Proceedings of the workshop on land evaluation for forestry

International Workshop of the IUFRO/ISSS
Wageningen, The Netherlands
November 10–14, 1980

Edited by
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International Institute for Land Reclamation and Improvement / ILRI
P.O. BOX 45, 6700 AA Wageningen, The Netherlands 1981.

The International Workshop on Land Evaluation for Forestry was sponsored by:

IUFRO

INTERNATIONAL
UNION OF
FORESTRY
RESEARCH
ORGANIZATIONS

ISSS

INTERNATIONAL
SOCIETY OF
SOIL SCIENCE

A committee, consisting of Prof. Dr. Ir. K. J. Beek, Prof. Ir. M. Bol, Ir. C. P. van Goor and Ir. P. Laban, was responsible for the preparation and organization of the workshop.

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ISBN 90 70260 68 9

Printed in The Netherlands.

PREFACE

Under the auspices of Divisions 1, 3 and 4* of the International Union of Forestry Research Organizations (IUFRO) and the Working Group on Land Evaluation of the International Society of Soil Science (ISSS), an International Workshop on Land Evaluation for Forestry took place at the International Agricultural Centre in Wageningen, The Netherlands on November 10-14, 1980.

This workshop was a result of

- the growing need among foresters to coordinate and integrate studies concerned with site and terrain classification and forest management planning;
- the wish to incorporate forestry in a recently developed land evaluation approach, mainly oriented towards agriculture.

The organizing committee consisted of K.J. Beek, chairman of the Working Group on Land Evaluation of ISSS, M. Bol, coordinator of Division 3 of IUFRO, C.P. van Goor, deputy coordinator of Division 1 of IUFRO and P. Laban, secretary.

The preparations for this workshop were made possible through the efforts of staff of the Dorschkamp Research Institute for Forestry and Landscape Planning, while staff of the International Agricultural Centre accounted for the smooth progression of the workshop week. The publication of the proceedings came about under the responsibility of the International Institute for Land Reclamation and Improvement (ILRI).

Wageningen, January 1981

* *Division 1: Forest Environment and Silviculture*
Division 3: Forest Operation and Techniques
Division 4: Planning, Economics, Growth and Yield, Management and Policy

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ABSTRACT

These proceedings assemble the papers presented at the International Workshop on Land Evaluation for Forestry, while the discussions held during the workshop week are considered in an elaborate set of conclusions and recommendations.
The papers are divided into two groups. The first group, "The State of the Art", deals with subjects profoundly studied in the past, namely the ecological dynamics of forests and other woody vegetation types, inventory techniques of vegetation and land, land classification systems and classification systems describing specific use/single factor relationships between vegetation and land. These subjects provide the physical and ecological data and knowledge incontestably needed for a wise application of the subjects treated in the second group: "An Integrative Land Evaluation Approach". This land evaluation approach has been developed only in the last ten years and mainly for agriculture. This second group of papers reviews concepts and procedures and elaborates on the applicability of this approach to forestry. The papers provide ideas and proposals for a further development of land evaluation for forestry, particularly regarding the definition of land utilization types, the relationships between land qualities and land use requirements of land utilization types, the use of a systems approach in land evaluation and the applicability of land evaluation for forestry to Europe and developing countries.

MAIN CONCLUSIONS AND RECOMMENDATIONS

Whereas problems of land degradation, deforestation, erosion, floods, increasing scarcities of fuel wood, timber, pulp wood and other forest resources and products, are increasing on a world-wide scale;
whereas the actual use of the land often no longer responds to the needs of society;
whereas the need for comprehensive planning at all generalization levels is increasing;
whereas tendencies towards strong specialization of disciplines and monodisciplinary studies are recognized;
whereas the above mentioned situations are particularly important in the Third World countries;
the International Workshop on Land Evaluation for Forestry *concludes that*

a) the methods of the discussed land evaluation approach are applicable to both forestry and agriculture;
b) this land evaluation approach is an important tool to solve the above mentioned problems in an integrative way;
c) there is a great need to integrate land evaluation procedures with land use planning processes.

The workshop *recommends that*

a) organizations and scientists of different disciplines involved with the above mentioned problems join and coordinate their efforts and activities to arrive at practical and comprehensible solutions in an integrative way;
b) special guidelines on land evaluation for forestry be prepared, particularly referring to the specific problems in the different regions of the Third World;
c) efforts made in site and terrain classifications as well as in forest management planning be coordinated and integrated;
d) a Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry be established;
e) a permanent secretariat to enforce the activities of the above working group be established;

f) the Dorschkamp Research Institute for Forestry and Landscape Planning and the International Institute for Aerial Survey and Earth Sciences (ITC), both in the Netherlands, join forces to find financial support to initiate such a working group and its secretariat, while pursuing more permanent arrangements on an international basis, possibly with FAO cooperation;

g) research to better define relationships between land characteristics, land qualities and land use requirements of land utilization types be promoted;

h) monitoring of these relationships be highly emphasized;

i) the concept of land utilization types be considered as a practical model developed and used for evaluation and planning;

j) the dynamics and the continuance of the ecosystem, wherein the application of a certain land utilization type is considered, be recognized as important preconditions of the land utilization type;

k) proper management of forest ecosystems, in view of its important impacts on the environment as a whole, be highly stressed;

l) monitoring of these impacts be highly stressed;

m) much study be devoted to the definition of overall land suitability criteria to serve overall development objectives;

n) results of land evaluation be presented as simply as possible.

1 INTRODUCTION TO THE WORKSHOP

1.1 Opening speech by Dr. W.M. Otto, Director-General for Land Development and Forestry of the Netherlands Ministry of Agriculture

On behalf of the Netherlands Ministry of Agriculture, I am happy to cordially welcome all participants to the Workshop on Land Evaluation for Forestry. This workshop is especially important since much attention in the world today is focused on forests and forestry. The continuously increasing consumption of wood exceeds wood production of the existing forest area on the basis of sustained yield principle. This means that total forests are cut down for consumption, but that the trees, the production capital, are not replanted, resulting in loss of forest area.

Wood as raw material for wood consuming industries is becoming scarce in developed countries. This is affecting the forest situation in the entire world. For example, Canada and Northern Europe, traditionally wood exporting regions, are now importing. In 1973 Sweden imported about 10 million m^3 of wood, which will probably amount to 20 million m^3 in 1980. Within the EEC-countries wood consumption outruns production by more than 100 million m^3 of wood. This deficit will increase to about 230 million m^3 annually by the year 2000.

In spite of the efforts to afforest wasteland and less productive land, in the developed countries it appears impossible to keep pace with the demand of wood. As a consequence, many industrial countries turn to the forests of the developing world in the tropics and subtropics, accelerating land degradation in these regions.

In larger parts of Asia, Africa and Latin America a degradation process of rural areas is taking place through loss of soil productivity and environmental qualities manifest in erosion, silting up of irrigation systems and storage lakes, floods, salinization and desertification. The main causes of this process are improper land use, such as overgrazing, agriculture on too steep slopes, shifting cultivation, neglect of maintenance of irrigation systems and above all, deforestation, which in turn are side-effects of fast changing socio-economical and political circumstances.

The tropics, having about half the world's forests, has an estimated population of one billion people, most of which are the poorest in the world.

20 Million ha of primary forests is opened up and utilized annually of which 5 million ha is definitely lost.
Two human actions are of paramount importance in this respect. The first, *shifting cultivation*, is applied by about 200 - 250 million people, only a part making use of it in the traditional way. The second action is related to the harvesting of wood. About 80% of the wood produced in the tropics is used for fuel; 20% is used otherwise. Half of this quantity is exported mostly to Japan, Europe and the United States. Considering the increasing demand for wood in industrial countries, the need for hard currency in the developing countries and the people's dependence on wood for energy in most of the tropical countries, it is obvious that the tropical forests will severely suffer under the growing pressure of the competition for wood. If no measures are taken to turn the trend of events, in the near future one will be faced with:

- seriously endangered means of living for 200 million people;
- insufficient supply of timber and energy, with consequences for a much larger group of people;
- further soil degradation, acceleration of erosion and disruption of the hydrology of catchment areas.

It is therefore obvious that forestry has to be *integrated* with the other relevant kinds of land use in land use planning. In the developed countries the goal of integration will mainly be to increase wood production so as to lessen the gap between consumption and production. In the developing countries, however, the goal is more complex and deals mainly with rehabilitating environmental qualities of the land and supplying wood for energy and raw material for wood-consuming industries and export.
Let us concentrate for a moment on the *developing countries*, having the greatest necessity for finding solutions.
The relationship between rural community and forestry is different for each individual country. There is not only a difference in physical and forestry conditions, but also in population density and nature. The Southeast Asian and Sahel countries, for example, differ immensely regarding not only the actual situation, but also the land use problems and the land use planning. Each country has its specific forestry problems and requires a specifically adapted approach for forestry development.

However, to stop the ecological deterioration, many very serious difficulties must be overcome to be able to develop an efficient strategy for rehabilitation, maintenance and management of the natural resources. *Firstly*, the disruption process is rather slow and generally not well monitored. Governments have the tendency, of course, to give priority to short term problems to be solved immediately. *Secondly*, each activity to tackle these problems includes costly measures, which are politically and administratively unattractive. Moreover, legislation of these measures is often insufficient. *Thirdly*, current problems, hunger and poverty for example, are urgent and require all efforts, leaving little time and energy for the study, let alone the solution, of tomorrow's problems. Therefore conservation, maintenance and rehabilitation of natural resources are still far from being an important part of rural development policy.
Nevertheless, integrating the action programmes of rural development, agriculture, forestry, ecology and nature conservation is the only solution. Mr. Tolba, executive director of the UNEP, suggested the same this year. He considered land use planning as *one* way of finding a solution. Land use planning can result in rational land management, influencing environment as well as use of natural resources and living conditions of the population.

Forestry is familiar with long term planning, natural and semi-natural ecosystems and economical problems such as production and marketing. Therefore in rural development forestry is particularly qualified to function as a bridge between agriculturists and ecologists.
The initiative of IUFRO and ISSS to organize this Workshop on Land Evaluation for Forestry was well taken. The FAO framework for land evaluation provides a sound basis for the procedures to be applied for agricultural development. It includes not only agrotechnical aspects, but also the socio-economical characteristics of the region to be developed and the ecological impacts and consequences of the land use. It is very worthwhile to study possible modifications of this framework adapted to forestry with its long term effects on the ecological and hydrological situation of specific regions.
I welcome this initiative because it brought together the various specialists in forestry - ecologists, economists, operation experts, silviculturists - with the specialists in soil and land use. These experts have to

supply the information so that politicians and administrators become aware of the consequences of the decisions they do or do not take, regarding land use and land use planning in their countries. I hope the study and discussions will be fruitful.

There is one remark to be made. As I explained before, rehabilitation of the environment and prevention of further land degradation is especially urgent in the tropical countries. Therefore, since our colleagues from these countries have the toughest job, they might be most interested in the progress made in this field. May I suggest to send the important workshop results to these colleagues, as far as they are not represented here.

May I conclude, Mr. Chairman, with a personal remark. Having practiced both forestry and soil science, I became familiar with quite a peculiar *difference* in approaches between foresters and soil scientists, both involved in site classification. The forester was always inclined to first look *upward* to the tree tops, the soil scientist *downward*, digging into the soil. I hope the participants of this workshop can find a way to do *both*. In land evaluation looking upwards to the trees and downwards to the soil is apparently the best way to see the future of our Mother Earth.

I wish you all success and I am happy to declare this workshop open.

1.2 Welcome address by Dr.Ir. W.G. Sombroek, Secretary-General of the International Society of Soil Science

Mr. Chairman, esteemed representatives of the Dutch Ministry of Agriculture and of IUFRO, participants of this workshop, ladies and gentlemen,
it is my great pleasure to say a few words of welcome at this International Workshop on Land Evaluation for Forestry on behalf of the Executive Committee of the International Society of Soil Science (ISSS), one of the organisers.
For those of you not familiar with this soil science organisation, I would like to mention that it is a society of persons and institutions engaged in the study and the application of all aspects of soil science. The society exists nearly 60 years and now has a membership of about 7000 soil scientists from practically every country of the world. It has seven standing commissions, each dealing with a major branch of soil science, namely soil physics, soil chemistry, soil biology, soil fertility and plant nutrition, soil genesis, classification and cartography, soil technology, and soil mineralogy. Each of these commissions may have ad-hoc working groups on subjects that merit special attention.
Land assessment for its productive capacity is as old as Kain and Abel. As an applied scientific activity, it emerged in the early twentieth century and became known as land capability classification. In this monolithic system of land appraisal, areas of prime inherent quality were always to be reserved to grow annual arable cash crops. Viewing that forests would grow nearly everywhere and that their productivity would be small anyhow, land suitable for forestry was considered only at the bottom of the list of capability classes.
Understandably, forestry people went their own way, trying to safeguard the remaining natural forests and developing their own site and terrain classification methods for forest productivity. While soils and land development people tried to bring the farmer in, the forestry people tried to keep him out, in many countries resulting in a definite antagonism between forestry research or management organisations on the one hand and agricultural development organisations, including soil survey units, on the other hand.
Recently, however, some change for the better has taken place. The unique value of forests for land conservation and recreation has become widely

appreciated, and the productive capacity for fuel, timber, pulp and other products, has in its own right become increasingly acknowledged. Dr. Otto has already elaborated on this, especially with regard to developing countries.

The new idea of "agro-forestry" is to harmonise forest and crop functions of land in the tropics and to replace the predominant attention to arable crops in land capability classification by equal attention to all relevant kinds of land use through the development of a new methodology called "land evaluation".

The basic concepts for this methodology were developed in the early seventies by two closely cooperating interdisciplinary working groups, one in Wageningen and one at FAO, Rome. It drew on a number of new field procedures for land classification, notably those applied by the FAO staff in Brazil and Iran.

Precisely because of its interdisciplinary and multi-purpose character, without bias towards arable crop production, soil scientists and land use planners have gradually accepted the methodology as a suitable framework for application in very diverse circumstances, both in temperate regions and in developing countries.

It was therefore logical that in due course an official Working Group on Land Evaluation be created within ISSS, as part of its standing Commission on Soil Technology, to deepen concepts and promote application. With Prof. K.J. Beek as chairman and Dr. D.E. McCormack as secretary, it was decided to get together soonest with the forestry research people as united in IUFRO to explore possibilities for an effective scientific cooperation on "land evaluation for forestry". And here we are at the start.

I would like to take this opportunity, Mr. Chairman, to recommend another under-valued type of land use for future attention by the ISSS working group. Forestry may be as old as Adam in his paradise (the tree of life!), but his immediate offspring apparently had to deal with the harsh life of extensive grazing. For this "range management" type of land use, prevalent in many of the drier parts of the world, there is a definite need to harmonise concepts and procedures in land value assessment also.

There seems to be a fair chance that the tsetse fly infestation of so many parts of Africa will be overcome in the near future. Vast areas of potential range lands will then be opened up. An adequate methodology to assess the

range potential in comparison with other relevant uses of the land is highly needed. The ISSS land evaluation working groups, in cooperating with range management specialists and development organisations like FAO, may well want to take the lead in harmonising methodologies.
Now, ladies and gentlemen, returning to forestry, the subject of the day, I wish you a very successful workshop. Judging from the contents of the submitted papers, the elements for agreement certainly exist. Hopefully you will together arrive at some kind of manual of procedures to be followed in land evaluation for forestry, both in temperate and tropical regions. For the well-being of our Mother Earth and all her inhabitants, may this workshop mark the disappearance of any competition, replacing it with cooperation at all levels of research and development.

Thank you.

1.3 Welcome address and introduction by Ir. C.P. van Goor, Deputy Coordinator of Division 1 (Forest Environment and Silviculture) of the International Union of Forestry Research Organizations

On behalf of the International Union of Forestry Research Organizations (IUFRO), I am very delighted to welcome you to this Workshop on Land Evaluation for Forestry, jointly organized with the International Society of Soil Science.

For those among you who do not know IUFRO, I would like to very briefly explain its aims and organization. The main aim of IUFRO - a scientific forestry society of more than 80 years - is to promote international cooperation in scientific studies, embracing the whole field of forestry related research, including forestry operations and forest products. Among others, this aim is achieved by exchange of ideas among forest scientists, by encouragement of cooperation between member organizations, by promotion of dissemination and application of research results. Cooperation with other organizations, particularly the Food and Agricultural Organization (FAO) of the United Nations, is an important activity. On this occasion, we are very pleased indeed to also welcome FAO participation and contribution.

The IUFRO organization consists of six divisions, subdivided into research groups composed of working parties. Three divisions are cooperating in this week's workshop, namely Division 1: "Forest Environment and Silviculture", Division 3: "Forest Operations and Techniques" and Division 4: "Planning, Economics, Growth and Yield, Management and Policy". Both Prof. Bol and Prof. Plochmann, coordinators of Divisions 3 and 4 respectively, are participating in and contributing to this workshop.

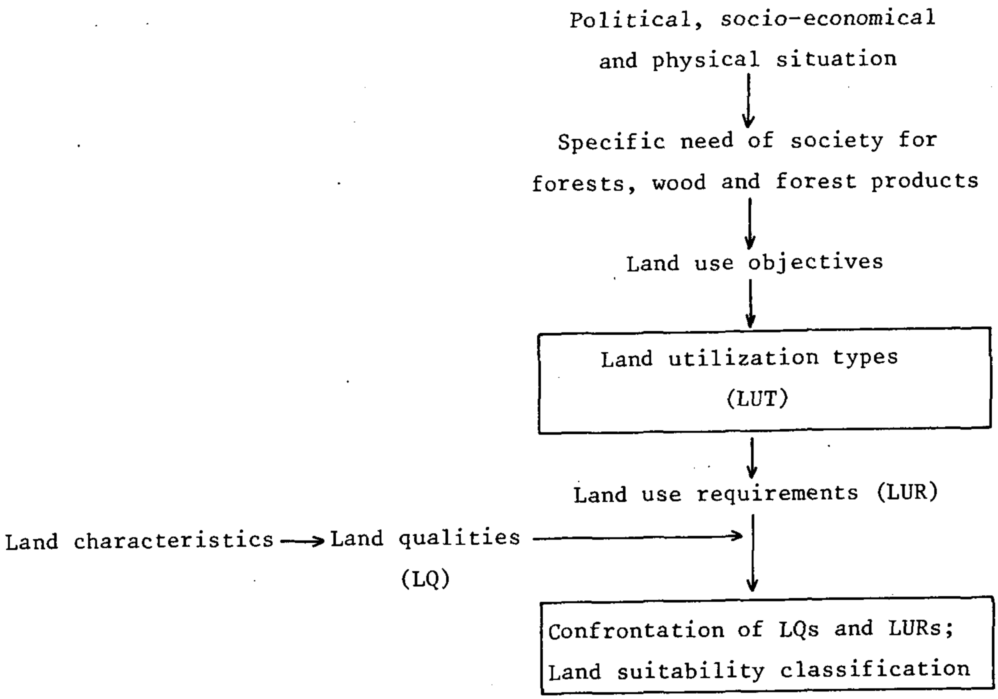
The idea to initiate activities in land evaluation for forestry has existed for a long time. Site classification, particularly directed to the relationship between growth of trees or stands and site, has been receiving ample attention within IUFRO since its beginning. Terrain classification, focusing on the relationship between terrain operations and conditions, has been in development since World War II. IUFRO members also cooperate on research regarding erosion and avalanches with respect to forestry and soil conservation. It is regrettable that, although requested, the IUFRO groups active in this field will not contribute to this workshop.

It was felt that this sectorial approach, aimed at a specific kind of "land classification", should be integrated, but the IUFRO project group, established to study this problem, did not succeed in finding the right way. After the FAO framework for land evaluation came into being, the perspectives for integration became more hopeful and realistic. This framework is fundamental and although it is mainly applied to agriculture, in principle it can also be used in forestry. However, the specific ecological characteristics of a forest, such as being part of the land and having long production processes, may create certain complications. Therefore it is of great importance that both IUFRO and ISSS pool their knowledge and experience to study adaptation of this framework to land evaluation for forestry. For many of us this will be an experiment and the organizing committee is grateful that a number of you were willing to give your opinion on land evaluation for forestry in view of your specialization.

Land evaluation for forestry is, if I may use my own words, a systematic approach to the process of fitting forestry into the land use planning of a certain country or region. That "certain" country or region is essential. Its political, socio-economical and physical conditions determine the specific needs of its society for forests, wood and other forest products. These needs are not only related to the removable produce, but also to the significance of forests for an efficient land and water management of watersheds or even larger regions.

Subsequently those specific needs are translated into land use objectives. Based on these objectives and the overall physical conditions of the regions, land utilization types (LUT) for forestry are defined. These LUTs, derived from the land use objectives and at the same time specific for the land use requirements, are the centre-piece of the land evaluation process. The land use requirements refer to growth, operations and sustained maintenance of forest ecosystems. In the accompanying table this process is given schematically. The land use requirements of the relevant LUTs are confronted with the qualities of the land. Through this confrontation the suitability of the land for the relevant LUTs can be concluded.

Simplified scheme of the process of land evaluation for forestry.



I have given this schematic and very simplified synopsis of the land evaluation process to assist us in staying on the right track during our discussions of the coming days.

I hope this workshop will be successful and bring us a bit further in the field of forestry, land evaluation and land use planning.

2 CONCLUSIONS, RECOMMENDATIONS AND ACTIONS

2.1 Introduction

The conclusions and recommendations stated below were arrived at as follows:

a. Each presentation of papers was followed by a discussion covered by appointed rapporteurs (Monday through Wednesday, November 10-12).

b. On the basis of their reports, a recommendations committee consisting of FAO representatives, session chairmen, rapporteurs and the organizing workshop committee, drew up a list of recommendations and other remarks for one or more of the following subject groups:
   - strategy and objectives for follow up;
   - basic data collection; relationships between land characteristics and land qualities, between land qualities and land use requirements; monitoring of land qualities; functional land classification and descriptive land evaluation;
   - identification and definition of actual as well as prospective land utilization types and land use systems; prescriptive land evaluation with special reference to land use planning and multiple land uses (overall land suitability criteria); application of land evaluation to forest planning and management;
   - conservation aspects and ecological constraints of land evaluation.

c. A separate discussion group dealt with each of the above subject groups (Friday morning, November 14).

d. The conclusions and recommendations resulting from these group discussions were presented, commented on and approved in a plenary session of the workshop, conducted by Prof.Dr.Ir. A.P.A. Vink (chairman) and Ir. P. Laban (secretary) (Friday afternoon, November 14).

2.2 General conclusions

- The effort to develop and apply a systematic and logical approach to land evaluation is justified by the observation that in many cases the actual land use situation does not correspond with the desired land use.
- For a better understanding of land classification systems used in different parts of the world terminology and approaches must be

standardized. For forestry, the concepts of land evaluation can be used to improve communication, leading to further progress in classification and evaluation, and to make possible comparison between forestry and other land uses.

- Land degradation, deforestation, and increasing scarcities of fuel wood, pulp wood, timber and other forest resources and products are becoming more and more a problem on a world-wide scale. The workshop emphasizes the need for integrated approaches to find solutions in which forestry has to have its proper part.
- In view of these problem areas and other specific aspects of forestry (such as long rotations, multiple use objectives, etc.), there is a world-wide need for comprehensive planning regarding forestry at all levels of generalization.
- A land evaluation approach, as discussed in this workshop, can be considered as a useful tool to collect and analyze data within a continuous land use planning process.
- It is necessary, however, to define within which historical, administrative, political, socio-economical and legal context land evaluation is applicable.

2.3 General recommendations

- The workshop recommends that the role of land evaluation within the overall planning process be studied and clarified at specific levels of detail.
- Due to the increasing need for fuel wood, it is recommended that action be taken in the field of energy supply, forestry and rural development. The workshop recommends land evaluation studies as a base for such activities and to be integrated in concerning programmes.
- The workshop recommends that special guidelines on land evaluation for forestry be prepared (see 2.5).
- The workshop recommends that research and development in the fields of site and terrain classification as well as in forest management planning be coordinated and integrated.

- The workshop recommends IUFRO to revitalize the activities of their interdivisional Project Group P1.02-00, Land Classification, emphasizing land evaluation approaches.
- The workshop recommends close cooperation between IUFRO and ISSS on land evaluation by establishing a Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry (see 2.4).
- The workshop recommends the following international agencies: IUFRO, UNEP, UNESCO, MAB, ICRAF, ECE, OECD, International Development Banks, other multilateral and bilateral development aid organizations and particularly FAO and its related working commissions
  - to encourage development and application of land evaluation methods as an accepted integral part of land use planning;
  - to promote testing of land evaluation methodology in specific case studies, especially in the Third World countries.
- To achieve an integrated methodology of land evaluation for forest land use planning, the agencies concerned should give special attention to close cooperation between foresters, soil scientists, socio-economists and land evaluation specialists.
- The workshop recommends professional organizations in soil science and forestry to join their efforts and activities at a national level to achieve a common approach to land evaluation for forestry.

2.4 Establishment of a Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry

- The workshop recommends the Executive Boards of the International Union of Forestry Research Organizations (IUFRO) and the International Society of Soil Science (ISSS) to consider the establishment of a Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry.
- The workshop recommends that the Dorschkamp Research Institute for Forestry and Landscape Planning and the International Institute for Aerial Survey and Earth Sciences initiate the activities of the above mentioned joint working group.
- The workshop expresses the hope that temporary organizational and financial support can be found in the Netherlands to enable an early start of the activities of such a joint working group. More permanent

arrangements on an international basis, however, should be pursued, possibly with FAO cooperation.

- The activities of the Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry should be based on a working plan (see 2.7).

2.5 Preparation of guidelines on land evaluation for forestry

- The workshop recommends the Food and Agricultural Organization (FAO) of the United Nations to consider the preparation of guidelines on land evaluation for forestry.
- Such an activity should be strongly supported by the Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry.
- To develop such guidelines, the following four-step effort is recommended:
  a. preparation of a preliminary draft methodology for land evaluation for forestry;
  b. examination of the draft methodology and necessary improvements by a special working group;
  c. testing of the methodology (guidelines) in a number of case studies in a wide range of physical and socio-economical conditions;
  d. revision of the methodology, according to feedback from test projects and dissemination of this for wider use.
- In a publication of above guidelines, attention should also be paid to those forms of forestry that are of special interest to rural community development.
- Such guidelines should be developed within the "Framework for land evaluation" (FAO Soils Bulletin no. 32, 1976, Rome).

2.6 Technical recommendations and conclusions

2.6.1 On data collection and monitoring

- There was general agreement that an integrated approach for environmental surveys is required to facilitate more comprehensive planning and management.
- The integrated holistic approach to land inventory is being applied with increasing frequency around the world. It allows organization of

complex ecological information in hierarchical systems in a taxonomic as well as a mapping sense. Experience by government agencies and the FAO demonstrates that the various planning and management levels (world, national, regional, local, etc.) can be effectively served by comparable land inventory levels.

- Monitoring is an important land evaluation aspect.

2.6.2 On land, land characteristics, land qualities and land use requirements

- It is recommended that existing inventories and surveys, including site-, terrain classification and integrated land inventories, be interpreted to determine their relationships to land qualities.
- It is recognized that more research is needed in
  a. better defining the relationships between land characteristics and land qualities;
  b. evolving a checklist of land qualities important for forestry, which should also include the relationships between vegetation and land qualities;
  c. better defining the relationships between land qualities and land use requirements of land utilization types; in this context productivity ratings should also be investigated.

2.6.3 On the difference of land evaluation for forestry or agriculture

- Land evaluation for forest and non-forest areas is similar, but some parameters are different.
- The applicability of the Framework for land evaluation to forestry should be ascertained. Several concepts, such as land characteristics, land qualities and land utilization types (LUT), as defined by Beek (1978, p. 331), are considered appropriate for forestry purposes.
- The fact that forests can have a rotation length longer than a human life-span should be considered.

2.6.4 On land utilization types for forestry

- Usually the LUTs for a man-made forest will be different from those for a natural forest, even if the objectives are similar.

- LUTs should be formulated for production (timber, firewood, etc.), conservation, recreation and other objectives, although it is often possible and necessary to devise multiple LUTs combining several objectives.
- The definition of LUTs should specify the forest produce and resources to be obtained from the land. Such a definition may be made at different levels of generalization.
- These generalization levels will influence data and the detail needed for land evaluation.
- Recognizing that LUTs might change in the future, the following points are pertinent:
  a. The purpose and procedure may within an existing forest ecosystem be changed for a given stand, although most aspects of the ecosystem are retained. This will result in a change in the LUT.
  b. Human intervention in forests and related ecosystems has to leave room for changes of the LUTs in the same forest and ecosystem by future generations.
  c. Alternative LUTs should be defined for future land use planning decisions.
- Procedures for selecting and defining LUTs for forestry should be tested.

2.6.5 On LUTs and ecosystems

- The workshop expressed the need for a clear distinction between the concepts of ecosystems and LUTs.
- Although both concepts relate to land (see FAO definition), LUTs are defined for management objectives and therefore are more appropriate for planning purposes.
- In defining LUTs, however, existing knowledge of forest ecology should be taken into account.
- LUTs have to include considerations of ecological dynamics and stability, land degradation and land improvement.

2.6.6 On land conservation

- Forest conservation is defined as follows:
  management of forest land to achieve a set of management objectives,

including maintenance or improvement of production on a sustained basis, environmental protection and maintenance of genetic resources.

- Conservation of land and forest should be an integral component of every LUT, although individual LUTs can emphasize specific land conservation objectives.
- There is a need to determine how to incorporate land qualities related to land degradation and other environmental impacts in the land evaluation process.
- There is a need for an integrated approach combining forestry, soil science, ecology, economics and sociology to respond to the world problems of land degradation, deforestation and increasing scarcity of forest products.

2.6.7 On management of forest ecosystems and ecological constraints

- Management should take account of ecological constraints, particularly regarding the effects on land qualities of rotation length, harvest intensity, site preparation, period without soil cover, intensity and type of mechanization and other silvicultural practices.
- Application of management of forest ecosystems must regard the dynamics of these ecosystems as well as its impact on the environment as a whole, particularly to:

  a. the potential for changes in ecosystems, e.g. canopy structure, species composition, and other physical, chemical and biological conditions;
  b. the potential for ecological flexibility of LUTs to be able to respond to changes in society's needs;
  c. the effects of treatments on off-site values and adjacent ecosystems; the interrelationships between ecosystems;
  d. the potential for natural catastrophes such as erosion, land slides, floods, desertification, etc.

- Monitoring the effects of forest management practices in both short and long term for natural forests as well as forest plantations should be highly emphasised.

2.6.8 On land evaluation and land use planning

- Land evaluation should be viewed as an integral part of the overall land use planning process for forestry, although its precise role in this process should still be studied and clarified.
- In some cases, however, it may be desirable to evaluate land strictly in terms of physical qualities. The result may eventually be used for political decisions to change the legal and administrative constraints in view of current and future needs of society.
- More study should be given to the definition of overall land suitability criteria to serve overall development objectives.
- The results of land evaluation should be presented as simply as possible for use in planning.

2.7 Working plan of the Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry

2.7.1 Objectives

To encourage development and implementation of land evaluation methodology as an accepted (integral) part of the land use planning process is an important objective of the Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry.

More detailed objectives are:

a. standardization of approach and terminology;
b. coordination and encouragement of research and development in land evaluation for forestry;
c. establishment of priorities related to research and development and to applications in developing countries;
d. methodology tests and demonstrations;
e. dissemination of information on land evaluation, emphasizing benefits and cost of land evaluation;
f. encouragement of training programmes and activities at all levels related to land evaluation.

2.7.2 Outputs

a. A *series of reports* related to land evaluation for forestry, including case studies, will be promoted. Such reports will be considered as volumes within a "Land Evaluation for Forestry" series. However, the individual volumes of such a series do not necessarily have to be published by the same institution. The proceedings of this workshop will be the first volume in the series.

b. An overview report on the *role of land evaluation in land use planning*, in non-technical language for an outside readership of planners, with reference to specific intensity levels and to specific geographic and political considerations will be made.

c. The preparation of *guidelines on land evaluation for forestry* will be supported (see 2.5).

d. *Priorities for research and development* (reporting to IUFRO, ISSS, FAO, etc.) will be reviewed periodically.

e. A *bibliography* on land evaluation for forestry will be prepared.

f. *Contributions to future meetings* of ISSS, IUFRO, FAO and other organizations will be made.

g. An international network of *pilot studies* will be planned.

h. *Seminars* for land use planners and students will be organized.

i. An *international workshop* for land use planners and policy makers will be organized.

j. *Regional/national workshops* on the topic of land evaluation for forestry will be encouraged.

2.7.3 Organization

Provisional suggestions to consider to arrive at more precise proposals for a Joint IUFRO/ISSS Working Group on Land Evaluation for Forestry, are given below:

a. *A permanent secretariat*

To enable such a secretariat to start, representatives of the Dorschkamp Research Institute and the ITC are willing to explore possible sources of funds on a temporary basis. In the long run more permanent arrangements should be pursued, eventually under the auspices of an international organization as FAO.

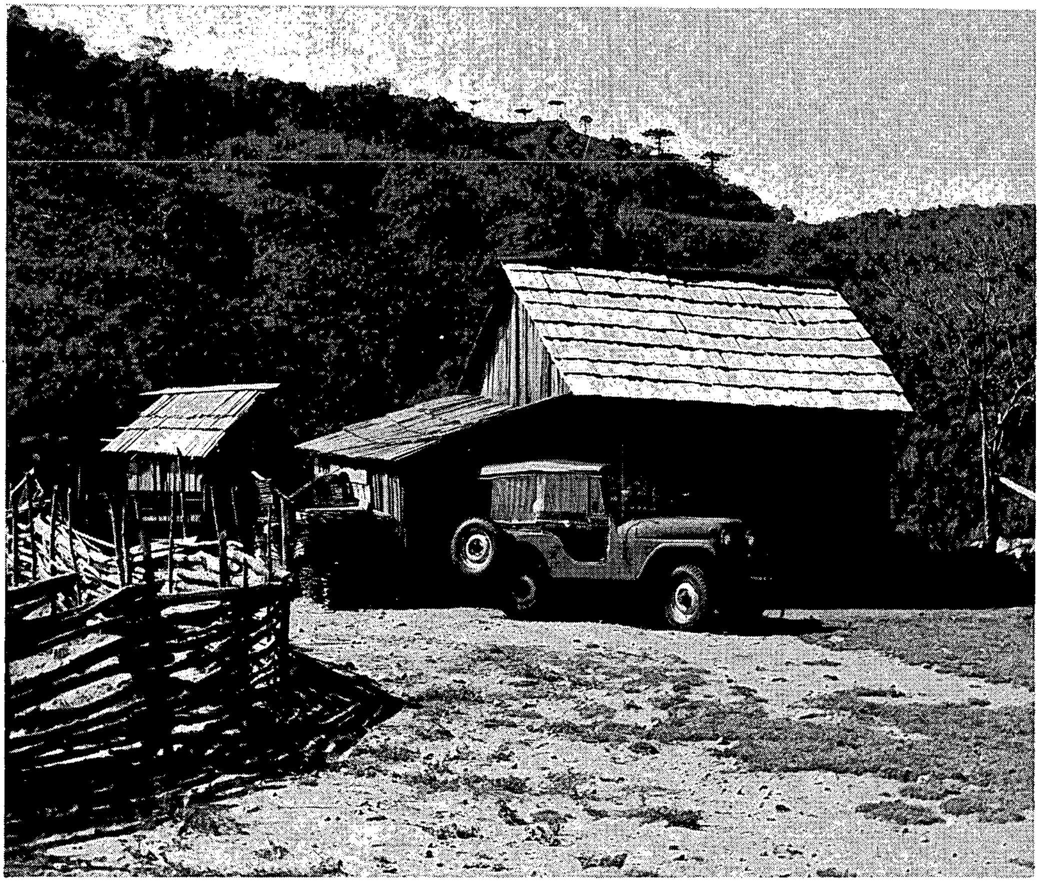
b. IUFRO and ISSS should be the initiating bodies sponsoring such a working group and its secretariat.

c. The IUFRO Project Group on Land Classification (P1.02-00) should be reconvened.

d. This IUFRO project group together with the ISSS land evaluation working group could be the executive bodies for IUFRO and ISSS.

e. IUFRO and ISSS members interested in this topic should be listed in a directory.

f. There should be close contact between the two chairmen (IUFRO and ISSS) of this working group.



Conflict between forestry, agriculture and grazing in Southern Brazil.

3 PAPERS PRESENTED AT THE WORKSHOP

3.1 Papers on "The state of the art"; Session 1, November 10, Monday

<u>"Dynamics of forest ecosystems"</u>

Chairman: I.S. Zonneveld; Rapporteur: P.J. Wood

- R.M. Lawton
  Dynamics of forest ecosystems in relation to their utilization; subtropical and tropical regions
- D.C. Malcolm
  Dynamics of forest ecosystems in relation to their utilization; north temperate zone

DYNAMICS OF FOREST ECOSYSTEMS IN RELATION TO THEIR UTILIZATION; SUBTROPICAL AND TROPICAL REGIONS

R.M. Lawton

Land Resources Development Centre, Overseas Development Administration. Tolworth Tower, Surbiton, Surrey, England.

Summary

An ecosystem is defined. Natural forest ecosystems are traditionally considered to be land available for agricultural development. The social, economic and political attitudes to forest land are discussed. The dynamics of the forest canopy are considered to be the key to the ecology of the forest and management is the ability to manipulate the canopy in order to obtain natural regeneration of valuable timber species. Intensively supervised research (Kennedy, 1935; MacGregor 1934) achieved successful regeneration, but could not be applied on a large scale. The history of the Tropical Shelterwood system and Selection System of management is reviewed. The taungya system and enrichment planting is described. Forest plantations are discussed and the different methods of management in terms of LUT's are considered.

The ecology of miombo, *Brachystegia-Julbernardia* woodland and its utilisation for charcoal and timber is described. The value of woodland ecosystems in semi-arid and arid regions to stabilise sand dunes, to condense mist and to protect the environment and agricultural crops are discussed.

