic aerial photo-interpretation and stratified sampling and includes reporting
3/ The progress of exploratory surveys depends on its objectives and the degree to which fieldwork is required (sampling approach)
4/ Progress in irrigation surveys in alluvial valleys is estimated at approximately 50 km/ha/year

Table 3.2 Level of detail of surveys and their role in agricultural land use planning.
Source: adapted from Spiers and Voorhuis, 1978
to the present use of the land, either with existing or improved management practices, or to a different use.

A classification of potential suitability refers to the suitability, for a defined use, of land units in their condition at some future date, after specified major improvements have been completed where necessary.

In classification of potential suitability it is important for the user to know whether the costs of amortization of the capital costs of improvements have been included. Where these are included, the assumptions should state the extent to which inputs have been costed and the rates of interest and period of repayment that have been assumed'.(1) Usually the choice of the period of repayment, determines the final outcome. It is further recommended to look for secondary effects, both positive and negative when using these data for a cost/benefit analysis.

'Classification with amortization is only possible if the repayment of capital costs can be apportioned to identifiable areas of land. If the benefits from major expenditure are not confined to the agricultural sector (as in multi-purpose irrigation and power schemes), responsibility for capital repayments is difficult to assess. In these circumstances, amortization costs will usually be excluded from the evaluation' (2).
4 LAND UTILIZATION TYPES

The definition of land utilization types is one of the main activities in land evaluation (cf. Fig. 2.2). Below some general principles for their definition and specific guidelines for Mozambique conditions are presented.

4.1 Major Kinds of Land Use and Land Utilization Types

'One of the principles of the Framework for land evaluation (FAO, 1976) states that land suitability is assessed and classified with respect to specified kinds of use. It follows that types of land use for which the land is being evaluated must be clearly defined. The Framework recognized two levels of detail at which land use is defined:

- A major kind of land use is a major subdivision of rural land use.
- A land utilization type is a kind of land use defined in more detail, according to a set of technical specifications in a given physical, economic and social setting'. (2)

Rainfed agriculture itself is a major kind of land use, but as such not very meaningful for evaluation. Even at a reconnaissance scale it is more useful to base the evaluation on land utilization types, defined at least as individual crops under broadly specified management levels (e.g. high and low levels of inputs/management).

4.2 What Constitutes a Land Utilization Type?

'A land utilization types consists of a set of technical specifications within a socio-economic setting. As a minimum requirement, both the nature of produce and the setting must be specified. A single crop can be regarded as a land utilization type only provided a statement is made as to the socio-economic setting in which it is cultivated, as productivity varies considerably according to the technology available to the farmer'. (2)

Below a checklist of headings is given that can be used for a detailed description of land utilization types. Some of these may be common to groups of land utilization types, others specific to individual types. The number of aspects to be described, and more particularly their detail, depends on the scale and objectives of the survey. In rapid reconnaissance surveys, some aspects may be omitted or noted only briefly.

- Crops grown
- Market orientation
- Capital intensity
- Technical knowledge and attitudes
- Power
- Mechanization
- Size and shape of farms
- Land tenure
- Infrastructure requirements
- Cropping characteristics
- Material inputs
- Cultivation practices
- Livestock
- Forestry
- Other non-crop outputs
- Yields and production
- Economic information.
4.3 Disaggregated Description of Land Utilization Types

'Consideration of the range of land utilization types to be evaluated in any particular study usually indicates that individual land utilization types have many elements in common. These common elements may relate to the socio-economic setting, the nature of the produce or various technical specifications. In order to avoid needless repetition in the final report, an hierarchical system of land utilization type description is proposed, as shown by the example of Fig. 4.1.

Apart from saving space in the final report, this form of description has advantages at the stage of matching with land qualities or characteristics. Instead of having to match all the individual requirements of each land utilization type with land attributes, land requirements common to groups of land utilization types are matched and the results reaggregated to give combined suitability ratings for each land utilization type'. (2)

Crop Production system (setting) Cultivation Factor Power Source

Maize
  State Farm
  Cooperative
  Traditional Small holders

100 % 66 % 33 %
Tractor Oxen Tractor Oxen Tractor Oxen

Fig. 4.1 Example of disaggregated description of land utilization types

4.4 Land Utilization Types Relevant to Mozambique

Information on farming systems and agronomic practices is very scanty in Mozambique. Therefore, the description of land utilization types as defined before the field survey, will merely consist of single crops or cropping patterns grown under management circumstances defined in a general manner. These can be high, intermediate and low levels of input/management circumstances for which the likely attributes are summarized in Table 4.2.

Usually these descriptions have to be linked up with the sectors of agriculture commonly distinguished in Mozambique:

- family sector
- cooperative sector
- private sector
- state sector

The family sector roughly corresponds to low input/management circumstances as defined before.

The state and private sector are planned to be high input/management circumstances and the cooperative sector takes an intermediate position. In practice however the situation is more complex. Levels of inputs are usually only intermediate due to major organizational and transport problems in the state sector. In addition management levels are moderate to poor. As a result crop yields are low when compared with the intended level of inputs/management but also in relation to actual inputs and degree and cost of mechanization.

Further refinements of land utilization types may be based on local agro-climatic conditions or on fieldwork according to evidence derived from present land use or specific soil conditions that require detailed land management specifications.

As such, the land utilization types as defined at the end of a study are also a major result of the study, since the land evaluator procures to include solutions for constraints on production in the definition of the land utilization type.

In addition to the above, particular attention should be given to the duration of rest fallow periods, when defining land utilization types. Most of Mozambique's agricultural production is still obtained in semi permanent and shifting cultivation systems in which rest fallow is the only means of restoring the fertility of the soil.

The duration of the fallow periods can be expressed by the R-factor as follows:

\[ R\% = \frac{\text{years under cultivation}}{\text{years under cultivation} + \text{years of fallow}} \times 100 \]
<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>LOW INPUT LEVEL</th>
<th>INTERMEDIATE INPUT LEVEL</th>
<th>HIGH INPUT LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Systems</td>
<td>Rainfed Cultivation of Presently Grown Mixture of Crops</td>
<td>Rainfed Cultivation with Partly Change to Optimum Mixture of Crops</td>
<td>Rainfed Cultivation of Optimum Mixture of Crops</td>
</tr>
<tr>
<td>Labour Intensity</td>
<td>High, Including Uncosted Family Labour</td>
<td>High, Including Partly Costed Family Labour</td>
<td>Low, Family Labour Costed if Used</td>
</tr>
<tr>
<td>Capital Intensity</td>
<td>Low</td>
<td>Intermediate with Credit on Accessible Terms</td>
<td>High</td>
</tr>
<tr>
<td>Market Orientation</td>
<td>Subsistence Production</td>
<td>Subsistence Production Plus Commercial Sale of Surplus</td>
<td>Commercial Production</td>
</tr>
<tr>
<td>Infrastructure Requirements</td>
<td>Market Accessibility not Necessary. Inadequate Advisory Services</td>
<td>Some Market Accessibility Necessary with Access to Demonstration Plots and Services</td>
<td>Market Accessibility Essential High Level of Advisory Services and Application of Research Findings</td>
</tr>
<tr>
<td>Land Holdings</td>
<td>Fragmented</td>
<td>Sometimes Consolidated</td>
<td>Consolidated</td>
</tr>
<tr>
<td>Recurrent Inputs Required*</td>
<td>Seed Traditional Human Labour</td>
<td>Seed Traditional/Improved Human Labour/Animal Power Fertilizer N-P-K Pesticides</td>
<td>Improved Seed Mechanical Power Fertilizer Fertilizer N-P-K Fertilizer N-P-K Pesticides</td>
</tr>
</tbody>
</table>

Table 4.1 Attributes of Input levels
Source: Shah et al. 1983
In a more general manner the cultivation systems can be classified in the following manner (Ruttenberg, 1980):

- Shifting cultivation  $R = 30\%$
- Semi-permanent cultivation  $R = 30-70\%$
- Permanent cultivation  $R = 70\%$

It should be noted that the land suitability evaluation for individual crops only refers to those years when a crop can be on the field within an adequate rotation.

Similarly an $R$-value can be attributed to more advanced land utilization types, which require grass leys in order to prevent excessive erosion etc.

Estimates of which $R$-factor ensures sustained production of satisfactory levels can often only be obtained by interviewing farmers. The reliability of such information is difficult to check. A first estimate of proper $R$-values by FAO soil type can be obtained from Table 4.3. These values indicate which cultivation intensity is ecologically relevant when defining land utilization types for a given area based on major soil types, climate and management system.

4.5 Land Utilization Types not Relevant for Particular Areas

In many cases there will be particular land utilization types which are not relevant for consideration on particular land units. For example, if the assumptions are that there will be no large-scale movements of population, then land utilization types which support a low density of population are not relevant for consideration on land units which are already densely settled. If the assumptions state clearly that there are to be no changes to the boundaries of forest reserves, then no purpose is served by evaluating the land in these reserves for crop production. The assumptions underlying the evaluation, as determined during the initial consultations are the most common cause of non-relevance of land use on certain areas of land, but there are other causes. Clear dietary preferences of the population may rule out of consideration crops which on climatic grounds would have been included in the evaluation. Economic realities or sheer common sense may indicate the exclusion of some uses from certain area. (2)
<table>
<thead>
<tr>
<th>Level of Inputs</th>
<th>Low</th>
<th>Intermediate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing Period, Days</td>
<td>Rain Forest Zone 270 - 365</td>
<td>Savanna Zone 120 - 269</td>
<td>Semi-Arid Zone 75 - 119</td>
</tr>
<tr>
<td>R, Q Regosols and Arenosols</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>F, Ferralsols</td>
<td>15</td>
<td>15</td>
<td>(20)</td>
</tr>
<tr>
<td>Fa</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Fh</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A, Acrisols</td>
<td>15</td>
<td>15</td>
<td>(20)</td>
</tr>
<tr>
<td>Ah</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L, Luvisols</td>
<td>25</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>B, Cambisols</td>
<td>35</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>N, Nitosols</td>
<td>25</td>
<td>30</td>
<td>(40)</td>
</tr>
<tr>
<td>Nd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ne</td>
<td>(40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H, Phaeozems</td>
<td></td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>V, Vertisols</td>
<td></td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>J, G, Fluvisols and Gleysols</td>
<td></td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 4.2 Cultivation factors (R)
- All values refer to the cultivation factor, expressed as a percentage. For definition see Chap. 4.4
- Values in brackets relate to soils unlikely to occur within the climatic region
- Source: Adapted from Young and Wright, 1980.
4.6 **Examples of Land Utilization Types**

Below three examples of land utilization types are described as well as the underlying reasons for their definition. The examples are taken from a land resource and land evaluation study of Angonia district, Tete Province (Voortman and Spiers, 1985). Before commencement of the survey it was intended to evaluate single crops under two levels of inputs/management, a high and a low (see table 4.1). During field survey though it appeared that for both levels of inputs a main differentiating factor in the suitability of the land concerns the possible cultivation intensity (R-factor). It also appeared that the implied level of mechanization for high inputs would not be relevant for the area with the best soils which were densely occupied with fragmented land holdings. During the land evaluation it appeared that specific management systems would be required for certain areas whereas under 'standard practice' these areas would be not suitable.

The above has led to the definition of recommended land use which consist of land utilization types which are considerably more relevant to agricultural land use planning than the original simple land utilization types considered.

In this particular case of Angonia district it was decided to define recommended land utilization types mainly on land management systems and not on crops. Climatic conditions are so varied within the district (600–700 m. a.sl.) that it is preferable to indicate firstly the most appropriate land management system and then based on climatic conditions select the most appropriate crops for each individual land unit.

**Land utilization type 1** (see below) is a mixture of high and low input conditions. High levels of production inputs and management are required but no mechanization is foreseen. This is determined by the socio-economic realities of the district. This land utilization type has been defined in order to cater for a situation where productive soils (Phaeozems) under a favourable climate are densely occupied by small fragmented land holdings cultivated by peasant farmers. Obviously production will have to be increased for which higher levels of inputs like fertilizer and improved management are required. Though, on-farm mechanization is not likely to be an economic proposition whereas increase in area cultivated is not possible within acceptable distance. In this particular case some degree of mechanization maybe only pursued through service cooperatives. Due to the land pressure in the area concerned integration of arable farming with livestock production is also not considered relevant.

**Land utilization type 1:**

Improved, permanent arable farming for commercial and subsistence production, based on manual labour with hand tools by family sector. Use of improved cultivars, chemical fertilizer and some chemical pest and disease control. Weeding by manual labour. No or minimum fallow periods and complete physical conservation measures but only low intensity required. Large scale mechanization of field operations or animal traction not relevant, whereas areas concerned densely occupied with small fragmented land holdings which makes expansion of area per farmer impossible. Ox-drawn carts, required for transport of inputs and produce, to be cooperatively owned and managed (stall-fed oxen).
ii Land utilization type 2 defines fully mechanized holdings which include a livestock component based on grass leys. This land utilization type was defined to cater for a part of the survey area, which is hardly in use by the peasant sector and thus can still be occupied by large holdings (a government priority). The area consists of Ferralsols under good climatic conditions for annual crop production. Conditions are favourable for full mechanization i.e. slopes do not exceed 5%, physical soil properties are good and erosion hazard is limited. In fact, the only limitation refers to nutrient availability and nutrient retention capacity. This is an over-ruling constraint for low input arable farming but under high inputs fertilizer can be applied to overcome the nutrient availability constraint. In order to increase soil nutrient retention capacity, mixed farming using grass leys are defined to increase organic matter content of the soil and consequently nutrient retention.

Land utilization type 2:

Improved, semi permanent arable farming or mixed farming with 50% of the years grass leys on large fully mechanized holdings. Arable farming component for commercial production using improved cultivars, chemical fertilizer and chemical pest, disease and weed control. Complete physical conservation measures, but only low intensity required. Main purpose of grass leys regarding land management concern restoration of fertility, in particular nitrogen and to increase soil nutrient retention capacity.

iii Land utilization 3 has been defined in relation to an area with good climatic conditions and reasonably fertile but very erodible soils (Albic Luvisols). Erodibility in mainly determined by the medium to light textured topsoils which overlay a fairly compact Bt horizon. If using standard assumptions of the land evaluation system concerning the nature and density of erosion control measures, these soils had to be rated not suitable due to erosion hazard. Therefore it was necessary to introduce a lower cultivation intensity as well as very stringent erosion control measures that ensure a sustained use of the land. It was calculated by using the SLEMSA model (Ellwell, 1980) that under such circumstances erosion would be reduced to acceptable limits. Within the areas recommended for the below land use, local conditions concerning possibilities for mechanization vary and like crops have been included in the evaluation of individual land units.

Land utilization type 3:

Improved, semi-permanent arable farming or mixed farming with 65% of the years grass leys. Arable farming component for commercial and subsistence production, using improved cultivars, chemical fertilizer and some chemical pest and disease control. Manner of weeding dependant on degree of mechanization. Complete and very intensive physical conservation measures required including storm water drains and cultivation on big ridges (> 20 cm), with grades flatter than 1% and with tie ridges. Main purposes of grass leys regarding land management concern erosion control as well as restoration of fertility, in particular nitrogen, and to increase soil nutrient retention capacity. Power resources vary with land conditions. The areas concerned are to be occupied for above use only if high level of management in relation to erosion is ensured and if economical feasible. Other-
wise low intensity shifting cultivation is only recommended arable land use applicable on a sustained basis. Alternatively to be considered for plantation forestry.
"Logic is the tool that is used to dig holes deeper and bigger to make them altogether better holes. But if the hole is in the wrong place, then no amount of improvement is going to put it in the right place. No matter how obvious this may seem to every digger, it is still easier to go on digging in the same hole than to start all over again in a new place. Vertical thinking is digging the same hole deeper; lateral thinking is trying again elsewhere.' de Bono (1972).

