Land evaluation for forestry

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FOREWORD

These guidelines present procedures for conducting land evaluation with particular reference to forestry. The principles and methods described here will be found applicable to most forest land use planning situations. These could deal with choices among kinds and intensities of land uses, for example forestry versus agriculture, or timber production versus soil/water conservation, selection versus intensive forest working; or could relate to different levels of planning, for example national, provincial, district or local. Effort has been made to give a balanced emphasis to different aspects of land evaluation, viz. technical, economic, social and environmental.

FAO's activities in land evaluation began with practical experience in field projects dating from the early 1970s. Contributions were brought together in a series of meetings, starting in 1973, culminating in the publication of the Framework for Land Evaluation in 1976.

Experience in using the Framework in field projects and in training courses showed that, although it provided a comprehensive coverage of the basic concepts and approaches, substantially more detail was required regarding the specific needs of evaluation for different purposes. This led to the idea of preparation of a series of more specific guidelines, for example, rainfed and irrigated agriculture, and the present one on forestry.

The present guidelines should not be regarded as a definitive manual on land evaluation for forestry. Rather, they represent a summary of present knowledge and experience. In future, it may be possible to prepare more specific guidelines on land evaluation for different forestry purposes, e.g. afforestation, wildlife management, soil and water conservation etc. The immediate need is to put these guidelines to the test of practical experience in field projects, in order that the experience gained can lead to future improvements. I sincerely hope that foresters and other specialists engaged in forestry land use planning or training activities on the subject will find this work useful and interesting.

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The present work owes its origin to the Workshop on Land Evaluation for Forestry, jointly sponsored by the International Union of Forest Research Organizations (IUFRO) and the International Society for Soil Science (ISSS), held at Wageningen in 1981.

From the beginning of 1982 Land Evaluation for Forestry was included as an element in the Regular Programme of FAO's Forestry Department. Within its framework a small Task Force was created to discuss various aspects of the problem and to guide the work. In October 1982 a Technical Workshop was organized by FAO, in which a number of specialists of both developing and developed countries took part. The basis of discussions in the Workshop was a draft prepared by Dr. Willard H. Carmean. The first draft was reviewed chapter by chapter at the meeting and a revised second draft elaborated by the group.

The revised version was circulated widely for review, both inside and outside FAO. The final text was prepared, based on comments received, including a major input from Professor A.Young, currently working at ICRAF, Nairobi. Within FAO's Forestry Department, Mr. M. Stevens until the end of 1982 and, since then, Dr. K.D. Singh, coordinated the work and contributed to its development in the present form.

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CHAPTER 1

THE NATURE AND PURPOSES OF LAND EVALUATION FOR FORESTRY

1.1 Introduction

Decisions about the use of land have always been part of human society. One of the earliest decisions was concerned with the question: which forested land should be cleared and converted to agricultural uses? Such decisions continue today in areas where growing populations require more land for food production. Increasing demands for timber and, more recently, fuelwood, have led to land use changes in the opposite sense, the establishment of forest plantations.

Besides changes between forest and non-forest uses, there is a wide range of decisions involving choice between different types of forestry. To what extent should the management of a particular forest be directed towards timber, pulpwood or fuelwood production? How important are non-timber forest products, the soil and water conservation functions of forestry, use by local communities for grazing, or recreational uses? Recent emphasis on multi-purpose forestry has widened the range of such management options.

Forestry planning has always taken account of the influence of conditions of the land, whether on inputs, as in the higher maintenance and harvesting costs on steep or rocky slopes, or on potential output, as in climatic and soil effects on the growth rates of trees. The approach and methods of land evaluation were developed in order to provide a systematic framework for assessing the effects of land on potential production and other benefits.

The basis of land evaluation is comparison between land use and land. The land uses considered can range from broadly defined classes, e.g. softwood plantations, conservation forestry, to uses described in more detail, e.g. by tree species, silvicultural methods and harvesting practices. Land refers to all features of the natural environment which can influence its use by man; land includes not only landforms and soils but also climate and vegetation, including existing forest stands.

Each kind of land use has a set of conditions which are favourable or adverse to that use, its requirements and limitations. What is a severe limitation to one kind of use may be less serious or even beneficial to another. The focus of land evaluation is to assess the requirements and limitations of each kind of land use and compare these with the properties of different areas of land. This provides assessments of the suitability of the different types of land present in an area for each of the uses. Comparison between these suitabilities provides information to guide decisions on land use planning and management, particularly on the choice between alternative sites.

1.2 Features of forest land use

Forestry as a form of land use has a number of distinctive features, as compared with agricultural and grazing uses, which have important consequences for land evaluation.

i. Long time scale The period from planting a tree to harvest is rarely less than six years, frequently at least 15 and sometimes over 100. This means that forest management decisions, once taken, are difficult to change. Sustained yield forest production must take account of the long time scale by producing an orderly sequence of tree stands of different ages.

ii. Multiple functions Forest lands usually have many uses and values. Wood products, whether timber, pulpwood or fuelwood, are often the major product. Non-wood forest products (sometimes called 'minor forest products'), such as gums and resins, thatching materials, fruit and roots, can be of substantial importance. Water is frequently a product from forest lands; for some river catchments the value of water in streamflow exceeds the potential value of wood products. Soil conservation is an element in all forest management. Forests may be planted specifically for reclamation of degraded land. Biological conservation is a valued benefit, including both conservation of flora, or genetic resources, and fauna (wildlife). Uses for recreation and tourism range from wilderness areas with restricted access, through the use of plantations for walking and riding, forested national parks for tourism to highly commercial development for camping, boating, etc. There are also benefits which consist of the use of forest land for what are normally non-forest uses: agriculture, grazing and fisheries. These include forms of agroforestry, a group of land use systems in which woody plants and crops or livestock are maintained on the same area of land, with an ecological and economic interaction between the tree and non-tree components. Many of the forest products and benefits other than timber can be of special importance to local communities, for example, fuelwood, non-timber products and forest grazing .

Multiple use forest management is management designed to optimize the benefits, in goods and services, from the different functions of the forest. There are incompatibilities between maximizing all benefits, leading to management conflicts. Land evaluation needs to take into account all of the multiple functions, and also the interests of each of the beneficiaries from them: government or other owners of the forest, local communities, and more distant communities which benefit from conservation.

iii. Different levels of management intensity There is a wide range of forest management intensity, from unmanaged wildlands, with more or less natural vegetation, to intensively managed forests composed of selected species with their growth and form improved by management.

The spectrum of management intensity commences with natural forests valued for their conservation function and managed only by protection. Also at low management intensity are forests subject to selective logging and without any effort towards regeneration. At the next stage come those productive natural forests in which regeneration is almost wholly natural. This is followed by forests improved by a variety of silvicultural practices for obtaining regeneration of desired species. The next stage is that of forest plantations. The tree species are selected and planted, and may include exotic species and improved genotypes of native species. Tree form is improved by pruning and thinning, there may be protection against insect damage, and possibly improvements in site quality, e.g. by drainage.

Land evaluation needs to take account of these different levels of management intensity. At the lower levels, it is frequently not practicable or economic to apply high levels of inputs; forest productivity is dependent on natural growth potential. This lends added emphasis to land qualities affecting growth and, in particular, to site limitations which it may not be possible to correct. As management intensity increases, so also does the capital invested and the value of the product per unit area. A correspondingly greater survey effort becomes justifiable, involving more detailed gathering of information and more sophisticated methods of analysis and forecasting.

iv. The role of conservation A conservation function is always present in forestry. Where the primary aim is wood production, conservation is still essential. In other types of forestry the conservation of water, soil and biological resources is the primary objective. This situation is not found in agricultural forms of land use, and requires adaptations to land evaluation procedures.

v. The need to plan in space and time One of the main planning needs in forestry is for a sustained flow of output. This has to be achieved on land with widely differing characteristics, and hence variable potential for tree growth. Achievement of sustained production requires forecasts of growth rates on different sites, coupled with a programme of phased planting.

Reconciliation of the various multiple uses also calls for careful spatial planning. A particular case arises in watershed management projects, in which parts of the area are allocated to various kinds of productive use, both agricultural and forestry, whilst in other areas, conservation is given priority.

1.3 The nature of decisions in forest land use planning

The basic kinds of planning decision found in forest land use planning, including development projects and forest management, are as follows:

i. Which kind of land use? Frequently of critical importance in land use planning are decisions between forestry and other major kinds of land use. Such decisions include the conversion of forests to agriculture; the conversion of other uses of land to forestry, as in the establishment of forest plantations; and the allocation of land between different uses in multi-purpose land settlement, development or watershed management projects.

ii. Which kind of forestry? Before management can be planned, decisions need to be taken on the relative importance of the different multiple uses of forests. A basic choice is between forests intended first and foremost for timber production, and those in which conservation is the primary aim.

iii. Which kind of forest management? Given the land that is to be under forest, and the kinds of products and other benefits expected from it, there are decisions on methods of forest management designed to achieve these aims.

Cutting across the types of decision are spatial scales at which forestry planning takes place. These may be classed as:

i. Global or continental level This refers to strategic studies undertaken in international agencies as a basis for broad planning guidelines. The FAO/UNEP Tropical Forest Resources Assessment Project is a major world-wide study of this nature, not itself an evaluation, although providing much related data (Lanly, 1982).

ii. National or provincial level These are studies of whole countries, or the major regions or administrative divisions of larger countries. They may be the basis for decisions on allocation between major types of land use, e.g. transformation of forested land to agriculture, establishment of national parks, catchment protection zones; and also for establishing guidelines for different types of forestry, e.g. that land with certain slope classes should remain as protective forest.

iii. District or project level These are studies which cover smaller administrative divisions such as districts or counties, larger watersheds, or project areas. Objectives may include the location of land to be allocated to timber production, fuelwood production and conservation forestry; selecting the best available areas for establishment of forest plantations; coordinating future forest production in terms of space and time; or allocation of land between forestry, crop production and grazing in multi-purpose development projects.

iv. Local level These are studies carried out for detailed management purposes, frequently of a compartment, the boundaries of which are already determined. Changes in kind of land use, between forest and non-forest, can also take place at this scale, e.g. to regularize and limit the extent of incursions, or to prepare a village land management plan.

There is an interaction between planning at these different scales. On the one hand, strategic guidelines at the national and provincial levels clearly provide a framework for district or project level planning, and similarly as from the district to the local levels. There is also a converse effect. Every decision taken at a local level, e.g. to expand or reduce the area of production forest, has a cumulative impact on the overall position. Proposed land use changes at any level of planning therefore need to be appraised in the light of their effects on the wider situation.

Table 1.1 gives examples of combinations between type of decision and level of planning. In conducting a land evaluation it may be helpful to identify where the objectives lie in relation to this matrix.

Table 1.1 Examples of land use planning decisions in forestry

LEVELS OF PLANNING	TYPE OF DECISION		
	Kinds of land use	Kinds of forest use	Kinds of forest management
Global/ Regional	Strategic studies of forest resources, supply potential and demand	Regional watershed management studies, regional forest resources development studies and promotion of cooperation among countries.	
National/ Provincial	Conversion of forest to agriculture or non-forest uses to forest, national criteria. National parks.	National guidelines on forestry for production, protection, recreation etc. Catchment protection zones.	Forest management policy
District/ Project	Conversion of forest to agriculture or non-forest uses to forest. Establishment of forest plantations. Land allocation in multi-purpose projects.	Implementation of forest land allocation for production, protection, recreation, etc.	Preparation of forest management plans
	Watershed management		
Local	Adjust boundaries of forest reserve. Extend village forest area.	Local needs and their incorporation in forest management plans.	Implementation of forest management plans.

1.4 Functions and outputs of land evaluation

Land evaluation is concerned with identifying possible changes in land use or management, such as will meet national or local needs, and with making estimates of the consequences of alternative changes. Two situations in which land evaluation is appropriate have been described in informal terms as follows (Hamilton, 1981):

- A kind of land use in mind, where best to do it?
- An area of land at hand, how best to use it?

Although incomplete, this description draws attention to the focus of land evaluation, that of deciding where proposed changes in land use or management should be carried out. The need for change can arise from national requirements, e.g. for increased timber production; from local needs, e.g. for fuelwood; or from a requirement to check or reverse land degradation.

The results of land evaluation give the following kinds of information:

i. Descriptions of land utilization types, covering not only basic descriptive data, such as tree species, but also management practices, for example, land preparation, tree spacing, dates of thinning and harvesting.

ii. Suitability maps, showing the assessed suitabilities of the land units for each of the relevant land utilization types.

iii. Estimates of the consequences of applying each relevant land utilization type to each land unit. These consequences include inputs, e.g. materials, labour and capital works; outputs, both material and intangible, e.g. timber production, watershed protection, tourist potential; environmental impact, both positive and negative, of alternative patterns of land use and management; social consequences, both favourable, such as meeting local needs for fuelwood, and adverse, such as displacement of existing population; and economic analysis based on pricing of benefits and costs.

iv. There may also be data from basic surveys and specialist studies, e.g. soil survey, forest inventory, economic and social data.

The results of an evaluation study are presented as maps and a report. Land suitability maps provide a summary of the main findings of the survey, in a form in which it can be readily understood and used as the basis for planning. The report gives recommendations and the reasons which led up to them, as well as detail needed in land use planning and management.

Land evaluation does not take decisions for the user, whether land use planner or forest manager. It outlines various alternative courses of action and presents the consequences of those alternatives for each of the different types of land present in an area. These consequences include:

- How is the land currently managed, and what will happen if present practices remain unchanged?
- What changes in use, or improvements in management practices, are possible?
- For any such changes in use of management, and on each type of land:
    - What possible adverse effects might occur?
    - What inputs, capital and recurrent, are necessary?
    - What are the estimated benefits in production or services from each change?
    - What is the best multiple use forest management, to achieve the desired balance of inputs, production and conservation?

1.5 Relation to other forestry techniques

Many established techniques in forestry can contribute to the procedures of land evaluation. Which methods are employed in a particular study will depend on the objectives, scale and intensity. Such related techniques include the following:

Forest inventory An assessment of existing forest resources, primarily the standing crop of timber but, in some inventories, also the site types, e.g. slope, soil and drainage. A forest inventory is likely to form a major part of the basic resource surveys in land evaluations for natural forests (FAO, 1981a).

Forest volume estimation An assessment of the timber volume of natural forests. This technique forms part of forest inventory and thus has a similar role in land evaluation (Cailliez, 1980).

Forest yield prediction Prediction of the rates of growth of timber, either of natural forests or forest plantations; includes site index methods. This contributes to the basic survey component of land evaluation for both natural and plantation forestry and is a diagnostic technique of much importance in the latter case (Alder, 1980).

Assessment of logging costs This can form a component of the assessment of inputs in the land evaluation procedures (FAO, 1978a).

Land/terrain/site classification for forestry This is not a single technique but a range of methods for classifying either vegetation or climatic and soil-based site types (e.g. Kilian, 1981; Carpenter, 1981, Part II). The difference between land classification and evaluation is that classification consists of description and mapping of the physical land characteristics, without interpretation for specific uses. Land classifications may form part of the basic surveys in an evaluation. It should be noted that some past surveys called 'land classification for forestry' or similar terms, have, in fact, been evaluations, e.g. for plantation establishment.

Environmental impact of forestry Environmental impact is a required stage in land evaluation procedures and the established methodology, in as great a detail as circumstances require, can be employed (Zimmermann, 1982).

Economic analysis of forestry projects The economics of land evaluation by no means extend to the whole of project analysis, although the boundary is difficult to define. Some standard techniques of economic analysis can be employed in land evaluation. Conversely, results of economic land suitability evaluation are an important part of the input to project analysis (Gregersen and Contreras, 1979).

1.6 Plan of the guidelines

Many past surveys have been conducted for the establishment of forest plantations, or selection of sites for different tree species, which employed the basic approach of land evaluation. These surveys contributed to the principles outlined in the Framework for land evaluation (FAO, 1976). Experience showed that the Framework did not provide enough guidance on the detailed procedures to be followed in evaluations for specific purposes, nor was it alone adequate for training purposes. The principles need to be amplified and, in some aspects, adapted to meet the distinctive features of forest land use, just as in the parallel account of evaluation for rainfed agriculture (FAO, 1983a).

The objective of the present guidelines is to set out the principles, and outline the procedures, for the evaluation of land for forestry, including comparison with non-forest uses. They are intended for use by government officers, FAO field staff and others engaged in forest and multi-purpose land use planning, and by people training for such purposes. The guidelines do not constitute a detailed evaluation system. The variety of kinds of forest use, scales of application and physical and socio-economic circumstances is such that no specific set of criteria and critical values could have general validity. Such criteria and values must be established in the light of local circumstances, either specific to each evaluation survey, or with general validity for a given type of forest use within a broad physical and socio-economic environment.

In preparing this account it would have been possible to produce a series of descriptions of land evaluation for each of the major purposes - wood production, conservation, recreation, etc. This approach was not adopted, first, because the basic principles and procedures are the same whatever the kinds of benefit; and, secondly, for the practical reason that forestry is nearly always being considered for multiple use. Instead, the approach has been to outline each procedure in its general aspects, branching into separate consideration of different functions where necessary. In each case, the separate functions are treated in the order production - conservation - recreation and tourism, with the main emphasis on the production and conservation functions.

Chapter 2 explains the basic concepts which underlie land evaluation, and gives definitions of the terminology. Chapter 3 presents an outline of the stages and procedures involved in an evaluation. Chapters 4 to 11 describe each of the successive stages and procedures, commencing with the objectives and planning of an evaluation and ending with the land suitability classification. Chapter 12 provides some guidelines for writing the report of an evaluation and for use of the results in land use planning. Finally, a glossary of technical terms used in land evaluation is given for reference purposes.

CHAPTER 2

PRINCIPLES AND BASIC CONCEPTS

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2.1 Principles

2.1.1 General

Land evaluation rests on a set of principles derived from consideration of the practical needs of land use planning and management. These principles distinguish the approach from other methods of land resource survey and land classification.

i. Land suitability is assessed with respect to specified kinds of use. This is the most fundamental principle of suitability evaluation. Each kind of land use has its own special requirements; hence, different types of land will be best suited to each use. This applies at any level of decision-making. The different major kinds of land use - forestry, agriculture, livestock production, etc. - clearly have different requirements. The various kinds of forestry, e.g. for timber production, conservation, recreation, also differ widely in their requirements and thus very different types of land are best suited to each. Within production forestry alone, there are different requirements for mechanized and non-mechanized methods of management; for example, rock outcrops and boulders are a less serious limitation to the non-mechanized methods that are common in community forestry. Finally, even within one kind of management, different tree species vary in their growth requirements.

ii. Evaluation involves comparison between different uses of land. Evaluation should provide information on alternatives. Planning and management decisions are by no means exclusively based on land evaluation, but must take into account information from many other sources. If the evaluation only presents results for a single kind of use, there is no scope of choice based on other grounds. The comparison may be between forestry and non-forest uses, or between different kinds of forestry. Where the broad type of use is specified by the objectives, e.g. fuelwood plantations, then the alternatives cover different tree species or methods of management. Another comparison is between the proposed and present uses.

iii. A multidisciplinary approach is required. Evaluation needs information from environmental sciences from the technology of land use, in the present case silviculture, and from economics and sociology. Sound land use decisions cannot be made if any of these aspects are ignored. Evaluation procedures are designed to integrate these different sets of information.

iv. Evaluation is made in terms relevant to the physical, economic and social context of the area. There is no unique set of land conditions that is 'best' for a particular form of forest production and management. The choice depends on the circumstances of the area, e.g. labour and capital availability, levels of demand for different forest products, and the range of land types available in the country.

v. Land suitability refers to use on a sustained basis. This principle requires that the conservation aspect should always be taken into account, including when the primary objective is for production forestry.

vi. Evaluation requires comparison between inputs required and outputs obtained. The difference between more and less suitable land for a particular purpose is often not one of higher or lower forest yields, but is caused by variations in costs of inputs and management. Trees on steep slopes may grow as well as on gently sloping land but the higher costs of road construction, maintenance and harvesting render the steep land less suitable.

vii. The intensity of required surveys and evaluation vary with the intensity of forest land management. Where land has a low value and there are few opportunities for increasing its benefits through management, a relatively low intensity of survey and evaluation is appropriate. As both the productive capacity of the land and its management intensity increase, so also does the need for more detailed evaluation as a prerequisite for sound land use planning and management.

2.1.2 Comparison with other approaches

The basic approach of land evaluation is the comparison of alternative kinds of land use with available types of land; more precisely, the requirements of each use are compared with the properties of each mapped unit of land. This distinguishes it from other approaches to land resource survey and assessment, those of land capability classification, land classification, and the site class system. There is also a system of soil potential ratings which rests on fairly similar principles to the approach described here.

Land capability classification, developed by USDA Soil Conservation Service. is a well established form of survey, applied mainly in agricultural land use planning, with emphasis on its conservation requirements. It places land into a graded series of capability classes, from Class I, land with no limitations to agriculture, to Class VIII, land with no potential for agriculture, production forestry or grazing. Capability classification indicates which land is 'capable' of being used for a major kind of use, without comparative assessments of the desirability of different uses. The system has never found favour in forest land use planning since it carries an underlying implication that agriculture is to be the preferred form of use wherever possible. Whilst in principle, Classes I - IV have a capability for forestry as well as agricultural use, in practice much forest land is placed in capability classes VI - VIII.

The term land classification has been employed in the past in two distinct senses. What will here be called 'descriptive land classification' refers to surveys which lead to the production of maps and accounts of the environment as such, without reference to its potential uses. Examples are soil maps, vegetation maps, and maps of forest types or forest land classes (e.g. Kilian, 1981; Carpenter, 1981, Part II; FAO, 1983b). Thus a map showing units such as 'lowland rain forest', 'montane forest','swamp forest' is a land classification as also is a map with units such as 'coniferous forest on hill land', 'coniferous forest on gently sloping land', etc. Descriptive classifications can be used as a basis for an evaluation, possibly supplying appropriate land units, but if they do not appraise the units with respect to defined alternative uses, then they are not evaluations.

However, land classification has also been used on occasion to describe what were essentially studies in land evaluation; for example, assessments of the suitability of various sites for pine plantations.

The site class system, employed in forestry practice, is a means of classifying the relative productive capacity of a site for a given tree species. The classification is based on measurements of tree growth, not on prediction from climatic and soil factors. The rate of tree growth self-evidently integrates the relevant features of climate, soils, etc.

Site class is thus a powerful means of measuring land suitability for tree growth and, as such, is incorporated into land evaluation procedures. (Chapter 7). It is a feature of land evaluation for forestry that greater use can be made of observed growth rates than can be made of the corresponding crop yield data in evaluation for agriculture.

The method of soil potential ratings has been developed in the United States. It is a system for analysis of the relative quality of soils for particular uses. Applied to forestry it leads to soil-woodland ratings. The soil-woodland rating system includes measurements of forest productivity, limiting soil properties, the effects of these limitations on use and possible corrective measures. Each of these factors is converted to numerical values, leading to estimates of the percentage yield reduction (as compared with optimal conditions), the cost of corrective measures and by combining these, an overall soil potential index. For conditions in the United States, a considerable volume of detailed information has been built up (McCormack *et al.*, 1981; U.S. Soil Conservation Service, 1980, 1983).

The system of soil potential ratings places emphasis on soil factors but some other environmental conditions, e.g. slope, flooding, windthrow hazard, are also included. It covers effects on management as well as tree growth. This is a detailed system of land evaluation, based on similar principles to those described in the present volume. Some of its features, notably the conversion of ratings to relative percentage values, could be adapted for use in evaluations in other countries.

2.2 Basic concepts and terminology

2.2.1 Introduction

Land evaluation is the process of assessment of land performance under specified kinds of land use. It consists basically of comparison between land and land use, where land refers to all features of the natural environment which can exert a significant influence on the use of land by man. More specifically, land evaluation involves comparison of the requirements of land use with the qualities possessed by land. This comparison is the basis for predicting the consequences of applying the different land utilization types to each of the mapped land units.

This section provides an introduction to the basic concepts employed to describe land use, land, and the relations between these. Also covered are certain terms derived from forestry practice - site, site class, site index and site quality - which can be incorporated into forest land evaluation.

Only the more basic terms are introduced here, others being defined in appropriate chapters. For the sake of clarity, some definitions are given in the text in simplified form. Formal definitions are found in the Glossary.

2.2.2 Land use

Description of the land use forms the most distinctive feature of land suitability evaluation as compared with other approaches. It is the basis for the principle that land suitability can only be assessed with respect to specified kinds of use. Only by describing the potential uses can their requirements be determined as the basis for comparison with the land qualities.

At a highly generalized level, an evaluation can be in terms of major kinds of land use, defined as the broad divisions of rural land use, e.g. forestry, agriculture, livestock production. It is possible to treat forestry either as a single major kind of land use or subdivided (Section 5.1.1).

Major kinds of land use are only taken as the basis for evaluations of large areas at low intensity, leading to qualitative suitability classification, e.g. at national level.

Most evaluations are based on the land utilization type, which consists of a set of technical specifications within a given physical, economic and social setting. The degree of detail in which a land utilization type is described varies with the purpose and intensity of the evaluation: at the minimum a summary description, but in intensive studies giving technical specifications in substantial detail. Examples of land utilization types at level of summary description are:

i. A government-operated softwood plantation for pulpwood production, with high capital intensity, low labour intensity, and largely mechanized technology.

ii. Government-owned natural forest in a catchment zone, primarily for water output and soil conservation, with subsidiary wildlife conservation functions.

iii. An improved village woodlot for fuelwood and domestic timber, operated communally by manual methods.

The phrases 'land use' and 'kind of land use' are employed in a general sense to refer to any form of use of land by man, in circumstances where the technical connotation of a land utilization type is not necessarily implied.

Each kind of land use has a set of environmental conditions which are favourable or adverse to its practice. The land use requirements are the conditions of the land necessary or desirable for the successful and sustained practice of a given land utilization type. Examples are suitable temperatures and soil rooting conditions to permit tree growth, or terrain conditions favourable for mechanized forestry operations, such as gentle slopes and absence of rock outcrops. Limitations are environmental conditions which adversely affect the potential of land for a specified use. Examples are poor drainage (for most tree species) or saline soils, as limitations to growth, or frequent rock outcrops or boulders as limitations to mechanization.

In most cases limitations are land use requirements expressed in the opposite sense. Thus deep soils are a land use requirement for good tree growth, shallow soils a limitation, few or no rocks and boulders a requirement for mechanized operations, many rocks and boulders a limitation. It is a matter of convenience whether some condition affecting the performance of a land utilization type is expressed as a requirement or a limitation.

Land use requirements and limitations always relate to a specific kind of land use. For example, there are certain trees for which poor drainage is a requirement, whilst the scenic impact of rock outcrops can be an asset rather than a limitation to the recreational potential of forests.

2.2.3 Land

The term land has already been introduced. It refers to all features of the natural environment of a part of the earth's surface, to the extent that they exert a significant influence on its potential for use by man. Thus land covers not only the geology, landforms and soils, but also the climate, vegetation and fauna, including pests and diseases. Where any forest stands are present, these form part of the land.

Land units are delineated areas of land with specified environmental conditions, employed as the basis for land evaluation. A land unit does not refer to any particular kind or scale of mapped area, but is a term of convenience to cover any such area that is selected for evaluation. Thus, at a reconnaissance scale, the land units might consist of land systems or forest types, whilst at a detailed scale, land facets or soil series might be chosen as appropriate.

Land qualities and characteristics are properties of land units. A land quality is an attribute of land which acts in a distinct manner to influence the suitability of the land for specific kinds of use. Examples of land qualities widely applicable in forestry are temperature regime, moisture availability, soil drainage, rooting conditions, potential for mechanization, and erosion hazard. It is important to note that land quality is not the same as site quality, as employed in forestry practice. A land quality refers to one attribute only, not to the total environmental conditions of a land unit.