Introduction

Although the concept of an ecosystem was recognised last century, the term was introduced by Tansley (1935) and has since been used and modified by a number of workers including Duvigneaud (1974). In a discussion on land evaluation for forestry in terms of ecosystems, an ecosystem may be defined as: "a unit of vegetation that consists not only of the plants of which it is composed, but the animals habitually associated with them, including man, and all the physical and chemical components of the immediate environment, or habitat, which together form a recognisable entity".

An area of natural forest is an ecosystem, so is a timber plantation, a cocoa, oil palm or rubber plantation, or a plot of yams or plantains; all of these are man-made ecosystems derived from the forest. This paper is mainly concerned with forest ecosystems, that is natural forests and man-made plantations for the production of timber and other forest resources. Ecosystems however cannot be considered as self-contained entities. There is an exchange of energy between them and they are inter-dependent, for example, a forest ecosystem on a catchment area will reduce erosion and regulate the water supply to agricultural ecosystems on lower slopes and in the valleys. In the terminology of the FAO framework for land evaluation, the different forms of management of natural forest ecosystems will be described as different Land Utilization Types, and the man-made forest plantations (i.e. derived ecosystems), will also be different Land Utilization Types. The objective of land evaluation is to determine the most suitable Land Utilization Type (LUT) for forestry with particular reference to the multiple use of forest resources.

With this background it is proposed to discuss the dynamics of the tropical high forest ecosystems first, followed by the open forest or woodland ecosystems of the seasonally dry tropics, and finally, the woodland ecosystems of the semi-arid and arid tropical regions. But first of all it is necessary to consider the social, economic and political aspects that affect forest utilisation, because these factors sometimes raise problems that are more difficult to solve than those of an ecological and silvicultural nature.

Social, economic and political aspects

An area of natural forest is traditionally considered to be a piece of land waiting for development. The cultivator knows that if he clears an area of natural forest he will obtain good agricultural yields for a few seasons, this is because he is utilising the organic matter and nutrient capital built up by the forest. If the wishes of the local community are considered, it is almost certain that the remaining areas of natural forest would ultimately be cleared and utilised for agriculture.

Fortunately many tropical countries have established a forest estate that includes the protection of forest cover over catchment areas, and the reservation of some lowland forests that are rich in economic timber species. With increasing human population pressure there is a demand for the release of forest land for agriculture, and it is necessary for the central government to have control over the forest estate, even though the land may be under tribal ownership. This may lead to unpopularity and there is a risk that forests may be used to obtain political gain. Forests are part of the national heritage and they should not play a role in the field of party politics.

Under traditional form of "slash and burn" or "swidden" agriculture, forest and woodland regrowth is the fallow crop. Even mature stands of tropical forest often bear evidence of ancient human occupation (Jones 1950). Nowadays secondary forest regrowth is cleared and recultivated after only a few years. Eventually a planted leguminous fallow crop will probably replace the natural forest fallow in the agricultural system.

It is difficult, probably impossible, to assess the economic value of some of the attributes of the natural forest. The hardwood timbers are of course of considerable value and as they become rarer their value will increase. The protective role of forests in catchment areas and on steep slopes cannot be assessed in economic terms. They reduce soil erosion and ensure that rainfall feeds the watertable that supports agriculture. The forests yield wild fruits, leaves, fungi, snails, caterpillars, small mammals, honey, drugs and medicines etc., all of which form part of the cultural heritage of the local community. The value of forests plants in the field of homeopathic medicine is still largely unknown.

Apart from countries like Nigeria, that has its own oil resources, the energy crisis has created economic difficulties in some of the poorer tropical countries. Kerosene, oil and electricity are now expensive and it is necessary to use firewood and charcoal for domestic purposes. The fast-growing pioneer and secondary species of the tropical forest, in particular *Musanga cecropioides* and *Maesopsiseminii* in Africa, *Cecropia* spp. in South America and *Macaranga* spp. in Southeast Asia, are potential sources of fuel and charcoal.

Recent technological advances, particularly the introduction of the chainsaw that has replaced the axe, have made it easier to clear the natural forest and therefore remnant patches of forest are at risk.

All these factors form the background to a discussion on the dynamics of tropical forest ecosystems.

The dynamics of tropical high forest ecosystems

The key to the ecology of the tropical high forest is a knowledge or understanding of the dynamics of the canopy. Under natural conditions the over mature canopy emergent dies and may disintegrate in situ, gradually shedding its crown and main stem. As the light reaches the forest floor, seedlings of pioneer, secondary and economic species and climbers become established and occupy the gap. Sometimes the over mature dominants and emergents are thrown by the wind and create large openings in the canopy, which may then be colonised by fast growing light demanding pioneer species, or by climbers, or by a combination of both depending upon the chance availability of seed.

Fruit bats feed off the catkins of *Musanga cecropioides*, one of the West African pioneer species, and distribute the seed over the gaps in the canopy. Some of the light demanding secondary species like *Terminalia ivorensis* and *Triplochiton scleroxylon* have winged fruits that are distributed by the wind. Seed of the valuable timber trees that belong to the genera *Khaya* and *Entandrophragma* are released from capsules and dispersed by the wind. Both *Khaya* spp. and *Entandrophragma* spp. require shade during the early stages of development, so conditions favour their establishment under the light canopy of the secondary species, but once they have reached the sapling stage they require full light in order to grow up into the canopy.

The climbers may form a tangle or dense carpet over the whole of the gap (Jones 1950), but eventually some of the secondary species will find a way through the climber tangle, and will shade out the climbers. Favourable conditions will then be created for the natural regeneration of the valuable timber trees.

In the past elephant have played a role in the ecology of the tropical forest. They may create gaps by pushing down some of the understorey trees, or they may open up the climber tangles so releasing the suppressed secondary species. When their migratory routes are closed through agricultural development and the elephant is confined to the forest, they may become destructive as was the case in the Budongo forests of Uganda (Eggeling 1947).

The management of tropical high forest ecosystems

If the key to the ecology of the tropical high forest is a knowledge of the dynamics of the canopy, then the key to management will be the ability to manipulate the forest canopy in order to obtain natural regeneration of the valuable timber species.

In the 1920's and 30's some silvicultural experiments were carried out in the forests of Nigeria. Kennedy (1935) started by clearing an area of *c.* .8 ha around the stumps of exploited trees, but regeneration failed to colonise the gaps. He then decided to attempt to establish regeneration around standing trees which were below the minimum exploitable girth (2.4 m), but sufficiently mature to produce seed. The selected trees were kept under observation until they were seen to be in flower. The undergrowth, climbers and a number of understorey trees were then cut, opening up a gap of *c.* .8 ha. All the branchwood and debris was removed from the parent tree and left to dry and rot a little before burning. The direction of the prevailing wind was noted during seed-fall and the gap was opened to *c.* 1.6 ha to provide a natural seed bed.

Triplochiton scleroxylon, a light demander, was one of the species under investigation. It comes into seed just before the harmattan, a dry wind that blows from the north, and the young seedlings require light overhead shade to protect them from dessication. The shade will consist mainly of herbaceous forest floor plants which will be completely removed by weeding as soon as the harmattan is over. A few months later the seedlings are thinned to about a density of 1 m × 1 m and later a second thinning to 2 m × 2 m is required. Where natural regeneration failed, seed or transplants, were dibbled or planted in the gaps.

The *Meliaceae* (*Khaya*, *Entandrophragma* and *Lovoa*) are in seed during the rains. The young seedlings will tolerate shade, but they require freedom from overhead shade once they have reached the sapling stage (Jones, 1956).

Kennedy succeeded in establishing large groups of natural regeneration of these valuable timber species. MacGregor (1934) carried out similar experiments in the mixed deciduous forests of Nigeria and was successful. The research undertaken by Kennedy and MacGregor was intensively supervised by experienced foresters. Each stand of natural forest is unique. It has its own combination of species and its own structure. It requires individual and skilled management by foresters with a knowledge of the autecology of the main species and a knowledge of the synecology of the forest.

It is difficult to apply intensive methods of management on a large scale and in the late 1940's it was decided to try the Tropical Shelterwood System (TSS) of management in West Africa. The TSS had already been practiced successfully for some time in Southeast Asia.

The aim of the TSS is to open the canopy and establish natural regeneration of the desired species before exploitation. The objective is to let sufficient light on to the forest floor to obtain regeneration, but not to encourage a dense growth of climbers and weeds. Climbers, particularly *Acacia pinnata* and *A. ataxacantha* are light demanders and it has been noted that they quickly colonise gaps and may form part of the natural succession back to high forest (Jones 1950, 1956). A gradual canopy opening may favour tree growth at the expense of the climbers.

A series of operations was laid down and amended in the light of experience (Lancaster 1961). Treatment started with a climber cutting six years before exploitation, this was followed by a gradual removal of understorey trees by poisoning and a second climber cutting. Weeding or freeing any natural regeneration followed. After exploitation there was a series of cleaning or weeding operations. Details are given in the review of the TSS by Baur (1964). In some forests the TSS was successful, Gutzwillen (1956) reported satisfactory regeneration of *Mansonia* and *Entandrophragma* after seven years of TSS treatment in the Bobiri Forest Reserve, Ghana. Regeneration of *Terminalia* and *Triplochiton* was often successful, but there were many failures. Competition from climbers and fast growing weeds suppressed regeneration. It is unsatisfactory to apply a routine system of management to a forest that requires individual and intensive management. The TSS has now been abandoned in most countries.

A modified selection system has been practiced for some years in the forests of Ghana (Baidoe 1970, 1972). The object is to increase the survival rate and the development of immature valuable timber trees. Only forests with a stocking of approximately 22 immature (2 m girth) merchantable trees per hectare are treated. The initial operation is a stock survey to determine whether the forest is suitable for treatment. If the stocking is satisfactory, climber and unwanted tree species are cut to free the valuable species from competition. The forest is exploited on a 15 year felling cycle, but there is no provision for establishing natural regeneration under this system. It has been suggested that 'permanent' sample plots should be established to measure yields, natural regeneration and the effects of silvicultural treatments (Baidoe 1972, Palmer 1975), these plots already exist on some of the old research stations.

Sometimes the forest is resilient and regenerates following exploitation without any treatment. The Benin forests in Nigeria were exploited in the mid 1920's and Onyeagocha (1962) reported a high stocking of valuable timber trees forty years later, although there were also climber tangles. The *Lovoa swynnertonii* forests of Kenya (Plate I) have been exploited and the gaps have been colonised by *Maesopsis eminii* (Plate 2). Under the light shade of the *Maesopsis* canopy there are seedlings and saplings of *Lovoa* and the other forest dominant *Newtonia buchanani*. This forest is capable of regenerating without any form of cultural treatment or management.

Artificial regeneration of the tropical high forest

1. Enrichment planting

Various methods have been used to enrich poorly stocked, or heavily exploited natural forest. Line planting has been tried, but the young trees are frequently destroyed by browsing, or suppressed by weeds. Rarely has the method succeeded.

The Anderson group method (placeaux Anderson) was tried at Yangambi in Zaire (Dawkins 1955). A small plot 4 m × 4 m was cleared completely and planted or sown at a spacing of 1 m × 1 m. The central nine plants in the group of 25 grow straight and are kept free from weeds and climbers. The group will need weeding around the edge for the first few years. Eventually one of the central trees will become dominant. The method has succeeded; the groups were visited in 1975 and well grown trees were found in many of them (Pierlot pers. comm.). The system simulates the small natural gaps that occur when an over mature tree dies. A large number of groups could be established to enrich the forest and provide a sustained yield of valuable timber.

2. Agri-silviculture or taungya method

The taungya system has been practiced in West Africa for many years. A farmer, a group of farmers, or a village is allocated a block of forest to clear and cultivate. At the same time the Forestry Department plant out saplings of valuable trees at a spacing of 20 m × 20 m. The cultivators tend and weed the trees during the period of cultivation which may cover two, three or more years. Once the trees are established and their crowns begin to form a light canopy, cultivation will cease, and the cultivators will be allocated another block. The system has been practiced successfully in Ghana with *Terminalia* spp. *Triplochiton*, (Plate 3) and the *Meliaceae*, although a shoot borer may deform some of the stems of the *Meliaceae*. In Zaire *Terminalia superba* has been successfully raised in banana taungya (Dawkins 1955). Bananas are a good nurse crop for trees. Root crops like cassava and yams are unsuitable because harvesting may damage the tree roots.
The taungya system works well where there is a shortage of land for the cultivation of food crops. The situation in Nigeria has been reviewed by Olawoye (1975), and Kio (1972) has suggested that planted tree crops, like the fast growing *Gmelina arborea* should be grown as a fallow crop between periods of cultivation.

3. Plantations

Where the natural forest contains no valuable timber trees it may be necessary to establish plantations. In fact over the past ten to fifteen years many countries have abandoned any attempt to manage their natural forests and have concentrated their resources on creating plantations. Where there is a demand for fuel and charcoal there may be a case for *Eucalyptus* spp. and *Gmelina* plantations, but the pioneer and secondary species in the natural forest could also be exploited for this purpose (Earl 1975). *Triplochiton scleroxylon* and *Terminalia ivorensis* are two indigenous species that have been used in plantations. It has been found that *Triplochiton* can be propagated from young healthy leafy stem cuttings, so the most favourable provenances can be selected (Jones 1969, Jones and Howland 1974). Monoculture plantations can lead to problems; in Ghana, plantations of *Terminalia ivorensis* begin to die before they reach the age of 30 (Ofosu-Asiedu and Cannon 1976). The leaves become chlorotic and small and the crowns die-back. Research by CTFT and ORSTOM have shown that plantations of this species die at between 12-20 years; nitrogen mineralisation in the litter is completely inhibited. A leaf extract from *T. ivorensis* was found to inhibit nitrogen mineralisation in the soil (UNESCO 1978). Although *T. ivorensis* will grow in a species-rich natural forest it will not grow as a monoculture even in its own environment.

Forest management in terms of land evaluation

There are signs that there is a desire to attempt to manage the natural forest (Kio 1976, Palmer 1975). Where the natural forest has a stocking of at least ten valuable timber trees per hectare, below the exploitable girth limit, but with some of them mature enough to produce viable seed, it may be possible to establish regeneration under the Kennedy system, possibly with modifications to include a 15 year felling cycle and the production of charcoal from the understorey trees. Provided of course that there are foresters who will be able to carry out the intensive supervision that this method requires. This may be the most favourable LUT for such natural forest ecosystems.

Where the forests are poor in economic species, whether through failure to establish natural regeneration, or due to heavy and destructive exploitation, it is suggested that the Anderson group method should be applied. This method simulates the dynamic ecology of the natural forest ecosystems and was successful in the only area where it was known to have been tried. Although the method will be new to many foresters, it is fairly simple and should not be difficult to introduce. It is recommended that this would be a suitable LUT provided the foresters and rangers are able to give it the intensive supervision and management it requires.

If there is a shortage of land for the cultivation of food crops outside the forest area or forest estate, the taungya system is likely to succeed. Under these circumstances it is recommended that this system would be the appropriate LUT for the establishment of a forest crop.

In the vicinity of large towns and cities there is a demand for fuel in the form of firewood and charcoal and plantations of fast growing trees like *Eucalyptus* spp., *Cassia siamea* and *Gmelina arborea* are required to meet this demand. These plantations are derived of man-made forest ecosystems, that require intensive management and under the circumstances are the most suitable LUT.

The protective role of natural forest cover in catchment areas and areas of steep topography, like escarpments, must be maintained and take priority over other forms of utilisation. The main objective is environmental protection in this LUT, but the forest will be a source of plant genetic material and wild fruits and all the other produce that can be collected from the natural forest. With skilled management it may be possible to extract a limited amount of timber from some catchment areas, provided the protective role has priority.

The dynamics of open forest or woodland ecosystems

In the seasonally dry tropics there are deciduous woodland communities or ecosystems. In Africa, miombo or *Brachystegia-Julbernardia* woodland forms a light closed canopy at a height of about 12-15 m. The equivalent in Asia is probably the Sal or *Shorea robusta* forests and the teak (*Tectona grandis*) woodlands, and in the cerrado of South America there are woodland communities that resemble those of Central Africa. In Central America the open pine savannas occur in the seasonally dry tropics.

Fire is an important factor in the ecology of these ecosystems and in Africa the presence of the tsetse fly has had an influence on their utilisation. Man has been associated with miombo for a very long time, particularly as a hunter-gatherer and as a cultivator. In fact it is difficult to discuss the dynamic ecology of miombo without including the effects of human activity, but there are areas where the concentration of the tsetse fly make it unsuitable for human occupation and these areas usually support wildlife populations, in particular, elephant. Elephant browse the miombo trees and open up the canopy by pushing down groups of trees. If the dry grass is burnt during the early part of the dry season, when the trees are dormant, the trees will not be destroyed and will regenerate through coppice regrowth. But if the grass is burnt during the latter half of the dry season, after the trees have come into new leaf, then they will be burnt back and if late fires are repeated for a few years, the miombo species will be destroyed. A fire-hardy type of open woodland known as chipya will replace the miombo woodland. Most fires are caused by man, particularly hunters, therefore man has had an influence on the regeneration of the natural miombo woodland ecosystem.

There is a natural succession from fire-hardy chipya vegetation back to the miombo woodland. Some of the species form colonies of coppice regrowth that provide ground cover and shade out the grass. Seedlings of *Brachystegia* spp. and *Julbernardia* spp. become established in this coppice cover and under its protection from fire they grow up through the sapling stage to form a woodland canopy. Once the saplings of the canopy species reach a height of about 4 m they can survive grass fires (Lawton 1978).

The management of woodland ecosystems

A specialised form of agriculture has evolved in miombo woodland and much of the woodland is part of the agricultural system. The crowns of trees over an area of about 2-4 ha are lopped (Plates 4-6) and the branches stacked into circular patches which are burnt just before the beginning of the rains (Plate 7). The small patch is cultivated for 3-6 years. The system is known as 'chitimene'. Ideally the woodland should be allowed to regenerate for a period of 20-30 years before it is lopped again, but due to human population pressure the fallow period has been reduced to a few years. Eventually the 'chitimene' system will give way to some other form of agriculture.

Mature stands of miombo are a commercial source of beeswax and honey. They yield wild fruits, caterpillars, fungi and wildlife, all of which are of economic and cultural value to the local rural population.

There is one valuable timber tree, *Pterocarpus angolensis*, scattered throughout the miombo. It is not lopped or cut when the woodland is being cultivated, but is slow growing and therefore unsuitable as a plantation tree. The tree is exploited mainly for the local market, and natural regeneration of *P. angolensis* should be freed from competition in the miombo forest estate. Where there are large human populations, like the copperbelt of Zambia and the Shaba Province of Zaire, miombo supplies charcoal and general purpose timbers for domestic use. It also supplies the copper mines with charcoal and smelter poles.

Eucalyptus spp. plantations have been grown to provide tobacco farmers with poles for their barns and fuel for curing.
Industrial pine plantations have been established on the copperbelt of Zambia. It has been observed that pine litter accumulates on the soil surface and is slow to decompose. The soil nutrients may be immobilised in the litter and this could lead to site degradation and a decline in productivity. Most of the plantations are still in the first rotation and so far there is no sign of a decline in productivity.
In Swaziland, which is south of the miombo zone, industrial pine plantations are being grown for pulp. These plantations are now in their second rotation and Evens (1980) who has monitored the growth rates in both rotations has found no decline in productivity.
Soil and site changes under conifer plantations in East Africa have been investigated by Lundgren (1978). It was found that the nutrient content under pine and cypress plantations was generally lower than under the natural forest. The soil structure deteriorates, although it may improve as the plantation grows older and a ground flora enters.

Management of miombo ecosystems in terms of land evaluation

Where there are large centres of population the miombo should be exploited for charcoal on a sustained yield basis. Coupes of woodland will be clear-felled at ground level, and early burnt each year to ensure natural regeneration through coppice regrowth. The rotation should be between 40 and 60 years. It may be possible to allow selected stems, including any *Pterocarpus angolensis*, to grow on for two rotations to reach timber size. This will be the most suitable LUT for the copperbelt of Zambia and other centres of population.
In addition the copper mines will require smelter poles which have to be fresh when they are utilised. The poles are fed into the smelter to oxidise the waste material in the molten copper. So the LUT for the mines will include the selection of fairly straight large poles for the smelters, and then the coupe will be utilised for charcoal.
In remote areas where the rural population is sparse, *P. angolensis* timber may be exploited and the woodland may be managed for beeswax and honey and perhaps for wildlife. Early burning will be required in this LUT.

The industrial pine plantations must be located near centres of population like the copperbelt and the line-of-rail. The plantations will need to be protected from fire. They will require the use of fertilizers and mechanised weeding, and will need intensive management. It is suggested that 'permanent' sample plots should be established in these man-made forest ecosystems to monitor growth rates in the first and subsequent rotations, and so determine whether there is any decline in productivity in this LUT.

The short rotation (4-6 year) *Eucalyptus* spp. plantations will form another LUT. Their aim is to provide poles and fuel for the tobacco farmers. The plantations will require fertilizers, particularly boron, mechanised forestry and treatment plants for the poles.

Where the miombo covers river headwaters, catchment areas and watersheds, the woodland cover should be maintained for environmental protection. This LUT can still be used for the production of beeswax and honey and other minor forest produce.

The ecology and management of woodland ecosystems in semi-arid and arid tropical regions

In the semi-arid and arid regions of Africa woodland ecosystems consist of open stands of trees in grazing land. In many regions it is stretching the concept to its limit to consider them as woodland ecosystems, they are grazing lands with a scatter of trees. But the trees are an essential part of the ecosystem and their removal has led to increased aridity. Trees provide shade, fodder, fuel, timber and some of the *Acacia* spp. in particular are a source of gum and honey.

On alluvial soils in the Sudan an agricultural system is dependent upon *Acacia albida*, which is leafless during the rains and comes into leaf at the beginning of the dry season (Robertson 1964, Radwanski and Wickens 1967). Bulrush millet is grown under the leafless crowns of the tree during the rains. It ripens as the tree comes into leaf at the beginning of the dry season. After the harvest, cattle eat the crop residues and feed off the *Acacia* pods which are rich in protein. The cattle remain under the shade of the tree and add organic matter to the soil.

A. senegal is a promising potential plantation tree. It can be grown on a 15 year rotation and will yield fodder, gum arabic and fuel (FAO-SIDA mission

1974). For the first five years the plantation should be protected from grazing and browsing. It can then be grazed and lopped for fodder, under control, and it will yield gum arabic. At the end of the rotation the trees can be felled for fuel and small timber. The land can then be cultivated for millet for a few years, before it is replanted with *A. senegal*.

There are sociological problems; it will be necessary to ensure that the nomadic pastoralists do not allow their stock to browse the young trees before they are well established, i.e. after five years of age. If plantations are to be successfully established in arid regions the cooperation of the local people is essential.

Trees play an important role in the stabilisation of sand dunes (Kaul 1970; Goor & Barney 1976). Natural stands of *Tamarix* spp. occur on the coastal dunes of Oman (Plate 8). Open stands of *Prosopis cineraria* in Oman stabilise the sand and are a source of fodder and timber (Plate 9).

Natural woodland ecosystems of *Anogeissus dhofarica* and *Commiphora* spp. on the south-facing escarpments in Dhofar, southern Oman, condense the mist that blows from the Arabian Sea during the monsoon (Plate 10). This is the main source of precipitation which may be as much as 500 mm per annum. The moisture feeds the springs (Plate 11) that supply water for the irrigation of agricultural crops on the coastal plain.

Even in the central desert of Oman, which is the southern limit of the Rub al Khali, *Tamarix* sp. condense the dew that falls during the night (Plate 12 & 13). This moisture feeds the tree and probably supports the desert fauna also. From these few examples it is clear that trees are essential for the maintenance of the environment in arid tropical regions.

Land evaluation for forestry in semi-arid and arid regions

Where soil conditions are favourable it is suggested that *Acacia albida* should be grown at a wide spacing, perhaps 20 m × 20 m. The land should then be cultivated and grazed as described in the previous section. The agricultural system is dependent upon the tree crop in this LUT.

Plantations of *A. senegal* and other *Acacia* spp. would be the most suitable LUT for many semi-arid and arid tropical regions. *A. senegal* on a 15 year rotation will yield timber and fuel as well as gum arabic, fodder for livestock and forage for honey bees. Sociological constraints must be overcome.

Where the watertable is within reach of tree roots, and this may be at a depth of 10 m in the case of *Prosopis cineraria* it is recommended that tree plantations should be established. It may be necessary to start the trees under irrigation, until their root systems have reached the watertable. This would be expensive and can only be considered in countries where funds are available.

Natural and man-made tree crops that are used to stabilise sand dunes, or condense mists, have an important effect on the environment and on other ecosystems. The primary role in this LUT is environmental protection, although controlled exploitation of the fodder and timber resource is possible. The large *Tamarix aphylla* grows to timber size on the dunes and could be exploited. The branches of *Anogeissus dhofarica* are used in house building, but only a small amount is cut, partly because the population is low.

REFERENCES

BAIDOE, J.F. (1970). The selection system as practiced in Ghana. Com. For. Rev. Vol. 49(2) No. 140 pp. 159-165.

BAIDOE, J.F. (1972). The management of the natural forests of Ghana. In: 7th World Forestry Congress (Buenos Aires, Argentina). CFM:1/4 E pp. 2510-2516.

BAUR, G.N. (1964). The ecological basis of rain forest management. André Mayer Fellowship 1961/62. FAO. p. 499.

DAWKINS, H.C. (1955). INEAC in the "Forest-Dense", impressions of some high forest research in the Congo. Em. For. Rev. Vol. 34 pp. 55-60.

DUVIGNEAUD, P. (1974). La synthese ecologique. Doin. Paris. p. 296.

EARL, D.E. (1975). Forest energy and economic development. Clarendon Press, Oxford. P. 128.

EGGELING, W.J. (1947). Observations on the ecology of the Budongo rain forest Uganda. Journal of Ecology. Vol. 34 pp. 20-87.

EVANS, J. (1980). Long term productivity of tropical plantations - an overview. IUFRO symposium on Fast Growing Trees - San Paulo, Brazil. p. 11.

FAO-SIDA MISSION (1974). Report on the Sahelian zone -FAO/SWE/SF117. p. 123.

GOOR, A.Y. and C.W. BARNEY (1976). Forest tree planting in arid zones. Second edition. The Ronald Press Co., New York. p. 504.

GUTZWILLER (1956). Principales pratiques sylvicoles en vue de la production de bois d'oeuvre en forêt dense equatoriale, Journal Forestier suisse No. 3. pp. 1-20.

JONES, E.W. (1950). Some aspects of natural regeneration in the Benin Rain Forest. Empire Forestry Review. Vol. 29 No. 2 pp. 108-124.

JONES, E.W. (1956). Ecological studies on the rain forest of Southern Nigeria. IV The plateau forest of the Okomu Forest Reserve. Journal of Ecology - Vol. 44 pp. 83-117.

JONES, N. (1969). Forest tree improvement in Ghana. Commonwealth Forestry Review. Vol. 48 No. 4 pp. 370-376.

JONES, N. and P. HOWLAND (1974). Report on West African hardwood improvement project. Commonwealth Forestry Review. Vol. 53 No. 3 pp. 190-194.

KAUL, R.N. (1970). Afforestation in arid zones. Monogr. Biol. 20 W Junk NV Pub. The Hague. p. 435.

KENNEDY, J.D. (1935). The group method of natural regeneration in the rain forest at Sapoba, Southern Nigeria. Empire Forestry Review. Vol. 14 pp. 19-24.

KIO, P.R. (1972). Shifting cultivation and multiple use of forest land in Nigeria. Commonwealth Forestry Review. Vol. 51 pp. 144-148.

KIO, P.R. (1976). What future for natural regeneration of tropical high forest? An appraisal with examples from Nigeria and Uganda. Commonwealth Forestry Review. Vol. 55 No. 4 pp. 309-318.

LANCASTER, P.C. (1961). History of TSS. Technical Note No. 12. Dept. of Forest Research, Nigeria. p. 11.

LAWTON, R.M. (1978). A study of the dynamic ecology of Zambian vegetation. Journal of Ecology. Vol. 66 pp. 175-198.

LUNDGREN, B. (1978). Soil conditions and nutrient cycling under natural and plantation forests in Tanzanian Highlands. Reports in Forest Ecology and Forest Soils 31. Dept. of Forest Soils. Swedish University of Agricultural Sciences, Uppsala. p. 426.

MACGREGOR, W.D. (1934). Silviculture of the mixed deciduous forests of Nigeria. Oxford Forestry Memoir. No. 18.

OFOSU-ASIEDU, A. and P. CANNON (1976). *Terminalia ivorensis* decline in Ghana. PANS 22(2). pp. 239-242.

OLAWOYE, O.O. (1975). The agri-silvicultural system in Nigeria. Commonwealth Forestry Review. Vol. 54 pp. 229-236.

ONYEAGOCHA, S.C. (1962). The development of the system of natural regeneration in Malaya compared with Nigeria. Special study. Commonwealth Forestry Institute, Oxford. Unpublished.

PALMER, J.R. (1975). Towards more reasonable objectives in tropical high forest management for timber production. Commonwealth Forestry Review. Vol. 54 pp. 273-289.

PIERLOT, M. (1975). Personal communication.

TANSLEY, A.G. (1935). The use and abuse of vegetational concepts and terms. Ecology 16. pp. 284-307.

UNESCO (1978). Tropical forest ecosystems. A state of knowledge report prepared by UNESCO/UNEP/FAO. Natural resources research series No. XIV. UNESCO. p. 683.

DYNAMICS OF FOREST ECOSYSTEMS IN RELATION TO THEIR UTILIZATION; NORTH TEMPERATE ZONE

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Summary

The distribution, development and composition of forest ecosystems are a response to long term environmental fluctuation or random dramatic events. These spatial and directional responses are predictable only as probabilities and the systems are inherently unstable. Utilization through management must take the potential for change into account.

Introduction

The concept of the ecosystem generally accepted is that of a system of living organisms interacting with their non-living environment. Ecosystems are not closed but are dynamic in both space and time and are subject to imports and exports of energy and materials from and to neighbouring systems. It is difficult therefore, in theory, to delineate an individual system either physically or in a classification. In practice it is usually possible to demarcate ecological units which are sufficiently discrete for separate description and mapping for management purposes. The value of the ecosystem concept is that it directs attention to the interaction of the processes that link the components of the system and encourages consideration of the likely consequences of intervention. The utilization of the system may then be arranged so that its capacity to continue to supply benefits is not impaired.

Forest ecosystems may be divided into the forest trees, the associated plants and animals (the biome) and their habitat, which is both a geographic location and its associated physical environment. Although no two ecosystems can be identical it is possible to find communities which are similar enough in specific composition and recur in similar environments with sufficient frequency to distinguish them as <u>forest types</u>. The environments in which particular forest types occur may be described and classified as <u>site types</u>.

The complexity of the interaction between the forest type and the site often leads to their being jointly evaluated for utilization but it is important to remember that the occurrence of a particular forest type does not depend solely on the present characteristics of the site but also on the assemblage of plants that have been available to occupy it. The evaluation should therefore take into account the history of both the vegetation and the habitat.

The dynamics of forest ecosystems, that is the changes that take place between and within forest communities, occur on different scales. The development of the forest type can be related to major climatic change following glaciation over thousands of years, the succession of species following forest destruction over several hundred years or the progression over decades of component species from seedling to maturity. In addition to these phasic changes, which are paralleled by the scale of the areas involved, there are a series of more or less closed cyclic processes within individual forest stands. Although it is convenient to separate the dynamics of ecosystems on the basis of time scale, they result from similar causes and are integral parts of a single process.

The purpose of this paper is firstly to briefly examine some aspects of the dynamics and 'stability' of forest ecosystems drawing examples from some of the major forest types in the North Temperate Zone. Secondly some of the responses of these systems to intervention by man are considered and parallels drawn with the development of man-made forests.

The evolution of forest types

The forest types recognised today are of relatively recent origin having developed since the last major glaciation. The Würm and Wisconsin ice sheets began to recede only about 12000 - 14000 BP and finally melted from northern latitudes about 8000 BP. The glaciation areas were reinvaded by the species that had retreated southwards or which had found non-glaciated refugia. It was thought until recently that assemblages of species found today would have migrated as communities, returning to similar sites after glaciation in a series of 'waves' as climates ameliorated, so that pioneer species adapted to cooler conditions would be followed in succession by more thermophilic species. These would be more effective competitors and become dominant over considerable areas with the pioneers confined to sites edaphically or otherwise limiting to the major species. The concept of climatically adapted communities of tree species migrating in response to changes in climate has now been shown to be wrong. For example by interpretation of pollen analysis in the eastern United States, Davis (1976) has been able to trace the post glacial migrations of the components of the chestnut-oak-hickory forests, demonstrating that hickory arrived from the south west reaching its present northern limit about 4000 BP, while chestnut came from the east reaching approximately the same limit at only 1000 BP.

Further evidence for postglacial migration patterns can be adduced from a study of the distribution of ecotypes or genetic populations within the overall range of the species.

Scots pine in Scotland has recently been shown (Forrest, 1980), by monoterpene analysis of the few residual stands, to have several genetic populations which appear to be related to widely separated provenances in North Europe and those of South France and Spain. This suggests the possible migration of the species by different routes to the same general area.

While for survival a species or a forest type clearly must be adapted to the climates prevailing throughout its range, it does not follow that other ecotypes or species may not be equally well or better adapted than those that currently occupy the area. The classic example is the migration of Norway spruce around the Gulf of Bothnia and <u>southwards</u> through Norway where the indigenous ecotypes are productively inferior to those introduced from the Harz mountains in Germany.

If the time since glaciation is thought of in terms of the potential longevity of many of the major temperate forest species, say 300 - 500 years on suitable sites, it is apparent that many forest types now recognised have had a rather short period to reach an equilibrium with their climatic or edaphic environment. If continuing climatic change and disturbance by man (beginning about 3000 - 4000 BP) or natural catastrophe are taken into account the presently recognised forest types are evidently still evolving. That most north temperate forest species show marked ecotypic differentiation is an illustration of the force and speed with which natural selection operates on the inherent variability of populations.

Structure and development of forest ecosystems

The development of a complex vegetation type has often been described as a process of succession from bare land through simpler forest structures to multilayered communities, in which the dominant species of the overstorey are the most shade tolerant. These dominants are considered capable of regenerating in their own shade and surviving, until the death of some of the overstorey allows them to develop to maturity. The end of this process is the development of an all-aged stand which is considered to be in 'equilibrium' with the environment, although the 'equilibrium' stage is still characterised by a steady and quite rapid turnover in individual trees and sometimes species. (McMahon 1980)

The trends implicit in such a model undoubtedly do occur and it provides a useful working hypothesis for their interpretation but examples of the final climactic stages are rare. The requirements for the full progression are the occurrence of suitable species in an environment with an equable climate and at least mesotrophic soils. Such combinations in the Northern Hemisphere only appear to occur in oceanic climates (e.g.N.W.America) and on base-rich lithologies of certain mountain chains (e.g.European Alps). Elsewhere, as in most of the Boreal forests, the later seral species are absent, the climate too severe to support them or even allow frequent seed production or the soils limiting in either water or nutrient supply. Where these conditions apply the forest retains a simple structure of a single canopy and sometimes a single species, becoming less dense and finally passing into scrub vegetation as site limitations become more restrictive. Ponderosa pine, east of the Cascade Mountains in America, provides an example of this where it gives way in increasingly dry conditions to juniper. In the opposite direction, that is progressing towards more mesophytic conditions, the later seral species occur first as an understorey and become progressively more able to enter the dominant canopy. In the ponderosa pine example Abies species take this role as they also do in Scots pine forests in N.W.Turkey.

In the undisturbed condition the distribution and structure of forest types appears to be conditioned by the prevailing climate with increasing complexity of specific composition and structure as limitations are reduced. The chief limitation is frequently available moisture, that is the annual precipitation and most importantly, its predictability. (McMahon 1980). Available moisture interacts with other site variables such as soil texture, soil depth, slope and aspect to extend or limit the areas of particular forest types. The effect of these site variations are generally clearest in areas of marked relief and are less obvious in regions of uniform topography.

The acceptance of the concept of a primary or secondary succession to a climactic forest has been implied in many of the classifications of forest types for botanical or management purposes from Cajander (1926) onwards. The classification usually identifies the hypothetical final state of the forest and requires some subjective allocation of seral stages, or subsets of variants, to the main type, In the conditions found in northern latitudes such a system is relatively simple to apply but becomes more difficult in complex topography and less limiting climates. For example the current method in British Columbia (Klinka 1979), which adopts a phytosociological approach, requires the identification of climactic 'zonal' types in mesotrophic sites and constructs a hierarchy of variants, subzonal and zonal classes to cope with the complexity. Similar forest types are more simply classified in Oregon and Washington by Franklin and Dyrness (1973) but here too difficulties may arise because the seral species have greater longevity and stature than the supposed climax.

While these approaches provide a conceptual framework for classifying forest ecosystems and allow interpretation of the changes taking place in them, the reality is that the succession is curtailed by disturbance. Disturbance through catastrophic fire, windblow or pestilence is the main factor that renews forest in the north temperate zone. Fires, whether natural or man-set, have played a major part in the distribution of forest types, their structure and specific composition. Some forest types are perpetuated by and adapted to frequent fire occurrence as in many pine ecosystems (jack pine, lodgepole pine). On mesotrophic sites where fire is less frequent, and thereby normally more devastating, it can ensure persistence of long-lived species at the expense of less resistant late-seral species as in the case of Douglas fir in the hemlock zone of coastal N.W.America. Most forests can burn but the periodicity and severity of fires is an expression of short term climatic variation, accumulation of fuel and the flammability of the species concerned.

Forest destruction by hurricane-force winds is most prevalent in oceanic climates where devastating fire tends to be less common. Windthrow of individuals or small groups of trees is of course a prime cause of the removal of decadent trees in mature forest but the destruction of whole stands leads to the setting back of the succession to an earlier phase.