This chapter covers the second main component of land evaluation, the land. By means of basic land resource surveys the region covered by the evaluation is divided into relatively homogenous areas, the land units. Land units have a number of complex attributes which affect land uses in a specific manner, termed land qualities; and a very much larger number of properties which can be measured or estimated, and employed to describe the land qualities, termed land characteristics. Below the above terminology is further explained.

5.1 Land Resources Survey

Land resources surveys consist basically of data gathering on land characteristics. Data gathering on climate is separated from other land attributes and is limited to a desk exercise on the basis of historical records from the meteorological services. Mapping of climate however, may still be improved, for example by using vegetation phenological zones as determined by field survey. The survey of other land attributes like geomorphology, soils and vegetation requires fieldwork with varying degree of detail (see Chapter 3). The fieldwork consists of stratified sampling of land units, (for definition see below), previously delimitated by aerial photo and/or satellite image interpretation. After the fieldwork these are re-interpreted to obtain the final map and legend.

In order to ensure consistency in field observations, a data sheet is required which is filled at each sampling point. The data sheet presently in use and designed by the author (1982) is presented in Appendix A. An additional sheet is available for complete vegetation releves at the sampling site where each species and its cover/abundance is recorded. A preliminary guide for filling the data sheet is available and a more comprehensive version 'the field manual' is in preparation, together with a revised data sheet.

5.2 Land, Land Units and Landscapes

Land is a broad, holistic concept of the surface of the earth in natural science and the object of study in land resource survey. Its use (in language) commonly involves specific surface areas and land as such is a geographical concept. The best definition of land is one which involves the geographical aspects of a "tract of land" and reads: "A tract of land is defined geographically as a specific area of the earth's surface: its characteristics embrace all reasonably stable, or predictably cycle attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying rocks, the topography, the hydrology, the plant and animal populations and the result of past and present human activity.
to the extent that these attributes exert a significant influence on present and future uses of the land by man." (Adapted from Vink, 1975, Brinkman and Smyth, 1973, and Christian and Stewart in Rey et al., 1968).

A land unit* is the basic unit of evaluation, which requires uniformity for all practical purposes throughout its extent. On Basement Complex land units are typically the individual members of a soil catena. These require over most of its extent similar management practices to obtain a certain crop yield (land management unit).

A land mapping unit is each holistically defined unit of land, which has been depicted separately on the map. As such it may comprise one, two or more land units which are evaluated separately but for reasons of convenience of mapping at a determined scale are put together (e.g. intricate pattern of different alluvial soils). Thus, the degree of homogeneity of the land mapping unit is determined by the scale of the map.

Common map scales are 1:50 000 for semi-detailed surveys and 1:250 000 for reconnaissance surveys. At 1:50 000 most of the land mapping units consist of land units. At 1:250 000 only land units of large extent can be shown on the map individually. Usually an aggregation of individual land units into landscapes is necessary for mapping purposes. A landscape is defined as a typical and recurrent pattern of land units which are geographically and genetically related.

At a still higher hierarchical level, landscapes may be grouped into major landscapes, based for instance on geological patterns. Even broader defined units may be called ecological regions, e.g. based on climatic and vegetation zones. Obviously even such kind of broadly defined zones should have some common features as regards to other land attributes when considering land a holistic concept.

An example of maps showing the above land mapping units as depending on scale is presented in Fig. 5.1.

* Please note that the given definition of land unit differs from the FAO guidelines (1983), where land unit is used in the sense of land mapping unit.
Fig: 5.1 LAND MAPPING UNITS AT VARIOUS MAPPING SCALES AND DETAIL OF DEFINITION

Source: VOORTMAN and SPIERS, 1985
5.3 Land Qualities and Land Characteristics

'Land qualities and land characteristics are properties of the land units.

A land quality is an attribute of the land which acts in a distinct manner in its influence on the suitability of the land for a specific kind of use. Examples of land qualities that are widely applicable to rainfed cropping are temperature regime, moisture availability, drainage, nutrient supply, rooting conditions, potential for mechanization, and erosion hazard.

A land characteristic is an attribute of land that can be measured or estimated and which can be employed as means of describing land qualities or distinguishing between land units. Examples of land characteristics are mean annual rainfall, slope angle, soil drainage class, effective depth, topsoil texture, soil available water holding capacity, pH, and soil nitrogen percentage.

Land qualities are properties of the land, but an essential feature is that they influence land use in a particular manner. In contrast, many land characteristics influence suitability in several different ways, and thus influence several land qualities'.

In conformity with the 'Framework' (FAO, 1976) the present land evaluation system is based on the use of land qualities.

5.4 Time Requirements for Land Resource Surveys

At the initial consultations, it is important to assess the duration of a survey and evaluation. As a guideline, a time schedule presented by Christian and Stewart (1968) is given below. The time schedule has been derived from reconnaissance land system surveys in Australia and is valid for regional reconnaissance land resources surveys executed by a team of about three persons.

- phase 1 pre-fieldwork, collecting of information, aerial photo-interpretation, planning of fieldwork 3 months
- phase 2 fieldwork 3 months
- phase 3 final air photo interpretation 3 months
- phase 4 specialist evaluation of field data and coordination of description of mapping units 3-4 months
- phase 5 preparation of report 4-5 months

Thus, a well planned and intensive fieldwork of 3-4 months can be completed in two years including the final report, allowing some time for logistical problems, holidays and a limited amount of other activities (e.g. training). For surveys with a different scope or fieldwork period a proportional estimate can be obtained from the above time schedule.
6 LAND USE REQUIREMENTS

6.1 General Considerations

Once the land utilization types have been defined, the associated land use requirements need to be identified. Such requirements are defined land quality specific and include the definition of optimal conditions (without limitations for production) for the land utilization types and varying degrees of sub-optimal conditions where yields are likely to be affected.

Possibly, the lack of quantitative information on land use requirements remains the weakest point of land evaluation today. At present only the influence of a few land characteristics on crop yield are well established e.g. salinity, pH. Further, only general trends of the influence of individual land qualities/characteristics on crop yield or cost of production are well identified. However, a practical requirement for quantitative ecological land evaluation is that the range of values of a land characteristic can be subdivided in classes which have a known effect on yield e.g. 5 classes where class one implies that 80-100% of the maximum genetic yield can be obtained, class 2 implies that 60-80% of the maximum can be obtained, etc. Thereafter the various land characteristics which constitute a land quality have to be scored in a similar manner. This is still a hazardous exercise and most evaluations can not claim to be more than semi-quantitative.

The obvious solution to the above is to obtain crop yield data under known management circumstances together with soil and climatic observations and analysis from the same spot. This is a tedious job and requires several years of work before being meaningful. Moreover, the analysis of the influence of individual land qualities/characteristics on crop yield is very difficult, due to the multivariate environment in which the crop grows (cf. Radcliffe, 1982). Where comprehensive sets of yield data are available the evaluator might as well convert yields obtained from different land units directly into suitability classes (when the aim of evaluation is to assess productivity levels under existing types of management). Where yield data are scarce interpolation can be used but it still depends on the experience, insight and honesty of the evaluator what yield ranges are attributed to the different land units.

The land use requirements are implicitly taken into account in the land quality rating system (Chapter 7) and therefore not presented separately here. Below some general observations on land use requirements and the presented land quality rating scheme based on them, will be described.

6.2 The Approach Towards Defining Land Use Requirements

Optimum soil conditions for sustained production, under good management of high crop yields defined in a general manner i.e. not crops specific are easily defined. There is general agreement that good soils can be summarized as 'deep freely drained, medium to moderately heavy textured soil, well structured, with adequate organic matter and some weatherable minerals within rooting depth' (Young, 1976).
However, not only has each crop its own specific requirements, they also differ in their tolerance to sub-optimal conditions. In literature, many sources can be found which describe crop requirements in terms of optimal and sub-optimal conditions. From these, general trends can be derived but evaluation criteria often differ and no authoritative source is available. A further problem with existing literature is that a number of publications show fairly similar criteria often without indicating the source. Thus it is possible that these are basically derived from the same publications.

More advanced, at present, is the evaluation of land qualities related to climate. In 1978, FAO presented the methodology of the Agro-ecological zones project, which permits the quantitative evaluation of climate in terms of crop yield. The model is based on the physical laws of nature and a broad body of knowledge on crop climatic requirements. Potential crop production is calculated from the duration of the growing period i.e. the period with sufficient moisture available to sustain crop growth. In addition the effect of temperature on crop yield is assessed. The calculation of agro-climatic yield potential includes reduction in yield due to agro-climatic constraints related to the length of the growing period:

- quality and variability of moisture supply during the growing period
- occurrence of pests and diseases
- constraints to workability and efficiency of farming operations.

The above climatic evaluation has been chosen as the backbone of the present land evaluation system.

As stated above, for the soil related land qualities various difficulties were encountered when trying to design a proper land quality rating scheme based on land requirements. Two examples of such problems will be briefly treated below.

In literature it is often found that the total possible range of values of a land quality/characteristic are subdivided arbitrarily irrespective of crop requirements. For example it occurs that 'available phosphorous' in the class 'high' is rated 2 and 'very high' rated 1, whereas based on crop requirements and crop response to fertilizer the values of available phosphorus in both classes would not limit crop production. Thus such systems tend to evaluate in a very negative manner which can not be justified.

Another example is also derived from the evaluation of nutrient availability. On Basement Complex soils in Northern Mozambique, with no other major soil limitations than fertility and with good climatic conditions maize yields under good traditional management (no inputs) are still in the order of 600 kg/ha. Thus, based on fertility alone, a class of 'not suitable' could not occur when defining 'not suitable' as less than 20% of the maximum attainable yield under such management circumstances i.e. 1.8 t/ha.
The above kind of considerations have been used when matching land quality ratings as presented in literature with the experience of the author from the Basement Complex of Mozambique. Consequently in most cases first the most relevant rating scheme was selected from literature and then adapted for the present purpose. Some of the land quality ratings include new elements and some are altogether different from existing ones. Sometimes the presented ratings may seem to be optimistic, but it is thought that these ratings possibly reflect better the influence of individual land qualities on crop yield.
LAND QUALITIES AND THEIR ASSESSMENT

"If all else fails, follow the instructions"
Confucius (?)

The present chapter describes the rating system of the land qualities judged to be relevant for Basement Complex conditions in Mozambique. Further, a justification for the omission of other land qualities is presented.

The format of description of the individual land qualities is adapted from the FAO Guidelines (1983). Each quality is treated under the following headings:

- diagnostic land characteristics
- application to evaluations
- nature and effects
- land use requirements
- assessment
- survey of diagnostic land characteristics

7.1 The selection of relevant land qualities

Table 7.1 presents a list of land qualities that may affect land suitability for rainfed crop production. Land qualities 1-15 are related primarily, although not exclusively, to crop requirements, qualities 16-23 are primarily related to management requirements and 24 and 25 cover conservation requirements.

From these, the following are judged to be most relevant for rainfed arable farming on Basement Complex:

- LQ I: Temperature regime
- LQ II: Moisture availability
- LQ III: Oxygen availability to roots
- LQ IV: Nutrient availability
- LQ V: Nutrient retention capacity
- LQ VI: Rooting conditions
- LQ VII: Soil workability
- LQ VIII: Potential for mechanization
- LQ IX: Erosion hazard
<table>
<thead>
<tr>
<th>Reference No.</th>
<th>Land Quality</th>
<th>Subdivision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Radiation regime</td>
<td>Total radiation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day length</td>
</tr>
<tr>
<td>2</td>
<td>Temperature regime</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Moisture Availability</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Oxygen Availability to Roots (Drainage Conditions)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Nutrient Availability</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Nutrient Retention Capacity</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Rooting Conditions</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Conditions Affecting Germination or Establishment</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Air Humidity as Affecting Growth</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Conditions for Ripening</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Flood Hazard</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Climatic Hazards:</td>
<td>Frost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Storm</td>
</tr>
<tr>
<td>13</td>
<td>Excess of Salts</td>
<td>Salinity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sodicity</td>
</tr>
<tr>
<td>14</td>
<td>Soil Toxicities</td>
<td>Aluminium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calcium Carbonate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gypsum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manganese</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acid Sulphate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
</tr>
<tr>
<td>15</td>
<td>Pests and Diseases</td>
<td>Pests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diseases</td>
</tr>
<tr>
<td>16</td>
<td>Soil Workability</td>
<td>Land Preparation</td>
</tr>
<tr>
<td>17</td>
<td>Potential for Mechanization</td>
<td>Vegetation Clearance</td>
</tr>
<tr>
<td>18</td>
<td>Conditions for Land Preparation or Clearance</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Conditions for Storage and Processing</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Conditions affecting timing of production</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Access within the production unit</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Size of potential management units</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Location</td>
<td>Existing accessibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential accessibility</td>
</tr>
<tr>
<td>24</td>
<td>Erosion hazard</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Soil degradation hazard</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.1 Land qualities for rainfed agriculture
Source: FAO, 1983
An other important quality that could be considered is 'the duration of restoration of soil fertility under fallow'. This property of the land possibly has the greatest bearing on the terrain choice of the peasant farmer. However, insufficient knowledge on this subject impedes the elaboration of an adequate evaluation system.

It has therefore been suggested (Chap. 4) to use the soil type of the FAO classification and the levels of inputs of land utilization types to assess what the proper cultivation factor (R) could be for the land under consideration. This then should be included in the definition of the land utilization types relevant to the area, but in fact also constitutes an evaluation.

7.2 The Land Quality Rating System

The land quality rating system has preferably as many classes as the final land suitability classification. The latter classification has been selected in conformity with the land suitability assessment of the national agro-ecological zones inventory and assessment (Kassam et al, 1982), and comprises five suitability classes:

- very suitable - 80 - 100% of maximum possible yield
- suitable - 60 - 80% " " " "
- moderately suitable - 40 - 60% " " " "
- marginally suitable - 20 - 40% " " " "
- not suitable - 0 - 20% " " " "

Thus five land quality ratings have been used which are indicated with S1, S2, S3, S4 and N respectively. S1 implies that the land unit under evaluation for a certain land utilization type would be very suitable if one could consider one land quality alone for suitability assessment. S2 corresponds to 'suitable', etc.

In addition, the above designations may be given a suffix 'b', where land qualities or land characteristics classify for a certain S-rating, but are very close to the limit of a lower rating. This makes the evaluation system more flexible and allows to assess properly those land units where the rating of several land qualities is close to a lower rating class, in which case land suitability may have to be downgraded, or differentiated as a subclass from 'normal' suitability in the same class.

7.3 The Land Evaluation Data Sheet

The land evaluation data sheet (see next page) has been designed in order to ensure that the following land evaluation rules are applied systematically. It allows in one page a full documentation of one land unit from the values of the individual land characteristics to their integration into land quality ratings and from there to the land suitability classification.