Most land qualities cannot be measured directly; they need to be estimated by means of land characteristics. A land characteristic is a property of the land which can be measured or estimated, and which is employed as a means of assessing land suitability. Examples are mean annual rainfall, slope angle, soil texture, biomass of vegetation, and volume of standing timber.

Some land qualities can be measured or estimated by means of a single land characteristic. For example, the quality of soil drainage is normally expressed by the soil drainage class as employed in soil survey. Alternatively, the same quality could be diagnosed by means of vegetation communities known to reflect drainage conditions. Other land qualities reflect the interaction of several characteristics. Erosion hazard, for example, results from the interation between rainfall intensity, soil permeability and erodibility, and vegetation cover. Moisture availability could be represented, for example, by rainfall, length of growing period and soil water storage capacity.

Land use requirements are frequently expressed in the same terms as land qualities; for example, temperature requirements and temperature regime, nutrient requirements and availability of nutrients. This correspondence is intentional and facilitates comparison between the two. Each land utilization type has its own specific set of requirements, for temperature nutrients, drainage, etc. Similarly, every land unit has its own set of land qualities, including temperature regime, nutrient availability, soil drainage conditions, etc. A specified range of temperature, say 15° - 25°C throughout the year, is a land use requirement if it is being employed to describe the conditions necessary for a particular tree species. The same range of temperature is a land quality when employed to describe the temperature regime to be found on a particular land unit.

2.2.4 Relations between land use and land

Land suitability is the fitness of a given type of land for a specified kind of land use. The assessment of suitability is made by comparison between land use requirements and land qualities, coupled with analysis in environmental, economic and social terms. Land suitability always refers to a specified land utilization type, whether broadly defined or described in detail; there cannot be 'land suitability' without reference to the kind of use for which the land is suitable.

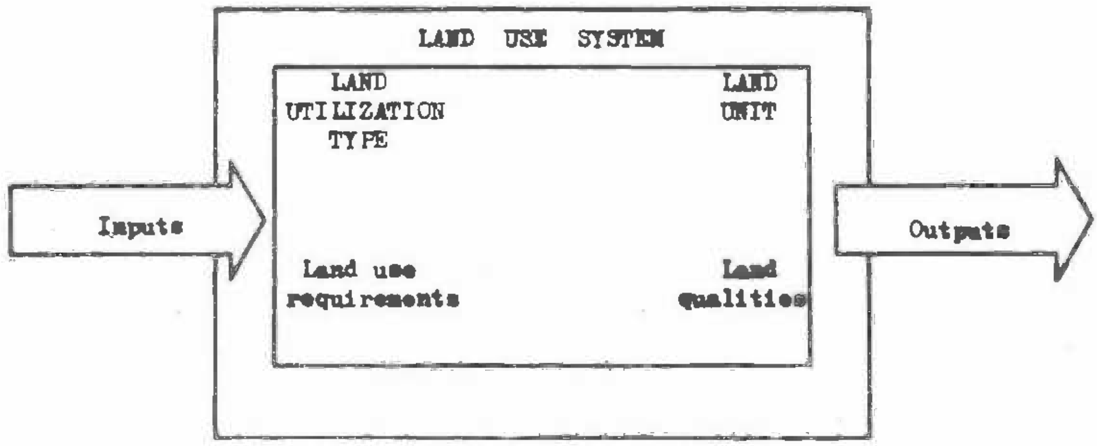
Three terms from forestry practice are closely linked to the concept of land suitability, in that they concern the productive capacity of a site for a given tree species. Site class (or site quality class) is a measure of the relative productive capacity of a site (land unit) for a specified tree species or stand, based on the volume, height or mean annual increment that is attained or attainable at a given age. Site classes are expressed numerically, as 1, 2, 3 ... or I, II, III ... and there is no uniformity of practice as to whether low numbers refer to better or poorer growth than high. 'Site quality class' has the same meaning as site class. Site index is a particular measure of site class, based on the height of the dominant trees at a chosen age (p.62).

It is important that people previously familiar with one or the other terms do not confuse the concept of land quality with that of site quality. Land quality refers to one attribute of land only: temperature, moisture, nutrients, etc. A land unit possesses certain conditions of each land quality irrespective of the uses to which it may be put. Site quality refers to the combined effects of all environmental conditions upon the growth of a given tree species, i.e. to suitability for a particular use. Site quality is not the same as land suitability, however, in that it only covers conditions affecting tree growth, not those affecting management or conservation. The nearest equivalent of site quality in the terminology of land evaluation would be 'land suitability for growth' of a specified tree species.

The outcome of the comparison of land use with land can be expressed in terms of land use systems. A land use system consists of a specified land utilization type practised on a given land unit, together with its associated inputs and outputs. (Figure 2.1). In essence, it is a particular combination of land use with land. In the terminology of land evaluation, the land use possesses specific requirements, whilst the land unit offers given land qualities. For a given level of inputs, as specified in the description of the land utilization type, the land use system yields a certain set of outputs (products, services and other benefits).

The concept of the land use system serves two purposes. First, it is a convenient short way of referring to a combination of land utilization type with land unit. Secondly, it provides an analytical framework for assessing the effect of variations in the system. A change in any one of the major components - inputs, the land utilization type and its requirements, the land unit and its qualities, and outputs, will have repercussions for others. Hence, the concept provides a basis for analyzing the consequences of change: to the land qualities (by land improvements), to the land utilization type (by modifying its specification), or to the inputs. Further discussion of this basic approach, fundamental to land evaluation, is given by Beek (1981).

Figure 2.1 Elements of a land use system



Source: based on Beek (1981)

2.3 Land suitability classification

2.3.1 Structure of the classification

The results of an evaluation are presented partly in terms of land suitability classifications. The suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. Four categories are recognized (Figure 2.2):

Figure 2.2 Structure of land suitability classification

Order	Class	Subclass	Unit
S Suitable	S1		
	S2	S2m	
	S3	S2e	S2e-1
	etc.	S2es	S2e-2
		etc	etc.
phase: Sc, conditionally suitable			
N Not suitable	N1	N1m	
	N2	N1e	
		etc.	
NR, not relevant			

i. Land Suitability Orders : reflecting kinds of suitability

ii. Land Suitability Classes : reflecting degrees of suitability within Orders

iii. Land Suitability Subclasses : reflecting kinds of limitation, or main kinds of improvement measures required, within Classes

iv. Land Suitability Units : reflecting minor differences in required management within Subclasses

Land suitability orders indicate whether given types of land are suitable or not for the land utilization type concerned. This is the first thing the user wants to know and by eliminating unsuitable land early, much time and effort can be saved. There are two orders, represented by the symbols S and N:

Order S Suitable:	Land 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
Order N Not Suitable:	Land which has qualities that appear to preclude sustained use of the kind under consideration.

Areas which have not been assessed for a given use because that use is precluded by the assumptions of the evaluation are shown on maps and tables as NR, Not Relevant.

Land Suitability Classes reflect degrees of suitability. Within the order Suitable, three classes are normally recognized: Highly, Moderately and Marginally Suitable, indicated by symbols S1, S2 and S3 respectively. (Table 2.1). For the general case, there are no quantitative definitions of the S1/S2 and S2/S3 boundaries; defined limits, e.g. in terms of relative yields, costs or economic return, may be adopted for particular evaluations.

Within the order Not Suitable there are two classes: N1, Currently Not Suitable, and N2, Permanently Not Suitable. Land is assessed as Currently Not Suitable if its limitations cannot be overcome at currently acceptable cost. In the case of Permanently Not Suitable Land, the limitations are so severe as to make the use so clearly impracticable or uneconomic that detailed analysis of inputs and outputs is unnecessary.

The boundary of Class N2, Permanently Not Suitable, is normally physical and permanent. In contrast, the boundary between Classes S3 and N1 is set by economic conditions and will vary in time with changes in relative costs of inputs and prices of outputs.

Table 2.1 Definitions of land suitability classes

Class S1 Highly Suitable	: Land having no significant limitations to sustained application of the given land utilization type, or only minor limitations 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 in aggregate are moderately severe for sustained application of the given land utilization type; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use will be appreciably inferior to that expected on Class S1 land.
Class S3 Marginally Suitable	: Land having limitations which in aggregate are severe for sustained application of the given land utilization type and will so reduce productivity or benefits, or increase required inputs, that this expenditure will only be marginally justified.
Class N1 Currently Not Suitable	: Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained application of the given land utilization type.
Class N2 Permanently Not Suitable	: Land having limitations which appear so severe as to preclude any possibilities of successful sustained application of the given land utilization type.
NR, not relevant	: Land which has not been assessed for a given use because the application of the use to that area is precluded by the initial assumptions of the evaluation.

Land Suitability Subclasses reflect kinds of limitations, e.g. moisture deficiency, erosion hazard. They are indicated by lower case letters, e.g. Subclasses 2m, 2e. Only the most important limitation, or where necessary, two of equal importance should be shown. There are no subclasses within Class S1 as by definition this has no significant limitations. The symbols for subclasses are not standardized and will vary from one evaluation to another. Among subclass symbols which may be employed are the following:

c conservation
e erosion hazard
l location
m moisture availability
n nutrient availability
p pests and diseases
q potential for mechanization
r rooting conditions
t temperature regime
w drainaga (water)
z salinity/sodicity

The subclass c, conservation, may be used in a positive sense, to denote a need for conservation forestry, as well as in the negative sense of indicating lowered suitability on grounds of conservation (p. 50)

2.3.2 Types of land suitability classification

Land suitability classifications may be qualitative, quantitative or economic. In a qualitative classification the suitability classes are defined in qualitative terms only. The economic and social context is taken into account as a broad background to the evaluation but there are no detailed calculations of costs and returns.

It should be noted that the description 'qualitative' refers to the definitions of boundaries between suitability classes, not to the procedures employed in evaluation which should always be in quantitative terms wherever possible.

Qualitative classifications allow the different kinds of consideration contributing to the evaluation to be combined in a more flexible manner. Economic classifications provide essential information required as input data to project analysis where investment is expected to follow. If an economic suitability classification is produced, it is important to ensure that it is not allowed to outweigh or dominate suitability considerations based on other aspects.

In a quantitative classification the distinctions between classes are defined in common numerical terms. In certain limited circumstances these may be quantitative physical terms, e.g. growth rates of timber species, it being assumed that management costs are approximately uniform. Most commonly, however, comparison between land use and land units requires an economic basis, both to compare different kinds of output and to compare production costs with benefits. If the class boundaries are defined in economic terms, it becomes an economic suitability classification.

Land suitability units are subdivisions of a subclass. All units within a subclass have the same degree of suitability at the class level and similar kinds of limitations at the subclass level. The suitability units differ from each other in their production characteristics or in minor aspects of their management requirements. Land within the Order N, Not Suitable, is not subdivided. Units are distinguished by numbers following a hyphen, e.g. 2m-1, 2m-2. There is no limit to the number of units recognized within a subclass.

A phase of Conditionally Suitable may be added to cater for circumstances where small areas of land may be unsuitable or marginally suitable for a particular use under the management specified for that use, but suitable given that certain conditions are fulfilled, e.g. leaching out of salts. The employment of conditional suitability complicates the presentation of results and should be avoided where possible.

Nearly all evaluations are taken at least to the level of suitability classes and subclasses but most reconnaissance and some semi-detailed surveys do not subdivide in more detail. Land suitability units are mainly employed in detailed surveys and where management specifications for different kinds of land are required. They permit interpretation at the forest compartment level.

2.4 Land suitability maps

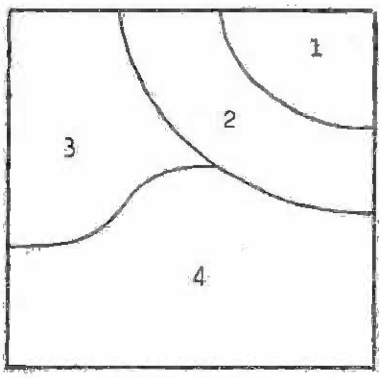
Figure 2.3 gives examples of how land suitability classes are represented on maps. At the top left, the basic land units are shown, here represented by numbers. The remainder of part (a) of the figure shows individual suitability maps for three land utilization types. In part (b) of the figure, the same data are shown in the form of a combined tabular legend. This would accompany a map of the land units on a larger scale.

Tabular legends of the form given in Figure 2.3(b) can be used in two different ways. Read horizontally, they answer the question, "What is the best use for this land unit?" In the example, Land Unit 1 should be under protection forestry, whilst Land Unit 2 is best suited to fuelwood production. Read vertically, the legend answers the question, "Where are the best areas for this kind of land use?" In the example Land Unit 4 is the most suitable for timber production and also for fuelwood production.

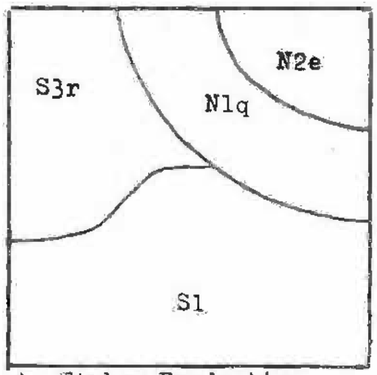
This example also illustrates how the results of land evaluation leave an element of choice open to planners. In the hypothetical case illustrated in Figure 2.3(b) Land Unit 1 should clearly be under protective forest, whilst Land Unit 4 is best suited to meet timber demands. Beyond this, there are several choices open, in accordance with relative demands for timber and fuelwood: extend timber plantations onto part or all of Unit 4, locate fuelwood plantations on Unit 4 if not used for timber, or on either or both of Units 2 and 3. This element of guided choice is a consequence of having evaluated the land separately with respect to each defined kind of use.

Figure 2.3 Examples of land suitability maps

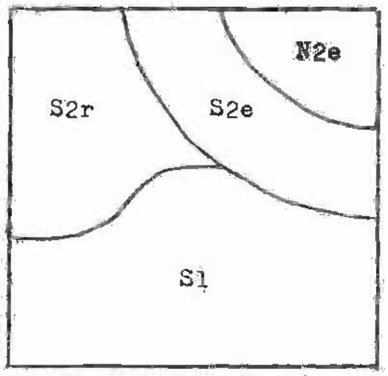
(a) Suitability maps for individual uses



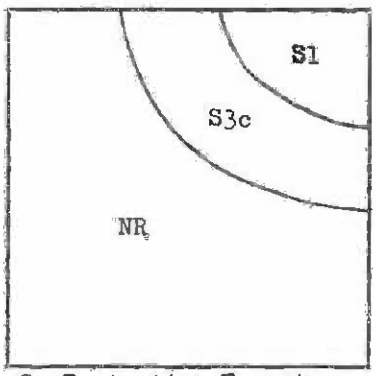
Land Units



A. Timber Production
Mechanized Harvesting



B. Fuelwood Production
Manual Harvesting



C. Protection Forestry

(b) Combined tabular legend.

LAND UNIT	LAND UTILIZATION TYPE		
	A. TIMBER	B. FUELWOOD	C. PROTECTION
1	N2e	N2e	S1
2	N1q	S2e	S3c
3	S3r	S2r	NR
4	S1	S1	NR

Land suitability subclass symbols: c = need for conservation, e = erosion hazard, q = conditions for mechanization, r = rooting conditions.

CHAPTER 3

OUTLINE OF PROCEDURES

CHAPTER 3

OUTLINE OF PROCEDURES

This chapter contains an outline of the basic procedures of a land evaluation, intended for those not previously familiar with such studies. The procedures of land evaluation are fundamentally the same whatever kind of land use is being considered; the distinctive features of forest land use lead to modifications in detail. In particular, where the kinds of land use considered include conservation forestry, there may be a need for a more flexible approach.

The outline is divided into two parts: a descriptive account, explaining how one stage leads into another, and a concise summary of the successive steps, with reference to the corresponding sections of these guidelines.

3.1 Account of procedures

Figure 3.1 gives a generalized view of land evaluation procedures. These commence with planning the evaluation, based on discussions between those who requested the evaluation and those responsible for carrying it out. The first need is to clarify the objectives of the evaluation: the needs of the people that it is expected to fulfil, policy aspects and so the kinds of land use which are relevant for consideration - timber plantations, fuelwood plantations, forestry for watershed management, etc. At the same time any constraints to land use changes are ascertained, e.g. that existing users of land may not be resettled. The organization responsible for the survey then conducts a rapid review of the physical, economic and social context of the area, and the kinds of data available, e.g. soil surveys, silvicultural studies. This leads to the planning of the programme of work, covering specifications of the results, information needed, surveys and studies required, staff, timing, and an estimate of cost. Final approval for carrying out the evaluation may be delayed until this point.

Three sets of field activities are then set in motion: studies of land utilization types, surveys of land units, and collection of economic and social data.

The studies of land utilization types commence with basic descriptions of each alternative (e.g. plantation or natural forest management or complete protection) and first estimates of required inputs and expected outputs. As the survey progresses, these descriptions are amplified and refined to provide one of the main sets of results from the evaluation.

Parallel with the above, surveys and specialized studied of land units are started. The purpose of these is to provide a mapped basis of relatively homogeneous areas of land, to which suitability for use will be related. The kind of land units chosen will vary with the objectives, ranging from forest types or land systems in a survey at national level, to site classes, soil series, land facets or other more specific mapping units in detailed surveys for forest management planning.

The third set of basic studies is the collection of economic and social data needed for analysis of alternatives. Like the basic surveys of physical data this is a time-consuming activity and so needs to be started early on. Besides its use later on in the procedures, there is an early need for such information in working out details of the land utilization types.

Following on from the description of land utilization types comes determination of their land use requirements. These are the sets of conditions needed for the successful operation of the land utilization type; examples are the growth requirements of possible tree species, or terrain conditions favourable to alternative methods of harvesting. They include also the conservation requirements, the conditions necessary to avoid soil erosion, adverse effects on water flow regime, or other undesirable environmental changes. From this review of land use requirements we learn what kinds of land will be best suited to each possible use.

As the land units are surveyed, some of their land qualities and characteristics will have been determined; for example, slope angle may be employed as a basis for defining land units and is also one of the properties of those units. Other land characteristics may need to be surveyed after the initial mapping, particularly if the land units have been taken from an existing survey.

Now comes the critical stage of land evaluation, the comparison of land use with land. At this point the requirements of each of the defined land utilization types are known, and so are the relevant features of climate, slope, soils, etc., for each of the land units. The first stage of comparison is called matching, in which these two sets of data are combined. This is initially done by assigning factor ratings which indicate partial suitabilities based on each land quality considered: moisture requirements compared with moisture availability, requirements for erosion avoidance as compared with erosion susceptibility of the land, and similarly. The separate ratings are then combined to give a first approximation to the land suitability classes.

These provisional suitabilities are then analyzed with respect to their environmental impact, economic consequences and social consequences. Environmental impact will already have been taken into account in land use requirements and matching, but an overall review is conducted at this stage as an added precaution. The nature and amount of economic analysis will vary considerably with the purpose of the survey, ranging from a strategic review in resource inventories for national planning purposes to detailed analysis of costs and returns wherever investment is intended to follow. Social analysis of proposed changes should always be conducted; it covers such aspects as whether the changes will fulfil needs, whether they will prove acceptable, and if any indirect economic and social consequences will occur, e.g. reduction in the area of communal pasture land.

After the provisional suitabilities have been analysed by these further means, the final land suitability classification is drawn up. This shows the suitabilities of each alternative kind of land use on each area of land.

The final stage is that of presentation of results. These include details of the land utilization types, together with land suitability maps (cf. Figure 2.3, p.20). Comparison of requirements of use with properties of the land will have led to management specifications being drawn up; for example, which establishment methods are best for each type of land, for each use on each relevant land unit. An analysis of the environmental impact of the possible changes is given, together with the results of the economic and social analysis. Finally, there will usually be data from basic surveys and specialized studies, e.g. of climate, vegetation, and economic information, which is placed on record for future use.

The end-product of a land evaluation survey is not a land use or management plan. Rather, it provides information on the consequences of several alternative kinds of land use, as applied to different mapped parts of the study area. For example, in a survey for the siting of teak plantations, the evaluation will indicate which are the best and which the relatively favourable sites from a land suitability viewpoint, as well as areas on which plantations should certainly not be sited. Except in broad reconnaissance surveys, estimates of costs and timber yields will be given. But the planning decision on whether to go ahead with a plantation project is certainly based on considerations beyond those of land evaluation, whilst even the matter of location may be influenced by such external considerations. The same applies in a survey intended for a forest management plan; evaluation provides considerable information on which to base such a plan, consisting of alternatives and their predicted consequences, but the actual management planning forms a later stage in the process of land development.

3.2 Computerized methods

Computers have important applications in all types of natural resource surveys. This includes not only the storage, retrieval and processing of field data but also the mapping of capability. For a detailed account the reader may refer to FAO Report on LECS - A Land Evaluation Computer System Methodology (Wood & Dent 1983). Developments in the field of the geographic information system could also be useful to the land evaluation.

Some parts of land evaluation procedures lend themselves readily to the use of computerized methods. This applies particularly to the initial matching, the comparison of land use requirements with land qualities (Steps 9, 11 and 12 in Section 3.3). In small surveys, such comparisons are more rapidly achieved by manual methods. In surveys involving large numbers of land units and/or land utilization types, comparison can be made by storing in computerized form:

- factor ratings for land utilization types;
- land characteristics of land units;
- rules for combining land suitability ratings into land suitability classes.

The computer first compares factor ratings with land characteristics to produce land suitability ratings, and secondly combines these ratings into land suitability classes. (Figure 3.2) (cf. Wood, 1980; Lee, 1981; Dent and Young, 1981, 210-219).

Other possibilities for computerization include conversion of land characteristics into land qualities, yield forecasting, economic analysis and output of land suitability classes by methods of automated cartography. A computer program has also been devised which combines land evaluation with the success of alternative land use options in meeting specified and weighted development objectives (Ive, 1981).

In addition to convenience in handling large amounts of data, an advantage of computerized methods is that where changes are made to the initial data (e.g. a revised factor rating, or modified value of a land characteristic) a revised set of results can be rapidly obtained. For example, the effects on land suitability of modifying the specifications of land utilization types, and therefore the factor ratings, can be examined.

In computerized methods there is need for a continuous check (i.e. human control) to ensure that the results are in accord with common sense and judgement. Although sophisticated procedures can be programmed, as a guideline, it is better to automate those steps of an evaluation which involve relatively routine processing of a large amount of data.

3.3 Summary of successive steps in an evaluation

The previous section has given an explanatory account of the stages in a land evaluation survey. Such a survey is by no means a routine task, and the detailed procedures need to be adapted to circumstances. However, as an aid to those training for land evaluation or conducting a survey for the first time, the following is a step-by-step guide, with references to the text descriptions of each step and to the relevant tables:

	Sections	Tables
1. Jointly with the governmental or other agency commissioning the evaluation, determine the objectives, constraints, data and assumptions	4.1 - 4.4	
2. Plan the necessary surveys and specialized studies; draw up the work programme	4.5	
3. (a) Identify and select the land utilization types to be considered in the evaluation	5.2	
(b) Decide which parts of the area, if any, are not relevant for certain land utilization types		
4. For each land utilization type, complete a provisional description based on the headings listed	5.3 - 5.5	
5. For each land utilization type, select the land use requirements and limitations that are likely to be relevant to assessing its suitability within the area	6.1 - 6.4	6.1, 6.2
6. Decide on the land units to be used for the evaluation. Where necessary, carry out surveys and produce a map of land units	7.2 - 7.3	
7. Decide which techniques for estimation or prediction of forest resources or yield are to be used. Conduct the necessary studies	7.4 - 7.5	
8. (a) Identify the land qualities to be used which correspond to the selected land use requirements and limitations	7.6, 7.8	7.1, 7.3
(b) Decide which land characteristics (diagnostic factors) are to be used to measure or estimate those land qualities		
9. For each land unit, survey or determine the value of land characteristics selected in Step 8(b). Draw up tables listing the characteristics for each land unit	7.4 - 7.7	
10. Decide on the data needed for economic and social analysis of land use alternatives. Conduct necessary surveys to collect such data	10.2.2 10.3.3	
11. Assess the factor ratings for each land utilization type	8.2	8.1, 8.2
12. (a) By comparing the factor ratings with land characteristics of the land units, obtain land suitability ratings. Summarize these as tables, one for each land utilization type on each relevant land unit (each land use system)	8.3-8.5	8.3, 8.4
(b) Combine the land suitability ratings to obtain provisional land suitability classes for each land use system		

		Sections	Tables
13.	Review the environmental impact of each land use system	9.1 - 9.4	9.1
14.	Conduct economic analysis of each land use system to the extent required by the purposes of the evaluation	10.2	10.1
15.	Review of social consequences of alternative possible changes in land use	10.3	
16.	(a) Based on Steps 13-15, review the provisional suitability classes of Step 12(b) to obtain the final land suitability classes, for each land use system	11.1 - 11.3	11.1
	(b) Draw up maps and tables showing the land suitability classes		
17.	Present the results in ways appropriate to each type of user	12.1 - 12.4	12.1,12.2

Figure 3.1 Outline of Procedures in Land Evaluation

The chapters which describe different stages in the procedures are indicated

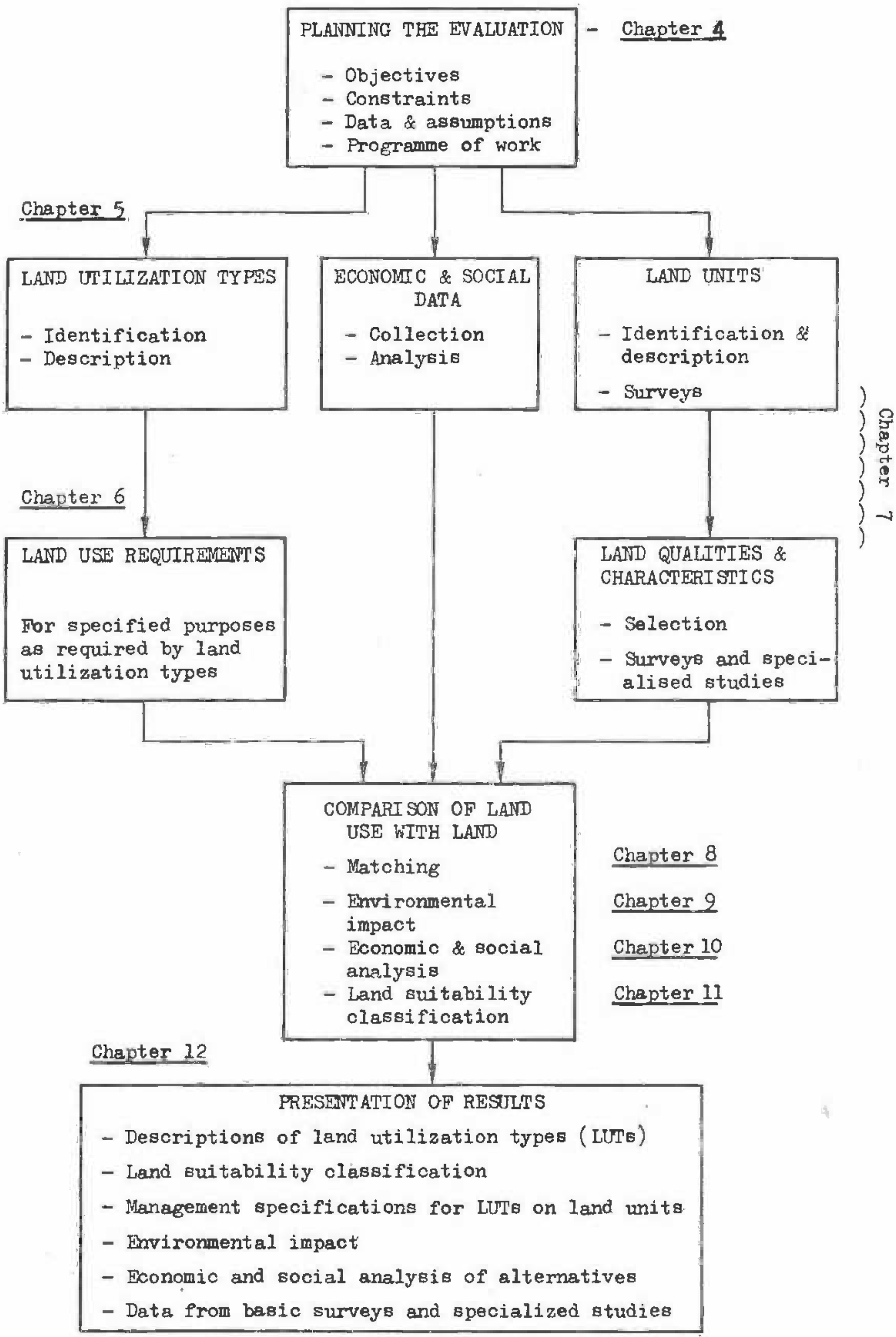
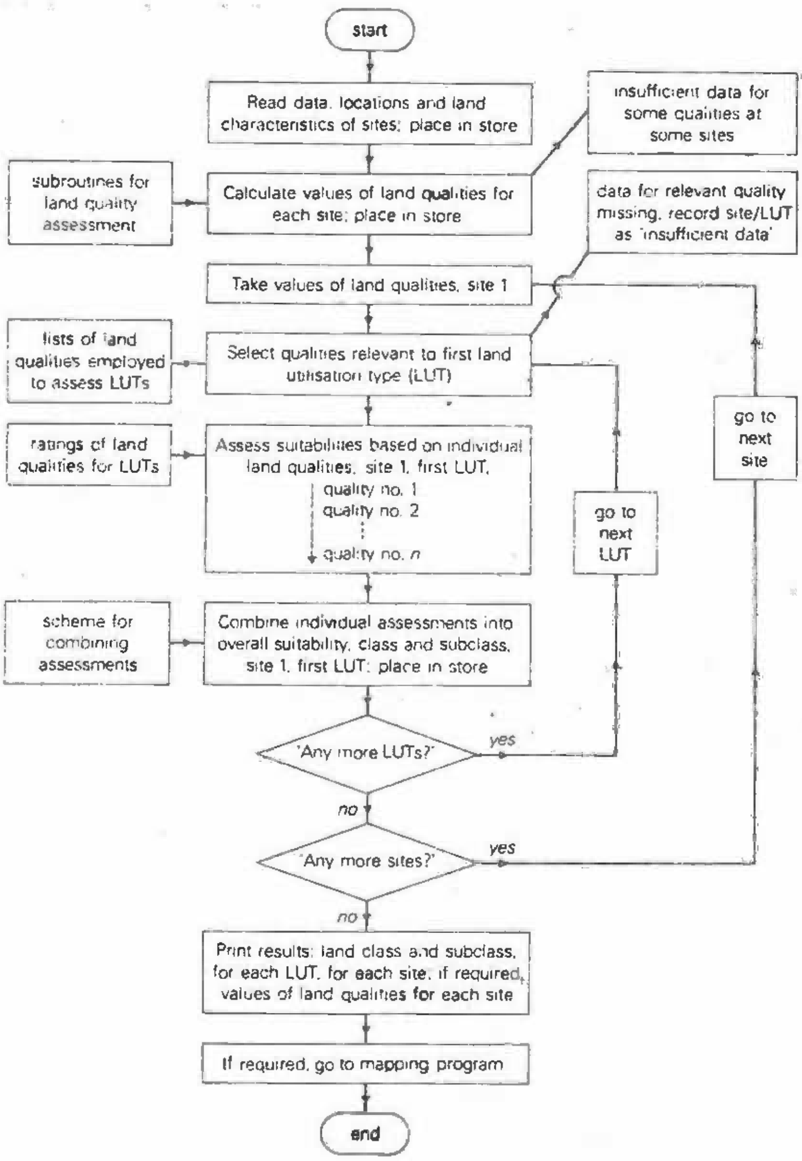


Figure 3.2 Generalized flow chart for land suitability classification by computer



Source: Dent and Young (1981).