Both fire and wind have considerable effects on the soil. Fire may destroy accumulated organic matter in the humus horizons of the soil, in which a high proportion of the site nitrogen is bound in unavailable forms and, although this may largely be lost, the bases and phosphorus liberated in the ash allow increased microbal activity stimulating the accretion of mineral nitrogen. Without this effect forest regeneration in the Boreal zone stagnates (Siren, 1955).

In W.N.America fire also stimulates the germination of Ceanothus which fixes appreciable quantities of nitrogen after immediately colonising the site. On mesotrophic sites red alder rapidly invades and can build sizeable nitrogen reserves before conifers again take over the canopy. Similarly the uprooting of trees by wind in moister conditions improves aeration and subsequent mineralisation of organic matter, mixes soil horizons and on shallow rooting soils creates pockets of deeper rootable material as described for mixed leaf-tree forests in the N.E.United States (Lyford and Maclean 1966) and in hemlock-spruce in the Queen Charlotte Islands (Day 1957).

The influence of these major disturbances on the long-term structure of the forest is profound. The effects are random, depending on the chance combination of climate, site type and interval since the last disturbance. The result is a mosaic of age classes on a site related scale. The influence on species distribution also depends on the scale and intensity of the disturbance. If the disturbance is not complete there may be 'residual' seed bearing trees which have an advantage in regeneration; if the disturbance coincides with a heavy seed year of a neighbouring species this will also confer an advantage on it and, in addition, some species may be able to store propagules on the tree (serotinous cones) or in the soil. It follows therefore that a 'succession' can restart after disturbance in any number of ways and with any combination of seral species. In severe disturbances only a few individuals may regenerate immediately and full stocking of the site may take some time. Some recently described old-growth Douglas fir stands in Oregon, which have uniform canopies and were thought to have regenerated as even-aged stands following fire, have been shown to be of this kind, with age spans of up to 250 years in the dominant canopy (Franklin and Waring, 1980).

The third kind of disturbance is that of mortality due to insect or fungal attack. The forest ecosystem supports a wide range of organisms that are dependent on the tree cover without generally impairing its growth, until it is stressed in some way. If large numbers of trees are stressed conditions arise where insect populations can be decisive in destroying, or enabling fire to destroy, whole stands as occurs in overmature balsm fir in E.N.America. Bark beetle attacks on individual lodgepole pine in central Oregon are concentrated on trees whose efficiency has been reduced by nitrogen stress (Waring, 1979). In this case the death of a proportion of the stand results in the relief of the stress.

Epidemic fungal attack is less frequent but when a mutant form occurs (Dutch elm disease) or a new introduction made (pine blister rust, chestnut blight), it can virtually eliminate a species from its range.

The inference that can be drawn from the effects of disturbance on forest ecosystems is that, in many instances, it is necessary for their continued existence and that it is not deterministic. Disturbance is thus a potent force for maintaining diversity in the landscape.

Development of forest stands: production and productivity

The progression of a forest stand from the seedling stage to maturity is characterised by competition between individual trees. Competition only occurs once the resources of radiation, water or nutrients become inadequate to meet the collective demand of the population as a whole. Competition for scarce resources also occurs between different parts of the individual tree leading to changes in morphology and habit that have important consequences for its utilization. The intensity of competition within a stand is density dependent and leads to a hierarchical stratification, where some individuals display higher relative growth rates than others and gradually dominate neighbouring trees. Despite a possible clumped or random distribution of individuals following regeneration the dominant trees ultimately become regularly spaced. Before any resources become limiting, the increase in the stand's leaf area is exponential but soon becomes asymptotic as radiation available for photosynthesis is largely absorbed.

The attainment by a stand of its maximum leaf area has important consequences. Firstly it implies that there is an upper limit to the productivity of a stand, that is the rate at which it can accumulate biomass. The differences in productivity between species and between sites can then be interpreted in terms of the total leaf area that can be maintained. Although the maximum leaf area is ultimately limited by radiation it is mediated by the availability of water for transpiration and sometimes by nutrients. The relation between stand leaf area and available soil water has been shown to be linear in the west-east transect across the forest types of central Oregon (Grier and Running 1977). The coastal hemlock-spruce forest reaches a total leaf area of 20 m^2 m^{-2} with no water stress while the inland juniper forest only attains about 4 m^2 m^{-2} with a consistent water deficit. This productive relationship can also be expressed in terms of the 'actual' evaporation from a stand, a measure that can be estimated from the soil water balance, and which integrates several climatic variables important for growth. 'Actual' evaporation can be correlated with the productivity of vegetation on a world scale (Rosenzweig 1968) while it has been used recently to separate forest types in British Columbia (Klinka 1979).

The second implication of the attainment of a maximum leaf area in a stand is that, if individual trees are to continue to grow in size, there must be a redistribution of leaf area. Thus some individuals are removed from the population as mortality. This density-dependent mortality can be expressed in terms of the maximum weight that the mean individual can attain for any population density (Drew and Flewelling 1977) and within species appears to be independent of age, growth rate or site conditions. For most stands there is therefore a steady reduction of stem numbers as the trees grow in size and this process continues until the overall growth diminishes with age.

As there is a direct correlation between the leaf area of the tree and the cross-sectional area of its conducting tissue (sapwood basal area) (Grier and Waring, 1974) it is possible to see the connection between stand productivity controlled by climate and the wood increment of the individual trees. This last relationship can also be used to estimate the loss of efficiency of the foliage either due to harsh environments or due to stress within a stand (Waring *et al*, 1980).

As the undisturbed stand approaches maturity the respiratory demands of the accumulated biomass increase and this together with the incidence of density-independent mortality (insects and fungi) results in a slowing down of net production until a balance is reached between gain in new growth and loss to mortality. The total amount of accumulated biomass has reached its maximum. This total production is not related in other than a general way with productivity as some relatively slow growing stands can develop large volumes if they remain undisturbed for long enough. The very large biomass accumulated by old growth forests in coastal N.W.America is attributed by Franklin and Waring (1979) to their long continued height growth, longevity and their ability to continue photosynthesis throughout the greater part of the year. The rate of production of these stands, however, can be quite low compared, say, to that of pines in the South of the U.S.A. The difference between production and productivity may be important in economic appraisals with their emphasis on rate of return but in a world of limited resources total production from ecosystems of low productivity can hardly be ignored.

Stands in the mature stage have reached a condition where their internal cycling processes are at their most complex. In the Boreal forest such stands are starved of available nitrogen, most of that present being organically bound. In N.W.America additional nitrogen is fixed in foliose lichens and in some of the slowly decomposing dead logs (Carroll, 1979). The abundance of accumulated organic matter is a distinguishing feature of undisturbed stands at maturity providing direct or indirect energy sources for many different organisms. The slow decomposition rate of this material acts as a buffer against nutrient loss and in accord with the severity of disturbance is more or less carried through to the next succession. It also can influence the form of the succession by providing differential seed bed conditions.

Stability of forest ecosystems and their utilization

A consideration of the ecological stability of productive ecosystems is crucial to their management for goods and benefits. The description above of some of the dynamic properties of forest ecosystems has somewhat unrealistically excluded the interventions of man. Even primitive man intervenes in the forest by setting fire, favouring herbivores and selective harvesting. Modern man makes much greater demands in forest clearance for agriculture, exploitation of fuelwood, fibre and timber while at the same time expecting the forest ecosystem to supply aesthetic and social benefits such as conservation, water quality control and recreation. The land planner and forest manager in trying to balance these multiple objectives need an appreciation not only of the dynamic properties of the system but of its sensitivity and response to intervention. Although considerable advances have been made in understanding ecosystem processes there is still difficulty, often semantic, in defining the state of an ecosystem which will allow it to persist and yet absorb the effects of interventions.
The Clementian concept of directional succession inevitably leading to a climax has largely been discarded on the grounds that it postulates determinism in the ecosystem, although the validity of the successional process is still accepted (McMahon, 1979). On the other hand, O'Neill and Reichle (1980) in attempting to construct a basic theory of the ecosystem describe it as a 'functional unity' and accord it strategies for its persistence based on the components of producers (trees), heterotrophic rate regulators

(animals) and a large storage component with a slow turnover time (organic matter). They point out that the concept of 'stability' depends on the reference 'state' defined. A 'state defined in terms of biomass, productivity and nutrient cycles may be able to persist whereas one defined by the species composition and their distribution cannot and is inevitably 'unstable'. O'Neill and Reichle (1980) emphasise the importance of spatial heterogeneity in patterns of species composition and genetic information if systems, like forests, with large biomass accumulation are to display resistance and flexibility in persisting in an unpredictable environment. While this may be acceptable in theory the manager of a forest ecosystem is interested in maintaining a flow of products based on particular taxa and cannot afford to ignore the species composition.

Much of the discussion on ecological stability has made use of a physical analogy in which a stable system is in an equilibrium 'state' which is unchanging (i.e. the system is at rest). Some conservationists still consider the equilibrium state to be 'natural' and any perturbation of it to be 'bad'. Holling (1974) expanded the equilibrium concept of stability by introducing the ideas of 'resistance' to change and 'resilience', the ability to absorb change and return to equilibrium.

Consideration of the development and dynamics of forest ecosystems does not support the equilibrium concept of stability. Ecosystems appear to have several possible equilibrium states and there is no clear deterministic pattern of recovery from disturbance (Botkin 1980). Predictions in this situation have to be based on probabilities. Botkin proposes that the manager should allow the forest to vary within bounds (i.e. the total number of possible 'states' has to be limited) to ensure persistence. These 'states', defined in terms of age classes, successional stages and specific composition would then recur within the ecosystem.

It is interesting that these ideas should develop in America where forest management is relatively novel whereas some European forests have been managed for the recurrence of defined 'states' for several centuries with the aim of a sustained output of products, normally timber. Here the response to 'environmental perturbation' has been to evolve, on an empirical basis, more sophisticated silvicultural and management methods depending on the species and site combinations.

The problems of integrating the increasingly complex demands being made on forest utilization are now being approached through simulation of different management strategies by computer modelling. Manipulation of the forest ecosystem has to take into account the effects on adjacent systems, a principle now embodied in forest law in some countries.

Within the forest the tendency to intensify harvesting of wood products has led to considerable effort to predict and quantify the potential effects on the ecosystem resulting from practices such as whole-tree harvesting, drainage, fertilisation and so on (Leaf 1979). Most of these simulations are not as yet very comprehensive for lack of sufficient good data and tend to be budgetary and not process oriented. There is no doubt they will rapidly become more refined and reliable.

Managed forest ecosystems

Natural forest ecosystems may be brought under management either by introducing controlled regeneration though partial harvesting techniques or by total clearance and replacement with plantations of desired species. The latter are akin to afforestation of bare land but differ in retaining most of the features of a forest soil whereas afforestation has frequently to deal with degraded or eroded soil types.

Comparison between unmanaged and managed ecosystems can be made in terms of their basic properties. The large biomass accumulation of the unmanaged stand is normally curtailed under management where the emphasis is on productivity and the replacement of stands as soon as their incremental rate (mean annual increment) starts to fall. Structurally, forests primarily managed for timber production tend to be simpler, with fewer canopy layers in which only one or two species may be represented. With the reduced vertical distribution of leaf area there is usually an attempt to maintain higher stand densities to maximise absorption of radiation and hence total production. The greater density is manipulated to encourage the changes in stem form and branching habit that influence wood quality and hence economic return.

In managed forests the need to attain uniformity of industrial products, maximise productivity and reduce wastage leads to concentration on early or mid-seral species so that successional stages are rarely permitted. Skillful silvicultural treatments (e.g.shelterwood) are applied to ensure regeneration of the desired species or where the environment makes this too difficult planting is resorted to. The random start and slow development of succession in many natural stands can rarely be tolerated in intensively managed forests.

The most obvious intervention in managed forest ecosystems is the periodic removal of biomass in harvesting. Two basic properties of the ecosystem are affected. Firstly, the reserve of organic matter in the system is greatly reduced; the lack of dead logs and increased mineralisation of soil organic matter reduces the turn-over time of nutrient elements and releases 'pulses' of nutrients to downstream systems at more regular intervals and sometimes greater frequency than from unmanaged forests. The seriousness of these enhanced losses depends on the balance between them and atmospheric or soil weathering input. If these gains are inadequate to balance the losses by leaching and timber harvesting the manager has to resort to fertilisation to maintain production and on initially poor or degraded sites economic production may sometimes only be obtained by this means. Secondly the habitat of a range of organisms adapted to old growth forest is removed leading to their local extinction while simultaneously increased potential for those organisms that thrive in young growth forest is provided. The overall effects of this remain unclear.

The analogies between the periodic and catastrophic renewal of natural forest and silvicultural treatments commonly applied by management (e.g. clearfelling, cultivation) are of limited value (Malcolm 1979) because of the different selection pressures and the time scales involved. In managed or extensively managed forest, species are selected for survival in competitive conditions whereas, with increasing pressure on land resources, intensive management systems select for productivity and remove as many site limitations as is economically possible. The appropriate analogies are agronomic.

Conclusions

The essential features of any classification or evaluation of forest ecosystems has to be based on the two main environmental gradients of the rootable volume of soil together with its nutritional status and the climate, best expressed in terms of the site heat and water balances. As the environment so described is not static but is continually changing the associated assemblage of organisms is subject to dynamic change in both space and time. Study of the environmental relations of individual organisms allows the prediction of their behaviour in response to change and the probability of survival in different circumstances. The combined response of individuals of the community level, however, is dependent on numerous chance occurrences such as the presence or absence of propagules or the frequency and severity of environmental perturbation. The changes in the ecosystem that ensue are therefore predictable only as probabilities. According to Boyce(1978) the organisation of the natural community is an expression of the mortality of individual organisms which thereby alters the state of the system. In his view energy and nutrient flows are ultimately unidirectional and only slowed by cycling within parts of the system for a time. Thus the changes taking place in the system are irreversible and he concludes that 'a natural, unmanaged forest is an aimless system.' If the conclusion that forest ecosystems are inherently unstable is correct, forest management must accept change as one of its constraints. The potential for change is not only in the elements of the forest ecosystem but in the demands made for its utilization. While it is now possible to simulate a hypothetical organisation of the forest, that provides for a suitable balance of different benefits as presently perceived, it must be able to accommodate future change in the ecosystem and in its utilisation.

References

BOTKIN, D.B.1980 A grandfather clock down the staircase:Stability and disturbance in natural ecosystems. In R.H.Waring (ed.) Forests:Fresh perspectives from ecosystem analysis. Oregon Sta.Univ.Press. 1-10.

BOYCE, S.G.1978 Theory for new directions in forest management. U.S.D.A. For. Serv. Res. Pap. SE-193, 1-19.

CAJANDER, A.K. 1926 Theory of Forest types. Acta For.Fenn.31, 1-108.

CARROLL, G.C. 1980 Forest canopies: Complex and independent subsystems. In R.H.Waring (ed.) Forests:Fresh Perspectives from ecosystem analysis. Oregon Sta. Univ. Press. 87-108.

DAVIS, M.B. 1976. Pleistocene biography of temperate deciduous forests. Geoscience and Man 13, 13-26.

DAY, W.R. 1957 Sitka spruce in British Columbia. Bull.For.Commn.Lond.28, 1-110.

DREW, J.T. and FLEWELLING, J.W. 1977 Some recent Japanese theories on yield - density relationships and their application to Monterey pine plantations. For. Sci. 23, 517-34.

FRANKLIN, J.F. and DYRNESS, C.T. 1973 Natural vegetation of Oregon and Washington. U.S.D.A. For.Serv.Gen.Tech.Report. PNW-8, pp 417.

FRANKLIN, J.F. and WARING, R.H. 1980 Distinctive features of the North-west coniferous forest:Development, structure and function. In Waring,R. H. Forests:Fresh perspectives from ecosystem analysis. Oregon Sta. Univ. Press. 59-86.

FORREST, G.I. 1980 Genotypic variation among native Scots pine populations in Scotland based on monoterpene analysis. Forestry 53, 101-128.

GRIER, C.C. and WARING, R.H. 1974 Conifer foliage mass related to sapwood area. For. Sci. 30, 205-206.

GRIER, C.C. and RUNNING, S.W. 1977 Leaf area of mature Northwestern coniferous forests: relation to site water balance. Ecology 58, 893-899.

HOLLING, C.S. 1974 Resilience and stability of ecological systems. Ann. Rev. Ecol. Syst. 4, 1-23.

KLINKA, K. 1979 Biogeoclimatic units of Central and Southern Vancouver Island. Ministry of Forests, Victoria B.C. pp 120.

LEAF, A.L. (editor) 1979 Impact of intensive harvesting on forest nutrient cycling. Proc. Conf. Sta. Univ. New York.

LYFORD, W.F. and MACLEAN, W.D. 1966 Mound and pit microrelief in relation to soil disturbance and tree distribution in New Brunswick, Canada. Harvard For. Pap. 15. Harvard Univ. Mass. 1-18.

MCMAHON, J.A. 1980 Ecosystems over time: Succession and other types of change. In Waring, R.H. (ed.) Forests:Fresh perspectives from ecosystem analysis. Oregon Sta. Univ. Press, 27-58.

MALCOLM, D.C. 1979 The future development of even-aged plantations: Silvicultural implications. In Ford E.D., Malcolm, D.C., Atterson, J. (eds.) The ecology of even-aged forest plantations. Institute of Terrestrial Ecology, N.E.R.C. Cambridge, 481-504.

O'NEILL, R.V. and REICHLE, D.E. 1980 Dimensions of ecosystem theory. In Waring R.H. (ed.) Forests:Fresh perspectives from ecosystem analysis. Oregon Sta. Univ. Press 11-26.

ROSENZWEIG, M.L. 1968 Net primary productivity of terrestrial communities: predictions from climatological data. Am. Nat. 109, 67-74.

SIREN, G. 1955 The development of spruce forest on raw humus sites in N. Finland and its ecology. Acta For. Fenn. 62, 1-405.

WARING, R.H. 1980 Vital signs of forest ecosystems. In Waring,R.H. (ed.) Forests: Fresh perspectives from ecosystem analysis. Oregon. Sta. Univ. Press, 131-6.

WARING, R.H., THIES, W.G., and MUSCATO, D. 1980 Stem growth per unit of leaf area: a measure of tree vigor. For. Sci. 26, 112-117.

Natural Eucalypt forest in Southern Australia.

3.1 Papers on "The state of the art"; Session 2, November 10, Monday

"Inventory techniques and land classification"

Chairman: D.E. McCormack; Rapporteur: J. Thie

- S. Andel
  Inventory techniques and classification of forest resources
- I.S. Zonneveld
  The role of single land attributes in forest evaluation
- R.G. Bailey
  Integrated approaches to classifying land as ecosystems
  Presented by K.N. Larson
- L.S. Botero (ed., FAO)
  FAO's experience in land classification for forestry with
  particular reference to developing countries

INVENTORY TECHNIQUES AND CLASSIFICATION OF FOREST RESOURCES

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Summary

An overview is given of major steps involved in the inventory of forest resources at various survey scales.

The importance of appropriate classifications of vegetation, land use and terrain/soil types is discussed, emphasizing the role of remote sensing techniques.

The recent introduction of more integrated ground survey procedures is highlighted with examples of inventory work in tropical forest areas. Integrated field sampling may combine aspects of vegetation (species, stocking, qualities), accessibility (terrain, drainage and infrastructure) and soil (depth, organic matter and stoniness).

It is very important to produce maps with adequately detailed legends.

The presentation of inventory results for subsequent use, is particularly important regarding specific locations on maps.

The urgent need for frequent monitoring of the resources given the rapid changes that are occurring in areas, quantities and qualities, is shown to lead to continuous inventory techniques, computer-based

data banking and periodic area, growth and yield assessments, both for more natural and plantation forests. It is concluded that for land evaluation purposes, considerable inventory research and development work is required in the fields of comprehensive resources classification, monitoring with remote sensors and continuous, computer-based data banking and analysis.

Introduction

Inventory data on forest resources, in categories of vegetation types, terrain types and soil types, as well as in terms of infrastructure (use, ownership and access to location), will form a most important information base for land evaluation for forestry.

Until recently, forest inventory has mainly concentrated on enumerating the tree stocking ("counting the trees"). Techniques developed for this purpose, e.g. the specialized skills of forest mensuration, sampling and data processing, use of remote sensors for mapping, are well documented in a number of handbooks (some of those written in English are given in the References below: Husch et al 1972, Spurr 1952, Loetsch et al 1964 and 1973, Howard 1970, Küchler 1967, Dickinson 1969, Lawrence 1971).

More recently, techniques have been developing towards combining stock enumeration with land use assessment, terrain classification and soil fertility rating. This has been done because of the urgent need to plan for maximum sustainable production from the resource base, which is being seriously depleted in places even as total world consumption of forest products continues to rise significantly.

Inventory data will be used to answer vital and politically oriented questions such as: which forest resource base is the most permanent in the longer-term view? which forest areas need to be set aside without commercial exploitation for purposes of nature conservation and protection of the environment? which low-productive or unstocked degraded lands can be developed to fully productive forest stocking? and last but not least, which forest areas must be made available primarily for the production of food.

Examples of the more recent, integrated survey approaches to tropical forest development areas are being discussed to some extent (FAO 1972 and 1978, Lundgren 1980).

Scales of survey

Four levels of intensity are usually distinguished in forest inventory:

a. exploratory - map presentation at a scale of 1:500 000 and smaller

b. reconnaissance - map presentation at a scale of 1:100 000 - 1:500 000

c. semi-detailed - map presentation at a scale of 1: 25 000 - 1:100 000

d. detailed - map presentation at a scale of 1: 25 000 and larger.

The specific objectives of an investigation determine the level of intensity: a. for a broad, qualitative evaluation at regional or national level, b. for a still largely qualitative analysis of amounts of resources at national level for longer-term planning, c. for a mainly quantitative evaluation of the feasibility of more defined development projects for medium-term planning and d. for quantitative analysis of resources for project-implementation (De Vos 1979).

Regardless of the scale of survey, the inventory will always be concerned with four major areas of investigation:

(i) the classification of resources

(ii) the ground sampling or field checking

(iii) the mapping and area estimation

(iv) the data analysis and monitoring or up-dating.

These four major areas are interdependent to a greater or lesser degree: their interdependence increases concomitantly with the intensity of the survey. For instance, in exploratory surveys, the resource classification may not depend on a ground sampling scheme (although some check of ground truth must be included), while in detailed surveys the occurrence of commercially important stock (example: rattan) in the forest may not be detected even from the highest resolution aerial photography and has to be ascertained by sampling on the ground.

Survey results are usually presented in the form of thematic maps and descriptive legend for lowel-level intensities and in the form of resource information in overlays printed onto topographic maps with matching tables of analysis results for higher-level intensities. In all cases, however, data bank storage enabling easy retrieval of basic information related to specific locations on maps, is of great importance in rapidly changing development situations (Susanto 1979).

Availability, performance and trends of the resources can be shown rapidly from computer comparisons in time and space. Nowadays, in most places frequent monitoring of the resource base is necessary for any scale of survey. The important task of inventory in these modern systems is to ensure that the data in the bank give accurate ground truth at a specified time and related to a specific location on a map. This will ensure flexibility in continuous analysis and interpretation of data and results.

Classification of Resources

Forest land classes shown on maps will give information on types of vegetation (forest types), landform (terrain classes) and soils, besides showing details of existing land use and infrastructure (access). The nomenclature used in practice tends to be simple with the implicit assumption that much information can be deduced by people familiar with local conditions: "peat swamp forest" will tell the local forester quite a lot about the vegetation, landform and soil in his locality.

Attempts have recently been made to translate and integrate locally meaningful classes into classifications for wider application and comparison. This is particularly important if large areas are to be monitored frequently with the help of remote sensors on space platforms (Hempenius 1978).

To achieve the comprehensive, standardized classifications, that are so urgently needed, the following studies should be referred to:

- "Classification of World Life Zones or Plant Formations", Holdridge 1967
- "International Classification and Mapping of Vegetation", Unesco, 1973
- "FAO Proposed Classification of Existing Land Use and Forest Classes", FAO, 1973.

These studies deal mainly with vegetational aspects and are partly based on measurable properties of the environment (humidity provinces, latitudinal regions and altitudinal belts; see Holdridge) and partly on the structure of vegetation sampled on the ground and its appearance on remote-sensing images.

Landform/terrain classification in forestry based on measurable properties of slope (% and length), drainage pattern, obstacles and eveness of ground surface (Dent 1978), is relatively young. It is commanding increasing attention due to its great importance for highly-mechanized forest operations which have to use longer and cost-critical transport lines (FAO 1972 and FAO Forestry Paper 1978). Forest soil classifications intended to provide fertility ratings for intended crops have become important in development areas under more intensified management for converting more natural secondary forests into high-yielding forest plantations, for replanting deforested and degraded lands and for the eventual conversion of forests into agricultural uses (for foodstuffs, range or tree crops such as rubber and oilpalm). Soil measurements include effective depth (to rock or impermeable pan), groundwater level, organic matter contents of layers, their mineralogy, pH, base saturation and an indication of current erosion features (Lundgren 1980).

Although a start has been made, forest inventory still has a long way to go, particularly in tropical areas, in providing a comprehensive classification of resources that integrates vegetation, terrain and soil types and that can be used in future satellite monitoring. The urgently needed development of comprehensive classification could be achieved most quickly by making regional or national inventories with built-in continuity. The first stage in such large-area inventories should be done at a reconnaissance scale, using ground sampling as well as remote sensing techniques (including radar in tropical areas).

Ground sampling

Ground sample data serve two basic purposes in inventory. They provide:

- a means to check the interpretation of remote sensing images against "ground truth" (ascertaining what the patterns and differences detected on images represent in reality);
- a body of statistical information on the resources that can be analysed by mapped area classes to give means and variations of resource information.

The classification of resources shown in mapped areas, will provide a stratification for sampling analysis. However, where some of the important resource characteristics cannot be reliably interpreted from images or require preliminary research, the classification will have to rely on ground sampling to a certain extent, at least initially. This particularly applies to tropical forest areas, where part of vegetation and terrain characteristics may be obscured by a dense upper canopy of trees and where generally little knowledge is available on the distribution of soil types.

Systematic ground sampling on grid-intersections is recommended as most practical under these circumstances. This is even more the case where comprehensive classifications require research and development and where it is intended to build up a monitoring network. Operational inventories for forest exploitation are usually done on a systematic basis. FAO (1972) and C. Lepitre of the Centre Technique

Forestier Tropical, France (1977) have studied ground sampling combining characteristics of vegetation and terrain in tropical forests. A minimum amount of soil descriptive information was also collected at the same time (note: research on soil fertility does not usually receive much attention in more permanent tropical forests, as the natural forest ecosystem is thought to be independent of soil fertility to a considerable extent: "the natural forest grows largely on its own litter").

On the basis of these field experiences, the following ground sampling scheme appears most promising for continuous monitoring and the development of an appropriate and comprehensive classification:

I. the delineation of sampling block areas at systematic grid-point locations (for instance for the inventory of a large forest area, the blocks could be 1 km^2 each at intervals of 10 km);

II. the lay-out of a fixed number of sample plots systematically placed within each block (cluster samples, for instance 25 plots, each of 0.2 ha, per km^2);

III. the enumeration of forest vegetation in each sample plot (species determination, measurement of diameters and heights, assessment of quality and imperfections for all trees over a certain minimum diameter; sampling in sub-plots for smaller trees, shrubs, weeds, etc.);

IV. the measurement and observation of terrain characteristics along the borders of each sample plot (slope gradients and lengths, number of drainage crossings, surface eveness, soil firmness, amount of undergrowth, number of windfalls, number of boulders or rock-outcrops and occurrence of erosion features);

V. the measurement and observation of soil characteristics by auger samples taken at regular (and rather frequent) intervals along all survey transect lines within the sampling block (effective soil depth, structure of horizons, their organic matter content and porosity).

From a sub-sample of V. soil samples may be collected for laboratory analysis of mineralogy, organic matter, pH, CEC, base saturation, etc.

Some of the ground samples should be marked to enable exact relocation and remeasurement after a period of several years. It is suggested that such permanent observation plots for continuous inventory should be mainly located in selectively logged forests and in plantation areas, to determine forest growth and developments of aspects of terrain (erosion) and soil fertility (organic matter, compaction).

Mapping and Area Estimation

The first concern of inventory mapping is the provision of adequate base-maps, for which aerial photography and geodetic control may be required. A certain amount of topographic information must always be included in base-maps for forest inventory purposes. Shown contour-intervals required will vary with the scale of the survey: they may be 100-250 m for reconnaissance level and 25 m and less for detailed surveys.

Usually the first mapping procedure is to prepare draft maps from interpreted remote-sensing images showing classes of vegetation/ land use, landform/terrain and if possible broad soil types in forest land areas. The next step will be checking the draft map against known ground truth.

For this latter purpose, maps of the forest vegetation, terrain classes and soil types should be prepared for each sampling block (see before) from the field data collected on the regularly-spaced cluster-plots and line-transects. Such block maps will represent a significant area of forest land (of, say, 1 km^2) at regular distances (say 10 km) over the entire survey area. They offer an opportunity for research and development of the classification to be used in interpreting remote-sensing images and will provide detailed ground truth for monitoring changes through periodic complete or partial re-surveys.

Maps will also show forest ownership and/or administrative divisions. Climatic zones and current accessibility status may also be superimposed.
Maps then show ultimately a pattern of forestry land lots of different size and shape, each having a unique combination of vegetation, terrain, soil, current land use/ownership, administration, climate and access status.

To estimate areas on such maps, counting and recording on a grid-intersection basis, directly used as computer-input in the data-bank system, seems most efficient. This enables all numbered land-lots in a certain area possessing selected combinations of characteristics, with their locations, to be rapidly recalled by computer at any time.

As the pressure of development on the resources increases, the interdependence of areas (forestry land lots) becomes more obvious. What happens in one land-lot may significantly influence the development potentials of other lots. It will be necessary to have a good overview, particularly for land evaluation. The assessors/planners will have to call up information from the data-bank selectively; the selection of land-lot particulars will be done, at least partly, by studying the maps.

To serve their purpose efficiently, good maps must include adequate legends. As far as possible, the legends should contain pertinent quantitative and/or qualitative data on the described resources classes shown. This will be a great help when selecting for call-up of computer detail. The most important class data on means and variations, derived from sampling analysis (see below), should not be hidden in a bulky survey report, but appear in the map legends first and foremost.

Data Analysis and Monitoring

Analysis of sampling data (e.g. tree stock enumeration, slope percentage and length, effective depth of soil etc.) will serve two main purposes:
- it will provide estimates of averages and variations in resource

characteristics and amounts per unit area (ha) by strata recognized on the map (a stratum may be any combination of classes of forest type, terrain, soil type, land use, ownership, administrative, climatic and access zones). Pertinent resource sampling results will be used in the map legends

- together with area estimations (counts of land-lot areas), it will provide estimates of total resources available in certain categories of land (e.g. to answer such vital questions as: is there enough volume available within x km radius to operate a processing plant of minimum input capacity y?).

To enable flexible, alternative evaluations of this nature, the analysis should be computer-based. There are very many feasible combinations in a thorough evaluation where it is necessary to investigate at the level of land-lots (and this will ultimately be so in meaningful land evaluation).

Land lots will be contained in a sampling stratum but need not be groundsampled themselves. To minimize the risk of error in lot estimates it would be most valuable to further develop locational analysis of variables for forest resources, along the lines that have proved to be so useful in surveys for mineral and fossil deposits (e.g. oil soundings and drillings). The data from equidistant plots in clusters within regularly-spaced blocks, enable the variation of resources in space (e.g. the predictability of spatial variations) to be studied. If a land lot lies in a certain distance from sampled blocks within the same stratum, research efforts will enable the probability that certain minimum amounts of resources will be contained in that particular land lot to be estimated.

Given the increasing pressure for development, with rapid and sometimes drastic changes in the resource picture, locational data require frequent revision and up-dating. Remote sensing images are very important for monitoring area information. The use of radar-sensors is a promising recent development, particularly for tropical areas with near-continuous cloud cover.

Data on growth of tree stock, most importantly in selectively logged forests (which may be expected to form the bulk of forest resources in most tropical areas within a few decades) and in intensively-managed, high-yielding plantations, are obtained from successive analysis of permanent sample plot data. These enable forest yield predictions (wood production).

At present there are no inventory procedures to monitor changes in terrain class (e.g. erosion caused by man and machines) and soil type (e.g. degradation resulting from compaction by heavy machinery and/or from drastic man-made change of vegetation type). Such procedures need to be developed from combined research on periodic remote-sensing images and observations on permanent samples (continuous inventory).

Conclusion

Forest inventory, as one of the important information bases for land evaluation in forestry, must continue to develop new approaches and techniques. Research and development needs to be done on:

- comprehensive classification of resources
- monitoring systems with remote sensors
- continuous inventory data banking and analysis.

Last but not least, this research and development needs to be based on ground survey of sample plots distributed over extensive areas, e.g. in a reconnaissance type of national forest inventory. This will be a time- and manpower-consuming operation, and its priority level is not always clearly recognized in national development planning policies.

The alternative, of a piecemeal building-up of the required systems and techniques for forestry evaluation from limited, pilot study investigations, in time to be useful for land evaluation proceeding in other fields (e.g. agriculture, including on lands recently converted from forests), is unsatisfactory and unpracticable.

REFERENCES

Dent, F.J. 1978. Data requirements for land use planning with emphasis on requirements for land evaluation studies. SIDA/FAO Seminar on Forest Resources Appraisal in Forestry and Land use Planning, New Delhi - Dehra Dun.

Dickinson, G.C. 1969. Maps and air photographs. Arnold, London.

FAO. 1972. Evaluation of accessibility of forest resources. FAO: MISC/72/15, Rome.

FAO. 1973. Manual of forest inventory, with special reference to mixed tropical forests. Rome.

FAO. 1978. Assessment of logging costs from forest inventories in the tropics. Rome. Forestry paper, nr. 10.

Hempenius, S.A. 1978. Remote sensing technology, prospects for developing countries. Intern. Symp. Integrated Surveys in Resource Management, ITC, Enschede.

Holdridge, L.R. 1967. Life zone ecology (rev. ed.).Trop. Science Centre, San Jose-Costa Rica.

Howard, J.A. 1970. Aerial photo-ecology. Faber & Faber, London.

Husch, B., C.I. Miller & T.W. Beers. 1972. Forest mensuration. Ronald Press, New York.

Küchler, A.W. 1967. Vegetation mapping. Ronald Press, New York.

Lawrence, G.R.P. 1971. Cartographic methods. Methuen, London.

Lepitre, C. 1977. Classifications des terrains pour l'exploitation forestière tropical.

Loetsch, F. & K.E. Haller. 1964. Forest inventory, Vol. 1. BLV, Munich.

Loetsch, F., F.Zöhrer & K.E. Haller. 1973. Forest inventory, Vol. 2, BLV, Munich.

Lundgren, B. 1980. Plantation forestry in tropical countries; physical and biological potentials and risks. Swedisch Univ. of Agr. Sci., Int. Rur. Dev. Centre, Uppsala (draft).

Spurr, S.H. 1952. Forest inventory. Ronald Press, New York.

Susanto A. 1979. Collection of natural resources data as a basis for regional development planning in Indonesia. ITC Journal 1979-3, Enschede.

Unesco. 1973. International classification and mapping of vegetation. Ecology and Conservation no. 6, Paris.

Vos, J.H.T.N.C. de. 1979. Land evaluation for land use planning. ITC Journal 1979-3, Enschede.

THE ROLE OF SINGLE LAND ATTRIBUTES IN FOREST EVALUATION

(Classification, Evaluation and Inventory)

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Summary

The author states that in forest evaluation the forest ecosystem should be considered as a whole. Nevertheless the single attributes of the ecosystem are important to know because integration is not a matter of mixing up. It is important to have some knowledge of single attributes and values to understand limitations and to direct amelioration. Often, within narrow ecological districts, evaluations of sites can also be made on the basis of single attributes with an integrated character, such as soil and vegetation. For pure holistic surveys the basic attributes may even be used for the description and classification of land units. So soil and vegetation and landform classification systems may well be the main basis for holistic land classification for forest evaluation. Climate classification can be of great help in judging the value of sites for exotic species that may have a niche outside their area of origin. Two basic concepts in classification and evaluation are discussed, since both have an ambivalent meaning. The term *characteristic* is used for intrinsic *character* determining properties as well as for features to be applied as diagnostic properties. Similarly the term *quality* is used as intrinsic *value* determining property as well as diagnostic feature to be used to recognize evaluation classes according to certain value criteria.

Introduction

Every forester and certainly every forest ecologist knows that in assessing the value of the forest site, one should use the forest ecosystem as a whole.

We know all about the intricate relationship between vegetation (including forest), flora, soil, landform, water, rock, atmosphere, animals and man, all within the three dimensions of space and the fourth dimension: time. The interaction between all factors and also the interdependence of environmental factors can be a reason for serious errors if only one or a few are taken into consideration and all the others are neglected. This holds true for land attributes, especially for single values of each land attribute. Other papers presented in this symposium will deal with the integrated approaches that have to be applied to avoid such errors. Here we treat the single attributes. There are four reasons for doing this:

1. "Integration" is not "mixing up".
2. Knowledge of single values can be important in describing, understanding and ameliorating of sites.
3. In spite of the introductory remarks, sometimes single values are used for detailed evaluation of specific factors.
4. Even if purely holistic evaluation methods are applied, the basic survey may be carried out separately for each component.

Reasons for the use of single attributes

1. So far in landscape ecological surveys, applying as comprehensive a concept as possible, it is still valid to utilize the various land attributes such as vegetation, soils and landform. At least the lowest (basic category), the ecotope (site), is characterized by the soil, vegetation and landform with the help of existing classification systems.

