ASSISTANCE TO LAND-USE PLANNING

ETHIOPIA

LAND EVALUATION
PART ONE : INTRODUCTION AND PROCEDURES

UNITED NATIONS DEVELOPMENT PROGRAMME
FOOD AND AGRICULTURE ORGANIZATION
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ASSISTANCE TO LAND USE PLANNING

ETHIOPIA

LAND EVALUATION

PART ONE INTRODUCTION AND PROCEDURES

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by

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based on the work of
R.B. Ridgway

UNITED NATIONS DEVELOPMENT PROGRAMME
FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS

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This technical report is one of a series of reports prepared during the course of the UNDP/FAO project identified on the title page. The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.
ABSTRACT

As part of the project activities in the preparation of a draft national master land use plan, a land evaluation was conducted at the rapid reconnaissance scale. The land evaluation integrates a number of the outputs of the project, particularly acting as a link between the basic resources surveys and agricultural and other land development planning. The main circumstances underlying the methodology were the small scale of the study (1:1 000 000), the paucity of previous information, and the need to obtain results for the whole of a very large country within a short space of time. A qualitative land suitability classification was used, employing the two-stage approach, in practice, it was not possible fully to integrate economic and social analysis with physical land evaluation within Phase I of the project. Detailed descriptions were made of 46 land utilization types (LUT's) based on rainfed crop production (selected from an initial list of 102 crops), together with 4 land utilisation types based on other major kinds of land use. 42 of the 46 rainfed LUT's were used in the final land suitability assessment. Land qualities and land characteristics by which to measure them were extracted from the Land Resources map, for each of the land mapping units. For purposes of matching, the 42 crops were combined into 20 crop combinations, being groups of crops which have similar environmental requirements. Land suitability maps were produced for each crop combination and for the 4 other kinds of land use. Future activities in land evaluation in Ethiopia are discussed. The detailed methodology for crop requirements is presented in Part Two of the report, and the main results of the evaluation in Parts Three and Four.
ACKNOWLEDGEMENTS

Part One of this report is based on the work of Dr. R.B. Ridgway, following guidelines suggested by Professor A. Young, Consultant. Part Two and Part Three are both based jointly on the work of Ms. Sue B. Edwards, Ato Abebe Mengesha, Mr. J.K.W. Niemeyer and Dr. R.B. Ridgway. Part Four is based on the work of Mr. J.K.W. Niemeyer, Dr. R.B. Ridgway and Ato Teshome Estifanos.

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RESULTS OF THE LAND EVALUATION

The results of the land evaluation are presented as a technical report in four parts, a field document, a series of land suitability maps and a summary map of land use potential, as follows:

Technical Report 5, Land evaluation:

- Part ONE: Introduction and procedures
- Part Two: Land utilisation types
- Part Three: Crop environmental requirements
- Part Four: Land suitability classification

Field Document 4, Land suitability classification tables

Maps:

- Land suitability. A series of maps showing suitabilities for individual crop combinations and land utilisation types
- Land use potential. A map summarizing the results of the individual suitability maps in simplified form.

HOW TO USE THE RESULTS

I. FOR BROAD-SCALE LAND USE PLANNING, AND TO SELECT AREAS FOR MORE DETAILED SURVEY AND EVALUATION:

First, consult the map of Land Use Potential. This supplies a generalized view of the areas of Ethiopia most suited to different kinds of land use. It can be used as a basis for assessment of priorities, and as an initial guide to selection of different groups of crops or other kinds of land use.

Having selected the crop or crops of interest, consult the map of Land Suitability Classification, for the crop combination which contains the relevant crop. This map enables the location of land resource units to be identified which are highly suitable, moderately to marginally suitable, and not suitable for the crop. A class of highly suitable (S1) indicates the best land in Ethiopia for the crop; moderately to marginally suitable (S2) indicates land
which is less favourable than SI land, but which is still considered suitable for the crop; not suitable (N) indicates areas which are not recommended for the crop, either because it will not grow successfully, is not expected to give an economic return, or will result in environmental degradation.

To find the reasons why land has been classified as SI, S2, or N for a particular crop, three sources may be consulted. First, the discussion of the relevant map contained in the report, Part Four, Land suitability classification. Secondly, the environmental requirements that have been used to assess suitability, which are given in the report, Part Three, Crop environmental requirements. Thirdly, the Field Document, Land suitability classification tables show suitability classes and subclasses for each land resource unit and crop combination.

To find details of the climate, geomorphology and soils of the land resource units on which the evaluation is based, consult the map, Land resources, with the extended legend to this map, as described in Technical Report 1.

II. TO CONDUCT LAND EVALUATIONS AT MORE DETAILED SCALES:

First, consult the report, Part One, Introduction and Procedures. This gives the methods used for the national, rapid reconnaissance-scale evaluation. These methods can be used as a basis, with appropriate modification, for more detailed-scale evaluations.

The crop or crops of interest will usually have been identified prior to the more detailed surveys. Consult the relevant sections on this crop in the report, Part Two, Land utilisation types; this gives descriptions of the biology of the crop, cultivation practices and expected crop yields. Next, consult the same numbered section in the report, Part Three, Crop environmental requirements; this gives the requirements for successful cultivation of the crop. These requirements are expressed in terms of land qualities, together with land characteristics, that is, measurable features of climate, geomorphology and soils, by which the land qualities can be estimated.
By means of more detailed surveys, map the land resource units of the area, and obtain the required land characteristics for these units. Compare these with the crop requirements to obtain land suitability classes, separately for each land resource unit with respect to each crop under consideration. In this way, construct more detailed maps of land suitability.

III. AS A BASIS FOR IMPLEMENTATION OF LAND USE PLANNING:

It should be strongly emphasized that the results of the present rapid reconnaissance evaluation cannot be applied directly to land use planning at the local scale. To do so would be likely to lead to crop failure, economic loss or environmental degradation. Further resource survey and land evaluation at more detailed scales is essential before field implementation of development.

The results of the present survey can, however, contribute to the implementation of land development, in conjunction with the results of more detailed surveys. First the crop environmental requirements, as given in the report, Part Three, can be applied to land facets or other land units mapped in the local area; the 'Notes on land qualities' are of particular relevance at this scale. Secondly, the description of land utilisation types, as given in the report, Part Two, can be used as a starting point for management specifications for the crops to be developed, e.g. suitable crop rotations, fertilizer requirements, problems of pests and diseases.
TABLE OF CONTENTS

ABSTRACT III
ACKNOWLEDGEMENTS IV

V LAND EVALUATION RESULTS AND THEIR USE

1. OBJECTIVES OF LAND EVALUATION
   1.1 Land evaluation and land use planning 1
   1.2 Land evaluation in relation to Project activities 3
   1.3 Introduction to the land evaluation report 9
      1.3.1 The four parts of report 9
      1.3.2 Introduction to Part One 10

2. PRINCIPLES AND APPROACHES 11
   2.1 Main circumstances of the evaluation 11
   2.2 Principles 11
   2.3 Scale 14
   2.4 Approach 15
   2.5 Type and level of land suitability classification 16
      2.5.1 Type of classification 16
      2.5.2 Levels of classification 17

3. PROCEDURES 20
   3.1 Initial consultations 20
   3.2 Land use 20
      3.2.1 Major kinds of land use 20
      3.2.2 Land utilisation types 21
      3.2.3 Crop combinations 24
   3.3 Land resources data 29
      3.3.1 The Land Resources map 29
      3.3.2 Land qualities and land characteristics 29
   3.4 Land use requirements 33
      3.4.1 Crop requirements 33
      3.4.2 Evaluation for major kinds of land use other than rainfed agriculture 37
3.4.3 Treatment of soil erosion hazard 38

3.5 Comparison of land use with land 39
3.5.1 Matching of land use with land 39
3.5.2 Environmental impact 44
3.5.3 Economic and social analysis 44

3.6 Presentation of results 46

3.7 Future activities in land evaluation 47
3.7.1 Linking socio-economic data with physical land evaluation 47
3.7.2 Automated data handling 49
3.7.3 Land evaluation at more detailed scales 51

APPENDIX A. Erosion hazard mapping for environmental impact assessment 52

APPENDIX B. Glossary of land evaluation terms 56

REFERENCES 61

LIST OF FIGURES

1. Schematic representation of activities in land evaluation 5
2. Extract from the revised Project activities flow chart, showing stages in land evaluation 7
3. Summary structure of the land suitability classification used in the evaluation 19
4. Matching of land use with land 42
5. Suitability classification summary 43
6. Relationship between socio-economic unit and land mapping units 48
LIST OF TABLES

1.1 Procedures in land evaluation followed by the Project 8

3.1 Format for the description of rainfed crop land utilisation types 22
3.2 Initial list of crops considered 25
3.3 List of crops considered 26
3.4 Crop combinations and representative crops 28
3.5 Relationship between land qualities and land characteristics 32
3.6 Crop environmental requirements of highland maize 34
3.7 Probable reductions in yields and required levels of inputs employed to define suitability classes 40
OBJECTIVES OF LAND EVALUATION

1.1 LAND EVALUATION AND LAND USE PLANNING

Land evaluation is the process of the assessment of land performance when used for specified purpose. Although its precise role varies in different circumstances, it is always an integral part of the process of land use planning.

There are three stages to land use planning, briefly referred to as description, evaluation, and development planning.

i. Description: the survey of basic resources, which are physical (natural resource surveys), economic and social.

ii. Evaluation: the assessment of the various uses to which the resources can be put, and the consequences which can result from each alternative use.

iii. Development planning: making plans to put the chosen kinds of land use into operation, together with their implementation.

Within each of these stages three kinds of activities may broadly be distinguished:

a. Activities related mainly to land use.
b. Activities related mainly to land.
c. Activities involving relations between land use and land.

The function of land use planning is to guide decisions on land use in such a way that the environmental resources of the land are put to the most beneficial use, whilst at the same time conserving those resources for the future. The value of land evaluation within the land use planning process is twofold:

a. To bring about an understanding of the relationships between given areas of land and specified land uses.
b. To present land use planners with comparisons of the most promising kinds of land use.
Land evaluation involves the interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative kinds of land use. These may be major kinds of land use such as rainfed agriculture, livestock production, forestry, etc., or land utilisation types described in more detail, for example, individual rainfed crops such as tef or coffee.

The suitability of the land is assessed, classified and presented for each kind of use. To be of assistance in land use planning the ranges of land uses considered have to be limited to those that are relevant within the physical, economic and social contexts of the area considered, and so the comparison must involve economic considerations. The essential output of land evaluation, which is incorporated into the land use planning activities, is usually given as descriptions of land utilisation types and as suitability maps showing the suitability of each area of land for each defined kind of use.
1.2 LAND EVALUATION IN RELATION TO PROJECT ACTIVITIES

Land evaluation occupies a central and co-ordinating position within the project. It provides the means by which the basic surveys of natural resources---geomorphology, climate, soils and vegetation---are assessed with respect to their potential for different kinds of land use, both actual and potential. This assessment is linked in turn with economic and social analysis. The project studies of existing kinds of land use and rural economy---agricultural systems, livestock production and forestry---have also in part made contributions to the land evaluation. Thus the land evaluation has been the process through which the basic surveys of resources have been translated into potential for development. The output from the evaluation provides a major basis for land use planning at the national level.

