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SITE SELECTION FOR MULTIPURPOSE TREES

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SITE SELECTION FOR MULTIPURPOSE TREES

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ABSTRACT

As applied to forestry plantations, the method of land evaluation provides answers to the questions: (i) where should trees be planted?; (ii) what species should be chosen?; (iii) what methods of management are necessary to overcome site - specific environmental limitations?; (iv) how does forestry compare with use of the same land for other purposes? Land evaluation consists essentially of comparison between the environmental requirements of different kinds of land use (here multipurpose trees) and properties possessed by different areas of land. Requirements can be grouped into those for tree growth, management and conservation. The results of an evaluation include a mapped land suitability classification, site-specific management recommendations, and estimates of inputs, outputs, environmental impact, social consequences and economic analysis. Research is needed to widen the range of choice of multipurpose species, and to determine their growth requirements, particularly tolerance to adverse conditions. Recommendations for regional research in tropical Asia are: (i) systematic assembly of available data (in conjunction with the ICRAF world survey); (ii) trials along selected environmental gradients; (iii) the recording of all trial sites on a standardized environmental data base.

INTRODUCTION

Objectives

In site selection for the planting of multipurpose trees (MPTs), there are five questions to be answered:

i. Where should the trees be planted?

ii. What species should be planted?

iii. What should be the methods of management?

iv. How does forestry compare with use of the same land for other purposes?

v. Where should trials be located?

All of these are basic questions whenever a forest plantation is established, and have had to be answered for so long as planned afforestation has been in existence. What, then, is distinctive about the choice of site for MPTs? It is not that the sites are partly dictated or constrained by administrative and social considerations or the need to give priority to agriculture; indeed, it has been found on occasion that multipurpose forestry can be economically competitive with agriculture, at least on agriculturally 'marginal' land. The features which distinguish MPT planting from forest plantations intended primarily for timber production are:

(a) The users of the products will often be local communities.

(b) Information on the growth requirements of MPTs is at present less well established than for the better known timber-producing species.

The orientation towards communal management and/or utilization can affect the location and size of areas for planting, and also methods of management. Small farm or village woodlots can be considered, in addition to larger plantations. This is also the reason why Question (i) above was not expressed as "Where should plantations be sited?"; one promising means of increasing production of fuelwood and other tree products in areas of land pressure is through techniques of agroforestry, in many of which the trees are not isolated in blocks but intimately mixed with crops or pastures. However, to avoid repetition of the phrase, "plantations and other tree plantings", the word "plantation" will be taken to include agroforestry designs.

The shortage of reliable information on growth requirements for MPTs forms the main gap in present knowledge,considered in Sections 4 and 5 below.

With regard to the fifth question, the location of trials, the short answer is that trials should be located on sites representative of the range of environmental conditions on which plantations are expected to be sited. Where relevant, the range of social or institutional conditions should also be covered, e.g. both government and community-managed plantations. This applies both to trials established concurrently with plantations, to monitor growth and production, and those established in advance of widespread planting, to test establishment and growth. In the latter case, in order that trial sites

should be representative, survey of the range of potential land for planting should precede selection of trial sites.

The rest of this paper will assume choice of sites for plantations as the basic situation, it being assumed that representative sites for trials will be based on the range of environments of the plantations.

In terms of the outline structure of papers for the Workshop, the remainder of this section together with those on 'Land evaluation' and 'Land evaluation applied to site selection for MPTs' may be called "the state of the art". "Gaps and present knowledge" and "research needed" are then treated jointly in two sections, general and with respect to tropical Asia, whilst "potential applications" are covered in the final section.

Land classification, land capability classification and land evaluation

Various methods of site selection for forestry have been devised, some of which could be adapted to selection for MPTs. Among the basic approaches that have been employed are:

- land classification (descriptive);
- land capability classification;
- the site index method;
- land evaluation.

Mention should also be made of forest inventory, but this technique is applicable to existing stands and so not relevant in the present context.

Land classification is used as a term of convenience to cover methods which group land into a set of descriptive classes, without necessarily implying suitability for future purposes. The classification may be on the basis of the legal status of the forest land, its purpose (wood production, protection, etc.), existing forest type (e.g. montane forests, swamp forests), environmental conditions (e.g. climate, slope, soil, including the land systems approach), or a combination of forest type with environment. Some forest land classifications for Asia were summarized in Carpenter (1981); a summary of the approaches described in this volume is given in Table 1. Many examples of classifications based on forest types in Asia are described in FAO (1983 b).

Systems of land classification can form one basis for land evaluation and site selection, namely the descriptive basis, as exemplified by Davidson (1981) for Papua New Guinea. They do not alone constitute assessments of site suitability for specific purposes, and are thus not land evaluations. However, some studies called "land classification" have in fact been evaluation (e.g. Cooling, 1977, summarized in Botero, 1981, p. 124).

Land capability classification refers to the many adaptations of the system originally devised for the United States (but now largely superceded there). In it, land is grouped into a set of capability classes, ranging from Class I with no limitations for agriculture to Class VIII with very severe limitations (Klingebiel and Montgomery, 1961). In the original version of the system, Classes I-V have a 'capability' for agricultural use, and by implication are to be preferred for that use even though they also have a high capability for forestry. Since Class VIII is limited to aesthetic and conservation purposes, this leaves Classes VI and VII for productive forestry.

Table 1. Approaches to forest land classification in tropical Asia

As reviewed in country papers in Carpenter (1981).

Author	Country	By purpose or legal status	By forest type	By environmental conditions	Land capability classification
Pandey	India	✓			
Kartawinata	Indonesia		✓	✓	✓
Sandy	Indonesia			✓	
Lee	Malaysia		✓		✓
Moss	Malaysia			✓	
Qureshi	Pakistan		✓	✓	✓
Davidson	Papua N.G.		✓	✓	
Revilla	Philippines	✓			
Umali	Philippines	✓	✓		
Wacharakitti	Thailand		✓		

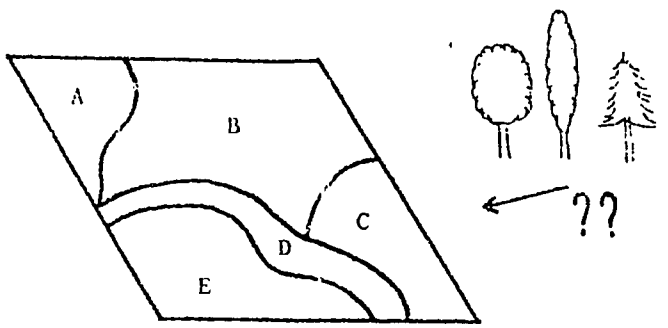
Land capability classification has the merit of simplicity, and is employed at a broad level of planning in a number of Asian countries. However, its implicit assumption that agricultural use is to be preferred wherever possible does not commend the system to foresters, and as a basis for site selection it has been largely superceded by land evaluation.