   Normally the data are expressed on maps. There the final classification appears in the form of a legend (chorological classification). In the most useful cases the legend shows the components (land attributes) in table form. Indeed there are trials to make a typification (non-chorological classification) on the base of ecotopes. But such classification

systems (outside Russia) are not yet important. But even here existing land attribute classifications could be used.
For convenience in comparison, it certainly seems useful to apply whenever possible the "language" of existing soil classification systems, vegetation classification systems, geological systems, climatological systems, geomorphological systems, etc.
Besides classification units of existing attribute systems, single values of land attributes are also used in landscape classification. So in a certain simplified land survey sometimes one uses soil types or other units which are not fully classified, merely treating the depth or a combination of depth and texture. In the same way certain landscape surveys may use only the main structure as far as vegetation is concerned, or the main life form, or just the dominant species, or only one or a few indicator species.

2. Knowledge of the single land attributes and their single values is not only important for the description (classification) of the site units. This knowledge may also lead to understanding of certain properties that show some potentialities and that may be considered for improvement ("qualities"). Combinations of those known single values in particular may also give a clue for comparison of remote units. An example of the latter is certain soil fertility parameters and climate parameters.

3. One comes across situations where, in spite of the generally accepted statements at the beginning of this paper, single land attributes are still used for forest site quality evaluation. This should not be rejected in all cases. It depends very much on the scale and purpose of the application of land attributes. We will see in the following paragraphs that in certain cases such procedures can be justified only at small scale (macro climate), as opposed to large scale (soils). We will also see that it is not always easy to judge the extent to which certain types of survey can be considered as mono-attribute surveys.

4. The basic surveys for land evaluation can be carried out in two main ways:

a. by single attribute surveys (even single value surveys) of the various separate components. Eventually the data can then be integrated;

b. by more holistic land(scape) surveys directly.

Especially in the first case it is important to choose the mono-attribute classification systems and inventory techniques that best serve the purpose. There is still choice between more parametric or more holistic (comprehensive) methods in converting the basic data in terms of land evaluation.

In subsequent paragraphs, some guidelines for selection of inventory techniques and classification systems and their use in land evaluation will be discussed for each relevant land attribute. First some notes on the concept classification and inventory are necessary (see also Zonneveld 1979; see references).

Classification, evaluation and inventory

To avoid misunderstanding in terms used, we will describe some concepts and terms in classification, evaluation and inventory, as used in this paper.

1. *Classification* means the "systematic ordering of data". This ordering is done by using properties of the item to be classified. These properties are selected (= abstracted)* from the total set of properties available. Properties selected for this purpose are then called "characteristics" or "diagnostic characteristics". The selection is done according to a set of guidelines. One guideline is that abstracted properties (the diagnostic characteristics) should be relatively easily observable, measurable and morphometric. Usually another guideline is that the chosen set of (diagnostic) characteristics will correlate with such properties of the items that are of interest, in this case, for

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* *Hence each classification is an abstraction.*

the aim of ecological characterization of the site.* It may still be indirect at this stage (see under "qualities").

Guidelines are also necessary for the chosen hierarchy. This can be purely morphometric e.g. given by a cluster or polyfactor program in a computer, resulting in dendrogrammes based on a purely statistical comparison of similarities and differences. For practical purposes, however, one can use a guiding principle for hierarchy in such a way that for certain purposes a convenient system exists.

So in the world of soil classification systems usually climate is chosen as a guiding principle to ensure that those soil characteristics that depend on (and are caused by) it are used at the highest hierarchical level. This means that these units coincide easily with legend units on world maps. We will see that this is less favourable when using such classifications at more detailed levels. Another example is the vegetation classification system in which soil fertility indication appears at the highest level, soil moisture indication on the next and other ecological factors at a lower level (see references: Bannink, Leys and Zonneveld 1973; Zonneveld 1961; Zonneveld 1977). Guidelines for selection of parameters and subdivision into classes in climate classification are usually such that general geographically well-known landscapes as desert, tropical rain forest, Mediterranean areas, etc. can be distinguished as clearly as possible on climatic criteria.

2. *Evaluation*. The classification units serve as a base for evaluation, interpreted in terms of suitability for a certain purpose. The classification units should be selected in such a way that an evaluation is possible! This means that those properties that should be known during the evaluation process can be derived from the basic classification units (and the legend units composed of these units).

In this paper we mention such properties as *qualities*. The word quality has two meanings:

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* *The term characteristic is often also used for intrinsic properties, not only for those selected as recognition marks. Therefore it is necessary to indicate the latter with the term "diagnostic" characteristics. (See b.)*

a. It indicates the "force" determining (causing) the value for a certain purpose.

b. At the same time it indicates the parameter (the diagnostic value) used in the evaluation process.

Qualities usually have a complex character (fertility, erosion hazard, humidity, etc.). The diagnostic value is usually expressed in classes (fertility, classes 1-5, etc.).

In fact, also the common use of the term "characteristic" has a double meaning, as does "quality". Also here we use the word for something inherent in a certain type, determining character. At the same time we use the word for a measurable parameter (diagnostic characteristic) to distinguish one item from another.* So qualities are used as diagnostic characteristics of an evaluation system (a system of pragmatic land classes, or forest site classes in this case).

3. An *inventory* can be made in various ways. We will restrict ourselves here to those types of inventory resulting in maps. Two aims of mapping are considered here, for which field observation or photo interpretation combined with field observations provide the necessary data.
One aim involves *typification*: the classification of the content of the mapping units. The other aim involves the *chorology*: the position of lines and units in the map. Enough has already been said about direct and indirect data used in classification. In chorology one should be aware that the less detailed the map, the less appropriate the direct single value or mono-attribute observation.
On a scale 1:5,000 one can still do the survey on foot and note direct soil augering data, slope angles, vegetation communities. On scale 1:50,000 all this is impossible and one should map comprehensive land units, even if one is interested in single values. The single values then have to be indirectly interpreted. This gives almost all reconnaissance soil maps and vegetation maps (certainly those of scales smaller

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* *The Dutch word "Kenmerk" is more clear in one way, meaning clearly diagnostic characteristic that can be measured (estimated) with the help of diagnostic criteria.*

than 1:200,000) a rather holistic character, even if the legend is expressed in pure mono-attribute terms or even single values.

Climate

1. Classification

A multitude of single values of climatic factors exist in map form, including precipitation, temperature, cloudiness, wind velocity, wind direction maps, etc.

Somewhat more comprehensive climate classifications exist in various forms. They are usually expressed in formulas with parameters such as precipitation, temperature, potential evapotranspiration. More sophisticated systems also include sun radiation, distribution of these data over the seasons (seasonality, length of the most unfavourable and favourable months). Examples are the formulas of Thorntwaite, De Martonne, Mayer, Emberger, Lange (see references: among others Lemee 1967; Thorntwaite 1931; UNESCO-FAO 1963). The Köppen system is widely applied; it is more comprehensive and shows a real hierarchy (see references: Köppen 1936).

At the highest level (indicated with a capital letter) the main division is given in terms of arid zones, temperate zones, equatorial climates, etc. These are defined in terms of precipitation and temperature ratio (according to quotient similar to Lange's index) in combination with absolute temperature limits. These are all based on year averages.

The second level, indicated with a second capital letter introduces seasonality (summer or winter rains or monsoon influences, etc.) and some subdivisions (especially in arid zones) according to the same criteria as the first level.

The third level gives a subdivision based on temperatures, yearly means as well as monthly data (warmest and coolest months).

The origin of the system is purely empirical. The boundaries are selected to correlate as closely as possible with well defined vegetation zones (including land use). So the vegetation zones serve as guidelines. The diagnostic characteristics are pure morpho-metrical properties of climate itself.

Quite different ways of using climate for evaluation of sites are presented by the parametric approaches of Lieth and others (see references: Lieth 1974) and also various kinds of production models (including parameters other than climate). These use direct qualities without an intermediary classification.

2. Inventory

Direct climatic inventory requires long years of measuring in weather stations. The number of such stations is necessarily limited. Therefore climate classification maps using such pure data are necessarily of a reconnaissance type.

But even on such worldwide climate maps the density of stations is not sufficient to design proper boundaries. So inventory techniques make use of the indication value of other land attributes especially the vegetation (including land use) and relief (altitude).

Good examples are almost all very small scale climate maps of Köppen, Thorntwait, de Martonne, Lange, etc. appearing in many geography and forestry text books as well as the climatic zones maps of UNESCO-FAO (see references: UNESCO-FAO 1963). The well-known maps of Holdridge (see references: Holdridge, Gremke, Hatheway, Liang and Tosi 1971) can also be mentioned here although these are not pure climatological maps. They have a clear vegetation component and even landscape features.

The same can be said for climatic data on maps of much more detailed scales as applied in Germany (e.g. Hartmann 1968; Hartmann and Schelle 1969: see references) often indirectly by indication of vegetation, etc. Some parameters often have to be determined indirectly. The potential evapotranspiration estimation systems of Penman are good examples (see also Holdridge system).

Climate classes can be defined by ranges of numeric expression of certain climate indexes added with some expressions about seasonality. (For examples of indexes see the next paragraph.) The seasonal aspects per station can be expressed very well in graphs of various kinds.

3. Evaluation

Most climatic systems are expressed in terms of a formula representing qualities. The diagnostic parameters (characteristics) for general classification coincide with the quality parameters. Of these, temperature is a factor acting directly (kenetic energy is important for life processes), but also indirectly (influencing evapotranspiration).

Rainfall itself is not a real quality, but via the evapotranspiration (in combination with temperature) and the water bearing capacity of the soil it has influence.

In the literature a multitude of indices for a variety of climatic qualities exist. As mentioned before, the subdivision of climates is based on the outcome of one or a combination of quality parameters. Some characteristic examples are mentioned below (derived from a compilation of Lemée 1967; see references).

Evaporation: $E_{mm}/\text{day} = 1.4\ (1 + 0.17\ \bar{u}_2)(e_s - e_a)$ (Penman)

(derived from: $E = k\ (e_s - e_a)\ f\ (\bar{u})$ (Dalton))

in which E = evaporation above a free water surface, k = a diffusion constant of water vapour, e_s = water vapour pressure at the surface, e_a = water vapour pressure in the air at a certain distance from the surface (in mm mercure), $f(\bar{u})$ = an empirical function of the wind velocity at 2 meters above the surface in miles per hour.

Potential evapotranspiration is the amount of water per unit of time by a certain area of earth surface which is supplied with water constantly.

$$ET_v\ (\text{mm/month}) = (R_g + 50)\ 0.4\ \frac{t}{t + 15}\ \text{(Turq)}$$

in which R_g = solar radiation, t = mean temperature in the shade.

A more complex quality is the climatic humidity factor of Transeau:

$$I = \frac{P}{E}$$

in which P = precipitation and E = potential evaporation.

The climatic humidity quotient of Mayer (NSQ) uses the saturation deficit in the air (ds in mm mercury):

$$NSQ = \frac{P}{ds}$$

A well-known simple climate index is the rain factor of Lange:

$$R = \frac{P}{T}$$

in which P = mm rain and T = temperature in centigrades.
Tha aridity index of the Martone is similar; only a constant value of 10 has been added to the temperature to avoid negative values:

$$I = \frac{P}{T + 10}$$

Emberger has introduced an aridity index which is especially applicable in the Mediterranean area. Here the temperature fluctuation during the year (and not only the average temperature) is taken into account as follows:

$$I = \frac{P}{\frac{M + m}{2} (M - m)} \times 1000$$

in which P = precipitation in mm, M = mean maximum temperature of the hottest and m = mean minimum temperature of the coolest months expressed in centigrades Kelvin.
Walter 1964 (see references) uses simple regression between climate factors as precipitation and production, within similar areas which do give reasonable results for grassland. Using the Köppen system one cannot work with qualities as such.

4. Application

The most common application of climatic data in forestry is related to the introduction of exotic species. A keen comparative study of climate classifications or special climax indices is then done to study areas from which species could be introduced. For this purpose comparative studies of North America and Europe have been made (see references: Smeets 1957; Veen 1949; Veen 1951).
In more detailed planning such data is rarely used. In these cases it is normal to use a combined integrated approach in which climatic indication is gained with the help of vegetation, altitude and aspect (in mountainous areas), and direct measurements. Good examples of these combined systems on small scale are the Holdridge maps (see references:

Holdridge, Gremke, Hatheway, Liang and Tosi 1971) and on large (detailed) scales the German forest site classification (see references: Hartman and Schelle 1969).
The Italian Forestry Service of the Mediterranean Forestlands in Southern Italy uses altitude zones separated at the 800 m and the 12 m level of altitude. These are supposed to coincide with important vegetation zones (resp. the Lauretum, Castanetum and Fagetum). These altitudinal zones are used as climatic qualities for tree species selection.
(Although it would be better to use the vegetation communities that indicate the zones much better than the absolute altitude figures. Exposure, local differences in topo climate, besides soil conditions, cause marked deviation.)
In all cases it is clear that a pure climatological quality (irrespective of whether this is determined directly or indirectly and is related to main climate, topo climate or even micro climate) only can be used in comparing sites that are the same in all other aspects (soil, exposition, etc.).

Soils

1. Classification

Soil survey data are widely used for evaluation of forest sites. Intensive studies on site quality correlated with soil type is done in most developed forest areas in the world. In many cases soil is used as an important element in integrated site quality assessment. A very extensive literature exists on soil and forest vegetation relationships (see references: Bannink, Leys and Zonneveld 1973; Bastide and van Good 1970; van Eck and Whiteside 1958; Ellenborh 1967; Erdmann 1957; Jones 1979; Kundler 1956; van Lynden 1966; Mrãz 1961; Mückenhausen 1957; Ohmasa 1951; Schelling 1955; Schelling 1960; Zonneveld 1961; Zonneveld 1977).
Some general remarks about soil classification and forest site quality should be made.
In most soil classification systems the guiding principles are focussed on (a) climatic influence on soil genesis, and (b) agricultural

applicability. The climate-based guiding principles work at high levels (large soil groups). For practical application of soil classification systems on the scale of forest management this is not often very favourable. The trend to have these subdivisions according to the climatic soil factor is fed by the wish to make reconnaissance soil maps at a small scale (smaller than 1:500,000) in which the units are not too complex. Such maps, focussing on zonality, are very useful in teaching and other scientific purposes but the soil information on such maps is much less useful for practical evaluation at the level of forest management. The main groups correspond to climatic zones of the past, and may still correlate with climatic zones that, however, are much better depicted on vegetation maps or climate maps of different kinds. Those differences in (diagnostic) characteristics, which are of direct importance in site quality evaluation, appear at the lowest levels (phases often) in the classification.

Here we see that subdivisions are usually made for agricultural practice, and for forests some of these are not relevant. For example stonyness as a quality may be of no importance for forest growth as long as tree roots can penetrate deep enough to reach minerals and moisture. On the other hand, small differences in mineral content, especially related to the condition and kind of humic layer (A and F horizons = forest floor), may be of major importance in forest evaluation, while the latter is often neglected because of disturbance of that layer by agriculture, or is judged to be of minor importance.

Real depth of root penetration and overall soil consistency are most important qualities in relation to the role of soil in support of trees, being a major factor in forest site classification (which is much less the case in agricultural application).

Existing systems should be surveyed for potential as well as actual use (preferably integrated with other land attributes). Good examples are the studies done in the Netherlands at a rather detailed level. A clear correlation was shown within a rather narrow soil classification unit of humic podzols, between Scotch pine growth and the combined factors soil humidity and mineral supply. Both factors could be partly correlated with the most detailed levels of the soil classification, but

were not sufficiently narrow to be of practical value if other survey techniques were not also taken into account.
For the defining qualities in relation to the water factor it appeared necessary to do extra observations on groundwater (via soil morphometric features combined with direct groundwater measurements for calibration). Also the spontaneous vegetation (forest floor vegetation) could give information on this. The latter was indispensable to indicate the differences in mineral supply. The latter is connected with the type of humus, which is determined also by certain biological and anthropogenic differences in the past (partly independent of the overall soil type!).

2. Inventory and evaluation

The best way of inventory of soil data is mapping.
In most cases pure soil survey (without integration with the other land attributes) is feasible at rather detailed scales, within climatological homogeneous areas. Here they represent the main way to make site quality classification for (re)forestation of areas where forest no longer exists. In the Netherlands there are good examples of this survey and their evaluation.
On reconnaissance scale actual climate may already play a too active role to be neglected; therefore soil survey alone is not sufficient.
In mountainous areas, even on rather detailed scales, topo climate plays such an important role that site evaluation mainly on base of soil data may be too risky. It follows that it may be necessary to make special surveys using characteristics different from those of usual soil surveys for agricultural practice.
The advantage of using vegetation data in combination with the soil indication has been mentioned already. As each surveyor knows, soil survey will usually also make use of terrain data (landform, physiography). The less detailed the survey, the more the landscape, especially physiography, will be used.
In general it can be said that an integrated approach is most suitable. However, even there a good soil classification focussed on forestry problems should be applied.

Vegetation

Vegetation classification systems form a widely used base for forest evaluation (see references: Bannink, Leys and Zonneveld 1973; Erdmann 1957; Ellenborh 1967; Hartmann 1968; Hartmann and Schelle 1969; Knoch 1957; Zonneveld 1961; Zonneveld 1977). Here the use for evaluation can be distinguished in three ways.

1. Inventory of the actual tree composition

For the first aim usually no vegetation classification systems are used, but an inventory is made of species, with the help of various sample-methods based on statistics. This means that the species and not a comprehensive vegetation type is the basic unit of classification and inventory. The inventory is made with the help of various transect methods in which species and volume characteristics are sampled. Aerial photos can be used. Methods may vary from qualitative to strictly quantitative inventory per tree species. The latter are very important in controlled forest exploitation of natural forests.

2. Indication of the potential tree species composition

The second aim of vegetation inventory in forests makes use of floristic vegetation classification systems. Good examples are the Braun-Blanquet system, which is commonly applied in several forms in Europe and Japan, as well as in America and various tropical areas. The classification units are comparable in character to soil units. A statistically found characteristic combination of species is used as a characteristic for subdivision and hierarchical agglomeration. The tree composition of natural forests may give the potential tree composition. These data can be used for selection of tree composition in areas where the tree layer has been removed or replaced, but the forest floor vegetation still indicates the original vegetation type. In the mountainous areas of Germany this principle is applied (see references: Hartmann 1968; Hartmann and Schelle 1969). However, particularly in Europe, many open "niches" exist in forest vegetation as far as the shrub and tree composition is concerned. So potentially from various points of view other tree species (e.g. from America) could also be introduced.

3. <u>Indication of the site forming factors such as climate, soil and hydrology</u>

For a wider reaching potential use, the third aim may be of help. The same holds true for any kind of improvement one should like to apply in the forest, such as drainage and fertilisation. A natural system of vegetation types can serve as a good base for all kinds of other forest values. Also for this indication purpose floristic vegetation classification using the full species composition of the forest ecosystem especially the forest floor vegetation (being the most spontaneous) is the most appropriate.

Structural types like formation systems, using a maximum of only a few dominant tree species, are better than nothing in areas where the plant species are not sufficiently known, but are liable to quick alteration and usually have a lower indication value. However, it is good to have structural data incorporated at a lower level too. For Europe and Japan reasonable floristic classification systems with a hierarchical structure already exist.

For detailed evaluation it may still be useful to design local systems (compatible with general ones(!), to be able to make a generalisation and comparison with other areas) using original vegetation data and correlation studies with the environment. Examples are our studies in the Netherlands (see references: Bannink, Leys and Zonneveld 1973; Zonneveld 1961; Zonneveld 1977).

Again, the suitable inventory technique is survey, vegetation survey in this case. As has already been said, a combination with soil survey is preferable. In certain cases single vegetation surveys may have an advantage over single soil surveys because besides potential natural species composition, the vegetation expresses soil, water and (topo) climatic factors all in one, so it has rather an integrated character. However, because the vegetation in certain places (especially in densely populated areas) may be absent or disturbed, the assistance of direct soil and landform observations may be very useful.

In some cases the deepest groundwater influence may be less clear in forest floor vegetation and need verification by (deep) soil data. Often so-called vegetation maps include direct information on other attributes or are at least based on those data. This applies for most reconnaissance maps. The Holdridge maps are clear examples. The vegetation zones maps of E. Smidt in Switzerland are another example (see references: Ellenborh 1967).

Other land attributes

Examples are known of how the *geology* and the *landform* expressed in map form help in studying the site quality. However, use of these factors individually are not known to the author. The previously mentioned altitude zones used as potential forest areas in Southern Italy may be an example, but here the altitude zone is used as a climate indicator, to assist the soil or vegetation or climate surveyor to make his maps. Usually they are taken into account in any integrated approach. At least the previously mentioned Holdridge maps of Latin America (see references: Holdridge, Gremke, Hatheway, Liang and Tosi 1971) (at least the best ones of them) are examples as far as small scale mapping is concerned. The "standortskartierung" in Germany represents examples of more detailed surveys (see references: Ellenborh 1967; Kilian 1980; Knoch 1957). The terrain classification as explained by Löffler in this symposium also makes intensive use of landform and geological data.
Good geological classification systems do exist, landform systems exist mainly in the form of legend description applied for geomorphological terrain analysis (e.g. van Zuidam and van Zuidam-Cancelado 1979: see references.

REFERENCES

BANNINK, J.F., H.N. LEYS and I.S. ZONNEVELD (1973). Vegetation, habitat and site class in Dutch conifer forest. Bodemkundige studies 9. Stiboka.

BASTIDE, J.G.A. and C.G. VAN GOOD (1970). Growth-site relationships in plantations of Pinus ellioti and Araucaria augustifolia in Brasil. Plant and soil 32: 349-366.

ECK, W.A. van and E.P. WHITESIDE (1958). Soil classification as a tool in predicting forest growth. Forest soils conference 8-11.

ELLENBORH, H. (1967). Ecological and pedological methods of forest site mapping. Veroff. Geob. Inst. der E.T.H. stiftung Rübel. Zürich. Helf 39.

ERDMANN, E.F. (ed.) (1957). Standortkartierung in Nordrhein-Westfalen. Sonderhelt. Alg. Forst und Jagd Zeitung.

HARTMANN, F.K. (1968). Ergebnisse klimatisch-ökologischer Untersuchungen in deutschen Mittelgebirgen. Vortrag 25-4-68. Münchener Hochschulwoche, München.

HARTMANN, F.K. and F. SCHELLE (1969). (Unter mitarbeit von E. Franken, H.W. Moll und M. Scheider.) Klimagrundlagen natürliche Waldstufen und ihre Waldgesellschaften in deutschen Mittelgebirgen. Gustav Fischer Verl. Stuttgart.

HOLDRIDGE, L.R., W.G. GREMKE, W.H. HATHEWAY, T. LIANG and J. TOSI (1971). Forest environments in tropical life zones. Oxford. Perg. Press.

JONES, G. (1979). Vegetation productivity. Topics in applied geography. Longman, London, New York, 100 p.

KILIAN, W. (1980). Site classification systems used in forestry. This symposium.

KNOCH, R. (1957). I. Vegetationskundluche Schulen. II. Die Standortstypen bildung von R. Knoch. Mitteilungen. Schw. Anst. Forstliche Versuchswesen.

KÖPPEN, W. (1936). Das geographische System der Klimate. Handbook der Klimatologie Bd. I.

KUNDLER, P. (1956). Beurteilung forstich genutzter Sandböden in nordostdeutschen Tiefland. Archiv. für Forstwesen Bnd. 5. Heft 9/10: 585-672.

LEMÉE, G. (1967). Precis de Biogéographie. Masson & Sie Editeurs. Paris.

LIETH, H. (1974). Comparative productivity in ecosystems. The primary productivity. Proceedings of the first international congress of ecology, The Hague: 36.

LYNDEN, K.R. Baron van (1966). Indeling van gronden naar hun geschiktheid voor de bosbouw. Ned. Bosb. Tijdschr. 38(8): 280-291.

MRÀZ, K. (1961). Zur Frage der Ökologischen bewertung von Waldböden. Comm. Int. Forestalis, Chechosloveniae, Vol. 2.

MÜCKENHAUSEN, E. (1957). Grundsatzfragen der Bodenkartierung, ins besondere für die forstliche Standorterkundung in Nordrhein-Westfalen. Alg. Forst und Jagdzeitung, Jrg. 128, April.

OHMASA, M. (1951). Studies on beech forest soils. Forest soils of Japan. Rep. 1. Govern. forest exp. station, Meguro, Tokyo, Japan.

SCHELLING, J. (1955). Stuifzandgronden (Inland dune sand soils). Detailed reports of the forest research station TNO. Bnd. 2, nr. 1: 1-58.

SCHELLING, J. (1960). De hoge bosgronden van Midden-Nederland (The high forest soils of the central Netherlands). Bodemkundige studies. Stichting voor Bodemkartering.

SMEETS, J.G.P.M. (1957). Een vergelijkend ecologisch onderzoek (A comparative ecological study). In opstanden van Quercus Borealis en Quercus Robus. Versl. Landb. Onderz. no. 63.6.

THORNTWAITE, C.W. (1931). The Climate of North America according to a new classification. Geographical rev. Bd. 21: 633-655.

UNESCO-FAO (1963). Bioclimatic map of the Mediterranean zone. Arid zone research. UNESCO Paris.

VEEN, B. (1949). Klimatologische indelingen toegepast op Nederland. Med. Landbouwhogeschool, Wageningen. Bd. 49: 157-212.

VEEN, B. (1951). Herkomstenonderzoek van de Douglas in Nederland (Provenance research of the Douglas fir in the Netherlands). Diss. LH Wageningen, December 1951.

WALTER, H. (1964). Productivity of vegetation in arid countries. The Savannah problem and bush encroachment after overgrazing. Proc. IUCN technical meeting III. The impact of man on the tropical environment: 221-229.

ZONNEVELD, I.S. (1961). Zusammenhäuge Forstgesellschaft Boden - Hydrologie und Baumwuchs in einigen Niederländischen Pinus-Forsten auf Flugsand und aud Podsolen. Anthropogene Vegetation. (Intern. Symposium Stolzenau).

ZONNEVELD, I.S. (1977). Klassifiseren en evalueren van bos *mede* met behulp van de spontane vegetatie. Ned. bosb. tijdschrift 49: 44-65.

ZONNEVELD, I.S. (1979). Land evaluation and land(scape) science, 2nd edition. ITC textbook: VII-4.

ZUIDAM, R.A. van and F.I. VAN ZUIDAM-CANCELADO (1979). Terrain analysis and classification using aerial photographs. ITC textbook VII-6.

INTEGRATED APPROACHES TO CLASSIFYING LAND AS ECOSYSTEMS

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Summary

Systems for classifying and evaluating land as ecosystems have developed in different parts of the world during the past century. These systems describe and analyze relatively homogeneous units of land on local or regional scales. They classify land both as holistic ecosystems and according to their components. An example of a hierarchical system for classification of natural terrestrial ecosystems based on a combination of biotic and abiotic criteria is outlined for the United States.

Introduction

Classification of land is required to provide an effective basis for resource assessment and management and land use planning. Most disciplines such as forestry, range management, and wildlife management have developed numerous classifications, and most land-management agencies have several systems. Also, most classification systems have focused on individual elements, such as vegetation and soils. Little progress has been made toward developing a classification system that deals with individual land elements in conjunction with their spatial relationships in an ecological framework.

An interagency team of the Resources Evaluation Techniques Research and Development Program at the Rocky Mountain Forest and Range Experiment Station has been working since 1976 to develop an ecological classification system for the United States. The team, represented by the Bureau of Land Management, Forest Service, Fish and Wildlife Service, Geological Survey, and Soil Conservation Service, has been improving the framework developed by Driscoll, Russell, and Meier (1978) and refined by Merkel et al. (in prep.). The framework consists of four ecosystem components--vegetation, soil, landform, and water--which are examined to describe and define taxonomic ecosystems and ecosystem associations in relation to their geographic arrangement. This paper provides an overview of a procedure to describe and define geographical ecosystems as a part of the ecological classification framework.

Background

During the 1930s, the federal government began to inventory and study a broad range of individual resources and plan for their development (Bailey, Pfister, and Henderson 1978). By the late 1950s, it was apparent that looking at individual resources by themselves was too limited. What was lacking was a uniform and integrated classification system. At the same time, land managers became aware of the integrated nature of ecosystems.

A major problem in the development of such a system has been component integration. How ecosystems are integrated cannot be determined solely by analysis of their components. Furthermore, land is commonly inventoried either by units of area or by statistical sampling procedures. Also, land is not managed by individual ecosystem component; instead, it is managed, or should be managed, as an integrated entity considering both biotic and abiotic characteristics. It is important to establish a scheme to identify land units where ecosystem components are integrated in a similar way, thereby classifying land as ecosystems.

The Ecosystem Concept

In simple terms, the ecosystem concept states that the earth operates as a series of interrelated systems within which all components are linked, so that a change in any one component may bring about some corresponding change in other components and the operation of the whole system. An ecosystem approach to land evaluation stresses the interrelationships among components rather than treating each one as a separate characteristic of the landscape.

Rowe (1961) defined an ecosystem as ". . . a topographic unit, a volume of land and air plus organic contents extended areally over a particular part of the earth's surface for a certain time." This definition stresses the reality of ecosystems as geographic units of the landscape that include all natural phenomena and that can be identified and surrounded by boundaries. The boundaries of ecosystems, however, are never closed or impermeable; they are open to transfer of energy and materials to or from other ecosystems. The open nature of ecosystem boundaries is important, for even though we may be dealing with a particular ecosystem as a land unit, we must keep in mind that the exchange of material with its surroundings is an important aspect of the system's operation.

The term "ecosystem" is used quite generally without reference to spatial dimensions. The largest terrestrial ecosystem is formed by the ecosphere; examples of small ecosystems would be a narrowly limited, homogeneous stand of vegetation and a small pond. Therefore, to cover all ecosystems at all levels of planning and management, it is necessary to set up a definite hierarchy of ecological units of different sizes. Since we are dealing with spatial systems, they will be consistently inserted, or nested, into each other. Each level constitutes the environment of the system at the level below it; and, therefore, conditions or controls the behavior of the system at the level below it (Warren 1979). For example, climate controls runoff in a watershed, which, in turn, interacts with hillslopes to produce stream channels. At each level, new processes emerge that were not present or not evident at the next level below. As Odum (1977) noted, results at any one level aid the study of the next level in a set but never completely explain the phenomena occurring at that higher level, which itself must be studied to complete the picture.

Levels of Integration

Ecosystem components cannot function as independent systems, because they exist only in association with one another (e.g., thin soils on steep slopes, flat floodplains of fine textured soil and inadequate drainage, or the taiga areas dominated by narrow-leafed evergreen forest with spodozol soil and subarctic climate). How components are related can be viewed at different levels from the standpoint of complexity and relationships. One level provides an understanding of relationships within the local area, and another provides an understanding of local areas within the context of a larger area or region.

Integrated classification of small, relatively homogeneous areas follows directly from the components and involves the combination of two or more components. The concept of using more than one component system to identify integrated homogeneous units of land at the local level was expressed in ECOCLASS (Corliss 1974), Modified ECOCLASS (Buttery 1978), and ECOSYM (Henderson, Davis and Ryberg 1978). Several component classifications, each with its own hierarchy, can be linked to define ecological land or water units. Integrated units as defined this way, are place-independent because interrelationships of surrounding land units are not considered. These units can be grouped on the basis of their similarities into higher classes, which reflect increasing generality of information. For example, spruce-fir forest ecosystems can be grouped with Douglas-fir forest ecosystems into a category called needle-leaf evergreen forest. Because geographic location is not considered, larger land units do not necessarily result from such a process. In addition, all data from discontinuous areas of the same type would be pooled regardless of geographic location. This kind of information is necessary to make independent inferences about forest, grassland, and shrubland ecosystems. However, the local system can never be understood fully except in the context of the larger system that encompasses it.

For such an understanding, it is necessary to view ecosystems in a geographic or spatial hierarchy that reflects how they fit together in the landscape. The grouping of ecosystems to define units at this level of integration is analogous to using combinations of soils in defining soil catenas (associations) or landforms in defining watershed basins. However, ecosystems related by geography are not necessarily related by taxonomic properties. The catena, for example, comprises different taxonomic soil series which are geographically related. An advantage of combining ecosystems into larger geographical units is that they can be related to surrounding units with which they interact. This is important in evaluating the effect of management of one type of system on surrounding systems (e.g., the effect of grazing in the alpine zone on the adjacent subalpine zone).

A Multipurpose System

Land areas are classified according to intended use. The set of characteristics chosen as significant for classifying a ecological unit for one resource use must often be revised to suit another purpose. The result is likely to be a different pattern of units for each activity considered.

This approach is not going to satisfy the need for integrated information about the ecosystem and its resources. The expense alone of collecting separate information on timber, wildlife, recreation, and other resources precludes it. In the United States, we must consider interaction between these separate outputs on the same unit of land if environmental laws and multiple use mandates are to be complied with. For these reasons, a general classification system which can be used for multiple purposes is needed. This does not mean that special purpose, functional classification of land units will no longer be needed. They will, but should be done within the context of the multipurpose system.

Classification of Land as Ecosystems

Classification of land as systems for resource management has been proposed and developed by ecologists and geographers since Tansley (1935) coined the term "ecosystem." However, the concept of land as an ecosystem is much older. The ancient Greeks recognized such a concept. In the 18th century, Baron von Humbolt provided an outline of latitudinal zonality and high-altitude zonality of the plant and animal world in relation to climate. Of immense significance for the development of the theory of integrated concepts was the work of Duckuchaev (1899) who pointed out that within the limits of extensive areas (zones) natural conditions are characterized by many features in common, which change markedly in passing from one zone to another. As Kalesnik notes (1962), he "called for the study, not of individual bodies and natural phenomena, but certain integral territorial aggregates of them." These ideas formed the basis for subsequent work in integrated land classification.

At the world scale, natural regions have been mapped by Herbertson (1905) and further refined by Biasutti (1962). In Russia, Berg (1947) detailed landscape zones while similar work related to landscape science was developed by Passarge (Troll 1971) in Germany. Veatch's (1930) research in Michigan outlined "natural geographic divisions" and "natural land types." In surveys undertaken within the British Empire, Bourne (1931) derived his concepts of "sites" and "site regions." Sukachev's (Sukachev and Dylis 1964) investigations into biogeocoenology followed similar lines. Other studies which make use of integrated concepts have been developed in Australia (Christian and Stewart 1968) and the United States (Wertz and Arnold 1972), under the title of "land systems." In Canada, such a concept is used in "biophysical" or "ecological land classification" (Wiken and Ironside 1977). This methodology calls for total integration of landform, lithology, relief, climate, soils, and vegetation.

While similar concepts have evolved in different countries, different systems of units have been developed during the past 20 years for dealing with ecosystems at different levels of integration. As table 1 indicates, there are differences in the number of levels and the units at approximately the same level have different names. This makes it difficult to compare and contrast work derived from different countries. They all, however, share a common approach by the application of certain well recognized principles which are followed in constructing a system of classification.

Principles of Integrated Land Classification

Because subsystems can be understood only within the context of the whole, a classification of ecosystems usually begins with the largest units, and successively subdivides them by levels. While the concept of ecosystem implies equality among all the components, all components may not be equally significant at different levels in the hierarchy. Further, it is difficult to systematically deal with all components simultaneously. Therefore, it is necessary to establish a clearly defined hierarchy of components that reflects their level of control on the location, size, productivity, structure, and function of the system. Thus, components which exert the most control are highest in the classification. The differentiating criteria at the upper levels are broad and general in importance, with the greatest control, while those at lower levels are narrow and more specific in importance. Integrated classification comonly involves, therefore, alternative use of components along with information on process for the differentiation of successive levels.

For broad-scale classification of a continent into a small number of large units, the large ecological climate-zones are a possible approach (Walter and Box 1976). The formulation of soils and vegetation types is determined primarily by the climate; this is less true for the fauna. The macroclimate is a primary factor for the ecosystem. Surface configuration

Table 1.--System of units in ecological land classification.

Australian land research approach[1]	British land unit approach[2]	Canadian ecological land classification[3]	Soviet Union landscape approach[4]	United States land systems/ ecosystem approach[5]
			Zone	
				Domain
	Land Zone			Division
	Land Region	Ecoregion	Province	Province
	Land District	Ecodistrict		Section
			Landscape	
Land System	Land System	Ecosection		District
	Land Type	Ecosite	Urochishcha	Landtype Association
Land Unit				
Land Type	Land Phase			Landtype
Site		Ecoelement		Landtype phase
			Facia	Site

References: 1 - Christian and Stewart (1968); 2 - Brink et al. (1965); 3 - Wiken and Ironside (1977) 4 - Isachenko (1973); 5 - Wertz and Arnold (1972), Bailey (1976).

at the broad level is less influenced by climate than is either vegetation or soil; but the influence is great enough for the minor features to reflect the climate of the area where they occur.

For further subclassification, below climate, the broad-scale vegetation conditions appear to be appropriate criteria, which also provide a very delicate index of climate. Its predominance in the landscape also insures its consideration in any scheme of zoning. Usually, the boundaries of vegetation regions or major plant formations coincide with those of major relief units; this strengthens the primary division. However, the surface features are more useful at lower levels, that is, for zoning biotically circumscribed areas.

For detailed discussion of the principles of integrated land classification, several references are recommended: Pfister (1977), Rowe (1979), Platts (1980).

An Example

Land units which are relatively homogeneous in biological and physical characteristics at any level of generalization are ecosystems. The degree of homogeneity decreases with increasing levels of generalization. A small pond often is homogeneous with respect to all of the components, whereas the humid tropics are homogeneous only for certain climatic characteristics. However, the other components of the humid tropical ecosystem still have a lot in common, and collectively, they are different from those of other kinds of broad-scale ecosystems.

In the United States, no single, generally accepted hierarchy of ecosystem units can be identified, nor is there a generally accepted terminology. One system, developed by Bailey (1976, 1978) from concepts advanced by Crowley (1967) and Wertz and Arnold (1972), is presented in table 2. This nine-level system is based on climate and vegetation at the upper levels with soil, landform, and potential natural vegetation at the lower levels. This kind of ecological partitioning follows existing national and regional schemes; whereas the basic concepts and principles of the approach were based on international experiences. These include work in Australia (Christian and Stewart 1968), England (Brink et al. 1965), Russia (Isachenko 1973), and Canada (Wiken and Ironside 1977).