More specifically, the major objectives of the land evaluation stage of the Project are:

i. The identification and description of a series of land utilisation types, or different kinds of land use, which are relevant for consideration in Ethiopia.

ii. The assessment of the suitabilities of mapped land areas of the country for each of a number of different uses. These uses are primarily rainfed crop production, but also livestock production forestry, and conservation.

iii. Description of the management requirements and recommendations for these land utilisation types.
In its simplest form, land evaluation can be considered as the comparison between land use and land, the result being the suitability of each mapped area of land for each defined kind of land use.

In slightly more detail, the basic steps are shown in Fig. 1. In the stage of initial consultations, the objectives of the evaluation are determined, basic assumptions are decided upon, and the evaluation activities are planned. This leads to two sets of activities, related to land use and to land resources respectively.

The land use activities (left-hand side of Fig. 1) commence with identification of kinds of land use relevant for consideration. This is followed by assessment of their requirements and limitations, that is, the environmental conditions which are favourable or adverse to these kinds of use.

The land resource activities (right-hand side of Fig. 1) begin with the mapping of basic resources: geomorphology, climate, soils and vegetation. For each of the resulting mapping units on a map of land resources, certain features to be used in suitability evaluation, called land qualities and land characteristics, are extracted.

These two sets of activities are brought together in the comparison of land use with land. This leads to land suitability classification, and to the preparation and presentation of the results of the evaluation.
Fig. 1

SCHEMATIC REPRESENTATION OF ACTIVITIES IN LAND EVALUATION.

Initial consultations
a. objectives
b. data and assumptions
c. planning of the evaluation

Kinds of land use
Major kinds of land use or land utilization types

Land use requirements and limitations

Comparison of land use with land
a. matching
b. economic and social analysis
c. environmental impact assessment
d. field check

Resource surveys
Land mapping units

Land characteristics and land qualities

Land suitability classification

Presentation of results

Land improvements

The way in which these basic procedures were put into operation in the present project is illustrated in Fig. 2 and Table 1.1. It should be noted that in Fig. 2, the basic procedures of Fig. 1 have been turned on their side; the time element, which in Fig. 1 is down the page, in Fig. 2 is from left to right. 'Identification and delimitation of the main physical regions' represents the basic resource surveys; 'identification and description of present and potential land utilisation types' represents the kinds of land use, and 'establishment of the physical criteria...' the land use requirements.

The two final arrows in the sequence of activities on Fig. 2 are shown broken. For reasons explained in Section 3.5.3, it was not possible fully to incorporate economic suitability classification into Phase I of the project. The main output from the land evaluation is the 'qualitative characterisation of suitabilities...', or qualitative land suitability classification. The related economic activities are separately reported (Technical Report 8). In more detailed studies to follow, economic and social analysis will be more fully incorporated into the evaluation.

In Table 1.1 these activities have been arranged into those preceding field survey, or the planning phase, the main phase of field survey- and the phase of analysis and preparation of results.
Identification and delimitation of the main physical regions, based on climate, geomorphology, soils, etc. (land mapping units).

Determination of the land characteristics and/or qualities of the physical regions (land qualities).

Assessment of environmental impact.

Qualitative characterisation of suitabilities of the physical regions for present and potential land utilisation types and thus characterisation of the main agroecological zones (qualitative land suitability classification).

Establishment of the physical criteria for present and potential land utilisation types (land use requirements and limitations).

Economic suitability classification of all or some of the present and potential land utilisation types in relation to the agroecological zones (economic suitability classification).

Establishment of economic, social and demographic criteria for present and potential land utilisation types.

Identification and description of present and potential land utilisation types relevant for consideration kinds of land use.

Land development planning.
Table 1.1 Procedures in land evaluation followed by the Project

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activities related to land use</th>
<th>General activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Land utilisation types to be considered; data needed for assessment for land utilisation types</td>
<td>Initial objectives; context of the study area; planning of the evaluation.</td>
</tr>
<tr>
<td>Field survey</td>
<td>Study of present and possible future land utilisation types; requirements and limitation of land utilisation types. Modifications to land utilisation types, if necessary.</td>
<td>Interim reviews, including matching; comparison of land use with land-matching, field check, socio-economic analysis, environmental impact assessment; final stage of matching.</td>
</tr>
<tr>
<td>Results</td>
<td>Land utilisation types; descriptions, input produce relations; management specifications.</td>
<td>Land suitability classification; preparation of results, tabular legends, maps of land suitability, report, cartography and presentation of results.</td>
</tr>
<tr>
<td>Post evaluation</td>
<td>Applications of the results to land use planning and land management.</td>
<td></td>
</tr>
</tbody>
</table>
1.3 INTRODUCTION TO THE LAND EVALUATION REPORT

1.3.1 The four parts of the report

This report on the activities and outputs of the land evaluation is presented in four parts.

Part One describes the procedures employed in the evaluation. It is shown how the basic principles and procedures of land evaluation have been adapted to the requirements and circumstances of the reconnaissance-level survey of Ethiopia. This Part has two purposes: (i) to describe for users of the evaluation the techniques on which it has been based, (ii) to serve as a guide for future land evaluation activities in Ethiopia.

Part Two describes what was a major element in the evaluation, the determination of crop environmental requirements. The means by which the crop requirements were assessed, in terms of the data available from the basic resource surveys, are given. This serves similar purposes to Part One, with special reference to crop requirements.

Part Three presents the first of the major outputs from the evaluation, consisting of three elements:

i. Descriptions of a series of land utilisation types, or kinds of land use considered for potential development.

ii. The environmental and other requirements of these land utilisation types.

iii. Management specifications for the land utilisation types.

This Part serves as a major basis for land use planning, indicating to planners the conditions which need to be fulfilled for the successful operation of each kind of land use. It also provides agricultural and other extension services with a compact summary of recommended management practices for each crop.

Part Four presents the second major output, the series of land suitability maps. This shows the areas in Ethiopia which are highly suitable, suitable, and not suitable for the range of land utilisation types considered. This serves as a second major basis for land use planning, indicating areas in which different kinds of development may be appropriate.
1.3.2 **Introduction to Part One**

The principles and procedures employed in the project are based on those outlined in three publications: the 'Framework for land evaluation' (FAO, 1976); chapters 8 and 10 of 'Soil survey and land evaluation' (Dent and Young, 1981); and part of the text, available to the project in draft form, of the forthcoming 'Guidelines on land evaluation for rainfed agriculture' (FAO, in the press).

It would be superfluous to repeat the principles and procedures given in the above sources. Nevertheless, some brief account of these is necessary as a basis for understanding the outputs from the present evaluation. The general form of Part One of this report is therefore to outline very briefly each stage or activity, followed by a description of how the basic procedures were adapted to the circumstances prevailing in the current survey.

Chapter 2 describes the application of the basic principles of land evaluation to the present survey of Ethiopia. Chapter 3 gives an account of adaptations of the various procedures, leading to the preparation of results. Note that the results themselves are given in parts Three and Four. Chapter 4 shows how the results of the evaluation can be applied to land use planning, and in addition contains a short discussion of future evaluation activities required. Chapter 6 is a summary of the output from the evaluation, together with recommendations. A glossary of standard terms relating to land evaluation and used by this Project is included at the end of this Part.
CHAPTER 2

PRINCIPLES AND APPROACHES

2.1 MAIN CIRCUMSTANCES OF THE EVALUATION

A combination of circumstances dominates the nature of the present land evaluation, affecting both the methods employed and the nature of the results. These circumstances are:

- the large size of the country, \(1,220,000 \text{ km}^2\)
- the paucity of previous information on the land resources
- the requirement, for planning purposes, to obtain results in a short space of time.

Taken together, these led to the necessity to conduct the evaluation on a small mapping scale, the basic resource maps being on \(1:1,000,000\). Correspondingly, the results are necessarily in very generalised terms. Further studies at more detailed scales are essential prior to implementation of land developments at the local level.

Ways in which these dominant features of the evaluation have influenced the methods employed are considered further below.

2.2 PRINCIPLES

Land suitability evaluation is based on six principles. The following is a statement of these, giving in each case first, the principle as stated in the 'Framework for land evaluation' (FAO, 1976), and secondly, how the principle is applicable to circumstances of the present survey.

1. Land suitability is assessed and classified with respect to specified kinds of use. This principle recognises that different kinds of land use have different requirements. The land itself and the land use are equally fundamental to land suitability evaluation.

The specified kinds of use considered in the present survey are primarily 42 selected crops (section 3.2.2). In addition, livestock
production, forestry, soil conservation and wildlife conservation are considered, although not in every case by the same methods. The environmental requirements are assessed individually for each of the different kinds of land use.

ii. Evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land. Suitability for each use is assessed by comparing the required input, such as labour, fertiliser and improved seeds, with the goods produced.

This principle could only be applied to the present survey to a limited extent, and in a qualitative manner. This is a consequence of the small scale of the survey, which meant that precise require requirements of land utilisation types (Part Two) do indeed give estimates of both inputs (fertiliser requirements types of seed, etc.) and output (crop yield estimates, etc.). But it is recognised that these are in generalised terms only, and not at this scale sufficiently precise to form the basis for input/output analysis. Inputs required have been used in assessing land use requirements and hence land suitabilities. Specifically, requirements were assessed for three levels of inputs: low, intermediate and high. In practice, it was rarely possible to differentiate between the requirements of the low and intermediate input levels.

iii. A multidisciplinary approach is required. The evaluation process requires contributions from the fields of natural science, the technology of land use, economics and sociology. It follows that a team carrying out an evaluation requires a range of expertise.

The present survey incorporates contributions from all of the disciplines employed on the project, namely geomorphology, soil science, agroclimatologia, agroecology (vegetation, land use and agricultural, livestock production, forestry, economics, and sociology, in addition to the discipline of land evaluation itself.
iv. Evaluation is made in terms relevant to the physical, economic and social context of the area concerned.

The physical context of Ethiopia is extensively described in other Technical Reports. Considered with respect to the African continent as a whole, it is in some respects unusual. Where as the Ethiopian lowlands are typical of large areas of the African Sahel belt, the highlands possess a highly distinctive assemblage of physical features, found elsewhere in only extremely small areas of Africa or, for that matter, the world. High altitude, volcanic rock often basic in composition, the soils associated with such rocks, particularly Nitosols and Vertisols, and the (for the most parts potentially) montane forest vegetation are the major distinctive features of these highlands. A consequence is that some crops are grown which are little found in other countries, most notably tef and enset. Another consequence is that crop environmental requirements had in most cases to be assessed ab initio, there being no comparable environments in which previous studies had been carried out.