The site index method is too well known to foresters to require description here. As the site index alone, its application is limited to even-aged stands, frequently based on permanent sample plots. Alternative methods of yield prediction are available for mixed-age stands (Alder, 1980, Chapter 6). The site index and related methods can be combined with growth-site correlation to give a powerful approach to the prediction of forest yield. As such, it is to be preferred as the basic method for yield prediction whenever data are available, being more accurate than the predictions based on site conditions only, such as are common in evaluation for agricultural purposes.

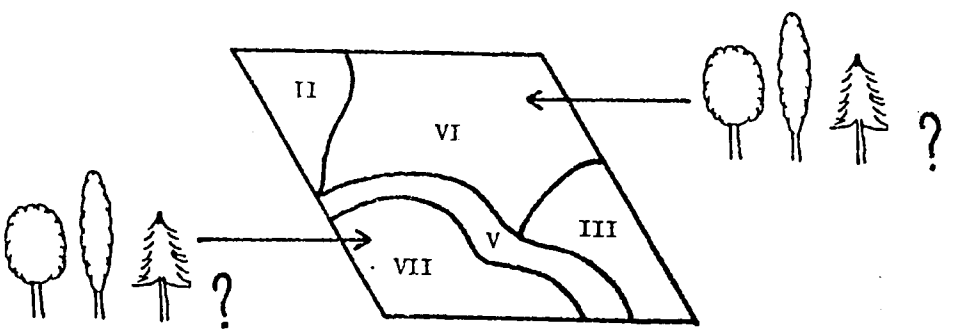
Finally, there is the approach of Land evaluation, based on comparison between requirements of the forest land use and properties of the land. This approach forms the subject of the remainder of this paper. A schematic comparison between the results from descriptive land classification, land capability classification and land evaluation is shown in Figure 1.

Figure 1 Schematic comparison between the results of land classification, land capability classification and land evaluation

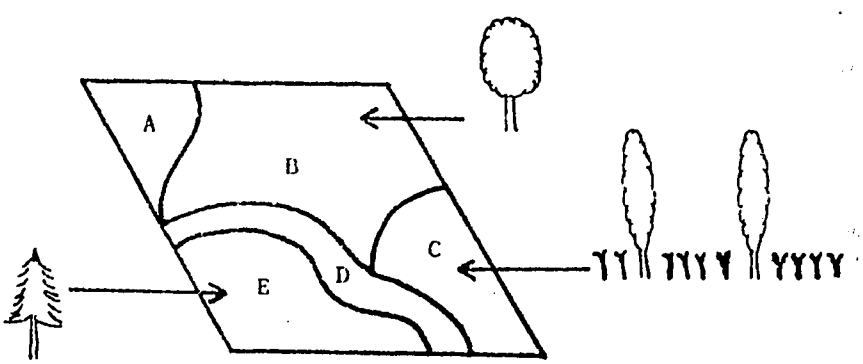
(a) Land classification



(b) Land capability classification



(c) Land evaluation



LAND EVALUATION

What is land evaluation?

Land evaluation is the process of assessment of land performance when used for specified purposes, in order to identify and compare promising kinds of land use. Essentially it is a procedure for comparing land use with land. The kinds of land use that form our present concern are plantations of MPTs, managed primarily for fuelwood production. The term land refers not just to soil but to all factors of the physical environment that can affect suitability for use, including climate, landforms, soils, and pests and diseases.

More precisely, evaluation involves comparison between the requirements of the identified kinds of land use and the properties possessed by different areas of land. For example, the moisture requirements of different tree species are compared with the moisture availability of land units, the requirements for nutrients with nutrient availability, and so on. By such comparison, coupled with other methods of analysis described below, a classification is made of the suitability of each mapped land unit for each defined kind of land use.

A fundamental feature of land evaluation is that as much attention is given to the identification and description of the most promising kinds of land use as is given to the survey of areas of land. It is this feature which distinguishes it from previous approaches, in many of which the land resources were surveyed in some detail but the land use defined in only a highly generalized way. Unless the land use is specified in some detail, it is impossible to make an adequate assessment of its requirements, and so to achieve a satisfactory comparison with the environmental resources.

One consequence is that evaluation requires a multidisciplinary approach. It calls for the expert knowledge of specialists in land use, in this case foresters, and scientists concerned with land resources, such as agroclimatologists and soil surveyors. Moreover, it is not enough for these specialists to carry out their respective tasks in isolation. There must be cooperation and frequent interchange of information between them if the optimum matching between types of forest plantation and land resources is to be achieved.

For further discussion of the approach and principles of land evaluation, reference may be made to FAO (1976) and Dent and Young (1981, Chapters 8, 10 and 11).

The development of methods

The approach and methods of land evaluation grew out of the practical needs and experience of land use planning. This was brought together in the Framework for land evaluation (FAO, 1976), which sets out the approach and principles of land evaluation, defines the terminology and gives an outline of procedures. The Framework is not specific to any form of land use, drawing its examples from agriculture, forestry and livestock production.

Experience in using the Framework, both in field projects and for training, has shown that the general approach stands up remarkably, perhaps unexpectedly, well. Relatively few substantial additions or modifications to the principles, or to the procedures taken in outline, have been found necessary. However it has become equally clear that not enough details of specific procedures are given, particularly for training purposes.

Such details vary according to the special circumstances associated with the kind of land use under consideration. Evaluation for forestry, for example, has to take account of the relatively long time-scale of production, evaluation for irrigated agriculture the high capital costs; in livestock grazing, the units of production can move from one area of land to another! This situation led to the preparation of more detailed guidelines on land evaluation for each of the major kinds of land use: for rainfed agriculture or crop production (FAO, 1983a) , forestry (FAO, 1984a), irrigated agriculture (FAO, 1984b) and extensive grazing (in preparation). 1/ These are considerably more detailed than the Framework---that on forestry is 123 pages long---but even so are still to be treated as guidelines, requiring adaptation to local circumstances.

The preparation of the forestry guidelines was initiated by a workshop held in Wageningen in 1980; much useful material is contained in the Proceedings of this meeting (Laban, 1981). This was followed by a second workshop held at FAO, Rome in 1982. In preparing these guidelines, particular attention was given to the multipurpose nature of forest production, including the situation in which fuelwood and not timber is the primary aim. The circumstances of community forestry were also kept in mind, including the need to take account of the social consequences of allocating land to forest use. The following account of procedures is based on the Guidelines on land evaluation for forestry (FAO, 1984a), to which reference should be made for further details.

LAND EVALUATION APPLIED TO SITE SELECTION FOR MULTIPURPOSE TREE PLANTATIONS

Procedures

The procedures of land evaluation (Figure 2) commence with initial discussions between those requesting the evaluation and those responsible for carrying it out. The first need is to determine the objectives. In the present case, these will be broadly to establish plantations of MPTs for fuelwood production and other purposes. Such objectives need to be extended for the circumstances of each area. For example, what is the balance of local needs for forest products, as between timber, fuelwood, browse and forest grazing, or reclamation of degraded land? What is the estimated quantity of fuelwood requirements, and how soon is it needed?