CHAPTER 4

PLANNING THE EVALUATION

CHAPTER 4

PLANNING THE EVALUATION

4.1 Introduction

The process of land evaluation commences with discussions between the governmental or other organization requesting it and the organization responsible for carrying it out. In aid-assisted projects, the donors or lenders may constitute a third party. These initial consultations, which will probably take place prior to the final approval of the survey, are of critical importance. They set the objectives of the study, and lead to a plan for a land evaluation designed to meet those objectives.

The initial consultations should not be a one-way process, that of government directing the precise details of the studies required. There needs to be a free interchange of ideas on what are the problems of the area, how proposed changes in forest land use and management can help to solve those problems, and what is the extent and nature of surveys necessary to provide guidance on sound land use. Terms of reference should be flexible, permitting review during the course of the evaluation in the light of interim findings.

Aspects to be covered during the planning stage include the following:

- objectives of the evaluation
- constraints and assumptions which limit or underly the alternative solutions to be appraised;
- the physical, economic and social context of the study area;
- information needed, and surveys and specialized studies required;
- specifications of the evaluation and programme of work.

4.2 Objectives

The first activity is to clarify the objectives of the land evaluation. Foresters and others familiar with the area probably have a good idea of the social needs and the forest land use problems, and possible alternatives that might help to resolve such problems. For example, the Forestry Department and other government agencies will be aware of projected national requirements for forest products, needs of the local people for fuelwood, construction, timber, etc., and problems such as mismanaged forest stands, watershed problems of erosion and flooding, and needs for conservation. But before embarking on surveys, these needs and problems have to be set out in more detail. There must be discussions on the kinds of changes in land use planning and management that will help to meet those needs, and the extent of evaluation surveys necessary to provide guidance on such changes.

The main types of land use decision relevant to forestry evaluations, as outlined earlier, include changes between forestry and other major kinds of use, where there is competition for land; decisions as between different purposes of forestry or their relative role; and forest management planning. The objectives will usually fall within one of these groups.

The formulation of objectives is carried out jointly by all parties concerned, with government taking the lead in setting of problems and needs, whilst government and the survey organization may contribute equally to discussion of proposed solutions.

Aspects to be covered during discussion of objectives include:

- What are the limits of the study area?
- Which groups have interests in the forestry production, present and potential, of the area (e.g. local people(s), Forestry Department and other Government departments, national and/or local)
- What are the production needs from the area, (e.g. for wood products, other forestry products, water)?
- What are the conservation needs of the area, for protection or reclamation?
- What changes in land use, or improvements in land management, are proposed to help meet these needs? Hence, what kinds of forest land use are relevant for consideration?
- What is the extent of competition between forestry and non-forest uses of the land?
- What relative weighting should be assigned to the several objectives?

A simplified example of a set of objectives might be:

i. To provide fuelwood plantations capable of meeting, on a sustained basis, a projected local demand of 1 600 m^3 per year.

ii. To permit grazing access to the planted land to the maximum extent compatible with forest management.

iii. To ensure that plantations are sited on land which, under the anticipated level of management, will not lead to adverse environmental consequences.

4.3 Constraints and assumptions

Distinct from the objectives are a set of constraints and assumptions which will underly the evaluation. Constraints are restrictions or limitations to the possible changes in land use; for example, that it is socially and politically impossible to displace existing agricultural users of land except with their consent, or that under no circumstances can excision of part of a national park be considered. Assumptions are conditions which will underly the evaluation; for example whether remoteness from existing roads be taken as a criterion for classifying land as not suitable for productive forestry, or whether this be ignored at the present stage on grounds that new road construction can be considered.

The constraints are set primarily by government, the assumptions jointly between government and survey team. Examples of the kind of questions that need to be decided are:

- Is the survey area fixed, or can it be modified in the light of interim findings?
- Can changes to forest reserve boundaries be considered?
- Can resettlement of existing population be considered?
- Are possible modifications in land tenure or rights to be considered? What are the political constraints to any such change?

- In what manner is the factor of location to be assessed in the evaluation?

- What is the time scale to be considered for evaluating the land use changes which may follow the evaluation?

- How detailed should be the economic analysis within the evaluation, and on what assumptions should it be based (e.g. pricing, discount rates)?

4.4 Context of the study area

One of the principles of land evaluation is that it is made within the context of local physical, economic and social conditions. This context needs to be reviewed at the start of the evaluation, preferably during the formulation of the detailed proposal. Such a review is primarily the responsibility of the survey team, although it will be based on available material supplied by local research and governmental organizations.

The three sets of conditions to be reviewed are:

1. Physical context Location and accessibility; climatic and vegetation zone; types of relief, range of soil types believed to exist; present forest types; role of the area with respect to need for, and supply of, water; general conditions of resource conservation or degradation, and role of the area with respect to national conservation needs.

2. Economic context Basis of the present economy, forest production and demand for forest products, levels of living, wage rates, economic infrastructure (e.g. roads, services), general levels of costs and prices, location of markets, government subsidies, needs for import substitution or export revenue.

3. Social context Population and its rate of change, education and attitudes of land users, land tenure and land rights, needs of the population which are met from forest land.

4.5 Specifications and programme of work

4.5.1 Information, surveys and specialized studies

Based on the above consultations, the survey team draws up a plan for the evaluation, together with a model of its results. The objectives and assumptions will indicate the necessary form of the results, including the required degree of detail. This is the basis for deciding on the information needed, which in turn determines the necessary surveys and specialized studies. The basic sequence is thus:

- objectives;

- information needed to achieve these objectives;

- surveys and specialized studies required to obtain that information.

There are no fixed procedures for planning the evaluation. Experience of previous surveys for similar purposes and in comparable environments will be drawn up where possible. Usually there will be financial constraints to the conduct of the survey, particularly the man-years of professional services that can be supported. However, the cost of additional information has to be balanced against the future costs of mistakes which could arise from insufficient information or inadequate analysis.

Aspects which need particular consideration are the degree of detail to be used in description of land utilization types, the nature and intensity of required natural resource surveys and specialized studies, the degree of economic analysis to be incorporated into the evaluation, and the ways in which the results will be presented.

The descriptions of land utilization types vary in detail according to the purposes of the study. In evaluations for strategic planning at the national level they may be brief indications only, e.g. 'natural hardwood forests for timber production', 'natural forests for watershed conservation', 'pulpwood plantations'. At the opposite extreme, surveys for forest management planning require detailed specifications of silvicultural and harvesting methods best suited to each type of land.

The role of natural resource surveys and specialized studies in an evaluation differs widely according to the information already available. Occasionally it will be possible to base the evaluation on existing surveys. More often, decisions have to be made on the types, scale and intensity of surveys needed, which then form an integral part of the evaluation.

The degree of economic analysis depends primarily on whether the evaluation is intended to provide policy guidelines only, in which case such analysis may be in broad terms only; or whether it is intended to lead to investment decisions, when considerably more detailed studies of land use alternatives will be necessary. There is a corresponding decision on whether the land suitability classification, one means by which the results are expressed, is to be qualitative or economic.

The methods of presentation of results should be agreed in advance. The results may have to suit the needs of high level decision-makers, planners, practising foresters, extension staff, and perhaps local people. This will call for presentation in several different ways, e.g. executive summary, detailed report, and extension guides.

4.5.2 Programme of work

Based on the decisions on the types of surveys and kinds of analysis needed, estimates are prepared of the staff requirements of the evaluation and their time scheduling. This leads to a programme of work which, in turn, forms the basis for an estimate of cost.

No hard and fast rules can be laid down for staffing, other than that as the team is enlarged, a balance should be kept between the various disciplines represented. At one extreme comes a one-man survey, carried out either by a forester applying the techniques of land evaluation or an evaluation expert specializing in forestry problems; in such a "team", any shortcomings in specialized knowledge might be compensated by good integration! A balanced four person multidisciplinary team might consist of an environmental scientist (e.g. ecologist, geomorphologist/soil surveyor), a land evaluation specialist, a forester, and an economist/sociologist. Larger surveys, finance permitting, call for several environmental scientists (say in climatology, ecology, geomorphology, soil survey), one or more land evaluators, specialists in silviculture and forest harvesting, other technologists (e.g. in agriculture, livestock production) where there are competing kinds of land use to be assessed, a forest economist, a sociologist and a conservation specialist.

The time taken for the necessary surveys and studies can only be estimated from previous studies. Substantial allowances should be made for contingencies, e.g. administrative delays, breakdowns, flooding. It will be apparent from the outline of procedures that different sets of information are called for at certain stages of the evaluation and, therefore, a network analysis could be useful to ensure that such needs are met. The procedure of matching can often be taken as the focal point for such analysis, and to ensure that the necessary data from different sources has been assembled at that point. Experience has shown that economic analysis of land use systems cannot take place until information on land utilization types, land units and the provisional results of matching are available.

4.5.3 Specifications

At the end of the initial consultations a document is drawn up giving the specifications for the land evaluation. This will be discussed with the commissioning and donor agencies, perhaps modified, and will then serve as the basis for the project document, contract, or other basis for action.

The specifications should contain an outline of the problem and its proposed solution, including:

- a statement of the problems of the study area and the objectives of the evaluation;

- the possible ways of resolving those problems which the evaluation is designed to investigate;

- the required information, and the surveys and specialized studies necessary to obtain this;

- the programme of work;

- the manner of presentation of the results.

CHAPTER 5

FOREST LAND UTILIZATION TYPES

CHAPTER 5

FOREST LAND UTILIZATION TYPES

5.1 General

5.1.1 Major kinds of land use in forestry

The basic concepts and terminology for the description of land use have been given earlier (pp.18-19). Forestry as a whole may be divided into a number of major kinds of land use, distinguished on the basis of primary purposes and type of forest. These are as follows:

Commercial forestry	)	
Community forestry	)	- based on natural forests
Environmental forestry	)	- based on forest plantations
Recreational forestry	)	

Commercial or production forestry is directed at supplying national or export markets. In the tropics, commercial forestry based on natural forests consists mainly of the management of the hardwood rain forest formation. Commercial forest plantations can be subdivided into intended use for timber or for pulpwood. Community or social forestry is that directed primarily at the needs of the local community. Fuelwood carried manually or by pack animal for sale at nearby towns forms an intermediate case between commercial and social functions. Most social forestry was formerly based on collection from natural vegetation, with little or no deliberate silviculture. Farm and village woodlots established by planting of seedlings form the social equivalent of plantation forestry.

Environmental or conservation forestry covers cases where the primary object is either to conserve the natural ecosystem or to restore degraded land. It may be subdivided according to whether the reclamation purpose is included. Purposes may include watershed management, soil conservation, soil reclamation, conservation of plant genetic resources and wildlife conservation, usually several of these objectives. Recreation forestry, frequently combined with environmental objectives, may include functions both of revenue from tourism and provision of recreation.

Commercial and social forestry can be treated in land evaluation by a fundamentally similar approach, comparison of land use requirements with land qualities, differing in the social context and level of technology normally employed. Recreational purposes also lend themselves to the same methodology. Environmental forestry has the distinctive feature that it is need for conservation, rather than 'suitability' in the literal sense of the term, that is the major determinant of whether land should be allocated to that purpose. This difference in approach calls for more substantial modifications to evaluation procedures.

5.1.2 Land utilization types

Only studies at a broad reconnaissance scale are likely to refer to major kinds of land use. Most, if not all, evaluations for forestry will be based on the land utilization type, a set of technical specifications in a given physical, economic and social setting. The specifications cover tree species or forest type, methods of management (silviculture and harvesting) and conservation measures.

The terminology of land evaluation as a whole distinguishes as a special case a multiple land utilization type, as one in which more than one kind of use or purpose are simultaneously undertaken on the same area of land. As one of the distinctive features of forestry is that land use is nearly always, to a greater or lesser degree, multi-purpose, the multiple land utilization type becomes the normal state of affairs; a forest land evaluation must be based on this situation.

There are four reasons for using the concept of the land utilization type:

i. Only by defining the land use precisely is it possible to determine what will be its specific requirements and limitations.

ii. By knowing the requirements for physical data, the survey activities can be specifically directed, neither omitting critical information nor gathering irrelevant data.

iii. Provisional identification of the land utilization types at the start of an evaluation ensures that they will be relevant, socially and with respect to policy, to the needs of the area.

iv. Although not all parts of the descriptions will be relevant to land use requirements, the more detailed technical specifications are needed as a basis for economic analysis. The descriptions also form independently one of the outputs from an evaluation, for use as a basis in subsequent management planning.

5.2 Selection of relevant land utilization types

5.2.1 Determinants for identification

The identification of relevant land utilization types is made at an early stage in the evaluation, at least partly during the initial planning stage. They are first described in very broad terms, e.g. 'community fuelwood plantations', and then successively refined and described in more detail as the evaluation progresses, e.g. by giving tree species, silvicultural methods, rotation age.

Relevant uses of land are selected on the basis of policy objectives and the physical, social and economic context of the area. This is a stage at which economic and social considerations play a major part in all evaluations, including those in which the results will be presented only as a qualitative classification. Selection of land utilization types which meet needs and objectives, and which are realistic in the light of the economic and social situation, ensures that when land evaluation activities locate land units that are physically suitable for them, there is a reasonable chance that they will also prove to be economically feasible and socially acceptable.

Determinants for identificaton of relevant land utilization types include the following (a more detailed list is given in Andel et al., 1981):

i. The terms of reference of the land evaluation. This covers cases where selection has already been made prior to the commencement of the evaluation, e.g. where it has been commissioned specifically for watershed management, or softwood timber plantations. This situation, called preselection of land utilization types, anticipates and subsumes the criteria which follow.

ii. Policy needs and objectives. These cover national and local needs both for production and conservation; e.g. a national need to reduce timber imports, local needs for forest products, or either a national or local need for conservation.

iii. The economic and social context of the area. The most relevant economic attributes are the general level of wage rates and income expectations, and the level of capital availability. These will determine, for example, whether labour-intensive or mechanized methods of management are relevant for consideration, and thus whether potential for mechanization is a significant land quality. The social context includes present land use, past trends and future outlook, population pressure, communications and other infrastructure. The extent of, and reasons for, illegal incursions into protected forests can be a guide to local needs.

iv. The broad physical context, e.g. climatic zone, or whether plains or mountainous lands, can be used to limit the realistic types of land use, prior to more detailed physical evaluation.

5.2.2 Procedure for identification and selection

Where not preselected, an approximate procedure for selection of relevant uses is as follows:

i. Identify the potential users, those organizations and communities with relevant interests in the land use. These will nearly always include the national and/or district forestry department and the local rural community. Also included should be bodies whose present interests outside forestry may be affected by proposed changes, e.g. pastoralists.

ii. In the case of governmental interests, list the policy objectives and constraints. Ascertain whether constraints are rigid, e.g. modifications to forest reserve boundaries may or may not be considered.

iii. In the case of community interests, list the needs of the local population for forestry products and benefits, and assess their approximate importance. This can be done through community spokesmen, or by interviews with a sample of farmers or other land users.

iv. Although covered in theory by policy objectives and needs, it is useful in forestry projects to give additional attention to specific conservation needs, present and future, of the area.

v. Assembly the previously available material on the physical background, supplemented, if possible, by a reconnaissance field tour.

vi. Summarize the above information by parallel lists of objectives, needs and constraints, arising from each interested party and from the land itself. An example might be the headings:

National forest policy	District Forestry Department	Other Government Departments	Local Community	Conservation needs	Broad physical constraints

vii. List the types of forest land use to be found both in the area and elsewhere in the country under similar conditions. The land utilization types need not, of course, be confined to those already in existence.

viii. Based on the previous material, make an initial identification of possible land utilization types. This will usually be larger in number than those later selected, e.g. a wider range of tree species, management both with and without mechanical harvesting, conservation forestry both alone and in combination with limited production objectives.

ix. Compare the initially identified land uses with the objectives, needs and constraints of each type (Step vi). Assess the extent to which each has the potential to fulfil needs and objectives, and to meet constraints. On this basis, make a selection of the most promising land utilization types, defined at this stage in broad terms. These selected uses form the starting point for subsequent evaluation.

5.2.3 Elimination of non-relevant use/area combinations

By no means every one of the land utilization types selected will be relevant for consideration over all parts of the survey area. For example, it is unrealistic to consider establishing large scale industrial plantations on densely settled farmland, and survey effort would be wasted in assessing the physical suitability of such land for that purpose. Such areas can be delineated, if necessary, from air photo-interpretation, and marked on the suitability map as 'not relevant' for the particular use. They are then not evaluated for that use. Considerable savings in survey time may be possible by this means, allowing available effort to be concentrated on the most promising combinations of land use with land.

5.3 Description of land utilization types

The main attributes for the description of forest land utilization types are as follows:

- Outputs: products
  other benefits
- Markets
- Labour
- Capital
- Material inputs
- Technology: silviculture
  harvesting
  protection and conservation
- Infrastructure requirements
- Land improvements
- Management
- Scale of operations

Each of these features can affect land use requirements and limitations, or management specifications on a particular land unit, although by no means all will be relevant in every case. They also serve to provide a background or context to the land use, which may indirectly be needed in order to specify requirements or management practices.

Outputs consist of products, including both timber and non-timber forest products; and other benefits, such as conservation and tourism. Water forms an intermediate case, being a material product, although partly treated on a conservation basis. Details of possible outputs are noted on page 11. Summary descriptions, as proposed at the start of an evaluation, give the types of output only. More detailed descriptions give estimates of types and yields of timber, including their timing; quantities of other forest products; and further details, quantitative where relevant, of intangible benefits, e.g. water flow regimes, wildlife numbers, expected intensity of recreational use.

Markets refer to the intended destination of produce, and also to the beneficiaries of intangible benefits. The primary distinction is between commercial forestry, for industrial uses or for large scale marketing, e.g. of fuelwood to towns; and community forestry for local needs. Location and distance to primary markets, e.g. sawmills, pulpmills, urban markets, may be given.

Labour is dscribed initially in qualitative terms as high, intermediate or low labour intensity, according to the relative extent of mechanized and manual operations. Proportions of skilled or specialized labour, such as for operation of machinery, are estimated. For management specifications and economic analysis, estimates of man-days per unit area will be required.

Capital is described qualitatively as high, intermediate or low capital intensity, according to the scale of initial costs for land improvements, infrastructure, roading, machinery, etc., and establishment costs. For economic suitability evaluation, all such capital inputs must be estimated quantitatively. Capital intensity can then be expressed as currency units per unit land area. Because of the long rotations in forestry and the considerably greater costs of establishment as compared with maintenance, capital requirements are relatively more important, as compared with recurrent costs, than in most forms of agriculture.

There is normally an inverse relation between labour and capital intensities, capital-intensive operations requiring skilled labour but in relatively smaller quantities, whilst low capital intensive land utilization types require a higher labour intensity.

Technology refers to the complex of technical practices employed in the management of a land utilization type. In forestry it is useful to distinguish three groups of practices: silvicultural technology, harvesting technology and measures for protection and conservation.

Silvicultural technology covers the technical operations necessary for forest establishment or regeneration, and maintenance. Establishment refers to forest plantations, regeneration to post-harvest operations for the next cycle in natural forests. Descriptions for plantations include planting methods, spacing, thinnings, weeding and pruning and fertilization and plant protection, and length of rotation. For natural forests, the corresponding measures to ensure regeneration of desired species are given.

Harvesting technology is an area of special techniques that requires separate description. Not only can logging operations have various degrees of mechanization, but this can take many forms (skidding, overhead leads, etc.), each having specific requirements as to terrain conditions. For natural forests, harvesting technology should include the construction of the necessary road network. Selection of harvesting methods takes account of conservation needs, e.g. to minimize soil disturbance.

Protection and conservation technology covers a group of management activities which are necessary in plantation forestry and in both commercial and environmental natural forestry. Fire protection and measures for protection from illegal incursion are widespread requirements. Forests for flora and fauna conservation require specific measures for protection of rare species.

Infrastructure requirements specify the on or off-site infrastructure needed for the proposed operation of the land utilization type. Examples are the required capacity of sawmills or pulpmill, and any necessary construction or improvement of roads from the forest to markets.

Land improvements are alterations in the properties of the land which improve its potential for use. They are treated as a distinct stage in land evaluation, on the basis that the land after improvements will have different potential to its state before. In the case of forestry, where there is frequently substantial initial capital investment, the specified land improvements may subsequently be included in the description of the land utilization type, e.g. specifying that former swampy or peaty land is to be improved by construction and maintenance of drainage works.

Management is a key attribute linked to technology, labour, capital and outputs. Aspects described include the general level of management skill and form of land tenure. The basic distinction in forestry is between forest areas owned by the government forestry department or other agency and managed at a relatively high level of technology and skills; and community forests managed by smallholders or village organizations, with less availability of advanced technologies and skills.

Scale of operations includes the anticipated scale of the total area covered by the land utilization type, the size of individual management units, and the proposed annual felling area.

5.4 Modification of land utilization types during the evaluation

When identified and selected at the start of the valuation, land utilization types are described briefly either as major kinds of forest use, e.g. community fuelwood plantation, watershed protection forest, or in the slightly greater degree of detail of the summary description. As the evaluation proceeds, it becomes possible to give progressively more technical specifications, amplifying the descriptions to full accounts which form the basis for a management plan.

This modification involves more than simply the addition of detail. In the process of matching (Chapter 8), it will be found that the initially selected land utilization types are less than highly suited to many of the land units. This situation can be improved in either or both of two ways. First, the properties of the land can be changed through land improvements, e.g. drainage, fertilization. Secondly, the land use requirements may be modified through changing the technical specification, for example, from one form of mechanized harvesting to another. Suitabilities for the modified land utilization types are then revised. This process of iteration, known as matching, is one of the most powerful techniques in land evaluation, leading to adaptations in methods of management best suited to conditions on each of the land units of the area.

5.5 Examples of land utilization type descriptions

Example 1 Small-scale timber concession in South-east Asian Dipterocarp forest regions

Broad group: commercial forestry, natural forests.

A land utilization type of natural dryland forests with wood production and soil and water conservation as main objectives. Major products are quality timber for sale as logs, usually in small quantities at a time (less than 100 m^3 as individual sales). Secondary forest products like rattan, bamboo and stakes are of importance. Markets are the locally operative commercial markets for saw logs. Labour is semi-skilled under skilled foremen, numbering ten to thirty people. Level of capital investment is moderate, at most US$250 000 and substantially less if only second-hand machinery is purchased. Technology is of intermediate level, operators mostly using second-hand machinery of older types (especially army surplus with winches fitted and adapted for log extraction). Forest machinery consists of two to five vehicles. Infrastructure needed is earth road access from concessions to sawmills. Forest access roads are of dry weather type only. There is no river-rafting of logs. There are no land improvements. Level of management is intermediate; there is no regard for continuity of log production during wet periods. Forestry Department supervision of the management of applied selective tree cutting can only be adequately arranged for a number of smaller concessions combined in one work area. The scale of operations is indicated by a concession agreement over 400 - 4 000 ha for a period of three to twelve years; the minimum annual felling area is 125 ha for a production of 5 000 m^3 log volume per year.

Example 2 Improved village woodland in Africa

Broad group: social forestry, based on natural vegetation.

The two main products, fuelwood and poles for domestic construction; those woodlands on steeper slopes also fulfil a conservation function. The produce is for use by the associated village (= market). Labour is drawn from farmers, with larger tasks performed by communal work parties. Level of capital investment is very low. Technology consists of improvement of the existing vegetation, first by limits to volume of harvest and, secondly, by enrichment planting, using seed supplied by the Forestry Deptment. Harvesting is manual, by panga and headloading. The only infrastructure needed is a village nursery, and there are no land improvements. Management is by the village community organization, if possible through appointing a forest management committee; level of management will vary between villages. The scale is small, individual woodlands being of the order of 20-100 hectares.

Example 3 Recreation forestry in densely populated areas in North-western Europe

Broad group: environmental forestry, for recreation.