The economic and social context is also distinctive. Ethiopia belongs to the group of least developed, or poorest, countries in the world, those with a mean per capita income of under $200. Socially, there are two outstanding features: a traditional very complex social system, inherited from the past, overlain by the modern structure dating from the post-Revolutionary period, the dominant rural feature of which is the organisation of nearly all the rural population into Peasant Associations. These economic and social features were taken as the basis for land utilisation type descriptions.

v. Suitability refers to use on a sustained basis. The aspect of environmental degradation is taken into account when assessing suitability. This principle does not require that the environment should be preserved in a completely unaltered state. What is required is that the probable consequences of a proposed land use for the environment should be assessed as accurately as possible.
This principle is of the highest importance in the context of Ethiopia. The country has one of the most severe problems of soil erosion of any nation in the world. To combat this problem is recognised by the Government as an urgent development priority. In the land evaluation, the existence of this situation has been applied in two ways, negative and positive. Negative, in that hazard of soil erosion formed an important land quality in the determination of suitabilities for productive use. Positive, in that areas in need of protective forestry or other environmental protection were taken as a land utilisation type, and mapped, the interpretation of 'suitable' in this context being in need of protection.

vi. Evaluation involves the comparison of more than one kind of use. Evaluation is only reliable if benefits and inputs from any kind of use can be compared with at least one, and usually several, different alternatives.

A very wide range of alternative uses was considered in the present evaluation: 42 crops, selected from an initial list of 102, together with 4 other kinds of land use.

2.3 SCALE

There are four ranges of mapping scale at which the land evaluation and overall land use planning procedures are carried out:

i. Rapid reconnaissance - at scales of 1:1 000 000 to 1:2 000 000

ii. Reconnaissance - at a typical scale of 1:250 000, sometimes 1:500 000, used to locate approximately development projects

iii. Semi-detailed - at 1:50 000 to locate precisely the boundaries of farming projects and to provide a basis for settlement planning, used particularly in feasibility studies

iv. Detailed - usually at 1:20 000 or 1:25 000, required for implementation of land use planning, e.g. to provide detailed farm layouts and conservation works.
The circumstances of the present project, as outlined in Section 2.1, dictated that the evaluation should be at the rapid reconnaissance scale. The basic Land Resources map is on a scale of 1:1 000 000, which was, therefore, the most detailed scale to which national coverage in evaluation terms could be achieved. To have attempted at even the scale most commonly used in reconnaissance surveys, 1:250 000, would have required approximately 16 times the number of men-years available.

For brevity "rapid reconnaissance" is abbreviated to "reconnaissance" in the rest of the report.

2.4 APPROACH

As the survey scale can vary so also can the methods of relating the resource surveys to economic and social analysis. In the two-stage approach, evaluation is first carried out in physical terms and the results are then subjected to economic and social analysis. In the parallel approach, physical and economic analysis proceed concurrently, leading to a single combined set of results. The two-stage approach is more straightforward and is preferable in surveys involving a wide range of uses and types of land.

In the flow-chart of project activities (Fig. 2) it was envisaged that initial physical suitability analysis would be followed by economic and social analysis, that is, that the two-stage approach would be followed. In practice, two major difficulties prevented this aim from being achieved. The first is the simple fact that in the two-stage approach, the results of stage one are needed as a starting-point for stage two, since the results of physical suitability evaluation did not become available until the end of Phase I of the project, it was impossible for economic analysis directly to build upon these results. The second reason is that full integration of economic with physical analysis is impossible at the reconnaissance scale; physical data are obtained for land units bounded by natural boundaries (e.g. landforms), whilst economic data are available for administrative units.

Thus the major output from the land evaluation is in physical terms only, i.e. in the output from stage one of the two-stage approach. However, a large volume of economic and social data required for land use planning on a
national scale was collected concurrently with the evaluation, and is available as a further output from the project (Technical Reports 8 and 9). This economic and social data should be used alongside the land evaluation when implementing land use planning. It may thus be said that in one sense, a form of parallel approach has in practice been followed, although without the full integration which is normally implied by this approach. This aspect is discussed further in Section 3.7.1.

2.5 TYPE AND LEVEL OF LAND SUITABILITY CLASSIFICATION

2.5.1 Type of classification

The results of land evaluation are given in terms that are qualitative, quantitative physical or economic. A qualitative evaluation is one in which the suitability of land for alternative purposes is expressed in qualitative terms only, such as highly, moderately or marginally suitable, or not suitable for a specified use. Economic considerations are present as a background only and there are no calculations based on specific costs and prices. A quantitative physical evaluation is one that provides quantitative estimates of the production or other benefits to be expected, and is most frequently carried out as the basis for economic evaluation. An economic evaluation is one that includes results given in terms of profit and loss, for each specific enterprise on each kind of land. Boundaries between land suitability classes are defined in economic terms. Economic land evaluation is always required for project appraisals and feasibility studies and must precede decisions to invest in land development schemes.

This project uses qualitative land suitability classification. The suitability classes are defined in general terms, without precise calculations either of physical input/output relations or of costs and returns. Estimates are given, however, in general terms both of inputs required and of crop yields. Moreover, it is in general terms the case that areas mapped as suitable for a given kind of land use can be expected to show an economic profit under that use. Such calculations should be conducted, however, prior to implementation.

It should be emphasised that the description 'qualitative' refers to the manner of definition of suitability classes, and not the methods employed in the evaluation. At all stages, these methods have been quantitative, to the extent that the data available on the scale of the survey permitted.
2.5.2 **Levels of classification**

There are four categories, or levels of classification, recognized in land evaluation: suitability orders, classes, subclasses and units.

Suitability orders separate land assessed as suitable (S) from that which is not suitable (N) for the use being considered. Suitable land is that on which sustained use of the kind under consideration is expected to yield benefits which justify the inputs, without unacceptable risk of damage to land resources.

Suitability classes indicate degrees of suitability. Within the order suitable (S) it is usual to recognize three classes, 'highly', 'moderately' and 'marginally' suitable. In this evaluation only two classes have been recognized, with the classes 'moderately' and 'marginally' suitable combined in the class S2, because the data are insufficient and the time and effort required do not justify the separate classification of marginally suitable land. Highly suitable (S1) land is that which has no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level. Moderately to marginally suitable (S2) land is that which has limitations which, on aggregate, are moderately severe for sustained production of a given use.

Within the order not suitable (N) two classes are recognized in more detailed surveys. N1, indicating 'currently not suitable', refers to land on which the use under consideration is technically possible but not economic. Changes in the relative prices of the product and inputs, or advances in technology, can result in upgrading of N1 land into S3 or S2 land. N2 land 'permanently not suitable', is that which is unlikely to be viable for the use, whatever the changes in technical or economic consideration. The use of the class N1, however, requires calculation of costs and returns, since the upper boundary of N1 land is that at which a profit is achieved. Hence in the present survey, the order not suitable (N) is not subdivided into classes.
Thus in summary, three suitability classes have been employed:

S1 Highly suitable
The best land for the specified kind of land use. The crop is expected to grow well, and to yield an economic return.

S2 Moderately to marginally suitable
Land on which the specified kind of use can be practised. Although less well suited than S1 land, the crop should grow satisfactorily and yield a positive economic return. Note that areas of land marginal for the use are included in S2.

N Not suitable
Land on which the specified kind of use is not recommended, either because the crop would not grow satisfactorily, such that a economic loss would be expected, or because there would be unacceptable environmental damage.

Land suitability classes reflect kinds of limitations, e.g. moisture deficiency, temperature limitation, erosion hazard. Subclasses are indicated by lower-case letters with mnemonic significance, e.g. S2m, Nta. There are no subclasses in class S1. The subclasses used in this evaluation are:

- d drainage deficiency
- e erosion hazard
- m moisture deficiency
- n nutrient deficiency
- p management limitation
- r rooting condition deficiency
- t temperature limitation
- x toxicity limitation

The number of subclass letters has been kept to not more than two for any suitability evaluation, and then only when two limitations are considered to be equally severe two letters have been used.

Suitability units are divisions of subclasses that differ from each other in detailed production characteristics or management requirements. They are
numbered successively, e.g. S2d-1, S2d-2. Suitability units are not employed in reconnaissance evaluations, and thus not in the present survey. They should be distinguished in detailed surveys preceding implementation, at which level they form the basic units for farm planning and management.

A summary of the suitability classification employed is given in Fig.3.

Figure 3.

SUMMARY STRUCTURE OF THE LAND SUITABILITY CLASSIFICATION USED IN THE EVALUATION

<table>
<thead>
<tr>
<th>order</th>
<th>category class</th>
<th>subclass</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. Suitable</td>
<td>S1</td>
<td>S2d</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>S2e</td>
</tr>
<tr>
<td></td>
<td>S2m</td>
<td>S2n</td>
</tr>
<tr>
<td></td>
<td>S2p</td>
<td>S2r</td>
</tr>
<tr>
<td></td>
<td>S2t</td>
<td>S2x</td>
</tr>
<tr>
<td>N. Not suitable</td>
<td>N</td>
<td>Nd</td>
</tr>
<tr>
<td></td>
<td>Ne</td>
<td>Nn</td>
</tr>
<tr>
<td></td>
<td>Np</td>
<td>Nr</td>
</tr>
<tr>
<td></td>
<td>Nt</td>
<td>Nx</td>
</tr>
</tbody>
</table>
CHAPTER 3

PROCEDURES

3.1 INITIAL CONSULTATIONS

The initial consultations to define the land evaluation objectives were carried out prior to the commencement of the technical input into the project, with the objectives being as stated in the project document. In particular the project aims at contributing to the improvement in the conservation and rational use of vegetation, soil and water resources to ensure a permanent productive agriculture and an increasing food supply for the Ethiopian people.

To achieve this objective it was accepted that a general purpose rapid reconnaissance qualitative evaluation would be undertaken, to assess the suitability of each land unit throughout the country for all relevant forms of land use, both existing and new forms. The evaluation undertaken is a two-stage one of current land suitability for each of two input levels, termed low and medium, and of potential land suitability for one high input level, where it is envisaged that certain major land improvements can be completed. The environmental information utilised in the evaluation is that prepared by the land resources sections of the Project, similarly the economic and social contexts are considered by the economics and sociology sections.

Some major features of the economic and social context have been noted under 2.2.iv above. One particular feature of the social context supplies a basic assumption underlying under the evaluation. This is that land use planning will take place mainly within the framework of Peasant Associations producer cooperatives and State Farms. This was employed as the underlying assumption in the descriptions of land utilisation types.

3.2 LAND USE

3.2.1 Major kind of land use

Suitability evaluation involves relating land mapping units to specific kinds of land use. The kinds of land use that serve as the subject of any land evaluation are limited to those that appear to be relevant under the general physical, economic and social conditions that prevail in the study area.
The specific types of land use may be major kind of land use or land utilisation types. Major kinds of land use are broad divisions such as rainfed agriculture, forestry or livestock production. Land utilisation types are kinds of use described in greater detail. In land evaluation procedures the land utilisation types play a balancing role to that of land mapping units. The land utilisation types can be described in as much detail as the land evaluation requires.

The major kinds of land use being considered by the Project were broadly specified at the commencement, and were subject to some modifications and adjustments as the evaluation proceeded. The major kinds of land use that have been considered are:

- rainfed agriculture
- irrigated agriculture
- livestock production
- forestry
- wildlife conservation

Within these major kinds of land use the largest proportion of the evaluation effort has been directed towards rainfed agriculture. This is because of the predominance of this major kind of land use throughout the well populated Ethiopian highlands, and because most agricultural improvements are envisaged as being directed towards rainfed agriculture.