Also at this initial stage, constraints to siting are established. Much land may be excluded from consideration for plan-

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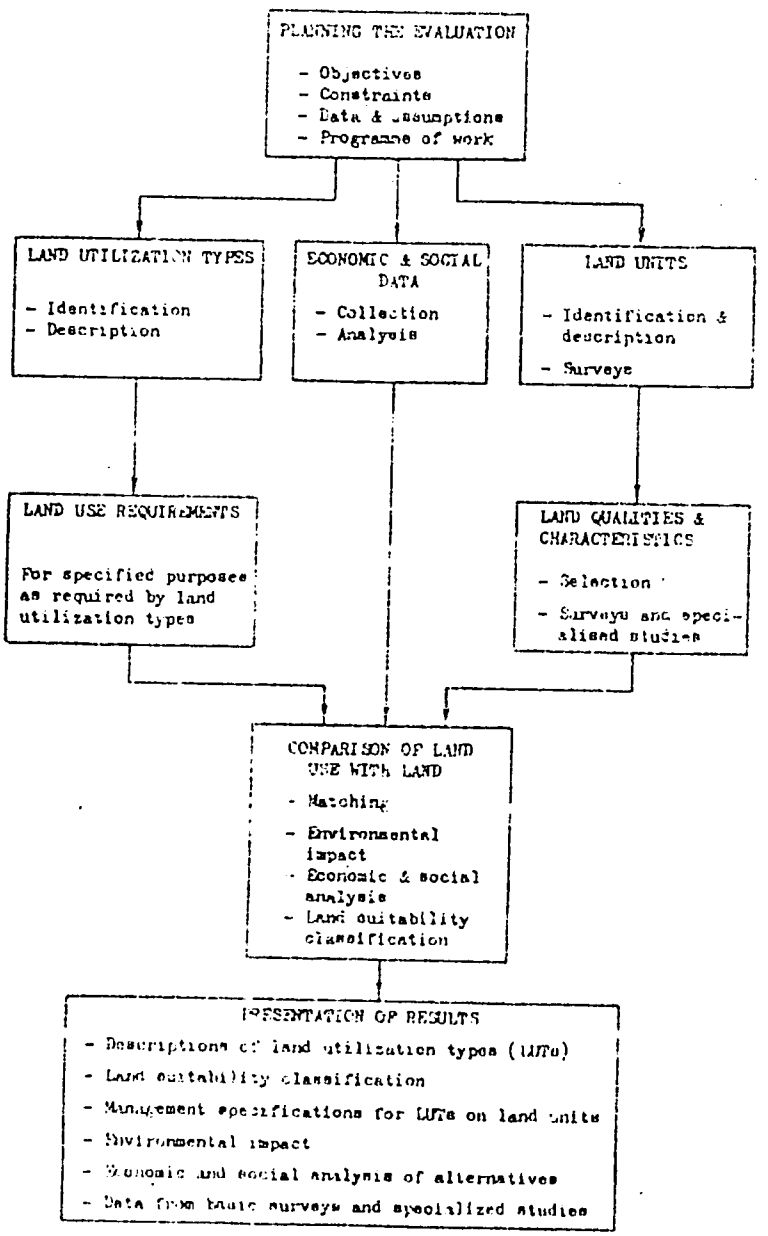
1/ See Note on References, p. 28

Figure 2. Outline of Procedures in Land Evaluation

Source: FAO (1984a, p. 27)



tations, on grounds of legal status or present use. Where nearly all land is already under agricultural use then the evaluation must be directed towards either farm-scale plantations or agroforestry designs.

The initial discussions lead into two parallel sets of activities: studies of land use and surveys of land resources. The studies of land use consist first of the identification of a number of land utilization types, those which appear to hold promise for fulfillment of the objectives in the area concerned. A land utilization type consists of a set of technical specifications within a given economic and social context. An example is "plantations of Cassia siamea, primarily for fuelwood production, with secondary use for provision of browse and forest grazing; managed by village communities, using non-mechanized methods, high labour intensity and low capital intensity".

Note that not only the tree species to be grown but also the methods of management, including establishment, sylviculture and harvesting, form part of description of the land utilization type. For brevity, reference may be made to, e.g. "Cassia siamea" as a land utilization type, but this is understood to be within a specified context of institutional arrangements and methods of management.

Next, the land use requirements of each land utilization type are determined. It has been found useful to divide these into three groups(Table 2):

- requirements for growth;
- requirements for management;
- requirements for conservation.

The growth requirements, or more precisely the requirements for survival and growth, refer to the basic needs of plants: suitable temperatures, adequate moisture, drainage (aeration) and nutrients, conditions for the development of a satisfactory root system, and absence of various hazards----salinity or other soil toxicities, frost, wind damage, flooding, and diseases. These requirements are specific to individual tree species. Thus some species require moisture throughout the year, others are tolerant of drought; some tolerate seasonal waterlogging, others not; many trees suffer severely on saline or on strongly acid soils, whilst there are species tolerant of each of these conditions.

Management requirements are the conditions of land necessary for successful management of the plantation, under the conditions specified in the land utilization type. These are not usually specific to individual tree species but to types of operation. For example, requirements for mechanized operations differ from those for non-mechanized, labour-intensive management; conditions permitting satisfactory forest road construction and maintenance will be necessary on large -scale plantations, but may not be needed on village or farm plots.

Of the conservation requirements, the most widely relevant is tolerance to soil erosion. Some trees form a dense canopy and

Table 2. Land use requirements for multipurpose tree plantation. Based on FAO (1984a, p. 47), modified.

A. Growth requirements

Radiation			
Temperature			
Moisture			
Aeration (soil drainage)			
Nutrients			
Rooting			
Salinity/sodicity		)	Limitations.
Toxicities		)	Requirements are for
Climatic hazards	- fire	)	absence or specified
	- wind	)	levels of severity
Physiographic hazards	- flood	)	
	- landslide	)	
Pests and diseases		)	

B. Requirements based on estimates of forest volume, growth and yield

Required growth rates
Required survival rates
Required yield of non-timber products

C. Management requirements

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

D. Conservation requirements

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

once established, protect the soil, whilst others leave it exposed to raindrop impact for part of the year. Teak has a bad reputation in this latter respect. Some MPTs, particularly those suited to agroforestry, have relatively open foliage, in which case attention to the severity of erosion hazard becomes particularly important.

Parallel with studies of potential land use are surveys of the land. The first task is to define and map the land units present in the area. The term land unit is a neutral one, not referring to a particular scale or type of land area but to any relatively homogeneous area used as the basis for an evaluation. Thus land facets, soil series, or site types could form land units. If a soil survey or other form of land classification already exists, a state of affairs that is increasingly being achieved in some of the countries here represented, it may be possible to take this as the basis for the evaluation.