While the definitions offered in table 2 are provisional and have not been accepted nationally, they illustrate the principles of the approach. Definitions of the lower levels (i.e., levels 6-9) in particular are most variable from one region to the next.

Table 2.--Levels of generalization in a hierarchy of ecosystems.

Levels of generalization and common scales of mapping	Current definitions
1. Domain 1:3,000,000 and smaller	Subcontinental areas of broad climatic similarity identified by zonal heat and water balance criteria.
2. Division 1:1,000,000 to 1:3,000,000	A part of a domain identified by macroclimatic criteria generally at the level of the basic climatic types of Köppen (Trewartha 1943).
3. Province 1:500,000 to 1:1,000,000	A part of a division identified by bioclimatic and soil criteria at the level of soil orders and classes of vegetation formations. Highland regions (e.g. mountain systems) with complex climate-vegetation zonation are distinguished at this level.
4. Section 1:250,000 to 1:500,000	A part of a province identified by a single climatic vegetation climax at the level of Küchler's (1964) potential vegetation types.

Table 2.--Continued

Levels of generalization and common scales of mapping	Current definitions
5. District 1:125,000 to 1:250,000	A part of a section identified by Hammond's (1964) land-surface form types.
6. Landtype association 1:20,000 to 1:125,000	A part of a district determined by isolating areas whose form expresses a climatic-geomorphic process (e.g. fluvial, glacial, etc.).
7. Landtype 1:10,000 to 1:20,000	A part of a landtype association having a fairly uniform combination of soils (e.g. soil series) and chronosequence of vegetation at the level of Daubenmire's (1968) habitat types.
8. Landtype phase 1:2,500 to 1:10,000	A part of a landtype based on variations of soil and landform properties such as soil drainage and slope that affect the productivity of the habitat type.
9. Site 1:2,500 and greater	A part of a landtype phase that is homogeneous in respect to all components, their appearance, potential to produce biomass, limitations to use and response to management. It is the basic geographic cell of the ecological classification.

Applications and Refinements

The preceding example, assigning prime importance at different scale levels to different components, is not completely tested. Adjustments in the number of levels and the criteria for division of the levels will have to be made. This process, however, appears to be conceptually sound, and should form a basis for grouping the individual components into land units and those units into regional units that will provide a locator for any ecosystem in the United States. Because it is based on an approach used throughout the world, it will provide a means for relating ecosystems of the United States to those of other nations.

Literature Cited

Bailey, R. G. 1976. Ecoregions of the United States (map). USDA Forest Service, Intermountain Region, Ogden, Utah.

Bailey, R. G. 1978. Description of the ecoregions of the United States. USDA Forest Service, Intermountain Region, Ogden, Utah. 77 p.

Bailey, R. G., R. D. Pfistér, and J. A. Henderson. 1978. Nature of land and resource classification--A review. Journ. For. 76:650-655.

Berg, L. S. 1947. Geograficheskiye zony Sovetskogo Soyuza (Geographical Zones of the Soviet Union). Vol. 1, 3rd ed. Geografgiz, Moscow.

Biasutti, R. 1962. Ll paesaggio terrestre. 2nd ed. Unione Tipografico, Torino.

Bourne, R. 1931. Regional survey and its relation to stocktaking of the agricultural and forest resources of the British Empire. Oxford Forestry Memoirs 13, Clarendon Press, 169 p.

Brink, A. B. A., J. A. Mabbutt, R. Webster, and P. H. T. Beckett. 1965. Report of the Working Group on land classification and data storage. Military Engrg. Exp. Establ. Rep. No. 940. Christchurch, England. 97 p.

Buttery, R. F. 1978. Modified ECOCLASS - A Forest Service method for classifying ecosystems. <u>In</u> Proceedings integrated inventories of renewable natural resources. Tucson, Ariz. Jan. 8-12, 1978. USDA Forest Service Gen. Tech. Rep. RM-55, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. p. 157-168.

Christian, C. S. and G. A. Stewart. 1968. Methodology of integrated surveys. <u>In</u> Aerial surveys and integrated studies. Proc. Toulouse Conf. 1964, UNESCO, Paris. p. 233-280.

Corliss, J. C. 1974. ECOCLASS--A method for classifying ecosystems. <u>In</u> Foresters in Land-Use Planning. Proc. 1973 Natl. Convention Soc. Am. For., Washington, D.C. p. 264-271.

Crowley, J. M. 1967. Biogeography. Canadian Geog. 11:312-326.

Daubenmire, R. 1968. Plant communities: a textbook of plant synecology. Harper & Rowe, New York. 300 p.

Driscoll, R, S., J. W. Russell, and M. C. Meier. 1978. Recommended national land classification system for renewable resource assessments. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. mimeo, 44 p.

Duckuchaev, V. V. 1899. K Ucheniyu o zonakh prirody, gorizontalnyye i vertikalnyye zony (Concerning the study of the zones of nature, horizontal and vertical zones). Moscow.

Hammond, E. H. 1964. Analysis of properties in landform geography: An application to broad-scale landform mapping. Annals Assoc. Am. Geog. 54:11-23.

Henderson, J. A., L. S. Davis, and E. M. Ryberg. 1978. ECOSYM: A classification and information system for wildland resource management. Utah State University, Logan, Utah. 30 p.

Herbertson, A. J. 1905. The major natural regions: An essay in systematic geography. Geog. Journ. 25:300-312.

Isachenko, A. G. 1973. Principles of landscape science and physical-geographic regionalization. J. S. Massey, ed. R. J. Zotorski, tr. Melbourne Univ. Press, Carlton, Victoria, Australia. 311 p.

Kalesnik, S. V. 1962. Landscape science. <u>In</u> Soviet Geography Accomplishments and Tasks. Am. Geog. Soc. Occasional Publ. No. 1. p. 201-204.

Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States (map and manual). Am. Geog. Soc. Spec. Publ 36. 116 p.

Merkel, D. L., R. S. Driscoll, D. L. Gallup, J. S. Hagihara, D. O. Meeker, D. W. Snyder, and T. T. Terrell. In prep. National site (land) classification system - status and plans. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Odum, E. P. 1977. The emergence of ecology as a new integrative discipline. Science 195:1289-1293.

Pfister, R. D. 1977. Ecological classification of forest land in Idaho and Montana. In Proceedings of Ecological Classification of Forest Land in Canada and Northwestern USA. Univ. of British Columbia, Vancouver. p. 329-358.

Platts, W. S. 1980. A plea for fishery habitat classification. Fisheries 5:2-6.

Rowe, J. S. 1961. The level-of-integration concept and ecology. Ecology 42:420-427.

Rowe, J. S. 1979. Revised working paper on methodology/philosophy of ecological land classification in Canada. In C. D. A. Rubec, ed. Proceedings Second Meeting Canada Committee on Ecological (Biophysical) Land Classification April 4-7, 1978, Victoria, B.C. Lands Directorate, Environment Canada, Ottawa. p. 23-30.

Sukachev, V. and N. Dylis. 1964. Fundamentals of forest biogeocoenology. trans. by J. M. Maclennan, Oliver & Bond, London. 672 p.

Tansley, A. 1935. The use and misuse of vegetation terms and concepts. Ecology 16:284-307.

Thornthwaite, C. W. 1931. The climates of North America according to a new classification. Geog. Rev. 21:633-655.

Trewartha, G. T. 1943. An introduction to weather and climate. 2nd ed. McGraw-Hill, New York. 545 p.

Troll, C. 1971. Landscape ecology (geoecology) and biogeocenology--a terminology study. Geoforum 8:43-46.

Veatch, J. O. 1930. Natural geographic divisions of land. Mich. Acad. of Sciences, Arts and Letters. 19:417-427.

Walter, H. and E. Box. 1976. Global classification of natural terrestrial ecosystems. Vegetatio. 32:75-81.

Warren, C. E. 1979. Toward classification and rationale for watershed management and stream protection. Corvallis Environmental Research Lab. U.S. Environmental Protection Agency. Corvallis, Oregon. EPA-600/3-79-059. 142 p.

Wertz, W. A. and J. F. Arnold. 1972. Land systems inventory. USDA Forest Service, Intermountain Region, Ogden, Utah. 12 p.

Wiken, E. B. and G. Ironside. 1977. The development of ecological (biophysical) land classification in Canada. Landscape Planning 4:273-275.

FAO'S EXPERIENCE IN LAND CLASSIFICATION FOR FORESTRY WITH PARTICULAR REFERENCE TO DEVELOPING COUNTRIES

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Summary

FAO's experience in land classification for forestry is from world level to project level. Although land classifications have been made specifically for forestry, many current land classifications have forestry as one of several alternative land uses evaluated. Land classification projects for forestry have been designed and carried out in response to locally defined needs and consequently have great diversity. Standardized land evaluation principles and methods have not been widely used. A need for a "guideline" for land classification for forestry is recognized.
This paper reviews examples of FAO's recent experience in land classification for forestry in developing countries. It is written to show the status of this work in FAO as a basis for charting future work in land classification.

Introduction

Historically, forest land has been treated as a stock of land which may be drawn on to convert to agricultural land or other use as that use becomes economic, the timber cover being treated as a free good which may be utilized or not according to whether it was marginally economic to do so. This history has been repeated in many countries until a point was reached when the future supply of wood was perceived as no longer secure and that wood was therefore not a free good anymore and that uncontrolled destruction of forest cover could have serious environmental effects particularly in relation to soil and water conservation. The position that forest is recognised as contributing important social and economic benefits and must be managed jointly with other forms of land use to optimise the return to the community as a whole has been reached in most countries of the developed world. Though a position of insecurity of future wood supply and environmental harm from forest destruction has been reached in many developing countries, clear perception of the situation by the body politic supported by introduction of appropriate control systems has been achieved in relatively few.

Necessary to the achievement of the optimum contribution of land resources to the social and economic benefit of the community is that each individual area should be utilised in such a way that it makes maximum contribution in relation to the situation of the community. Planning implies the identification of possibilities (feasible uses - crops); assessment of the cost of effort and materials in their production and the value of the products; selection from the collection of production possibilities, the set that fulfills to the greatest extent the wants of the community and then mapping the course to achieve that combination of production. Land evaluation constitutes a major information requirement for ascertaining the production possibilities - the feasible crops and their potential production. The other broad areas of information are the supply of labour and materials and the community's demand for the potential outputs of the various possible crops. In addition, the externalities have to be taken into consideration. These include the effects on others than immediate producers and consumers - such as soil erosion and consequent siltation, water conservation, pollution, shelter, harbouring pests and diseases - associated with particular production possibilities.

Land classification means many things. In the strictest sense it is the organization of land units to satisfy specified needs. As used in this paper, it is a means to gather natural resource information for land use decision making in which land units having significance to a particular kind of land use are identified, analysed and interpreted. Land classification is similar to land evaluation (FAO 1976b) with perhaps greater emphasis on land as the expression of an integration of natural resources and land units as whole, definable entities. The focus on units of land removes studies dealing with specific sites or individual resources although site studies are used as a guide for interpretation of land units and individual resources can serve as criterion for land unit identification.

Land classification can be used in forestry, first to provide information specifically for forestry, i.e. for forest stand establishment or manipulation to provide maximum economic and social benefits, secondly to support planning in the several fields allied with forest management such as watershed management, pasture and grazing, recreation and wildlife management and, third to support forestry as one element in land use planning where agriculture is frequently the major land use. With the demand for careful planning of natural resources and land use in economic development, item three is probably FAO's major activity requiring land classification for forestry.

Nearly any kind of land classification in an area of forest or potential forest has implications to land classification for forestry. The following is a review of examples of FAO activities in this field going from the general to the specific.

World classification of forest lands

This type of survey of the world's forest resources is a land classification in the sense that it identifies units of land on the basis of major forest types. The information produced, however, has been specifically for forestry. FAO's involvement in such surveys reaches back to the 1948 *Forest Resources of the World* report. More recently (Pringle, 1978) a summary location of the tropical forests of the world was made as a guide to improving utilisation of these forests. A summary of the world's forest resources shows that about 30% of the world's land surface or 4,000 million hectares is under forests. Half of this is in developing countries, of which 1,300 million hectares is closed forest. The remainder in developing countries is other wooded land, open woodland and various types of scrubland, wooded savannas and the like. It is estimated that some 1,000 million ha or 80% of the area of closed tropical forest is virtually undisturbed. The current rate of intervention leading to conversion from closed forest or the destruction of closed forest is estimated to be of the order of 7 million hectares per annum while the tree cover on an additional 3 million hectares of other wooded land is destroyed each year. The extent of disturbance through grazing and burning in the area of other wooded land is very much greater than the area actually destroyed each year. The total area of forest plantations in tropical countries is of the order of 10 million ha. This brief summary illustrates the central role of forestry in all development activities in tropical countries and reinforces King's (1978) call for "Inventorying the forests of the world as rapidly as possible, using the most modern techniques and the technologies that are available".

The Soil Map of the World (FAO-Unesco, 1975) can be cited as a kind of land classification involving forestry. The volumes in this series give a brief but excellent overview of the natural vegetation regions on a continental level. The soil unit descriptions treat forestry as one of the land uses.

The Agro-ecological Zones Project (FAO, 1978) makes an indirect contribution to forestry by documenting alternative land uses in forested lands.

FAO is presently engaged, with the financial assistance of UNEP (Global Environment Monitoring System), in a reassessment of the world's tropical forest resource which should be completed by the beginning of 1981. The first results for Latin America confirm those given above especially as far as destruction of closed forests is concerned.

National level land classification

At national and regional levels most FAO land classifications for forestry are made using aerial photographs and/or satellite imagery. Broad vegetation and land use types and physiographic classes have been used to separate the productive forest lands from those areas which are unproductive or nonforested for a variety of reasons: topography, edaphic conditions, nonwoody vegetation types or nonproductive woody types, e.g. stunted tree vegetation above timber line. Sometimes this classification is superimposed on an econological classification such as an FAO reconnaissance inventory in Panama where the Holdridge life zone system was used to make the first stage of stratification (FAO, 1972). Another example is the FAO/UNEP forest cover monitoring project in Togo, Benin and Cameroon where a broad "ecofloristic" classification was made as a framework for subsequent woody vegetation classification (FAO/UNEP, 1980). The extensive use of side looking airborne radar imagery for national and regional forest surveys in Latin America has given event more emphasis to physiographic classification of forested lands (PRORADAM project in Colombia, RADAMBRASIL project (FAO, 1975c). The forest maps at national and regional levels also separate classes within the productive forest types when the types can be easily identified on the map base. Types are separated on the basis of the dominant species in the case of temperate or subtropical forests and, in the tropics, the coniferous stands, the pure stands of some gregarious species (such as some Caesalpiniaceae in West and Central Africa) and the mixed broadleaved forests are separated.

As part of National Forest Inventories, detailed data on land and forest is collected on the basis of statistical sampling spread over the whole country. Among others, the following are some important items generally included:

Site:	topography, slope, aspect, terrain soil (depth, texture, and structure of upper soil horizon), etc.;
Stand:	vegetation, forest type, age/size class, growing stock; and
Management data:	accessibility data, cutting priority, thinning needs, etc.

As National Forest Inventories aim to provide data on a continuous basis for forestry and land use planning and control, effort is generally made to have an extended data-base keeping in view not only the needs of the forestry sector planning but also making strategic decisions concerning alternative land uses. These have been the basic ideas in the formulation of recent FAO National Forest Inventory projects in the Philippines, Burma and Indonesia.

Intermediate level land classification

More refined classifications are generally designed and used at the intermediate levels, for example, for *preinvestment forest surveys* (Lanly, 1976, Singh, 1978). These classifications, using height and density of canopy as the main criteria, are applied first to the forest stands within each broad forest vegetation type as defined in the first level of classification. The classes, called "forest condition classes", are delineated on maps through interpretation of aerial photographs and are used as strata in the field sampling design (FAO, 1973). Although not necessarily closely correlated to nonforest characteristics, they may serve also as a useful stratification for site evaluation. More precise site and stand data is collected on a sampling basis including among other the soil, slope measurement, identification and measurement of the tree, undergrowth and herbaceous layers. These are the types of forest surveys which have been carried out by the developing countries in the last twenty years, often with the collaboration of UNDP/FAO and bilateral agencies, e.g. CIDA, USAID, French aid, O.D.A. FAO has assisted in such surveys in northwestern Ecuador, Venezuela, Guyana, Surinam, Guatemala, Honduras, Dominican Republic, Congo, Gabon, Nigeria, Sri Lanka and Sarawak. Preinvestment forest surveys carried out in connection with pulpmill projects in mixed tropical forests are those which provide the most detailed information since all trees even of small dimensions are enumerated and measured (Cameroon, Gabon, Ivory Coast). In some cases a good coordination is secured with soil surveyors who use the inventory lines for soil sampling. An example of this is for the forest surveys in Bastar area, India.

Land classification for forest management

Most detailed land and forest classification is carried out as part of forest management or working plans. The total area of intensively managed forests in the tropics, however, is very small and limited to few countries such as India, Burma, Indonesia (more particularly Java). For management plans, mapping is done on a stand basis identifying type, age, density and site classes. Growing stock data is collected either on the basis of intensive sampling or complete enumerations.

For the mixed tropical forests, which constitute the major forest formation of the tropics, mapping has been limited to broad types, stand height and density classes. For such formations no suitable technique for site assessment is known, though it is one of the most important prerequisites for scientific forest management.

Land classification for integrated development

Most forest land classifications began in the last thirty years, essentially for wood production purposes. More comprehensive approaches have been adapted only recently. Some countries, e.g. Ivory Coast, Peru and Brazil, have made natural resource reconnaissance surveys of forested lands for land use planning. FAO has suggested guidelines to the Government of Paraguay (FAO, 1977a) to assist with forest land classification.

FAO has been involved in land classifications for multiple land uses under the heading of *rural development* or *integrated development*. In Marocco (FAO 1965) such a project covered soil erosion control, forest production and reforestation, irrigation, and agricultural production. In Indonesia, the Solo project (FAO, 1976a) used a land classification approach to gather data for a broad spectrum development project on the island of Java. The classification resulted in land capability estimates for erosion control and several different agricultural crops as well as forestry. The Integrated Watershed Project in Nepal (FAO, 1974a) classified the lands using input from foresters, soil scientists, extension specialists, cadastral surveyors and watershed specialists in preparation for a plan for the development of the Phewa Tal watershed.

The UNDP/FAO/Malaysia forest development project carried out, in cooperation with the various agencies, a land classification for forest land use and management plans in the Kuantan district (State of Pahang) to determine the areas to be finally assigned to permanent agriculture, to hydroelectric projects (after clearing of the forests) and to recreation forestry, protection forestry and production forestry (FAO, 1977c).

The FAO Remote Sensing Centre is also active in classifying lands for broad land use decision making, using satellite imagery as the principal mapping component. Forestry, though not usually the central interpretation, is a land use which benefits from these land classifications and the fund of natural resource information they generate. The approach is based on earlier work related to the application of airborne remote sensing to the hierarchical classification of land units, as reviewed and updated in the context of experience with Landsat imagery (Mitchell & Howard, 1978a). Recent examples of this classification, based on vegetation and land forms, includes Nepal (Pacheco, 1977), Gambia (Sampa-Cessay, 1979), Paraguay (Travaglia, 1980) and China (Howard, 1980). In addition, the concept has been extended using Landsat imagery to the mapping of soil degradation at a scale of 1:5,000,000 in Western Africa and Sierra Leone and Jordan at 1:1,000,000 (Mitchell & Howard, 1978b).

The concept of hierarchical classification used in these studies is to divide a country, for purposes of planning inventory and management, into smaller and smaller relatively homogeneous units, which are based primarily on criteria of land forms and vegetal structure (Howard, 1980). Within a climatic zone (i.e. agro-ecological zone), macro-units are best identified and delineated in terms of their physical geography (land provinces) and their geomorphology (e.g. land systems) and then further subdivided, when required, into land catena and land facets, using geomorphic characteristics and vegetal structure based on height and cover.

Land classification for wildlands

A balanced development and maintenance of the human environment requires that some areas be retained in their wild state. Particular attention has been given to establishment of protected areas, such as national parks and areas for wildlife management. An ecosystem approach which considers the multiplicity of environment factors in total must be used.
In a Latin American example (FAO, 1974b) FAO has developed methodologies which form a basis for the rational planning and management of wildlands. These have been further elaborated by other workers and applied in different field situations. Basically the approach involves zonation into various categories of area designed to meet various primary conservation objectives. The compatibility of the different categories in terms of objectives is summarized in Table 1, which presents a typical set of objectives and categories.

Land classification for watershed management

Watershed management touches on every aspect of land use making an assessment of a wide range of land use suitabilities necessary. The objectives of watershed management must usually be achieved within the broader framework of integrated regional or river basin land use development. In this perspective land evaluators have to provide the answer to such questions as:

- What is the erosion hazard (sheet, wind, gully, landslide and other solifluxion processes, torrent phenomena, etc.)?
- What are the physical constraints for reclamation?

Table 1. Alternative categories of areas for the management and development of natural resources to achieve primary conservation objectives

	Alternative Management Categories									
	Group I Categories of special concern					Group II Categories of general concern			Group III Categories used by international programmes	
	I. scientific reserve	II. national park	III. natural monument	IV. nature conservation reserve	V. protected landscapes	VI. resource reserve	VII. anthropol. reserve	VIII. multiple use management area	• biosphere reserve	• world heritage site (natural)
Primary conservation objectives										
Maintain sample ecosystems in natural state	1	1	1	1	2	3	1		1	1
Maintain ecological diversity and environmental regulation	3	1	1	2	2	2	1	2	1	1
Conserve genetic resources	1	1	1	1	2	3	1	3	1	1
Provide education, research & environmental monitoring	1	2	1	1	2	3	2	2	1	1
Protect sites and objects of cultural, historical, archeological heritage		1	3		1	3	1	3	2	1
Protect scenic beauty and green areas	3	1	2	2	1			3	2	1
Conserve watershed production	3	3	3	3	2	3	3	3	3	3
Control erosion, sediment and protect downstream investments	3	3	3	3	3	3	3	3	3	3
Produce protein and animal products from wildlife, sport hunting and fishing			2		3	3	3	1	3	
Provide recreation and tourism services		1	2	3	1		3	1	3	1
Produce timber and forage on sustained yield basis				3	2		3	1	3	
Maintain open options; management flexibility, multiple use					3	1	3	1	2	3
Stimulate rational use of marginal lands and rural development	2	1	2	2	1	3	2	1	2	2

1. Primary objective for management of area and resources.
2. Not necessarily primary, but always included as an important objective.
3. Included as an objective where resources and other management objectives permit.

- What is the hydrological behaviour of the catchment area?
- What are the actual erosion phenomena and their causes and the amount of soil loss and of sediment yield?
- What watershed values (soil, water, vegetation, wildlife) are being or may be affected and what downstream effects occur or may be expected?

FAO forestry watershed projects have used a number of land evaluation methods. Many of these are described in Conservation Guides 1, 2 and 3 (FAO, 1977b, 1976c, 1976d). The methods currently employed (Botero, 1970; FAO, 1974c) are either classifications based on the integration of physical parameters, landscape and land system classifications, classifications expressing the potential or constraints due to inherent natural factors, parametric and quantitative classifications, classifications based on vegetation indicators, classifications according to land use suitability, classifications introducing other production factors in addition to physical factors and classifications based on the economic variables. However, the methods which have been most often used are the USSCS Land Capability classification and Holdridge's Life Zone Ecology classification, though the limitations of these methods in providing the planner with the above mentioned interpretations are well recognized, particularly in the context of mountain areas with high population pressure. FAO experts T.C. Sheng and T. Michaelsen (1977) have proposed a pragmatic approach to land classification for hilly areas based essentially on two parameters: slope gradient and soil depth. The Working Party on the Management of Mountain Watersheds has also devoted some attention to this question. In this regard, recent contributions to the Eleventh Session of the EFC Working Party on Management of Mountain Watersheds (FAO, 1975b, FAO, 1978) have been obtained. The Interlaken Symposium also considered this topic (FAO, 1975a).

FAO field projects in watershed management require three basic levels of surveys:

- national/regional level: cartography at scales 1:100,000 to 1:500,000 for reconnaissance surveys and framework plans;
- river basin or major watershed level: cartography at scales of 1:200,000 - 1:100,000, for feasibility and pre-investment surveys;
- small watershed (100 to 5,000 ha) or village level, with scales of 1:5,000 to 1:20,000, for detailed planning for implementation.

We mention some examples of recent work of FAO field projects covering these three levels, to illustrate the problems, the needs and the methods being used.

National and regional land classification for watershed management

At the national level, the Integrated Watershed Management Project in Nepal (NEP/74/020) has conducted a reconnaissance inventory of the major ecological land units of the entire country (Nelson et al., 1980). The inventory was made during a two-year period on a land system basis. Its purpose was to identify major problem areas of erosion, landslides and torrents in upper catchments, as a first step planning tool to help the Department of Soil and Water Conservation in setting priorities and selecting catchments for demonstration work and for more detailed surveys. The inventory was based on 1:500,000 Landsat imagery (band 7, near infrared) supplemented with small scale aerial photography (available for 60% of the country) and limited Skylab imagery. Aerial and ground transects were made to gather more detailed information. The following are the basic planning tools produced by the inventory:

- a 1:500,000 map and a description of the major ecological units of Nepal classified in 4 categories: Zones, Regions, Land systems and Land types;
- major types of land use: agriculture, forests and other;
- watershed conditions: expressed through five classes according to an index relating current soil erosion in comparison with "well managed" conditions;
- vegetation types, administrative location, elevation and relief; climate, ecology, soil, population density;
- landslide hazard, soil erosion hazard and terrace suitability.

In Tunisia, the project of assistance to the development of Forestry Action conducted regional erosion surveys covering most of the country (27,000 km^2) at a scale of 1:200,000 (Diamache, 1978). Seventeen erosion regions were distinguished through interpretation of aerial photographs with scales of 1:20,000, 1:25,000 and 1:40,000. On the basis of sedimentation measurements made in several reservoirs, the rates of erosion could be estimated for the four main river basins in the country. The purpose of this survey was to establish priorities for watershed management projects, prepare framework surveys for the major river basins and indicate areas where more detailed erosion surveys would be desirable.

Surveys at the river basin or major watershed level

An example of a river basin land classification is provided by the Mae Sa Integrated Watershed Project in Thailand. One of the main problems in Northern Thailand is human pressure (both of Thai and hill tribe population) of the forest reserves which are vital for the protection of the water resources. Swidden cultivation and expanding agricultural encroachments led the Royal Forestry Department to develop with FAO/UNDP cooperation the Mae Sa Integrated Watershed Management and Forest Land Use Project in Chiang Mai Province. One of the first steps of the project was to make a survey of the forest lands that would serve as a basis for land allocation and land lease to the villagers in the project area (41,128 ha) on the condition that soil and water conservation be practiced. A land capability classification was made at scale 1:15,000, based on soil surveys (considering soil groups, soil depth and soil limiting factors) and on a slope map (slope analysis on topographic maps: 1:15,000 and 20 m contour). The classification considered cultivable land types (1 and 2), pasture land, land for tree crops, forest land and reserved or protection forest. Superimposing the present land use map and other relevant information, an integrated land use map was drafted (Sheng, 1979).

In the Department of Itapúa in Paraguay, a similar problem, deforestation and improper land use by settlers, is the subject of a Forestry Development Project. Since detailed aerial photography is not available, a survey is being completed by means of 8 transects totalling 32,825 km. Soil sampling and soil description from 80 sites have been made along the transects. A land use suitability map 1:20,000 will be prepared.

Detailed survey level

For small watersheds, the Phewa Tal watershed management project near Pohkara, Nepal is an example. With the assistance of the FAO/UNDP project previously mentioned, surveys have been conducted on 23 small watersheds ranging from 200 to 1,500 ha. Firstly, a semi-detailed soil survey was carried out (scale 1:32,000). A soil erodibility survey was also done considering quality and quantity of vegetation cover, soil, texture and permeability, degree of soil compaction, clay content, slope gradient, slope lengths, runoff and observed data on erodibility. Water samples are being collected from the main river and from sets of runoff plots located in three different soil types. A correlation between the rainfall pattern, runoff and suspended sediment was to be investigated to get an indication of soil movement from the watershed area (Kraayenhagen, 1980). The physical information collected in the watershed will be combined with detailed social-economic information, including land ownership, to produce a development plan for the watershed.

Land classification for afforestation

At the national or regional level, classification is usually done on a climatic basis. An example of FAO involvement in such a classification is the bioclimatic zoning of Brazil by Golfari *et al.* (1978). In this work mapping of bioclimatic zones was supplemented by a list of species recommended either for large scale planting or for testing in each of the zones.

At the other extreme is the case where macro-evaluation has already been done and a policy decision taken to allocate for afforestation a certain area which is available in a suitable climatic zone. A good example is the FAO/UNDP project in Turkey (Gaddas, 1976; Cooling, 1977). In this case the objective already defined was for the establishment of coniferous plantations by mechanized techniques in certain forest localities. A system of site evaluation or classification of planting suitability was developed to assist the allocation of species to specific sites, to facilitate the prediction of growth rates and to determine the type of reforestation appropriate to a given site. The classification was inspired by various systems of land suitability classification used for agricultural land. Emphasis was given to the potential productivity of the site on the basis of various factors, notably climatic conditions, soil texture, rockiness, land form and slope, taking into account the feasibility of mechanized operations and also the hazard of erosion.

Sites were classified into four classes suitable for planting: P1, very good land; P2, good land; P3 medium land; and P4, poor land. Land unsuited for mechanized reforestation was designated NP, unplantable.
In the pilot plantation areas, which varied from a few hundred to over a thousand hectares, one pit was dug per 4 or 5 ha and profile descriptions were supplemented by surface observations and auger borings between pits. Vegetation was described at the same points. Soil laboratory analyses were carried out and the field work led to the preparation of 1:10,000 maps of (i) soil; (ii) vegetation; (iii) site (a combination of the vegetation and soil maps; and (iv) plantation suitability.
Table 2 shows the planting suitability classes for mechanized coniferous plantations in Turkey. The terms used were explained by a key "classification of selected site factors", e.g. "slightly saline" is defined as 4-8 mmhos/cm.
In Nigeria a similar system was used for afforestation planning (Barrera, 1971), but the survey was of larger areas, of the semi-detailed type, and mapping was at scales of 1:20,000 to 1:50,000. Five suitability classes were used and were related to the five land capability classes defined for agriculture in Nigeria. Climate was assumed to be fairly constant throughout the Turkey project area because the individual areas were small and the topography was gentle. For the bigger areas surveyed in Nigeria the authors stressed the need to take account of climatic variation in addition to soil.

Both the surveys in Turkey and Nigeria were of a qualitative nature, i.e. no attempt was made to define the various suitability classes in terms of either volume or value yield. It is possible to describe the classes in quantitative terms if there are already crops growing in the area. An example of this type of work was that done on the Viphya Plateau in Malawi (Adlard *et al.*, 1974). Here the main species used was *Pinus patula* and the survey combined a detailed study of yield over 23,000 ha of existing plantations with soil studies in both the planted and unplanted areas. This enables prediction of yield from the yet unplanted areas to be made on the basis of proximity and similarity in rainfall, topography and soils to the planted areas of known productivity. In areas where there are no plantations in existence, the practice of planting small-scale replicated species and provenance trials in order to evaluate site quality well in advance of large-scale afforestation

Table 2. Planting suitability classes for mechanized coniferous plantations

Class / Site factor	P1 Very good land	P2 Good land	P3 Medium land	P4 Poor land	NP Unplantable land
	Maximum acceptable factor level, by classes				Eliminating level
1. Land form	rolling	hilly	hilly	steeply dissected	mountainous
2. Microtopography	slightly rough	slightly rough	rough	rough	very rough
3. Gradient	20%	30%	40%	60% in north 50% in south	over 60% in north over 50% in south
4. Erosion hazard	slight	slight	slight	moderate	high
5. Exposure	slight	moderate	moderate	severe	very severe
6. Stoniness	slightly stony	stony	stony	very stony on over 50% ground	extremely stony
7. Rockiness	rock free	fairly rocky	rocky	very rocky	extremely rocky
8. Water table	absent or at depth	at depth	at moderate depth	shallow	permanently at or near surface
9. Salinity	non-saline	non-saline	slightly saline	slightly saline	saline or very saline
	Acceptable range in factor level, by classes				
10. Soil depth	91 cm +	61 cm +	31 cm +	16 cm +	less than 15 cm unless on fissile parent material
11. Texture	P1-1 medium to heavy; P1-2 light to coarse	P2-1 medium to very heavy; P2-2 light to coarse	very coarse to very heavy	very coarse to very heavy	very coarse * to very gravelly
12. Drainage	well drained	imperfect to somewhat excessive	excessive to poor	excessive to poor	very excessive or very poor
13. pH	acid to slightly alkaline	very acid to alkaline	very acid to alkaline	very acid to very alkaline	excessively acid or excessively alkaline

* Usually only if associated with other eliminating factors.

has yielded valuable information in many countries. An approach along this line was followed in a project in Tunisia (Institut de reboisement). The site quality system was based on the two types of information:

i) the use of natural vegetation as indicator of the soil types (soil-plant relationship);

ii) the relations of tree growth to soil types as determined from arboretum (some 50 arboretum in the country established in various climatic zones). The combination of these two types of information tested first under experimental conditions and then under small-scale afforestation project proved very reliable and practical and the method is actually used for all afforestation programmes.

It is important to realise that forest site evaluation should be a dynamic, not a static, activity. Productivity is the resultant of the interaction of site, genotype (species, provenance and individual) and cultural treatment. Therefore site quality or planting suitability classes could change if genotype or treatment is changed. In addition, the inherent quality of the site itself may change as the result of afforestation, especially the use of fast growing monocultures on tropical soils. This requires special studies such as those of Lundgren (1978) and Chijioke (1980), the latter being conducted as an FAO André Mayer Fellowship.

Conclusions

1. This review has dealt in particular with land classification at various levels, based essentially on climatic, edaphic vegetational and topographic characteristics. However, in practice land classification is user oriented: it has to fulfill certain needs, either of the local community or of the commercial sector and it has to provide goods and services to the regional and national economies. Therefore, economic and social criteria should interact in land evaluation with the physical characteristics in order to decide among alternative uses. FAO's Forestry Department has also carried out work which is relevant to multi-purpose planning of forest lands which has not been reviewed here, but would also be relevant.

2. Classification of the suitability of land for various purposes is an essential part of many FAO field projects, for example land resource

surveys and projects for agricultural development, irrigation, soil conservation and land use planning. Commonly in the course of such projects the suitability of land for forestry must be assessed because it is unsuitable for agriculture or because forest products are required (e.g. village woodlots) or because government environmental policy dictates that certain areas should be in forest land. In such circumstances the land evaluators have generally used the same sort of system as for agriculture, that is same form of site-factor evaluation in relation to the supposed requirements for forestry. This is fairly satisfactory on a small scale, for example for land resource inventory of a whole country or region for macro-planning (recent examples from Indonesia, Sierra Leone, Sudan can be cited). It is less satisfactory at watershed or project level and still less at the village or small watershed level. The special features of land suitability assessment for forestry (such as the long time scale and the need to take account of other benefits than purely local economic ones) are not considered adequately unless special attention is directed to them.

3. The experience is broad and diverse. In fact, FAO has much experience in land classification in a wide range of environments and at all levels of intensity. Each application is a response to a specific need and therefore differs in many aspects from every other land classification. Although this independent approach has much to offer in meeting the specific project and country requirements, it has the shortcomings of inefficiency as each land classification is reinvented, and of impeded communication among land classifiers. Development agencies, e.g. World Bank and the Regional Development Banks, must contend with a variety of land classification and evaluation methods. Greater uniformity is therefore needed in land classification for forestry.

4. Most land classifications have been made for several land uses. Forestry is usually one element in a wide range of land uses in view by the planner. Non-foresters are making land classifications for forestry and foresters are making them for agriculture. It is time for greater emphasis on the interdiscipline aspects of land classification.

5. More spinoff is needed. The land classifications cited were made to satisfy an information need for a specific project. With a few exceptions, the land classification methodology has not become a working tool for the forester in the developing countries. An effort must be made to communicate land classification methods to local people in the field.

6. The *Framework for Land Evaluation* (FAO, 1976b) has not been sufficiently applied. This document has much to offer in overcoming the lack of uniformity and communication problems mentioned previously. The explanation for this oversight should be determined and remedied.

7. Planning takes place at many levels. At the macro level the concern is to determine the broad composition of activities over regions and subregions. The role of land evaluation is to determine the feasibility regions for the main land using crops and to allow the broad assessment of their productivity. It has also the role of identifying areas with physical characteristics making conservation aspects of critical importance. At the micro level it is to provide a basis for selecting the particular allocation of land to specific crops. It is important to recognise that the detailed study of relationship between land characteristics and crop productivity necessary for the micro planning also provides the productivity indicators that in a simplified form are used in the macro assessment. A matter of major concern in land use planning is that forest is considered as a crop of economic and social importance rather than as an automatic source of land for other uses, that the timber that the forest contains is recognised as an economic resource and that the risks of externalities from uncontrolled destruction of forest with their serious economic and social costs are fully recognised.

The next step

It is apparent that a guideline for land evaluation for forestry, for use in developing countries, is needed. The guideline would be based on the principles of the *Framework for Land Evaluation*. It would help FAO and national personnel to meet the rising need for base line information created by the great increase in planning. A review of FAO experience in land classification for forestry shows that a guideline would have to satisfy many needs. Some of these are:

1. A need for rapid, inexpensive data collection. Project formulation and the pace of planning does not permit any alternative. The Sheng-Michaelson method of focusing on slope and soil depth is an example of the level of simplicity and practicality required.
2. A need to be adaptable in developing countries. The concepts must be readily understandable. Its operation must not exceed the equipment, education level and experience available. These vary from country to country. Computers, satellite data receiving stations and sophisticated remote sensing methods are used in some countries, but in other countries aerial photographs and topographic maps may be unavailable.
3. It must be integrative. Integrative means that, in the general land classification approach, it must consider the effect of the interactions of natural resources on a particular land use. Growing awareness of environmental needs shows that individual natural resources, such as soils or climate, can only be viewed in the context of a larger whole, the land itself. An interdiscipline team is usually necessary to gather the scope of data needed.