On the left-hand part of the data sheet the diagnostic land characteristics and partially their ratings are to be filled. How to fill the data-sheet, rate individual land characteristics and the rating of land qualities is explained in this chapter under each land quality separately. The second copy of the data sheet indicates to which land quality the different parts of the data sheet refer. The integration of land qualities
LAND EVALUATION DATA SHEET

DIAGNOSTIC LAND CHARACTERISTICS

<table>
<thead>
<tr>
<th>LGP:</th>
<th>PATTERN:</th>
<th>OBS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(AL) T:</td>
<td>SOIL TYPE:</td>
<td></td>
</tr>
<tr>
<td>P/I/E/T:</td>
<td>SOIL DRAIN. CL:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEPTH</th>
<th>% N</th>
<th>P</th>
<th>TEB</th>
<th>Ca/Mg</th>
<th>Mg/K</th>
<th>pH</th>
<th>OBS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RATING

<table>
<thead>
<tr>
<th>DEPTH</th>
<th>TEXT.</th>
<th>CONSIST.</th>
<th>STRUCTURE</th>
<th>% GRAVEL STONES</th>
<th>OBS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOPSOIL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUBS. 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUBS. 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SLOPE %:</th>
<th>WORKAB. R</th>
<th>MECHAN. R</th>
<th>OBS.</th>
<th>OBS. ROOTING LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAVEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STONES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROCKS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EFF. DEPTH</th>
<th>RAINF:</th>
<th>ENERGY:</th>
<th>LAND USE / COVER:</th>
<th>MECHANIZATION</th>
<th>HEAVY:</th>
<th>LIGHT:</th>
<th>WORKABILITY:</th>
<th>NUTRIENT RETENTION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>R LOW:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R INT:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R HIGH:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R LV:</th>
<th>SUMMARY / RECOMMENDED LAND USE:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PAST EROSION</th>
<th>R LOW:</th>
<th>SUMMARY / RECOMMENDED LAND USE:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SUFACE FEATURES</th>
<th>R LV:</th>
<th>SUMMARY / RECOMMENDED LAND USE:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| RLV 4/85 | PED 85057 |
## LAND EVALUATION DATA SHEET

### Diagnostic Land Characteristics

<table>
<thead>
<tr>
<th>LGP:</th>
<th>LQII</th>
<th>Pattern:</th>
<th>LQII</th>
<th>OBS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(AL) T:</td>
<td>LQI</td>
<td>Soil Type:</td>
<td>LQII</td>
<td></td>
</tr>
<tr>
<td>Project:</td>
<td>LQII</td>
<td>Soil Drain. CL:</td>
<td>LQII and LQIII</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth</th>
<th>% N</th>
<th>P</th>
<th>TEB</th>
<th>Ca/Mg</th>
<th>Mg/K</th>
<th>pH</th>
<th>OBS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td></td>
<td></td>
<td>LQIV</td>
<td>and</td>
<td>LQV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Rating

<table>
<thead>
<tr>
<th>Depth</th>
<th>Text.</th>
<th>Consist.</th>
<th>Structure</th>
<th>% Gravel</th>
<th>Stones</th>
<th>OBS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil</td>
<td>LQVII and LQVIII</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subs. 1</td>
<td>LQVI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subs. 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Slope %:

<table>
<thead>
<tr>
<th>LQVIII and LQIX</th>
<th>Gravel</th>
<th>Workab. R</th>
<th>Mechan. R</th>
<th>OBS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>LQIX</td>
<td>LQVII</td>
<td>LQVIII</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Eff. Depth

<table>
<thead>
<tr>
<th>LQVI</th>
<th>Stones</th>
<th>Workab. R</th>
<th>Mechan. R</th>
<th>OBS:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LQVII</td>
<td>LQVIII</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rocks</th>
<th>LQVII</th>
</tr>
</thead>
</table>

### Rainfall

<table>
<thead>
<tr>
<th>FAO Soil Type + Text:</th>
<th>ABR Arg</th>
<th>LQIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>LQIX</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Erosion Hazard

<table>
<thead>
<tr>
<th>Lms 1:</th>
<th>LQIX</th>
<th>Lms 2:</th>
<th>LQIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lms 4:</td>
<td>LQIX</td>
<td>Lms 5:</td>
<td>LQIX</td>
</tr>
<tr>
<td>Lms 6:</td>
<td>LQIX</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Land Use / Cover

<table>
<thead>
<tr>
<th>Land Use / Cover:</th>
<th>LQVII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary / Recommended Land Use:</td>
<td>LQV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workability:</th>
<th>LQVII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient Retention:</td>
<td>LQV</td>
</tr>
</tbody>
</table>

### Past Erosion

<table>
<thead>
<tr>
<th>Past Erosion</th>
<th>LQIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>R Low:</td>
<td></td>
</tr>
<tr>
<td>R Int:</td>
<td></td>
</tr>
<tr>
<td>R High:</td>
<td></td>
</tr>
</tbody>
</table>
into a land suitability classification is explained in Chapter 8.

7.4 Land Quality I: Temperature Regime

Diagnostic land characteristic: monthly averages of mean daily temperature (°C) during the growing period.

Application to Evaluations

This land quality is essential for the assessment of crop production potential in any land evaluation study. In local and some regional studies the temperature regime may be considered background information, since it does not constitute a differentiating factor within the area under consideration. Each land unit is then attributed the same rating for temperature regime. In other regional surveys the temperature regime may be a main differentiating factor, particularly in areas, which include zones of altitudes above 1 000 m. Here indeed recommended cropping pattern may largely depend on the prevailing temperature regime.

Nature and Effects

Crops are divided in five adaptability groups on the basis of the photosynthetic carbon assimilation pathway and responses of photosynthesis to radiation and temperature. Between the minimum temperature for growth and the optimum temperature for photosynthesis, the rate of growth rises more or less linearly with temperature; growth rate then reaches a plateau within the optimum temperature range before falling off at higher temperatures. This relationship interacts with radiation; that is, the highest potential for growth is achieved with temperature in the optimal range and high amounts of radiation. (2).

In Mozambique, the main effect of temperature on crop production is that the rate of plant growth varies with temperature. Very high temperatures ( > 35-40°C) which have adverse effects on the rate of growth, and very low temperatures ( < 6.5°C) at which growth ceases do not occur in significant extent during the period of the year, when moisture availability permits rainfed crop production. Also, radiation is not limiting crop production during this period.

Land Use Requirements

Land use requirements for temperature regime can be defined in terms of the above described optimum range for maximum production and in addition, in terms of operative range i.e. the limits within which photosynthesis will take place, though at a limited rate. The crop adaptability groups, their optimum and operative temperature ranges are presented in Table 7.2.
<table>
<thead>
<tr>
<th>Crop Groups</th>
<th>Photo synthesis pathway</th>
<th>Optimum temperat. °C</th>
<th>Operat. range °C</th>
<th>Crops*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>C3</td>
<td>15 - 20</td>
<td>5 - 30</td>
<td>potato, chickpea, phaseolus bean (TEC), sunflower (TEC), barley, wheat, arabica, coffee.</td>
</tr>
<tr>
<td>II</td>
<td>C3</td>
<td>25 - 30</td>
<td>10 - 35</td>
<td>groundnut, cowpea, soybean pigeonpea, phaseolus bean (TRC), tobacco, sunflower (TRC), sesame, rice, cotton, sweet potato, cassava, citrus, robusta coffee, banana, coconut</td>
</tr>
<tr>
<td>III</td>
<td>C4</td>
<td>30 - 35</td>
<td>15 - 45</td>
<td>maize (TRC), sorghum (TRC), pearl millet, sugarcane</td>
</tr>
<tr>
<td>IV</td>
<td>C4</td>
<td>20 - 30</td>
<td>10 - 35</td>
<td>maize (TEC), sorghum (TEC)</td>
</tr>
<tr>
<td>V</td>
<td>CAM</td>
<td>25 - 35</td>
<td>10 - 45</td>
<td>sisal, pineapple</td>
</tr>
</tbody>
</table>

Table 7.2 Crop adaptability groups.
Source: FAO, 1978

*TRC = Tropical cultivar; TEC= Temperature cultivar
Assessment

The temperature regime is assessed by using Table 7.3: 'Temperature regime ratings'. In this table ratings are provided for thermal zones with a standard 2.5°C interval. These ratings are easy to apply where the length of the growing period (cf. LQ II) does not exceed 150-180 days, whereas variation in monthly temperature averages from November to April (the growing period) is slight. If thermal zones could not be mapped according to the class limits of Table 7.3, then a rating can be obtained by interpolation.

Special attention should be given to areas with extended growing period durations, where the growing period contains a moderately warm (Wm) part and a moderately cool (Cm) part (for their definition see table 7.4). Most short duration tropical crops (< 120 days) will not be affected where the Wm part is still 150 days or more. However, tropical crops (Group II and III) are likely to suffer yield decrease due to the low temperatures at the end of their growth cycle if this period is shorter. In such cases the longer moderately cool part may permit the growth of temperate crops.

Thus rating should be done carefully considering the growth cycle of the crop to be evaluated, its yield formation period and the proportion of the Wm and Cm parts within the growing period. In summary: the temperature regime rating for short duration crops depends on the range of temperatures during the months the crop will be on the field and not the range of the whole growing period.

The rating for perennial crops and cassava depends on the temperature range of the whole growing period.

An example of how the rating of thermal zones can be achieved is presented in table 7.4. The generalized thermal zone map of Mozambique is presented in figure 7.1.
<table>
<thead>
<tr>
<th>CROP</th>
<th>THERMAL CHARACTER OF GROWING PERIOD (°C)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 25</td>
</tr>
<tr>
<td>PEARL MILLET</td>
<td>S1</td>
</tr>
<tr>
<td>SORGHUM (LOWL)</td>
<td>S1</td>
</tr>
<tr>
<td>SORGHUM (HIGHL)</td>
<td>N</td>
</tr>
<tr>
<td>MAIZE (LOWL)</td>
<td>S1</td>
</tr>
<tr>
<td>MAIZE (HIGHL)</td>
<td>N</td>
</tr>
<tr>
<td>WHEAT</td>
<td>N</td>
</tr>
<tr>
<td>BARLEY</td>
<td>N</td>
</tr>
<tr>
<td>RICE</td>
<td>S1</td>
</tr>
<tr>
<td>PHASEOLUS BEAN (PHAS-VULGARIS)</td>
<td>N/S3</td>
</tr>
<tr>
<td>GREEAN GRAM (PH.AUR)</td>
<td>S1</td>
</tr>
<tr>
<td>GROUNDNUT</td>
<td>S1</td>
</tr>
<tr>
<td>SOYBEAN</td>
<td>S1</td>
</tr>
<tr>
<td>COWPEA</td>
<td>S1</td>
</tr>
<tr>
<td>PIGEON PEA</td>
<td>S1</td>
</tr>
<tr>
<td>SWEET POTATO</td>
<td>S1</td>
</tr>
<tr>
<td>WHITE POTATO</td>
<td>N</td>
</tr>
<tr>
<td>CASSAVA</td>
<td>S1</td>
</tr>
<tr>
<td>SUGAR CANE</td>
<td>S1</td>
</tr>
<tr>
<td>SUNFLOWER</td>
<td>S1</td>
</tr>
<tr>
<td>SESAME</td>
<td>S1</td>
</tr>
<tr>
<td>TEA</td>
<td>N</td>
</tr>
<tr>
<td>COFFEE ARABICA</td>
<td>N</td>
</tr>
<tr>
<td>COFFEE ROBUSTA</td>
<td>S2</td>
</tr>
<tr>
<td>TOBACCO</td>
<td>S1</td>
</tr>
<tr>
<td>COTTON</td>
<td>S1</td>
</tr>
</tbody>
</table>

Table 7.3 Temperature regime ratings
Source: A.H. Kassam and H.T. van Velthuizen; unpublished
* mean daily temperature
### Table 7.4 Example of crop suitability ratings by thermal zone

Source: Kassam et al, 1982

<table>
<thead>
<tr>
<th>Crop</th>
<th>Thermal Zones*</th>
<th>W</th>
<th>Wm</th>
<th>Wm-Cm</th>
<th>Cm-Wm</th>
<th>Cm</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize (lowland)</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Maize (highland)</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S1</td>
<td>S1</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Sorghum (lowland)</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Sorghum (highland)</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S1</td>
<td>S1</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>S1</td>
<td>S1</td>
<td>S2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>N</td>
<td>N</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S3</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Groundnut</td>
<td>S1</td>
<td>S1</td>
<td>S2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td>S1</td>
<td>S1</td>
<td>S2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>S1</td>
<td>S1</td>
<td>S3</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

**Code**

<table>
<thead>
<tr>
<th>Description</th>
<th>Growing period temperatures(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Warm</td>
</tr>
<tr>
<td>Wm</td>
<td>Moderately Warm</td>
</tr>
<tr>
<td>Wm-Cm</td>
<td>Moderately Warm and Moderately Cool</td>
</tr>
<tr>
<td>Cm-Wm</td>
<td>Moderately Cool and Moderately Warm</td>
</tr>
<tr>
<td>Cm</td>
<td>Moderately Cool</td>
</tr>
<tr>
<td>C</td>
<td>Cool</td>
</tr>
</tbody>
</table>
Fig: Thermal zones (generalized)

LEGEND

- W
- WM
- WM-CM
- CM

Source: Kassam et al., 1982

Escala: 1:3,000,000

Distancia: 150 320 620 km
Survey of Diagnostic Land Characteristics

A first impression of temperature regime can be obtained from the national climatic resources inventory map at scale 1:2 million (Kassam et al. 1982). For regional and local surveys in which a higher level of detail is required, this can be obtained in the following manner:

1) determine the average beginning and end of the growing period (cf. LQ II).
2) take the mean monthly values of neighbouring meteorological stations with similar environmental conditions from the national climatic data bank (e.g. don't mix coastal and non-coastal stations).
3) establish for each month regression formulas of altitude and temperature and based on these,
4) calculate the mean monthly temperatures for the altitudes of the area under consideration for each 100 m interval
5) establish the growing period temperature as depending on altitude and the beginning and the end of the growing period
6) for extended growing periods quantify the duration and temperature regime for the Wm and Cm parts.
7.5. Land Quality II: Moisture Availability

7.5.1 Diagnostic Land Characteristics
- Length of the reference growing period
- the ratio of the precipitation over potential evapotranspiration (P/PET) during the growing period
- soil type and texture
- soil drainage class

7.5.2 Application to Evaluations

The utilization of this land quality is essential to any rainfed land suitability assessment in Mozambique, since moisture supply is often the most critical factor determining crop production. As with temperature regime, the first two of the above diagnostic land characteristics can form background information of the survey area or constitute a differentiating factor. Soil type, texture and soil drainage class normally vary within short distances. Moisture availability is evaluated crop-specific and by level of inputs/management.

7.5.3 Nature and Effects

1 Growing Period Duration

Plants have an obligatory development pattern in time, which must be met if the photosynthetic assimilates are to be converted into economically useful yields of satisfactory quantity and quality. Satisfactory yields can only be obtained when sufficient moisture is available during a time period, which is equal to or longer than the growth cycle of the crop or variety under consideration.

The period of the year during which sufficient moisture is available can be quantified using the concept of the growing period (FAO, 1978; Cochemé, 1968). The growing period is defined as the period (in days) during the year when precipitation exceeds half the potential evapotranspiration, plus a period required to evapotranspire up to 100 mm of water from excess precipitation (if available) stored in the soil profile. Thus, the reference growing period is defined, irrespective of landform and soil conditions.

If the length of the growing period is limited and does not match the growth cycle of the crop/variety, then reduction of yield and quality occur, because the time available for yield forming activities is curtailed. Also, the growing period can be too long from the agronomic point of view. If humid conditions still prevail, when the crop has completed its growth cycle, then mechanized harvesting is hindered, drying and storage conditions are poor, increased incidence of pests and diseases reduces yield and its quality and the quality of the yield may be directly affected by rain (e.g., cotton, tobacco). Hence, high yields of good quality can only be obtained in a limited range of length of growing period.
The analysis and assessment of the length of the reference growing period is complicated by the fact that the total growing period in one year may be a sum of two or more growing periods separated in time. This has been described as the 'pattern' of the growing period (Kassam et al, 1982) and in fact the pattern quantifies the occurrence of dry spells during the rainy season. It implies that a crop is forced to ripen off due to moisture stress, whereas later in the year again sufficient moisture is available to sustain crop growth. In most cases the second and/or third growing period in a year are of fairly short duration and therefore omitted from evaluation. In some cases a crop could be grown successfully but often a farmer could not have foreseen such a second period.

The reference growing period length and the pattern are depicted in a generalized manner in Fig. 7.2 a and b respectively. Please note that on the national climatic resources inventory map the sum of the lengths of the growing period is depicted for those areas where in most years more than one growing period occur.

The growing period defined in a reference manner does not always fully reflect the moisture availability which the plant encounters. This is further determined by the actual available waterholding capacity (AWC) of the soil and also the total amount and distribution of rainfall in relation to potential evapotranspiration.