A land utilization type of mainly man-made forests near concentrations of population, with as main objective the provision of space and agreable forest environment for leisure and recreation (outputs). At the same time this use produces wood from slow-growing hardwood species of high quality, for industrial utilization. Labour is both skilled and unskilled; numbers depend on the type of infrastructure, about 1.5 man-years per 100 ha. Level of capital investment is high, mainly because of the planning of forestry work, the intensity of visits, the planning of the recreation facilities, public relations and the financial organization.

Technology for establishing and tending is simple, but for harvesting and transport is advanced. Size of individual forest compartments is small to promote diversity of the area (25 ha). Income is from recreation facilities and wood. Costs are mainly for maintenance of infrastructure and for a small part for forest work such as planting and thinning. Wood production will be on 30 percent of the area; yield in forest areas is about 5-8 m^3/ha/year. About one-third is open space and another one-third is water. Management is through local government organizations. On scale, supervision by university-trained foresters requires at least an area of 5 000 - 10 000 ha; since the average area of a recreation forest will rarely be more than 500 ha, combinations will have to be found.

Source: Examples 1 and 3 based on Laban (1981); Example 2 original.

CHAPTER 6

LAND USE REQUIREMENTS

CHAPTER 6

LAND USE REQUIREMENTS

6.1 General

6.1.1 Requirements and limitations

Having selected the land utilization types the next step is to identify the conditions of land necessary for their operation. The land use requirements are the conditions of the land necessary or desirable for the successful and sustained practice of a given land utilization type. Examples are suitable temperatures and soil rooting conditions to permit tree growth. The converse of requirements are limitations, conditions which adversely affect the practice of a land utilization type, e.g. saline soils, or impediments to mechanization, such as steep slopes and rock outcrops.

It is a matter of convenience whether a condition is expressed as a requirement or a limitation, e.g. a requirement for good soil rooting conditions or a limitation of poor rooting conditions. In the present text those features capable of being described in a positive manner are treated as requirements, only those which invariably have negative effects where present, e.g. salinity, frost hazard, pests and diseases, being termed limitations.

The land use requirements and limitations subsequently form the basis for deciding what information needs to be collected from basic surveys of land.

In principle, the identification of land use requirements precedes surveys of land resources in order that the survey activities shall be directed towards collection of the information needed. In practice, it is only the initial identification and selection of promising land utilization types which is done first, followed by identification of their approximate requirements. This first approximation to the requirements serves to guide the basic survey operations. Thereafter, surveys of land and refinement of the land utilization types proceed in parallel.

In these general guidelines it is not possible to give details of critical values for the requirements of particular kinds of use: to say, for example, that for mechanized forest plantations, slopes of less than 5° are rated highly suitable, 5° - 10° moderately suitable, etc. Such critical values will vary considerably with details of the land utilization type and with the physical and socio-economic context. The values must be set for individual evaluation surveys or for particular countries or regions. This chapter outlines the types of requirement for different kinds of forestry, with check lists.

6.1.2 Requirements for growth, management and conservation

It is convenient to divide the land use requirements into three groups: requirements for forest growth, for management, and for conservation.

The growth requirements are those land conditions necessary for the successful survival and growth of trees. They are based mainly on climate and soils. These cover both requirements for growth, such as suitable temperatures, adequate moisture and nutrients; and requirements for survival of the trees, such as absence of frost, pests and diseases.

In some circumstances the growth requirements are partly replaced by estimates of present forest conditions. In the case of natural forest, where the forest itself forms part of the land resources, an inventory of the existing forest forms the major basis for growth requirements; that is, the major land use requirement is that a forest stand of good quality shall already be present. There may also be estimates of growth rates (natural or plantation forests), survival rates (plantations) and yields of non-timber products. Where the intention is to harvest the natural forest in its present condition, these direct estimates largely or entirely take the place of growth requirements. If the intention is to improve the natural forest, e.g. by enrichment planting or change in management practices, then the growth requirements may be relevant as well.

Management requirements are the conditions necessary or desirable for successful management of the forest. It would be possible to subdivide these into requirements for land preparation, establishment, maintenance and harvesting, but in practice there is considerable overlap between such requirements. The requirements for initial land preparation and clearance, which in evaluation for agricultural land use are treated in a separate manner, are here included with management requirements, since in forestry they are normally treated along with other establishment costs.

In production forestry, whether from natural forests or plantations, a third group of conservation requirements is always present. These are the conditions likely to affect response of soils, streamflow and vegetation to proposed changes in land use and management. In conservation forestry these become by definition the major group of land use requirements.

The advantage of this subdivision is that the different groups of requirements can be treated separately to some extent. For example, there is a set of growth and survival requirements for *Pinus patula*, which are independent of whether it is harvested by mechanized methods or manually. Conversely, there is a set of requirements for mechanized harvesting from softwood plantations which is largely independent of the species grown. In the process of matching, the three sets of requirements for tree growth, management and conservation can be used in different combinations to build up and refine alternative land utilization types.

6.1.3 Treatment of requirements based on economic and social conditions

It is emphasized that land use requirements, in the sense in which the term is employed in land evaluation, cover only the requirements from the land. They are not intended to cover requirements arising from economic and social conditions, e.g. availability of low cost labour for manual operations, or of capital where mechanized management is envisaged. Such conditions are indeed equally significant 'requirements' in the normal, non-technical, sense of the word, but they are taken into account at different stages of the land evaluation procedure: first, during the initial consultations and selection of relevant kinds of land use, secondly, during the formulation of detailed specifications for land utilization types and, thirdly, during subsequent economic and social analysis. The present central stage in procedures is concerned with identification of requirements from the land only, taken in the context of the economic and social setting.

6.1.4 Comparison with requirements for agricultural land use

A note on the distinctive features of land evaluation for forestry may be useful first, for land evaluation specialists previously familiar with studies for agricultural production and, secondly, to assist in reconciling procedures in evaluations which cover both forestry and non-forest forms of use. The distinctive features vary according to whether plantation establishment, management of existing forests, environmental forestry, or recreation forestry is being considered.

In the case of plantation forestry, there are no differences in principle from evaluation for perennial agricultural crops and only minor changes in procedures. The process of estimating likely growth, yield and survival are similar whether the crop is to be agricultural, e.g. rubber, oil palm, cocoa, or a timber tree crop. Where the agricultural crops are to be grown on a plantation basis, many of the management requirements are also similar, whilst conservation requirements apply to both cases. Differences are only in the details of requirements, e.g. the specialized harvesting requirements for timber arising from its high bulk as compared with different requirements (e.g. frequency of access) for agricultural crops. The requirement for soil nutrients is relatively less important in forestry than agriculture. The attention given to pests and diseases is at least as important in plantation forestry as in agriculture, possibly receiving more emphasis relative to other factors.

In the case of management of existing forests, the fact that the forest is already present means that direct estimates of its composition take the place of forecasting based on climatic and soil attributes. Agricultural evaluations make use of crop yield data to a much lesser extent than forestry, not because data is absent, but because variations in inputs and standards of management frequently have such a large effect on yields that they swamp relationships with land variables.

The recreation and tourism component of forestry, despite the varying distinctive range of requirements, nevertheless lends itself to treatment in the same basic manner, that of comparison between requirements of the use and qualities possessed by the land.

Environmental forestry is treated by an approach which is substantially different from that used for agricultural evaluation. Conservation is always present as a secondary aim in agricultural production but never, by definition, as the primary aim. The distinctive nature of the objectives in conservation forestry call for a greater flexibility of treatment.

6.2 Requirements for specific forest uses

This section outlines the land use requirements associated with each of the main purposes of forestry: production forestry, conservation forestry, and forestry for recreation and tourism. In multi-purpose forestry, the requirements for each purpose are first identified separately, and subsequently combined.

6.2.1 Selection of relevant requirements

By no means all of the requirements listed will be relevant to a particular evaluation survey. The present check lists must, by their nature, aim to be comprehensive, giving, for example, land conditions which might be relevant in any environment ranging from rain forests to deserts, or mechanized plantation forestry to farm woodlots. For any particular broad physical environment, and type of land use and management, it will often be found that quite a small number of requirements are significant in differentiating land suitability (see example, Section 6.4).

At this stage in procedures, therefore, the land use requirements that are significant to each kind of use considered, and within the context of the study area, should be identified. It may be useful to designate some of these as 'important' to ensure that survey data relevant to them is collected in greater detail or with higher reliability.

6.2.2 Requirements for wood production

Wood production covers requirements for production of timber, fuelwood and pulpwood, on either a commercial or a social forestry basis, and from both natural forests and plantations. The detailed requirements for these different purposes differ substantially, but are all of a basically similar nature, allowing them to be treated within the same set of headings. The principal modification is that the requirements for growth are applicable mainly to forest plantations, being replaced by estimates of growth of existing forests in the case of natural forests.

A checklist of land use requirements for production forestry is given in Table 6.1. It is divided into requirements for forest growth, for management and for conservation.

Table 6.1 Land use requirements and limitations for production forestry

A1 Growth requirements

- Radiation
- Temperature
- Moisture
- Aeration (soil drainage)
- Nutrients
- Rooting conditions
- Salinity/sodicity
- Toxicities
- Climatic hazards - fire
  - frost
  - wind
- Physiographic hazards - flood
  - landslide
- Pests and diseases

A2 Requirements based on estimates of forest volume, growth and yield

- Present forest stands
- Estimated growth rates
- Estimated survival rates
- Estimated yield of non-timber products

B Management requirements

- Mechanized operations
- Harvest operations
- Road construction and maintenance
- Internal access
- Nursery sites
- Vegetation clearance
- Size of potential management units
- Location - existing accessibility
  - potential accessibility

C Conservation requirements

- Tolerance to soil erosion
- Conditions affecting streamflow response
- Tolerance to vegetation degradation
- Requirements for preservation of plant and animal species

Growth requirements All trees need radiation, suitable temperatures, moisture, aeration, nutrients, suitable rooting conditions, and an absence of conditions which adversely affect growth or survival: adverse soil conditions, climatic and physiographic hazards, and attack by pests and diseases (cf.Lundgren, 1981). Broadly speaking, the first six are growth requirements of a positive nature; the next two, salinity/sodicity and other toxicities, are soil conditions which may adversely affect growth; and the remainder are conditions which affect survival of the tree. There is, however, an overlap; for example, poor drainage or salinity can result in the death of a tree whilst frost-burn or pests and diseases can adversely affect its growth.

The requirements most commonly relevant in evaluations for forestry are for suitable temperatures, adequate moisture, for a supply of oxygen to the roots (commonly referred to as soil drainage), for adequate nutrients and for sufficient depth of soil to provide satisfactory rooting conditions. Many of the lists of growth requirements for individual tree species are based on temperature (or its surrogate, altitude), moisture (sometimes as broad climatic zones or as drought resistance) and drainage. Nutrient requirements are usually less specific. All trees need adequate rooting conditions, both to provide support and as a basis for taking up moisture and nutrients. Conditions of radiation, which include photoperiodic effects, are biologically a fundamental need for growth, but, in practice, are rarely employed directly as a land use requirement, being taken into account by selection of species appropriate to the latitude, altitude or climatic zone.

Salinity and sodicity can be ignored in many forest environments but become highly significant in two circumstances: arid zones and coastal plains. Of the other soil toxicities the commonest is aluminium toxicity, caused by the presence of free exchangeable aluminium ions at soil pH values below 5.5, becoming substantial below pH 5.0.

The hazards to forests can be of climatic, physiographic or biological origin. Fire hazard is common to most areas other than rain forests. Hazards of frost and wind damage are common to upland forestry in the temperate zone, with frost damage at high altitudes in the tropics and wind damage in typhoon affected regions. Hazards of flooding and landslides affect management as well as tree survival but are listed under growth requirements for convenience. A low level of endemic or epidemic pests and diseases is a widespread requirement in forestry, of particular importance in mono-species plantations.

Conditions for survival and growth apply to natural as well as plantation forests. In the case of natural forests, however, the inherent conditions of climate, soil, landforms and biological hazards have already been integrated in nature, being reflected in the varying composition of the standing trees. Thus areas with thin soils, poor drainage or severe wind exposure will be reflected in different (and for timber production usually inferior) species composition and biomass. In this circumstance, the use of growth requirements is largely or entirely replaced by requirements based on estimates of forest volume, growth and yield. These estimates are derived from forest inventory and related methods. Land use requirements in this form express directly the condition required, e.g. that there should be a certain volume of utilizable timber.

Direct estimates of forest growth and yield can also be employed to express requirements for plantation forestry. For example, where there is an established system of site classes for the tree species under consideration, a land use requirement could be in the form of preferred site classes; alternatively, the requirement could be for given mean annual increments or yields after a specified number of years. Such growth estimates are in some cases (growth-site correlation, Section 7.5.1) derived in turn from climatic and soil conditions for growth; the difference in procedure is that the land use requirement is expressed in terms of required volume, the prediction being done at the stage of obtaining the corresponding land quality, namely the growth and volume estimates.

Management requirements There is overlap between the first four management requirements listed in Table 6.1, not all of which will be employed in a particular evaluation (cf. Löffler, 1981). They have in common the fact that they are influenced particularly by terrain conditions, especially slope angle, rockiness and drainage. Conditions affecting mechanized operations can either be taken to include harvest operations or else the latter treated as a separate requirement, depending on whether, for the kind of land use under consideration, mechanized harvesting and other mechanized operations have distinctive requirements. Conditions permitting economic road construction and maintenance are a requirement for commercial plantation forestry, but in evaluations for logging of natural rain forests might be subsumed in conditions for harvest operations. The requirement for good access within the production unit will normally be an alternative to conditions for road construction and maintenance but is listed to cover cases where access is not by roads, e.g. in village forestry.

The next two management requirements are of more limited applicability. In some circumstances it may be necessary to consider requirements for establishment of forest nursery sites, for example availability of a water supply. Conditions affecting vegetation clearance covers situations where natural forest must be cleared before planting, e.g. clearance of secondary rain forest.

The last two management requirements are common to most forms of forestry. A production forest must normally be of a certain minimum size, e.g. to permit balanced stands of different ages. Otherwise favourable land may be lowered in suitability if it occurs as small and isolated patches. The location requirement refers primarily to location in relation to markets, or to road, rail or water links with such markets. It can be subdivided into existing accessibility, based on transport infrastructure already present; and potential accessibility, in which terrain favouring, or adverse to, possible construction of access roads is assessed.

Conservation requirements listed in Table 6.1 refer to those conservation constraints that need to be taken into account in all forms of production forestry (cf. Nelson, 1981). Requirements where conservation is a major objective are discussed in Section 6.2.4. Low tolerance to soil erosion (high erosion hazard) can render some areas unsuitable for forest plantations, e.g. teak plantations on steeply sloping land under high rainfall. Applied to the danger of erosion during and shortly after harvest, it may also be a criterion for dividing forest areas into those for production and conservation forestry. A requirement for minimum disturbance of streamflow may be called for. Tolerance to vegetation degradation applies to natural forests, for example, those in semi-arid areas subject to pressures from fires, grazing or harvest. Lastly, in some production forests there may be subsidiary requirements for preservation of wildlife, e.g. deer.

6.2.3 Requirements for non-timber forest products

In principle, any of the requirements for tree growth and forest management may be applicable to use for non-timber products. In practice, this form of use is nearly always subsidiary to other uses. The main addition to the direct estimates of present forest conditions is namely estimates of the potential sustained yield of each identified product. This is compounded of its present abundance, growth rate, and capacity to regenerate after harvesting.

A few selected growth or management requirements may also be relevant, for example, conditions affecting harvesting of the product, or distance to markets (especially for perishable products). There is the specific conservation requirement, the survival under harvesting pressure of the utilized species itself.

6.2.4 Requirements for environmental forestry

Land utilization types intended primarily for conservation purposes differ in the balance of emphasis between the environmental resources to be conserved or reclaimed These can be:

i. Catchment protection for water conservation and yield.

ii. (a) Protection against soil erosion and associated off-site sedimentation.

(b) Reclamation and conservation of eroded areas.

iii. Conservation of flora or fauna, including of genetic resources and endangered species.

There is a difference in principle between the conservation requirements in circumstances of production forestry, and the nature of the requirements and objectives in environmental forestry. In the case of production forestry, the overall conservation requirement is that no severe adverse effects shall result from the proposed forest land use. Taking erosion hazard as an example, the more severe is the predicted erosion under the proposed land use, the less suitable is the land for that use. The need for conservation, however, applies to all areas.

In environmental forestry, by contrast, it is the relative need for conservation that is the main determinant of land suitability. For example, of two land units both currently under natural forest, it is the unit which has the higher erosion hazard, if the forest were to be removed, that has the higher suitability for retaining that forest cover. The same situation applies to water conservation. For flora and fauna conservation, suitability depends on how great would be the loss in biological resources if the forest were not retained.

Where environmental forestry is for purposes of reclamation, e.g. of eroded areas, suitability depends both on the severity of present degradation and on the extent of likely improvement under forest. Again, suitability for the use depends in part on relative need.

Thus land suitability for environmental forestry is assessed to a large extent on the basis of relative need for conservation, including the adverse effects that would result if the forest cover were not retained (or, in the case of reclamation, was not established). The relative need can be represented by the land suitability subclass letter c = need for conservation. In this special case, the subclass should be applied to S1, highly suitable land. Thus S1c denotes land with the highest suitability (i.e. priority need) for conservation, S2c denotes land where environmental forestry is still desirable but less essential, whilst N2c means that there is no substantial need for environmental forestry.

In cases where conservation needs on various different grounds were being compared, appropriate subclass letters could be set up for soil, water, flora and wildlife conservation needs.

The meaning of 'land use requirement' in this situation therefore becomes modified. In production forestry, a requirement is a land condition necessary for the successful practice of the forest use. In environmental forestry, the requirement refers to relative need, assessed on the basis of:

i. How severe would be the adverse environmental effects if the land were not under a protective forest cover?

ii. How effective is the forest cover in protecting the land against those adverse effects, i.e. in conserving the resources?

These questions can be applied to each kind of environmental resource.

For water conservation, the requirement is assessed on the basis that the proposed form of conservation forestry (usually that of retaining the existing forest cover) shall have a favourable effect upon flow regime, as compared with the adverse consequences that would result from its removal. For soil conservation, the same reasoning applies. In both cases the need, or requirement, for conservation forestry is greatest where the adverse environmental impact in the absence of such conservation is highest. In reclamation forestry, the main aspects determining need are the severity of existing degradation, and the estimated improvement through afforestation.

Conservation of flora and fauna covers a spectrum of circumstances ranging from the nature reserve, with zero public access other than by authorized scientists, to the combination of controlled public access with conservation, as in national parks in which the conservation and tourism functions are combined. For the purely conservation functions, the main factors are:

- variety and uniqueness of the plant genetic reserve;
- presence of rare or endangered plant or animal species.

The strongest case for conservation arises where a site is the unique remaining habitat of a particular plant or animal. In the case of migratory animals or birds, conservation of breeding grounds or annual feeding sites is relevant.

Land suitability for conservation of animal species can be assessed not only on grounds of need, i.e. the presence of rare or interesting species. The suitability of the land for conserving the species can also be assessed by the standard method of comparing requirements with land qualities. 'Land use' requirements for animal species include availability of food supply, availability of drinking water (both by season), and areas of adequate size and characteristics for territorial, breeding and migratory needs.

Further discussion of the environmental impact and benefits of forestry is given by Singh and Nilsson (1974) and Zimmerman (1982).

6.2.5 Requirements of forestry for recreation and tourism

Land evaluation for recreation is a specialized subject, applicable equally to forested and non-forest land. The planning decision to be taken is normally for the establishment, retention, or change in boundaries of one specific area for recreational/tourist use, e.g. a national park, rather than evaluating land in general for this purpose. Nevertheless, this objective forms a component in multi-purpose forest use and may need to be integrated into evaluations for other purposes.

Some common requirements are listed in Table 6.2. The place of 'plant growth' in production forestry is taken by resources for recreation. Most widely applicable are requirements for scenery, comprising both landforms and vegetation and covering both aesthetic quality and variety. Experience shows that the presence of water bodies - rivers, waterfalls, lakes or sea - can greatly add to recreational attractiveness. In the case of plant and animal species of interest, there is an overlap between recreational and conservation purposes, calling for management compromise. Climate can be a resource, particularly high altitude, cooler areas amid hot tropical regions. Resources for specialized activities cover suitable conditions for rock climbing, skiing, fishing, etc.

Management requirements for recreational use include either road construction and maintenance or internal access in general, and presence of suitable sites for hotels or other facilities. The size of units and their location in relation to potential users, especially road access, are important. Conservation requirements include the special case of response of the land - vegetation or soil - to recreational pressures, e.g. footpath erosion.

Table 6.2 Land use requirements of forestry for recreation and tourism

A. Resources

Scenery, aesthetic quality and variety - landforms
- vegetation

Water bodies

Species of interest: - plant
- animal

Climate

Resources for specialized activities

B. Management requirements

Road construction and maintenance

Internal access

Sites for specialized facilities

Size of potential management units

Location

C. Conservation requirements

Resistance to degradation under recreational pressures: - vegetation
- soil

Fire hazard

6.3 Combination of land use requirements in multi-purpose forestry

For cases of multi-purpose forestry, the selected requirements for each of the functions are combined. For example, a softwood plantation intended primarily for timber production, but with subsidiary functions of recreational use and conservation of deer, would involve adding the requirements for recreational use, plus specific aspects related to deer, to the basic list selected for the purpose of timber production.

In some cases these sets of requirements will be conflicting; for example, the scenic qualities desirable for recreational use will cause unfavourable access conditions for forest maintenance and harvesting. Such conflicting requirements may be retained initially. Later, at the stage of matching with land qualities, it will be found that some areas are rated more highly for one objective than another. This may lead to subdivision or modification of the land utilization types, e.g. the introduction of purely production forestry, with no recreational use, over part of the survey area.

6.4 Description of land use requirements: an example

Large scale fuelwood plantations in part of the semi-arid zone of West Africa; managed by government, using mechanized harvesting, but other operations manual.

Significant land use requirements

Growth requirements	- moisture
	- aeration
	- rooting conditions
Management requirements	- terrain conditions affecting roading and mechanized harvesting
	- conditions for nursery sites
	- location in relation to markets
Conservation requirements	- erosion hazard

Reasons for selection

Of the growth requirements, radiation, temperature, fire hazard and incidence of pests and diseases are relatively uniform over the study area. Nutrients are believed not to be seriously limiting to the species involved and wind hazard slight. Salinity, other toxicities, and frost hazard are absent. Land for satisfactory tree growth will therefore be selected on the basis of moisture availability, aeration (drainage) and adequacy of rooting conditions.

For management, there is a need, first, for road access by landrover and truck during establishment and maintenace and, secondly, for access by machinery onto the planted areas during harvest. It is considered in this instance, that, owing to their similarity, both these needs can be treated by a single requirement, terrain conditions affecting roading and mechanized harvesting. There is a need for nursery sites with groundwater. Plantations must not be too remote from urban markets. Owing to non-mechanized establishment and maintenance, size of units is not critical.

The net effect of plantations, under the specified management, is likely to be beneficial or to have slight effects on streamflow and there are no important biological resources. The conservation requirement is therefore for avoidance of areas with a high erosion hazard.

CHAPTER 7

SURVEYS AND SPECIALIZED STUDIES OF LAND

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SURVEYS AND SPECIALIZED STUDIES OF LAND

7.1 Introduction

7.1.1 Objectives, information and survey requirements

The second major component in land evaluation, balancing that of land use, is the land itself. This comprises the resources of climate, landforms, hydrology, soils and vegetation (including the forest cover itself where present) fauna and disease. Land supplies the resources for different forms of forest use, and also the hazards to use, such as soil erosion.

There are two stages to land resource surveys: the identification and mapping of land units, and the description of the land qualities and characteristics belonging to those units. For definitions of the terms land unit, land quality and land characteristic see pages 13-14.

Foresters familiar with the term site should note that at the more detailed scales of survey, this is equivalent to land unit. However, land units in small scale surveys may also consist of larger and less uniform areas, e.g. watersheds, land systems, which would not normally be referred to as sites. Thus systems of site classification for forestry, where they exist, can be employed for delineating land units.

The principle underlying surveys of land is that the survey activities should be directed towards obtaining the information required. This principle applies both to the types of information obtained and to its detail and accuracy. In this way the time and cost of surveys and other specialist studies of land resources is most efficiently directed. For example, if tree growth in the area is known to be correlated with length of growing period and soil effective depth, then survey effort is profitably directed at measuring these characteristics. Conversely, if previous studies have failed to show any correlation between growth and, say, soil nitrogen content, the expense involved in laboratory analyses of nitrogen would be wasted. In summary, the principle requires that the need for land survey activities should be appraised by the following stages:

i. Objectives What are the objectives of the information on land? What functions does it have in the evaluation?

ii. Information What kinds of information on land are needed to fulfil those objectives? How detailed should it be, and what standard of accuracy is called for?

iii. Activities What surveys and specialist studies are needed to collect information of the required nature, detail and accuracy?

The greater part of this chapter is concerned with studies of land in evaluations for production forestry. The specialized data needs for environmental and recreation forestry are treated more briefly in Section 7.7.

7.1.2 Land units and their qualities and characteristics

The studies of land can be broken down conceptually into two stages: survey of land units, and determination of the land qualities and characteristics of each unit. The land units form the mapping basis of an evaluation. The main map at the basic, or largest, scale of the evaluation shows the land units, and all of the boundaries between mapped land suitability classes are derived from this map. The land qualities and land characteristics form the basis for comparison with land use requirements.

In more detail, the steps in surveys and studies of land are:

i. Identify and define appropriate land units

ii. Survey and map the extent of those units

iii. Select the land qualities relevant to the evaluation

iv. Decide which land characteristics are to be used to measure or estimate the land qualities

v. Determine the values of the required land characteristics for each of the land units.

This chapter covers only surveys of the physical environment of land. The corresponding collection of data for economic and social analysis is discussed in the context of that analysis. It is not the intention of these guidelines to provide detailed instructions in the methods of natural resource surveys. Manuals for this purpose already exist, e.g. for surveys of soil and for the specialized methods of forest inventory and related studies. The present chapter is intended only as a guide to the types of surveys and specialized studies which may be required, and the way in which the data on land resources are applied in the procedures of land evaluation.

7.2 Choice of land units

7.2.1 General

Early in an evaluation, at the stage of planning the basic resource surveys, a choice of the land units on which it is to be based needs to be made. Land suitabilities for various kinds of use will be based on the land units; therefore these are the smallest areas about which statements of suitability, and thus land use planning decisions, can be made.

The appropriate land units are determined by the objectives of the survey. For national or regional planning purposes, broad units such as land systems may be sufficient. Detailed forest management planning will require data at the level of the land facet or the soil series, or even the more detailed level provided by maps of individual soil properties. Surveys for the allocation of land use in multi-purpose development projects call for land units of intermediate size. As noted earlier, existing systems of forest site classification can be reviewed to assess whether they provide appropriate land units.

Three approaches to the survey of land units may be distinguished: that based on landforms and their associated soils, that based on vegetation and ecological relationships, and that based on observed or estimated tree growth. The first is more commonly employed in agricultural land evaluation, on the basis that agricultural crops have a high dependence on soil properties, whilst landforms can be seen on air photographs. There is a recognized hierarchy of soil mapping units.

The vegetation-based or ecological approach may be appropriate to surveys for forest land use, particularly at smaller scales, although the methodology for this kind of survey is less well established. The third approach, utilizing land units based on forest inventory data or a forest site classification system, is the most directly related to growth requirements, and will often form the most appropriate basis where adequate data exists.

In descending order of scale, from large areas containing a certain diversity of land characteristics to small areas which are relatively homogeneous, possible land units on which to base an evaluation include the following:

- Climatic zones, agro-ecological or ecological zones; including altitude-based vegetation zones

- Land systems, or comparable units based on ecological survey

- Composite mapping units based on landforms, soils, vegetation, or combinations of these; e.g. soil landscapes, soil associations, generalized vegetation types

- Relatively uniform mapping units; e.g. land facets, soil series, vegetation associations, forest site classes

- Land units derived from overlay of maps if individual land characteristics, e.g. slope angle, soil depth, soil reaction indicator plants.