   It must be integrative from a land use perspective also. Forestry, agriculture, grazing, mining, recreation and other uses are intermingled in most developing countries. Development plans often consist of setting priorities among the alternative uses. This means the basic natural resource data collected and the land units identified in the land classification process must have meaning to a wide range of uses. It also means that the guidelines must show non-foresters how to gather and interpret data for forestry.

   Foresters may have to do the same for agriculture. This suggests, as envisaged in the *Framework for Land Evaluation*, that a single classification or inventory interpreted for many uses is needed.

   The guideline must lead to land classifications that are integrative vertically also. General high-level classifications with large land units must provide a structure for assessing information needs and extrapolating information gathered at lower levels. There should be an orderly hierarchy of land units so that a continuing information gathering programme can be planned and systematically carried out.

A guideline for land classification that would meet these needs would be widely adopted, and thus, as a secondary benefit, reduce the problems resulting from the great diversity in today's methods.

Information systems, such as land classifications, have been evolving for thirty-five years in FAO. There is much experience with data collection methods and knowledge of the environments in which they must be used. What works and what does not work is known. This experience and knowledge must be used to make a practical field guide for land classification. This should be the next step.

REFERENCES

ADLARD, P.G., T.J. WORMALD and P.R. TOMLINSON (1974). Plantation inventory and site classification study for the Viphya project, Malawi. FO:DP/MLW/73/003, FAO, Rome.

BARRERA, A. (1971). The use of soil surveys in assessing sites for forestry potentials in some areas of the northern states of Nigeria. Savanna Forestry Research Station. FO:SF/NIR 16, Tech. Rep. 5, FAO, Rome.

CHIJIOKE, E.O. (in press). Impact of monocultures of *Gmelina arborea* and *Pinus caribaea* on soils of lowland humid tropics. André Mayer Fellowship report. FAO Rome.

COOLING, E.N.G. (1977). Industrial forestry plantations, Turkey. Final report - Plantation silviculture. FO:DP/TUR/71/521 Working doc. No. 28 FAO, Rome.

DIMANCHE, P. (1978). Rapport final de l'expert en écologie. Assistance au développement des actions forestières en Tunisie. Document de travail. FAO, Rome.

FAO (1965). Rural economic development in the Western Rif. Vol. I. UNDP/SF Report. Rome.

FAO (1973). Manual of forest inventory with special references to mixed tropical forests. Rome.

FAO (1974a). Integrated watershed management, torrent control and land use development. Project document NEP/74/020. Kathmandu, Nepal.

FAO (1974b). Wildland management. A programme for environmental conservation in Latin America. UNDP-RLA/72/028. Regional Office for Latin America, Santiago, Chile.

FAO (1974c). Approaches to land classification. Soil Bulletin 22. Rome.

FAO (1975a). Environmental objectives in Interlaken Forest Land Management Symposium on Forests and Wood: their Role in the Environment. Interlaken, Switzerland, 22-26 September 1975.

FAO (1975b). Report on the Eleventh Session of the Working Party on the Management of Mountain Watersheds. Ankara, Turkey, 3-14 June 1974.

FAO (1975c). The uses of side-looking airborne radar imagery for tropical forest surveys - based on the work of P.E.T. Allen. FO:MISC/75/10 Rome.

FAO (1976a). A field termination document, Upper Solo Watershed Management and Upland Development Project, Indonesia, UNDP/SF/INS/72/006, Rome.

FAO (1976b). A framework for land evaluation - Soils Bulletin 32. Rome.

FAO (1976c). Hydrological techniques for upstream conservation - FAO Conservation Guide No. 2, Rome.

FAO (1976d). Conservation in arid and semi-arid zones. FAO Conservation Guide No. 3, Rome.

FAO (1977a). Criterios para la clasificación de bosques y determinación del uso potencial de tierras en Paraguay - FO:DP/PAR/72/001. Technical Report No. 8 - based on the work of Mr. G. Hartshorn, Asunción.

FAO (1977b). Guidelines for watershed management. FAO Conservation Guide No. 1, Rome.

FAO (1977c). Forest land use and management plans for the Kuantan Forest Management Unit and operations plans for first three-year exploitation. (A description of resource surveys and planning appraisals carried out for the period 1976-1996 and regulatory control measures to be applied with detailed description for operations in 1977/1978.) Forestry Department, Peninsular Malaysia, Kuala Lumpur.

FAO/CTFT (1972). Reconocimiento general de los bosques e inventario detallado de Azuero. FO:SF/PAN 6. Informe Técnico, 12. FAO, Rome.

FAO/UNEP (1980). Report on the pilot project on tropical forest cover monitoring (under publication) - based on the work of R. Baltaxe, Rome.

FAO-Unesco (1975). Soils map of the world. Unesco, Paris.

GADDAS, R.R. (1976). Industrial forestry plantations, Turkey. Final report - Soils and site evaluation. FO:DP/TUR/71/521 Working Doc. No. 19. FAO, Rome.

GOLFARI, L., R.L. CASER and V.P.G. MOURA. Zoneamento ecológico esquemático para reflorestamento do Brasil (2nd aproximação). PNUD/FAO/IBDF/BRA-45, série técnica No. 11. Centro de pesquisa florestal da Região do Cerrado, Belo Horizonte.

HOWARD, J.A. (1980). Regional landscape analysis in forestry using a photo-geomorphic approach. Proceedings: FAO Training Course on the Application of new Remote Sensing Techniques to Forest Resources Surveys. Harbin China.

HOWARD, J.A. (1980). Personal communication.

KING, K.F.S. (1978). Improved utilization of tropical forests - Proceedings of Conference on Improved Utilization of Tropical Forests, Madison, Wi. U.S.A. Forest Products Laboratory, Forest Service.

KRAAYENHAGEN, J. (1980). Watershed management planning for the Phewa Tal (manuscript).

KUNKLE, S.H. and G. CHILD (1975). Evaluation and planning for wildlands and forestry. Paper 14, p. 119-123. *In* Report on the ad hoc expert consultation on land evaluation, Rome, Italy, 6-8 January 1975. World Soil Resources Report, 45. FAO, Rome.

LANLY, J.P. (1976). Tropical moist forest inventories for industrial investment decisions. Unasylva, 28 (112-113). Rome.

LUNDGREN, B. (1978). Soil conditions and nutrient cycling under natural and plantation forests in Tanzania highlands. Reports in Forest Ecology and Forest Soils 31, Swedish Unit of Agricultural Sciences, Uppsala.

MICHAELSEN, T. (1977). Un sistema de clasificación de la tierra por capacidad de uso para tierras marginales. Proyecto PNUD/FAO/HON/75/109. Doc. de trabajo No. 1, Tegucigalpa, Honduras, 1977.

MITCHELL, C.W. and J.A. HOWARD (1978a). Land unit classification of Jordan, Technical Report, FAO, Rome.

MITCHELL, C.W. and J.A. HOWARD (1978b). Final summary report on the application of Landsat imagery to soil degradation mapping of 1:5,000,000. AGLT Bulletin 1/78, FAO, Rome.

NELSON, D. et al. (1980). A reconnaissance inventory of the major ecological land units and their watershed conditions in Nepal. Integrated Watershed Management Project, FAO, Rome (manuscript).

PACHECO, R. (1977). Land inventory Karnali-Mahakali watersheds. FAO. Government of Nepal.

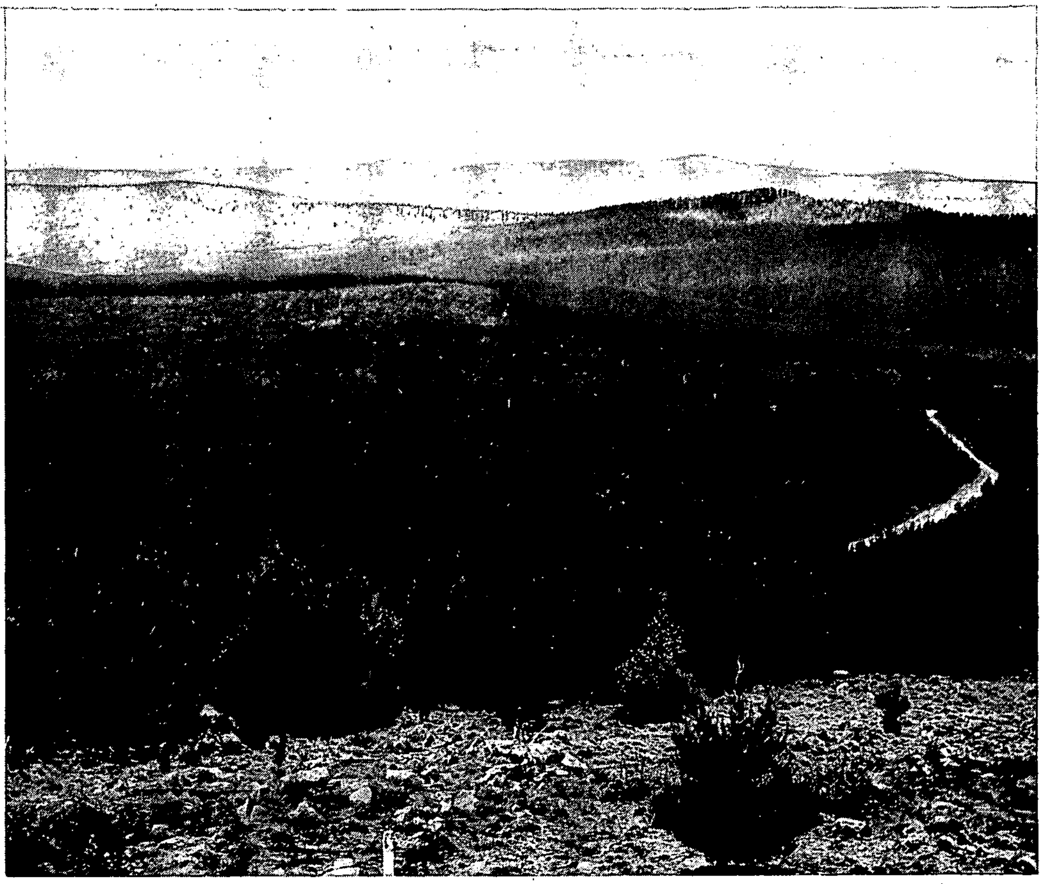
PRINGLE, S.L. (1978). Quantity and quality of the tropical forests. Proceedings of Conference on Improved Utilization of Tropical Forests, Madison, Wi., U.S.A. Forest Products Laboratory, Forest Service.

SHENG, T. (1979). Watershed management and conservation farming in Northern Thailand. Mae Sa Integrated Watershed Management and Forest Land Use Project. Working paper No. 11. FAO. Chiang Mai, Thailand.

SINGH, K.D. (1978). On pre-investment survey of forest resources. Background paper for the 8th World Forestry Congress.

SOMPO-CESSAY, M.S. (1979). Landsat imagery as a means to monitor vegetation changes in Gambia and Mali. Final Report. Remote Sensing Centre, Rome.

TRAVAGLI, C. (1980). Identification from Landsat interpretation of South Paraguay lands affected by water logging and flooding. FAO, Rome (in manuscript).



Large scale plantation forestry with Pinus radiata in Southern Australia.

3.1 Papers on "The state of the art"; Session 3, November 10 + 11, Monday and Tuesday

"Site and terrain classification"

Chairman: H. Löffler; Rapporteur: D.A. MacLeod

- W. Kilian
  Site classification systems used in forestry
- S. Berg
  Terrain classification systems for forestry in the Nordic countries
- D.E. McCormack, R.E. Hartung and K.N. Larson
  Evaluations of forest land in the United States
  Presented by D.E. McCormack

SITE CLASSIFICATION SYSTEMS USED IN FORESTRY

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Summary

The paper deals exclusively with ecological concepts of forest land classification.

Although site classification systems must be tuned to practical purposes, they should comprehend independent scientific descriptions of the ecosystem complex, both the environmental factors and the interrelated forest phytocenosis, not least to make them suitable also for furture applications, not yet known when the survey is running.

Site evaluations are a next step, based on site classification, but not a part of it.

A great number of methods have been developed according to the environmental conditions, scopes and the historical background in the different countries. Generally they can be divided into phytosociological, physiographic and combined systems. There is also to distinguish between regional and local classifications. Both should be part of a hierarchic system in a survey project, but must be based on different principles.

By means of a few examples the main methods are described and the state of work done in different countries is dealt with.

Introduction

Land evaluation classifies land suitability with regard to different kinds of land use and comprehends environmental, technical, economical, and social aspects.

Forest site classification concerns only the ecological part of that concept. It provides information on the environmental resources, tuned to the particularities of wooded land, both as a basic scientific information, and for practical purposes, comprising prediction of yield, of responses on hazards and measures and proposals for management. The objective of forest site surveys however should not be a mere evaluation and prediction of land productivity in terms of increment, classes of equal measures etc., but the description of the ecological facts, the differentiation of the various ecosystems in the landscape, at least as a first step for more integrated concepts.

Forest ecosystems are complex geographic units as a result of interrelations between climate, relief, parent material, time and organisms (ANNAS et al. 1979). Therefore the biotic community and its physiographic factors must be studied together. Forestry has been aware of this complex nature since its earliest attempts at site classification (KRAUSS 1936). This in contrast to agricultural areas, where the interdependence between crop and the environment is weaker, and monodisciplinary approaches, such as soil classification, may be adequate. Besides, also in agriculture the complexity of site has recently been taken into consideration (DUDAL 1979).

As a consequence of these different view-points, site classification in agriculture and forestry in many countries has developed separately and today there exist great difficulties for a synthesis or even for a comparison of units only.

The long term goal should be a universal system for classifying the environment independent from the actual vegetation cover and land use, just for deciding these alternatives. It should satisfy as far as possible all the multiple needs of land use planners and managers.

A great number of forest site classification systems have been developed, depending on scale and purpose, the applicants and the landscape concerned, but partly also on the intellectual environment in each country. For wide, little explored and partly inaccessible areas of uniform landscapes (like Canada) another system will be appropriate than for intensively managed and investigated, heavily structured areas with largely altered forest vegetation (like central Europe).

Because of all these aspects it will be impossible to develop and to recommend one optimal, universal method usable for all purposes, for research work as well as for productivity estimation, both of global and local validity.

The intricate diversity of methods shows after closer study many kindred features, so that they fall into a few main categories. Moreover the development of most of the systems seems to converge into one direction.

Some aspects for discussing site classification systems

1.) As mentioned above two principal ideas of site classification are to be distinguished:
The basic delineation of ecological units and the evaluation related to forest management. Thus the definition of site units may range from "areas with physiographic qualities of similar ecological effect" to "localities of similar productivity and silvicultural possibilities and hazards". In any case pure units of appraisal cannot indicate the ecological conditions; an ecological division must precede any evaluation as a first step. In general the following sequence should be adhered:

. Exploration of site conditions
. Classification
. Mapping
. Evaluation of units

At least steps 1 to 3 should be carried out in one continuous drive and by one and the same institution.

2.) Concerning the prededure there are various possibilities:
a) Landinventory by differentiation and survey of areal units in the field;
b) Classification by statistical sampling procedures, with or without using mathematical models; no delineation of areas;

c) Mapping from aerial photographs based on indicator criteria, developed by methods mentioned under b).

3.) Contrary to clearly differentiated plant species or chemical compounds the sequence of sites in the landscape forms a continuum of all kinds of transitions. On this fact, as is known, two tendencies developed, the one regarding the biocenosis as an accidental combination of single factors, the other as a "superorganism", an indivisible unit, derived from interaction of the factors. The latter idea culminated in the twenties and thirties in Europe,with BRAUN BLANQUET (1928) as a typical representative.

Today this difference has lost its importance - the truth lies somewhere between the two extreme conclusions - but there are still a few facts to be considered:

. Ecosystems are indistinctly differentiated in nature, they cover an unprecise band width. Their delimitation is, therefore, more or less arbitrary and depending on purpose and the factor emphasized. There must be made abstractions, perhaps discontinuities searched for (by mathematical methods), which can be used for differentiation. For the characterization of units the definition of their boundaries is more efficient than the description of the very type.

. A complete hierarchic, taxonomic system, such as Braun Blanquet attempted, will not be effective. Also a rigid framework of several graded factors cannot reflect sufficiently the character of the entire site and would, besides that, lead to an impracticable number of units. The basic site units must be described as "local forms" on the basis of a local division, which are valid only within individual geographical regions. In addition to that, they can be grouped into a loose framework of a few simple criteria (e.g. levels of water and nutrient supply) to allow superregional comparsions.

4.) The units on the one hand should be defined very narrowly by using as many criteria as possible, among others to make the classification adaptable also for later applications, not yet known or intended when the survey is running. On the other hand we must limit ourselves to a reasonable number of easily detectable features to facilitate the survey work.

Furthermore there are two principal ways: to classify and map the single factors separately and to compose the site units only afterwards, or to survey the entire site already in one process in the field. The second method should be prefered.

5.) Time factor: Ecosystems are dynamic systems. Forest communities often are temporary successional stages, developing to a stable final (Climax) community. They may be altered by human impact or natural disasters.

Thus for classification we must distinguish between:

a) stable, independent site properties

b) fluctuating features (humus, surface soil), with which the temporary, actual site condition can deviate from the potential site quality.

6.) Regional and local classifications must be based on different principles. Regional units may be delineated by factors, decisive for large areas such as climate or landmorphology and can be mapped in scales up to 1:1 - 1:10 Mio. They comprehend each a pattern of rather different individual site units. For delineation of the latter mapping scales from about 1:5000 to 1:20000 are adequate.

A satisfying classification system therefore has to encompass at least two levels.

7.) The classification of forest ecosystem is principally possible by the following means

a) species and communities as indicator of site properties;

b) description of physiographic site factors, such as climate, parent material, relief, soil properties, moisture regime;

c) both vegetation and physiographic features.

Correspondingly all the different methods can be divided into: phytocenologic, physiographic and integrated site classification systems.

It is not possible to present a more complete review of all the programs and systems in the limited space available in this paper. Only an outline of the main systems practiced today, with illustrations by way of examples, can be given.

Comprehensive reviews were given by KOPP-SCHWANECKE (1972) for Europe, BURGER (1972) for Canada, CARMEAN (1975) for the USA and partly Canada, more worldwide ones by DYRENKOW-TSCHERTOW (1975), and CIRIC et al. (1976).

Local Differentiations

Phytocenologic Classifications

Vegetation is a very sensitive and quickly reacting site indicator. Yet phytocenological systems interpret the ecological site conditions indirectly. They also give no information on the concrete influence of the single site factors (convertibility of factors), and as to whether the community is a naturally stable or a degraded secondary one. Furthermore the indicator value of species may change with the region.

Pure floristic systems give satisfactory results in areas with native or only slightly altered forest vegetation. Within combined methods, however, vegetation is a very adequate means to indicate the fluctuating site conditions. Some main types of vegetation-oriented systems are to be distinguished:

1.) The simplest approach is that based on the dominant tree species, as early practiced in USA for delineation of "Forest Cover Types" or "Major Forest Types". It records only the stand, temporary stages or planted forests and has no ecological message.

2.) Cajander's ground vegetation types, based on dominant plant species, one of the oldest systems, are still used in Scandinavia. In such regions with very uniform climate, parent material and land surface, these types may indicate quite well the remaining site variability. But even in Finland recently a more detailed classification, using also soil properties, and rating potential productivity has become necessary.

3.) Integrate record of trees and ground vegetation. Here the evidence is much stronger already, especially when characteristic species are used in the sense of Braun-Blanquet.

In this system mappings in a scale 1:50000 were carried out to a wide extent in Japan (USUI, H. 1975). To overcome the shortcoming of undifferentiated inventory of perishable states the maps will be revised in short periods (4 years!).

Rather similar to the ideas of Braun Blanquet, but without his stringent hierarchic taxonomy and introducing also the concept of successions is the "habitat type Classification" (PFISTER 1975),which orginates in the classification of potential vegetation by DAUBENMIRE (1952). This is doubtless one of the highest developed phytocenologic systems and is used to a large extent in western USA by DEITSCHMAN (1973), LAYSER (1974) and also with modifications by many others, but first of all by PFISTER et al. (1977) in Montana. The central unit, the "habitat type", is defined as "those parts of the landscape capable of supporting a given plant association in the absence of disturbance"(DAUBENMIRE 1968).

The problem of distinguishing between site factors and perishing successional vegetation is overcome by using potential vegetation, whereby the climax concept is somewhat mitigated.
The system uses three classification levels: Series, expressed by dominant climax tree species. Habitat types (climax- associations), expressed by climax tree species and ground vegetation indicator species (e.g. Pinus ponderosa-Festuca idahoensis - habitat-type).Phase, a subdivision according to minor site differences and expressed by a differentiating species (e.g. P.ponderosa - Fest. idahoensis h.t.-Festuca scabrella-phase).

Until 1976 areas have been mapped of about 4 million ha in scales between 1:50000 and 63360, and 400 000 ha in scales from 1: 7920 to 31000, as Pfister indicated in a IUFRO inquiry. From 1976 work was also extended over grass- and shrubland.

In whole Montana 7 ecoregions are divided into 5 - 15 altitudinal zonated habitat types to a total of 64 types for all Montana - a number that seems rather small to us, but is perhaps a consequence of a homogeneous landscape. Today a great humber of (quantitative) data concerning the relationships between the classified units, management factors, and site factors are available (PFISTER 1975). The standardized description of the units now comprises occurrence, vegetation (successions, indicator species), soil, productivity, management (species selection, wildlife, recreation) and "other studies".

With these data the system, however, leads over to a more ecological one, including physiographic features, a trend that can be observed in most phytocenological apporaches.
The phytocenologic methods used previously in Hungary and Bulgaria have been replaced by combined methods at all.

4.) An approach which deviates somewhat is to use "ecological species groups", as for example ZLATNIK (1960) does in CSSR. Plant species were related to levels of various ecological factors, such as nutrient supply, hydrology, or temperature and then the sites were classified according to the abundance of these species, in some cases by use of mathematical methods (MINORE 1972).

Physiographic classifications

These methods consider only the environmental factors such as climate, relief, parent rock, soil and moisture regime. They give direct information on the site features which are usually not liable to alterations. Maps of permanent features are certainly of higher value than those of perishable qualities or resources, but the suitability for plant species cannot be comprehended doubtless without survey of the vegetation itself. Such approaches have been successfully applied in regions with disturbed vegetation and ready availability of detailed data of environment, such as in Eastern USA (COILE 1952).

Classifications of single factors today are used for certain limited purposes, for example the Swedish Terrain Classification being discussed in this meeting (BERG 1980). It records slope, ground roughness and snow conditions and is oriented to operational evaluations only. It cannot be called an ecological site classification.

Soil classifications could be considered as monothematical too, but soil is a result of climatic and physiographic factors, including time, and therefore expresses a more comprehensive site quality. A soil map comprehends a great deal of all the permanent (or relict!) site features, but, as mentioned above cannot substitute completely a site classification. The principles of both must be different; at least soil units cannot indicate regional climatical differences and therefore they can only be applied within local growth areas.

More integrated physiographic systems were developed mainly in North America. A typical physiographic concept is the perfectly elaborated classification of SMALLEY (1979) for the Cumberland Plateau in USA. The differentiation of site units is extremely oriented to landscape-morphology. This on the one hand enables units to be plotted on a good topographic map or aerial photographs (or in the special case on the geological map 1:24000); on the other hand this system assumes uniform soils and is only of local validity. Very attractive is the systematical display of this approach: The description of the units includes soil fertility, economic problems (classified by progressive numbering), proposal for tree species selection and the site index for some alternative tree species. Soils (from the soil survey) and indicator vegetation are described, but they are no basis for the classification.

A physiographic system also, based on climate, relief and soil, and giving the site index of the main tree species, is used by the Weyerhaeuser Company. Until 1976 - according to a IUFRO inquiry - 5.5 mill. ha in a scale of 1:31560 were mapped. The projected final area are 9.5 mio. ha. The maps have to be used obligatorily as a basis of forest management.
On the whole, however, pure physiographic surveys are rather rare. The vegetation is almost always included in the regional division and in the descriptional part in some way or other.

In the USA the soil survey of the Soil Conservation Service has been revised intensively to establish "woodland suitability classes". These are, however, used rather to ascertain the site index of the main tree species than for areal surveys. The woodland suitability groups comprise sites with equal management requirements, productivity potential, regeneration potential, priority of tree species, erosion hazard, exposure to windfall, pests and diseases, competition with weeds, accessibility and suitability for special use (cit. CIRIC et al. 1976).

Combined (biophysiographic) methods

Most wide spread are the approaches considering both the biotic and the environmental factors simultanousely.The basic units are created through the synthesis of climatical, pedological and vegetational, in some cases also productional criteria. Only this integrated procedure provides enough elements for the proper description and rating of forest sites. It complies with the modern concept of ecosystem but is dating back already to KRAUSS (1936) and in USSR to SUKATCHEW (1932).
The vegetation can, as already mentioned, serve in two ways, namely for delineation of regional potential forest communities and for indicating the temporary site condition. The combined methods began to be employed in Central Europe and Canada and are now being used almost all over the world.

<u>Varieties</u> of combined methods, <u>concerning the procedure</u>:
1.) The single parameters are surveyed separately, a synthesis to site units

is made afterwards. This way has been chosen in France, in Slovenia (Yugoslavia) by CUK et al. (1968) and up to recently also in Nordrhein-Westfalen (FRD).
In France there is a set of 6 thematical maps available in scales between 1:4000 and 1:25000. The soil map is the most complex one among them. A clever color system is used for showing up some important, graded characteristics (carbonate, acidity, moisture, organic matter). Recently a geo-pedologic-botanical map has been introduced, which indicates the correlation of soil, humus and vegetation and thus comes very near to the Central European combined site units.

This way of composing may be of value, if the basic maps exist already and if they are used as an auxiliary means for delineation of site units, checked in the field. A schematic put together "on paper" , without any control in the terrain, however, may result in units which cannot render the actual ecological conditions sufficiently.

2.) More abstract seem the methods of differentiating site units by use of mathematical analysis of various site factors. The procedure is due to the consideration, that a synoptic and more qualitative survey of vegetation and site in the field derives only from unproved "guesstimations". To avoid vicious circles therefore,first interrelations among site factors and with the vegetation must be searched for.
So have MORRIS et al. (1979) separated patterns of units by factor analysis and discriminant analysis from 58 (!) quantitative site variables. HAVEL (1976) describes a survey of southwest Australia using combined units rather similar to those of HILLS (1973) -see below- but these units were previously delineated as continuum segments by principal component analysis.

3.) All the site factors are surveyed simultaneously in the field, the resulting complex units being defined directly and synoptically.The exploration of the sites and definition of units can be carried out by a team of specialists, but the mapping must be done by one and the same person, who of course must be multidisciplinarily trained. This procedure is most widely used.

<u>Varieties</u> of combined methods, <u>concerning</u> the <u>factors regarded</u>:
In the one case the soil may be stressed more, in the other the vegetation.

This depends on the geographical conditions and on the extent to which the forest plant communities are native or altered by man. Some systems, e.g. that of Baden-Württemberg (FRD) even uses investigations on forest history as a third basis. It distinguishes primary, secondary, "technified" and "tertiary" (=regraded) types.
Occasionally tree growth itself is used as a criterium for classification. But this very deductive feature can hardly show up the basic site conditions.

The methods vary also wether and to what extent an inflexible framwork of standardized characteristics is given. This is extremely the case for example with the "Ukrainian School" (DYRENKOW 1975), where 6 levels of moisture and 14 of fertility, degrees of soil acidity and climate sequences are combined to (theoretical) forest types. In these compartments the vegetation types are pigeonholed, divided into natural or productive stands (altered by man).
At the other extreme, local forms are differentiated as a whole and only for superregional comparisons they are grouped into a loose system of one or two graded factors (e.g. Austrian site survey).

The site can be regarded as static or as a stage of evalution. Also long-term formations such as the development of soil profiles during pleistocene and holocene may be brought into the differentiation of sites, as KOWALKOWSKY (1980) did with catenas in the Polish lowlands.

Site conditions: Many physiographic and combined systems take into consideration only the stable features and the potential (climax) forest plant communities. In other approaches, however, particular stress is laid even on the separate presentation of the permanent site unit and the temporary site condition, as for instance in Austria (JELEM 1960). For management recommandations, especially in strongly disturbed forest areas, this method seems very useful. A periodical revisional survey could evaluate even the success of management.

As an example for a combined classification system, that of the German Democratic Republic (KOPP 1969) with its several changes and additions might be cited:
First, beginning in 1951, "Standortsformen" (habitat types) were separated as

local units within growth areas according to the criteria mentioned above, the emphasis of the factors being changed depending on the local conditions. The favorite way with rather natural stands was to determine the natural forest plant community.

In 1953 "site condition forms" were introduced additionally. The site unit represents the invariable site factors and the potential productivity, the "site condition forms" the fluctuating features (like humus) and the actual productivity, which often deviates greatly. The latter is indicated by vegetation types in the sense of Cajander. From 1958, furthermore, the site units, which had become too numerous, were assigned to groups.

Until 1961 the site unit was simultaneously the production unit, the unit of similar management requirements. The single site factors were not recorded separately. With the 4th approximation, after 1961 these factors (soil form, moisture, etc) themselves were delineated, partly based on quantitative (analytical) data. The total site unit now was represented on the map by a corresponding combination of symbols. This way aimed at achieving the character of an independent scientific basis. The main soil series could now be coordinated with those of the agricultural survey just started at the time, and interdisciplinary mappings, also beyond forest areas thus became possible. From our point of view however this step meant also a setback into schematism.

Furthermore with this 4th approximation the ground vegetation types were defined by "ecologic species groups" and divided into potential and actual types.

From 1969, as a 5th approximation, humus forms were mapped over large areas and periodical revisions were introduced. Also on the group level actual and potential "basic units" were now distinguished. The "basic groups" were divided according to 5 levels of nutrient supply, 16 levels of moisture regime and according to the growth areas and districts. This resulted in about 90 groups for the lowlands only.

As a last step the assessment of site productivity was begun.

By 1969 2.24 million ha, that is 79% of the entire forest area of the German Democratic Republic, were mapped at a scale of 1:10000. Consequently the remaining area was completed and about 1.4 million ha of previously mapped area were revised in a second and even third operation according to the latest state of the method.

The system of the GDR in also used in Vietnam, in two degrees of intensity: 1:10000 for afforestations and 1:25000 in virgin forests.

The methods in Western Germany and Austria are basicly similar, since they all orginate in the conception of KRAUSS like that in the GDR. Even classifications used in Canada (see below) differ very little, as MÜLLER (1980) has pointed out.

Regional differentiations

Land regions will be differentiated according to the regional climate and major geomorphologcal formations. Because just climatic data are not sufficiently available for whole areas and it is not even clear which parameter is relevant, climate is usually expressed by vegetation (regional climax forest plant communities). But it should be taken into consideration, that vegetation units are not always adequate for the climatic - morphological differentiation. Therefore also in this regional level a more combined way should be employed (SCHLENKER 1975).

It may be stated, however, that the climate, indicated by regional communities on higher levels, and soil, landform and vegetation types on the lower levels are most usable for classification systems.

Only a few systems work out the regional differences uniformly on the one level of local units; this would be meaningful only in regionally rather uniform countries. Otherwise the number of units would rise rapidly to an unsurveyable extent.
Normally regional classifications are a separate step within a two (or multiple) leveled system. The regional units themselves can be divided up and/or generalized in several hierarchic levels. Nearly all well developed site classification systems today comprehend such a regional superstructure. Superregional differentiations are often the only available and practicable approach in little explored regions, especially in the tropics.
In the USSR the development of a regional system is one of the main tasks of forest site research. A completed division exists so far for Lithunia (DYRENKOW 1975). Dyrenkow himself describes a method to delineate growth areas by "conformation" of 10 separately mapped parameters on a mathematical basis

of set theory (DYRENKOW 1974). His system comprises 4 levels, the lowest of which encompasses at least 3000 km^2, which gives an idea of the dimensions in the USSR.

In Southwest Germany a multiple levelled regional classification is almost completed (SCHLENKER 1973, KREUTZER 1977) and is being worked out uniformly for the whole Federal Republic of Germany across all the different existing local site surveys. Similar approaches - for itself or as the superstructure over local surveys - are running or started, among others, in Bulgaria (GARELKOW 1980), Hungary - with rather narrowly defined 50 regions (SZODFRIDT 1978), Western Turkey (KANTARCI 1976), parts of Greece (MAVROMATIS 1976) and Yugoslavia (CIRIC et al. 1976).

As a framework to transfer information over large distances, superregional or even worldwide classifications have recently become of great interest. Such attempts of course are rather difficult because of the various regional systems existing already. For example in Montana alone there are 4 different regional differentiations, as PFISTER (1976) demonstrated. BURGER's (1976) concept of "Ecosystem-Regions", which he developed in Canada and which he suggested might be applied on a worldwide scale (by means of IUFRO), represents a remarkable attempt of such a spacious classification.

In order to understand the ecological effect of the climatic differences between the regional units, "normal sites" must be picked out from each site pattern as a reference point. In the "Ontario System" these standard sites are defined as "gently undulating well drained loam with no significant deficiencies or excess of nutrients and not exposed, protected or in a frost pocket" (cit. BURGER 1972). Equal to that is the "Plakor" of the Soviet classification. Also in SW-Germany such standard sites have been chosen for the comparison of site productivity.

Multilevel-combined systems

Multilevel combined vegetation and terrain approaches with delineation of the temporary condition and including productivity assessment may be regarded as the best and most highly developed form of forest site classifications. Some exemples have already been noted.

A very complete system for the whole USA, with 9 hierarchic levels of units based on biotic and abiotic factors, is described by BAILEY (1975). It is demonstrated by the author in paper 1.2.2 of this workshop.

Another very comprehensive system, which has been practiced in North America for a long time, is the Ontario Classification-System, created about 35 years ago by HILLS (1953) and his colleagues, who formulated the term of "total site".

It comprises 4 levels: site region, land type (depending on parent material), physiographic site types and "site condition". The first 3 give a frame of stable features, the latter is the actual, temporary state, expressed by vegetation-types.
For differentiation are used: "available features " (ecoclimate, soil moisture, nutrient regime) and "potential features", which govern the limits of the available ones (relief, pore distribution and potential nutrients), all estimated in 11 digit scales. The soil type is described, but is not a classification criterion, except for nutrition and water supply.

With regard to the vast expanses of Canada for the present only the higher categories are mapped on a scale of 1:250 000 or 1:125 000; a few maps in 1:50000 exist until now only by way of trial. Single site units cannot be plotted in such scales. For mapping therefore, other, summarizing units are developed, such as "land type mosaics" or "land units" (least area 10 km2) and so on (see BURGER 1972).
As a last step of this system a site evaluation has been added.

Similar, yet emphazising the biotic part somewhat more, is the "biophysical classification" of the Canadian Forest Service, developed by LACATE (1966, 1969), JURDANT (1969) and others.
The precise guidelines (LACATE 1969) name 4 levels of units: the biggest, the land region (1:1 - 3 Mill) is characterized by regional climate and vegetation; it is segmented according to physiography. The lowest, the "land type" (1:10 -20000) is the central unit with a certain soil series and vegetation chronosequence, for which the capability rates are estimated. The name of one unit "Orthic Dystric Brunisol on well drained gravel terrace, supporting Pinus contorta -Vaccinium scoparium-vegetation" may be noted as an illustration.
A great number of surveys in North America on equal or similar principles

were described by HOLLAND (1974), JEFFREY et al. (1968), KLINKA et al.(1979), MUELLER-DUMBOIS (1965), ANNAS et al. (1979), SPROUT et al. (1966) and others.

Conclusion

The development of the manifold site classification methods has recently shown a convergent trend toward multiple-level combined biophysical systems. The attempt to achieve one worldwide standardized system, however, seems unrealistic, in view of the present state of development and the successful application of the existing approaches. Such a single system, moreover, would not meet with the geographical particularities and purposes of all countries.

But what could be achieved, and what is urgently needed, is the standardization and ample, practical interpretation of the terminology used. This should be a main task of future site research, possibly within the IUFRO working party concerned. A better comparability and a better understanding of site classification and maps by its users could lead to an increased application of these surveys, which up to now many institutions, engaged in site research, have found insufficient.

Literature cited:

ANNAS, R.M., and COUPE, R., 1979: Biogeoclimatic zones and subzones of the Cariboo forest region. Province of British Columbia. Ministry of Forests. 103 p.

BAILEY, R.G., 1978: Description of the ecoregions of the United States. USDA Forest Service, Intermountain Region, Ogden, Utah. 77 p.

BERG, S., 1980: Terrain classification for forestry in the nordic countries. Proc.Int.Workshop on Land Evaluation for Forestry, Wageningen (in print).

BURGER, D., 1972: Forstliche Standortsklassifizierung in Kanada. Mitt.Verein f.forstl.Standortskunde u.Forstpfl.Zchtg, 21.

BURGER, D., 1976: The concept of Ecosystem Regions in forest site classification. Proceedings XVI. IUFRO World Congress, Oslo.

BRAUN-BLANQUET, J., 1928: "Pflanzensoziologie". Berlin

CARMEAN, W.H., 1975: Forest site quality evaluation in the United States. Advances in Agr.27, 209-269. N.Y.

CIRIC, M., STEFANOVIC, V., DRINIC, P., 1976: "Types of Beech and mixed Beech, Fir and Spruce forests in Bosnia and Herzegovina". Sumarsk.Fakult.Sarajewo, spez.publ.No 8; engl.transl.by NOLIT, Belgrade

COILE, T.S., 1952: Soil and the growth of forests. Adv.Agron. 4, 329-396

DAUBENMIRE, R., 1952: Forest vegetation of northern Idaho and adjacent Washington and its bearing on concepts of vegetation classification. Ecol.Monogr. 22:301-330.