The low waterholding capacity of coarse textured soils (+ 60 mm/m), firstly will decrease the length of the growing period if compared with the length of the reference growing period. Secondly, it will increase the likelihood of incidence of moisture stress, when dry spells occur, which are underestimated by using a standard 100 m storage capacity.

The probability of occurrence of moisture stress is further enhanced by low P/PET ratio's during the reference growing period. However, these poorer moisture availability conditions are only likely in watersheding upland'areas i.e. soils better drained than imperfectly. At water-receiving sites moisture supply conditions are improved by lateral groundwater inflow.

7.5.4 Land Use Requirements

Optimum land use requirements for length of the growing period and moisture conditions during the growing period differ from crop to crop. Below, for common crops, a summary is given, of common ranges of growth cycles for highly productive varieties as well as the degree of drought resistance of these crops. (Table 7.5)
FIG 7.2a: DURAÇÃO MÉDIA DO PERÍODO DE CRESCIMENTO EM DIAS POR ANO

180º - Isolinha da duração do período de crescimento

FONTE: Kassam et. al 1982
Escala: 1:8.000.000

INIA, Departamento Terra e Água
FIG 7.2b PADRÃO DO PERÍODO DE CRESCIMENTO

LEGENDA*

<table>
<thead>
<tr>
<th>1</th>
<th>Cada ano 1PC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2a</td>
<td>90% dos anos 1PC e 10% dos anos 2PCs</td>
</tr>
<tr>
<td>1-2b</td>
<td>75% dos anos 1PC e 25% dos anos 2PCs</td>
</tr>
<tr>
<td>1-2-3</td>
<td>60% dos anos 1PC, 30% dos anos 2PCs e 10% dos anos 2PCs</td>
</tr>
<tr>
<td>2-1-3</td>
<td>45% dos anos 2PCs, 30% dos anos 1PC e 25% dos anos 3PCs</td>
</tr>
<tr>
<td>2-3-1</td>
<td>55% dos anos 2PCs, 30% dos anos 3PCs e 15% dos anos 1PC</td>
</tr>
</tbody>
</table>

*PCs Período de Crescimento
<table>
<thead>
<tr>
<th>Crop*</th>
<th>Growth cycle (days)**</th>
<th>Drought resistance ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize (TRC)</td>
<td>90 - 120</td>
<td>low</td>
</tr>
<tr>
<td>Maize (TEC)</td>
<td>&gt; 120</td>
<td>low</td>
</tr>
<tr>
<td>Sorghum (TRC)</td>
<td>90 - 120</td>
<td>medium - high</td>
</tr>
<tr>
<td>Sorghum (TEC)</td>
<td>&gt; 120</td>
<td>medium - high</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>70 - 90</td>
<td>medium - high</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>100 - 130</td>
<td>medium - low</td>
</tr>
<tr>
<td>Upland rice</td>
<td>100 - 120</td>
<td>low</td>
</tr>
<tr>
<td>Phaseolus bean (dry grain)</td>
<td>90 - 120</td>
<td>medium - low</td>
</tr>
<tr>
<td>Soybean</td>
<td>90 - 120</td>
<td>medium</td>
</tr>
<tr>
<td>Groundnut</td>
<td>90 - 120</td>
<td>medium - high</td>
</tr>
<tr>
<td>Cassava</td>
<td>180 - 330</td>
<td>medium - high</td>
</tr>
<tr>
<td>Sweet Potato</td>
<td>120 - 150</td>
<td>medium</td>
</tr>
<tr>
<td>Potato</td>
<td>90 - 150</td>
<td>medium - low</td>
</tr>
<tr>
<td>Cotton</td>
<td>170 - 180</td>
<td>medium - high</td>
</tr>
</tbody>
</table>

Table 7.5: Growth cycle and drought resistance of common crops

* TRC=Tropical cultivar,  TEC=Temperature cultivar

** Source: FAO, 1978

*** Source: Adapted from Doorenbos and Kassam, 1979
(For further detail and other crops the reader is referred to the above two publications).

7.5.5 Assessment

The length of the reference growing period can be assessed in different manners depending on the level of detail required. The quickest assessment can be obtained from the 1:2 million climatic resources inventory map (a), where a mean growing period duration is presented which is derived from year by year analysis using monthly rainfall data. In regional surveys more detail may be required in particular in zones where the location of the meteorological stations used in the national inventory is biased towards big mountains in the surroundings e.g. most meteostations in Alto Zambezia are located in the
tea areas. In such cases the national climatic resources inventory map may require some adaptations which can be achieved by using the records of rainfall stations (b). The evaluation can be carried out year by year instead of based on average growing period length, but still using monthly data, if the year to year variability of yield is important (c). Where a high level of detail is required, the growing period can be analysed with 10-day rainfall figures (d). Below these four levels of analysis (a-d) are discussed.

a) Based on the national agro-ecological zones assessment programme.

This survey has dealt with the most important crops for Mozambique: maize, sorghum, millet, upland rice, wheat, phaseolus bean, cowpea, pigeon pea, green gram, soybean, groundnut, sweet potato, white potato, cassava, cotton and sugarcane.

The simplest method of evaluation consists of reading for the area concerned, the pattern and the length of the growing period from the climatic resources inventory. The climatic yield potential and climatic suitability class can be obtained by matching the above readings with the climatic suitability bar charts, produced for high and low level of input circumstances, by pattern, by length of growing period and by thermal zone (Kassam et al, 1982). Thus, thermal regime is implicitly evaluated in this case.

b) Revised mapping based on additional analysis

A more detailed approach consists of revised mapping of agro-climatic zones based on additional analysis of the length of the growing period and pattern for rainfall stations, not included in the national survey. In addition care may be taken of local conditions of relief, which may include rain shadow areas or increased orographic rainfall.

At the rainfall stations, as the name says, only rainfall is recorded. Thus, the necessary parameters to calculate PET are not available and this impedes the calculation of the length of the growing period. A best possible approximation of PET can be obtained by using the method of Frére and Popov (1979). Some of the missing parameters can be obtained from the tables presented herein. Others have to be estimated by analysing the values of neighbouring stations located in similar environmental conditions. Sometimes a simple correlation of altitude and evapotranspiration will give satisfactory results.

Normally first a mean annual rainfall map is produced which together with the altitude map is used as an aid in drawing length of growing period isolines. The mapping can be further supported by the study of correlations e.g. between altitude and mean annual rainfall and between mean annual rainfall and length of growing period. Again care should be taken not to
use mixed populations in the analysis. The pattern is analysed simultaneously with the length of the growing period. Mapping can further be aided by analysis of vegetation phenology by using landsat and NOAA satellite imagery. Once the revised length of growing period and pattern map is produced, the climatic suitability can be assessed (see 7.6).

c) Year by Year Evaluation

The above two evaluations (a, b) refer to the evaluation of the average length of the growing period, derived from a year by year analysis of the LGP. The evaluation may be carried out year by year, in detailed studies and/or for few selected crops or in cases where variability of yield is important. This implies that agro-climatic constraint 'a' should not be included in the evaluation (see Kassam et al, 1982). A yield curve has to be constructed based on potential yield (By) and applying only 'b, c and d' constraints. Then, for each year the agro-climatic yield can be read from the curve. This more detailed method can also include the assessment of yield reductions due to dry spells or extended first and/or second intermediate periods. The yield reductions can be quantified using the methodology presented in 'Yield response to water'. (Doorenbos and Kassam, 1979)

d) Detailed analysis using 10-day rainfall data

In detailed studies year by year assessment using 10-day rainfall records is recommended. Preferably such analysis also takes into account the measured available waterholding capacity of the different soil types of the area. Usually the analysis is hampered by the lack of meteorological stations near the study area resulting in similar problems as mentioned under 'b'. The evaluation of the above analysis requires the use of methods as presented in 'Yield response to water' (Doorenbos and Kassam, 1979).

ii Growing Period Pattern

The assessment of pattern is important only where average growing period lengths are evaluated. For method 'a' the assessment is readily available (Kassam et al, 1982) which is also used after revised mapping as described under 'b'. Sometimes, locally stations may show some deviation in pattern from the nationally mapped averages and it may be worthwhile to investigate if the climatic yield potential would be different when taking the exact pattern of these stations. This is done in the following manner.

Quantify the percentages of the years with one, two and three growing periods and for each of these groups of years calculate the average length of the growing period (s). Determine their yield potential separately and calculate the total average yield potential considering the percentage of occurrence of the groups of years with one, two and three growing period(s).
iii Edafic Factors in relation to climate

The quality of moisture supply during the reference growing period is used here as a modifier. Potential climatic yield is assessed with one of the above methods (see 7.6) and then converted into a rating (cf. Chapter 7.2)

This rating is modified according to soil type and texture, in relation to P/PET during the growing period, for upland soils better drained than imperfectly. The previous rating remains the same or is downgraded one or more classes according to Table 7.6. Downgrading is one class less than indicated for crops with a marked drought endurance and limited yield response to moisture stress, like: sorghum, millet, groundnuts, cassava and cotton.

<table>
<thead>
<tr>
<th>Average P/ET during G.P.</th>
<th>Sandy Soils</th>
<th>Medium to heavy soils with sandy topsoil and Ferralsols</th>
<th>Medium to heavy soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1.3-1.5</td>
<td>-1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1.0-1.3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>0.7-1.0</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
</tr>
<tr>
<td>0.5-0.7</td>
<td>-4</td>
<td>-3</td>
<td>-2</td>
</tr>
</tbody>
</table>

Table 7.6 Modification of moisture availability rating due to quality of moisture supply during the reference growing period.

- Note that sandy soils refer to sand and loamy sand, medium to heavy soils refer to sandy clayloam, sandy silt or clay. Except for topsoils, sandy loam and clayloam textures are rare on basement complex soils and soils with a high silt content do not occur.

- The average AWC for the broadly defined soil types is as follows (Ilaco 1981, van Wambke 1974):
  - sandy soils
  - medium to fine textured soils with a sandy topsoil
  - medium to fine textured soils
  - ferralsols

  \[\pm 60 \text{ mm/m}\]

  \[\pm 100 \text{ mm/m}\]

  \[\pm 140-180 \text{ mm/m}\]

  \[\pm 100 \text{ mm/m}\]
- Modifications may have to be made, if factors like effective depth and presence of coarse fragments limit availability of moisture to the crop. For annual crops and shallow rooting perennials these limitations are only considered if they occur within 1 m depth. For deep rooting perennials 1.5 m should be used.

- The rating scheme may require revision for arid conditions where heavy soils are sometimes more prone to drought than sandy soils and for soils with reduced infiltration like some 'Lurio Belt Soils'.

- Please note that this table replaces the standard yield reduction of 50% assumed in intermediate growing periods as utilized in the National Agro-Ecological zones assessment (Kassam et al, 1982).

7.5.6 Survey of Diagnostic Land Characteristics

The type of survey for LGP depends on the intended level of assessment as described under a-d in the previous section. In most cases the national climatic data base will supply sufficient information. If additional stations have to be analysed for LGP, one first has to calculate ET-Penman-AGP according to the method of Frere and Popov (FAO, 1979). Not all necessary data may be available for this, but a survey of the values of the different inputs of neighbouring stations will provide the best possible estimates. Various correlations can be carried out, like the relation between temperature and altitude, mentioned before.

The analysis of the length of the growing period is carried out for each year based on monthly values of precipitation and evapotranspiration (method a-c). The analysis can be executed by computer or by hand, using the graphical method and a electronic calculator. The latter is only necessary for the analysis of the carry-cover of available soil moisture from one month to the next. P/ET can also be taken from the national data bank or calculated if necessary. Texture, effective depth, coarse fragments, etc. are standardly recorded in land resources field survey.
Agro-climatic Yield Potential as Determined by LQI and LQII

Agro-climatic yield potential is determined by using the previously described land qualities "temperature regime" and "moisture availability" but disregarding the edaphic modifier (7.5.5 iii). The combined effect of the two land qualities is assessed in different manners depending on the level of detail required. Therefore, in the next paragraphs the integration of the two LQ's into climatic yield potential is discussed according to the four levels of detail of analysis (a-d) of the length of the growing period as described under 7.5.5.

a) For rapid assessments the national climatic resources inventory is used which includes length of growing period, pattern as well as thermal zones. The applicable evaluation of climatic yield potential presented in Kassam et al. (1982) is shown in bar-charts which present climatic suitability class and yield by length of growing period, by pattern and by thermal zone. Thus the integration of the two land qualities is already worked out in these bar-charts.

b) More detailed analysis may be aimed only at improving the cartography i.e. the spatial extent of mapping units. In this case the classes of pattern and thermal zones of the National inventory are maintained but mapped on the basis of additional analysis. In such cases the climatic yield potential can also be read from the bar-charts presented in Kassam et al. (1982).

Where revised mapping is executed with a different mapping legend for thermal zones and pattern, the land evaluator himself has to take care of the integration of both land qualities into climatic yield potential. Firstly pattern classes are to be established, which define in how many percent of the years there are either 1, 2 or 3 growing periods. Thereafter the mean length of the growing period for each group of years with 1, 2 or 3 growing periods is calculated. In case of two or more growing periods the average length of each individual period is established. The average possible yield is determined by considering the contribution to yield of each group of years with 1, 2 or 3 growing period separately and the individual growing periods in cases of more than one growing period per year. The bar-chart for pattern 1 of Kassam et al. (1982) is used for this purpose.

To assess potential climatic yield properly, due attention should be given to additional constraints for pest, diseases and workability in cases where the evaluated individual growing period is shorter than the total growing period per year (patterns 2 and 3). In addition the average occurrence of intermediate lengths of growing periods should be accounted for.

The obtained yield based on length of growing period and growing period pattern should be modified according to temperature regime. For temperature regime ratings S1, S2, S3, S4 and N the yield reduction to be applied is 0, 20, 40, 60 and 80% respectively. Alternatively the yield calculated on the basis of growing period length and pattern may be firstly converted into a rating. Thereafter the rating for agro-climatic yield is obtained by subtracting 0, 1, 2, 3 or 4 suitability classes for temperature regime ratings S1, S2, S3, S4 and N respectively.
c) In a year by year evaluation the agro-climatic yield potential is assessed as described in the above paragraphs, but for each year separately. Based on these yearly figures a mean agro-climatic yield can be established.

d) The more detailed analysis with 10-days rainfall data aims at a more detailed assessment of growing period pattern and length of growing period. The evaluation of climatic yield potential thereafter can be identical to what has been described under b or is executed by using methods as described by Doorenbos and Kassam (1979): Yield Response to Water.

The agro-climatic yield potential ratings for each crop under high and low level of inputs are filled in on the land evaluation data sheet. The edaphic modifier is indicated under 'moisture availability'.
7.7 Land Quality III: Oxygen availability to roots

Diagnostic land characteristic
- Soil drainage class

Application to evaluations
Oxygen availability to roots is one of the most important land qualities in any agricultural land evaluation study. The quality is applied crop specific and irrespective of management.

Nature and Effects
'With a few exceptions, notably rice, plants need to take in oxygen through their rooting systems, and suffer restricted growth and ultimately death if deprived of this. Since oxygen diffuses 10 000 times more quickly in soil air than in soil water, it is available above the water table and limited or absent below it'. (2) Generally speaking, the damaging effect on crops, i.e. yield reduction, by stagnating water on the soil and in the upper soil horizons (rooting zone) increases with its duration.

Land Use Requirements
For most crops land requirements for optimal conditions of oxygen availability are well and moderately well soil drainage classes. However, crops vary in their tolerance of short periods of waterlogging.

Assessment
By crop, the soil drainage class has been rated in Table 7.7. The presented ratings are largely based on Sys and Riquier (1980), where optimum drainage conditions and a range for each crop have been defined. This, and a number of other sources on crop requirements have been used to obtain a rating for each drainage class for each crop. For adequate assessment intermediate drainage classes e.g. moderately well to imperfect are judged to be necessary.