3.2.2 Land utilisation types

In this Project, the land utilisation types have been taken to be equivalent to one rainfed crop, or one of the small number of livestock, irrigation or wildlife kinds of land use. It should be noted that the descriptions refer not to a crop considered in isolation, but to a specified crop grown within a stated economic and social context, e.g. maize grown by Peasant Associations (low to medium inputs), or maize grown on State Farms (high inputs). For the rainfed crop land utilisation types the description of their attributes has been arranged in the order given in Table 3.1.
Table 3.1  FORMAT FOR THE DESCRIPTION OF RAINFED CROP LAND UTILISATION TYPES

<table>
<thead>
<tr>
<th>CROP NAME</th>
</tr>
</thead>
</table>

**BACKGROUND DESCRIPTION**

**SETTING**

**BIOLOGY**

- Botanical name
- Common English names
- Local names
- Growth habit
- Photosynthesis characteristics
- Harvested part
- Harvest index
- Main product and uses
- Other products and uses

**CROPS GROWN IN ASSOCIATION**

**GENERAL STATEMENT ON CROPPING**

- Peasant farmers - individual holdings
- Peasant farmers' co-operatives - medium inputs
- State farms - high inputs

**CULTURAL PRACTICES**

- Recommended varieties
- Land preparation
- Planting practices
- Fertiliser application
- Weeding
- Crop protection measures
- Harvesting
YIELDS AND PRODUCTION

ENVIRONMENTAL REQUIREMENTS

VARIATIONS IN LAND CHARACTERISTICS WITH INPUT LEVELS

Low level - Peasant farmers, individual holdings
High level - State farms

NOTES ON LAND QUALITIES

SELECTED REFERENCES
Within rainfed agriculture individual crops have been considered as the basis for separate land utilisation types. Initially a list was drawn up of the majority of crops known to grow or considered as being likely to be able to be grown in the country, amounting to the 102 crops, as given in Table 3.2

Since there was insufficient time or information available to evaluate the suitability of each of these crops, the list was reduced in size at the commencement of the evaluation. The criteria used for assessing whether or not a crop would be selected for evaluation were based on the present area occupied by the crop, the total production of the crop and the potential foreseeable for those crops not yet grown in the country to any significant extent. These criteria in particular very considerably reduced the list of fruit and vegetable crops and herbs and spices. The deletions to these crops lists were also increased because little environmental information was available on the crop requirements of these crops and, being high value crops, they are frequently grown as irrigated rather than rainfed crops. Hence only three high value and high potential fruit crops, and one spice, have been included in the evaluation. By these means the overall list was reduced to a final short list of 46 crops, as in Table 3.3. Of these 46 crops, however, only 42 were used in final land suitability assessment because of time constraints.

3.2.3 Crop combinations

A final reduction in the number of rainfed crop land utilization types was made at the beginning of the matching process. The limited time available for matching demanded a reduction, and the 42 crops were combined into 20 crop combinations such that each crop combination contains crops which each have approximately similar crop environmental characteristics. Nine of the 20 combination, however, consist of only one crop. This is a result of the limited degree of overlap between the crop environmental characteristics of those treated individually and others of the 42 considered for grouping.

Within each combination one crop was identified as a representative crop, environmental requirements of which broadly characterise those needed by the remaining crops in the combination. The selection of each representative crop was based primarily on the agroclimatic requirements (i.e. length of growing period and temperature requirements) of the various crops in a particular crop combination. Topography and soil factors were only considered after first
<table>
<thead>
<tr>
<th>Cereals</th>
<th>Pulses</th>
<th>Oil crops</th>
<th>Root crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>rye</td>
<td>horse bean</td>
<td>linseed</td>
<td>white potato</td>
</tr>
<tr>
<td>barley, food</td>
<td>field pea</td>
<td>safflower</td>
<td>sugar beet</td>
</tr>
<tr>
<td>barley, malting</td>
<td>lentil</td>
<td>rape seed</td>
<td>enset</td>
</tr>
<tr>
<td>oats</td>
<td>chickpea</td>
<td>niger seed</td>
<td>taro</td>
</tr>
<tr>
<td>wheat, bread</td>
<td>grass pea</td>
<td>sunflower</td>
<td>yam</td>
</tr>
<tr>
<td>wheat, durum</td>
<td>pigeon pea</td>
<td>castor</td>
<td>sweet potato</td>
</tr>
<tr>
<td>teff</td>
<td>kidney bean</td>
<td>sesame</td>
<td>cassava</td>
</tr>
<tr>
<td>maize, highland</td>
<td>lima bean</td>
<td>groundnut</td>
<td>arrowroot</td>
</tr>
<tr>
<td>maize, lowland</td>
<td>haricot bean</td>
<td>soya bean</td>
<td></td>
</tr>
<tr>
<td>sorghum-highland</td>
<td>cow pea</td>
<td>oil palm</td>
<td></td>
</tr>
<tr>
<td>sorghum-lowland</td>
<td>mung bean</td>
<td>tung</td>
<td></td>
</tr>
<tr>
<td>finger millet</td>
<td>adzuki bean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pearl millet</td>
<td>black gram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paddy rice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibre crops</td>
<td>Fruits</td>
<td>Vegetables</td>
<td>Stimulants</td>
</tr>
<tr>
<td>cotton</td>
<td>orange</td>
<td>onion</td>
<td>coffee</td>
</tr>
<tr>
<td>sisal</td>
<td>lemon</td>
<td>lettuce</td>
<td>tea</td>
</tr>
<tr>
<td>kenaf</td>
<td>grapefruit</td>
<td>beetroot</td>
<td>tobacco</td>
</tr>
<tr>
<td>hemp</td>
<td>mandarin</td>
<td>cabbage</td>
<td>chat</td>
</tr>
<tr>
<td>kapok</td>
<td>grape</td>
<td>cauliflower</td>
<td></td>
</tr>
<tr>
<td>henequen</td>
<td>strawberry</td>
<td>brussel sprouts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>banana</td>
<td>cucumber</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pineapple</td>
<td>melon</td>
<td></td>
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<tr>
<td></td>
<td>apple</td>
<td>pumpkin</td>
<td></td>
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<tr>
<td></td>
<td>pear</td>
<td>tomato</td>
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<tr>
<td></td>
<td>avocado</td>
<td>celery</td>
<td></td>
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<tr>
<td></td>
<td>fig</td>
<td>carrot</td>
<td></td>
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<tr>
<td></td>
<td>granadilla</td>
<td>okra</td>
<td></td>
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<tr>
<td></td>
<td>mango</td>
<td>egg plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>papaya</td>
<td>bamboo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>passion fruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>guava</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>date palm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>jackfruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbs and spices</td>
<td>Other crops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>chillie pepper</td>
<td>pyrethrum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fenugreek</td>
<td>sugar cane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cardomom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ginger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tamarind</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>chicory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mustard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>black pepper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>turmeric</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>garlic</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Table 3.3 LIST OF FINAL 46 INDIVIDUAL RAINFOED CROP LAND UTILISATION TYPES

<table>
<thead>
<tr>
<th>Cereals</th>
<th>Pulses</th>
<th>Oil crops</th>
<th>Root crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>barley, food</td>
<td>horse bean</td>
<td>linseed</td>
<td>white potato</td>
</tr>
<tr>
<td>barley, malting</td>
<td>field pea</td>
<td>safflower</td>
<td>sugar beet</td>
</tr>
<tr>
<td>oats</td>
<td>lentil</td>
<td>rape seed</td>
<td>ensset</td>
</tr>
<tr>
<td>wheat, bread</td>
<td>chickpea</td>
<td>niger seed</td>
<td>taro</td>
</tr>
<tr>
<td>wheat, durum</td>
<td>grass cca</td>
<td>sunflower</td>
<td>sweet potato</td>
</tr>
<tr>
<td>tef</td>
<td>lima bean</td>
<td>sesame</td>
<td>cassava</td>
</tr>
<tr>
<td>maize, highland</td>
<td>haricot bean</td>
<td>groundnut</td>
<td></td>
</tr>
<tr>
<td>maize, lowland</td>
<td>cow pea</td>
<td>soya bean</td>
<td></td>
</tr>
<tr>
<td>sorghum, highland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sorghum, lowland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>finger millet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>paddy rice</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fibre crops</th>
<th>Fruits</th>
<th>Stimulants</th>
<th>Other crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>cotton</td>
<td>citrus</td>
<td>coffee</td>
<td>pyrethrum</td>
</tr>
<tr>
<td>sisal</td>
<td>grape</td>
<td>tea</td>
<td>chillie pepper</td>
</tr>
<tr>
<td>kenaf</td>
<td>banana</td>
<td>tobacco</td>
<td>sugar cane</td>
</tr>
</tbody>
</table>
establishing agroclimatic compatibility between crops. In any one crop group, the representative crop usually has the narrowest limits of agroclimatic suitability of all the crops included in that group. Because the crop environmental requirement tolerances of the representative crop in a particular combination are for the most part narrower than for other crops in the group, the suitability of subsidiary crops in the group to a particular land resource unit may, therefore, be somewhat wider than that indicated on the related land suitability map. In the list of crop combinations given in Table 3.4, the representative crop of each crop combination is underlined.

It should be noted that crop combination is a term of convenience referring to crops with similar environmental requirements. It does not imply that such crops should necessarily form either farming systems or mixed cropping systems. However, the fact that the crops listed in a combination can be expected to grow well in the same areas provides a favourable basis for the consideration of either farming systems or mixed cropping systems based on two or more of the crops within a combination. An additional consideration regarding farming systems concerns crops from different combinations. The fact that crops have been combined into the 20 groups indicated in Table 3.4 does not in any way exclude the possibility that individual crops from different groups can have overlapping environmental requirements sufficient to include them in a recommended cropping system in the future. This is particularly so far subsidiary crops in the different combinations because of their often wider tolerances in environmental requirements than those established for the representative crops. Such possibilities are beyond the scope of this document but should be examined on a case by case basis using the data in parts 2 and 3 of this report and Technical Report No. 2. Further study of suitable farming systems or mixed cropping systems will be of considerable importance when more detailed, particularly farm level, land use planning is required in the future.
### Table 3.4 CROP COMBINATIONS AND REPRESENTATIVE CROPS

<table>
<thead>
<tr>
<th></th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Barley, food oats horse bean white potato</td>
</tr>
<tr>
<td>2.</td>
<td>Wheat, bread wheat durum sugar beet</td>
</tr>
<tr>
<td>3.</td>
<td>Tef</td>
</tr>
<tr>
<td>4.</td>
<td>Enset</td>
</tr>
<tr>
<td>5.</td>
<td>Sorghum, highland maize highland grape</td>
</tr>
<tr>
<td>6.</td>
<td>Coffee</td>
</tr>
<tr>
<td>7.</td>
<td>Banana</td>
</tr>
<tr>
<td>8.</td>
<td>Sorghum, lowland maize lowland lima bean</td>
</tr>
<tr>
<td>9.</td>
<td>Finger millet</td>
</tr>
<tr>
<td>10.</td>
<td>Groundnut sesame</td>
</tr>
<tr>
<td>11.</td>
<td>Cotton</td>
</tr>
<tr>
<td>12.</td>
<td>Sugar cane</td>
</tr>
<tr>
<td>13.</td>
<td>Barley, malting rape seed</td>
</tr>
<tr>
<td>14.</td>
<td>Soya bean cow pea chilli pepper kenaf</td>
</tr>
<tr>
<td>15.</td>
<td>Pyrethrum</td>
</tr>
<tr>
<td>16.</td>
<td>Tea</td>
</tr>
<tr>
<td>17.</td>
<td>Tobacco sisal sweet potato</td>
</tr>
<tr>
<td>18.</td>
<td>Chick pea lentil field pea grass pea</td>
</tr>
<tr>
<td>19.</td>
<td>Niger seed safflower sunflower</td>
</tr>
</tbody>
</table>

**Note** First mentioned, underlined crops are those representative of the crop environmental requirements of respective combinations.
3.3 LAND RESOURCES DATA

3.3.1 The Land Resources map

The basic land resources data employed for evaluation are those produced by the Project itself, and described in other technical reports and field documents. The resources data are brought together in the Land Resources map at 1:1 000 000 scale. This map combines information on geomorphology, soils and climate, in the case of climate including both thermal zones and lengths of growing period. Information on the environmental features of each of the large number of mapping units on the Land Resources map is given in the extended legend to the map.