7.2.2 Land units for multi-purpose forestry

A special problem in land evaluation for multi-purpose forestry is that land units of differing size and nature may be appropriate to the different purposes. Taking the units selected for production forestry as a standard, the following purposes call for special treatment:

i. Forestry for water conservation needs to be based on the watershed catchment, either first order or higher order, to permit measurement and prediction of river flow. If such catchments are not appropriate to other purposes of the proposed forest use, different land units must be used to evaluate for different purposes, subsequently combined by an overlay.

ii. Forestry for wildlife conservation needs to define areas which cover the daily movement patterns of animals, especially to and from drinking water, and migration patterns where present. It will usually be desirable to base the evaluation on more detailed units, each of which supplies some ecological requirement of the animals, and later amalgamate these into larger management units.

iii. Forestry for recreation and tourism often includes lack of homogeneity, i.e. diversity of landscape, as a requirement. As with the previous example, this situation is handled by taking more detailed land units as the initial basis, then amalgamating them to provide areas having the variety which contributes to suitability for recreation.

Projects in watershed management present a special case. Clearly the watershed itself (or each one of several) is a fundamental basis for land use planning. Specifically, the land use in each part of the watershed is assessed with respect to its consequences for other parts. However, the land units on which to base such assessment will usually be chosen on the basis of slope, soil, vegetation, etc. Only when specifically assessing consequences for water flow will tributary catchments (first-order watersheds) be the appropriate land units.

Thus evaluation for multi-purpose forestry may sometimes require simultaneous use of different land units in assessments for different purposes. Later in the evaluation, at the stage of provisional land suitability classification, the suitabilities based on these different units can be combined by overlays, reconsidered and, where necessary, revised on the basis of their relationships.

7.3 Land resource surveys

7.3.1 General

The function of land resource surveys is to collect the necessary information on geology, landforms, climate, hydrology, soils, vegetation, fauna and disease. Surveys of vegetation include inventories of the standing forest where present. The surveys result in the production of maps with accompanying reports.

The role of resource surveys in a land evaluation study varies greatly with the amount of information already available. Occasionally, there will already exist adequate soil and ecological surveys, etc., on which to base an evaluation. The survey activities for the evaluation are then confined to collecting supplementary data needed for the required land characteristics.

More commonly, especially in developing countries, there is often lack of reliable and adequate basic information, in which case resource surveys form a major part of the evaluation itself. The results of such surveys may form an independent output, with a future value over and above the immediate purposes of the evaluation.

The first step is therefore to assembly all available natural resource information, and to assess its adequacy. A decision is then made as to what further information will be necessary to provide data for the evaluation, and how it is to be acquired. This is followed by planning of the required surveys. These investigations should be completed at the stage of initial planning of the evaluation.

7.3.2 Scale and intensity

Depending on the objectives of a land evaluation, three levels of intensity for resource surveys can be identified: reconnaissance (low intensity), semi-detailed(medium intensity) and detailed (high intensity).

Reconnaissance surveys are appropriate to planning on a national or large region scale. They are carried out using satellite imagery and small-scale air photo interpretation, combined with low intensity ground sampling. The scale of resulting maps is 1:100 000 or smaller. Land units are highly generalized, and usually based on physiographic units. An example is the surveys for the Canada land inventory for forestry (Lacate and Romain, 1978).

Surveys at semi-detailed level make use of medium-scale aerial photographs, typically 1:50 000, and involve more intensive field work. The mapping legend is more precise, the land units having fewer inclusions as compared with reconnaissance surveys. Quantitative interpretations for land evaluation are possible. Frequently such surveys are carried out as part of prefeasibility or preinvestment studies for locating suitable tracts for projects or more intensive forest management.

Detailed surveys are carried out using aerial photographs at scales 1:25 000 or larger. Numerous field observations are made. The mapping legends are more detailed, and the mapping units are relatively homogeneous. Such surveys are costly and time-consuming and are usually carried out for specific areas selected for implementing a planned land use, particularly for forest management planning.

The intensity of basic resource surveys sets a limit to the degree of detail and, more important, the reliability of the resulting land evaluation. It is impossible, for example, to attempt detailed forest management planning on the basis of the interpretation of satellite imagery. The marginal cost of acquiring more detailed or reliable information must be set against the marginal benefit from having that extra information; particularly relevant is the cost to a project of mistakes which might arise from incorrect or inadequate survey data. Although the cost of surveys, particularly soil surveys, may appear substantial when considered in isolation, it is often quite small in relation to total project development costs. The ultimate cost of mistakes, e.g. failure to locate areas liable to flooding, or to assess correctly the soil erosion hazard, may considerably exceed the cost of surveys through which such mistakes could have been avoided.

7.3.3 Surveys of individual factors of the physical environment

It is convenient to consider basic resource surveys in three groups: surveys of individual environmental factors - landforms, soils, etc.; integrated surveys of the environment; and the specialized surveys employed in forest resource assessment.

The major factors of the physical environment are geology, landforms, climate, hydrology, soils, vegetation, fauna and disease. Geology is mainly of indirect relevance, first, through its effects as a soil parent material, and, secondly, through its influence on groundwater hydrology.

Landforms have little direct effect upon forest growth, but affect growth indirectly through climate, drainage and soil. The effects of exposure, compounded of damaging winds, frost, hail, etc., can be rated on the basis of landform position and aspect (e.g. Pyatt et al., 1969, page 6). Landforms are, however, the most important environmental factor influencing forest management requirements through their effects on road construction and maintenance and ease of use of machinery. Landform survey may either be conducted independently, often as the basis for other resource surveys, or it may be combined with soil survey.

Climate acts through temperature, rainfall, and climatic hazards: frost, wind, hail. Temperature and rainfall are the major determinants for the selection of suitable tree species. Available forestry data on the requirements of tree species is often in terms of temperature (or latitude and altitude zone) and either mean annual rainfall, length of growing season/dry season, or broad climatic zones (e.g. FAO, 1974; Webb et al., 1980; Pandey, 1983). Climatic survey is conducted independently from other resource surveys, through collection and analysis of available records.

Studies of hydrology are of two kinds, surface water and groundwater surveys. Measurement and analysis of river flow regime is required for assessment of the impact on flow of proposed changes in land use. Surveys of groundwater may be needed in the special cases of irrigated forestry, and borehole sites may be necessary for forest nurseries.

Soil survey is often the major basis for forest land use planning, particularly at semi-detailed and detailed scales (FAO, 1977a; Dent and Young, 1981). What is called a soil survey is often in fact a soil-landform survey. If a soil survey is conducted as part of an evaluation, it is important to decide whether it shall be a general purpose or special purpose survey. A general purpose soil survey is one intended for a variety of future planning purposes, not all of them yet known. It is possible that a general purpose survey may be thoroughly desirable, giving information over and above the immediate needs of the land evaluation. Special purpose soil surveys are directed towards specific needs, in the present case, the land use requirements in the evaluation. They may thus map the required soil attributes directly, e.g. effective depth, texture, drainage class, texture, presence of peat, acidity, etc.

A system for description of soil characteristics devised by the Commonwealth Forestry Institute, U.K., has the merits of being simple, and of having a body of information on tree growth requirements related to it (Webb et al., 1980). The soil is allotted to groups for each of four characteristics:

Texture	Drainage	Reaction	Other features
- sandy	- good	- acid	- shallow
- loamy	- imperfect	- neutral	- saline
- clayey	- poor	- alkaline	

This can be a useful basic system in cases of assessment by non-specialists in soil survey. It is by no means a complete basis for soil properties relevant to forest use, however, and more broad-based and flexible methods of soil survey will frequently be necessary.

Surveys of vegetation, or ecological surveys may be distinguished from the special case of forest inventory. In areas where the natural vegetation is not greatly disturbed by man, it serves to integrate the effects of all other factors and can therefore be used as an indicator of climate, drainage, areas of shallow soils, etc. Since forestry is also based on the response of plants to environment, ecological survey can form a valuable basis for resource survey as a whole. This applies both at reconnaissance scales, where land cover interpretation from satellite imagery can be combined with field survey of vegetation communities, and at detailed scales where local plant associations can indicate variations in site conditions.

7.3.4 Integrated surveys: the land systems approach

The land systems approach provides an alternative to the mapping of each environmental factor separately. The mapping units, land systems and land facets, are defined in terms of the total environment, although identification and mapping is initially based on landforms and vegetation. More detailed studies of individual factors can then be conducted on the basis of these common mapping units. Originally devised on the basis of air photo-interpretation, land system mapping has been given a new lease of life through its application by means of satellite imagery (Dent and Young, 1981; Howard and Mitchell, 1980; Bailey, 1981).

The land system, defined as a repeating pattern of landforms, soils and vegetation, is an appropriate unit for land evaluation only at reconnaissance scales. The land facet, an area over which for most practical purposes, environmental conditions can be considered homogenous, can be used as a land unit at both semi-detailed and detailed scales, requiring a higher intensity of field observations in the latter case.

7.4 Estimation of forest volume growth and yield

7.4.1 General

The most distinctive feature of forest land evaluation, as compared with surveys for agricultural land use, is the greater role of surveys of the existing forest vegetation. In the case of management of existing forests, and if no substantial improvements to the forest stand are envisaged, techniques of forest mensuration largely or entirely replace survey for growth requirements. Studies of landforms, drainage and soils will still be needed for management and conservation requirements. In the case of plantations, use can be made of yield functions or tables based on data of permanent or temporary sample plot measurements.

In principle, techniques of direct measurement are to be preferred to indirect estimates based on climate, soils, etc., and should be used whenever there is available data. There are similarities with the use of observed crop yield data in evaluation for agriculture, but agricultural yields are a less reliable source owing to the very much greater influence of variations in inputs and management. Natural forests without inputs by man, and plantation forests with a uniform standard of management, both provide a relatively reliable and direct source of data from which to predict future forest response.

The methods involved are standard techniques in forest resource assessment, and described in manuals and textbooks. Only a brief outline is therefore given here, to guide evaluation specialists without a forestry background, and to show how the results of these techniques can be utilized in land evaluation.

7.4.2 Forest inventory

Forest inventories deal with the quantitive measurements and mapping of the forest resources and usually include an evaluation of tree characteristics, as well as the land upon which they grow.

Estimation of standing or harvestable timber is a major concern of most of forest inventories and for this purpose they include a description of the forested area and ownership; estimates of standing and commercial volume, of growth and drain. In any specific inventory there may be emphasis on estimation of one or more of these items, depending on the objectives, but for a complete evaluation and especially with a view to managing it on a sustained yield basis, all the above elements are of importance.

With the increased emphasis on multiple use forestry - watershed aspects, wildlife, recreation, etc. - the scope of forest inventories has been further widened. When these other values are important, different or additional observations and measurements are generally taken. In many cases, however, a great deal of the information usually collected in a timber-oriented forest inventory can also be used for evaluating other forest associated benefits. For example, forest composition and topographic information, always necessary for a timber-oriented forest inventory, are also essential when evaluating forest recreational possibilities or wildlife refuges. Similarly, information concerning the forest condition and stand density is useful for watershed management.

In land evaluation, forest inventory can supply quantitative data on the timber production potential of forests, replacing the use of growth requirements. Such data can then be combined with suitability ratings based on management and conservation requirements, obtained in the standard manner, to give overall suitability for production forestry.

In the case where non-timber forest products are of importance, direct estimates of the standing crop of such products could form the normal basis for evaluation.

7.4.3 Forest yield prediction: direct methods

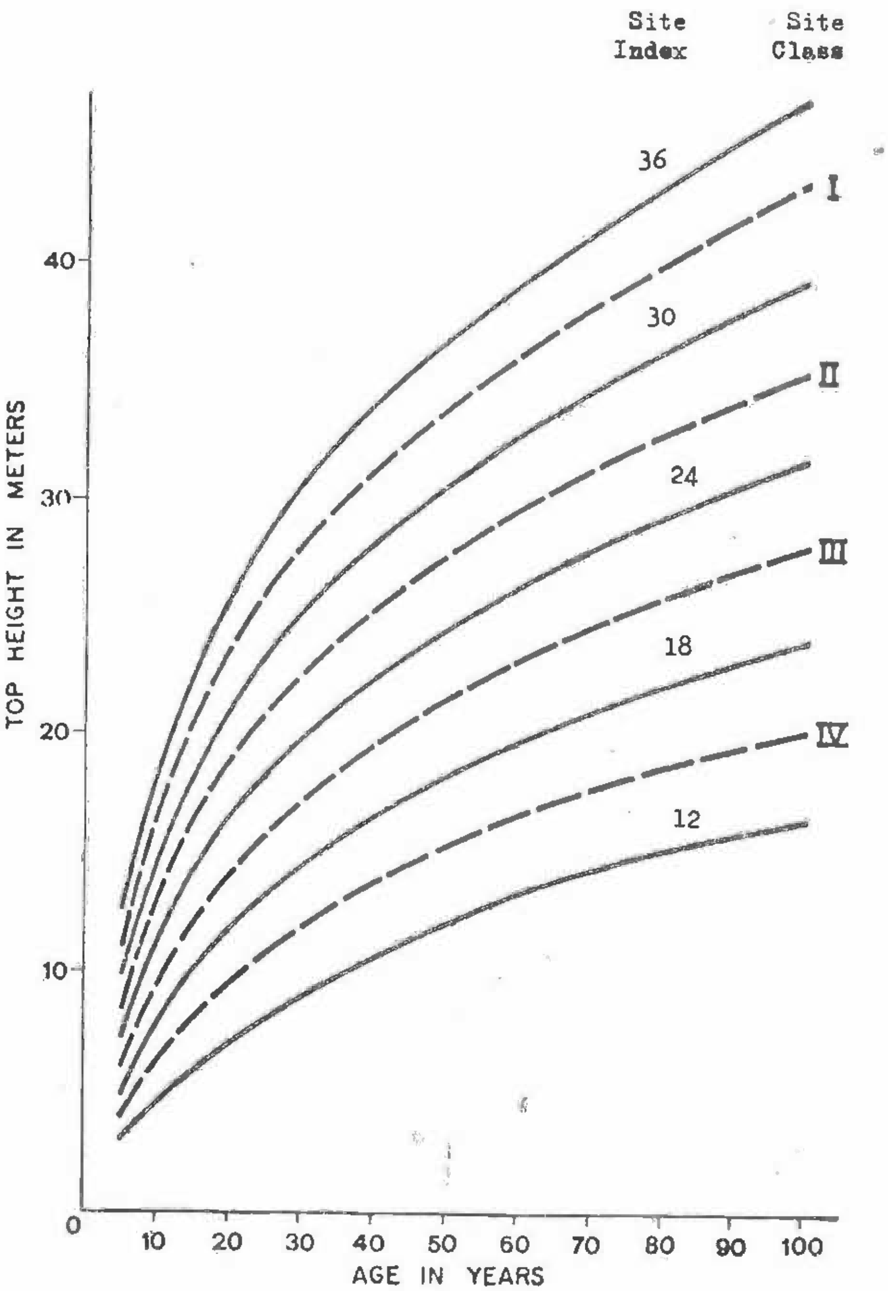
Forest yield prediction consists of a set of techniques designed to predict the growth rate of forest stands and thus their potential yield. It includes, but is not confined to, the site index method. Techniques are described, with a selected bibliography, by Alder (1980).

Yield prediction gives estimates of growth rates, or mean annual increment, by timber species and relative to specified classes of site. It can be applied to both natural forests and plantations.

The site index method is a technique of yield prediction applicable to even-aged forest stands. These may consist of planted trees or even-aged natural stands. They are normally based on permanent sample plots, established on varying site conditions for the purpose of predicting growth.

The principle on which the site index is based is that for fully stocked even-aged stands, the height of the dominant and co-dominant trees is closely related to site productivity. Dominant tree height is plotted against age, the latter obtained from growth rings in natural forests. Growth rates differ between better and poorer sites, resulting in a set of growth curves (Figure 7.1). The height in metres at some specified standard

Figure 7.1 Site index curves and site classes, Tectona grandis, India



Source: based on Pandey (1983, p.15)

is taken as the site index (in temperate forests the standard age is commonly 50 years, but this is inappropriate in tropical softwood forestry). For each value of site index, the volume and thus yield potentials at different ages are calculated.

Once a set of site index curves for tree species and for the region have been established, this technique allows the potential yield for a site to be predicted wherever an even-aged stand of any age is present. The dominant tree height is measured, and average age determined, the site index read off the graph of site index curves, and the corresponding yields obtained from tables.

A supplementary technique is that of the species comparison graph for site indices. Height-age courses for different species are plotted on one graph. This enables the yield of a species not present on a given site to be estimated from species that are present (e.g. Carmean, 1975).

For forest stands of mixed age classes, alternative methods of yield prediction are available, including static yield functions, transition matrix models and distance-independent tree models based on difference equations (Alder, 1980, Chapter 6). The principle is the same as for the site index method, that of predicting rates of growth and thus potential yield on the basis of direct measurement of existing forest stands.

Where a network of well chosen permanent sample plots has been in existence for some years, the site index technique provides the most reliable method for the survey of land resource potential, not only in forestry but as compared with techniques available for any other kind of land use. It should, therefore, be taken as the standard method for the assessment of timber output in land evaluation wherever the requisite conditions exist. Yield estimates derived from mixed age stands are somewhat less precise, but still superior to indirect estimates of growth rates. Direct methods of forest yield prediction should therefore be preferred in land evaluation, as a means of estimating potential production wherever reliable data of this type are available.

7.5 Predicting forest yield from site characteristics

7.5.1 Growth-site correlation

A powerful method for extending yield prediction from area with tree growth onto areas with no such data is growth-site correlation. The principle is simple. Sample plots are laid in a substantial number of stands well distributed over the range of climate, landforms, and soils found within an area, and measured repeatedly over a period of time to obtain growth data. For each of the sample plots, values of land characteristics thought likely to affect tree growth are also recorded. Simple or multiple correlations are established between growth as the dependent variable and site factors as independent variables. The site factors found to be significantly related to growth are then surveyed for other parts of the area, for which no direct growth data are available, so enabling yield predictions to be made for the entire study area.

The selection of land characteristics liable to be correlated with growth is discussed in Section 6.2.2. The reliability of yields predicted by this method is determined, first, by the reliability of the initial yield estimates and, secondly, by the strengths of the correlations; in practice, the latter is likely to be the larger source of error. Provided that the number of samples is large enough, confidence limits can be assigned to predict yields; for example, they might be expressed as mean and standard deviation, e.g. 15 $m^3 \pm 4.5$, or as 90% or other selected confidence limits, e.g. $< 11 - 19$ m^3 ($p < 0.1$)

7.5.2 Methods for yield prediction in land evaluation: summary

Summarizing the preceding outline, the following methods for predicting growth rates and thus potential timber yields are available. They are listed in approximate descending order of reliability; thus the methods higher in the list should be selected where appropriate data and conditions are available.

i. Forest inventory (survey of volume of standing timber)

ii. Direct forest yield prediction:

(a) Site index method

(b) Yield prediction methods based on mixed age stands

iii. Growth - site correlation

iv. Prediction based on comparison of requirements of tree species with surveys of the physical environment.

These methods are used for two purposes. First, for the selection of most appropriate tree species for plantation forestry. Secondly, for predicting yields, as part of the description of land utilization types and as a basis for economic analysis, applicable to both natural and plantation forestry.

Correlations with major environmental differences, e.g. altitude ranges extending over many hundred metres, or large rainfall differences, can be quite high. Correlations with soil properties are often rather low. In particular, quite a wide range of growth rates is often found within a single soil series; reasons for this variability are not clearly known. There is a problem, however, in that, if the data are taken from permanent sample plots, these will probably not have been established on the more obviously unsuitable sites, e.g. swampy or with very thin soils. Had such sites been present, the statistical correlations with growth would have been higher, but the added practical value is small. Predictions for such sites can be based on common sense.

7.6 Selection of land qualities and land characteristics

7.6.1 Choice between land qualities and land characteristics as the basis for an evaluation

Land qualities are attributes of land which have a distinctive influence on the suitability of land for use. This influence may be upon growth, ease of management or need for conservation. Examples are moisture availability, rooting conditions, fire hazard, terrain factors affecting mechanization and erosion hazard. Land qualities are relatively few in number. About 30 qualities cover the requirements of all kinds of forestry in all environments, but for any particular evaluation the number of qualities which have a significant influence on land suitability will often be less than half that number. It must again be stressed that the meaning of land quality is quite different from site quality (see p.14).

Land characteristics are attributes of land that can be measured or estimated, e.g. mean annual rainfall, soil depth, slope angle, present timber volume by species. Land characteristics are employed as a means to measure or estimate land characteristics. Many hundreds of land characteristics may influence forest growth, management or conservation, directly or indirectly.

It is possible to base a land evaluation either directly on land characteristics or on land qualities estimated by means of land characteristics. Comparative tests have found that both methods lead to very much the same result.

In the direct use of land characteristics, the evaluator lists those characteristics which are both measurable and are believed to have an influence on suitability. An example of such a short list might be altitude, length of dry season, slope angle, relative relief, soil drainage class, percentage rock outcrops and boulders, effective soil depth, soil texture class, soil pH, and type of present vegetation cover. These characteristics are then rated according to their assessed influence on suitability for specific uses (Section 8.2.2).

The main disadvantages of this procedure are, first, that it is not always made clear why a particular value of a characteristic is rated as more or less suitable, and, secondly, that it fails to take account of interactions between factors. Are rock outcrops and boulders being assessed for their influence on rooting conditions, i.e. available land for tree growth, or for the obstacle they provide to roading and/or mechanized harvesting? There is not necessarily a range from 'good' to 'bad' for all purposes. Heavier soil textures may be favourable to growth, but have inferior bearing properties for machinery; soil pH values preferred or tolerated by some tree species are adverse to others. There is also the problem of selection from among the very large number of possible characteristics. Despite these objections in principle, it should be said that some evaluations have been successfully conducted largely or entirely in terms of land characteristics.

The alternative course is to base the evaluation on land qualities, measured or estimated by means of land characteristics. Advantages of this procedure are:

- The relatively short checklist of land qualities provides a means of ensuring that no significant influences upon suitability have been overlooked.

- The same land quality can be estimated by different means, according to the data available. For example, soil drainage conditions can be estimated directly by field survey of the soil drainage class, or indirectly through field or remotely sensed records of vegetation communities.

- The use of land qualities directs attention to the essential feature of suitability evaluation, the assessment of land in relation to its influence upon potential for land use.

- Many land qualities correspond closely with land use requirements, e.g. moisture requirements with moisture availability. This correspondence facilitates comparison between requirements of the specified use and properties of land units.

In practice, for the circumstances of a particular survey many land qualities are estimated by means of a single characteristic: rooting conditions by effective soil depth, landslide hazard by slope angle, etc. It may then appear that characteristics are being used, although they have been selected through consideration of their effects on qualities and thus on land use. Other land qualities, however, will certainly require assessment of the combined influence of several characteristics, for example, ease of mechanization or soil erosion hazard.

The practice here recommended is to base an evaluation on land qualities. The necessary steps are therefore:

i. Select the relevant land qualities

ii. Select the land characteristics to be used to estimate these qualities.

The factors chosen as a means of representing land qualities are called the diagnostic factors. They are used in the procedure of factor rating described in Chapter 8. A diagnostic factor may consist of any of the following:

i. A single land characteristic.

ii. A set of land characteristics, combined in some specified way.

iii. A land quality, described by some system of classes or degree of limitation (e.g. 'very high, high, moderate, low, very low' nutrient availability, moisture availability, etc. 'nil, slight, moderate, severe, very severe' salinity limitation; cf. also the system of terrain classes in Table 7.2)

7.6.2 Land qualities

A list of land qualities which are likely to affect potential for forest uses is given in Table 7.1. There may be other qualities applicable in special circumstances. It should be noted that, as in the case of land use requirements, this checklist covers only properties of the land and is not intended to include economic or social factors which affect land suitability.

The land qualities are grouped into those affecting growth, management and conservation, qualities based on estimates of existing growth, and qualities specific to recreational and tourist potential. In many cases the land qualities correspond to land use requirements. Thus the land use requirements '(requirement for rooting conditions)' corresponds to the land quality 'rooting conditions (possessed by the land)'. Each land utilization type may have different requirements for rooting, and each land unit may offer different rooting conditions. The use of corresponding terms facilitates comparison between requirements and land qualities.

The terrain factors which may affect mechanized operations and internal access are grouped as a single land quality (No. 17). This can be used to assess any or all of the land use requirements for mechanized operations, harvesting, road construction and maintenance and other internal access, not all of which will be employed in a particular evaluation. Table 7.2 gives a set of terrain classes as one means of describing this land quality.

The procedure in an evaluation is to review this checklist, first, with respect to the land utilization types being considered, and, secondly, in the context of the environment of the study area. Two groups of land qualities are rejected: those irrelevant to the land use, e.g. those affecting recreation potential where no such use is intended; and those which have no limiting effects within the area, e.g. salinity in a humid upland area. Also rejected are qualities which, whilst necessary for the use, do not in practice have restricting effects in the area, e.g. conditions for nursery sites in an area where suitable sites are quite clearly to be found widely.

The remaining land qualities, selected as having significant effects within the study area, on at least one of the land utilization types under consideration, form the basis for the evaluation.

7.6.3 Land characteristics

The next step is to select the land characteristics which will be used to measure or estimate each relevant land quality. Table 7.3 is a list of land characteristics which may be used for this purpose, arranged according to the major divisions of the physical environment. The list is by no means exhaustive. It can be used to check the extent to which data of each kind can be obtained from surveys existing or in progress.