Survey of Diagnostic Characteristics
Soil drainage classes are described in terms of rapidity of water removal from the soil and length of periods during which the soil is wet (waterlogged). Drainage limitations can occur due to site drainage impedance i.e. the position of the soil unit in the terrain results in a high water table or to profile drainage impedance, where slowly permeable layers within the soil profile cause water to stagnate within certain parts of the profile.

The frequency and duration of periods when the soil is saturated with water are seldom accurately measured, but can be estimated from soil profile characteristics such as texture, structure, colour, mottling, quantity of organic matter and groundwater levels. However, many problems may arise for instance when colour and mottling do not reflect the present situation of drainage or both seem to be determined by parent material rather than drainage. Soil drainage class (together with structure and the presence of clay skins) is one of the most disputed characteristics when a group of land resources surveyors discuss a profile in the field. Indeed, it requires some experience for adequate assessment in the moderately well and imperfect range, which is critical for the suitability assessment of most crops.
The assessment of drainage conditions can be substantially improved when vegetation is studied alongside with soil profile characteristics. Various aspects of vegetation such as structure, species composition and the habit of individual species, are influenced by drainage conditions.
<table>
<thead>
<tr>
<th>Crop</th>
<th>E/SE/W/W-MW</th>
<th>MW</th>
<th>MW-I</th>
<th>I</th>
<th>I-P</th>
<th>P</th>
<th>P-VP/VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearl Millet</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3b</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Sorghum</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S2b</td>
<td>S3b</td>
<td>S4</td>
<td>N</td>
</tr>
<tr>
<td>Maize</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3b</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Wheat</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Upland Rice</td>
<td>S1</td>
<td>S1</td>
<td>S2</td>
<td>S2b</td>
<td>S3</td>
<td>S4</td>
<td>N</td>
</tr>
<tr>
<td>Phaseolus bean</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Groundnut</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Soybean</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Cowpea</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3b</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Pigeon Pea</td>
<td>S1</td>
<td>S1b</td>
<td>S2b</td>
<td>S3b</td>
<td>S4</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Sweet Potato</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>White Potato</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Cassava</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Sunflower</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Cotton</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Tobacco</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3b</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Banana</td>
<td>S1</td>
<td>S1b</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>S4b</td>
<td>N</td>
</tr>
<tr>
<td>Tea</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Coffee</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

Table 7.7 Ratings for oxygen availability/soil drainage class.

* E=Excessively drained
  SE=Somewhat excessively drained
  W=Well drained
  MW=Moderately well drained
  I=Imperfectly drained
  P=Poorly drained
  VP=Very poorly drained

(For definition of classes see FAO: Guidelines for soil profile description, 1977)

Intermediate classes are indicated by two drainage class codes connected with a hyphen e.g. W-MW.

Source: Reworked by RLV mainly based on Sys and Riquier (1980)
7.8 Land Quality IV: Nutrient Availability

Diagnostic Land Characteristics

Total N (%), available Phosphorus (ppm), total exchangeable bases, ratio Ca/Mg, ratio Mg/K, pH.

Application to evaluations

This land quality is important for low input farming where plant nutrients are entirely extracted from the nutrient reserve of the soil. Natural fertility is indeed one of the main factors governing site selection by the family sector, though sometimes overruled by workability constraints. This land quality is not applied to high input land utilization types (use LQ V), although of some importance in view of the cost of production (fertilizer). For intermediate levels of inputs both nutrient availability and nutrient retention need to be considered.

Nature and Effects

Like moisture, nutrients are essential to plant growth. Each nutrient needs to be available in sufficient quantity, but usually only one or two are limiting crop production (law of the minimum). Nutrients can also occur in excess and be toxic or limit the availability of other nutrients. Well known examples are Ca/Mg and Mg/K antagonisms and the influence of high Phosphorus content on Zinc availability. Further, nutrients may be present in sufficient quantities but in a form unavailable to the plant due to the tendency of the soil to fixation.

Land Use Requirements

Generally speaking optimal land conditions refer to a high and balanced nutrient status i.e. each of the major and secondary nutrients should be available in sufficient quantities so that they do not limit crop production. They should also occur in ratios to one another that one nutrient does not reduce excessively the availability of the other. Crops differ in their fertility requirements and a general subdivision in 'exacting' and 'non-exacting' crops is the following:

- exacting crops: wheat, cotton, banana, coffee, maize, sweet potato, white potato, phaseolus bean, soybean, groundnut.
- non-exacting crops: sorghum, pearl millet, upland rice, cassava, tea.

Specific requirements exist also for individual crops like low N, high K for flue-cured tobacco, however these have not been considered.

Assessment

Nutrient availability could be assessed using the soil analysis values of each individual plant nutrient. However only a limited number of plant nutrients are standardly analysed and although judged to be important (and sometimes crucial) in Basement Complex areas, microelements are not considered here.
The availability of primary and secondary nutrients (except sulphur) is assessed according to Table 7.8. The absolute value of Nitrogen, Phosphorus and Total Exchangeable Bases (TEB) is assessed together with cation ratios. These ratios themselves determine the availability of individual nutrients and together with TEB the absolute values of Ca, Mg and K are also evaluated. pH is further included, being an indicator of nutrient availability, although only occasionally a limiting factor on the Basement Complex of Mozambique.

Very shallow topsoils of less than 7 cm are ignored in the assessment. The values to be matched with Table 7.8 are to be taken from the following parts of the profile:

- total N: upper 30 cm
- available P: upper 30 cm
- TEB: range of values within 100 cm depth. This range of values usually falls within one class. Small deviations from the class limits of table 7.8 are ignored. If the range occupies the better part of two classes than the values which represent the upper part of the profile are taken.
- Ca/Mg and Mg/K: weighted average of all horizons within 100 cm depth. Thin or strongly deviating horizons are omitted. Often the exact calculation of the weighted average is not necessary, whereas the values of the individual horizons all belong to the same class.
- pH: the value of pH usually does not vary much with depth.

Where values are close to the limit of a lower class range value a suffix b has to be applied to the rating for exacting crops only.

**Overall rating** of nutrient availability is as follows:

Once the class ratings have been obtained for each of the 6 land characteristics of Table 7.8, take the lowest occurring class rating. If it occurs twice or more, then that class rating is the final one for the Land Quality. If, on the other hand, the lowest rating occurs only once, the end-rating for the Land Quality is then upgraded one class, unless the lowest value is for TEB and provided no more than one 'b' rating occurs in the upgraded class.

If 'b' ratings occur twice or more in the lowest class, the end-rating is downgraded one class.

**Examples:**

<table>
<thead>
<tr>
<th>Ratings for land characteristics</th>
<th>End-rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S3 S2 S3 S3 S1</td>
<td>S3</td>
</tr>
<tr>
<td>S1 S3 S2 S2 S1 S1</td>
<td>S2</td>
</tr>
<tr>
<td>S2b S2b S1 S3 S2 S1</td>
<td>S3</td>
</tr>
<tr>
<td>S1 S3b S2 S3b S1 S1</td>
<td>S4</td>
</tr>
</tbody>
</table>
The values of the land characteristics in the rating scheme have been selected in such a manner that with no other limitations and with a SI rating for nutrient availability, expected maize yields are in the 1.4-1.8 t/ha range under low input circumstances (equal to the class limits of the SI agro-climatic suitability class).

The cation ratio value ranges are fairly experimental and have been partly derived from literature* and partly from family sector maize yield data which were compared with the ratio values of soil pits located at the same spot. Further evidence of the importance of these ratios has been obtained from the behaviour of socio-ecological species groups of the vegetation (Voortman and Spiers, 1985). Some rooting problems may be evaluated, implicitly with these ratios since high relative Mg content usually implies poor physical properties in the subsoil. Distinction between the two effects is not yet possible.

Survey of Diagnostic Characteristics

The values of diagnostic characteristics are obtained from standard laboratory analysis of soil samples taken from the different horizons of soil profiles.

* (Anon, 1980; Dabin, 1956; Dugain, 1960; Forestier, 1964)
<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total N %</strong></td>
<td>&gt; 0.12</td>
<td>0.08-0.12</td>
<td>0.04-0.08</td>
<td>&lt; 0.04</td>
</tr>
<tr>
<td><strong>Available P ppm</strong></td>
<td>&gt; 10</td>
<td>5-9.9</td>
<td>&lt; 5</td>
<td>-</td>
</tr>
<tr>
<td><strong>TEB</strong></td>
<td>&gt; 7</td>
<td>5-7</td>
<td>3-5</td>
<td>&lt; 3</td>
</tr>
<tr>
<td><strong>Ca/Mg</strong></td>
<td>2.3-9.9</td>
<td>1.2-2.3</td>
<td>&lt; 1.2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>and</td>
<td>and</td>
<td>and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-24.9</td>
<td>&gt; 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mg/K</strong></td>
<td>2.0-4.4</td>
<td>1.0-1.9</td>
<td>&lt; 1.0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>and</td>
<td>and</td>
<td>and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.5-8.0</td>
<td>&gt; 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>5.5-7.5</td>
<td>5.2-5.5</td>
<td>4.5-5.2</td>
<td>&lt; 4.5</td>
</tr>
<tr>
<td></td>
<td>and</td>
<td>and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.5-8.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7.8 Ratings for nutrient availability

These ratings are applicable to data derived from the following methods of analysis:
- total N %: micro-Kjehldahl
- available P ppm: North Carolina
- Ca, Mg and K: Ammonium-acetate (1N, pH7)
- pH in H₂O
7.9  Land Quality V: Nutrient Retention Capacity

Diagnostic Land Characteristic

Total exchangeable bases (TEB) in meq/100 gram soil, of the rooting zone.

Application to Evaluation

This land quality should be applied in evaluations, which consider land utilization types, where fertilizer inputs are used for increased production. It is not applied for low input farming.

Nature and Effects

This quality refers to the capacity of the soil to retain added nutrients as against losses caused by leaching. Plant nutrients are held in the soil on exchange sites (cation and anion) which are provided largely by clay particles, organic matter or the clay-humus complex. Losses vary with intensity of leaching, as determined by the size of the moisture surplus coupled with the rate of movement of moisture through the soil. Leaching intensity may be reduced on low lying sites. Indirectly, soil texture affects nutrient retention in two ways, through its effects on exchange sites and permeability' (2).

An index for the amount of exchange sites is the Cation Exchange Capacity (CEC) of the soil, and Base Saturation (BS) provides an index of leaching intensity. Thus, the product of CEC and BS (expressed as a fraction), which is the total exchangeable bases (TEB), constitutes a convenient land characteristic for the evaluation of nutrient retention. It has the further advantage that TEB is not affected by the method of determination like CEC.

Land Use Requirements

Land use requirements for optimal conditions are a high TEB. However, intensive farming does not seem to be limited by nutrient retention on soils with a TEB higher than 7 meq (cf. Hill, 1978 Sanchez et al, 1982).

Assessment

Nutrient retention is assessed by using the range of TEB values within 100 cm depth and rated according to Table 7.9.

<table>
<thead>
<tr>
<th>TEB range</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 7</td>
<td>S1</td>
</tr>
<tr>
<td>5-7</td>
<td>S2</td>
</tr>
<tr>
<td>3-5</td>
<td>S3</td>
</tr>
<tr>
<td>1-3</td>
<td>S4</td>
</tr>
<tr>
<td>&lt; 1</td>
<td>N</td>
</tr>
</tbody>
</table>

Table 7.9: Ratings for nutrient retention capacity

* TEB values within 100 cm depth are used in the assessment.
Care should be taken as far as the TEB of the topsoil is concerned. The TEB of the topsoil may be considerably increased by the presence of organic matter, the quantity of which is strongly affected by management. Therefore the TEB of the lower horizons is preferred for evaluation purposes. However, the topsoil needs to be included in the assessment, when high organic matter levels in the topsoil seem to be an inherent property of the soil which is maintained even under semi-permanent cultivation (e.g. on Phaeozems).

Survey of Diagnostic Criteria

The TEB can be derived from the standard chemical analysis of the soils laboratory (extraction with Ammonium Acetate at pH 7).
7.10 Land Quality VI: Rooting Conditions

Diagnostic Land Characteristics

- Effective soil depth as determined by horizons, limiting root penetration, e.g. rock, gravel, indurated laterite, compact subsoil, waterlogged horizons;
- ease of penetration of roots as determined by structure and consistence;
- percentage of gravel, stones and boulders above a limiting horizon.

Application to Evaluation

In regional reconnaissance surveys, this quality may not be utilized, except when large mappable areas with limited effective depth or other rooting problems occur. With increasing survey detail, the importance of this land quality will also increase. Effective soil depth is evaluated crop specific but ease of penetration is evaluated in a general manner.

Nature and Effects

The rooting conditions of a soil determine firstly whether the crop encounters sufficient 'foothold' for its roots in order to keep the aerial parts of the plant in place. Secondly, rooting conditions determine whether a root system can be developed, which is effective in extracting available nutrients and moisture from the soil. (The availability of both is evaluated through other land qualities). Further, if rooting in depth is limited, roots may develop laterally which compete with neighbouring plants for moisture and nutrients.

If limitations in rooting occur, the aerial parts of the crop will usually suffer, resulting in decrease in yield.

Land Use Requirements

Generally speaking, optimal rooting conditions are realized in very deep soils, which do not have limitations in ease of penetration. Although optimal conditions are easily defined difficulties are encountered when trying to assess the effect on crop yield by reduced soil depth or limited ease of root penetration.

Special attention should be given to rootcrops, where additional requirements refer to the possibilities for tuber expansion, which may be more limited than penetration of ordinary roots.

Assessment

Effective depth is abstracted from field observation sheets and matched to Table 7.10. Overlapping effective soil depth classes have been used to accommodate for naturally occurring depth ranges.

Ease of penetration is used as a modifier. It is assessed, using field observations on consistence and structure of the subsoil from just below the plow layer till the depth of a limiting layer. Limitations to root penetration are not considered where these occur.
below the limit of the $S_1$ rating for effective soil depth. The applicable downgrading in number of classes is shown in Table 7.11. Additional downgrading based on the presence of stones, gravel and boulders in the profile may be necessary, for which Table 7.12 is used.

The topsoil characteristics are not included in the assessment of ease of root penetration. Under high level of management a good tilth should be obtained, which does not limit root penetration in the top soil. Under low level of input circumstance, topsoil characteristics will also be improved by tillage and poor properties normally imply poor 'workability' (LQ VII).

Survey of Diagnostic Characteristics

Effective depth in most cases is easily assessed in the field. However, situations occur where horizons only partly prevent roots to penetrate deeper. In these cases, a proportion of the partially limiting horizon can be included in the effective depth. It is most important that rooting limitations are properly described and evaluated in the field. The rating table for ease of penetration is fairly artificial and if rooting problems occur, they should also have been identified in the field.
# Table 7.10 Ratings for dominant effective soil depth range

The dominant soil depth range excludes exceptions from a fairly limited depth range within a single land unit.

<table>
<thead>
<tr>
<th>Crop</th>
<th>10</th>
<th>10-20</th>
<th>15-35</th>
<th>20-50</th>
<th>35-75</th>
<th>50-100</th>
<th>75-125</th>
<th>100-150</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearl Millet</td>
<td>N</td>
<td>S4</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Sorghum</td>
<td>N</td>
<td>S4b</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Maize</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Wheat</td>
<td>N</td>
<td>S4b</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Upland Rice</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Phaseolus Bean</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Groundnut</td>
<td>N</td>
<td>S4b</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Soybean</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Cowpea</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Pigeon Pea</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Sweet Potato</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>White Potato</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Cassava</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Sunflower</td>
<td>N</td>
<td>S4b</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Cotton</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Tobacco</td>
<td>N</td>
<td>S4b</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Banana</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1b</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Tea</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4b</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
</tr>
<tr>
<td>Coffee</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>S4b</td>
<td>S4</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
</tr>
</tbody>
</table>
Table 7.11 Modifications due to ease of root penetration

* 1-2 refers to weak to moderate grade of structure,
  3 refers to strong grade of structure.