DAUBENMIRE, R., and DAUBENMIRE, J.B., 1968: Forest vegetation of eastern Washington and northern Idaho. Washington Agr.Exp.Station, Techn.Bull. 60, 140 p.

DEITSCHMAN, G.H., 1973: Mapping of habitat types throughout a national forest. USDA for.serv.gen.techn.rep. INT-11, intermountain forest and range exp.st. Ogden, Utah, 14 p.

DUDAL, R., 1979: Die Weltbodenkarte der FAO - unter besonderer Berücksichtigung der europäischen Probleme
Vortrag z.25.Jubiläum der Österr.Bodenk.Ges.Graz

DYRENKOW, S.A., 1974: Praktische Empfehlungen für die Abgrenzung von Waldwuchsbezirken unter Verwendung mathematischer Methoden (am Beispiel des Gebietes Leningrad). Leningrader wissenschaftliches Forschungsinstitut f.Forstwirtschaft, Leningrad. 24 p.

DYRENKOW, S.A. and TSCHERTOW, O.G., 1975: Die Waldtypologie in der UDSSR und im Ausland. "Lessowedenije i lessowodstwo", in: Waldkunde und Forstwirtschaft, Moskau, vol.1:190-231.

GARELKOW, D., 1980: Principles for determination and mapping of forest sites in Beech-forests in Bulgaria; Proc.Symp.IUFRO S 1.02-06 and -07, Vienna (in print).

HAVEL, J.J., 1976: The potential of the northern Swan coastal plain for Pinur pinaster Ait.plantations. Bulletin No.76. Forests Department, Perth, Western Australia, 70 p.

HILLS, G.A., 1953: The use of site in forest management.
For.Chron.29:128-136.

HILLS, G.A., & PIERPOINT, G., 1960: Forest site evaluation in Ontario. Ontario Dept.Lands and Forests, Res.Br., Res.Report 42.

HOLLAND, W.D., 1974: Biophysical land classification of Banff and Jasper national parks. Can.for.serv.north for.res.centre, Edmonton, 221-237.

JEFFREY, W.W., et al., 1968: Landvegetation typology in the upper oldman river basin, Alberta. For.branch, Dept.of For.publication No.1202, 45 p.

JELEM, H., 1960: Grundsätze und Anweisungen für die forstliche Standorterkundung und Kartierung.
Forstliche Bundesversuchsanstalt, Schr.d.Inst.f.Standort, Wien; 1.

JURDANT, M., 1969: The ecological survey: the biophysical basis of forest land management. Pulp and Paper Magazine of Canada 70(9): 89-93.

KANTARCI, D., 1976: Die Gliederung der Waldgebiete Ost-Thrakiens auf Grund regionaler Standortsverhältnisse nach den natürlichen Baum- und Straucharten. Matbaa teknisyenleri koll.sti.Istanbul. 77 p.

KLINKA, K., NUSZDORFER, F.C., and SKODA, L., 1979: Biogeoclimatic units of central and southern Vancouver Island, B.C.Min.of Forests, Vancouver, Canada, 120 p.

KOPP, D., et al., 1969: Die Waldstandorte des Tieflandes. Ergebnisse forstl. Standortserkundung DDR, vol.1, Eigendruck VEB Forstproj.Potsdam, 141 p.

KOPP, D., SCHWANECKE, W., 1972: Zur Methodenwahl für großmaßstäbige forstliche Standortskartierungen.
Beitr.f.d.Forstwirtsch. 2/72, 4-10.

KOWALKOWSKY, A., 1980: Cartographic methods for description and interpretation of the soil cover as a site factor
Proc.Symp.IUFRO S 1.02-06 and -07, Vienna (in print)

KRAUSS, G.A., 1936: Aufgaben der Standortskunde. Jahresber.d.Deutschen Forstvereins. Berlin
KREUTZER, K., 1977: Die neue Regionale Standortsgliederung Bayerns. Forstwiss.Cbl. 96/1
LACATE, D.S., 1966: Wildland inventory and mapping. Forestry branch. Dept.of For.of Canada. 184-194.
LACATE, D.S., 1969: Guidelines for bio-physical land classification. For classification of forest lands and associated wildlands. Dept.of fish. and forest.can.forest.serv, publication No.1264, Ottawa. 61 p.
LAYSER, E.F., 1974: Vegetative classification: Its application to forestry in the northern Rocky Mountains. Jour.for. 72, No.6, 354-357.
MAVROMMATIS, G., 1976: Die ökologische Gliederung Attikas Publ.Greece forest res.Inst.Athine; 78.
MINORE, D., 1972: A classification of forest environments in the South Umpqua Basin. USDA, For.Serv.Research Paper PNW 129
MORRIS, L.A., MOLLITOR, A.V., and LEAF, A.L., 1979: Classification of floodplain forests in the northeastern United States through the use of quantitative site variables. For.serv., University of Florida, 27 p.
MÜLLER, S., 1980: Kanadische Methoden der Standortskartierung im Vergleich mit südwestdeutschen Verfahren. Mitt.Ver.f.Forstl.Standortskunde u.Forstpfl.Zchtg. Nr. 28, 28-36.
MEULLER-DOMBOIS, D., 1965: Eco-geographic criteria for mapping forest habitats in southeastern Manitoba. Forestry Chronicle, vol.41, No.2, 188-206.
PFISTER, R.D., 1975: Land capability assessment by habitat types. Soc.of americ.forest., Washington, 13 p.
PFISTER, R.D., 1976: Forest habitat types classification, mapping, and ecoregions in the northern Rocky Mountains. XVI IUFRO World Congress, Oslo, Norway, 11 p.
PFISTER, R.D., et al., 1977: Forest habitat types of Montana. USDA for.serv. gen.tech.rep. INT-34, 174 p.
SCHLENKER, G., 1975: Klima-Gliederung und Vegetations-Gliederung im Rahmen der Regionalen der Regionalen Standortsklassifikation. Forstwiss.Cbl. vol.94(6), 264-272.
SCHLENKER, G., MÜLLER, S., 1973: Erläuterungen zur Karte der Regionalen Gliederung von Baden-Württemberg. I.Teil. Mitt.Ver.f.Forstl.Standortskde u.Forstpfl.Zchtg. 23.
SMALLEY, G.W., 1979: Classification and evaluation of forest sites on the southern cumberland plateau. USDA for.serv.gen.tech.rep. SO-23, 59 p.
SPROUT, T.N., LACATE, D.S., and ARLIDGE, J.W.C., 1966: Forest land classification survey and interpretations for management of a portion of the Niskonlith provincial forest, Kamloops district, B.C.Dep.of For.pub. No.1159. T 60, 34 p.
STEINBRENNER, E.C., 1973: Mapping forest soils on Weyerhaeuser lands in the Pacific Northwest. In: "Forest Soils and Forest Land Management", Proceedings of IV North American Forest Soils Conference, Laval Univ., Quebec, Chapter 31, pp. 513-525.
SUKACHEV, V.N., 1932: Die Untersuchung der Waldtypen des osteuropäischen Flachlandes. Abderhalden's Handb.biol.Arbeitsmethoden 11,(6):191-250. Berlin.
SZODFRIDT, I., 1978: Standortstypen der Waldgesellschaften in Ungarn. Acta.bot.Acad.scient.hung., vol.24(1-2): pp 139-165.
USUI, H., 1975: Vegetationskarte von Japan, 1:50000. Enclosure to IUFRO Inquiry 1976 (impressum in Japanese characters).
ZLATNIK, A., 1960: Waldtypengruppen der Slowakei - Brno

TERRAIN CLASSIFICATION FOR FORESTRY IN THE NORDIC COUNTRIES

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Summary

Since the introduction of mechanized forestry, the Nordic countries have been endeavouring to describe forest terrain in a manner that is appropriate to forestry activities.

Initially, assessment of the terrain was to some extent to help determine wage rates in cutting and extraction work. During the 1950s, Norway adopted a uniform, descriptive system of terrain classification for use in its national forest survey. During the 1940s and 1950s, fairly comprehensive systems of terrain classification were drawn up in Finland and Sweden. In the late 1960s, Sweden adopted a national system for use in logging ("Terrain classification for Swedish forestry"), which formed the basis for a subsequent British system.

Since 1969, a joint venture concerned with terrain classification has been pursued by the Nordic countries under the auspices of NSR (The Nordic Forest Work Study Council). The work has now resulted in a proposal for a common, primary terrain classification system.

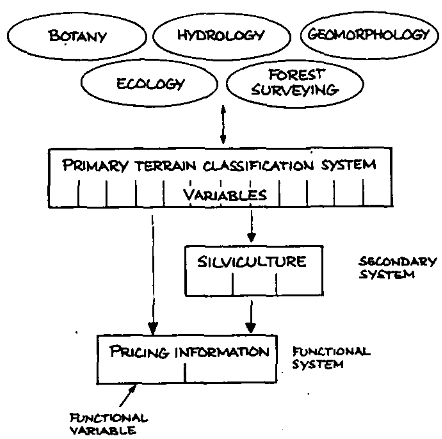
A wealth of studies have demonstrated the way in which productivity and results are correlated with the assessed terrain difficulty. In the Nordic countries, terrain descriptions are regarded as being an extremely valuable aid to machine R & D work and to the costing and planning of forestry activities.

Introduction

Terrain classification systems for the forestry sector have been developed in the Nordic countries in order to facilitate such activities as:

- The description of a tract of terrain
- The planning and control of operations, particularly mechanized processes
- The follow-up and development of mechanized systems
- Costing of the work.

The classification model may adopt a variety of forms, depending on the main purpose of the classification. However, every model will be based on a basic primary system, by means of which an objective description can be made of the terrain in accordance with a numerical scale.



Relationships between different terrain classification systems. The primary system forms the link between research and practical operations.
Source: Nilsson, 1979.

On the basis of the primary system, a secondary system can then be drawn up. This system can be designed for use in a given activity, e. g. logging operations, and the terrain factors can be measured objectively from a numerical or coded scale.

The primary system can also form the basis for the compilation of a functional system. Such a system is built on the terrain factors that are directly related to a given operating method or machine system.

A descriptive terrain classification system makes an objective assessment of the terrain according to a numerical or coded scale. In such a system consideration is only given to terrain factors that are constant, or which only change gradually over a period of time. These systems are not designed to suit any particular activity.

Thus, it is clear that a primary or secondary terrain classification system may also be descriptive.

A consensus has been reached within the Nordic countries about which variables constitute a primary terrain classification system (Eriksson, Nilsson & Skråmo, 1978), although the secondary systems vary in accordance with the requirements and terrain of a given country.

In a country such as Norway, with its extensive areas of varying and mountainous terrain, the type of secondary terrain classificatian system needed is different to that of Finland or Sweden. In Norway, it is important to have a broad description of the suitability of a tract for, say, forestry. Consequently, the emphasis in Norway has been placed on regional terrain classification (Samset, 1975).

In Sweden and Finland, on the other hand, the type of terrain classification system that is used, in the first instance, describes the difficulty of a given site. The systems that have been developed in Sweden (Anon., 1969, and Nilsson & Berg, 1979) are largely intended for use in planning and follow-up studies of forestry activities.

In spite of the earlier work carried out in Finland on terrain classification, as yet no generally applicable terrain classification system has been adopted. Most of the work has concentrated on the development of classification systems that can be applied in costing, planning and follow-up work. Thus, the Finnish systems may largely be regarded as functional systems.

Because of the keen awareness in the Nordic countries of the importance of a satisfactory description of the terrain, terrain classification systems are nearly always put to use before any forestry activities are started.

Terrain classification systems for different forestry activities

Logging

With the mechanization of logging operations, it soon became clear that there was a need to relate the type of terrain to the operating difficulty. Such work was initiated in the Nordic countries during the 1930s and 1940s. Initially, the main aim was to improve the basic information for costing, and the studies were therefore directed at establishing the influence of the terrain on certain specific operating methods. Thus, the earliest forms of terrain classification were mostly functional systems.

The first attempt at establishing a national terrain classification system for forestry was made in Norway during the 1950s (Samset, 1955). The system has been modified and improved on over the years, but the main features remain in the system presented by Samset (Samset, 1975). During the 1960s, a national terrain classification system (Anon., 1969) was developed in Sweden, which formed the basis for a subsequent British system. The two latter systems are to be seen as secondary, but also to some extent descriptive, terrain classification systems.

Because of the importance attached to terrain classification, the Nordic Forest Work Study Council (NSR) decided to start on the groundwork for a common Nordic terrain classification system. The results of the two projects concerned are reported by Haarlaa & Asserståhl (1972) and Eriksson, Nilsson & Skråmo (1978).

The above systems of terrain classification have been designed for different applications. The Norwegian system enables a descriptive classification to be made at a regional and a local level. The system can also be used as a basis for functional classification.

The purpose of the system, which is used constantly in the national forest survey in Norway, is to facilitate assessments of the accessibility and suitability of an area from a forestry point of view. The Swedish system is designed for use in planning and follow-up studies and in work studies. It is primarily intended for a description of a given site. The project carried out jointly by the Nordic countries has developed a primary system, which will mainly be used for the development of secondary and functional systems for the description of the terrain conditions on a site or forest tract.

Silviculture

The main purpose of the majority of the above systems has always been to describe the suitability of the terrain for logging and extraction work. Consequently, some of the difficulty factors that are highly significant to the difficulty of the silvicultural work are not included.

The need for a terrain classification system for silviculture became increasingly apparent with the spread of mechanization in silviculture, which took place during the 1960s and 1970s. In consequence, a terrain classification system for silviculture was developed in Sweden in the late 1970s (Nilsson & Berg, 1979). The system was based on the joint Nordic venture carried out by Eriksson, Nilsson & Skråmo (1978).

The composition of the terrain classification systems

A synopsis of a number of terrain classification systems developed since the 1940s (Table 1) shows that, in every case, the terrain characteristics described are the bearing capacity, ground roughness and slope.

Ground bearing capacity can only be determined through the inclusion of several factors, e.g. soil type, moisture content of the soil, ground reinforcement and vegetation. There are also practical difficulties associated with the use of a scale based on measured values.

There is generally no great difficulty in determining the second factor. An objective description of the incidence of obstacles of varying sizes forms the basis for a scale of four or five classes (Samset, 1975; Anon., 1969; Haarlaa & Asserståhl, 1972; Eriksson, Nilsson & Skråmo, 1978).

Nor is it difficult to describe the third factor, slope. Slope is classified in classes based on measured values.

In the systems included in Table 1, ground bearing capacity has been described in a variety of ways. In the Swedish system (Anon., 1969) for instance, the soil type, moisture content and field layer are assessed, and the bearing capacity is expressed in a ground-conditions class, which constitutes a scale of 1 - 5.

In Norway (Samset, 1975) the detailed system includes separate assessments of the factors, soil type, field layer and type of vegetation. No specific

Table 1 A synopsis of the terrain factors included in a number of terrain classification systems

	Terrain factors																	
	Soil type	Field-layer vegetation	Moisture content	Ground bearing capacity	Surface resistance to scarification	Slash	Ground roughness obstacles on surface	Stumps	Subsurface stones and rock	Slope	Slope: Type	Slope: Length	Terrain topography	Humus type	Shrub and tree layer	Snow and frost	Precipitation	Remarks
Putkisto 1947		*	*			*	*		*									
Finnish National Defence 1963	*			*			*			*								Highly functional
Skogsarbeten 1969	*	*	*	*			*			*						*		Secondary, for logging
Haarlaa, Asserståhl 1972 (NSR)	(*)	(*)	(*)			(*)	(*)			(*)					(*)	(*)		Proposed recommendations, primary
Samset 1975				*						*	*	*	*					Regional, descriptive
Samset 1975	*	*	*				*		*	*				*				Detailed, secondary
Eriksson, Nilsson, Skråmo 1978 (NSR)	*	*	*			*	*	*	*	*	*			*	*	*	*	Primary
Nilsson, Berg 1979	*	*	*		*	*		*	*									Secondary, for silviculture

scale for the classification of bearing capacity is included in this system. However, an assessment of the ground bearing capacity of an area of land is made in the regional classification.

In the co-Nordic primary classification system, the factors influencing bearing capacity are also assessed separately.

To describe the difficulty of the terrain as applied to silvicultural work, a comprehensive, primary, descriptive assessment can be made as accounted for by Eriksson, Nilsson & Skråmo (1978). In the report (Nilsson & Berg, 1979) a secondary terrain classification in five classes is made of the factors, surface resistance to scarification, the incidence of subsurface stones, and the incidence of slash and stumps.

Road construction

The above terrain classification system is also used by civil engineering works. A description of the difficulty of the terrain in an area is an important consideration in an investigation on the profitability of a road-building project.

A terrain classification system like this can also be used in the outline planning of a projected stretch of road, although a more-detailed survey along the planned route will be necessary to estimate the manpower, machines and fill that will be required.

A typical assessment of the terrain (Anon., 1965) may include:

Nature of land	(E.g. forest land, wetland)
Soil type	(The soil type is classified by means of three frost-sensitivity classes)
Subsurface stones	(The incidence of subsurface stones of varying sizes as per the functional division, large stones that can be blasted out, etc.)
Surface stones	(Stones with a given volyme protruding above the surface)
Peat thickness	
Visible boulders	
Slope conditions	

Haarlaa (1973) gives the following difficulty factors:

Thickness of the humus cover
Soil type
Moisture content in the soil
Depth to subsurface stones and rock
Surface resistance to scarification
Ground roughness
Number of stumps
Slope

This report was compiled within the scope of the Nordic project on off-road machines (Haarlaa & Asserståhl, 1972). Accordingly, most of the above difficulty factors are included in the 1978 report by Eriksson, Nilsson & Skråmo.

The influence of terrain difficulty on operating results and productivity

The influence of terrain difficulty on operating results and productivity has been demonstrated in a number of studies.

In the NSR project on off-road machines, Haarlaa (1971) examined the influence of the difficulty of the terrain on the operating speed of various forestry tractors. The terrain factors studied were bearing capacity, humus cover, soil type, moisture content and ground roughness. The results established that the operating speed of the machines was influenced (in descending order of importance) by ground roughness, slope and bearing capacity (Table 2). The combination of difficult ground roughness and difficult slope had a particularly strong effect on the operating speed.

Table 2 Examples of variations in the operating speed of a laden forwarder operating on different slopes. Source: Haarlaa, 1971.

Driving direction	Slope, %	Operating speed, m/min
Downhill slope	-50... -21	31,9
	-20... - 3	32,6
Level ground	- 2... + 2	33,8
Uphill slope	+ 3... +10	28,2
	+11... +20	24,5
	+21... +33	-

Under the same NSR project, Asserståhl (1973) conducted a study on forwarders. The operating speed of the forwarders was related to the terrain difficulty as defined in the terrain classification system for Swedish forestry (Anon., 1969). The variation in the operating speed of a laden forwarder, operating on main haul roads in different types of terrain, may be seen in Table 3. The conclusion to be drawn is that all departures from terrain that is fairly flat and has a low ground-roughness value will result in a reduction in the speed of the machine. In addition, Asserståhl, as Haarlaa (1971 and 1973), has observed that the combination of ground roughness and slope reduces the operating speed more than the factors do when occurring separately.

Table 3 Variations in the operating speed (m/min) of a laden forwarder on a main haul road in terrain of varying difficulty. Regression function taken from Asserståhl (1973).

Ground roughness class	Slope class					
	Uphill			Downhill		
	1	2	3	1	2	3
1	63,2	62,7	-	74,6	73,2	-
2	51,4	48,8	-	62,7	60,2	-
3	-	-	-	57,6	53,2	-

A study of the Kockum 875/78 processor in difficult terrain (Nilsson & Sondell, 1973) established that both ground roughness and slope had a great bearing on starting and stopping times, and on the operating speed (Fig. 1).

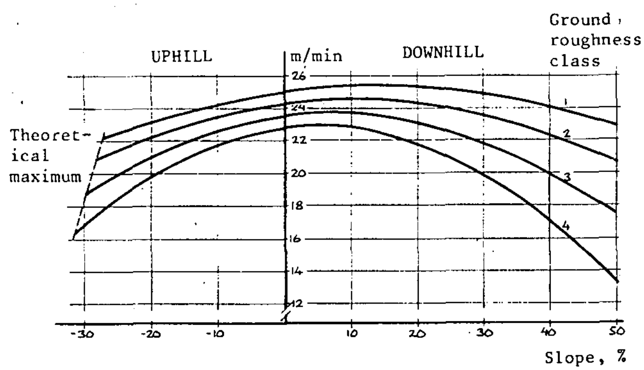


Figure 1 The operating speed of a Kockum 875/78 processor operating in different combinations of ground-roughness classes and slope classes. Source: Nilsson & Sondell, 1973.

Additional studies of the influence of terrain conditions on the operating speed of a machine have been conducted by Berg & Sondell (1974) and Sondell (1979). Once again, a strong correlation was observed between operating speed, ground roughness and slope (Figs. 2 & 3).

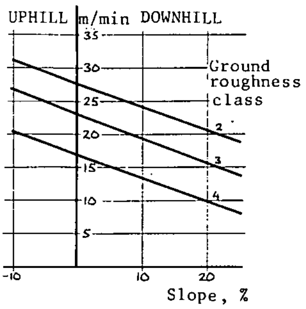


Figure 2 The operating speed of an ÖSA 670 feller-buncher operating in different combinations of ground-roughness classes and slope classes. Source: Berg & Sondell, 1974.

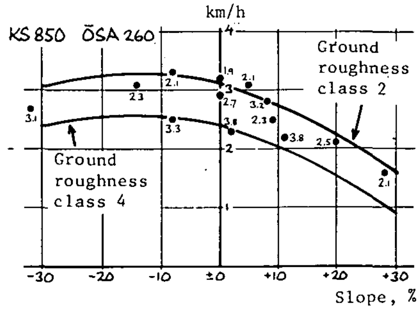


Figure 3 The operating speeds of a number of forwarders along various stretches of a test track. The dots indicate the speed on a given stretch of the track. The ground roughness is indicated by the figures alongside the dots. Source: Sondell, 1979.

The combined results of the above studies show that the difficulty factors, ground roughness and slope, distinguish fairly clearly how the operating speed of a machine is influenced in logging and extraction work. The effect of ground conditions on the speed of a vehicle is apparently rather small, provided that the ground is firm enough to hold the machine.

Studies of the influence of terrain conditions on silvicultural operations have largely concerned mechanized scarification.

Haarlaa (1973b) investigated the effect of terrain difficulty on productivity and operating results in scarification by means of a Sinkkilä Cultivator. The most important factors influencing the operating speed of the machine were soil type, moisture content of the soil, the incidence of subsurface stones and rock, and high ground-roughness values. The operating results, also, were adversely affected by increases in the ground roughness class and the incidence of subsurface stones. (Fig. 4)

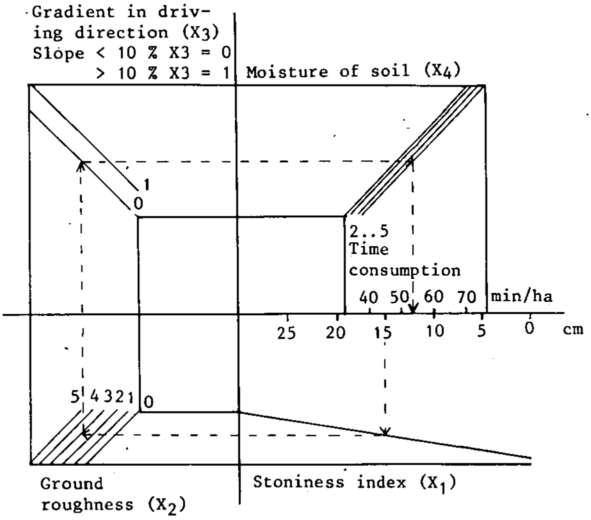


Figure 4 A typical nomogram for determining the time consumption in mechanized scarification by means of the Sinkkilä Cultivator. Source: Haarlaa, 1973b.

Scholander (1973 made a study of the strength of the ground on forest land and found that the ultimate strength of the field and ground layers on true forest land was primarily dependent on the nature of the vegetation, with the properties of the soil being of secondary importance.

In studies of the performance of numerous scarification units, Jahnke & Nilsson (1975) found that the main factors adversely affecting the operating results were:

High ground-roughness values

A high incidence of subsurface stones and rock

An extensive slash cover

A thick humus layer

A high incidence of stumps.

The nomogram constructed by the authors to estimate the operating results under varying terrain conditions is presented in Figure 5.

An investigation of the performance of the TTS 612 disc trencher (Skråmo, 1976) found that the extent and age of the slash cover had the greatest influence on the operating results. Skråmo established that the other terrain factors recorded were minor cause of the scatter around the mean values.

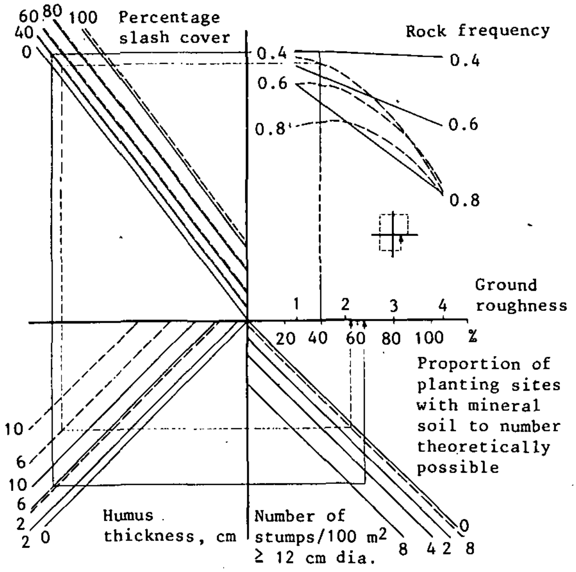


Figure 5 Nomogram showing the proportion of acceptable planting sites with exposed mineral soil in relation to the number theoretically possible, in varying terrain conditions. The solid line denotes the Bräcke-cultivator and the dotted line the TTS 612 unit. Source: Jahnke & Nilsson, 1975.

Numerous studies on the performance of scarification equipment were conducted in 1977 and 1978 (Berg, 1979). The operating results of all of the machines were affected most by the thickness of the slash cover. Thereafter, ground roughness, subsurface stones and rock, and the incidence of stumps also affected the results, although the extent varied from one unit to another (Figs. 6 & 7).

Investigations on time consumption i forest-road construction (Haarlaa, 1973a) found that the operating time of tractor-mounted excavators and of bulldozers was influenced by the incidence of subsurface stones and rock, the moisture content of the soil and the incidence of stumps (Fig. 8).

In addition, ground roughness and slope were found to have an influence on the time taken in excavation by tractor-mounted excavators.

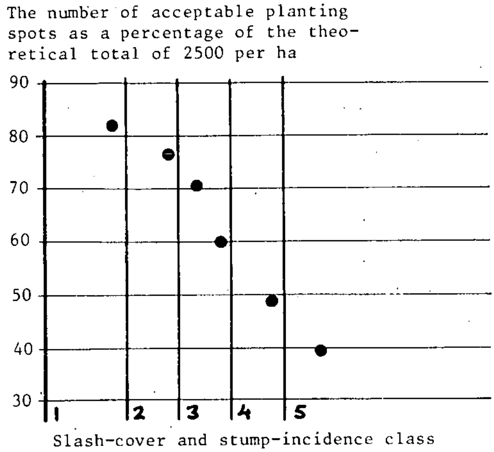


Figure 6 Operating results in scarification with various classes of slash cover and stumps. Site with ground-roughness class 2 and stone-incidence class 4. The difficulty factors are assessed according to a scale of 1-5, with class 1 representing the easiest conditions.

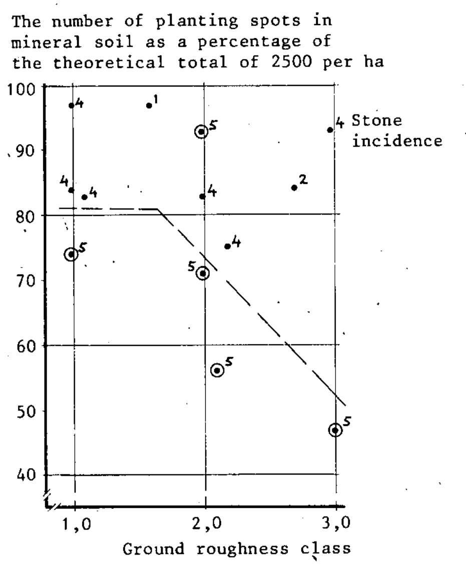


Figure 7 The number of successful plantings in mineral soil after scarification, expressed as a percentage of the theoretical total of 2500 per ha, and the correlation between this percentage and the stone-incidence and ground-roughness classes. The difficulty factors are assessed according to a scale of 1-5, with class 1 representing the easiest conditions. The graph shows the way in which the combination of stone-incidence and ground-roughness classes goes further towards explaining the scatter of the results than does the ground roughness class alone.

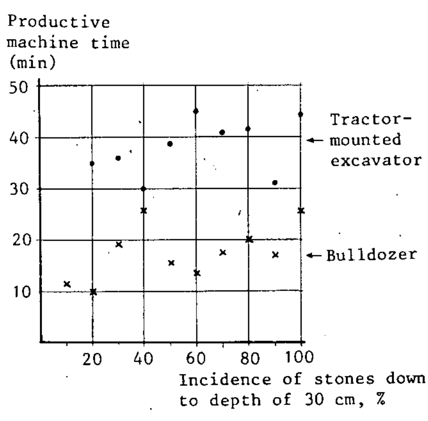


Figure 8 Productive machine time (min) for operation over one-tenth of a hectare with a varying incidence of stones and rock. Source: Haarlaa, 1973a.

Concluding remarks

From the results of the afore-mentioned studies conducted in forest terrain in the Nordic countries, it is clear that the terrain classification systems can be used successfully to demonstrate the influence of terrain on the productivity and operating results in logging, silvicultural and road-construction operations.

Obviously, fewer particulars are required for work carried out on top of the ground than for work that involves partial or total disturbance of the surface.

It has been established that the operating difficulty in logging and extraction work can be amply described by means of the terrain factors, ground roughness, slope and ground conditions.

All of the Nordic countries have terrain classification systems that clearly describe the two former factors. Ground conditions, or bearing capacity, on the other hand, are more difficult to describe precisely, since this factor is influenced by a variety of properties of the soil and vegetation. None the less, the factor is included in "Terrain classification system for Swedish forestry" (Anon., 1969), and in the system used in the national forest survey in Norway (Samset, 1975).

Mechanized silvicultural operations require a more-extensive description of the soil. All of the studies have shown that a description of the incidence of subsurface stones and rock, of the extent of slash cover and of the effect of the scarifier heads on the vegetation is necessary.

A description of primary terrain factors such as these is contained in the joint NSR report (Eriksson, Nilsson & Skråmo, 1978). On the basis of this report, a secondary system has been developed in Sweden (Nilsson & Berg, 1979), which deals with the surface resistance to scarification, the incidence of subsurface stones and rock and the incidence of slash and stumps.

A more-thorough description of the incidence of subsurface stones and rock is necessary for the purpose of road construction. The secondary terrain classification systems are presumably of too general a nature for use in the planning of earthmoving operations. The primary variables in the NSR report can probably give a better and more detailed description of a projected road.

Literature cited

Anon., 1965. Instruktion för markbeskrivning m m vid skogsvägsprojektering. Kungl Skogsstyrelsen, stencil, 1965.

Anon., 1969. Terrängtypsschema för svenskt skogsbruk. Forskningsstiftelsen Skogsarbeten, Redogörelse nr 9 1969.

Asserståhl, R, 1973. Terrängtransport med skotare. Analys av terrängfaktorers inverkan på hastigheten. Forskningsstiftelsen Skogsarbeten, Redogörelse nr 2 1973. (NSR)

Berg, H & Sondell, J, 1974. Tidsstudier av ÖSA 670 fällare-läggare. Forskningsstiftelsen Skogsarbeten, stencil, 1974-05-10.

Berg, S, 1979. Teknisk redovisning av markberedningsförsöken i Kosta och Bräcke 1977-1978. Forskningsstiftelsen Skogsarbeten, stencil, 1979-03-21.

Eriksson, T, Nilsson, G & Skråmo, G, 1978. The Inter-Nordic Project of Forest Terrain and Machines in 1972-1975. Acta Forestalia Fennica, Vol 164, 1978. (NSR)

Haarlaa, R, 1971. Maaston ja kuorman vaikutus metsätraktoreiden ajonopeuteen. Summary: Effect of terrain and load on the driving speed of logging tractors. Dept of logging and utilization of forest products, University of Helsinki, Research Notes No. 9.

Haarlaa, R, 1973. The effect of terrain on the output in Forest transportation of Timber. Acta Forestalia Fennica 128. (NSR)

Haarlaa, R, 1973a. Maaston Vaikutuksesta Metsäteiden rakennukseen. Summary: On the effect of terrain on forest road construction. Silvia Fennica Vol. 7 1973, No. 4:284-309. (NSR)

Haarlaa, R, 1973b. Maastotekijöiden vaikutuksesta metsämaan laikutukseen. Summary: On the effect of terrain to scarifying of forest soil. Dept of logging and utilization of forest products, University of Helsinki, Research Notes No. 23. (NSR)

Haarlaa, R & Asserståhl, R, 1972. The Inter-Nordic Forest Terrain Classification Project in 1969-1972. Dept of logging and utilization of forest products, University of Helsinki, Research Notes No. 20. (NSR)

Jahnke, B & Nilsson, G, 1975. Maskinell markberedning - resultat av arbetsstudier. Forskningsstiftelsen Skogsarbeten, Redogörelse nr 7 1975.

Nilsson, G & Sondell, J, 1973. Tidsstudier av Kockum processor 875/78 med hänsyn till terrängförhållandena. Forskningsstiftelsen Skogsarbeten, stencil 1973-04-17.

Nilsson, G, 1979. The Terrain Classification System for Stand Establishment. Operations in the Nordic Countries. Forskningsstiftelsen Skogsarbeten, stencilled publication 1979.

Nilsson, G & Berg, S, 1979. Terrängtypsschema för skogsvård. Forskningsstiftelsen Skogsarbeten, Ekonomi nr 12 1979.

Putkisto, K, 1947. Vanerikoivujen kasaamisisesta II. Työajan menekkiin vaikuttavien tekijöiden huomioon ottaminen palkkaperusteissa. Summary: Investigations concerning the logging of veneer birches. Metsäteho tied. 28.

Samset, I, 1955. Driftsteknisk klassifisering av skogforholdene i Telemark fylke. Taksering av Norges skoger utført av Landsskogstakseringen, 80-87.

Samset, I, 1975. Skogterrengets tilgjenglighet og terrengforholdenes innflytelse på skogstilstanden i Norge. Summary: The Accessibility of forest terrain and its influence on forestry conditions in Norway. Norske Skogforsøksvesen, Medd. nr 32.1.

Scholander, J, 1973. Skogsmarks rivhållfasthet. Summary: Tear resistance of some forest soils. Dept of operational efficiency. Royal College of Forestry, Research Notes No. 61 1973.

Skråmo, G, 1976. Effekten av en del vanskligheitsfaktorer på markberedningsresultatet vid bruk av TTS Skogsharv. Forskningsstiftelsen Skogsarbeten, Redogörelse nr 6 1976, 59-65.

Sondell, J, 1979. Körhastighet och bränsleförbrukning för skotare i terräng och på väg. Forskningsstiftelsen Skogsarbeten, Redogörelse nr 8 1979.

EVALUATIONS OF FOREST LANDS IN THE UNITED STATES

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Summary

Several approaches are being used in the U.S. for the evaluation of forest land. The most commonly used are the soil-woodland classification system used by the Soil Conservation Service (SCS), multiple-use evaluations used by the Forest Service, and soil potential ratings. Productivity and species adaptation are the factors that most commonly influence the evaluations and are given the most weight. The soil potential approach is being developed as a new evaluation tool for improved understanding of land quality (8). This approach relates economic considerations to specific soil properties and is the most thorough evaluation system used to date.

Introduction

A knowledge of the quality, value, or suitability of forest land for wood crop production and of its recreational, educational, wildlife, and other resource values is essential for deciding its use and management. An understanding of the basic productivity of each kind of soil plus knowledge of the cost and returns to management are required. For much of the forest land in the United States, secondary uses such as recreation, grazing, education, or wildlife enhancement must be properly evaluated along with wood crop production to maximize the returns of the land.

Evaluation approaches should consider what land use options are available or if there are opportunities for multiple use. A detailed analysis has limited value if it considers only one land use. Economic analyses are an obvious requirement. Soil potential analyses can ensure relatively consistent evaluations of several land use alternatives on a given tract of land. These evaluations provide a basis for sound decisions on land use and management.

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Forest Land in the U.S. and its Management

From 1958 to 1977, the acreage of forest land in the United States declined by more than 20 million ha (3). Most of this acreage was cleared and used for cropland; about 3 million ha was shifted to urban uses (11). These shifts in land use occurred largely on privately owned forest lands.

Privately owned forest land

A large acreage of privately owned forest land is divided among many small landholdings. About 5 million ha was cleared for cultivation from 1967 to 1975 (2) although currently most of the owners do not plan to change the land use.

Many of the small areas are not managed for optimum wood crop production. They are highly prized for their beauty, wildlife values, and recreation opportunities or are being held for speculative purposes. In the past few years, increasing numbers of owners have recognized that they can make a profit in managing these small forests without sacrificing secondary values.

About 14 percent of the private forest land in the U.S. is owned by large commercial firms. The owners generally practice highly sophisticated forest management to obtain the highest possible production and profits. As a result, they are learning a great deal about making forestry profitable on specific kinds of soil.

It is important that owners of forest land know the potential of the soil for a wide range of uses. This knowledge might deter some owners from clearing the forest to grow other crops and, instead, show them how to earn profits from wood crops.

Large areas of native forest land have been cleared that never should have been. Much of our most fragile and lowest quality cropland and pastureland, now severely eroding and degrading the environment, is in this category. An evaluation of this low quality cleared land could well show that net returns would be greater for wood crops and that environmental values would be improved.