Having determined the land units, the land qualities and characteristics of each are determined. Land qualities are attributes of land which act in a distinctive way in influencing suitability for use; examples are temperature regime, moisture availability, rooting conditions, drainage, nutrient availability, and the complex of terrain conditions that affects suitability for mechanized operations. Land characteristics are individual features which can be measured or estimated, and are employed to assess land qualities; examples are mean temperature (annual, hottest or coldest months), annual rainfall (mean or with specified confidence limits), range of slope angle, soil effective depth, reaction and mean content of specific nutrients.

There are a very large number of land characteristics that could be used, whereas the number of land qualities is relatively few. By no means all of the qualities listed in Table 2 will be found relevant in a particular area. The recommended procedure is to use the list of land qualities as a means of checking that all requirements have been given consideration. It must then be decided how each relevant quality is to be measured or estimated. For example, are moisture requirements to be measured in terms of mean annual rainfall, growing period, 75% confidence limits for either of these, or in some other way? A check list of land qualities and characteristics most likely to be employed in assessing suitability for MPT plantations in the tropics is given in Table 3. The land qualities given are those most often relevant. The selected land characteristics by which they can be measured are those which are well understood and for which data is commonly available.

These two sets of activities are brought together in the comparison of land use with land. This includes two main stages. The first, known as matching, consists of bringing together the requirements of each land utilization type and the properties of each land unit. By this means it will immediately become apparent that some combinations of land use with land are not suitable, for example tree species intolerant of acidity on strongly acid soils. Leaving aside such obviously unsuitable combinations, the second stage of comparison may include any or all of the following: analysis of environmental impact, assessment of social consequences, and economic analysis. Further land use/land combinations may be rejected on any of these grounds. Examples are plantations of deciduous species on steeply sloping land under high rainfall, as

Table 3. Land qualities and land characteristics commonly employed for assessing suitability for forest plantations.

Only selected characteristics, simple to obtain and widely applicable, are given. For a more complete [illegible] see FAO (1976, Table 7.1, p. 68).

LAND QUALITY	SELECTED LAND CHARACTERISTICS
A. Qualities affecting growth	
Radiation regime	Latitude
Temperature regime	Mean annual temperature
	Mean (or mean maximum) hottest month
	Mean (or mean minimum) coldest month
	Frost frequency
Moisture availability	Mean annual rainfall
	Growing period (days)
	Length of dry season (months)
Aeration (drainage)	Soil drainage class
	Presence/absence of seasonal/permanent surface waterlogging
Nutrient availability	Soil reaction (pH)
	Soil analytical data (mean N, P, K) where available
	Estimated fertility ("low..high")
Rooting conditions	Soil effective depth
	Soil texture
	Stones and gravel (%)
Salinity/sodicity	Presence/absence saline conditions
	Soil analytical data (mean ECE, etc.) where available
Other toxicities (aluminium)	Soil reaction (pH)
Climatic hazards - fire	Length of dry season
- wind	Frequency /severity of high winds
	Exposure (index)
Physiographic hazards - flood	Estimated frequency of flooding
Pests and diseases	Known incidence and severity in area
- landsliding	Estimated severity of landslide hazard
	Slope angle
B. Estimates of forest volume, growth and yield	
Predicted timber yield	Site index
Seedling survival rates	As known from previous experience for area
Predicted yield of non-timber products	
C. Qualities affecting management	
Terrain factors affecting mechanized operations.	Slope angle range
	Outcrops and boulders (%)
Location	Distance from tar road, earth road or users/markets
D. Qualities affecting conservation	
Erosion hazard	Slope angle
	Rainfall intensities
	Estimated soil loss (t/ha/y) under bare soil and under the type of plantation
Predicted response of streamflow	Hydrological modelling

liable to lead to unacceptable rates of soil erosion, or species which shade out pasture in areas where forest grazing is important to local communities.

The comparison is summarized in a land suitability classification, in which the suitabilities of each of the identified land utilization types for each of the mapped land units are assessed. In the classification normally employed there are two suitability orders, S Suitable and N Not suitable, divided into five suitability classes as follows:

S1	Highly suitable	N1	Currently not suitable (physically possible but not at present economically viable)
S2	Moderately suitable		
S3	Marginally suitable	N2	Permanently not suitable

NR Not relevant

The classification NR, Not relevant, is given to land which is not assessed for a particular use, on grounds that such use is precluded by the basic assumptions. For example, closely settled agricultural land might be assessed for agroforestry kinds of use, but would be considered Not relevant for monoculture forest plantations.

Land suitability subclasses refer to the kind of limitation which caused assignment to a class, e.g. S2m - moisture deficiency, S2e - erosion hazard.

The classification of a given combination of land use with land may be based on compatibility of requirements with land properties, on environmental or social consequences, or on estimated economic performance.

Results

The principal results of a land evaluation study are:

i. Descriptions of land utilization types relevant to the area.

ii. Maps of land units, with data on their relevant properties (where not previously available).

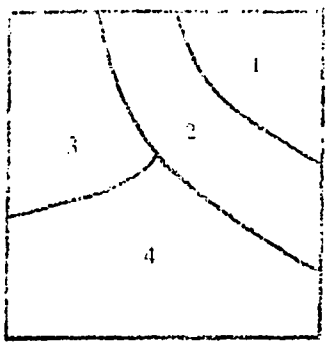
iii. A suitability classification of each land utilization type for each land unit, with reasons for the assessments; this is presented as tables and maps (Figure 3).

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

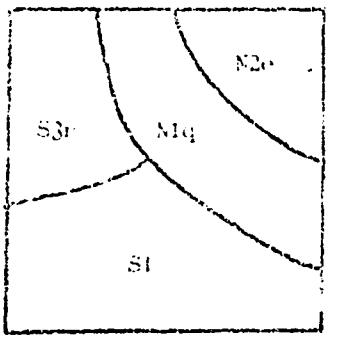
v. An account of the consequences of each land utilization type on each land unit, including required inputs, expected outputs (products, services and other benefits), environmental impact, social consequences, and economic analysis.

Figure 3. Examples of land suitability maps and tables.

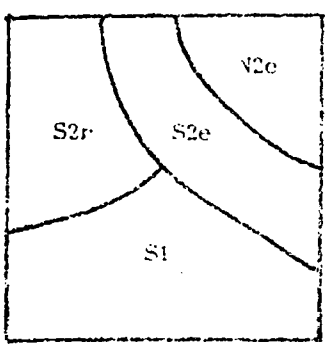
(a) Suitability maps for individual uses



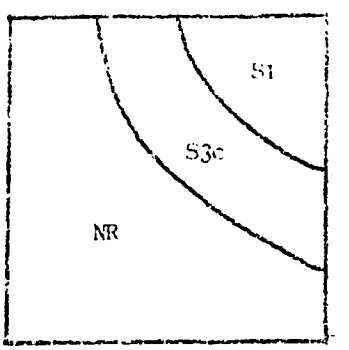
Land Units



A. Timber Production
Mechanized Harvesting



B. Fuelwood Production



C. Protection Forestry

(b) Combined tabular legend to map of land units

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.