In the 'Framework for land evaluation', the basic resource units are referred to as land mapping units, whilst in the more recent 'Guidelines on land evaluation for rainfed agriculture', this has been shortened to land units. The units employed as the resource basis for the present evaluation and for the mapping of the results are the land mapping units, as they are shown on the land resources map.

A simplification was adopted as an internal means of speeding up the otherwise immensely lengthy process of evaluation. On the land resources map, the soils are described in terms of soil management units. One representative soil management unit, termed the major soil management unit, and one representative thermal zone, were selected for evaluation in each land mapping unit. Composite information about the proportions of each land mapping unit is given within the land resources unit matrix tables.

3.3.2 Land qualities and land characteristics

The requirements of the given land utilisation types were next compared with the properties of the land mapping units by means of land qualities and land characteristics. Requirements can be expressed in terms of land quality is an attribute of land that acts in a distinct manner in its influence on the suitability of the land for a specific kind of use. Examples of land qualities are temperature regions, rooting conditions, degradation hazard and land preparation requirements. A land characteristic is an attribute of land that can be measured or estimated, such as mean annual rainfall, slope angle, soil texture and soil drainage class.
The distinction between land characteristics and land qualities can be illustrated by comparing slope angle, a land characteristic, with degradation hazard, a land quality, in the lists below. Slope angle is a single and measurable attribute of land and is thus a land characteristic. Degradation hazard is an attribute of land that has an identifiable and distinctive effect on land use and is thus a land quality. It is influenced by at least six land characteristics, including slope angle, rainfall intensity and soil texture and the quality of degradation hazard results from the interaction of these characteristics.

The advantages of using land qualities are that they are fewer in number, they direct attention to the effect on the land use and they take account of interactions between environmental factors. The main disadvantage is that of greater complexity, in that they require an intervening stage of converting characteristics into qualities.

The advantage of using land characteristics as a basis for land evaluation is that they are simple to use, permitting a direct link between the observed value of the characteristic and the suitability rating. Disadvantages are the very large number of land characteristics (Young, 1980 (a), lists 110 land characteristics that could be used in the assessment of land suitability for rainfed agriculture alone), the fact that it is not always clear which effect on the land use is being assessed and, most importantly, the failure to take account of interactions between different characteristics, as shown in the example of degradation hazard.

This Project has taken land qualities as the basis for the evaluation and has matched the land use requirements against nine land qualities, namely:

- temperature regime
- growing period and moisture availability
- drainage
- degradation hazard
- inherent nutrient status and nutrient retention
- rooting conditions
- toxicities
- land preparation requirements and potential for mechanisation and workability
- pests and diseases.
Land qualities are measured or estimated by means of land characteristics. Given the scale and extent of the present survey, straightforward methods of assessment were necessary. The land characteristics and their units of measurement used to assess the value of the land qualities, either single or in groups, were:

- mean temperature for the growing period (°C)
- calendar months with possible occurrence of frost hazard (months)
- length of growing period (days)
- rainfall during growing period (mm)
- slope angle (%)
- effective soil depth (cm)
- soil drainage (class)
- soil texture (class)
- soil reaction (pH)
- organic matter (%)
- soil unit (FAO - unit)
- stones and rock outcrops (%)
- electrical conductivity of saturation extract (mmhos/cm)
- exchangeable sodium percentage (%)

Table 3.5 is a summary of the land qualities employed to assess suitability, and the land characteristics used to measure or estimate each land quality. Where, as in most cases, more than one characteristic was used to assess a quality, the value of the least favourable (most limiting) characteristic was used to assess the quality. For example, rooting conditions were determined as whichever was the least favourable out of effective soil depth, soil texture, and stoniness.
Table 3.5  RELATIONSHIP BETWEEN LAND QUALITIES AND LAND CHARACTERISTICS

<table>
<thead>
<tr>
<th>Land quality</th>
<th>Land characteristics used to assess the land quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature regime</td>
<td>a. Calendar months with possible occurrence of frost</td>
</tr>
<tr>
<td></td>
<td>b. Mean temperature for growing period</td>
</tr>
<tr>
<td>Growing period</td>
<td>Length of growing period</td>
</tr>
<tr>
<td>Drainage</td>
<td>Soil drainage</td>
</tr>
<tr>
<td>Degradation hazard 1/</td>
<td>a. Slope angle</td>
</tr>
<tr>
<td></td>
<td>b. Mean temperature for growing period</td>
</tr>
<tr>
<td></td>
<td>c. Length of growing period</td>
</tr>
<tr>
<td></td>
<td>d. Soil texture</td>
</tr>
<tr>
<td></td>
<td>e. Soil unit</td>
</tr>
<tr>
<td></td>
<td>f. Stoniness</td>
</tr>
<tr>
<td>Inherent nutrient status and nutrient retention</td>
<td>a. Soil texture</td>
</tr>
<tr>
<td></td>
<td>b. Reaction (pH)</td>
</tr>
<tr>
<td>Rooting conditions</td>
<td>a. Effective soil depth</td>
</tr>
<tr>
<td></td>
<td>b. Soil texture</td>
</tr>
<tr>
<td></td>
<td>c. Stoniness</td>
</tr>
<tr>
<td>Toxicity</td>
<td>a. Salinity</td>
</tr>
<tr>
<td></td>
<td>b. Alkalinity</td>
</tr>
<tr>
<td>Land preparation requirements, potential for</td>
<td>a. Slope angle</td>
</tr>
<tr>
<td>mechanisation and workability</td>
<td>b. Stoniness</td>
</tr>
<tr>
<td></td>
<td>c. Soil texture</td>
</tr>
<tr>
<td>Pests and diseases in specific environments</td>
<td>a. Pests</td>
</tr>
<tr>
<td></td>
<td>b. Diseases</td>
</tr>
</tbody>
</table>

1/ Although initially assessed by means of the individual characteristics listed, degradation hazard was subsequently assessed through calculation of expected soil losses, see Section 3.4.3 and also Part Four of this report.
3.4 LAND USE REQUIREMENTS

3.4.1 Crop requirements

The next stage, the most critical stage in land evaluation, was to determine the land use requirements, that is, the environmental conditions favourable or adverse to each of the defined land utilisation types. This stage can be resolved into three components; the requirements of individual rainfed crops, the requirements of other major kinds of land use, and the manner of treatment of soil erosion hazard.

The determination of crop environmental requirements formed the most important element. A highly experienced consultant was employed for this purpose, who brought to the evaluation the experience of many years' work for the Ethiopian Institute of Agricultural Research. As a consequence, a collection and synthesis of information of the highest value has been achieved. The methods employed are detailed in Part Two of this report, and the environmental requirements of each crop, together with the descriptions of the land utilisation types, are given in Part Three.

In summary, environmental requirements at low to medium input levels were determined individually for each of the 46 selected crops. These requirements are listed in terms of land qualities, together with ranges of suitability for the land characteristics used to assess each quality. As an example of the format for crop requirements, the requirements of highland maize are given in Table 3.6.

The full tables of crop requirements, as given in Part Three of this report, form the 'land use' basis for subsequent comparison with the land resource units.
<table>
<thead>
<tr>
<th>No.</th>
<th>LAND QUALITY</th>
<th>LAND CHARACTERISTICS</th>
<th>UNIT</th>
<th>RANGES OF SUITABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TEMPERATURE</td>
<td>Altitude</td>
<td>m</td>
<td>SI Highly suitable: 1300 - 2200</td>
</tr>
<tr>
<td></td>
<td>REGIME</td>
<td></td>
<td></td>
<td>Ranges: 1000 - 1300, 2200 - 2400, &gt; 2400</td>
</tr>
<tr>
<td>1</td>
<td>TEMPERATURE</td>
<td>Mean temperature</td>
<td>°C</td>
<td>SI Moderately to marginally suitable: 17.5 - 22.5</td>
</tr>
<tr>
<td></td>
<td>REGIME</td>
<td>for growing period</td>
<td></td>
<td>Ranges: 15.0 - 17.5, 22.5 - 25.0, &gt; 25.0</td>
</tr>
<tr>
<td>1</td>
<td>TEMPERATURE</td>
<td>Calender months with</td>
<td>months</td>
<td>SI Not suitable: none</td>
</tr>
<tr>
<td></td>
<td>REGIME</td>
<td>possible occurrence</td>
<td></td>
<td>Ranges: frost in any month</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of frost hazard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>GROWING PERIOD</td>
<td>Length of growing</td>
<td>days</td>
<td>SI Highly suitable: 150 - 210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>period</td>
<td></td>
<td>Ranges: 120 - 150, &lt; 120</td>
</tr>
<tr>
<td>3</td>
<td>MOISTURE</td>
<td>Rainfall during</td>
<td>mm</td>
<td>SI Highly suitable: 700 - 1200</td>
</tr>
<tr>
<td></td>
<td>AVAILABILITY</td>
<td>growing period</td>
<td></td>
<td>Ranges: 600 - 700, 1200 - 1500, &gt; 1500</td>
</tr>
<tr>
<td>4</td>
<td>DRAINAGE</td>
<td>Soil drainage</td>
<td>class</td>
<td>SI Highly suitable: MW - W</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ranges: I, VP - P, SE, E</td>
</tr>
<tr>
<td>5</td>
<td>NUTRIENT STATUS</td>
<td>Soil texture</td>
<td>class</td>
<td>SI Highly suitable: L - SC</td>
</tr>
<tr>
<td></td>
<td>AND RETENTION</td>
<td></td>
<td></td>
<td>Ranges: LS - SL, SiC - C (rd), C (bl)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organic matter</td>
<td>%</td>
<td>SI Highly suitable: 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ranges: 1 - 3, &lt; 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil reaction</td>
<td>pH</td>
<td>SI Highly suitable: 5.5 - 6.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ranges: 5.0 - 5.5, 6.7 - 8.0, &gt; 8.0</td>
</tr>
</tbody>
</table>
### TABLE 3.6 (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>LAND QUALITY</th>
<th>LAND CHARACTERISTICS</th>
<th>UNIT</th>
<th>S1 Highly suitable</th>
<th>S2 Moderately to marginally suitable</th>
<th>N Not suitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>ROOTING CONDITIONS AND WORKABILITY</td>
<td>Effective soil depth</td>
<td>cm</td>
<td>100</td>
<td>50 - 100</td>
<td>&lt; 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil texture</td>
<td>class</td>
<td>L - SC</td>
<td>LS - SL</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SiC - C (rd)</td>
<td>C (b1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil structure</td>
<td>class</td>
<td>ACr, AGr, FB1 - MB1, FPr, FCo</td>
<td>CB1, MPr, MCo, FP1</td>
<td>CPr, CCo, MPL - CPl, Mas, Inc</td>
</tr>
<tr>
<td>7</td>
<td>TOXICITIES</td>
<td>Electrical conductivity of saturation extract</td>
<td>mmhos/cm</td>
<td>0 - 4</td>
<td>4 - 6</td>
<td>&gt; 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other limiting toxicities or deficiencies</td>
<td>ESP %, CaCO₃%</td>
<td>15</td>
<td>15 - 25</td>
<td>&gt; 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>15 - 30</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>8</td>
<td>DEGRADATION HAZARD</td>
<td>Slope angle</td>
<td>%</td>
<td>0 - 8</td>
<td>8 - 30</td>
<td>&gt; 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean temperature for growing period</td>
<td>°C</td>
<td>17.5 - 22.5</td>
<td>15.0 - 17.5</td>
<td>&lt; 15.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22.5 - 25.0</td>
<td>&gt; 25.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length of growing period</td>
<td>days</td>
<td>150 - 210</td>
<td>120 - 150</td>
<td>&lt; 120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil texture</td>
<td>class</td>
<td>L - SC</td>
<td>LS - SL</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SiC - C (rd)</td>
<td>C (b1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil unit</td>
<td>unit</td>
<td>JGRTHBLANF</td>
<td>Q</td>
<td>ZVYXO</td>
</tr>
</tbody>
</table>
### TABLE 3.6 (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>LAND QUALITY</th>
<th>LAND CHARACTERISTICS</th>
<th>UNIT</th>
<th>RANGES OF SUITABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>LAND PREPARATION REQUIREMENTS AND POTENTIAL FOR MECHANIZATION</td>
<td>Slope angle</td>
<td>%</td>
<td>S1 Highly suitable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stones and rock outcrops</td>
<td>%</td>
<td>0 - 8</td>
</tr>
<tr>
<td>10</td>
<td>PESTS AND DISEASES IN SPECIFIC ENVIRONMENTS</td>
<td>Soil texture class</td>
<td>L - SC</td>
<td>LS - SL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maize stalk borer</td>
<td>1500 m</td>
<td>1500 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spotted stalk borer</td>
<td>1500 m</td>
<td>1500 m</td>
</tr>
</tbody>
</table>