<table>
<thead>
<tr>
<th>Consistence Structure *</th>
<th>loose very friable</th>
<th>firm</th>
<th>very firm</th>
<th>extremely firm</th>
</tr>
</thead>
<tbody>
<tr>
<td>all granular and crumb all very fine and fine blocky, all very fine prismatic and columnar</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>1-2 medium blocky, 1-2 fine prismatic and columnar, porous massive</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td>3 medium blocky, 3 fine prismatic and columnar, 1-2 coarse blocky, 1-2 medium prismatic and columnar</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
</tr>
<tr>
<td>3 coarse blocky, 3 medium prismatic and columnar, 1-2 very coarse blocky, 1-2 coarse prismatic, and columnar mass (non-porous)</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
<td>-4</td>
</tr>
<tr>
<td>3 very coarse blocky, 3 coarse prismatic, 1-2 very coarse prismatic and columnar</td>
<td>-2</td>
<td>-3</td>
<td>-4</td>
<td>-4</td>
</tr>
<tr>
<td>3 very coarse prismatic and columnar</td>
<td>-</td>
<td>-4</td>
<td>-4</td>
<td>-4</td>
</tr>
</tbody>
</table>

Table 7.12 Modifications due to presence of gravel, stones and boulders

<table>
<thead>
<tr>
<th>Volume % of gravel, stones and boulders</th>
<th>Number of classes to downgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>0</td>
</tr>
<tr>
<td>10 - 30</td>
<td>-1</td>
</tr>
<tr>
<td>30 - 50</td>
<td>-2</td>
</tr>
<tr>
<td>50 - 70</td>
<td>-3</td>
</tr>
<tr>
<td>&gt; 70</td>
<td>-4</td>
</tr>
</tbody>
</table>

Table 7.12 Modifications due to presence of gravel, stones and boulders
7.11 Land Quality VII: Soil workability

Diagnostic Land Characteristics

Of the upper 20 cm of the soil:
- texture
- structure
- consistence
- occurrence of gravel and stones

Application to evaluations

Workability is widely applicable to land evaluations which consider animal traction and manual cultivation. In many areas, in particular for manual cultivation, it may be the most important factor affecting present land occupation. Often, heavy, fertile soils are not utilized by family sector agriculture due to workability constraints.

The ease of tillage of the soil is not evaluated separately for mechanized agriculture. In the absence of stones and boulders, the choice of proper machinery will ensure that in most cases no tillage problems are encountered (stonyness is included in possibilities for mechanization). Though, extreme cases like presence of plastic heavy clays or very poor soil structure are also included in the evaluation of possibilities for mechanization.

Nature and Effects

Workability, or ease of tillage, is the ease with which the soil can be cultivated or tilled. The workability of a soil depends on a number of interrelated soil characteristics such as texture, organic matter content, structure, consistence (particularly plasticity limits), and the occurrence of gravel or stones in the surface layer. Generally sandy soils are easier to work than clayey soils, weak or moderately structured soils better than strongly structured or massive soils. Moisture content also plays an important role. Certain soils are easy to work at nearly any moisture content, while other soils have a very narrow moisture range within which they can be worked.

Land Use Requirements

Obviously optimal land conditions for soil workability are that the topsoil can be easily worked i.e. with relatively little physical effort. Such conditions are likely to occur in light textured soils, soil with small aggregate sizes and soils with a friable topsoil consistence.

Assessment

The assessment of workability is carried out in three steps:

1. Firstly the texture of the topsoil is rated according to Table 7.13.
<table>
<thead>
<tr>
<th>Topsoil Texture</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>sand, loamy sand</td>
<td>S1</td>
</tr>
<tr>
<td>sandy loam</td>
<td>S1b</td>
</tr>
<tr>
<td>sandy clayloam, clayloam</td>
<td>S2</td>
</tr>
<tr>
<td>sandy clay, clay</td>
<td>S3</td>
</tr>
<tr>
<td>heavy clay</td>
<td>S4</td>
</tr>
<tr>
<td>heavy plastic clay</td>
<td>N</td>
</tr>
</tbody>
</table>

Fig. 7.13 Rating of topsoil texture for workability

ii Thereafter upgrading and downgrading is carried out based on soil structure and consistence, in the following manner:

- upgrade 1 class for
  + granular and crumb structure, or
  + loose, very friable or friable consistence
  + or both

- downgrade 1 class for
  + coarse and very coarse blocky, medium-coarse and very coarse prismatic and columnar, and massive structure
  or
  + extremely firm consistence

iii The then obtained rating is finally downgraded based on the presence of coarse gravel and stones or boulders according to Table 7.14.

Please note that the separate rating for gravel and stones/boulders should be applied in a cumulative manner. Thus two times - 1 means downgrading with 2 classes

<table>
<thead>
<tr>
<th>% cover of coarse gravel Ø 2.5 - 7.5 cm</th>
<th>% cover of stones/boulders Ø &gt; 7.5 cm</th>
<th>Number of classes to downgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3</td>
<td>&lt; 3</td>
<td>0</td>
</tr>
<tr>
<td>3 - 15</td>
<td>3 - 15</td>
<td>- 1</td>
</tr>
<tr>
<td>15 - 30</td>
<td>15 - 30</td>
<td>- 2</td>
</tr>
<tr>
<td>30 - 60</td>
<td>30 - 60</td>
<td>- 3</td>
</tr>
<tr>
<td>&gt; 60</td>
<td>60</td>
<td>- 4</td>
</tr>
</tbody>
</table>

Table 7.14 Modifications due to gravelyness and stoniness
Source: Adapted from Van der Kevie (1976)

Survey of Diagnostic Characteristics

All characteristics used for the assessment are standardly recorded during field survey. In addition the surveyor should at each site describe his opinion on workability. For the estimation of % cover gravel and stones the reader is referred to Land Qualities VIII under 'survey of diagnostic characteristics'.
7.12 Land Quality VIII: Potential for Mechanization

Diagnostic Land Characteristics

- slope angle
- presence of rocks
- presence of stones and gravel
- presence of heavy and/or plastic clays

(Extremely shallow soils, not suited to mechanized cultivation will be classified not suitable under land quality 'rooting conditions'. Locally occurring very shallow patches can be dealt with as rock outcrops).

Application to Evaluations

This land quality is essential in evaluations where mechanized land utilization types are considered. It should be noted that this land quality is distinct from LQ 'workability', which refers to the ease of cultivation (obtaining a good tilth) by means of hand tools or animal traction.

Nature and Effects

This land quality is used to evaluate direct hindrances to mechanized cultivation on reasonably large parcels of land through the presence of rocks, stones, etc. It also assesses the efficiency of the use of farm machinery as influenced by the slope of the land, texture and structure.

Although individual crops may have specific mechanization requirements, this quality is used to assess the common need for land tillage of annual crops.

The assessment of potential for mechanization has to be differentiated according to the type of machinery that is used. Here a distinction has been made between the use of heavy machinery like combined harvesters and lighter equipment.

Limitations for mechanization due to climatic conditions (humid conditions at harvesting time) have been evaluated using the reference growing period length.

Land Use Requirements

Optimal land conditions for mechanization refer to flat areas of reasonable size and complete absence of rocks, stones, heavy and/or plastic clays and topsoil structures which impede obtaining a good tilth.

Assessment

Firstly slopes are rated according to table 7.15 and rockyness, stonyness with table 7.16. An example of a decision model for rating of the combined effect is provided in table 7.17. The occurrence of plastic and/or heavy clays is used as a modifier, using table 7.18-
It is left to the discretion of the surveyor to assess the effect of poor topsoil structure (e.g. prismatic) and topsoil texture combinations where these occur.

Survey of diagnostic characteristics

Slopes are measured in the field and/or from 1/50 000 topographic maps (if available). From the latter a slope map may be compiled using the method of Raisz-Henry (Circles on a transparent film, with diameters which represent the slope class limits). Rockyness, stonyness and the occurrence of heavy plastic clays are observed in the field.

Stones and boulders may reduce possibilities for mechanization and workability although the surface covered is limited. In the lower ranges the percentage cover though is difficult to assess. Van der Kevie (1976) presented the following assessment rules which are easy to apply in the field:

<table>
<thead>
<tr>
<th>% cover</th>
<th>distance between individual stones</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.1</td>
<td>&gt; 10 m</td>
</tr>
<tr>
<td>0.1 - 3</td>
<td>2 - 10 m</td>
</tr>
<tr>
<td>3 - 15</td>
<td>1 - 2 m</td>
</tr>
<tr>
<td>&gt; 15</td>
<td>&lt; 1 m</td>
</tr>
</tbody>
</table>
Table 7.15 Slope class ratings for mechanization

* Land of this slope will be classified not suitable due to erosion hazard (LQ IX).

Table 7.16 Gravel, stones, rock ratings for mechanization

* 'heavy' and 'light' refer to type of machinery as used for rating of slope in Table 7.5

Source: Adapted from Van der Kevie 1976 and FAO 1983
<table>
<thead>
<tr>
<th>final rating</th>
<th>slope rating</th>
<th>gravel, stones, rock rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>S1</td>
<td>all S1</td>
</tr>
<tr>
<td>S1b</td>
<td>S1</td>
<td>one S2 permitted</td>
</tr>
<tr>
<td>S2</td>
<td>S1</td>
<td>two S2 permitted, or one S3</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>all S1</td>
</tr>
<tr>
<td>S2b</td>
<td>S2</td>
<td>one S2 permitted</td>
</tr>
<tr>
<td>S3</td>
<td>S1</td>
<td>three S2, or two S3 permitted</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>two S2, or one S3 permitted</td>
</tr>
<tr>
<td></td>
<td>S3</td>
<td>all S1</td>
</tr>
<tr>
<td>S3b</td>
<td>S3</td>
<td>one S2 permitted</td>
</tr>
<tr>
<td>S4</td>
<td>S1</td>
<td>three S3, or two S4 permitted</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>two S3 permitted</td>
</tr>
<tr>
<td></td>
<td>S3</td>
<td>one S3 permitted</td>
</tr>
<tr>
<td></td>
<td>S4</td>
<td>all S1</td>
</tr>
<tr>
<td>N</td>
<td>S1</td>
<td>one N</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>two S4</td>
</tr>
<tr>
<td></td>
<td>S3</td>
<td>one S4, or two S3</td>
</tr>
<tr>
<td></td>
<td>S4</td>
<td>two S2</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>all S1</td>
</tr>
</tbody>
</table>

Table 7.17: Decision making model for final rating potential for mechanization

- heavy clay - 1
- plastic heavy clay - 2

Table 7.18: Modifications due to topsoil texture
7.13 Land Quality IX: Erosion Hazard

Diagnostic Land Characteristics

- Rainfall erosivity as determined by rainfall energy
- Soil erodibility as determined by soil type and topsoil texture
- Topography: slope angle and length

Actual water erosion is further determined by management practices, which differ with land utilization type considered. These management practices refer to the presence/absence of physical erosion control structures, tillage techniques and crop cover as determined by cropping pattern, planting date and yield.

Application to Evaluations

The land quality erosion hazard must form part of any evaluation of Mozambique's upland soils, but particularly on the Basement Complex areas with undulating or hilly relief. Wind erosion hazard is not considered due to its rare occurrence in Mozambique. Exceptions may be the semi-arid areas of the interior of Gaza, Inhambane and Maputo Provinces and the Zambezi Valley area in Tete and Manica Provinces, where mean annual precipitation drops below 700 mm. Also coastal dunes South of the Save river are known to be affected by wind erosion, in places where the vegetative cover has been removed.

Nature and Effects

The detrimental effect of topsoil removal by water on present and future production is sufficiently well known and does not require further elaboration here.

Land Use Requirements

Optimal land conditions with reduced erosion hazard, obviously refer to low rainfall erosivity, low soil erodibility and flat areas with limited slope length. However, as described above, actual erosion also depends on land and crop management and moreover some soil loss is tolerated for sustained production.

In Zimbabwe (Elwell 1980) the following maximum soil loss targets have been established:

- sand, clayloam, loamy sand - 5-9 ton/ha/year
- sandy clayloam, clayloam, sandy clay - 4-6 ton/ha/year
- clay, heavy clay - 3-4 ton/ha/year

The lower limit of the above target figures can be achieved under best conservation practices. The upper limits should not be exceeded for broad planning purposes.

Land characteristics which permit attaining the above soil loss targets differ according to land utilization type i.e. type of crop (annual, perennial), cropping pattern, yield (cover), physical erosion control measures (channel terraces), agronomic erosion control measures (e.g. contour ploughing), etc. For example land requirements...
for topography are fairly strict for annual crops grown on lands without physical conservation structures, but perennial crops, on fields with correctly spaced and aligned channel terraces can be grown on fairly steep slopes. The model referred to below, actually permits the establishment of the correct land utilization type, as far as soil loss by erosion is concerned, based on land factors like the diagnostic characteristics mentioned above.

Assessment

Usually, the rate of erosion is assessed in a model where the combined effect of a number of land characteristics is calculated.

The recommended model here is the SLEMSA model (Elwell, 1980). The model is developed and tested in Zimbabwe, on Basement Complex soils, on slopes of 3-8%, under mean annual rainfall between 500 and 1 000 mm. For other rainfall ranges it will provide data of comparative worth. The model is presented in Fig. 7.3.

SLEMSA, like most others erosion models only assesses sheet erosion hazard. Therefore adjustments have to be made, when field evidence would indicate that downgrading of water erosion hazard is necessary due to particular additional hazards of gully erosion.

The model is also developed for circumstances, which assume correctly designed and spaced contour bunds. This is mostly not relevant in Mozambique conditions and consequently, other assumptions have to be made to arrive at meaningful results.

Moreover SLEMSA is intended for farm planning and the design of appropriate crop rotations under given environmental conditions (assuming correctly designed physical erosion control structures). This permits the calculation of soil loss depending on land management, crop rotations (definition of LUT) together with the environmental conditions, which is at a level required in local detailed surveys.

However for regional semi-detailed and reconnaissance surveys this level of detail is not practical and generalizations have to be made, in particular with respect to the land management specifications and the definition of crop rotations. Six land management systems (LMS) have been considered based on the size of fields and the degree to which conservation measures are applied.

LMS 1: large fields and cultivation 'on the flat'
LMS 2: large fields and cultivation on reasonably well aligned cultivation ridges
LMS 3: large fields and full conservation measures
LMS 4: small fields and cultivation 'on the flat'
LMS 5: small fields and cultivation on reasonably well aligned cultivation ridges
LMS 6: small fields and full conservation measures
**Physical Systems**

**Crop**

**Climate**

**Soil**

**Topography**

**Control Variables**

- Energy Interception $i$
- Rainfall Energy $E$
- Soil Erodibility $F$
- Slope Steepness $S$
- Slope Length $L$

**Submodels**

- Crop Ratio $C$
- Soil loss from bare soil $t/ha/a$
- Topographic Ratio $X$

**Main Model**

Soil loss from cropland $t/ha/a$

$Z = KCX$

**Fig. 7.3 SLEMSA framework**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Explanation</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E$</td>
<td>Seasonal rainfall energy</td>
<td>J/m²</td>
</tr>
<tr>
<td>$F$</td>
<td>Soil erodibility</td>
<td>Index</td>
</tr>
<tr>
<td>$i$</td>
<td>Rainfall energy intercepted by crop</td>
<td>per cent</td>
</tr>
<tr>
<td>$S$</td>
<td>Slope steepness</td>
<td>per cent</td>
</tr>
<tr>
<td>$L$</td>
<td>Slope length</td>
<td>m</td>
</tr>
</tbody>
</table>

| Submodels                      |                |
| $K$   | Bare soil condition              | -              |
| $C$   | Crop canopy                      | -              |
| $X$   | Topography                       | -              |

**Output**

- Predicted mean annual soil loss $= KCX$
  - ton/ha
The evaluation below takes into account a standard slope length which is 100 m for cultivation of large fields and 50 m for small fields. The first should be applied to modern agriculture (state sector) and the latter to the traditional family sector.