Source: FAO (1984a, p. 20).

The maps and tables showing land suitability classes, as in Figure 3, form the focus of the evaluation and the most concise statement of its results. As such, this is the output most likely to be used, providing as it does the basis for plantation siting or other land use planning decisions. A suitability classification table can be used in two ways. Reading horizontally it answers the question, "What are the possible, alternative, uses for a given land unit?"; e.g. in Figure 3(b), Land Unit 4 can be used either for timber or fuelwood production, whereas Unit 1 is suited only for protection forestry. Reading vertically, it answers the question, "Where are the best areas for a given land use?"; e.g. for fuelwood production, Unit 4 is best, and Units 2 and 3 also suitable.

This, however, is by no means the only output of an evaluation. The descriptions of the land utilization types, together with their management specifications adapted to each land unit, provide data for the preparation of forest management plans, whilst the estimates of inputs and yields form an essential basis to project analysis. Land evaluation is more than merely land suitability classification.

GAPS IN KNOWLEDGE AND RESEARCH NEEDED

Widening the range of choice of multipurpose trees

The first need for research is to widen the choice of multipurpose species available. Of the total area of tropical plantations, 9 eucalypt species, 8 pine species and teak together cover 80% of the area; 3 Acacia species form a further 4.5%(data for 1980, from Pandey, 1983). This refers mainly to timber species. Within multipurpose species also, however, there is presently too much dependence on a very limited range of species, the 'big names' in the MPT world.

In selecting a species for an area, there are at least three major questions to be answered: will it meet the needs of users, will it grow well, and is seed available? The first and last of these questions lie outside the scope of this paper, but all three must be answered positively if choice of species is to be right. One can think of the selection as a series of sieves, each of which progressively reduces the choice of species.

ICRAF is currently conducting an inventory of MPTs which will assist in answering these questions (von Carlowitz, 1984). Three broad groups of data are collected: environmental conditions, morphological and behavioural characteristics, and uses. The data are being stored in a computerized data base. Some 35 uses are identified, grouped into food, fooder, wood, other products and service uses. Everyone attending this meeting is urged to take three such forms and complete them----or get a colleague to do so!

Growth requirements of MPTs

With respect to site selection, there can be little doubt that the main research need is to collect, systematically classify and disseminate information on the growth requirements of MPTs. The long growing cycle of trees makes it particularly important to achieve correct species selection, matched to the environmental conditions of each site, in the first instance.

Information is needed first, on the optimal conditions for growth of each species. This is of limited applicability, however, and will relate mainly to preferred climatic regime. For soils, most species will fare best on deep, medium-textured, well-drained soils, not too acid or alkaline and of high inherent fertility! Land of this nature will not often be avilable for forestry plantations. What is needed, therefore, is information on tolerance to various kinds of adverse environmental conditions, climatic and soil, e.g. short growing season, frost, high temperature extremes, shallow soils, waterlogging, strongly acid or alkaline conditions, or salinity. Which species will best tolerate each of these limitations, singly or in combination, and how severely will their survival and growth be affected?

As a basis for defining suitability ratings, one means is to set limits defined by growth rates as a percent of growth under optimal conditions. For rainfed crop production, limits that have been suggested are S1 above 80% of optimal growth, S2 40-80%, S3 20-40% and N, not suitable, where yield was less than 20% of optimal. Foresters may well consider this last limit to be unrealistically low.

Given some such definition of suitability ratings, what is needed is to calibrate each of the environmental limitations in terms of growth reduction for each species; this is called rating of land use requirements. Thus for Cassia siamea, it is not sufficient to say "prefers deep soils". For the land quality rooting requirements, as diagnosed by the land characteristic of soil effective depth, what is ideally needed is a rating in the following form:

Suitability rating	Soil effective depth (cm)
s1	>120
s2	50-120
s3	30-50
n	<10

Such data will not often be obtainable. The critical point is that at which growth becomes so reduced that the species should be ruled out of consideration, i.e. the upper limit of Not suitable conditions. It would certainly be valuable to know how, for the same definition and land limitation, such a boundary varied as between different tree species---in plain terms, those species which are less tolerant and those more tolerant of shallow soils,

salinity, seasonal waterlogging, etc..

The use of site index and growth-site correlation

In the site index, forestry possesses an established method which can serve as a basis for suitability assessment of growth requirements, provided that it is linked to growth-site correlation. The method is outlined in the Guidelines on land evaluation for forestry. "Sample plots are set up 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." (FAO, 1984a, p.64).

THE ROLE OF REGIONAL RESEARCH IN TROPICAL ASIA

General

No single research station, or indeed national research organization, can adequately collect information, and establish the necessary trials, to produce a comprehensive inventory of the growth requirements of MPTs. It is a task pre-eminently suited to networks or other co-ordinated research.

In principle, there should be nothing 'Asia-specific' about growth requirements: a semi-arid climate or a saline soil are semi-arid or saline wherever they are found. In practice, there are two reasons why there is a role for co-ordinated research within Asia: distinctive features of the tropical Asian environment, and the need for local trials.

Certain features of the tropical Asian environment are not exactly replicated in other continents. The major feature is the greater strength of the Asiatic monsoon, which gives rise to exceedingly concentrated rainfall distributions; if you have a rainfall as high as 1330 mm, you do not in other continents expect 80% of it to fall in 3 months (Jhansi, Uttar Pradesh). There are also environmental features which, whilst occurring elsewhere, are particularly widely represented in Asia; the vertisols of the Deccan lavas and the Köppen Am ('monsoon-type')climate are examples. Insect pests and diseases may also be specific to, or more severe within, specific continental areas.

Additionally, however precise information on environmental response becomes, local trials will still be needed as a precautionary measure. Matching of environmental requirements with local conditions can lead to the identification of most promising ('best bet') species, but it would be foolhardy to rely on this alone, without the ultimate test of local trials.

Desirable as it would be from the present point of view, it is unlikely that many organizations will orientate their research programme primarily around the determination of growth requirements. There are, however, three practical ways forward: systematic assembly of available data, trials along selected environmental gradients, and standardized recording of environments at all trial sites.

Systematic assembly of available data

There are a substantial number of sources which give growth requirements of trees, mostly timber species it is true (e.g. FAO, 1974; Webb et al., 1980; National Academy of Sciences, 1980; Baumer, 1983; Pandey, 1983). These suffer from broad generalization and, in some cases, uncritical copying from one source to another. There is far too much data in forms such as "prefers deep soils" or "moderately drought-tolerant". On the matter of originality, it is a feature of the ICRAF MPT inventory that it rests on primary data, namely sites on which the tree is observed to be growing.

As a contribution to research of this kind, use can be made of part of the output from the ICRAF environmental data base. This is a data base designed to record and analyse environmental information on all aspects of agroforestry: trees, crops, land use systems, and experimental sites. The data on requirements of MPTs are classified in order of land qualities (temperature, moisture, drainage, etc.), each further ordered into the land characteristics employed to measure them (e.g. moisture requirements as measured by growing season, mean annual rainfall, length of dry season, etc.) Data collected by the MPT inventory forms a major input to the environmental data base.