OTHER INFORMATION INCLUDING KNOWN SUITABLE LOCATIONS:-
3.4.2 Evaluation for major kinds of land use other than rainfed agriculture

The major kind of land use, irrigated agriculture, was examined by a different means, use being made of a report, which selected 49 potential irrigation sites throughout the country (Halcrow/ULG, 1978). The method of selection is given in full in the report and is based on the methodological ranking of physical, infrastructural and demographic factors that affect the sites. For this evaluation of the national potential for irrigated agriculture the locations of these 49 sites were accepted as those areas suitable for irrigation.

For the evaluation of the major kind of land use, forestry, an approach was used similar to that used for rainfed crops. Forestry was subdivided into three land utilisation types, two productive or potentially productive and one protective. The areas of the country covered by remaining natural high forest were mapped as such (on the Land Cover map) and are recommended for conservation, with no further cutting until an effective forest policy is implemented (see Technical Report 7). Industrial/fuelwood forestry was evaluated as a separate land utilisation type in a manner similar to an individual crop evaluation. Thirdly, protective forestry is likewise evaluated for areas with average slopes in excess of 30%, and with other land characteristic values adequate to support tree growth. The environmental requirements of the industrial/fuelwood forestry land utilisation type and the protective forestry land utilisation type are given in tables in the background descriptions of these land utilisation types.

The major kind of land use of livestock production was evaluated for under different land utilisation types covering the highlands and the nomadic rangelands in Technical Report 6. Wildlife conservation areas have been mapped by the Wildlife Conservation Organisation, 1980, as national parks, wildlife sanctuaries and wildlife reserves, and the 23 designated areas over the country are assessed as suitable solely for wildlife conservation. Both these areas and the areas under natural high forest are recommended for no other forms of land use, on account of the diminishing 'natural undisturbed' environments left in Ethiopia.
3.4.3 Treatment of soil erosion hazard

The treatment of the land quality degradation hazard, by which is understood primarily soil erosion hazard, was the means through which environmental impact assessment was incorporated into the evaluation.

Initially, erosion hazard was assessed by means of the six land characteristics shown in Table 3.5. This assessment, however, was superseded by calculations of expected soil loss, based on the FAO methodology for soil degradation assessment (Arnoldus, 1980 and FAO, 1979). Soil loss (as tonnes per hectar per year) was first calculated partially, omitting the land use factor. Next, the appropriate land use factor for each of the land utilisation types considered was obtained, and multiplied by the partial value, giving a value of soil loss for the land mapping unit under the specified land utilisation type. Where the combination of land with land use resulted in a soil loss of greater than 100 t/ha/year, the land unit was classified as not suitable for the given use. Where the calculated loss was 51 - 100 t/ha/year, the suitability could not be higher than S2.

Additionally, protective forestry (or other forms of protection) was itself treated as a land utilisation type. All land having slopes of over 50% is considered to be on the one hand, not suitable for any other kind of use, and on the other hand, 'suitable for', by which is meant in this context 'in need of' protective forestry. Land with 30 - 50% slopes should only be used for agriculture provided that adequate soil conservation works are implemented. In practice, however, the land mapping units did not have the differentiation between these slope classes, so at the national scale of the survey, all land with predominant slopes over 30%, which in fact is likely to contain slopes over 50%, is classified as not suitable for uses other than protective forestry.

As a related exercise, a first draft of a soil erosion hazard map at 1:1 000 000 scale was compiled. This is described in Appendix A.
3.5 COMPARISON OF LAND USE WITH LAND

3.5.1 Matching of land use with land

At this stage in the land evaluation the land utilisation types have been described, their requirements determined, suitability class limits for these requirements have been set, the land units have been mapped and the necessary land resource data collected for each unit by the Land Resources Section. The next stage is that suitability assessments are made, by the comparison of the requirements of each kind of land use being considered with the qualities of each land mapping unit. This procedure, commonly termed matching, has as its object the bringing of the needs of the use of the land more closely into harmony with the resources of the environment.

In the rating of individual land qualities carried out by this evaluation only one class N has been used within the order Not Suitable, since at this stage it was not practicable to make a distinction between class N1 and class N2. This has left three classes, S1, S2 and N, and thus two boundaries between classes to be considered. Each suitability limit for each land utilisation type was defined by reference to published literature about its environmental requirements and local information relevant to Ethiopia.

The suitability limits are conceptually based on the approximate criteria given in Table 3.7; these are the reductions in yields caused by these limits, and the inputs needed to counteract the limits and so avoid reductions in yields. In the table, under the definition in terms of yields, the yields are those expected under optimal conditions in the absence of inputs specific to the land quality concerned. Under the definition in terms of inputs, the inputs or management practices are those specific to the land quality considered as necessary to achieve yields of at least 80% of those obtained under optimal conditions.

These yield reduction and levels of input estimations were used in the compilation of a yield table, which forms part of the land evaluation report. The table gives the estimated yields, in kilograms per hectare (kg/ha) of all the 42 rainfed crops studied by the evaluation, at the three different input levels and for the three different land suitability classes.
Table 3.7  PROBABLE REDUCTIONS IN YIELDS AND REQUIRED LEVELS OF INPUTS EMPLOYED TO DEFINE SUITABILITY CLASSES.

<table>
<thead>
<tr>
<th>Class</th>
<th>Definition in terms of yields</th>
<th>Definition in terms of inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>over 80%</td>
<td>none</td>
</tr>
<tr>
<td>S2</td>
<td>40 - 80%</td>
<td>inputs needed, which are likely to be both practicable and economic</td>
</tr>
<tr>
<td>N</td>
<td>below 40%</td>
<td>limitation can rarely or never be overcome by inputs or management practices.</td>
</tr>
</tbody>
</table>
The land use requirements at low/medium input levels and the land characteristics of each land mapping unit are matched for each crop combination by means of a matching table, of which Figure 4 shows the layout. In this table class SI, S2 or N is assigned to each land characteristic in the first column. For some land qualities, for example, length of growing period, there is only one land characteristic by which they will be assessed, whereas for others, for example, land degradation, up to six land characteristics are each assigned suitability classes (see Table 3.5).

The land qualities similarly each have a class SI, S2 or N assigned to them in the second column below, by direct transfer of the land characteristic class where only one land characteristic is used in the assessment of the land quality, or by selection of a composite rating where there is more than one land characteristic value in the first column. A composite rating class is normally the lowest suitability class given to the separate land characteristics. For example, if the land quality 'rooting conditions' has separate land characteristic classes SI, S2 and S1, then an S2 land quality class will be assigned to the second column.

These separate ratings for each land quality are then combined subjectively into a single rating of the suitability of the land mapping unit for the land utilisation type being considered. Normally this single rating is equivalent to the least favourable separate land quality assessment. Thus, if the least favourable assessment is S2, the single rating assessment for the suitability of the land is S2. Subjective judgment is used, however, where the least favourable assessment is related to a land quality considered less important in the evaluation. In all circumstance each case is assessed on its own merits.

At the bottom of the matching tables are given the single ratings for each thermal zone within each land mapping unit, and up to two subclass letters in the S2 and N class ratings reflecting the kinds of limitation resulting in the class being given. These single ratings are finally being combined in a suitability classification summary, of which Figure 5 is an example of the layout.

The summary is completed for each soil management unit and is repeated for each relevant length of growing period. Thus, if 10 lengths of growing period are found in a soil management unit then the suitability classification summary is repeated to cover them all. This final summary provides at a glance a full picture of the potential suitability of a soil management unit for each crop combination, and so gives the land use planner the data required to make decisions relating to land development.
Figure 4  MATCHING OF LAND USE WITH LAND.

Crop combination ___________________________ Length of growing period ____________
Soil management unit ___________ Landscape units ______________

<table>
<thead>
<tr>
<th>Land quality</th>
<th>Suitability with respect to individual land characteristics</th>
<th>Suitability with respect to land quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal zone</td>
<td>1    2    3    4    5    6    7    8    9    10</td>
<td></td>
</tr>
<tr>
<td>Temperature regime</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degradation hazard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inherent nutrient status and nutrient retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rooting conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toxicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation, potential for mechanisation, workability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pests and diseases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal zone</td>
<td>1    2    3    4    5    6    7    8    9    10</td>
<td></td>
</tr>
<tr>
<td>Suitability class and subclass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 5. SUITABILITY CLASSIFICATION SUMMARY

Soil management unit ___________________  Length of growing period __________

Landscape unit ____________________________

<table>
<thead>
<tr>
<th>Thermal zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop combination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<td>2</td>
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<tr>
<td>3</td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>9</td>
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<td>10</td>
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</tr>
<tr>
<td>11</td>
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3.5.2 Environmental impact

The procedures of comparison of land uses with land as outlined in the 'Framework for land evaluation' call for two further activities following matching, namely consideration of environmental impact, and economic and social analysis.