The right-hand column of Table 7.1 gives the land characteristics which may be used to measure or estimate each land quality. Selection may be based on comparison between Tables 7.1 and 7.3. Either one or several characteristics may be selected to represent a quality. The characteristics are listed in approximate order from those which more accurately represent the quality, but may be difficult or costly to obtain, to those which represent the quality less precisely but are more easily available. For example, nutrient availability is most directly represented by data from laboratory analysis of

Table 7.1 Land qualities for forestry, with land characteristics which may be used to measure or estimate the qualities. Characteristics which follow a colon provide indirect estimates

LAND QUALITY	LAND CHARACTERISTICS
A. Qualities affecting growth	
1. Radiation regime	Total radiation, sunshine hours, aspect; day length: latitude, climatic type
2. Temperature regime	Temperature - mean annual, mean for growing season, hottest, coldest months: altitude, aspect, climatic type
3. Moisture availability	Relative evapotranspiration deficit, rainfall/evaporation ratio, depth to groundwater; rainfall - mean for growing season, mean annual: aspect, vegetation indicators
4. Soil drainage	Soil drainage class, depth to mottling: vegetation indicators (communities or species)
5. Nutrient availability	Mean levels of N, P, K, etc., soil pH: topsoil thickness, soil type
6. Rooting conditions	Effective soil depth, stones and gravel, rock outcrops and boulders, soil structure: soil type
7. Conditions affecting germination and establishment	Soil texture, stones and gravel, surface sealing or capping
8. Salinity/sodicity	Electrical conductivity of saturation extract, exchangeable sodium percentage: soil type, vegetation indicators
9. Other toxicities	Observed toxicities, soil pH: soil type
10. Climatic hazards - fire	Observed frequency; length of dry season, rainfall/evaporation ratio, combustibility of ground vegetation
- frost	Mean frost days: altitude
- wind	Frequency/severity of high winds, typhoons; exposure index, aspect
11. Physiographic hazards	
- flood	Observed frequency/severity: topographic site
- landslide	Observed frequency/severity; slope angle, rainfall intensity, soil depth
12. Incidence of pests and disease	Observed incidence; relative humidity, temperature, soil factors of known influence

LAND QUALITY	LAND CHARACTERISTICS
B. Estimates of forest volume, growth and yield	
13. Present timber volume	By species, from forest inventory
14. Predicted timber yield	By species, from forest yield prediction or growth-site correlation: site index
15. Seedling survival rates	Recorded averages for site types or area as a whole, by species
16. Predicted yield of non-timber products	From forest inventory or prediction
C. Qualities affecting management	
17. Terrain factors affecting mechanized operations and internal access	Terrain class; slope angle, relative relief, stream frequency, microrelief, soil bearing capacity, presence of swamps, cracking clays.
18. Conditions affecting nursery sites	Available water supply (surface or ground-water), soil texture
19. Present vegetation cover	Ease of clearance
20. Size of potential management units	Size of blocks of suitable land
21. Location	Distances from earth road, tar road, rail, river; and from sawmills or other markets
D. Qualities affecting conservation	
22. Erosion hazard	Estimated soil loss, t/ha/year; slope angle, rainfall erosivity, soil erodibility, rainfall intensity, soil permeability, soil texture, vegetation cover: soil type
23. Water yield	Recorded or estimated
24. Predicted response of steamflow	Hydrological modelling
25. Tolerance to vegetation degradation	Observed or estimated; present condition of vegetation, vegetation type
26. Presence of valuable plant and animal species	Presence, rarity
E. Qualities affecting recreation potential	
27. Scenery	Aesthetic or scientific value, and variety, of landlands and vegetation
28. Resources for recreational and tourist activities	E.g. rock climbs, fishing resources
See also Qualities 10 (fire hazard), 20, 21, 22, 25, 26	

Table 7.2 Terrain Classes

Land characteristic		Measurement Classes				
		1	2	3	4	5
Relative relief[1/]	(m)	50	100	200	500	any
Slope angle[2/]	(Degrees) (Percent)	5 9	10 18	18 32	35 70	any
Active landsliding		absent	absent	infrequent	common	very common
Swamps (% of area)		2	10	20	50	any
Stream channels[3/]	(no./km)	1	2	5	10	any
Rock hindrances and boulders)	(outcrops %)	1	4	10	25	any
Stones, topsoil	(%)	1	5	15	40	any
Cracking clays		absent	absent	-	-	-

Values given are the maximum permitted in the class

1/ Height difference between interfluve crests and adjacent valley floors

2/ Angle exceeded by 33% of slopes in an area

3/ Number of stream valleys (including ephemeral watercourses) encountered in randomly-orientated traverses one kilometre in length

a statistically controlled sampling programme; in many cases, however, it may be necessary to diagnose nutrient availability indirectly, e.g. by thickness of the organic topsoil, or soil type.

Selection of land characteristics is achieved through reconciliation of two aspects:

i. Which characteristic(s) best represent the land quality?

ii. On which characteristics is it practicable to obtain reliable information?

For example, in a detailed survey for a forest management plan it might be possible to describe rooting conditions by means of field survey of effective soil depth (depth to a limiting horizon of rock, indurated ironstone, etc.), together with recorded percentage frequency of rock outcrops and boulders. In a reconnaissance survey for broad regional planning, however, survey of such intensity would be too costly, and the rooting conditions are represented indirectly and approximately by average slope angle.

Table 7.3 Land characteristics which may affect suitability for forest growth, management or conservation

A.	Geology	Rock type, rock hardness/strength (bearing capacity, road construction). Indirect means of estimating soil properties, groundwater hydrology.
B.	Landforms	Slope angle, relative relief, stream frequency, outcrops and boulders, swamps, aspect, shape of slope, exposure index, micro-relief. Landslide frequency. Scenic value. Indirectly altitude as a means of approximating to temperature.
C.	Climate	Annual temperature, temperature in growing season, temperature of hottest, coldest months, extreme temperatures, frost frequency, frost-free period. Annual rainfall, growing season rainfall; length of growing season, dry season, evaporation; rainfall intensity, energy. Total radiation, sunshine hours. Relative humidity. Frequency and severity of high winds. Climatic type.
D.	Hydrology	River flow regime, unit hydrograph, flood frequency. Groundwater depth, presence of aquifers.
E.	Soils (topsoil and sub-soil where relevant)	Effective soil depth, topsoil depth, depth to impermeable layer; texture, stones and gravel, structure, consistence; occurrence of crusting, pans, stone or gravel horizon, laterite horizon; drainage class, depth to mottling, permeability, available water capacity. Nutrient content, organic matter content, pH, base saturation, electrical conductivity of saturation extract, exchangeable sodium percentage. Bearing capacity. Soil type.
F.	Vegetation	Volume of standing timber, predicted growth rates, site index, volume or predicted yield of non-timber products. Indicator communities or species; combustibility. Genetic diversity, rare species.
G.	Fauna and disease	Animal, bird or insect pests or carriers; plant diseases, including soil borne. Animal population, rate species.

7.7 Studies of land in environmental and recreation forestry

7.7.1 Environmental forestry

As already noted with respect to land use requirements, the method of land evaluation for conservation forestry differ to some extent, in approach as well as in detail, from those appropriate to other forms of forestry. Just as the requirements are based upon need for protection, so also the surveys of land are directed towards assessment of the degree of need. The distinction between land use requirements and land qualities becomes less clear cut.

Details of procedures for studies of land with respect to conservation needs are given in specialized handbooks, e.g. on hydrology, soil erosion assessment. In principle, the approach is, first, to measure the existing situation and, secondly, to estimate the corresponding situation if the protective forest cover were to be removed.

For water conservation, the main aspects to be considered are:

- present flow regime;
- estimated response of flow regime to vegetation changes (permanent clearance, temporary harvesting, or afforestation).

The response is conditioned by rainfall characteristics, soil permeability, drainage pattern, the unit hydrograph, etc.

In forestry for soil conservaton relevant aspects are:

- present state of erosion;
- estimated response, in terms of catchment erosion and off-site sedimentation, to vegetation changes.

Methods for prediction of soil erosion are reviewed in FAO (1979b, 1983).

Forestry for conservation of flora and fauna calls for specialized studies directed towards the presence of distinctive genetic reserves, rare or endangered animal species, and the conditions necessary for their preservation.

7.7.2 Recreation forestry

Forestry for recreation and tourism is again a specialized aspect, although one which leads itself to treatment in terms of land use requirement and the corresponding land qualities. The requirements (Table 6.2, p.52) are mainly in terms of resources for recreational and tourist purposes and the studies of land will be directed towards assessment, qualitative or semi-quantitative, of those resources. There are established systems, developed mainly in Europe and the United States, for rating of aesthetic (scenic) values, whilst the Canada Land Inventory has an established methodology for classifying recreation potential, which could be taken as a model.

7.8 Examples

7.8.1 Examples of selection of land qualities and land characteristics

Objective, land utilization type and area: semi-detailed survey for location of mechanized coniferous plantations for timber production, Turkey. (Adapted from Cooling, 1977).

RELEVANT QUALITIES	LAND CHARACTERISTICS SELECTED AS DIAGNOSTIC FACTORS
Affecting growth	
Soil drainage	Soil drainage class Depth to water table
Rooting conditions	Soil depth Stoniness
Salinity	Salinity class
Toxicities	Soil reaction (pH)
(Combination of qualities affecting growth, employed for species selection)	Soil texture Soil reaction (pH)
Affecting management	
Terrain factors affecting mechanized operations	Landform class Slope angle Rockiness Microtopography
Affecting conservation	
Erosion hazard	Erosion hazard class (slight, moderate, severe)

Comment Climate over the survey area is relatively uniform, hence the omission of radiation, temperature and moisture qualities. Growth requirements for location of plantations are therefore dependent on drainage and rooting conditions, the presence of strongly acid or alkaline soils, and the hazard of salinity. The semi-detailed intensity of the survey permits field soil observations, e.g. of drainage class, depth and stoniness, but not laboratory sampling and analysis other than for pH.

For selection of tree species, two land characteristics are employed directly as diagnostic factors: soil texture and reaction. This is because information on species requirements are available in terms of these characteristics.

The relevant management requirement is terrain conditions affecting mechanization, including harvesting. Landform class is obtained from air photo-interpretation, slope angle, rockiness and microtopography by field survey. It was decided during initial consultations that location would be treated outside the framework of the initial qualitative evaluation.

Plantations are not expected to have adverse effects on streamflow, and there are no rare or important biological resources in the area. The need for conservation is therefore not to plant on areas of high erosion hazard, expressed on a qualitative scale of classes based mainly on slope angle.

Note In the original survey from which this example is adapted, evaluation was based directly on land characteristics.

7.8.2 Example of part of a description of land characteristics belonging to a land unit

LAND UNIT NO. 33 NAME: Mazlak Plains

SUMMARY DESCRIPTION: Low altitude, gently undulating plains with scattered hills; hot, semi-arid; calcareous soils of variable depth, with saline patches; thorn scrub.

LAND QUALITY	LAND CHARACTERISTICS	UNIT	VALUE	NOTES
Temperature regime	Mean temperature in growing season.	^{o}C	28^{o}	
	Mean for hottest month	^{o}C	35^{o}	
Moisture availability	Rainfall/evaporation ratio	r/Eo	0.18	
Salinity	Elec. conductivity	ECE	no data	1/
	Presence of saline areas	frequency class	few	
Terrain factor	Landform class	class	gently sloping	
	Slope angle	degrees	0 - 5	
	Rockiness	% cover	5 - 10%	

1/ Salinity is assessed in terms of electrical conductivity measurements where data are available, otherwise field observation of frequency of saline patches.

CHAPTER 8

MATCHING LAND USE WITH LAND

CHAPTER 8

MATCHING LAND USE WITH LAND

8.1 Introduction

The focal point in land evaluation is that at which data on land use and on land are brought together and compared, the comparison leading to land suitability classification. These data are:

- The relevant kinds of land use (land utilization types), and their requirements and limitations.
- The land units and their land qualities and characteristics.
- The environmental impact of land use on land.
- The economic and social consequences of each alternative kind of land use on each land unit.

Generally, economic and social analysis follows the comparison of requirements with land qualities, although, in practice, there may be considerable overlap between them.

The purposes served by matching are:

- To refine the description of land utilization types.
- To determine the management and improvement specifications of each land utilization type on each land unit to which it is suited, and thus to estimate the required inputs.
- To estimate the magnitude of the outputs from each land utilization type on each land unit to which it is suited.
- To appraise the provisional suitabilities in terms of environmental impact and social consequences.
- To provide an economic analysis of the relative costs and benefits of each relevant combination of land use with land unit.
- To produce a set of suitability classes for kinds of land use on land units.

In evaluations for production forestry, and also for recreation, there are three steps in the initial comparison of land use requirements with land qualities: setting of factor ratings for each land use requirement, comparison of these with the land units to obtain land suitability ratings, and combination of the latter into provisional land suitability classes. For environmental forestry this sequence of procedures may not be appropriate, as discussed in Section 8.3.3.

8.2 Factor ratings

8.2.1 General

At the start of matching, the evaluator has in front of him:

i. A set of land use requirements for each land utilization type, similar to those given in Tables 6.1 and 6.2. These will be similar in form to the example given in Section 6.4.

ii. A set of values of the diagnostic factors (land qualities, land characteristics, or a combination of the two) for each land unit, based on those given in Tables 7.1 and 7.3. These will be similar in form to the example given in Section 7.8.2.

The first stage is to decide on the factor ratings for each land utilization type. A factor rating is a set of critical values which show how well one particular land use requirement is satisfied by a condition of the corresponding diagnostic factor. For example, for the land quality of soil rooting conditions, as measured by soil effective depth, a soil depth of over 150 cm might be rated highly suitable, a depth of less than 20 cm not suitable, with corresponding values for moderately and marginally suitable.

The factor ratings are set for each selected land quality in turn: e.g. rooting conditions, moisture availability, erosion hazard. Different land utilization types will have different ratings; for example, some tree species will survive on shallower soils than others.

Factor ratings are shown by lower case letters, s1, s2, s3 and n, to distinguish them from suitability classes based on all factors combined. Ratings do not generally distinguish between n1 and n2.

8.2.2 Setting of factor ratings

An example of factor ratings is given in Table 8.1. For simplicity, only four requirements are listed, each of which is diagnosed by a single land characteristic.

In this example, moisture availability is diagnosed by the ratio of annual rainfall to potential evaporation, r/Eo. In the context of the semi-aridity of the survey area as a whole, coupled with the tree species selected, a ratio better than 0.5 (e.g. 800 mm rainfall to 1 600 mm evaporation) is here considered the best that can be expected, and rated as s1. A ratio below 0.2 is assessed as so unfavourable that unirrigated plantations would almost certainly fail, and is rated as n. Taking these limits as a starting point, a relatively narrow range is rated as marginal, s3, and a wider range as moderately suitable, s2.

The above example illustrates the guidelines to be followed in deciding suitability ratings. These are:

i. Rate as s1 those conditions which, whilst less than optimal, nevertheless would not be expected substantially to increase inputs or reduce outputs.

ii. Rate as n those conditions which would be expected to increase inputs and/or reduce outputs so severely that, on the basis of this land quality alone, the land use would be physically or economically impractical.

iii. For setting the critical value separating s2 from s3, there are two alternatives. Either the range is divided equally, for simplicity; or, as in the examples given in Table 8.1 a relatively narrow range is assigned to s3. This latter procedure has the effect of making s3 represent a range of uncertainty as to what constitutes the upper boundary of unsuitable conditions - a kind of 'thick boundary' to n.

Table 8.1 Example of factor ratings for a land utilization type

Land utilization type: Large-scale fuelwood plantations, mechanical harvesting, semi-arid zone of West Africa

Land use requirement/ land quality	Diagnostic factor	Unit	Factor ratings			
			s1	s2	s3	n
Moisture availability	Rainfall/evaporation ratio	r/Eo	> 0.5	0.3-0.5	0.2-0.3	< 0.2
Rooting conditions	Soil effective depth	cm	> 150	40-150	20-40	< 20
	Soil texture	class	any except clay		clay	-
Conditions for mechanized harvesting	Terrain class 1/	"	1	2,3	4	5
Ease of land clearance	Vegetation class 2/	"	1,2	3,4	5	-
Erosion hazard	Predicted	t/ha/year	< 12	12-25	25-50	> 50

1/ See Table 7.2

2/ It is assumed that vegetation types of the area have been assigned to 5 classes according to ease of clearance.

The remainder of Table 8.1 illustrates these principles applied to different circumstances. The second growth requirement, rooting conditions, is diagnosed by two land characteristics, effective depth and soil texture, taking the poorest of these as limiting the suitability rating. For depth, >150 cm is judged to be highly suitable, and <20 cm as not suitable. For texture, a clay texture is considered to lower the suitability class to s3, but there is no texture which would cause a rating of n. A management requirement, conditions for mechanized harvesting, is diagnosed by the terrain classes in Table 7.2 (p.70) which combine a number of land characteristics.

One means of rating erosion hazard is illustrated, the use of predicted soil loss. The soil loss to be expected under the given land use will be calculated for each land unit. The factor ratings consist of losses judged to be relatively acceptable: in this example, less than 12 t/ha/year is considered to be a condition that, in the context of the local environment, would be highly suitable. A loss of more than 50 t/ha/year is judged unacceptable, and thus a reason for classing any land that would produce such a loss as not suitable. For reviews of methods of predicting erosion loss, see FAO (1979b, 1983).

A refinement of Table 8.1 would be to subdivide the land utilization type into two subtypes based on different tree species. The ratings for mechanized harvesting and erosion hazard would remain the same, that for rooting conditions might or might not change, but the ratings for moisture requirements would probably be different. This illustrates a useful method for constructing land utilization types, based on disaggregating their land use requirements into requirements for growth, management, and conservation.

There are as yet no standard tables for the growth requirements of many of the tropical tree species nor for terrain and other requirements for different kinds of management or harvesting. Some sources give tree species preferences, in very generalized terms (e.g. FAO, 1974; Webb, Wood and Smith, 1980; Pandey 1983). Local experience is a good guide, provided that past management can be assumed as satisfactory. Experience from similar environments in different countries or continents should, in principle, be transferable, but needs to be treated with caution; for example, a rainfall of 600 mm falling in a single season may be substantially more concentrated, and thus probably less effective, in one area than in another.

8.2.3 Setting of factor ratings for estimates of forest volume, growth and yield

There is less experience of using estimates of existing growth, the land qualities in Section B of Table 7.1, as diagnostic factors for land suitability. In principle, they should be assigned factor ratings in a similar way. For example, in an evaluation for wood production from natural forests, the main type of basic resource survey is likely to be forest inventory. This will have given detailed estimates of harvestable timber per unit area, by species, and under given specifications. Assume for simplicity that the total harvestable volume is to be taken as the diagnostic factor. In a humid region a volume of more than 150 m^3/ha might be considered highly satisfactory and rated as s1; whilst it may be judged, if possible on the basis of a rapid approximate economic analysis, that anything less than 40 m^3/ha would be uneconomic to extract, and thus rated as n.

For the example in the preceding section, however, that of fuelwood plantations in a semi-arid zone, these critical values would be considerably lower. This illustrates the principle that suitability has to be assessed within the local context of physical and economic conditions.

Similar methods can be followed for estimates of forest growth and yield. Either site index or site quality class can be treated as diagnostic characteristics, and assigned factor ratings, as in the example given in Table 8.2.

Table 8.2 Example of factor ratings based on estimates of forest volume, growth and yield

Land utilization type: Teak, *Tectona grandis*, India

Land use requirement/ land quality	Diagnostic factor	Unit	Factor ratings			
			s1	s2	s3	n
Tree growth	Site class	class	I	II	III, IV	V
	OR					
	Site index	site index	30	24-30	12-24	12

Note: Either site class or site index, and not both, would be employed in a particular evaluation

8.2.4 Factor ratings for land qualities affecting conservation

For rating of conservation requirements there are two circumstances to be considered: that in which the primary objective is production forestry, in which fulfilment of conservation requirements is always a necessary condition; and that in which conservation is the primary or a major objective of the forest.

In the first case, production forestry, the relevant qualities are those numbered 22 to 26 in Table 7.1, the predicted effects of the land use on soil erosion, water yield, vegetation degradation, and the protection of valued plant and animal species. The recommended method of treatment has been illustrated in Section 8.2.2 for the case of requirements for avoidance of soil erosion. This method is as follows:

i. For the survey area as a whole, decide upon conservation criteria which can reasonably be taken as very satisfactory: erosion loss below some specified value, e.g. 12 t/ha/year; reduction in water yield not to be greater than, e.g., 10%; no danger of extinction from the area of a given list of plant and/or animal species. These target conditions are rated as s1.

ii. Decide similarly what environmental effects are to be treated as unacceptable, using similar diagnostic factors, quantitative where possible. These unacceptable conditions are rated as n.

iii. The environmental effects of the land use on each land unit are then estimated: e.g. impacts on erosion loss and water yield, and danger of extinction from the area of plant or animal species. Suitability ratings are determined by comparing these estimated effects with the criteria set in the factor ratings.

For the second circumstance, that in which forestry is primarily for conservation or reclamation, it may sometimes be possible to follow a similar approach. In other cases, however, broader-based, qualitative estimates of suitability may be more appropriate. For example, it may be found that certain watersheds are the main origin of perennially flowing rivers for a region. Even without calculating flow responses to temporary or permanent deforestation, it may be held that these should be kept as priority areas for conservaton forestry; in land evaluation terminology, this would be to assign them a land suitability class of S1 for watershed protection forestry.

Where land reclamation is an objective, observed severity of erosion can be taken as a diagnostic criterion for suitability - the areas most in need given the highest ratings on these grounds. Alternatively there could be separate ratings for the severity of present erosion, the value of the land if reclaimed, and the predicted success of afforestation in achieving such reclamation.

The assessment of environmental impact is considered further in Chapter 9.

8.3 Land suitability classification

8.3.1 Land suitability ratings

After the factor ratings have been set for each land quality belonging to each land utilization type, they are compared with the corresponding conditions of the land units. This leads to a set of partial or component suitabilities, called land suitability ratings. These show suitability of a land unit for a specified land use, based on one requirement alone, e.g. suitability based on rooting conditions alone. Thus, if a land unit has soils with an effective depth over 150 cm, the land suitability rating would be s1, highly suitable, for the land utilization type referred to in

Table 8.1. Another land unit, with an average soil depth of 10 cm, would give a land suitability rating of n, not suitable, for the same use. Land suitability ratings are shown in the same way as factor ratings, by lower case letters, s1, s2, s3 and n.

An example of a set of land suitability ratings is shown in Columns 1 and 2 of Table 8.3. Each set of land suitability ratings refers to suitability for one land utilization type on one land unit. Each individual suitability rating refers further to suitability based on one land use requirement/land quality. Thus, in Table 8.3 the uppermost land suitability rating of s1 results from comparison between:

- the moisture requirements of fuelwood plantations;
- the moisture availability in the Jalala Hills.

In this example, the rainfall/evaporation ratio of the Jalala Hills has been taken as 0.6; comparison with Table 8.1 shows that this falls within the critical limits for a factor rating of s1, therefore the land suitability rating is also s1.

Table 8.3 Example of combination of factor ratings to give provisional land suitability classification

Land utilization type: large-scale fuelwood plantations, mechanized harvesting

Land unit: 3 Jalala Hills

Land use requirement/ land quality	Land suitability rating		
Moisture availability	s1	Conditions for growth:	s2
Rooting conditions	s2		
Conditions for mechanized harvesting	s3	Conditions for management:	s3
Ease of land clearance	s1		
Erosion hazard	s2	Conditions for conservation:	s2

Provisional land suitability subclass: S3q

Notes: Slopes and broken terrain give marginal conditions for mechanized harvesting. Suitability might be upgraded to S2 if LUT changed to partly mechanized harvesting methods.

8.3.2 Combination of land suitability ratings

The next step is to combine the land suitability ratings into an overall land suitability classification. This process of combination is illustrated in Table 8.3. There are five suitability ratings. These have first been combined to give suitabilities separately with respect to growth, management and conservation requirements: in the example, s2, s3 and s2 respectively. The latter are then combined into an overall land suitability class of S3, marginally suitable. The limiting factor in this case, i.e. that which lowers the suitability class, is the conditions affecting mechanized harvesting, here assigned the subclass letter q, giving land suitability subclass S3q.

In this example, the rule has been followed that the least favourable factor is taken as limiting to the suitability; that is the overall suitability can be no higher than the lowest of the land suitability ratings. This is the most common method for combining ratings. A possible modification is:

i. Assess certain land use requirements as important, whilst others are only significant. Add this assessment to the table used for combination.

ii. The overall land suitability may not be higher than the rating for a single important requirement, but may be one class higher than a single significant requirement.

iii. Overall suitability may not be higher than any two ratings of significant requirements.

There are other methods for combining factor ratings, ranging from subjective judgement to various arithmetic procedures; these are outlined in FAO (1983a). A subjective method may be possible where the evaluation is coordinated by a single experienced forester/evaluator; there is the danger that the same rule may not be followed in all instances where it occurs. Precise rules are necessary for cases of classification by several members of a team, or by computerized methods.

It may sometimes be preferable to assess suitabilities by means other than combination of separate factor ratings. For example, a specialized study of conservation requirements may have been made, using different techniques, but yielding, as a result, an overall classification of land according to its need for conservation forestry. This could be adopted as the basis for suitability classification.

8.3.3 Land suitability classification for environmental forestry

The procedure described above, from factor ratings via land suitability ratings to provisional land suitability classes, may not be appropriate in circumstances of environmental forestry. The provisional land suitability classes may be assessed in a more direct manner, through assigning measures of relative need or benefit to suitability classes. For example, areas where the adverse environmental impact of forest removal are assessed as 'severe' could be assigned to suitability class S1, areas where such impact would be progressively less severe to S2 and S3, whilst suitability order N is appropriate where the need for a protective cover purely for conservation purposes is slight or nil.

8.4 Wider aspects of matching

Matching in the broader sense of the term is more than the comparison of land use requirements with land qualities. It may also involve changes to the requirements or to the qualities, with the aim of achieving higher land suitability.

Changes to the land use requirements call for modifications to the land utilization type. This is illustrated in the Notes to Table 8.3. The land utilization type being considered is one based on fully mechanized harvesting methods. Land unit No.3, however, has sloping and dissected terrain, making it marginally suitable for this use, despite the moderately suitable conditions for tree growth and consideration. If, however, the land utilization type were to be modified, to one using partly mechanized harvesting methods, then the factor ratings for harvesting conditions would become different. This, in turn, might upgrade to suitability rating for this land unit to s2, in which case the overall land suitability would become S2.

The other means of achieving a better match is to change the land qualities, by means of land improvements. In the example in Table 8.3 there is no opportunity for this, since terrain conditions cannot be changed. Suppose, however, that for another land unit poor drainage was the limiting factor, it might be possible to ameliorate this by a local drainage scheme. Given that this were properly maintained, this would improve the quality of soil drainage, which could lead to an upgrading of conditions for both growth and management.

In evaluations for agriculture, land improvements are treated in a separate manner, on the grounds that they require initial capital investment well above the recurrent costs of crop production. In forestry evaluations two courses of action are possible. Since forestry is, in any case, dependent on substantial initial investment, the measures necessary for land improvements (e.g. terracing, drainage) can be incorporated in the description of the land utilization type. Alternatively, the land improvements can be treated as a separate input, affecting the land qualities. The former course is appropriate whenever the improvements are considered to be an integral and necessary condition for the practice of the land utilization type, the latter when there is the option of making or not making the land improvements.

The breakdown of land use requirements into those for tree growth, management operations, and conservation requirements facilitates this two-way matching process. On finding that two of the sets of conditions are more favourable than the third, the evaluator should look for ways of modifying either the land use or the land qualities affecting the least less favourable set of requirements. This could be by changes to the land utilization type, by land improvements, or both. Matching in this broader sense is one of the most powerful techniques in land evaluation, leading to the construction of land utilization types best suited to each land unit in the area.

8.5 Provisional land suitability classification

The outcome of the combination of factor ratings is a set of provisional land suitability classes. These can be summarized in three ways:

i. Tables for each land utilization type, showing the suitability ratings and provisional suitability classes for each of the land units, e.g. Table 8.4(a).

ii. Tables for each land unit, showing the suitability ratings and provisional suitability subclasses for each of the land utilization types, e.g. Table 8.4(b).

iii. A combined table of land utilization types compared with land units, similar to that in Figure 2.3 (p.20).

These provisional suitability classes form the basis for further comparison in terms of environmental impact, economic and social analysis.

Table 8.4 Example of tables for summarizing results of provisional land suitability classification

(a) By land utilization types

Land utilization type: fuelwood plantations, mechanized harvesting					
Requirements for	Land Unit No.				
	1	2	3	4	etc.
Growth	s2	s2	s2	s1	
Management	s1	s1	s3	s1	
Conservation	s1	n	s2	s1	
Provisional land suitability	S2m	N2e	S3q	S1	

(b) By land units

Land unit:	3 Jalala Hills				
Requirements for	Land utilization type				
	A	B	C	D	etc.
Growth	s2	s2	s1	n	
Management	s3	s2	s2	s2	
Conservation	s2	s2	s2	s2	
Provisional land suitability	S3q	S2me	S2e	N2m	

CHAPTER 9

ENVIRONMENTAL IMPACT

CHAPTER 9

ENVIRONMENTAL IMPACT

9.1 Further stages in comparison of land use with land

The process of matching, leading to a provisional land suitability classification, is only the first stage in comparison of land use with land. It is followed by analysis of the consequences of alternative land use systems (combinations of land utilization type with land unit) in three ways: the expected environmental impact, economic analysis, and analysis of the expected social consequences of each alternative change in land use or management.

These further stages in analysis are confined to land use systems classified as Suitable in the provisional assessment. Systems provisionally classed as Not Suitable need not be further considered. If it appears that the demands for some of the land utilization types can be met from land units for which they are assessed as Highly or Moderately Suitable, S1 or S2, then further analysis may be of these only.