At present, a framework of basic environmental data to be collected has been established, including classification systems (for climate, soils, vegetation, etc.) and main variables. This framework is set out in An environmental data base for agroforestry (Young, 1983). A computerized data base for input, storage and retrieval of such information has been established. It still remains to collect and process the bulk of the hard data!

A sample of output is given as Table 4, illustrating the format in which material on MPT growth requirements is arranged and presented. Records are first grouped by land qualities: temperature, moisture, drainage, nutrients, etc.. Some land qualities are subdivided, for example temperature regime into temperatures for growth, tolerance to extremes of heat and tolerance to cold. Finally, within each land quality and subdivision, data are further arranged by the land characteristic employed to estimate the quality; for example, some sources give temperature for growth as mean annual temperature, others as means for the hottest and coldest months, and some by the surrogate of altitude. Records are shown by suitability level and whether this is bounded or unbounded (see legend to table), together with the source and estimate of its reliability. The final stage, that of integrating these diverse records, is at present left to the judgement of the user!

Table 4 Sample output from the multipurpose tree requirements file of the ICRAF environmental data base

Explanation of headings:

LAND USE	On this file, species of multipurpose tree.
LAND QUALITY	Requirements grouped according to broad type, e.g. requirements for temperature regime, moisture regime, rooting conditions.
SUBDIVISION	Subdivision of land quality, e.g. temperature regime. Subdivided into growth (general requirement), tolerance to high temperatures and tolerance to low temperatures.
LAND CHARACTERISTIC	The value employed to measure or express the land quality; e.g. different sources express tolerance to low temperatures as mean minimum of the coldest month, absolute minimum, and frost frequency.
LOCATION	The area to which suitability data refer.
SUITABILITY	The suitability level to which data refer:
OB	Observed (no data on growth or performance)
SS	Suitable (growth or performance satisfactory)
S1	Highly suitable
S2	Moderately suitable
S3	Marginally suitable
NN	Not suitable (performance not satisfactory)

The oblique stroke (/) indicates that suitability is bounded, the hyphen (-) that it is not bounded; e.g.

nn/ SS / nn	20 - 30 C	Suitable between 20° and 30° C and Not suitable outside this range
- SS -	20 - 30 C	Suitable between 20° and 30° C but suitability level beyond this range not known

LOWER VALUE/INCLUDED and HIGHER VALUE/EXCLUDED

Data in these columns appears in different forms illustrated by the following examples:

(a) Numerical data: example, temperatures for growth, expressed as mean annual temperature

- SS -	20 - 30 C	Suitable in range 20 - 30° C
- OB -	22 C	Observed on site with 20° C

(b) Non-numerical data: example, drainage (aeration) requirements, expressed as soil drainage class:

nn/ SS /nn	WELL DR.	* W'LOGGED	Suitable on well drained sites, Not suitable on waterlogged sites

SOURCE

Reference number to the source of data, details of which are stored on a separate file. Souce 1 is the ICRAF multipurpose tree inventory.

RELIABILITY

A subjective estimate of the reliability of the data:

1	High	Primary direct observation
2	Medium	
3	Low	Including highly generalized data

Note that certain land characteristics, including latitude, soil texture, soil reaction and soil type, may be employed to express suitability in a manner which does not make it clear which kind of effect, i.e. which land quality or qualities, is being assessed. Such land characteristics are grouped at the end of the lists.

Table 4 (continued)

LAND USE	LAND QUALITY	SUB-DIVISION	LAND CHARACTERISTIC	LOCATION	SUITABILITY			LOWER VALUE/ INCLUDED	HIGHER VALUE/ EXCLUDED	SOURCE	RELIABILITY
ACACIA SENEGAL	TEMPERATUR	GROWTH	ANN.TEMP.	W.AFR.	-	S1	-	25	- 27 C	3	2
ACACIA SENEGAL	TEMPERATUR	GROWTH	ANN.TEMP.	WORLD	-	S1	-	25	- 27 C	4	2
ACACIA SENEGAL	TEMPERATUR	GROWTH	ANN.TEMP.	AFRICA	-	SS	-	22	- 32 C	2	2
ACACIA SENEGAL	TEMPERATUR	GROWTH	ALTITUDE	SUDAN	-	OB	-	575		1	1
ACACIA SENEGAL	TEMPERATUR	GROWTH	ALTITUDE	AFRICA	/	SS	-	0	- 500	2	2
ACACIA SENEGAL	TEMPERATUR	GROWTH	MEAN MAX.	SUDAN	-	OB	-	39 C		1	1
ACACIA SENEGAL	TEMPERATUR	GROWTH	MEAN MAX.	WORLD	-	OB	-	37 C +-		4	2
ACACIA SENEGAL	TEMPERATUR	GROWTH	MEAN MIN.	SUDAN	-	OB	-	13 C		1	1
ACACIA SENEGAL	TEMPERATUR	GROWTH	MEAN MIN.	WORLD	-	OB	-	20 C +-		4	2
ACACIA SENEGAL	TEMPERATUR	HEAT TOL.	MAX.HOTMO.	W.AFR.	-	SS	/nn		<45 C	3	2
ACACIA SENEGAL	TEMPERATUR	HEAT TOL.	MAX.HOTMO.	AFRICA	-	SS	-	30	- 40 C	2	2
ACACIA SENEGAL	TEMPERATUR	COLD TOL.	MIN.COLDMO	AFRICA	-	SS	-	16	- 23 C	2	2
ACACIA SENEGAL	TEMPERATUR	COLD TOL.	ABS.MIN.	SUDAN	-	OB	-	9 C		1	1
ACACIA SENEGAL	TEMPERATUR	COLD TOL.	FROST FREQ	WORLD	-	NN	-		* SENSITIV	4	2
ACACIA SENEGAL	MOISTURE	GROWTH	ANN.RAINF.	SUDAN	-	OB	-	280		1	1
ACACIA SENEGAL	MOISTURE	GROWTH	ANN.RAINF.	WORLD	-	OB	-	250	- 750 MM	4	2
ACACIA SENEGAL	MOISTURE	GROWTH	ANN.RAINF.	W.AFR.	-	SS	-	200	- 500 MM	3	2
ACACIA SENEGAL	MOISTURE	GROWTH	ANN.RAINF.	AFRICA	-	SS	-	200	- 500	2	2
ACACIA SENEGAL	MOISTURE	GROWTH	ANN.RAINF.	WORLD	537	SS	-	300	-500 MM	4	2
ACACIA SENEGAL	MOISTURE	GROWTH	RAIN REGIM	SUDAN	-	OB	-	HIGH SUN		1	1
ACACIA SENEGAL	MOISTURE	GROWTH	RAIN REGIM	AFRICA	-	SS	-	HIGH SUN		2	2
ACACIA SENEGAL	MOISTURE	CRIT.PER.	DRY SEASON	W.AFR.	-	SS	-	8	- 11 MO.	3	2
ACACIA SENEGAL	MOISTURE	CRIT.PER.	DRY SEASON	AFRICA	-	SS	-	6	- 8 MO.	2	2
ACACIA SENEGAL	MOISTURE	CRIT.PER.	DROUGHT	WORLD	-	OB	-	TOLERANT		4	2
ACACIA SENEGAL	DRAINAGE	-	CLASS	WORLD	-	NN	-		* WELLDRAING	4	2
ACACIA SENEGAL	DRAINAGE	-	DRAIN.CL.	SUDAN	-	OB	-	SEMI.W/LOG		1	1
ACACIA SENEGAL	DRAINAGE	-	DRAIN.CL.	W.AFR.	-	SS	/nn	FREE DR.	* WELLDRAIND	3	2
ACACIA SENEGAL	DRAINAGE	-	DRAIN.CL.	AFRICA	-	SS	-	FREE DR.		2	2
ACACIA SENEGAL	ROOTING	-	EFF.DEPTH	WORLD	-	SS	-	TOL.SHALLO		4	2
ACACIA SENEGAL			LATITUDE	SUDAN	-	OB	-	13 N		1	1
ACACIA SENEGAL			LATITUDE	AFRICA	-	OB	-	11	- 18 N	2	2
ACACIA SENEGAL			SOIL TEXT.	SUDAN	-	OB	-	LIGHT		1	1
ACACIA SENEGAL			SOIL TEXT.	AFRICA	-	SS	-	LT/MED/HVY	* (NONE)	2	2
ACACIA SENEGAL			SOIL TEXT.	WORLD	-	SS	-	SDY/CLAY	* (NONE)	4	2
ACACIA SENEGAL			REACTION	SUDAN	-	OB	-	ALKALINE		1	1
ACACIA SENEGAL			REACTION	AFRICA	-	SS	-	NEUT/ACID		2	2
ACACIA SENEGAL			UP SOIL	SUDAN	-	OB	-	TYP.QUARTZ	=IPSAMMENT	1	1