At the broad reconnaissance level, environmental impact is treated primarily as part of the matching process. Sedimentation hazard is one of the land qualities considered for all land utilisation types; the methods by which it has been assessed have been outlined in Section 3.4.3. This land quality in practice played a substantial part in the determination of suitabilities. In addition, a draft map of erosion hazard was prepared (Appendix A). In the course of the project, FAO proposed a consultant on soil degradation to prepare a specialist account of this important respect of land evaluation, this request was refused by Government, and consequently no such account is available.

3.5.3 Economic and social analysis

The relation of economic and social analysis to evaluation at the broad reconnaissance scale has been discussed above in Section 2.3. Basically, in a two-stage approach, the economic and social analysis which forms the second stage cannot commence until completion of the first stage. Thus there has been no direct building of such analysis onto the physical land suitabilities during Phase I of the project. A discussion of how this could be done in future activities of Phase II is given below (Section 3.7.1).

The results of economic and social analysis from the present Phase thus appear as outputs in two forms. First, the economic and social setting was incorporated into the descriptions of land utilisation types (Part 3 of this report). Secondly, a considerable volume of source material basic to economic and social analysis appears in the 'Data book on land use and agriculture in Ethiopia' (Field Document 1).

An attempt was made to carry out highly generalized economic analysis of crop production, using data contained in the abovementioned data book. Tabulated data are given for regions showing costs of production of certain
crops, drawn from the FAO-assisted Agricultural Census of 1977/78. Also, market prices for selected centres are given for the same year. By taking the costs of production per quintal (100 kg), and the market price per quintal, attributing the market price at a centre to the region in which the centre is situated, a figure for profit and loss could be obtained. Economic suitability limits were defined as follows:

S1 Net return higher than the average for all Ethiopia
S2 Net return lower than the average for all Ethiopia, but greater than zero
N Net return negative, i.e. financial loss

A start was made on tabulating such suitabilities, with a view to preparing economic suitability maps at region level; these would serve as a simplified 'overlay' to the physical suitability maps, supplying some confirmation that the land classed as suitable physical grounds was also independently shown to be economically suitable.

The results of this exercise were clearly unsatisfactory. The cost data showed large and irrational variations, unrelated to any reasonably attributable causes. Moreover, regions known from general experience to be leading producers of certain crops showed an apparent financial loss. In the light of these results, the exercise was discontinued.

Possible reasons for the unreliability of the cost data are:

i. Inspection of the source data showed that in some cases, averages for a region were based on samples of as few as two farms, clearly insufficient for a reliable mean value.

ii. The costs were summed from three components: labour, traction and inputs. Under Ethiopian peasant conditions, both family labour and traction were likely to have been attributed costs, i.e. of no money cost to the farmer.
3.6 PRESENTATION OF RESULTS

Matching tables were completed for the crop combinations and other land utilisation types on each of the land resource units. The resulting suities for land mapping units were transferred to maps, initially at 1:2 000 000 scale. In this way, a series of suitability maps for individual kinds of land use were produced. Land areas under different suitability levels for each kind of use were calculated.

It is intended to combine the individual suitability maps in one or more maps showing Land Use Potential. This will identify areas suitable for various major kinds of land use and in addition, within rainfed agriculture, certain subdivisions, e.g. highland perennial crops. At the time of completion of Part One of this report, the detailed methods for construction of such a map have not been finalised. These methods will therefore be described accompanying the analysis of results, in Part Four.

The results of the land evaluation are presented as follows:

i. Descriptions of land utilisation types, together with outline management specifications: Part Two of this report.

ii. Land suitability maps: maps showing suitabilities for crop combinations and other major kinds of land use; one or more maps of land use potential, summarising the individual suitability maps.


iv. Results of basic land resource surveys: presented separately, as Technical Report 1, the Land Resources map, and associated documentation.

v. Results of economic and social studies carried out concurrently with, and in part contributory to, the land evaluation: Technical reports 8 and 9, and the 'Data book on land use and agriculture (Field Document 1).
3.7 FUTURE ACTIVITIES IN LAND EVALUATION

This section covers aspects of land evaluation studies which could or should be conducted in the future, either as part of Phase II of the project or in subsequent Government activities directed towards land use planning.

3.7.1 Linking socio-economic data with physical land evaluation

Section 2.3 gave the reasons behind the selection of a two-stage approach for this evaluation. The second stage does not demand a detailed socio-economic analysis, but the results of the qualitative land classification first stage should be subjected to a simple socio-economic analysis. In this Project this can take the form of a possible socio-economic 'override' being placed on any decisions reached about the physical suitability of each land mapping unit for each land utilisation type. The physical survey shows where land suitable for land utilisation types exists; when combined with socio-economic inputs the resulting land evaluation shows where land suitable for profitable and socially acceptable land utilisation types exists.

A few socio-economic criteria must be identified by which the overall suitability of land mapping units for land utilisation types can be assessed. These could include costs of production, yield estimates or known values, prices gross and net returns, accessibility to markets and acceptability of food products, they are being identified by the Socio-economic Section.

However, locational links are required to be made by the Project between these criteria and the physical data. For, whilst land resources data have been described and matched with the requirements of land utilisation types by land mapping units, socio-economic data have been collected by administrative districts. The boundaries of these two sets of areas do not coincide, with the administrative districts being larger and not usually bounded by prominent physical features. An example of this situation is shown schematically in Figure 6.

From agricultural sample farms 1-5 within administrative district X data are obtained on costs of production, returns and food preferences, are aggregated with prices obtained from district markets and are brought to the 'centre'. Within land mapping units B and C crop yields are obtained from agricultural experimental stations p and q and, after determining the mean values of these or those from neighbouring stations, expected yields are obtained for land mapping unit A.
Figure 6. RELATIONSHIP BETWEEN SOCIO-ECONOMIC UNIT AND LAND MAPPING UNITS.
The requirement now is to produce data on farm costs, returns and food preferences for the land mapping units within district X out of the 'centre'. This is most simply done by taking means from the 'centre' and attributing them to each land mapping unit within the district. For example, the physical evaluation has found that land mapping unit B is S1, highly suitable, for tef. Since unit B lies within district X, the costs and returns of tef production in district X are attributed to unit B, and a new suitability assessment is derived for tef grown in unit B, in which the socio-economic inputs can override the physical assessment.

If land mapping unit C is also S1, highly suitable, for tef from the physical evaluation then an anomaly in this procedure can occur. The land in unit C is, a priori, different from the land in unit A, so that it is very probable that the costs of production of tef will also be different, but by amounts unknown from this simple procedure. However, it is here considered that there is no possibility with such a generalized evaluation to cover the country with agricultural sample surveys tied to each land mapping unit. Therefore, this situation, resulting in a simple relationship between socio-economic and physical evaluations, will have to be accepted.

In the future, as a first step towards refining the results obtained by this procedure, it is recommended that much more agricultural sample data are collected, and that the land utilisation types be defined more closely on the basis of farming systems rather than as individual crops.

3.7.2 Automated data handling

The land evaluation being carried out by this project used manual methods for the matching of the different land utilisation types with the land mapping units, and for the subsequent production of suitability assessments. Such information on both the land use and the land as is being produced by these means can readily be stored in computerised form.

To computerise the land data it is necessary to measure on maps both the areas of each land mapping unit and thermal zone and, by means of an intermediate computer program, the areas of each significant land facet within each land mapping unit. For the land use data the areal extents of the separate suitability classes of the combined land mapping units and their associated facets for each land utilisation type are also measured.
By this technique a wide range of tabular information can be retrieved from the computerised data bank. For example, the extent of certain soils in a geographical region can be abstracted, or a table showing areas suitable for tef production, or by combining data of different kinds, the amount of land with steep slopes in an administrative district. Such a data bank is costly and time consuming to install, but once operational it allows regional land use planning to be undertaken on a well informed basis.

If the automation of the land evaluation procedure is taken further a large number of the stages can be computerised. The basic data or the land characteristics values found in each land utilisation type must first be acquired. These can then be processed by computer using programs such as those described by Dent and Young, (1981). The output can include:

i. The suitability class of each land mapping unit for each land utilisation type considered;

ii. The land qualities that resulted in the land mapping unit being placed in that suitability class, and hence the suitability sub-class for each land utilisation type;

iii. Computer printed maps showing suitabilities for each land utilisation type in turn, and showing the project area mapped into suitability classes by land utilisation type. Such maps can be combined with tabular information from the land data bank in any desired format to provide directly output fitted to the user's requirements.

Another obvious benefit for the land use planner is the ease with which the evaluation system can be modified. Suppose, for example, that soil texture is found to have been wrongly classed, such that fine textured soils should be S2, moderately suitable, and not N, not suitable, for several land utilisation types, and that consequently there are several thousand land mapping unit assessments to be changed. If the processing is being done manually this new information may be ignored because of lack of time needed for the reprocessing. However, if the system has been automated, it is quick and simple to insert revised values and to reassess the suitability of the land mapping units.
There are many long-term gains to be had from using a computerised land evaluation and data bank system, but at this stage in the work of the Project two notes of caution should be given concerning the initial setting up of the system. (Dent and Young, 1981). A suitability classification of quite modest complexity could take something in the order of six months to program, test and remove the inevitable crazy results which appear at first owing to a failure to realise tacit assumptions.

Secondly, land suitability classification, data banks or any other similar computerised system can never be better than the land and the land use data and their relationships that are fed into the computer in the first instance. Without very careful checking they can easily be worse than manually processed results, such as those being produced by this Project, since manual methods are subject to continual monitoring by common sense.

3.7.3 Land evaluation at more detailed scales

It cannot be stressed too strongly that the present land evaluation at broad reconnaissance scale should only be used for the purposes for which it is intended, to provide a broad and generalised view of development opportunities at the national scale, and for a first approximation to the location of possible development areas. Even for precise project location, the scale of 1:1 000 000 is inadequate, and needs to be followed by further reconnaissance mapping at about 1:250 000 scale. For feasibility studies and for field implementation, both basic surveys and further land evaluations at semi-detailed and detailed scales are essential.

To attempt to use the present broad reconnaissance evaluation for detailed planning purposes would be likely to result in crop failures, economic losses, environmental damage, or all three.
APPENDIX A. EROSION HAZARD MAPPING FOR ENVIRONMENTAL IMPACT ASSESSMENT

An output of the Project recommended by Young 1980(b) is a first approximation to mapping the degree of actual soil erosion in the country, and a map showing kinds and relative severity of potential erosion and other degradation hazards, as first steps in environmental impact assessments of different land utilisation types. Figure 2 of this report includes an assessment of environmental impact as part of the land evaluation stage in the production of the master land use plan. In order to go some way towards meeting this recommendation, and to meet a request from Government for a similar Project output, the Land Evaluation Section has produced a provisional erosion hazard map of the country, in three sheets at 1:1 000 000 scale. The objective and methodology of production are briefly discussed here.