9.2 Role of environmental impact analysis

Consideration of environmental impact, or the probable consequences of land use change for the environment, should permeate the matching process and, indeed, the evalution as a whole. Conservation requirements will already have been taken into account in determining the provisional land suitability classes, in production as well as in conservation forestry. Its further consideration at this stage is recommended to obtain an overall view of environmental impact and to ensure that no significant aspects, including off-site effects, have been overlooked.

As compared with other kinds of land use, a distinctive feature of forestry is that it may have favourable as well as adverse effects upon environmental conditions. This can be a powerful argument for retaining some areas under forest which might have yielded higher short-term returns under agriculture. The same reasoning can apply to afforestation of marginal or degraded lands, perhaps as part of a watershed management programme. Therefore environmental analysis of the effects of forest land use should include consideration of:

- the benefits resulting from retention of the present forest cover, as compared with consequences of its conversion to non-forest uses;

- the benefits resulting from afforestation of presently non-forested lands;

- possible beneficial and adverse environmental consequences of proposed changes in forest use or management, and what management measures can be taken to minimize the adverse effects.

In the case of production forestry, the impact needs to be analyzed separately for the periods of establishment, growth and harvest, with particular attention to the consequences of forest road construction and the use of heavy machinery.

9.3 Types of impact

The main types of impact to be considered are:

i. Soil erosion Sheet, gully or wind erosion, its magnitude (generally as predicted soil loss, t/ha/year), and effects of long-term soil productivity, for natural or planted vegetation.

ii. Sedimentation On and off-site effects of increased sediment load in streams; including possible effects on channel stability, aquatic life and fisheries, siltation of reservoirs, quality of water supplies.

iii. Water flow regime Increased storm runoff and/or reduced baseflow, with consequences on water supplies for domestic industrial or irrigation purposes and on flooding and navigation. Lowered quality of domestic water supply.

iv. Microclimate Deforestation may increase soil temperatures and lower humidity near the ground surface, with consequent effects on soil moisture, regeneration or resistance to wind erosion.

v. Vegetation Some forests may not regenerate after clear-cutting. Selective removal of desired species will result in relative increase in undesired species unless proper management measures are taken. Loss of genetic resources. Fire hazard from plantations.

vi. Wildlife Effects both of forest harvest methods and forest clearance upon existence and abundance of animal species. Effects of forest management practices on ecological niches of animal and bird species. Reduction in species diversity. Loss from the area, or extinction, of rare species. Disturbances to the natural balance between predators, herbivores and vegetation.

vii. Fisheries Effects of reduced light penetration and other effects of sediment on aquatic life, including fish spawning and nursery areas and on subsistence and commercial fisheries.

With respect to each of these kinds of impact, the environmental effects of land use change can be either favourable or adverse. For example, establishment of forest plantations on marginal agricultural lands with degraded soils may lead to a build-up of humus and restoration of fertility. In most cases the environmental effects of forest land use are favourable as compared with non-forest uses, although there will be exceptions.

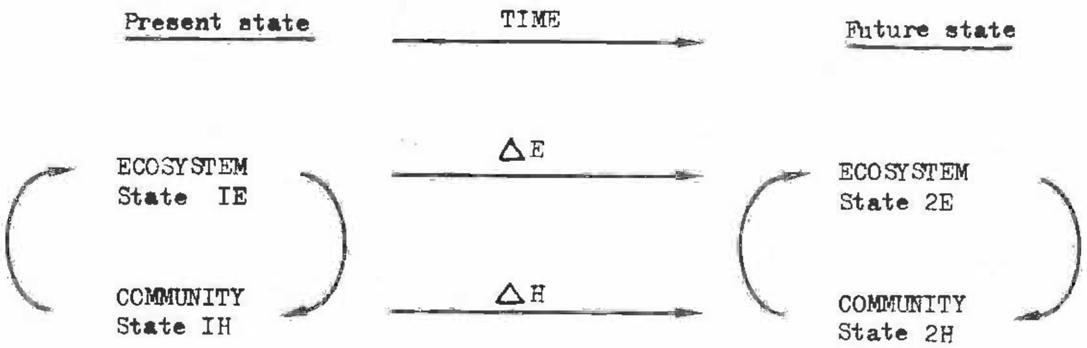
The principle of comparison between alternative land uses is important in this context. The environmental impact of non-forest land use (whether continuing from the present or as changes from forest use) should be assessed alongside, and on the same basis as, the impact of forestry.

9.4 Treatment in land evaluation

A possible framework for consideration of environmental impact is provided by consideration of the interaction between the natural ecosystem and the human communities. (Singh and Nilsson, 1974). At any time the ecosystem and the community are each in a given state, and there are interactions between them. (Figure 9.1(a)). Over any period of time there will be changes both to the ecosystem and the community, some of those changes being consequential upon the continuing interaction. At the present time, owing to rising population and limited resources, the normal changes are in the direction of depletion of the area of the forest ecosystem and an increase in the demands upon it from the community.

Figure 9.1 Interactions between the natural ecosystem and the human community. (Adapted from Singh and Nilsson, 1974)

(a) Change with time under present land use



E = change in ecosystem
H = change in community

(b) Effects of future land use alternatives

Change in land use

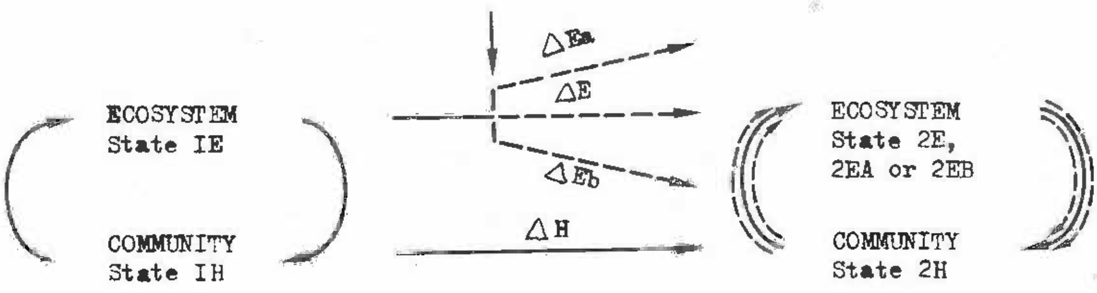


Figure 9.1(b) illustrates diagrammatically the effects of possible decisions on land use or management called A and B. In the case of unaltered land use, the change in the ecosystem is ΔE. The alternative kinds of land use will affect this change, first abruptly, during the actual process of alteration (e.g. afforestation or deforestation) and subsequently in a gradual manner. The different effects of land uses A and B are represented by ΔEa and ΔEb. These lead in turn to three alternative future states of the ecosystem, 2E with no alteration in land use, or 2EA or 2EB. The corresponding interactions with the human community will also be affected, e.g. as greater or reduced fulfilment of needs.

This approach can be applied to assessment of the environmental effects of alternative changes in land use (Table 9.1). The substems, components and state variables of the ecosystem are listed. Their current status is recorded, either qualitatively or, where data is available, in quantative terms (e.g. runoff, soil loss, number of rhinocerouses). The expected changes in the ecosystem state are then assessed for various alternative forms of land use. This again can be on a quantitative basis where reliable estimates can be made. More often they will need to be assessed in relative terms, e.g. on a scale of +3 through 0 (no change) to -3.

In circumstances where both conservation and other aims of forestry are both important components of the objectives, the environmental impact can be recorded as a separate land suitability rating, independently presented in the results. This allows for decisions to be taken in the light of value judgements as to the relative importance of production and conservation objectives.

Table 9.1 Format for description of environmental impact of land use changes

Subsystems, components and stated variables	Current status	Predicted effects of changes in land utilization type		
		LUT A	LUT B	LUT C
I Abiotic		(e.g)		
Microclimate		0	+1	0
Runoff	[x]	0	+1	-3
Soil erosion		-1	+2	-2
etc.		etc.		
II Biotic				
Tree cover				
Genetic reserve	[y]			
Animal species				
etc.				

[x] and [y] are matrices describing the current state of abiotic and biotic variables

Detailed discussion of techniques for watershed management and conservation is given in FAO Conservation Guides 1-4 (FAO 1976b, 1976c, 1977b, 1978b) and FAO Soils Bulletin 44 (Gil, 1979). Guidelines for assessment of the environmental impact of forestry in developing countries are given in FAO Conservation Guide 7 (Zimmermann, 1982), to which reference should be made for a range of techniques which may be applied as appropriate in land evaluation surveys. Particular attention is directed towards the following check-lists and summaries (page references are to Zimmermann, 1982):

- Checklist for preliminary assessment of environmental impact (pages 31-34)
- Summary of potential impacts of forestry activities, with emphasis on the tropics and subtropics (pages 35-41)
- Checklist of potential environmental impacts of individual forestry activities (logging, roads, etc.) (pages 43-48)
- Suggested definitions of "major impact" (pages 49-51)
- Possible means for mitigation of selected types of environmental impact (pages 53-60)
- Operational guidelines for environmental protection - review of publications and statement of further needs (pages 61-63).

CHAPTER 10

ECONOMIC AND SOCIAL ANALYSIS

CHAPTER 10

ECONOMIC AND SOCIAL ANALYSIS

10.1 The role of economic and social analysis in land evaluation

10.1.1 General

Without consideration of economic and social aspects there could be no land evaluation. Forest land use has the function of bringing benefits to people. It provides direct benefits, such as outputs of wood products, other forest products, grazing use, water, etc., and intangible benefits such as biological conservation and recreation. Forest lands also play a part in community social life, in patterns of work and leisure. Economic and social aspects clearly have a considerable influence upon the types of land use and management that are most suited to an area.

Many aspects of policy, economics and social conditions, however, form part of the wider process of land use planning and land development. Land evaluation makes a substantial contribution to this widerprocess but is by no means synonymous with it. The central function of land evaluation is to assess the potential of land: where is the best place for a particular kind of land use, and what is the best use for a certain area of land. Both these kinds of comparisonrequire economic and social information, as well as data from the physical environment and from forestry, to be answered.

Economic analysis is necessary in order to assess the relative effects of physical limitations. This can be illustrated by a simplified example. Suppose the objective is to establish 200 hectares of fuelwood plantation. The basic surveys show that available land consists of 100 hectares of gently sloping and well drained land, 100 of steep rocky land and 100 of swampy land. Onto which of the two poorer sites should the plantation be extended? There is no way of answering this question by reference to purely physical surveys, however detailed steep land is neither inherently 'better' nor 'worse' than swampy land. If it is assumed in this example that potential rates of tree growth are similar on the steep land and on the swampy land, if it is drained, then the question of which land is better suited for the plantation is answered by comparing the added establishment and maintenance costs of the steep land with the costs of construction and maintenance of drainage works in the swampy land. The answer is specific to the particular land utilization type considered; for example, whether felling and extraction is to be by mechanized or manual methods.

In the above example the different physical characteristics of the two land units were assumed to influence production costs. If the difference between sites if one of yields, e.g. timber growth rates, then the more productive land may be assumed more suitable, but even then only if there is no difference in location, or social factors such as existing local use for grazing. It is one of the basic principles of land evaluation that it requires a comparison between benefits obtained and inputs needed on different types of land. Such comparisons need to be translated into economic terms, by no means as the sole criterion for decision-making but as one important element.

Economic and social analysis can take place at two levels, generalized and detailed. Some evaluations are designed to provide broad planning guidelines, without leading directly to investment decisions. In such cases the effects of possible land use changes may be considered at a generalized level. Consideration should be given to possible consequences for labour, transport, population movements or settlement, subsistence requirements, land tenure, and the interests of minority groups. Some economic analysis may be carried out in a simplified form to ensure that the kinds of use being classified as suitable are financially viable. At the generalized level, economic and social analysis are closely related, and may be carried out as a single operation.

The position is different where evaluation is intended to lead to investment decisions. In this case, economic analysis is carried out at a considerably more detailed leve, in terms of costs of inputs and predicted outputs from different types of land. Without such analysis there is no way of comparing the relative effects of different kinds of physical limitations - slope, infertile soils, drought, etc. Social investigations are also more detailed, since the livelihood of people is at stake. At this more detailed level, economic and social studies will form distinct if inter-related components, usually conducted by different specialists.

10.1.2 The two-stage and parallel approaches

There are two ways of relating the economic component to the physical aspects of land evaluation. In the two-stage approach, qualitative analysis in physical terms is carried out, first, with economic and social considerations present as a background, leading to a qualitative or quantitative physical land suitability classification. This is then followed by economic and social analysis, confined to the more promising sites, as indicated on physical grounds, leading to an economic suitability classification.

In the parallel approach, economic and social analysis proceeds concurrently with physical studies with ongoing interchange of information, leading directly to an economic classification. Economic criteria are employed to guide assessment of suitabilities in physical terms. This approach calls for close cooperation between those responsible for physical and for economic aspects of the evaluation.

The parallel approach has the potential to lead more directly to the end result with less survey effort, and is thus in theory the more efficient. It may be considered when the evaluation is intended to lead directly to investment and when the team conducting it is well experienced. In practice, it is difficult to achieve the high level of integration between disciplines required. Most surveys follow the two-stage approach, which is therefore assumed for the remainder of this chapter, except where otherwise stated.

10.1.3 Role of economic and social information in evaluation procedures

Figure 10.1 indicates the main stages at which economic and social information is incorporated into land evaluation procedures. These are as follows:

i. At the start of the evaluation, in determination of the objectives and constraints and in the initial identification of land utilization types.

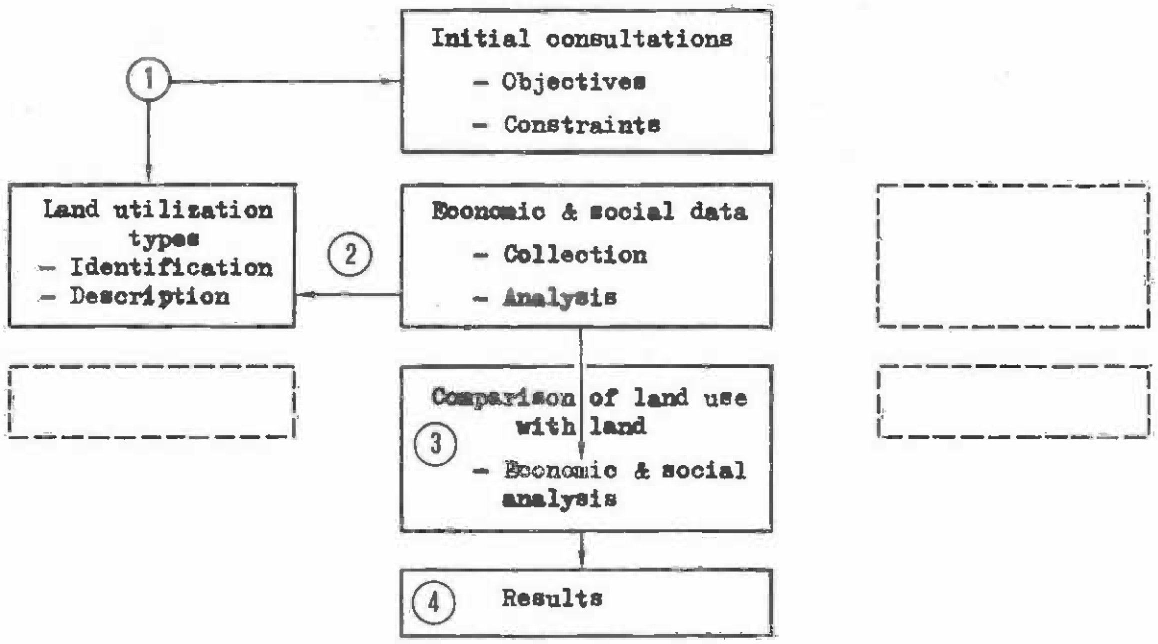
ii. During the progressive refinement of land utilization types.

iii. The main social and economic analysis takes place as part of the comparison of land use with land, following provisional suitability classification based on physical criteria.

iv. Statements of the economic and social consequences of land use alternatives form part of the results.

The above sequence applies to the two-stage approach to evaluation. In the parallel approach economics are more continuously involved in procedures, including during the initial matching process.

Figure 10.1 Role of economic and social analysis in two-stage land evaluation procedures. Cf. Figure 3.1



10.2 Economic analysis

10.2.1 Objectives

The purpose of economic analysis in land evaluation is to compare the performance of land utilization types on the different kinds of land which have been provisionally assessed as suitable. To make this comparison requires conversion of the inputs and outputs into costs and benefits, and the calculation of one or more measures of economic value. This analysis can be carried out on a financial and/or economic basis. The objectives are:

i. To compare the effects of land units with different qualities upon the economic performance of each specified kind of land use,

ii. To compare the economic performance of different kinds of land use on each type of land present in the survey area.

The economics of land evaluation should not be confused with project cost:benefit analysis. In land evaluation, economic analysis is applied to individual combinations of land utilization type with land unit. The results provide considerable source material for project analysis, particularly in supplying the management specifications, and thus the need for inputs of labour, materials and capital, for each combination of land use with land. By giving ranges of error, e.g. for annual rainfall, or predicted forest yields, they can also supply limits for sensitivity analysis based on this source of uncertainty. In project analysis, the results of economic land evaluation are aggregated, and are then subject to analysis in various other terms which lie beyond the scope of land evaluation.

An immediate problem that arises is that the results of economic analysis of the same set of physical conditions can vary substantially. Among the main sources of such variation are changes with time between the relative prices of inputs and outputs; the manner in which intangible costs and benefits are taken into account; whether multiplier effects are to be considered; whether the analysis is carried out in financial or economic terms; and the percentage rate assumed for discounting.

Economic techniques applied to land evaluation cannot escape these causes of variation, with the result that the same physical limitations, for example, poor drainage, may have substantially different economic consequences according to the underlying assumptions. The position is more intractable for cases of forestry than for agriculture. For agricultural production of annual crops, a solution is to adopt gross margin analysis as the basis for economic land evaluation, giving comparative data independent of the discount rate. The highly uneven flow of costs and benefits in forestry, with its high early establishment costs and the greater part of the revenue at the time of future harvest, makes this solution unavailable.

The recommended procedure is to take a single set of economic assumptions as a basis in the first instance, and to carry out analysis of all land utilization type/land unit combinations on that basis. These assumptions must be clearly stated when presenting the results of the evaluation, since not only are the absolute measures of economic value dependent on the assumptions, but, in some cases, also the relative economic effects of different land qualities will be altered. At a later stage, the economic land evaluation may be recalculated on a different set of assumptions, particularly if this is necessary to accord with the assumptions adopted in the corresponding project evaluation.

For further discussion of the assumptions underlying economic analysis of forestry projects and details of techniques, reference may be made to Gregersen and Contreras (1979). Case studies with examples of calculations are given in FAO (1979), and techniques for economic analysis of community forestry in Shaikh (n.d.). Problems arising in the economic aspects of conservation are discussed in FAO (1981b).

10.2.2 Data requirements for economic analysis

Data collection for economic analysis proceeds concurrently with natural resource surveys. If the land evaluation is being conducted as part of a wider study, e.g. for project feasibility, then part of the basic economic data is common to the project as a whole. This common data includes markets and prices for products, and availability and costs of inputs of materials and labour.

The specific economic data requirements for land evaluation are the effects of variations in land qualities upon both inputs (quantities and costs) and outputs (quantities and revenue). The data can be obtained either for the effects of indivual land qualities or, in some cases, directly for land units.

For the case of outputs, relatively accurate data may be available in two circumstances:

i. For wood production from natural forests, where output data are based on forest inventory.

ii. Where site index values, or other comparable yield estimates are available for land units.

Information on relative costs of inputs may be harder to obtain. For example, it is certain that roading and harvesting costs will be substantially higher on steeply sloping land, but specific data may be difficult to find. The means for translating effects of land qualities into input costs lies in the detailed management specifications for land utilization types. These must be expressed in terms permitting conversion into costs, e.g. as hours of labour and of use for machinery, quantities of seedlings, fertilizers, pesticides, etc. Examples of the effects of terrain on use of logging machinery are given by Berg (1981). For a basis for assessment of logging costs, see FAO (1978a).

Unless reliable data on the effects of land qualities upon costs and benefits can be obtained, detailed economic analysis of land use systems should not be attempted, as the results would give a misleading impression of accuracy.

10.2.3 Calculation of land suitability in economic terms

The sequence of steps for calculating land suitability in economic terms for a single land use system - combination of land utilization type with land unit - is as follows:

i. Decide on the set of economic assumptions to be used as the basis for calculation; these include financial or economic basis, costs and prices to be used, discount rate, and which measures of value are to be employed for comparison.

ii. Select the land use system to be analyzed. If there is land classed as S1, Highly Suitable, for the land utilization type under consideration, this may be taken as a standard for comparison.

iii. For the selected land use system, estimate the quantities and costs of inputs, capital and recurrent, and their distribution in time; and similarly for the quantities and value of outputs or benefits.

iv. Obtain the chosen measures of economic value for the land use system.

The next stage is to repeat these calculations, on an identical basis, for the same land utilization type on other types of land. For this purpose, the original land units are aggregated into land suitability subclasses, or where distinguished, land suitability units.

Where subclasses are the lowest category employed, calculation is carried out for each suitability class and subclass represented in the provisional classification, e.g. for S2m, S3m, S2q, S3q, S3mq, etc. Land already classed as N2 is not analyzed. The sequence of steps at this stage is as follows:

v. For the selected suitability subclass (or suitability unit) abstract and summarize the land qualities which may affect inputs or outputs.

vi. Determine the effects of those qualities upon inputs, outputs, or both, in quantitative physical terms and in economic terms.

vii. Repeat the calculation for the chosen measures of economic value for the land use system.

The procedure is illustrated by a simplified example in Table 10.1. The example taken is that of a softwood plantation, thinned after ten years and harvested at twenty years. Costs have been generalized into those of initial land preparation, forest establishment, maintenance, and harvesting. Table 10.1(a) shows the data for S1 land. For the assumed discount rate of 5 percent there is a net present value of 783 currency units and a benefit:cost ratio of 1.24.

Three examples of land with lower suitability are considered, with the results summarized in Table 10.1(b).

S3w Poor drainage The land in its present condition is too poorly drained for satisfactory tree growth. This limitation can be met by a land improvement, the construction and maintenance of a set of drainage works. Estimated costs are 500 currency units for initial construction and 20 units per year for maintenance, raising total maintenance costs from 100 to 120 units per year.

S3q Adverse conditions for mechanization Sloping and dissected terrain causes maintenance costs (e.g. of forest roads) to rise by 50 units per year, and doubles harvesting costs. Yield is assumed to be unaffected.

S3r Poor rooting conditions Shallow soils are estimated to reduce rates of tree growth by 0.75 (for simplicity, harvesting of a lower volume but at the same date is assumed). Harvesting costs are reduced slightly less than proportionately, by 0.8.

The results of analysis at the 5 percent discount rate are shown in Table 10.1(b). The effects of poor drainage and those of shallow soils, the former affecting inputs and the latter outputs, are very similar, both reducing the net present value to close to zero. The area with sloping terrain is substantially less favourable on the basis of these economic assumptions.

Table 10.1 Effects of land limitations on economic analysis of a forest plantation. All values are in currency units

(a) Calculation for S1, Highly suitable, land

	Years							
	0	1	2	3-9	10	11-19	20	NPV at 5%
BENEFITS								
Thinning & harvest	0	0	0	0	1 700	0	8 000	4 060
COSTS								
Land preparation	500	0	0	0	0	0	0	
Establishment	400	200	100	0	0	0	0	
Maintenance	100	100	100	100 p.a.	100	100 p.a.	100	
Harvesting	0	0	0	0	300	0	1 500	
Total costs	1 000	300	200	100 p.a.	400	100 p.a.	1 600	3 277
Net benefits	1 000	(300)	(200)	(100)p.a.	1 300	(100)p.a.	6 400	783
					Benefit: cost ratio = 1.24			

(b) Other land suitability subclasses

Suitability subclass	Land limitation	Effect on costs, benefits	At 5% discount NPV	B:C
S1	None	-	783	1.24
S3w	Poor drainage	Land preparation + 500 Maintenance + 20 p.a.	34	1.01
S3q	Adverse conditions for mechanization	Harvesting x 2.0 Maintenance + 50 p.a.	-406	0.91
S3r	Poor rooting conditions	Yields x 0.75 Harvesting x 0.8	-44	0.99

The relative effects of different land qualities may be altered under changed economic assumptions. In the example above, the results of a ten percent discount rate are:

Suitability subclass	NPV	B:C ratio
S1	-607	0.76
S3w	-1 277	0.59
S3q	-1 165	0.61
S3r	-987	0.58

The relative disadvantage of the sloping terrain as compared with poor drainage and shallow soils has virtually disappeared, all three types of land giving closely similar measures of economic value. This illustrates an inherent difficulty of assessing land suitability in economic terms.

10.2.4 Economic land suitability classification

An economic land suitability classification is one in which the boundaries between suitability classes are defined in economic terms. There is no standard method for defining class limits, other than the requirement that the S3/N1 limit should lie at the lower limit of positive economic return. One possible procedure (derived from that of the U.S. Bureau of Reclamation for Irrigation Investigations) is as follows:

i. For a given land utilization type, take the best possible land qualities present in the area, and calculate the economic return. This forms an upper limit. Suppose this to be, as in the example in Table 10.1, a net present value of 780 currency units.

ii. The range between the best economic return and zero return is divided into three equal parts, taken as the economic returns corresponding to S1, S2 and S3. In the example cited, these ranges would be S1: 520-780 (or over 520), S2: 260-520, and S3: 0-260. Land yielding a negative economic return is classified as N1. Land classed as N2 during the earlier stage of matching is not subjected to economic analysis and remains as N2.

In the example in the previous section, if it were decided to take five percent as the discount rate and present value as the measure for economic suitability classification, the cases given would be reclassified as follows:

Provisional (qualitative) land suitability class	Net present value under stated assumptions	Economic land suitability class
S1	783	S1
S3w	34	S3w
S3q	-406	N1q
S3r	-44	N1r

Economic suitability classification should be applied only to land use systems assessed as suitable on environmental and social grounds.

There are both advantages and disadvantages in using an economic as compared with a qualitative land suitability classification. Investment decisions invariably call for economic analysis of alternatives and the results of land evaluation will not carry adequate weight unless such information can be provided. An economic suitability classification, however, has a relatively short time validity, being rendered obsolete by changes in relative costs and prices, or changes in assumptions on interest rates.

Qualitative suitability classifications have a longer time validity, being based to a greater extent on natural potential and limitations of the environment. This is particularly valuable in forestry, where today's decisions will usually have to hold good in very different economic conditions of 20 years or more ahead. Qualitative classifications also allow the various aspects of suitability, such as productive output, fulfilment of local needs, and conservation, to be more fully integrated in a subjective manner.

The applicability of economic land suitability classification to forestry is limited. Considerable problems arise in comparing land utilization types which have different time scales for costs and benefits. It may be employed in production forestry in cases where the objectives and assumptions of the evaluation are that the proposed forest land use is expected to yield an economic return.

10.3 Social analysis

10.3.1 General

At all levels of intensity, analysis is not confined to production-oriented objectives nor to return on capital invested. Changes in land use have consequences for other national or local objectives, such as employment, reduction in numbers of landless people, regional development, or changes in income distribution between sectors of the community. Consideration of these consequences forms part of the evaluation process and is incorporated in the suitability classification.

Forest lands form part of the way of life of local communities. There may be gathering of fuelwood, fruit or roots, hunting, fishing, grazing of livestock or the traditional use for shifting cultivation. Forests may also have a role in non-economic needs, for example, religious functions, the social element of hunting, or recreational use.

In the past, some forests have been maintained or developed without relation to the people living in the area, or even in opposition to their wishes. Some more recent development studies pay lip service to the need to take account of social effects, but conduct such studies in a superficial manner, without adequate objectives or procedures.