Sources: 1: ICRAF LPT Inventory 2: Webb et al., 1980 3: FAO, 1974 4: Baumer 1983

Whether there is need or facilities for an Asia regional data bank, or data assembly and disemmination centre on growth requirements of MPTs is a matter for discussion. ICRAF is undertaking this task on a world basis, and will, of course, make results available. This will include both published output and the running of selective computer retrieval for specified environmental conditions.

Trials along selected environmental gradients

Research stations situated in semi-arid to arid regions have a strong practical need for knowledge about drought-resistant species: those where saline soils are common want to know about tolerance to salinity. Other regions will have problems arising from the common occurrence of strongly acid soils (aluminium-toxicity) or shallow and stony land.

There is a way forward to be found in this situation. Let those research centres with particular environmental limitations be assigned special responsibility to study tree response to such conditions. This would include research designs in which each of a number of MPT species were tested on sites ranging from absence to very severe occurrence of the selected limitation. There would be some pre-selection of species believed to be tolerant, but given this, each species would be planted on all sites along the chosen gradient.

The following are some possible environmental gradients to be studied in this way; the "upper" value suggested is that at which the limitation concerned ceases to be severe for a wide range of species:

1. Drought. Tolerance to low rainfall and long dry season. To cover a mean annual rainfall range of 700 to <200 mm.

2. Acidity. Tolerance to low soil pH and high exchangeable Al. To cover a pH range of 5.5 to <4.0.

3. Salinity. Tolerance to: (i) free salts, and (ii) exchangeable sodium. To cover a range from non-saline/alkaline to highly affected soils.

4. Shallow and stony soils. Tolerance to a range of sites of soil effective depth <50 cm and percent stones >20%.

5. Moderate to steep slopes under high rainfall. The design and measurements here would differ from 1-4 above. For a number of sites with slope >20° (36%) and annual rainfall >2000 mm, rates of soil erosion under different species should be monitored.

A basic environmental data base for MPT research

Over and above studies specifically intended to determine environmental requirements there will be numerous trials or plantations established primarily for other purposes but which nevertheless lend to monitoring the growth of species on sites. The features of growth recorded are well established in forestry research practice. It would greatly increase knowledge on growth/site relationships if the environment of all sites were similarly to be recorded in a standardized manner.

A draft of such a standardized recording sheet is given as Table 5. It is intended as a basic minimum of information to be recorded for all sites. Other data available and believed to be significant may optionally be added. Each environmental factor---geology, landforms, climate, hydrology, soils and vegetation---begins with a broad classification, followed by numerical or other data on individual properties. In the case of soils (where classification can arouse such strong feelings!), the class may be given on any recognized classification, followed if possible by its equivalent in the FAO system.

Most data are recorded once only. Monthly rainfalls, however, should be recorded throughout the duration of a trial, as variability is such that it may differ substantially from the long-term averages.

One further exercise in monitoring is desirable, but may not often be practicable, namely changes in soil properties. Ideally, soil sampling and analysis should be carried out in a standardized manner at the start of a trial, and repeated every 1, 3 or 5 years. Owing to microvariability of soil properties (within apparently uniform sites) the number of samples required to establish statistically significant changes is quite large. A possible sampling design is given in Soil monitoring for forestry and agroforestry trials (ICRAF Working Paper, in preparation).

APPLICATIONS OF RESEARCH

General

The outcome of a successfully completed programme of research, correctly applied, is as easy to state as it would be desirable to achieve, namely:

i. choice of the right sites for MPT plantations;

ii. choice of the right species for a site;

iii. specification of site-specific management measures.

The research programme proposed here would lead to a data bank of the environmental requirements of MPTs with information on growth performance under optimal conditions and tolerance to the various site limitations likely to be encountered.

Table 5. An environmental data base for multipurpose tree research. Adapted from Young (1983).

IDENTIFICATION AND LOCATION

Data supplied by: Name ..... Institution .....

Trial or plantation site: .....

Country ..... Location .....

Latitude ..... Longitude ..... Altitude (m).....

Type of trial/plantation .....

MPT species .....

Reference for details .....

GEOLOGY

Classification:

1 Crystalline, felsic
2 Crystalline, basic
3 Sedimentary, siliceous
4 Calcareous
5 Superficial deposits
6 Other
9 No data

Description .....

LANDFORMS

Classification:

1	Steeply sloping	>17°	>30%
2	Moderately sloping	5 - 17°	8 - 30%
3	Gently sloping	< 5°	< 8%
4	Depositional landforms		
5	Swamps		
9	No data		

Description .....

Slope angle, or range ..... degrees or ..... %

CLIMATE

Broad Classification:

		Köppen classes included
1	Humid tropics	Af, Am
2	Subhumid tropics	Aw, Aw", Cw, Cw"
3	Semi-arid	BShw, BSk
4	Arid	BWh, BWk
5	Humid subtropics	Cfa
6	Mediterranean	Cs, BShs
7	Temperate maritime	Cfb
8	Cool or cold	D, E
9	No data	

Climatic data based on nearest station at.....altitude.....m,.....km from site

Temperature (C): Mean annual ..... Mean max..... Mean min.....