A further generalization concerns the crop rotation and its influence on the crop canopy cover submodel. For the calculation of soil loss an i-value of 45% has been taken which results in a soil loss ratio (C) of 0.06. This constant corresponds to a maize crop planted at the beginning of the growing period and yielding 6 tons/ha. A fairly high maize yield has been chosen since a standard value was required and moreover most other crops (in rotation) produce a better cover than maize. Obviously in the traditional sector maize yields are lower but normally intercropping takes place by which cover is increased. No data are available on actual cover, the higher erosion losses would be compensated for by the longer rest fallow periods in such cultivation systems as compared to permanent cultivation where a few years cropping are alternated with a few years of grass ley.

With the above standard assumptions the erosion hazard assessment requires only the following inputs: mean annual rainfall, soil erodibility and slope angle.

Seasonal rainfall kinetic energy was found to be a good predictor of annual soil loss from field plots in Zimbabwe and to be particularly well correlated to soil loss from bare soils. Moreover it is well correlated with mean annual rainfall. Mean seasonal rainfall energy, E (Joules/m²), can be read from Figure 4, using mean annual rainfall as entry*. Different graphs have been produced for 'Guti', and 'non-Guti' areas. Guti areas are defined as those with more than 20 days of early morning drizzle annually. Such conditions are known to occur in the higher parts of Manica Province and Angonia district in particular on SE facing slopes. Similar conditions are likely to occur on SE facing slopes in Zambezia Province.

Soil erodibility is a main factor determining erosion hazard, but a suitable soil erodibility index that is simple to measure and reliable in application is not available. In Zimbabwe the basic soil erodibility index Fb is determined by using the soil types of the Zimbabwe soil classification system and the topsoil texture. Table 7.18 presents the basic soil erodibility indexes for the FAO classification units and their possible topsoil-subsoil texture combinations. These indexes have been obtained by correlating the Zimbabwe soil classification with the FAO classification. The method utilized is reported, in full in Van Wambeke (1985). In the SLEMSA model these Fb ratings are further modified into a final F value (Fm) based mainly on management practices. This step is omitted here but the previously defined land management systems will be assessed differently.

It is recommended to compare the Fb value with the past erosion field assessment giving due attention to the present land cover under which it was assessed. Discrepancies between Fb and past erosion require

* A slightly different correlation line was found for Mozambique, but analysis was based on a few stations and only 5 years of data. Pending further analysis the Zimbabwe line has been maintained
GUTI $E = 17,333\, P$

NON-GUTI $E = 12,846\, P$

Fig. 7.4: SELECTION of $E$ from MEAN ANNUAL RAINFALL
Source: Ellwell, 1980
<table>
<thead>
<tr>
<th>FAO* SOIL UNIT</th>
<th>TOPSOIL TEXTURE</th>
<th>SUBSTRATA TYPE **</th>
<th>LITHIC PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coarse</td>
<td>Medium</td>
<td>Fine</td>
</tr>
<tr>
<td>Ferric Acrisol</td>
<td>4.5</td>
<td>5.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Gleyic Acrisol</td>
<td>4.0</td>
<td>4.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Humic Acrisol</td>
<td>-</td>
<td>5.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Chromic Cambisol</td>
<td>-</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Eutric Cambisol</td>
<td>-</td>
<td>4.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Orthic Ferralsol</td>
<td>5.5</td>
<td>5.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Xanthic Ferralsol</td>
<td>5.5</td>
<td>5.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Rhodic Ferralsol</td>
<td>-</td>
<td>5.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Humic Ferralsol</td>
<td>-</td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>Lithosol</td>
<td>-</td>
<td>2.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Orthic Luvisol</td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Chromic Luvisol</td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Ferric Luvisol</td>
<td>5.0</td>
<td>5.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Gleyic Luvisol</td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Albic Luvisol</td>
<td>4.0</td>
<td>5.0</td>
<td>-</td>
</tr>
<tr>
<td>Halpic Phaeozem</td>
<td>-</td>
<td>5.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Gleyic Phaeozem</td>
<td>-</td>
<td>4.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Luvic Phaeozem</td>
<td>-</td>
<td>5.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Eutric Nitosol</td>
<td>-</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Dystric Nitosol</td>
<td>-</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Humic Nitosol</td>
<td>-</td>
<td>6.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Cambic Arenosol</td>
<td>6.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Luvic Arenosol</td>
<td>6.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ferralic Arenosol</td>
<td>6.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Albic Arenosol</td>
<td>6.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Eutric Regosol</td>
<td>6.0</td>
<td>6.0</td>
<td>-</td>
</tr>
<tr>
<td>Pellic Vertisol</td>
<td>-</td>
<td>-</td>
<td>5.0</td>
</tr>
<tr>
<td>Eutric Planosol</td>
<td>3.5</td>
<td>4.5</td>
<td>-</td>
</tr>
<tr>
<td>Solodic Planosol</td>
<td>3.0</td>
<td>4.0</td>
<td>-</td>
</tr>
<tr>
<td>Orthic Solonetz</td>
<td>2.0</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Orthic Solonchak</td>
<td>2.5</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Gleyic Solonchak</td>
<td>2.5</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Source: Van Wambeke, 1985

* Gleysols and Fluvisols not considered because mainly subject to gully erosion.

** Only applicable when topsoil and substrata texture classes are different. In addition subtract 0.5 for clear textural changes (< 5 cm) and/or compact subsoil.
further analysis and where judged appropriate an adjustment of Fb can be made. A further simple check on Fb is the rating system based on topsoil texture only which was used before SLEMSA was fully developed:

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Fb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands, loamy sands, sandy loams</td>
<td>4</td>
</tr>
<tr>
<td>Sandy clayloam, clayloam</td>
<td>5</td>
</tr>
<tr>
<td>Sandy clay, clay</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: adapted from Elwell (1978)

The F rating and the energy value are entered into Figure 7.5 to determine X. X and slope angle are entered in Fig. 7.6 and the suitability class can directly be read. This rating is valid only for cultivation 'on the flat'. The isolines of Figs. 7.6 represent under the previous assumptions the soil losses of 10, 20, 30 and 40 tons per hectare per year of cultivation. Under adequate rotations the annual soil loss (average) for the total rotation cycle will be about 50% of the above values. Land with slopes over 13% are considered 'not suitable' whereas such conditions require the construction of bench terraces which is costly and in most areas sufficient land with less slope is available.

With adequate erosion control measures through correctly designed and spaced contour bunds and grassed waterways as well as cultivation on correctly aligned ridges the suitability rating is SI irrespective of slope angle of the terrain (as long as this is below 13%) and X (still a correct rotation has to be chosen).

Due to the absence of a conservation as well as an extension service the above optimal land management will not be reached in near future. Therefore a different approach had to be designed to cater for conditions in which cultivation is on ridges but not well aligned to the contour and without physical conservation works (which occurs in some locations in Mozambique; it could be considered as conservation measures under intermediate level of input circumstances). In these cases the F value would be reduced due to poor alignment, but on higher slopes the lesser slope of the furrows between the ridges has to be used in the SLEMSA model. The following simplification is proposed. Take the land quality rating for on the flat and upgrade one class for terrain with a slope range of 5-8% and two classes for terrain with slopes of 8-13%.

For the above purpose the ratings of N2 and N3 had to be introduced for which the lower limits are 50 and 60 tons/ha for years under cultivation.

**Survey of Diagnostic Land Characteristics**

1. Mean annual rainfall is read from a map on this subject with sufficient detail i.e. it should be based on rainfall stations in addition to the main meteorological stations and the map should have been made considering local differences in altitude,
$K = \exp \left[ (0.4681 + 0.7663F) \ln(E) + 2.884 - 8.1209F \right]$
Fig 7.6 Rating of erosion hazard based on K-value and slope angle by standard slope length (Left graph: large scale agriculture. Right graph: small scale agriculture.)
Soil erodibility is assessed by FAO soil type and topsoil-subsoil texture combinations. The soils can be classified in the FAO system based on the profile description and the result of soil chemical and physical analysis. Textures are determined in the field and later by laboratory analysis.

Slope angle is measured in the field, but the dominant slope range of a land unit is better surveyed by using a 1:50 000 topographical map (if available).
7.14 Land Qualities not considered

Radiation regime. Amount of radiation is not limiting rainfed crop production in Mozambique.

Conditions affecting germination and establishment. Insufficient knowledge of the effect of sealing on establishment of a crop prohibits application of this land quality. Other land characteristics which affect germination and establishment, such as the possibility to prepare a good seed bed (tilth) and stonyness, have been included in the evaluation of other qualities. Where sufficient field evidence or experience is available of severe limitations in this respect, the land quality may be included in the evaluation as a modifier, e.g. downgrading land suitability by one or more classes.

Air humidity as affecting growth. The adverse effect of low humidities on the development of some crops is not well established (FAO Guidelines, 1983). Moreover extreme low values during the growing season do not occur in Mozambique. The effect of high humidities on incidence of pests and diseases is assessed crop-specific using the reference growing period length.

Conditions for ripening. Most crops require a period to mature or ripen at the end of its growth cycle, which needs to be at least dry and preferably also warm and sunny. The lack of such a period of sufficient length influences yield and its quality.

In tropical climates with a pronounced dry season the existence of suitable conditions after the end of the growing period can be taken for granted. However in zones with an extended length of growing period yield and quality may be affected. These effects have been evaluated crop-specific by means of the length of the reference growing period.

Flooding hazard. Flooding hazard on Basement Complex is limited to the hydromorphic valleys (Dambo's). These land units are adequately assessed by means of the land quality 'oxygen availability to roots' in view of their poor or very poor soil drainage class.

Climatic hazards. Climatic hazards consist of frost and storm where the latter may consist of high windspeeds, high intensity rainfall, hail or a combination of these. Frost is unlikely to occur during the growing period except for some isolated mountains. Destructive storms in terms of wind speed and rainfall occur frequently in the coastal zone of Mozambique, when hurricanes developed over the Indian Ocean soar the Mozambique Channel. However their haphazard pathway makes evaluation a difficult exercise.

Hailstorms do occur, though infrequently, particularly in zones of higher altitude but also occasionally in low altitude zones. Their erratic and local occurrence impedes systematic evaluation and moreover they occur mostly outside the growing period. In higher altitude zones with an extended growing period where perennial crops are grown (e.g. temperate fruit in Tsangano, Angonia) hail is a limiting factor and requires consideration. The quantification of
occurrence of hailstorms has often to rely on local field experience, whereas these areas often do not possess a recording station.

Excess of salts (salinity, sodicity). Excess of salt is not known and unlikely to occur in Basement Complex soils.

Soil toxicities. Possible soil toxicities in Basement Complex soils could include Aluminium, Manganese and other trace elements. None of these have been encountered so far.

Pests and diseases. Any but very general data on pests and diseases related to the land is difficult to obtain. Assessment is therefore included, in a general manner, in the evaluation of the length of the reference growing period.

Conditions for land preparation and clearance. Levelling, grading, terracing and clearance of rock outcrops are costly initial land improvements and should be avoided whereas plenty of land without such limitations is available for new developments. Therefore land over 13% slope is already classified as being not suitable in the previously presented land quality rating system. Above this limit bench terraces need to be constructed. Below this limit the hindrance by rocks has also been evaluated.

Vegetation clearance requirements can be evaluated by means of vegetation physiognomy. It is suggested to include this aspect only where exceptional clearance requirements occur. The evaluator should be very careful here since the dense vegetation in the case of forest normally contains valuable timber species and the land may be more profitably used for forestry than for arable farming.

Conditions affecting storage and processing. Storage of produce is adversely affected by high humidities which can cause deterioration in quality of the product or introduce an additional cost for storage facilities as far as this has to take place on-farm. An indication of the occurrence of such problems may be derived from the length of the growing period but post-harvest storage losses are not considered in the evaluation of the length of the reference growing period.

Processing may be affected by moisture content as well as soil adhered to produce due to the type of soil and/or moisture content of the soil at harvesting.

This quality is normally omitted from evaluation. However its use as a modifier is recommended in areas with extreme conditions and/or for crops with specific requirements.

Conditions affecting timing of production. According the FAO guidelines this quality refers to the economic advantage gained by some areas in producing crops for a market out of season.
As such it refers only to commercial production and mainly to fruit and vegetable crops. It is therefore not important in many evaluations in Mozambique. An other aspect of timing of production is however relevant. In Southern Mozambique, with very unreliable rainfall, planning of farm operations and timing of production is extremely hazardous even under high levels of management due to the specific climatic conditions. These conditions have already been evaluated through an additional 'workability constraint' (constraint 'd') applied in the evaluation of the reference growing period and its pattern.

Access within the production unit. This quality refers to terrain factors which affect the construction and maintenance of farm access roads, such as needed for harvest, transport of fertilizer, passage of farm machinery etc. The production unit referred to is a single farm in the case of large farms and estates but refers to village arable land as a whole where this consists of small holdings (2).

Access within the production unit is affected primarily by landform factors (cf. FAO Guidelines, 1983). The quality should be applied to crops and production systems which have specific harvest transport problems like sugarcane. However problems are unlikely to occur on otherwise suitable land under Basement Complex conditions.

For small holder cultivation and where people are living in a concentrated manner (villages) the distance from village to farmed field may constitute a serious problem. As a rule of thumb distance from homestead to field should not exceed 2.5 km.

Size of potential management units. Economic viability may determine a certain minimum size of a farm where processing is an on-farm activity and where factories and machinery require a minimal total production to be economically used. This quality frequently does not apply, particularly as far as small holder farming is concerned. In rare cases this quality may become relevant where large state farms need to supply the raw material for an agro-industrial complex.

Location (existing and potential). This land quality refers to location in relation to markets and supplies. It concerns the cost of transport of inputs and outputs. Location is one of the classical factors affecting present land use, particularly around big towns (Von Thünens principle). In the parallel approach to land evaluation it is an important land quality which will determine which land utilization types are to be considered from the very beginning of the study. In the two-stage approach, here proposed, the considerations of location do not form part of the land evaluation itself and are only studied after the eco-physical suitability evaluation has taken place. In the planning phase at national and regional level the relative advantage of areas based on location requires due attention.
The fact that this quality is not included in the evaluation system does not preclude the land evaluator to reject land utilization types from the beginning of a survey based on common sense.

Soil degradation hazard. Soil degradation hazard can be subdivided in physical, chemical and biological degradation of soil properties. Soil degradation is difficult to apply to land evaluation in the same manner as other land qualities, but at the same time is a widespread and potentially serious hazard (2).
LAND SUITABILITY ASSESSMENT

The land suitability assessment is based on the individual land quality ratings that have been determined using the guidelines presented in the previous chapter and which have been filled in on the land evaluation data sheet.

The land suitability assessment is carried out in two major steps. Firstly the ecological land suitability is assessed based on two sub-ratings: one is a combined rating for climatic yield potential and the edaphic modifier and the second is a combined rating for oxygen availability, rooting conditions and either nutrient availability or nutrient retention. The second major step consist of establishing the end-rating based on the ecological land suitability and the land quality ratings for erosion hazard and either workability or possibilities for mechanization, depending on the land utilization type. The various steps are schematically presented in Figs. 8.1 and 8.2.

The procedure to obtain the sub-rating based on climatic yield potential and the edaphic modifier has been explained in the previous chapter under LQII i.e. the rating for climatic yield potential is downgraded a number of classes depending on general soil properties and the P/PET ratio during the growing period.

The assessment of the sub-rating for oxygen availability/drainage, rooting conditions and either nutrient availability or nutrient retention is obtained in the following manner. Firstly it is considered that soil drainage class can be an over-ruling constraint under high as well as low input conditions and that nutrient availability can be an over-ruling constraint under low input conditions. Therefore the following rules have been defined.