The modern approach to the role of forestry requires that the people and social aspects are considered as the essential and as an independent element of land evaluation, and not merely as an adjunct or constraint (cf. Becket, 1983). Unless the people concerned are involved and participate in the inception, evaluation and decisions on land use, even the best of the land use options made purely on technical and economic grounds, are doomed to failure.

Prerequisites for adequate consideration of social aspects are:

i. Information required To decide the kinds of information needed to assess social consequences.

ii. Procedures To organize and conduct the necessary field activities.

Finance To allocate adequate staff and budget for this purpose.

10.3.2 Social aspects of forest land use

The main types of information needed to assess the social consequences of changes in forest land use (including changes between forest and non-forest uses) are:

i. Present needs and functions What role does the existing forest land have in supplying the present needs of local (including migratory) communities? Examples are needs for fuelwood, domestic timber, fruits, roots, medicines, grazing, hunting, fishing, shifting cultivation, religious or social functions, burial grounds.

ii. Future demands What future changes in needs are anticipated? Examples are increasing demands for fuelwood, grazing land.

iii. Institutional rights What legal or customary rights to the use of forest land exist? What are the possibilities, if any, of changing these?

iv. Effects of land use changes How will proposed land use changes affect these present and future needs and functions? Where a loss is unavoidable, what alternative measures can be taken to provide for the needs?

v. Acceptability Will the proposed changes be acceptable to, or adoptable by, the local communities?

Of the various aspects, the most important will often be the use of land for fuelwood collection or grazing. In the past, when forest land was abundant relative to population, use for these purposes came as an apparent bonus, a supply of essential needs with no inputs other than the labour of collection or herding; at the same time, the natural ecological balance was maintained. With increasing population, this balance has often been disturbed - are positive measures for land management necessary?

As an example, consider a situation in which it is proposed to increase forest productivity by the establishment of softwood plantations in an area presently under slow-growing indigenous hardwoods. The natural vegetation has previously supplied local fuelwood needs, although it is now in a degraded condition through over exploitation. Imposition of the proposed plantations will deprive communities of part of this supply and increase the pressure on remaining land. Possible measures to mitigate this impact might include:

i. Allocation of part of the new plantation land specifically to fuelwood production, with higher productivity through choice of fast growing species.

ii. Provision for local collection of prunings, early thinnings, sawmill waste.

iii. Concomitant establishment of on-farm forestry, with provision of seedlings and extension advice.

iv. Phased establishment of the plantations, to carry over the transition period.

In the case where there is grazing use of forest land it may be possible to maintain equivalent provision by including appropriate management measures. A system of cut-and-carry fodder can be initiated, or by means of fenced forest blocks, controlled grazing can be permitted once trees are sufficiently mature.

10.3.3 Methods of social data collection

The procedures for social analysis are less formalized than in most other components of land evaluation, requiring greater adaptation to local circumstances. What is essential is that there should be a set of field survey activities directed towards this aim. A broad outline which may serve as the basis for such activities is as follows:

i. Identification of communities These will include peoples resident in the study area, possibly divided into different ethnic or cultural groups; and others with partial dependence on such land, including migratory peoples.

ii. Unstructured interviews These consist of free discussion with community leaders and local people in the identified groups, the aim being to ascertain in a general way their needs, aspirations and attitudes to proposed land use changes.

iii. Structured questionnaire Based on the results from Step ii, a questionnaire is drawn up aimed at assessing the nature, strength and extent of the various aspects. Some measure of controlled stratification of these interviews is desirable to avoid biased sampling.

iv. Analysis for data The questionnaire results are tabulated and reviewed, to produce a summary of the present situation and attitude to change.

v. Design As part of the process of elaboration of land utilization types, appropriate measures to take account of social aspects are incorporated.

vi. Acceptability When the nature, extent and location of possible land use changes have been assessed, e.g. the land provisionally classified as most suitable for proposed uses is known, these proposals are explained to the communities affected to test whether they will be acceptable.

10.3.4 Assessment of social consequences of land use alternatives

Treatment of the social consequences of different courses of action in land use and management is necessarily flexible. Some of the data will be in qualitative form, and the consequences of change may be hard to predict except as to direction or trend. Every effort should be made, however, to obtain estimates in quantitative form, e.g. amount of employment provided, number of families, displaced, etc.

The criteria for what is a desirable and what an undesirable social impact are not all as self-evident as in the case of environmental impact. Such criteria must be discussed both with the relevant government agencies and with the people affected by land use changes. For example, some governments may give greater priority to more equable income distibution, others to greater total income.

A possible approach to assess social consequences is by means of a table similar to that illustrated for environmental impact (cf. Table 9.1 p.88). Criteria for social evaluation are listed, together with their present status. For each alternative form of land use, probable effects upon that status are assessed, either quantitatively (e.g. gain or loss in employment) or on a relative scale of +3 through 0 (no effect) to -3. Possible criteria on which to base such an assessment include:

- total income
- income distribution (equity)
- employment/reduction in unemployment or under-employment
- displacement of existing settlements
- gain or loss of land (to individuals or communities)
- loss to the poorest of benefits formerly gained from free use of forest land (grazing, fuelwood collection, thatching materials, etc.)
- effects on minority or under-privileged groups
- community participation in forestry activities.

Such an evaluation can be integrated into an overall rating of the social consequences of alternative changes in land use or management, again on a relative scale.

CHAPTER 11

LAND SUITABILITY CLASSIFICATION

CHAPTER 11

LAND SUITABILITY CLASSIFICATION

11.1 General

The provisional land suitability classification, obtained through the matching procedure, is based upon comparison of land use requirements with land qualities in physical terms. The final stage in comparison of land use with land is to revise this classification, taking account of the further stages in comparison: environmental impact, economic and social analysis. This leads to the final land suitability classification, based on all relevant physical, environmental, economic and social aspects.

Provisional suitabilities can be revised both upwards and downwards on the basis of the further stages in comparison. A basic criterion is that no land should be classed as Suitable for a given use unless both the environmental impact and the social consequences of that use are acceptable. Specific grounds for acceptability or non-acceptability may be defined to meet local circumstances. If specified in the assumptions of the evaluation, land classed as Suitable must also show a positive economic return.

There are no standard procedures for such revision. Two alternatives are suggested: successive elimination and relative comparison.

11.2 Successive elimination

In the procedure of successive elimination, a land use system is relegated to the suitability order Not Suitable if it fails to meet some defined threshold of acceptability on any one basis. Such elimination has, in fact, commenced at the stage of matching, in that systems provisionally assessed as N2 are not further considered. The remaining combinations of land utilization type with land unit are considered in turn, on the basis of results of environmental, economic and social analysis, each of which has been summarised by a statement of whether the system reaches an acceptable level. Denoting acceptability and non-acceptability by ✓ and X respectively, some examples are:

Land use system	Provisional land suitability class	Acceptability			Revised land suitability class
		Environmental	Economic	Social	
1-A	S2	✓	✓	✓	S2
1-D	N2	-	-	-	N
2-A	S3	X	-	-	N
2-B	S2	✓	✓	X	N

Land use system 1-A (i.e. land utilization type A on land unit 1) is acceptable on all grounds. System 2-A is lowered from S3 to N through unacceptable environmental impact, and system 2A is lowered from S3 to N through unacceptable environmental impact, and system 2-B, whilst physically, environmentally, and economically attractive, is revised to class N through unacceptable social consequences (e.g. large scale displacement of population).

Where economic suitability classification has been carried out, the environmental and social consequences are first treated on an acceptability basis. The remaining systems, acceptable on both grounds, are then revised to the economic suitability class.

11.3 Relative comparison

The procedure of relative comparison is illustrated in Table 11.1. The results of each of the further stages of comparison are converted to a scale from +3, highly favourable through 0, no effect, to -3, highly unfavourable or unacceptable. These are then compared with the provisional land suitability classes. At this stage a subjective revision is probably the most suitable, coupled with the rule that a single rating of -3 should lead to an overall assessment of N, Not suitable.

In the hypothetical examples in Table 11.1 land systems 1-A (Land Unit 1 with Land Utilization Type A) and 1-B have been left unchanged; 1-A has only slight other consequences, whilst economic analysis confirms the high suitability of 1-B. System 1-C is raised from S2 to S1 on grounds of its very favourable social consequences. The provisional suitabilities of 2-A and 2-B, however, are revised to Not suitable, the former on grounds of adverse environmental impact and the latter from undesirable social consequences. Land systems provisionally classified as N, in this case 1-D and 2-D, are not assessed further.

Table 11.1 Format for comparison of environmental, economic and social consequences of alternative land use systems

Land unit	Land utilization type	Land use system	Provisional land suitability class	Relative consequences: Environmental	Relative consequences: Economic	Relative consequences: Social	Revised land suitability class
1	A	1-A	S2	-1	+1	+1	S2
	B	1-B	S1	0	+3	+1	S1
	C	1-C	S2	+1	+2	+3	S1
	D	1-D	N2		———		N2
2	A	2-A	S3	-3	+1	0	N2
	B	2-B	S2	0	+1	-3	N2
	C	2-C	S1	-3	0	0	S1
	D	2-D	S3	0	-1	0	N1

11.4 Discussion

The successive elimination procedure is based on a simple 'hurdle' or accept/reject approach. Its use directs attention at clear definition of the consequences to be regarded as unacceptable, and provides a clear-cut reject of any land use alternatives that fail to meet these standards.

The relative comparison allows environmental, economic and social consequences to be summarized on a more refined relative scale, and allows an overview of the total consequences of different kinds. This can be helpful in offering a choice for subsequent decision-making; the comparison in the form of Table 11.1 is presented as part of the results, allowing decisions on the relative importance of different objectives to be reviewed in the light of the evaluation.

Whichever procedure is followed, the results of the evaluation should contain clear statements of the grounds on which the final suitability classes were based.

11.5 Relation of local changes to the wider context

There is a further aspect in which the suitability recommendations should be reviewed, the consequences of land use changes in a local area for the wider region of which they form a part. Such a review is an integral part of watershed management planning, in which interrelationships between land use components form a basic element of planning. Many other aspects should be considered. For example, if the finding within the area covered by the evaluation is that substantial areas of forest are suitable for conversion to agriculture, what effects would planning on that basis have on the national position with respect to land use, supplies of forest products, etc.? Just as, at the start of the evaluation, the wider context will have contributed to the objectives of the evaluation, so its results will have implications in modifying the balance of land use, production, employment, etc., in that wider area.

It is not suggested that land suitability classes as such should be altered on the basis of such considerations. The review of wider implications is an adjunct to the evaluation, to be taken into account in subsequent decisions on land use planning.

CHAPTER 12

PRESENTATION OF RESULTS

CHAPTER 12

PRESENTATION OF RESULTS

12.1 General

The results of a land evaluation should be clearly stated, in a form understandable by those for whom it is intended. The purpose of an evaluation is to provide information on which to base decisions on land use planning and land management, and the results should be presented in a way which will facilitate such use. The main report should concentrate on a clear statement of the findings; reasons for decisions reached are given, but much of the detail which underlay the analysis should be summarized or placed on record in supplementary reports or appendices.

The principal results from a land evaluation survey are:

i. A statement of recommendations, such as are called for in the objectives of the survey.

ii. Descriptions of land utilization types relevant to the surveyed area.

iii. Land suitabilities of each of the mapped land units for each land utilization type, together with reasons for the assessment.

iv. Management specifications for land utilization types on each of the land units for which they are suitable.

v. An estimate of the environmental impact of each land utilization type on each land unit; this may include reasons why certain land units have been assessed as not suitable for particular uses on grounds of adverse environmental impact.

vi. Predictions of the economic and social consequences of operating each land utilization type on each land unit for which it is suitable; in more detailed surveys this may include comparative economic returns.

vii. In cases where basic resource surveys and specialized studies (landforms, climate, soils, vegetation, forest mensuration, etc.) were conducted as part of the evaluation, the results from these surveys form a further element.

The results are presented in the form of one or more maps, together with a main report and possibly also other derived publications.

12.2 Land suitability maps

Land suitability maps are used more than their associated reports and the legends should be understandable independent of the report. Land suitability maps may be presented in three ways:

i. A single map with a tabular legend.

ii. A series of suitability maps, one for each kind of land use.

iii. A summary map.

Map with tabular legend One large map is printed at the basic, or largest, scale of the survey. This map shows boundaries of land units, numbered and named. The legend shows land suitabilities of these units for each of the land utilization types. An example of the basic form of the legend is given in Table 12.1.

Individual suitability maps A map is produced for each of the land utilization types, showing the distributions of different suitability classes and subclasses. The general form is that shown in Figure 2. 3 (p.20). These maps are usually on a smaller scale, often half that of the basic map (e.g. at 1:50 000 if the basic scale of the survey is 1:25 000). The visual effect of suitability maps is increased if colour shading is used, with solid colour for S1 land, less intense shadings for S2 and S3, and with N1 and N2 land left unshaded.

Table 12.1 Example of tabular legend to a land suitability map

Land unit	Area ha	A: Large-scale softwood plantations, mechanized — A1 Species Group I	A: Large-scale softwood plantations, mechanized — A2 Species Group II	B: Small-scale community fuelwood plantations	C: Watershed protection forest
1. Sinkedi Hills steeplands	3 200	N2e	N2e	N2e	S1c
2. Sinkedi Hills foothills	1 450	S2q	S3qt	N21	S2c
3. Juvenis Plateau	800	S1	S2t	N21	NR
4. Purnela Plains pediment zone	2 400	S2t	S1	S1	NR
5. Purnela Plains hill remnants	650	N2q	N2q	S1	NR

Land suitability subclass symbols: c = need for conservation, e = erosion hazard, l = location, q = conditions for mechanization, t = temperature regime. Species Groups I and II refer to tree species groups according to their climatic requirements.

Summary map In complex surveys covering many land utilization types, it may aid presentation to produce a simplified summary map, showing the recommended use for each land unit. If two or more alternatives are both recommended for consideration in some areas, both can be shown. However, the aim of the summary map is to show the main results clearly for those who have no time to study the more detailed maps, so simple and clear cartographic techniques are the priority. Such a map might be called 'Forestry development potential' or a similar title.

12.3 The land evaluation report

The report should normally contain three parts, directed at different readers.

i. The summary and recommendations are directed at senior personnel, who need to know how the results of the evaluation affect planning and policy, but do not have time or technical knowledge to study its details. It is short and clear, with emphasis on results and recommendations. Major reasons for recommendations are included but not in any detail (e.g. 'the Sinkedi Hills are not recommended for community fuelwood plantations because of inaccessibility'). Where appropriate, this section is given in more than one language.

ii. The main text is directed at a wider readership, particularly foresters who will be concerned with implementing its recommendations. Whilst technical in content, it should be possible to obtain the material relevant to forest planning and management without too lengthy diversions into matter not necessary for an understanding of the results.

iii. The appendices are directed at specialist readers who need to know the technical details of methods used. They include basic data which could be used to assess the soundness of the recommendations, or to revise the evaluation if necessary at some future date.

Depending on their length, these three parts may be produced as separate volumes or as parts of a single report. A specimen outline of contents is given in Table 12.2.

In addition, it may help to gain acceptance of the results if one or more derived publications are produced. These could include either or both the following:

i. Summary report This is a well produced, shortened version of the main report, intended for circulation among policy-makers and planners. Besides the summary and recommendations it contains a considerably shortened version of the main text, illustrated by summary tables and simplified maps.

ii. Management or Extension Recommendations This sets out those findings of the evaluation which relate to practical aspects of forest management or extension. It concentrates on how the different land units call for variations in methods of forest management. An example might be 'A guide to forest management in Abuna Province'. It is written in terms appropriate to this readership, where necessary in a local language.

Table 12.2 Specimen outline of contents for a land evaluation report

Preface

Summary of results and recommendations

1. Objectives of the survey
   Needs, problems, policy, etc.

2. Background of the area
   Physical environment
   Human environment

3. Methods of survey and specialized studies

4. Land utilization types
   General account, including summary tables
   Descriptions of each type:
   LUT A ....
   LUT B ....
   LUT C ...., etc.

5. Land use requirements
   Land use requirements, selection
   Land qualities and diagnostic factors
   Methods of factor rating
   Summary of factor ratings for land utilization types (tables)

6. Land units
   General account, including summary tables
   Summary of measurements of forest volume, growth and yield
   Descriptions of each land unit:
   LU 1 ....
   LU 2 ....
   LU 3 ...., etc.
   Land qualities and characteristics of land units (tables)

7. Matching land use with land
   Matching procedures and results
   Provisional land suitability classification

8. Environmental impact
   Methods of assessment
   Summary of impacts
   Implications for land suitability

9. Economic and social analysis
   Economic analysis of land use systems
   Social impact of proposed land use changes
   (In evaluations employing economic suitability classification, economic analysis and social impact will form separate chapters)

10. Land suitability
    Results of the suitability classification
    Recommended land use systems (including alternatives)
    Management specifications (or as appendix)
    Estimated outputs: products and other benefits

Appendices (in a large survey as a separate volume)
   e.g. Agroclimatic data and analysis
   Landform and soils data and analysis
   Specialized studies of forest resources
   Detailed management specifications for LUTs on LUs
   Supplementary tables

Glossary

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12.4 Using the results

12.4.1 Land use planning

On completion of a land evaluation survey, the results will have contributed to meeting a specific set of objectives in forest planning and development. These range from the setting of policy guidelines or priorities, through proposed changes between forest and non-forest uses of land, to improvements in forest management. The evaluation makes a major contribution to these objectives, but does not alone constitute a plan for forest development or management. Unless the results are put to use, the effort put into the survey will have been wasted.

These present guidelines are not intended as a manual on land use planning, development or management. Practical steps of this nature require substantial further studies, either subsequent to the evaluation or within the wider survey of which it forms an integral part. There is, however, a responsibility for the organization conducting a land evaluation survey to make every effort to ensure that the results are put to use, in policy formulation or practical forestry development.

12.4.2 Monitoring

Land development is not a once only activity of survey and planning but an ongoing process. This applies to all kinds of land use development, but is particularly relevant to forestry owing to its long-term nature. This situation calls for monitoring of the land use changes, with periodic modifications. Over the time scale of forest growth there will be variations in costs and prices, or unforeseen changes in demand. Some of the original predictions may prove inaccurate; a feedback of information can lead to better forest land evaluation in the future. The environmental impact needs to be continuously monitored, both in a general way and by specific surveys of sediment yields, species abundance, etc. Finally, there will be changes in policy, especially as a result of new demands upon land. All such changes call for re-evaluation of the land resources, leading to modifications to the earlier plans for development.

GLOSSARY

Note: Most of the terms are based on the "Framework for land evaluation" (FAO, 1976), in some cases modified. The definitions of factor rating and land suitability rating, terms not employed in the "Framework", are taken from FAO (1983a). The following definitions are based on Ford-Robertson (1971): forest, forest land, multiple-use forestry, site, site class, site index, site quality.

cf. = compare

q.v. = see term elsewhere in this Glossary.

AGROFORESTRY : a collective term for systems of land use in which woody perennials (trees and shrubs) are intentionally maintained in association with crops and/or livestock; in agroforestry systems there is both an ecological and an economic interaction between the tree and non-tree components.

BENEFIT:COST RATIO: the present value of benefits divided by the present value of costs.

COMPOUND LAND UTILIZATION TYPE: a land utilization type consisting of more than one kind of use or purpose, either undertaken in regular succession on the same land, or simultaneously undertaken on separate areas of land, which for purposes of evaluation are treated as a single unit (cf. multiple land utilization type).

CONDITIONALLY SUITABLE: a phase of the land suitability order Suitable, employed in circumstances where small areas of land within the survey are unsuitable or poorly suitable for a particular use under the management specified for that use, but suitable given that certain other land improvements or management practices are employed.

CONSERVATION REQUIREMENTS: the land use requirements (q.v.) largely or entirely related to conservation and sustained use (q.v.).

CRITICAL VALUE: a value of a diagnostic factor (q.v.) which forms the boundary between classes of land suitability rating (q.v.).

DIAGNOSTIC FACTOR: a variable, which may be a land quality, a land characteristic, or a function of several land characteristics, that has an understood influence on the output from, or the required inputs to, a specified kind of land use, and which serves as a basis for assessing the suitability of a given type of land for that use. For every diagnostic factor there will be a critical value (q.v.) or set of critical values which are used to define limits of classes of factor ratings (q.v.).

ECONOMIC LAND SUITABILITY CLASSIFICATION: a land suitability classification in which the boundaries between classes are expressed, at least in part, in economic terms.

FACTOR RATING : a set of critical values (q.v.) which indicate how well a land use requirement is satisfied by a particular condition of the corresponding land quality. (Note: suitability rating refers to the land use requirement; when this rating is combined with the value of a land quality possessed by a given land unit, it becomes a land suitability rating, q.v.).

FOREST (1) (Ecology): an ecosystem characterized by a more or less dense and extensive tree cover; more particularly, a plant community consisting predominantly of trees and other woody vegetation, growing more or less closely together, normally with at least 10 percent crown cover by trees.

(2) (Silviculture/management): an area managed for the production of timber and other forest products and/or maintained under woody vegetation for indirect benefits such as protection of catchment areas or recreation.

(3) (Law) : an area of land proclaimed to be forest under a forest act or ordinance.

FOREST LAND: (1)(Silviculture/management): land carrying forest (q.v.) or, if lacking, bearing evidence of former forest and not now in other use.

(2) (Law): land that has been legally designated as forest land.

FOREST LAND UTILIZATION TYPE: a land utilization type (q.v.) based on forest (q.v.).

FOREST PLANTATION : forest stands established artificially by afforestation, on land which previously did not carry forest, or on land which carried forest within the past 50 years, or within living memory and involving the replacement of the previous crop by a new and essentially different crop (Lanly, 1982, page 15).

GROWTH REQUIREMENTS: the land use requirements (q.v.) specifically related to the growth of trees and shrubs.

INPUTS : the material inputs (e.g. seed, fertilizers, fuel, chemical sprays) and other inputs (e.g. labour hours) applied to the use of land (cf. outputs).

LAND : an 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 ecology, the hydrology, 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: a system for classifying land which is based on its capacity to support agriculture, grazing, forestry or recreational/conservation use. The system is concerned with the fitness of land to support land use, rather than with productivity, and places emphasis on the risk of soil erosion.

LAND CHARACTERISTIC : an attribute of land that can be measured or estimated and which can be employed as a means of describing land qualities or distinguishing between land units of differing suitabilities for use.

LAND CLASSIFICATION : a means employed here to refer to systems of grouping land (q.v.) on the basis of its physical characteristics (including vegetation) without explicit assessment of suitability for kinds of land use. (Not a technical term in land evaluation).

LAND EVALUATION : the process of assessment of land performance when used for specified purposes, involving the execution and 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 FACET : a land unit (q.v.) with climate, landforms, soils and vegetation characteristics which for most practical purposes may be considered as uniform. A subdivision of a land system (q.v.).

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

LAND MAPPING UNIT : see land unit.

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

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 recognized:

Land suitability order: a grouping of land according to whether it is Suitable or Not Suitable for a specified kind of use.

Land suitability class: a subdivision of a land suitability order serving to distinguish types of land which differ in degree of suitability.

Land suitability subclass: a subdivision of a land suitability class serving to distinguish types of land having the same degree of suitability, but differing in the nature of the limitations which determine the suitability class.

Land suitability unit: a subdivision of a land suitability subclass serving to distinguish types of land having minor differences in management or improvement requirements.

LAND SUITABILITY CLASSIFICATION: an appraisal and grouping, or the process of appraisal and grouping, of specific types of land in terms of their absolute or relative suitability for a specified kind of use.

LAND SUITABILITY RATING: the partial suitability of a land unit for a land utilization type, based on one land quality or a partial set of land qualities. Land suitability ratings are combined to give a land suitability class (cf. note on factor rating).

LAND SYSTEM : a land unit (q.v.) with relatively uniform climate and with a repeating pattern of landforms, soils and vegetation. A land system may be divided into land facets (q.v.).

LAND UNIT : an area of land possessing specified land qualities and land characteristics, which can be demarcated on a map and which is employed as a basis in land evaluation. Land units may have various degrees of homogeneity, according to the scale of survey. Note: In FAO (1978) this was termed a 'land mapping unit'.

LAND USE : a phrase employed in a general sense to refer to any form of use of land by man, in contexts which do not necessarily carry the technical connotation of land utilization type. (q.v.).

LAND USE SYSTEM : a specified land utilization type practised on a given land unit and associated with inputs and outputs. (See Figure 2.3).

LAND USE REQUIREMENT : the conditions of land necessary or desirable for the successful and sustained practice of a given land utilization type (cf. growth requirements, management requirements, conservation requirements).

LAND UTILIZATION TYPE : a kind of land use described or defined in a degree of detail greater than that of a major kind of land use (q.v.). A land utilization type consists of a set of technical specifications in a given physical economic and social setting (cf. forest land utilization type).

LIMITATION : a land quality or land characteristic which adverse adversely affects the potential of land for a specific kind of use.

MAJOR KIND OF LAND USE : a major subdivision of rural land use, such as rainfed agriculture, forestry based on natural forests, forest plantations, grazing, irrigated land use.

MANAGEMENT REQUIREMENTS: the land use requirements (q.v.) largely or entirely related to management of a land utilization type.

MATCHING : this term is employed in two senses, broader (i) and restricted (ii):

(i) The process of mutual adaptation and adjustment of the descriptions of land utilization types and the increasingly known land qualities.

(ii) The (specific) process of comparing land use requirements with the land qualities of land units

MULTIPLE LAND UTILIZATION TYPE : a land utilization type consisting of more than one kind of use or purpose simultaneously undertaken on the same land, each with its own inputs, requirements and outputs.

MULTIPLE USE FORESTRY (= multipurpose forestry): any practice of forestry which fulfils two or more objects of management, whether products, services or other benefits.

NET PRESENT VALUE : the present value of benefits minus the present value of costs.

OUTPUTS : the products (e.g. wood products), services (e.g. recreational facilities) and other benefits (e.g. wildlife conservation) resulting from the use of land.

PARALLEL APPROACH: : a land evaluation methodology in which economic criteria are included throughout the process of identifying land use requirements and land suitability classification.

PLANTATION : see forest plantation.

PRODUCTS : see outputs

QUALITATIVE LAND SUITABILITY CLASSIFICATION: a land suitability classification in which the results are expressed in qualitative terms only, without specific estimates of outputs (e.g. timber yields), inputs, or costs and returns. Note: the description 'qualitative' refers to the suitability classification, not to the land evaluation, which is always conducted in quantitative terms as far as possible.

QUANTITATIVE PHYSICAL LAND SUITABILITY CLASSIFICATION: a land suitability classification in which the results are expressed in physical numerical terms (e.g. timber yields, amounts of fertilizer inputs) (cf. economic land suitability classification).

SITE : an area considered in terms of its environment, particularly as this determines the type and quality of the vegetation the area can carry. Sites are classified either qualitatively by their climate, soil and vegetation, into site types, or quantitatively, by their potential wood production, into site classes (q.v.). Sites may constitute the land units (q.v.) employed in a land evaluation.

SITE CLASS (= a site quality class)	: a measure of the relative productive capacity of a site for the crop or stand under study, based e.g. on volume or height (dominant, co-dominant, or mean) or the maximum mean annual increment that is attainable at a given age.
SITE INDEX	: a particular measure of site class, based on the height of the dominant trees in a stand at an arbitrarily chosen age.
SITE QUALITY	: a loosely used term, denoting the relative productivity of a site for a particular tree species.
SUSTAINED USE	: continuing use of land without severe or permanent deterioration in the resources of the land.
TWO STAGE APPROACH	: a land evaluation methodology in which a first approximation of land suitability is made on the basis of physical criteria and in which economic and social analysis is carried out as a second stage on the land use alternatives which appear most promising on the basis of physical evaluation (cf. parallel approach).

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