Mean hottest month ..... Mean coldest month .....

Frost: 1 Never or rare ..... 2 Common ..... 3 Every year ....

Mean rainfall (mm):

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
....	....	....	....	....	....	....	....	....	....	....	....	....

Mean annual evaporation, Eo (mm) ..... By which method? .....

Derived values (need not be completed):

Moisture class ..... Number dry months (<60 mm) .....

Rainfall regime ..... Rainfall driest month .....

Altitude zone ..... Humidity index, r/Eo .....

HYDROLOGY

Drainage class: 1 Well drained 3 Permanent waterlogging

2 Seasonal waterlogging

Groundwater: 1 Fresh 2 Slightly saline 3 Saline

Depth to groundwater (m). Mean ..... Lowest ..... Highest .....

Flooding: 1 Never or rare 2 Common 3 Frequent

SOILS

Classification:

(a) Generalized:	FAO soil classes included
1 Latosols	ferralsols, acrisols, luvisols, nitosols
2 Vertisols	vertisols
3 Calcimorphic soils	chernozems, phaeozems,
4 Desert soils	xerosols, yermosols
5 Saline or alkaline soils	solonchak, solonetz
6 Gleys, alluvial soils or peat	gleysols, fluvisols
7 Shallow or immature soils	planosols, histosols
8 Temperate soil types	lithosols, rankers, regosols, arenosols andosols
9 No data	cambisols, podzols podzoluvisols, greyzems

(b) FAO .....

(c) Other .....on.....classification

Properties:

Texture: 1 Heavy 2 Medium 3 Light

Reaction 1 Strongly acid (pH <5.0) 2 Acid (pH 5.0-6.5) 3 Neutral (pH 6.5-7.5) 4 Alkaline (pH >7.5)

Limiting horizon: 1 Yes Depth (cm).....Nature.....

2 No

Stones and gravel: 1 None 4 Very

2 Slightly

3 Moderately Amount.....%

Degradation: 1 Yes Type, severity.....

2 No

VEGETATION		Area as a whole	Site, before planting
Classification:	1	Rain forest	1
	2	Tropical deciduous woodland	2
	3	Savanna	3
	4	Thorn scrub or thorn woodland	4
	5	Grassland	5
	6	Semi-desert vegetation	6
	7	Desert	7
	8	Temperate deciduous woodland	8
	10	Coniferous woodland	10
	11	Montane vegetation	11
	12	Swamp	12
	13	No natural vegetation	13
	9	No data	9

Description: Physiognomy .....

Dominant species .....

FAUNA, PESTS AND DISEASES

Types, severity .....

.....

LAND USE

Land use (present or prior to plantation)

.....

ADDITIONAL ENVIRONMENTAL FEATURES

.....

.....

.....

Attach if possible: 1. Climatic records for nearest station

2. One or more soil profile descriptions for site, with analytical data if available.

Monthly rainfall values should be recorded, on site if possible, throughout duration of trial on plantation.

Output (i) correct choice of sites, would be based on considerations of growth, management and conservation. That is, sites might be eliminated on grounds of unsatisfactory growth potential, impracticable or uneconomic management requirements (e.g. maintenance of expensive drainage works, need for economically non-viable fertilizer inputs) or unacceptable environmental consequences (e.g. soil erosion, adverse effects on the hydrological regime).

Output (ii), choice of species, would lead to identification of a range of MPTs which, on the basis of land requirements, would perform satisfactorily. This would enable further choice to be made on the basis on the needs of users.

Output (iii) is that of site-specific management measures, that is, methods of site preparation and recurrent inputs made necessary by the environmental conditions of each site. Examples are measures to combat drainage impedance, or strong acidity and phosphorus-deficiency. Here there is an interface with succeeding papers in this Discussion Area.

Training

Whilst land evaluation is straightforward in principle, and its results easily understood, the detailed procedures are of some complexity.

At present, land evaluation will not have formed part of the training of many practising foresters. There are two strategies to meet this situation: to call in an external organization or expert in land evaluation whenever a site selection is required, or to take steps such that forestry planning organizations possess in-house capability. There is no doubt need for specialist input in major surveys, particularly where comparison between forestry, agroforestry and agriculture is involved. However, the training of foresters in evaluation techniques, and/or inclusion of evaluation specialists on the staff of forestry organizations, is more likely to lead towards land evaluation becoming accepted as an integral, standard element of forest land use planning.

Following publication of the Guidelines on land evaluation for forestry, it is the intention of FAO to hold training courses based upon it, the first probably in Asia. For more advanced training, masters degree level courses are available (Appendix A).

Site selection and forest management

It would be misleading to pretend that good site selection is a guarantee of successful forestry. In mathematical terms, the former is a necessary but not a sufficient condition for the latter. However, the history of land use abounds with examples in which subsequent efforts of sylvicultural management could not overcome initial mistakes in choice of site or species. By thorough survey of site conditions, elimination of unsuitable land, correct choice of species and specification of land-related management practices, the task of the practising forester is greatly eased. Good site selection aids successful forest management.

APPENDIX A. SOME POST-GRADUATE COURSES IN LAND EVALUATION

M.Sc Course in Resource Assessment for Development Planning, University of East Anglia, Norwich, England.

A one-year course combining instruction in the techniques of soil survey, land evaluation and land use planning with a study of the application of natural resource information in development planning.

Information: Dr. David Dent, School of Environmental Sciences, University of East Anglia, Norwich, NR4-7TJ, England.

International Post-graduate Course in Natural Resources Research and Land Evaluation, Sheffield, England.

A one-year course in the techniques of field and laboratory study in natural resources research. Land evaluation and development planning in the context of environmental relationships are the chief concern.

Information: The Registrar, Unviersity of Sheffield, Sheffield S10 2TN, England.

M.Sc. Courses in Land Resource management, Silsoe, England.

A one-year course in land resources and survey and evaluation, rural and agricultural planning.

Information: The Careers and Recruitment Officer, National College of Agricultural Engineering, Silsoe, Bedford MK45 4DT, England.

M.Sc. Course in Soil Science and Water Management, Programme in Land Evaluation and Agropedology, Wageningen, The Netherlands.

A two-year course for graduates from developing countries, orientated towards agricultural development.

Information: Director of Studies of the M.Sc. Course in Soil Science and Water Management, P.O. Box 37,6700 AA Wageningen, The Netherlands.

Source: Bulletin of the International Society of Soil Science, 62, (1982), pp. 43-47.

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Note At the time of preparation of this draft text, the guidelines on rainfed agriculture had gone to press, those on forestry were about to do so, and those on irrigated agriculture were in an advanced stage of preparation. It is anticipated that all three will be published before the Proceedings, some possibly by the time of the Workshop. The guidelines on land evaluation for extensive grazing are at an early stage of preparation

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