Whenever drainage is imperfect to poor (I-P), poor (P) or very poor (VP) and the drainage rating is the lowest of the three land qualities considered, then the final sub-rating is equal to the rating for oxygen availability. Whenever nutrient availability has the lowest rating of the three, then the sub-rating is equal to the rating for nutrient availability for low input land utilization types.

In all other cases the following procedures are to be followed. Take the lowest rating of the three: if it occurs twice this is also the final sub-rating. If the lowest rating occurs twice and is S3 and one of the two is S3b than the end-rating is S3b. For S1 and S2 the b-suffix is omitted. If the lowest rating occurs only once, than the sub-rating may be upgraded to one class higher than the lowest individual land quality rating, but not higher than any other occurring rating. Example:

\[S_{1/2} + S_1 + S_{2b} \neq S_{1b} \text{ but } S_{1/2}\]
AGRO-CLIMATIC YIELD POTENTIAL
EDAPHIC modifier

OXYGEN AVAILABILITY
ROOTING CONDITIONS
NUTRIENT AVAILABILITY

Sub-Rating

Sub-Rating

ECOLOGICAL YIELD POTENTIAL

WORKABILITY
EROSION HAZARD

LAND SUITABILITY CLASS

---

Fig. 8.1.: Flow chart of land suitability classification for low input rainfed arable farming.
Fig. 8.2.: Flow chart of land suitability classification for high input rainfed arable farming.
The ecological land suitability is determined by considering the two above sub-ratings. Whichever is the lowest of the two is also the rating for ecological land suitability. Whereas all land qualities considered in this case are ecological factors, it is assumed that the law of the minimum is operative.

The final land suitability class is determined by the rating for ecological land suitability and the individual ratings for the land qualities related to management and conservation: workability, possibilities for mechanization and erosion hazard. Workability is used for low input arable farming and possibilities for mechanization is used for high input agriculture. For erosion hazard the appropriate rating for the land utilization type under consideration is used i.e. one of the land management systems defined in the previous chapter under LQIX.

For further use in the land suitability assessment the lowest rating of either workability and erosion hazard or possibilities for mechanization and erosion hazard (land utilization type dependant) is selected. If the lowest rating includes a suffix 'b' than this b is ignored and if the lowest rating is a 'double' rating e.g. S2/3 than the highest rating is considered for further use (in this case S2).

The thus obtained rating is used in conjunction with the ecological land suitability to obtain the final land suitability class in the following manner. Take the ecological suitability rating and downgrade this 0, 1, 2, 3 or 4 classes if the lowest rating obtained as described above is S1, S2, S3, S4 or N respectively. The downgraded rating is the end-rating for the land suitability of the land utilization type under consideration. For the time being it is suggested to omit downgrading based on a workability rating of S2 and to downgrade one class only if the workability rating is S2/3.

The final land suitability class thus is determined by subtraction. Given a certain ecological potential or production capacity of the land, workability and possibilities for mechanization determine the effort or cost determined by efficiency of equipment that is required to attain the ecological potential. Secondly erosion hazard determines at what cost in terms of soil loss such a production could be obtained or alternatively is indicative of the costs involved in construction of adequate erosion control measures and the cost involved in appropriate land management.

In the next pages three fully filled in land evaluation data sheets are presented. These show how the land evaluation system presented in the previous sections is applied to three concrete land units as defined in a land resources survey in the Angonia district of Mozambique. These land units are representative for those areas for which the three recommended land utilization types presented in chapter 4.6 are relevant.

From the land evaluation data sheet, in this case with 12 crops, the final land suitability class for 36 low input land utilization types and 72 high input land utilization types can be derived through the various combinations of crops with input levels, land management system and type of mechanization. Although these land utilization types are fairly simple defined, the great amount and variety of them provides a good insight in the land potential as well as the management required to optimally use the land resource. In addition the overview of the various suitabilities facilitates the formulation of recommended land use.
## LAND EVALUATION DATA SHEET

### Diagnostic Land Characteristics

<table>
<thead>
<tr>
<th>LGP:</th>
<th>170-190</th>
<th>PATTERN:</th>
<th>1</th>
<th>OBS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(AL) T:</td>
<td>1300-1500</td>
<td>+ Ferrall soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIET:</td>
<td>1.3 - 1.5</td>
<td>SOIL DRAIN. CL:</td>
<td>well</td>
<td></td>
</tr>
<tr>
<td>DEPTH</td>
<td>% N</td>
<td>P</td>
<td>TEB</td>
<td>Ca/Mg</td>
</tr>
<tr>
<td>0-30</td>
<td>0.07-0.08</td>
<td>20</td>
<td>3</td>
<td>2.0-2.9</td>
</tr>
<tr>
<td>30-100</td>
<td>0.02-0.03</td>
<td>20</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>RATING</td>
<td>S3</td>
<td>S1</td>
<td>S4</td>
<td>S1/2</td>
</tr>
</tbody>
</table>

### Soil Type

- Topsoil: 0-15
  - Text: S4
  - Consist.: C
  - Structure: 0-1 wsbk
  - % Gravel: S4
  - Stones: S4
  - Rocks: S4

- Subs. 1: 15-60
  - Text: C
  - Consist.: C
  - Structure: 1 wsbk
  - % Gravel: S4
  - Stones: S4
  - Rocks: S4

- Subs. 2: 60-100
  - Text: C
  - Consist.: C
  - Structure: porous
  - % Gravel: S4
  - Stones: S4
  - Rocks: S4

### Obs. Roots Limitations

- None

### Land Use / Cover

- Rainfall: 900-1000
- Energy: 18000
- FAO Soil Type + Text: ABR ARG
- To: (Af+18) 3/2
- F: 6.5
- K: 35
- Past Erosion: mod. sheet and low colluvial
- Surface Features: moderately sealed

### Summary / Recommended Land Use

- Climatically best adapted crops are limited to temperate crops and varieties: maize, sorghum, wheat, white potato and phas beans.
- Production of these crops mainly limited by soil and climate constraint.
- Excellent conditions for the mechanised farming and low erosion hazard.
- Light to medium use with 80% of grass ley is recommended.
- It is estimated that S2 is an appropriate rating for the above crops.
- Nutrient retention is augmented by increasing organ. matter content.
**LAND EVALUATION DATA SHEET**

### Diagnostic Land Characteristics

<table>
<thead>
<tr>
<th>LGP:</th>
<th>170 - 185</th>
</tr>
</thead>
<tbody>
<tr>
<td>(AL)T:</td>
<td>1150 - 1300</td>
</tr>
<tr>
<td>P/E/T:</td>
<td>1.3 - 1.5</td>
</tr>
<tr>
<td>Soil Type:</td>
<td>Medium-heavy</td>
</tr>
<tr>
<td>Soil Drain. Cl.:</td>
<td>Moderate well</td>
</tr>
<tr>
<td>Pattern:</td>
<td>1</td>
</tr>
<tr>
<td>Land Unit:</td>
<td>10.2(a)</td>
</tr>
</tbody>
</table>

### Ecological Land Quality


<table>
<thead>
<tr>
<th>Crop Variety</th>
<th>HI</th>
<th>LI</th>
<th>HI</th>
<th>LI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Sorghum</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Groundnut</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Maize</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Wheat</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Cassava</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Cotton</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>White Potato</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td>Phas bean</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
</tbody>
</table>

### Summary / Recommended Land Use:
- Workability: S1/S2
- Mechanization: Moderate to Heavy
- Nutrient Retention: S1
- Erosion Hazard: Lms 1: S2/S3, Lms 2: S1/S2, Lms 3: S1/S2, Lms 4: S2/S3, Lms 5: S1/S2, Lms 6: S1
- Land Use / Cover: AGR-CLM. YIELD - POT.

### Erosion Hazard

- Lms 1: S2/S3, Lms 2: S1/S2, Lms 3: S1/S2, Lms 4: S2/S3, Lms 5: S1/S2, Lms 6: S1

### Past Erosion

- MODERATE, SHEET, locally gullies on field boundaries.

### Surface Features

- Lightly scarred.

### Remarks

- All individual plots were to be classified S2.
# LAND EVALUATION DATA SHEET

## DIAGNOSTIC LAND CHARACTERISTICS

<table>
<thead>
<tr>
<th>LGP:</th>
<th>150-180</th>
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<tbody>
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<td>900-1200</td>
</tr>
<tr>
<td>PIET:</td>
<td>1.0-1.3</td>
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</tbody>
</table>

**SOIL TYPE:** med.- heavy with sandy top

**SOIL DRAIN. CL.** well

**DEPT**

<table>
<thead>
<tr>
<th>DEPTH</th>
<th>% N</th>
<th>P</th>
<th>TEB</th>
<th>Co/Mg</th>
<th>Mg/K</th>
<th>pH</th>
<th>OBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>0.03-0.06</td>
<td>60-70</td>
<td>S-7</td>
<td>variable in this unit</td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-100</td>
<td>S-7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RATING**

| S3 | S1 | S2 | S3andS1 | S3andS1 | S1 |

## ECOL. LAND. QUAL.

<table>
<thead>
<tr>
<th>ROOT. NUTR. AVAIL</th>
<th>DRAIN. MOIST. AVAIL</th>
<th>CROP</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>MAIZE</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>SORGHUM</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>GROUNDNUT</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>SOYBEAN</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>SWEET POTATO</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>WHEAT</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>CASSAVA</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>COTTON</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
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<td>WHITE POTATO</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>SUNFLOWER</td>
</tr>
<tr>
<td>S4 S1/2 S1</td>
<td>1</td>
<td>TOBACCO</td>
</tr>
</tbody>
</table>

## SUMMARY / RECOMMENDED LAND USE:

Due to severe rooting limitations, highest ecological suitability class is S3.

**LAND USE/COVER:**

- **EROSION HAZARD:** Lms 1: N3 Lms 2: N1 Lms 3: S1
- **MECHANIZATION:** 8-10% part heavy: S4 Light: S3
- **WORKABILITY:** S1/2
- **NUTRIENT RETENTION:** S2

**R LOW:** 3.5

**PAST EROSION**

- **F:** 3.5
- **K:** 250

**SURFACE FEATURES**

- **moderately sealed**

**PED 85057**
During the elaboration of the present guidelines, a separate report on "Guidelines for Reporting and Report Writing" has been elaborated (Voortman and Spiers, 1984). It is intended for reports which deal with the whole sequence of work from land resources survey to land evaluation. It describes the structuring of a report as dependant on the type of survey i.e. general purpose or special purpose surveys. The report further deals with language use, typography, etc. The reader is therefore referred to the above publication. Additionally, in Spiers (1983) standards for the preparation of thematic maps are presented.
<table>
<thead>
<tr>
<th>REFERENCES</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Collection Techniques rurales en Afrique.</td>
</tr>
<tr>
<td></td>
<td>Ministère de la Coopération, République Française</td>
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<tr>
<td>Beek, K.J. and J. Bennema (1972)</td>
<td>Land evaluation for agricultural land use planning, an ecological methodology.</td>
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<td>Mimeograph, Afd. Bodemkunde und Geologie, Landbouwhogeschool, Wageningen</td>
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<td></td>
<td>Harmondsworth</td>
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<tr>
<td>Dabin, B. (1956)</td>
<td>Considerations sur l'interprétation agronomique des analyses de sols en pays tropicaux.</td>
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<td></td>
<td>6th Int. Congr. Soil. Sci, 6:403-409</td>
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<tr>
<td></td>
<td>Journal of Agricultural Engineering Research Volume 23 pp 117-127</td>
</tr>
<tr>
<td>FAO (1977)</td>
<td>Soils bulletin 32, FAO, Rome</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Title</td>
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<table>
<thead>
<tr>
<th>Author(s) and Year</th>
<th>Title and Details</th>
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</table>
Appendix A: Land Resources Survey Data Sheet.
### INIA LAND RESOURCES SURVEY DATA SHEET

**Region/Location/Village:**
- **Observation Type:** pit/roadcut/ auger/ vegetation relevé/
- **CLIMATE:**

**Coordinates:**
- **Latitude:**
- **Longitude:**

**Site and/or Land Unit:**
- **Geol. Form./Landform/Hydrology:**

**Slope Type:**
- **slope %:**
- **Exposition:**
- **Length:**

**Macro Relief:**
- **Very flat:**
- **Rolling (8-15%):**
- **Almost flat:**
- **Hilly (15-30%):**
- **Gently undulating:**
- **Steeply dissected:**

**Relief Intensity:**
- **Micro/Meso Relief:**

### Soil and/or Land Mapping Unit and/or Landscape

**Geological Form.:**
- **Landform:**
- **Hydrology:**

**Slope Type:**
- **Straight, convex, concave, irregular, complex:**

**Slope %:**
- **Exposition:**
- **Length:**

**Micro/Meso Relief:**
- **Surface Features:** compaction, sealing, cracking, gilgai

### Micro/Geological Data

<table>
<thead>
<tr>
<th>HOR.</th>
<th>DEPTH (cm)</th>
<th>COLOUR (cm/in)</th>
<th>MOTT. (orig.)</th>
<th>TEXT.</th>
<th>STRUCT.</th>
<th>CONST.</th>
<th>PORES (n²/cm²)</th>
<th>ROOTS</th>
<th>NODS.</th>
<th>CUTANS</th>
<th>MINER.</th>
<th>BY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>m</td>
<td>d</td>
<td>w</td>
<td>d</td>
<td>m</td>
<td>d</td>
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**Parent Material:**

**Summary Description:** salient features, interpretation, relation to other profiles.

**Remarks:**
- CM, HCl, soft lime, salts, cementation, pans, soil fauna, artefacts, resistance to auger etc.

**Pores:** continuity, orientation, distribution, morphology
**LAND EVALUATION DATA**

<table>
<thead>
<tr>
<th>ACCELERATED EROSION</th>
<th>POSITION ON SLOPE</th>
<th>SOIL DRAINAGE CLASS</th>
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<tbody>
<tr>
<td>none</td>
<td>very low</td>
<td>none</td>
</tr>
<tr>
<td>sheet</td>
<td>low</td>
<td>sheet</td>
</tr>
<tr>
<td>rill</td>
<td>moderate</td>
<td>r/g depth</td>
</tr>
<tr>
<td>gully</td>
<td>strong</td>
<td>r/g spacing</td>
</tr>
<tr>
<td>soil</td>
<td>severe</td>
<td>overwash</td>
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**AFFECTED AREA:**

<table>
<thead>
<tr>
<th>WORKAB. RATING</th>
<th>MECHAN. RATING</th>
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</thead>
<tbody>
<tr>
<td>GRAVEL</td>
<td>1/2/3/4</td>
</tr>
<tr>
<td>STONES</td>
<td>1/2/3/4/5/6</td>
</tr>
<tr>
<td>ROCKS</td>
<td>1/2/3/4/5/6</td>
</tr>
</tbody>
</table>

**REMARKS:**
- main soil limitations for arable farming (incl. seedling establishment)

**LAND USE AND VEGETATION DATA**

<table>
<thead>
<tr>
<th>TYPE OF LAND USE</th>
<th>PHYSIONOMY</th>
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<tbody>
<tr>
<td>ARABLE LAND</td>
<td></td>
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<tr>
<td>(incl. fallow)</td>
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<tr>
<td>CROP(S):</td>
<td></td>
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<tr>
<td>CULTURAL PRACTICES:</td>
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<td>CROP STATUS:</td>
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<tr>
<td>PESTS/DISEASES:</td>
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<tr>
<td>REMARKS:</td>
<td></td>
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</table>

**REMARKS:**
- past/present utilization, livestock/forestry potential, other uses, structural details, indicators, degradation, encroachment, vigor, seedling establishment.

**PHOTO'S/SLIDES**

<table>
<thead>
<tr>
<th>VEGETATION RELEVÉE SHEET YES/NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO:</td>
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</table>