The objective is defined as the identification of areas, at a rapid reconnaissance level, where agricultural productivity is threatened by excessive soil loss. The methodology is based on that developed for the FAO World Soil Degradation Assessment and described by FAO, 1979.

The provisional assessment for Ethiopia has divided the land into mapped units that are similar in their degree and kind of erosion hazard. There are four main environmental factors that control erosion on a broad scale and that have been mapped, at first separately and then, through combination by overlays, together to produce one erosion hazard assessment map. The four factors represent climate, topography, soil and vegetation.

1. Climate: the erosivity of the rain. This is defined as the ability of the rain to detach and move soil particles, and is a function of the rainfall intensity and duration. Erosivity assessment ideally requires data on drop size distributions over many short periods of intense rain, which is not available for Ethiopia. A simple approximate alternative that has been used here is the ratio $p^2/P$, where $p$ is the highest mean monthly rainfall and $P$ is the mean annual rainfall. This ratio gives a crude measure of the intensity of the rainfall and the erosion protection by vegetation, with the higher the ratio the more erosive the rainfall.
Isolines of direct $p^2/P$ values at 10 unit intervals have been plotted over the country, with the values varying between less than 10 and over 150. Values over about 60 denote a typically Ethiopian strongly seasonal climate with a marked dry season, during which the amount of plant cover declines, followed by a wet period of often intense rain.

2. Topography: the slope of the land surface. A slope map has been compiled by the Land Resources Section, dividing the country into five slope classes of increasing steepness and therefore approximately increasing erosion hazard. The classes are 0-10%, 10-25%, 25-35%, 35-50% and over 50%, with these being reduced to four in the final mapping by combining the two classes 25-35% and 35-50% into one 25-50% class. The slope factor for the erosion hazard map has been determined by giving a separate rating to each slope class as follows: 0-10% = 0.2, 10-25% = 5, 25-50% = 10 and over 50% = 20. Large areas of the country away from the highlands fall into the 0-10% slope class, but significant portions of the intensively cultivated highlands have slopes in the 25-50% and over 50% classes.

3. Soil: the erodibility of the soil. This factor is defined as the resistance of the soil to being detached by rain and moved by flowing water, or other less important agents not considered here. Erodibility varies principally with the soil texture, stability of the soil aggregates and infiltration capacity. FAO has drawn up approximate erodibility values for each soil type in the FAO Soil Map of the World, and these values have been calculated for Ethiopia according to the FAO methodology.

These sets of numerical values have been assigned to each soil unit determined by its physical and chemical characteristics, its texture and the presence or absence of stones and rock debris. The overall rating for the soil factor is then calculated by multiplication of the three values, and by calculations of the ratings of all the units they are divided into seven classes, with rating of 0.05, 0.1, 0.15, 0.2, 0.3, 0.4 and 0.6. The higher the rating the more erodible the soil unit, with the units of more erodible soils being found to be spread throughout the country.
4. Vegetation: the percentage plant cover of the ground. Generally the greater the percentage plant cover and the thicker the basal cover the less the erosion hazard. On this basis 30 land use types given on a map of present land use over the country, prepared by the Agrc-ecology Section, have been converted to plant cover classes, by assigning them to one of four rated classes, with ratings of 0.05, 0.3, 0.65 and 1.0. The higher the rating the less able is the land use type to provide adequate plant cover protection against erosion at the beginning of the main wet season, which is considered as the period with the greatest potential erosion hazard. The well vegetated south west of the country is generally the area best protected against erosion by vegetation, in this case natural, where it has not been destroyed, and the northern third of the country provides the largest areas of poorly protected, intensively used land.

The separate maps showing the four environmental factors were next combined by overlays to produce one composite erosion hazard map. By this means 453 units, each delineating approximately similar potential erosion hazard, were produced. One erosion hazard value was calculated for each unit, which was the product of the separate values of the four environmental factors within that unit multiplied together. For example, a unit with high rainfall erosivity value of 80, a moderate slope value of 5, allow soil erodibility value of 0.15 and a moderate vegetation cover value of 0.3 has an overall erosion hazard value of 18. Throughout the country erosion hazard values vary from 0.1, in the slight erosion hazard class, to 300, in the extreme erosion hazard class.

The erosion hazard units were finally combined into one of seven classes of erosion hazard, termed:

1. slight
2. slight-moderate
3. moderate
4. moderate-high
5. high
6. very high
7. extreme

With these classes a map was produced of 265 composite erosion hazard units within seven differently colour coded classes. On this map each unit has also been described by a sub-class letter or letters:

t, slope r, rainfall s, soil v, vegetation n, none
These sub-classes denote different dominant factors affecting the erosion hazard of each unit. For example, units with a high erosion hazard may be so classed because of an erodible soil, a poor plant cover, erosive rainfall, etc., the sub-class detailing the cause or causes of the hazard. The sub-class none is given where there is no dominant erosion hazard influence.
APPENDIX B. GLOSSARY OF LAND EVALUATION TERMS

COMPOUND LAND USE: More than one kind of use undertaken on area of land which are treated in land evaluation as a single unit. E.g. mixed arable-livestock farming.

CONDITIONAL LAND SUITABILITY: The suitability of land for a specified use where the land is not suitable in its present condition, but might be made suitable by some local modification, either to the land or to management practices. This term is not used by this Project, since it has been found to be confusing.

CROP COMBINATION: A grouping of rainfed crops brought together for purposes of land evaluation by their each having approximately similar environmental requirements. The requirements for the crop combination as a unit are taken as being representative of the requirements of each crop in the combination.

CURRENT LAND SUITABILITY: The suitability of land for a specified use in its present condition, without major land improvements.

ECONOMIC LAND EVALUATION: An evaluation which includes results given in terms of profit and loss, for each specified enterprise on each kind of land.

ENVIRONMENTAL IMPACT ASSESSMENT: An activity designed to identify and predict the impact on the natural environment of land development projects and procedures.

EVALUATION FACET: A specific area of land with distinct landform and soil characteristics, which can be evaluated as having a distinct potential for given types of land use and management practices.

KIND OF LAND USE: Either a major kind of land use or a land utilisation type, whichever is applicable, where the meaning is clear it is abbreviated to 'kind of use' or 'use'.

LAND: A specific area of the earth’s surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying rocks, the topography, the water, the plant and animal populations and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man.
LAND CAPABILITY CLASSIFICATION: The classification of land in terms of its potential for use in specified ways, or with specified management practices.

LAND CHARACTERISTIC: An attribute of land that can be measured or estimated.

LAND IMPROVEMENT: An alteration in the qualities of land which improves its potential for land use.

LAND MAPPING UNIT: An area of land demarcated on a map, and possessing specified land characteristics and/or land qualities.

LAND QUALITY: A complex attribute of land that acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use.

LAND SUITABILITY: The fitness of a given type of land for a specified kind of land use.

LAND SUITABILITY CATEGORY: A level within a land suitability classification. Four categories of land suitability are recognised: order, class, sub-class, and unit. The unit category has not been used by this Project.

LAND SUITABILITY CLASS: A level within a land suitability classification indicating a degree of suitability of land for a specified kind of use. In the system developed by this Project four suitability classes are recognised:

Class S1. Highly suitable. Land having no significant limitations to sustained application of a given use, or only minor limitation that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2. Moderately suitable. Land having limitations which on aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive will be appreciably inferior to that expected on Class S1 land.

Class N1. Currently not suitable. Land on which the use under consideration is technically possible but not economic. Changes in the relative prices of the product and inputs, or advances in technology, can result in upgrading of this land.

Class N2. Permanently not suitable. Land which is unlikely ever to be viable for the specified kind of use, whatever the changes in technical or economic considerations.
LAND SUITABILITY CLASSIFICATION: An appraisal and grouping of given areas of land in terms of their suitability for a specified kind of use.

LAND SUITABILITY EVALUATION: The process of assessment of land performance when used for specified purposes, involving the interpretation of surveys and studies of landforms, soils, vegetation, climate and other aspects of land, in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation.

LAND SUITABILITY ORDER: A level within a land suitability classification indicating whether land is assessed as suitable or not suitable for the use under consideration.

LAND SUITABILITY SUBCLASS: A level within a land suitability classification reflecting kinds of limitation to the suitability of land for a specified kind of use, e.g. moisture deficiency, temperature limitation, degradation hazard. Subclasses are indicated by lower-case letters with mnemonic significance, e.g. S2m, N1tr. There are no subclasses in class S1. The subclasses used in this evaluation are:

- d drainage deficiency
- e erosion hazard
- m moisture deficiency
- n nutrient deficiency
- p management limitation
- r rooting condition deficiency
- t temperature limitation
- x toxicity limitation

LAND USE PLANNING: The formulation of policies and programmes for the use of land, by means of the survey of basic physical and socio-economic resources, their evaluation for specified kinds of use and the production of plans for the implementation of the chosen kinds of use.

LAND USE REQUIREMENTS: The set of land qualities and land characteristics that determine the production and management conditions of a kind of land use.

LAND UTILISATION TYPE: A kind of land use described or defined in a degree of detail greater than that of a major kind of land use.

LEVELS OF INPUT: The quantity and quality of inputs into a land utilisation type. For generalised descriptive purposes three levels of inputs are recognised in Ethiopia: low, which is the peasant farmers' level; medium, which is the cooperative farms' level; high, which is the State farms' level.
LIMITATIONS: Land characteristics that have an adverse effect on land capability.

MAJOR KIND OF LAND USE: A major subdivision of rural land use, such as rainfed agriculture, irrigation, livestock production, forestry and wildlife conservation.

MAJOR LAND IMPROVEMENT: A large input in land improvement, which causes a substantial and reasonably permanent improvement in the qualities of land and which requires a large capital expenditure.

MAJOR SOIL MANAGEMENT UNIT: Where two or more not separately mapped soil management units occur within one land mapping unit, one major soil management unit is selected as that which is most nearly representative of the land characteristics of the whole land mapping unit, with respect to its areal coverage and agricultural development potential.

MATCHING: The comparison of the environmental requirements of a land utilisation type with the land characteristics of a given area of land, to produce an assessment of the suitability of the land for the land use.

MINOR LAND IMPROVEMENT: A land improvement which has relatively small effects on the suitability of the land, or is non-permanent, or which normally lies within the capacity of an individual farmer or other land user.

MULTIPLE LAND USE: More than one kind of use simultaneously undertaken on the same land. Eg. livestock grazing within a tree-crop plantation.

NATURAL ENVIRONMENT: The whole sum of the surrounding physical external conditions within which given land uses exist.

PARALLEL APPROACH: The method of combining physical with economic evaluation, in which physical and economic analyses proceed concurrently with more or less continuous interchange of data, leading to a single combined set of results.

POTENTIAL LAND SUITABILITY: The suitability of land for a specified use at some future date, if and when major land improvements have been carried out.

PRODUCE: The products, services of other benefits resulting from the use of land.

QUALITATIVE LAND EVALUATION: An evaluation in which the suitability of land for alternative purposes is expressed in qualitative terms only, such as highly or moderately suitable, or not suitable for a specified use.