Federally owned forest land

The federal government owns more than 114 million ha of forest land in the U.S. In a sense the land is held in trust for the people. It provides scenic beauty, recreation opportunities, and wildlife habitat. For many Americans, no other returns are needed to justify its continued ownership by the public.

These values are not diminished on much of the land by management and harvesting of wood crops. Such management and harvest is done extensively on federally owned forest lands as decided by the government forester. It is not necessary to persuade an individual land user as on private land. Furthermore, the management of federally owned forest land receives increasing scrutiny from the public; complaints by private individuals and groups can carry considerable political clout and are considered in management decisions. Management of this forest land must be based, therefore, on a thorough and objective evaluation of the productivity of each kind of soil as well as the environmental hazards of forestry practices and other land uses.

The soil-woodland rating of the Soil Conservation Service

On request, the Soil Conservation Service helps forest land owners and operators plan a conservation system for managing their forest resources. The soil survey and its accompanying interpretations, including the soil-woodland rating system, are the basic technical materials used in planning.

The soil-woodland rating system measures three aspects of the soil's suitability for wood crops: (1) productivity, (2) limiting soil properties, and (3) other site factors (optional). Each soil is assigned to a soil-woodland group identified by an alphanumeric symbol that summarizes these aspects. In group 7W1, for example, "7" means annual productivity is 6.6 to 7.5 m^3/ha, "W" designates soil wetness as a limitation, and "1" indicates a unique set of management problems.

With the rating system, forest soils can be ranked by productivity and species suitability. Soils with high productive potential for desirable species are given a high priority for intensive management.

Preparation and use of soil surveys

The soil survey is the backbone of the rating system. In SCS soil surveys, each soil map unit has a characteristic soil profile; it also occurs in a characteristic landscape position, supports a unique natural plant community, and has definable potentials and limitations for a variety of land uses. The soil profile is a reflection of complex interactions of soil, climate, and vegetation regimes. These interactions are considered in Soil Taxonomy (9), the system of soil classification used by the U.S. Department of Agriculture.

Soil temperature and moisture criteria in Soil Taxonomy limit the occurrence of given kinds of soil to given climatic regimes. This soil-climate interrelationship in the principal determinant of the kind and growth rate of native vegetation. In defining soil map units, SCS soil scientists not only measure and classify the soil's properties but also consider practical needs for land use and management. Map units are defined, therefore, to supply much information about landform and slope position that is important in understanding the forest site. For example, some soils occur only on concave lower slopes or only on convex ridgecrests; other soils occur on more than one kind of landform. Aspect, slope shape and position, and other landform characteristics important in forest site quality are represented by the soil map unit.

Since the soil survey classifies the landscape as a unique whole, it is a holistic approach to defining the environment (7). In contrast, factorial approaches (6) relate productivity to individual soil, climatic, or physiographic features.

Soil-woodland productivity and the site index

Productivity is given major emphasis in the rating system and is represented by the first part of the alphanumeric rating symbol. Productivity is expressed as the volume of annual growth in cubic meters per hectare and is determined through correlations with the site index.

Site index refers to the height, in feet (1 ft = 0.3 m), of a given species, at a given age, on a given soil. For example, on Winthrop gravelly loamy sand, 0 to 15 percent slopes, the site index is 65 for ponderosa pine (*Pinus ponderosa*) at 100 years of age. This means that ponderosa pine can be expected to grow to a height of 65 feet (29 m) in 100 years.

For practical reasons, site index is generally determined from measurements for the dominant and codominant trees on a site growing in usual competition--not overcrowded. The average of several measurements made on the same soil is considered reliable.

When the site index has been determined, it can be converted to other units, for example, cubic meters per hectare, as in the soil-woodland rating system. Only one species is chosen, however, to serve as the basis for the productivity rating. Commonly it is the species with the greatest productivity for a wood crop. This is a limitation of the rating system, because some soils are well suited to several tree species. Productivity estimates are made for the other adapted species.

Limiting soil properties

The second part of the symbol in the SCS soil-woodland rating denotes the presence of soil or physiographic factors that impose limitations in establishing, tending, or harvesting a wood crop. These factors are increasingly important as forestry tasks once done by manual labor are mechanized. The factors have a hierarchy that controls their use when more than one limiting factor is present. The symbols and their meanings, arranged hierarchically, are:

- X - presence of stones and rocks
- W - wetness
- T - toxic materials
- D - depth to rooting restriction
- C - clayeyness

S - sandiness

F - fragmental or skeletal soils

R - relief, steepness, or aspect

A - no soil factor imposes a significant limitation

Other site factors

The third part of the rating symbol is provided for optional use to help identify soils adapted to similar species of trees and understory vegetation or soils with specific management problems, e.g., seedling survival, erosion when cover is removed, windthrow, plant competition, and equipment limitations. These items can be interpreted from soils information.

Examples are:

1. 13X1 - Soils capable of producing 12.5 to 13.5 m^3/ha/yr; stones are present as a limitation; soils are sloping and subject to erosion.

2. 13X2 - Same as 1., except the soils are level and there is no erosion hazard.

3. 9W4 - Soils capable of producing 8.5 to 9.5 m^3/ha/yr; wetness is a limitation; clayey soils affect choice of equipment.

4. 10A3 - Soils capable of producing 9.5 to 10.5 m^3/ha/yr; no significant limitation; suited to Douglas-fir (*Pseudotsuga menziesii*).

Some applications of the system

SCS has leadership for a continuing program of determining site index for the principal tree species on specific kinds of soil. Usually this work is done before completion of soil mapping in the survey area. Automatic data processing systems are being developed to store, process, array, and display the data. Data from approximately 25,000 plots throughout the United States will be in storage by the end of 1980. Obviously, there will never be data obtained on all soil series, but by combining these data with factorial studies, accurate estimates of productivity can be made.

From the site index, it is possible to make some generalizations about the effect of specific soil properties. For example, in western Washington, the site index of Douglas-fir correlates with soil depth and total annual precipitation. In this area site index tends to decrease with increasing elevation and with gravel content of the soil. The soil texture in the A and B horizons also has an influence.

Soil and forestry interpretations are flexible tools. They are most commonly used in planning for individual ownerships, but are also used in broad resource planning of watersheds, counties, or larger areas.

SCS and the state of Washington have accelerated soil surveys on forest land (1). The potential productivity of indicator species and equipment limitations are the bases used for the state's land grading program. The state's Department of Revenue uses the data for assessing tax rates on privately owned forest land.

Tree planting guides are developed by SCS for each kind of soil. The species suggested for planting may include introduced species as well as species observed to grow naturally. Recommendations for introduced species are based on knowledge and experience of species planted on the same soil or on similar soils in the area. Whether one or several species are to be planted, soils information can help in making the best choice and avoiding expensive mistakes.

In central and southeastern United States, there is an abundance of commercial tree species. Lists of preferred species can be compiled and related to soil-woodland groups to take advantage of soil information in making improvement cuttings. In the western United States, there are fewer species from which to choose and such preference lists are less useful.

<u>Multiple-use Evaluations of the Forest Service</u>

The U.S. Department of Agriculture's Forest Service administers National Forest lands using the basic principles of multiple use and sustained yield. The lands are evaluated for a variety of purposes including forestry. Maintenance of long-term productivity is a basic management concept.

Soil information from soil surveys has long been used in making evaluations of National Forest lands. Information used most often is that relating to erosion, mantle stability, productivity, compaction, reforestation, and suitability of various management practices. Soil surveys are available on more than 80 percent of National Forest lands.

A national classification system has not been developed to evaluate land for forestry purposes on National Forest lands. Land evaluation is accomplished as an integral part of the preparation of management plans for individual National Forests. The plans are used primarily for allocating forest management personnel and deciding management practices and secondary land uses.

Soil surveys and other resource data are used to identify and delineate "capability areas." These are areas of land with similar responses to management Soil type, slope, and vegetation are the most common criteria used to delineate capability areas. Interpretations of inherent capabilities and limitations are made from these and the other criteria. Capability is expressed in cubic feet of wood per acre per year, pounds of forage, and other units that indicate productivity. The suitability of various management practices is then determined and suitable mitigating measures developed.

Classifications Using Ephemeral Criteria

Various land classification systems include location, existing vegetation, ownership, and other ephemeral characteristics in evaluations of land use potentials. (Location can be ephemeral because of new development in the vicinity at some time after the evaluation is made.) These systems may be helpful for short-term planning, but the primary determinant for decisions on the long-term use and management of land must be the inherent quality of the soil. The need for ephemeral criteria is likely to depend on changes in future priorities for land and its products.

Soil Potential

During the past 5 years, an approach for evaluating relative soil quality for specified uses has been under development in the U.S. (8). This approach, known as soil potentials, results in an array of soil mapping units from the best suited to the least suited. The general procedure is applicable to any land use. We believe it is a logical way to make the detailed analysis of land quality required for placing soils into the Land Suitability Classes proposed in the Framework for Land Evaluation (4).

Soil potential is a rating of the relative quality of the kind of soil or soil mapping unit in an area. The soil potential rating system evaluates and summarizes the interacting complexes of climate, vegetation, landform, geology, and soil in a discrete landscape segment.

Under the soil potential procedure, the limiting features of the soil and site--and the severity of the limitations--are identified along with the best available technology feasible for overcoming the limitations (10). The cost or degree of difficulty of corrective measures is determined. Limitations that would exist after the measures are installed are evaluated. Yield level below a standard defined for the local area is considered a continuing limitation. Index values related to costs of production and returns to management are developed. The procedure is illustrated in tables 1 and 2, where two soils with the same productivity rating have different potential. Both soils might be in the same Land Suitability Class of a three-class system but could well be in different classes of a five-class system.

In the examples in the tables, both soils fall short of the yield standard for the area despite the application of corrective measures. On the wet Guyton soil (table 1), bedding and ditches are measures designed to improve yields and to facilitate harvest. On the sandy, sloping Alaga soil (table 2), occasional replanting is designed to overcome high seedling mortality. In the future we may find other feasible practices for increasing yield levels. Such practices will be applicable only to specific kinds of soil or specific kinds of soil limitations.

The evaluation of technology--its costs and benefits--is considered a strong advantage of the soil potential rating system. Discussion among specialists in different disciplines is required under the procedure, and these discussions help ensure the best possible use of soil survey and other resource data. The ratings can be used to separate soils into the suitable and not suitable Level Suitability Orders (4) as well as to place soils into the Land Suitability Classes.

Table 1. Sample worksheet for preparing soil potential ratings

Soil use: Woodland — Area: Beta County

Mapping unit: Guyton silt loam, 0 to 1 percent slopes

Yield standard: 9.1 m^3/ha/yr
Yield estimate: 7.7 m^3/ha/yr

Evaluation factors	Soil and site conditions	Degree of limitation	Effects on use	Corrective measures: Kinds	Corrective measures: Index 1/	Continuing limitations: Kind	Continuing limitations: Index
Slope	0-1%	Slight	None				
Depth to high water table	<150 cm	Severe	Equipment limitation, seedling mortality	Special equipment, avoid wet seasons Bedding, ditches	10 5		
Flooding	None	Slight	None				
Available water capacity to 150 cm depth	>20 cm	Slight	None				
Surface texture	Loamy	Slight	None				
				Total	15	Total	18 2/

1/All index values are a percentage of the value of the harvested crop.

2/Yield reduction is 18 percent of the standard:

$$\frac{9.1 - 7.7}{7.7} \times 100 = 18.$$

$$\underset{\text{Performance standard index}}{100} - \underset{\text{Measure cost}}{15} - \underset{\text{Continuing limitation cost index}}{18} = \underset{\text{Soil potential index}}{67}$$

Table 2. Sample worksheet for preparing soil potential ratings

Soil use: Woodland — Area: Beta County

Mapping unit: Alaga loamy fine sand, 8 to 13 percent slopes

Yield standard: 9.1 m^3/ha/yr
Yield estimate: 7.7 m^3/ha/yr

Evaluation factors	Soil and site conditions	Degree of limitation	Effects on use	Corrective measures: Kinds	Corrective measures: Index 1/	Continuing limitations: Kind	Continuing limitations: Index
Slope	8-13%	Slight	None				
Depth to high water table	>150 cm	Slight	None				
Flooding	None	Slight	None				
Available water capacity to 150 cm depth	< 12 cm	Severe	Reduced yield, seedling mortality	Occasional replant	4		
Surface texture	Sandy	Moderate	Equipment limitation	Special equipment; schedule operations to avoid dry seasons	3		
				Total	7	Total	18 2/

1/All index values are a percentage of the value of the harvested crop.

2/Yield reduction is 18 percent of the standard:

$$\frac{9.1 - 7.7}{7.7} \times 100 = 18.$$

$$\underset{\text{Performance standard index}}{100} - \underset{\text{Measure cost}}{7} - \underset{\text{Continuing limitation cost index}}{18} = \underset{\text{Soil potential index}}{75}$$

References Cited

(1) Department of Natural Resources, State of Washington. 1980. Annual report: Private forest land grading system. Dep. Nat. Resour. Olympia, Washington 98504, 13 p.

(2) Dideriksen, R. I., A. R. Hidlebaugh, and K. O. Schmude. 1977. Potential cropland study. U.S. Dep. Agric. Soil Conserv. Serv. Stat. Bull. No. 578. U.S. Gov. Print. Off., Washington, D.C. 20402, 104 p.

(3) Dideriksen, R. I., A. R. Hidlebaugh, and K. O. Schmude. 1979. Trends in agricultural land use. In (Max Schnepf, ed.) Farmland, Food, and the Future. Soil Conserv. Soc. Am., Ankeny, Iowa 50021, p. 13-28.

(4) Food and Agriculture Organization of the United Nations. 1976. A framework for land evaluation. Internat. Instit. Land Reclam. and Improv. P.O. Box 4 Wageningen, The Netherlands, 87 p.

(5) Hartung, R. E. and W. J. Lloyd. 1969. Influence of aspect on forests of the Clarksville soils in Dent County, Missouri. J. Forestry 67:178-182.

(6) Jones, J. R. 1969. Review and comparison of site evaluation methods. U.S. Dep. Agric. For. Serv. Res. Pap. RM-51. Rocky Mountain For. Range Exp. Stn., Fort Collins, Colorado 80521, 27 p.

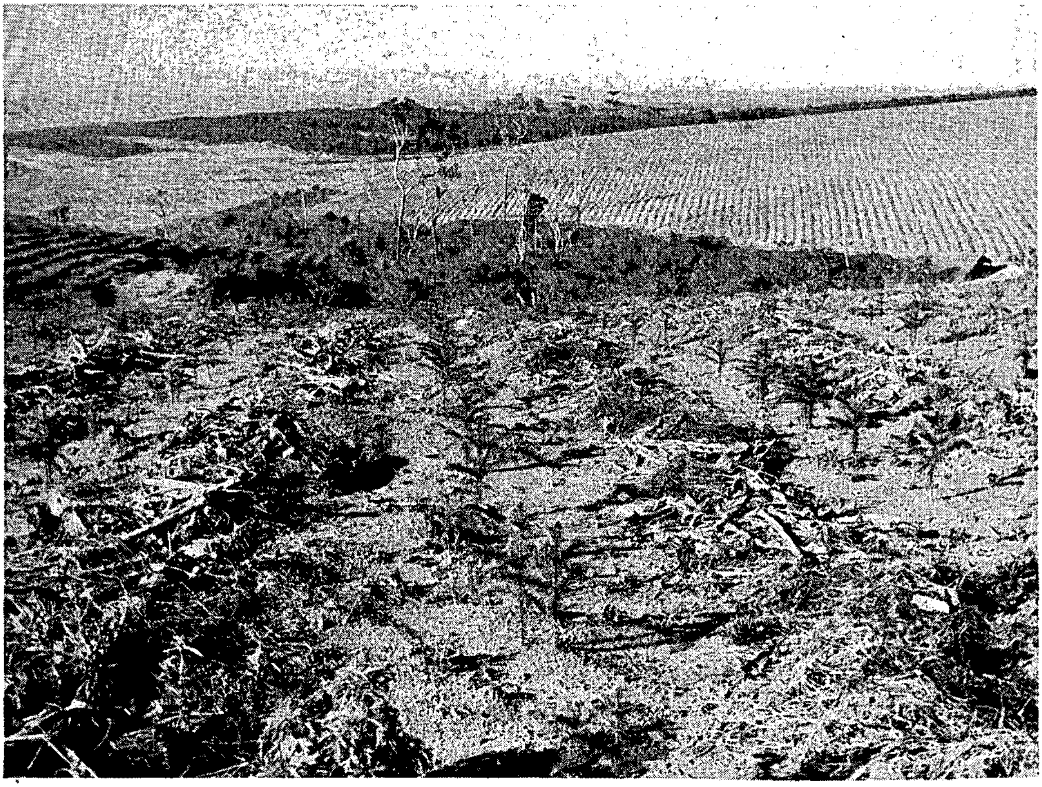
(7) Lloyd, W. J. and W. M. Clark. 1979. Timber production on intensive holdings. In Planning the Uses and Management of Land. Am. Soc. Agron. Agronomy No.21. 677 S. Segoe Rd., Madison, Wisconson 53711, p. 387-423.

(8) McCormack, D. E. 1974. Soil potentials: A positive approach to urban planning. J. Soil Water Conserv. 29(6):258-262.

(9) Soil Conservation Service. 1975. Soil taxonomy. U.S. Dep. Agric. Agric. Handb. 436. U.S. Gov. Print. Off., Washington, D.C. 20402, 754 p.

(10) Soil Conservation Service. 1978. Soil potential ratings. _In_ National Soils Handbook, Part II, Sec. 404. Soil Conserv. Serv., Box 2890, Washington, D.C. 20013.

(11) United States Department of Agriculture. 1978. 1977 national resource inventories. Soil Conserv. Serv., Box 2890, Washington, D.C. 20013.



Afforestation with Araucaria angustifolia in Southern Brazil.

3.2 Papers on "Land evaluation, a new approach"; Session 1, November 11, Monday

<u>"Concepts and Procedures"</u>

Chairman: M.F. Purnell; Rapporteur: R.E.F. Heslop

- J. Bennema, H.F. Gelens and P. Laban
  Principles, basic concepts and procedure in land evaluation, considered from a forestry angle
  Presented by J. Bennema
- P. Laban
  Co-authors: S. Andel, M.M.G.R. Bol, C.P. van Goor, E.M. Lammerts van Bueren and A. van Maaren
  Land utilization types for forestry
  Presented by E.M. Lammerts van Bueren

PRINCIPLES, BASIC CONCEPTS AND PROCEDURE IN LAND EVALUATION, CONSIDERED FROM A FORESTRY ANGLE

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Summary

Under auspices of FAO a framework for land evaluation has been developed. Thus far, this framework is mainly applied for agriculture; this paper reviews, and underlines, the applicability of its concepts and procedures in the field of forestry.

The main principles of this approach to land evaluation are
a) multidisciplinarity,
b) consideration of the physical as well as the socio-economic and political environment of the study area,
c) land suitability classification for specified kinds of land use,
d) comparison of more than one single kind of land use,
e) comparison of benefits and inputs for each kind of land use, and
f) use on a sustained basis.

These principles are at least as valid for forestry as for agriculture.

There are several aspects of land evaluation which, although not exclusively

specific for forestry, deserve high emphasis when evaluating land for forestry: e.g. the often long rotation periods, the environmental impacts of selected kinds of (forest) land use and the need to pursue more than one aim simultaneously (e.g. wood production as well as recreation and/or land conservation).

The second part of the paper describes briefly the procedure of the land evaluation approach. It emphasizes the need for socio-economic information. At the same time, however, a distinction is made between a physical and an integral land evaluation, socio-economic analysis playing an important role in the latter.

I. General introduction

In the past decade serious efforts have been made (on an international level) to achieve uniformity in the approach to land evaluation. Most of these efforts have been made under the auspices of FAO and FAO has done much of the co-ordinating work. The most important single result of all these efforts: "A Framework for Land Evaluation" was published by FAO at the end of 1976.

In the first two chapters of this Framework land evaluation is defined and a number of principles and basic concepts are introduced and put forward. These principles and concepts needed to be formulated to describe a land evaluation procedure which, hopefully, would be generally acceptable and applicable throughout the world.

It must be emphasized that the Framework is intended to provide guidelines for land evaluation for all rural purposes, not just for agriculture. Undoubtedly, forestry comes under this term "rural". Nevertheless, the Framework approach so far has been mainly applied and tested in the sphere of agriculture. And experience so far obtained suggests that the Framework is fulfilling its purpose.

It is logical that in a workshop on land evaluation for forestry we should now wish to assess the value of the Framework approach for forestry too. It has great advantages, particularly in rural development planning, when both

branches of rural use can be evaluated according to the same principles. After all, the Framework was meant to make this possible.
The purpose of this paper is therefore to consider the principles, the concepts and the procedure of land evaluation from a forestry angle. We want to see if the basic concepts retain their meaning if we apply them to forestry and if the principles remain valid when we deal with forestry rather than with agriculture. This will be done in the first part of the paper, as we need to be familiar with these concepts and principles for a good understanding of the procedure. The procedure is discussed in the second part, also against a forestry background.

II. Principles and basic concepts

Introduction

As mentioned above, we want to review the Framework's principles and concepts and see if they remain valid when applied to forestry. We may further question if there is a need for additional concepts when we consider land in a forestry context. Finally, there are a number of considerations, either specific to forestry or of a more general nature, which are not discussed in the Framework but nevertheless deserve our attention. But first, let us define land evaluation against a forestry background, thereby analysing the concepts used in such a definition.

Definition

The most concise definition of land evaluation given in the FAO Framework for Land Evaluation is:
"Land evaluation is .... (the process of) the assessment of land performance when used for specified purposes".
These purposes may be the present land use or other uses relevant for future considerations. As a good performance implies a high suitability the word 'performance' may be replaced by the term 'suitability'.

The definition remains valid when the land use is meant to be a form of forestry. The definition of land evaluation can be more specifically adapted to forestry, as follows:

"Land evaluation for forestry is the process of assessing the performance (suitability) of land when used for specified present or projected forms of forestry".

A number of terms in this definition can be considered as basic concepts and need individual attention.

'Land' in this context, besides being an area of the earth's surface, includes all the physical attributes of the area that are reasonably stable or predictably cyclic to the extent that these attributes are important for the land evaluation. They include: soil, underlying geology, hydrology, climate, present land use and/or natural vegetation, internal infrastructure. For forestry it is important to emphasize that the present stand of either natural or planted forest is part of the land.

The term 'forestry' in the definition is used in its widest sense and includes all the uses in which the forest or the forest ecosystem is the main source of the produce (timber, pulp, etc.) or where it fulfills specific functions in society or environment.

'Specified forms of forestry'. The framework recognizes major kinds of land use as a first sub-division of rural land use. Forestry is one of them. When a kind of land use needs to be described in greater detail we speak of a 'Land Utilization Type', sometimes abbreviated to LUT. A Land Utilization Type can be defined as a specific way of using the land, which for the purpose of land evaluation is described in terms of the following so-called 'key attributes': (1) produce, (2) labour intensity, (3) capital intensity, (4) technology, (5) level of know-how, (6) scale of operations. Differences in the key attributes enable the Land Utilization Types to be distinguished from each other. It is clear that, as in agriculture many types of forestry can be recognized on the basis of differences in the same key attributes we know from agricultural Land Utilization Types. The paper "Land utilization types for forestry" will deal in detail with this subject. As planting or maintaining trees on the land is a kind of use fully comparable with planting a crop or using the land for grazing cattle, we can also use the term Land Utilization Type for any specific form of forestry. There is no need to introduce a new term: Forest Utilization Type. Such a new term may be wrongly interpreted: it is not the forest that is used, but the land (which may include existing forest). When there is a need to stress that we are dealing with land use that can be considered forestry, the term 'Land Utilization Type for Forestry' might be suggested. In this paper we shall use this term when there is a need to emphasize the contrast with the agricultural Land Utilization Type, but it may well be that there are no compelling reasons to introduce it in land evaluation for forestry in general.

One remark may be made about the key attribute 'produce' when used in connection with forestry. In forestry, 'produce' has a wide meaning. As in agriculture there are many cases in forestry where the produce takes a palpable form like timber, pulp, fire wood, secondary forestry products etc., but in other cases the produce is more intangible and consists e.g. of supplying a recreational function or a soil conservation function. The term 'function' here can be interpreted as extending the concept of 'produce' and it may be argued that in land evaluation for forestry the two terms should be interchangeable. Different kinds of produce may be obtained from the same area without spatial separation. In this case we can speak of a 'multi-purpose land utilization type for forestry'. Two cases can be distinguished:

a. The aims are pursued simultaneously, in which case the multi-purpose land utilization type for forestry fits the definition of a 'multiple land utilization type' as given in the Framework. An example of this is a forest managed for the production of timber but which simultaneously has a distinct recreational function.
b. The aims are pursued one after the other in a rotation ('rotational multi-purpose land utilization type for forestry'). Examples of this

are several forms of agro-forestry whereby, after felling a forest stand, crops are grown for a few years before new trees are planted. In cases of multi-purpose land utilization types for forestry, the suitability of the land evaluation units has to be assessed for the different aims, taking any mutual constraints into account.

The principles of land evaluation

The Framework indicates 6 basic principles that are considered to be fundamental to the suggested approach to and methods of land evaluation. These principles are briefly reviewed below; at the same time it is ascertained whether they retain their validity when forestry rather than agricultural use is considered.

a. Land suitability is assessed and classified with respect to specified kinds of use.
Different Land Utilization Types have different requirements, which have to be met by certain characteristics of the land, the so-called land qualities. The requirements include requirements related to growth e.g. the availability of water, the availability of nutrients etc., requirements related to management e.g. the possibility for mechanization, the minimum size of potential management units, etc. and requirements related to land conservation e.g. resistance to erosion, not being susceptible to salinization etc. Because of the different requirements, the same piece of land will have different suitability for different Land Utilization Types. This also applies to Land Utilization Types for forestry: land with shallow rocky soil will be unsuitable for many species but for a utilization type based on the growing of a shallow-rooting species, it may be highly suitable.

b. Land evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land.
As in agriculture, land evaluation for forestry always has an economic background. To produce a product, land needs certain

inputs in the form of labour and investments. On different types of land these inputs will be different, while also the outputs in the form of a product or the fulfillment of a function will be different in quantity or quality. Even the so-called physical land evaluation should keep the estimated ratio between these inputs and outputs in mind.

c. A multidisciplinary approach is needed.
As pointed out under (a) above, the requirements of Land Utilization Types, whether for agriculture or for forestry, may vary greatly in kind and nature. E.g. the suitability for a timber production forest has to do with requirements related to growth (soil, climate), requirements related to management (conditions for the application of certain logging methods, the possibility of developing an infrastructure), while soil conservation aspects also need attention.
To evaluate these different aspects, people from different disciplines are needed.

d. Evaluation is made in terms relevant to the physical, economic and social context of the area concerned.
From (a) it follows that, when evaluating an area, the suitability for different Land Utilization Types has to be determined.
The number of Land Utilization Types has to be limited for practical reasons and the phrasing of this principle simply means that the choice of Land Utilization Types to be considered should be a logical one seen against the physical, economic and social backgrounds of the area concerned. In some cases the relevant Land Utilization Types will be agricultural ones, in other cases different Land Utilization Types for Forestry will be relevant. However, it should be evident that there are also many areas where the Land Utilization Types to be considered are partly of agricultural nature, partly Land Utilization Types for Forestry (see also f.).

e. Suitability refers to use on a sustained basis.
The most important condition for any form of rural land use is that

production can at least be maintained at a certain level over time, i.e. productivity should be sustained. This is in contrast to looking for high short-term profits that cause environmental deterioration and consequently decrease future benefits.
This principle, particularly with regard to forestry, should be seen in a broad regional sense. It means that not only the site conditions have to be maintained but also that a forest ecosystem should be maintained or created over a wider area, making sustained production possible. On the other hand, it should be considered acceptable that at a given moment in the course of the development of an area, an incidental decrease in potential takes place, provided that an acceptable level is maintained subsequently. E.g. the clearing of a primary forest usually means a loss of natural fertility. This is acceptable if after this a reasonable level of productivity can be assured and permanently maintained.

f. Evaluation involves comparison of more than one single kind of use. This principle has to be seen in close context with (a) and (d). The comparison should lead to a recommendation. The recommendation will lead to a choice that should be based on the physical suitability (a) and the economic and social backgrounds (d). The kind of choice will be related to the level of planning. In the first instance the choice may have to be between agriculture and forestry. In a further stage the kind of forest product or the tree species to be planted may be the object of choice.

In view of the principles mentioned under (b), (d) and (f), it may be appropriate to conclude this section with the remark that land evaluation is not an alternative to socio-economic planning. It is meant to provide the data on land use possibilities in a systematic way and can therefore be considered an essential basis for socio-economic planning and analysis.

Land units and land evaluation units

The concept of land has been discussed. However, an area of land has to be divided into parts that can be treated individually as units in the process of land evaluation. For this purpose the Framework indicates the 'land mapping unit', which is a mapped area of land with specified characteristics. Land mapping units are delineated and characterized as a result of natural resources surveys e.g. soil survey, forest inventory etc. In principle, a land mapping unit should have homogeneous characteristics, with a certain permissible internal variation. The degree of internal variation varies with the scale and intensity of the study.

In some cases a mapping unit consists of two or more distinct types of land, which for cartographic purposes have been combined in one mapping unit (associations and complexes). The component parts of such compound units may have completely different suitabilities. On the other hand, different land mapping units may offer the same possibilities for a specific Land Utilization Type because the one or more characteristics that distinguish them from each other, are irrelevant for the Land Utilization Type concerned.This is why the concept of a 'land evaluation unit' has been created: a unit that offers the same possibilities for a specific Land Utilization Type. A land evaluation unit may consist of one or more land mapping units.

The Framework notes that variation in soils is often the main cause of differences between land mapping units within a local area and that for this reason soil surveys are sometimes the main basis for defining land mapping units. This remark, which certainly holds for agriculture, is possibly less valid when evaluation for forestry is concerned. When evaluating the suitability for land utilization types for forestry, several soil mapping units with less striking differences may well constitute one land evaluation unit. On the other hand, for such an evaluation an inventory of natural vegetation and existing forest types and other land use, may yield boundaries for land evaluation units that would not have been brought out by a soil survey alone.

The Land Utilization Type as a part of the forestry enterprise

This may be the proper place to point out that to be of practical value, land evaluation cannot stop at determining the suitability of individual land evaluation units for each separate Land Utilization Type. In forestry, even more than in agriculture, three types of land evaluation should be recognized:

i. The land evaluation dealing with the suitability of each land evaluation unit for one or more individual land utilization types. This is called land evaluation in the strict sense, or internal land evaluation.

i.i. The land evaluation for one or more land utilization types (agricultural and/or forestry) dealing with the suitability of establishing a viable enterprise, taking into account the mutual influences of the different land utilization types that such an enterprise may contain.

i.i.i. The land evaluation dealing with the wider environment, taking into account the mutual influences of the enterprise and the environment. This may be seen from an ecological viewpoint as well as from a social, economic and/or political viewpoint. In this case we speak of an overall land evaluation.

The concept of 'enterprise' mentioned under (i.i.) deserves further attention. As we are dealing with forestry we shall henceforth use the term 'forestry enterprise', which can be defined as an economically viable management unit. This economic viability may imply certain requirements as to the minimum size and as to the (ecological) variation of the component parts of the enterprise.
A land utilization type for forestry may be part of a forest enterprise. The forest enterprise may include one or more land utilization types for forestry. The land evaluation for the different types will have to furnish data to optimalize the structure and management of the enterprise by means of a socio-economic analysis.

A forest enterprise may have one major aim (a particular product or a function) or it may have more major aims simultaneously e.g. timber production and the functioning as recreation grounds. In the case of different aims, these may be pursued in different parts of the enterprise. In this case the enterprise may include quite contrasting utilization types.

A land utilization type for forestry may also be part of an enterprise in which forestry is not the main activity, e.g. part of an agricultural enterprise or an agricultural community. In such cases, forest may be established to provide firewood and/or timber for local use (building of houses). Ample attention to this kind of activity is recommended, as it is of growing importance.

Land qualities

Earlier, mention was made of the fact that individual land utilization types have their own requirements and these have to be met by 'land qualities'. For a good understanding of the relationship between requirements and land qualities, it is necessary to express them in the same terminology. A few examples may clarify this:

- For a good performance all Land Utilization Types need water, though different Land Utilization Types may require different quantities. The question whether this requirement for water will be met, is answered by determining the land quality 'availability of water'.

- A certain land utilization type for forestry, aiming at the production of timber, implies mechanized logging methods. One of the requirements of this Land Utilization Type is therefore that such mechanized logging is feasible. The evaluation then has to pay attention to the land quality 'feasibility of mechanized logging'

A land quality may be defined as a complex attribute of the land that distinctly affects the performance of a certain use by meeting a particular requirement to a certain degree.

For practical use in land evaluation, land qualities have to be graded. This grading has to be done independently of the requirements of the relevant Land Utilization Types. E.g. a certain grade of water availability has been determined to be the water availability in a given land unit. This grade of water availability may be quite sufficient to meet the water requirements of a relevant Land Utilization Type A, whereas that same grade may be absolutely insufficient to meet the requirements of another relevant Land Utilization Type B. The same grade of water availability may then render that land unit suitable for Land Utilization Type A and not suitable for Land Utilization Type B.

It is often difficult to grade land qualities as they are usually the result of a set of interacting single land characteristics with varying weights in different environments.

As with the requirements, we usually distinguish some groups of land qualities. Land qualities that influence the growth of agricultural crops are also of great importance for the growing of forest trees. These qualities, (e.g. moisture availability, nutrient availability, oxygen availability in the rooting zone) need not be given special attention here.
Land qualities related to management, such as the possibility for mechanization, may have to be judged according to different criteria than those valid for agriculture. E.g. mechanizing logging operations is quite different from mechanizing in connection with the average agricultural crop.

There are, however, also land qualities that are of interest specifically for forestry. Several of these could be characterized as negative qualities that may only occasionally influence the forestry enterprise. But because of the long time interval between planting and the maturing of a tree crop, such qualities have to be taken into account especially seriously in forestry. Examples of such qualities are:

presence of forest fire hazard

presence of windfall hazard
risk of periodically occurring pests and diseases.

Special aspects of land evaluation for forestry

Land evaluation for forestry is greatly influenced by what could be called 'distant future-effect qualities', and this brings us to some further special aspects of land evaluation for forestry. In the first place there are a number of aspects inherent to the long rotation period of most land utilization types for forestry. This has consequences for management. Decisions taken when a forestry enterprise is established or renewed will have their influence for a long time. In agriculture, a wrong management desicion may prove itself wrong after one year and can then be corrected. In forestry this is often not the case. Prudence is therefore commended when it concerns long-term management decisions.

The possible influence of the management on a forest ecosystem after its establishment is restricted, if one does not want to run the risk of destroying it completely. Normally, management is more a matter of guiding the natural processes. A good understanding of these processes is therefore imperative.

The long rotation also means that several inputs that in agriculture are usually considered to be recurrent, become non-recurrent in forestry. Examples are tillage and the fertilizing of young trees.

Although already casually referred to in the previous sections, we would like to reiterate that very many land utilization types for forestry have a land conservation function. Sometimes this is their sole aim, but in many other cases this conservation function lies within a multipurpose land utilization type. When land evaluation for a land use planning is done in areas where conservation aspects are of great importance, two cases can be distinguished:

a. A forest ecosystem is present and it fulfills the protection function well. The major question then is: how can disturbance to the ecosystem be minimized, thereby assuring the maximum of protection?

b. No forest ecosystem is present but circumstances make a prospective form of land use imperative. The question to be answered then is what kind of forest will function most effectively in this respect, taking into account the suitability of the site for the different alternatives? The comparison of alternatives should not stop at a number of land utilization types for forestry. It is entirely possible that in given circumstances a non-forest land use can achieve the protection function more effectively.

This brings to an end part 1. The principles and concepts discussed above will now be used in part 2 to explain the land evaluation procedure. There is inevitably some overlap with part 1, but we hope that this will be forgiven, as it is intended to ensure good understanding.

III. The procedure of land evaluation

Introduction

Three stages can be distinguished in land evaluation (see fig. 1)

a) The preliminary stage, in which the fundamental information for the selection and description of land use objectives, alternative forestry enterprises and land utilization types is identified, and in which subsequently the land use objectives and the terms of reference for the land evaluation study are defined.

b) The main stage of land evaluation, which can be referred to as the physical land evaluation or as the land evaluation in the strict sense.
In this stage, the findings are used to reach a conclusion about the suitability of a certain land evaluation unit for a certain kind of land use.

c) The final stage, in which the feasibility of the Land Utilization Type is assessed taking into account the socio-economics of the whole enterprise and its physical and socio-economic environment.

Stages b and c may be seen as two stages in time; they may, however also be done simultaneously as two parallel stages. In both cases the land evaluation can be called integral land evaluation. In this paper the two-stage procedure will be used to illustrate the different stages and phases.

Fig. 1 Simplified flow diagram indicating the main principles of the procedure

Preliminary stage	Human and ecological environment with land use objectives, terms of reference
Main stage	Land use with its requirements → relation ← land with its qualities ↓ land use suitability
Final stage	↓ land use feasibility

The land evaluation can be used as a base for land-use planning. The following may serve as an example.
If it was decided at the outset that due to the general ecological conditions the project area should be used for forestry and if it is apparent that different kinds of forest enterprises are feasible, then a choice has to be made within the context of regional planning. However, this subject does not form part of the workshop.

The preliminary stage

Any evaluation of agricultural potentials needs to be based on a relavant set of basic considerations and information on the physical, political and socio-economic conditions of the study area. This set can be summarized as:

a) the over-all development situation in the study area

b) the over-all development objectives for the study area
c) the socio-economic aspects of the environment.
d) the over-all physical aspects of land, including existing land use and natural vegetation.

Given this fundamental information, the terms of reference of the land evaluation study as well as the land use objectives relevant in the study area can be defined. The necessary information can be assembled systematically using structured checklists of major and minor determinants e.g. those related to: existing development plans and targets; the produce; labour and capital.

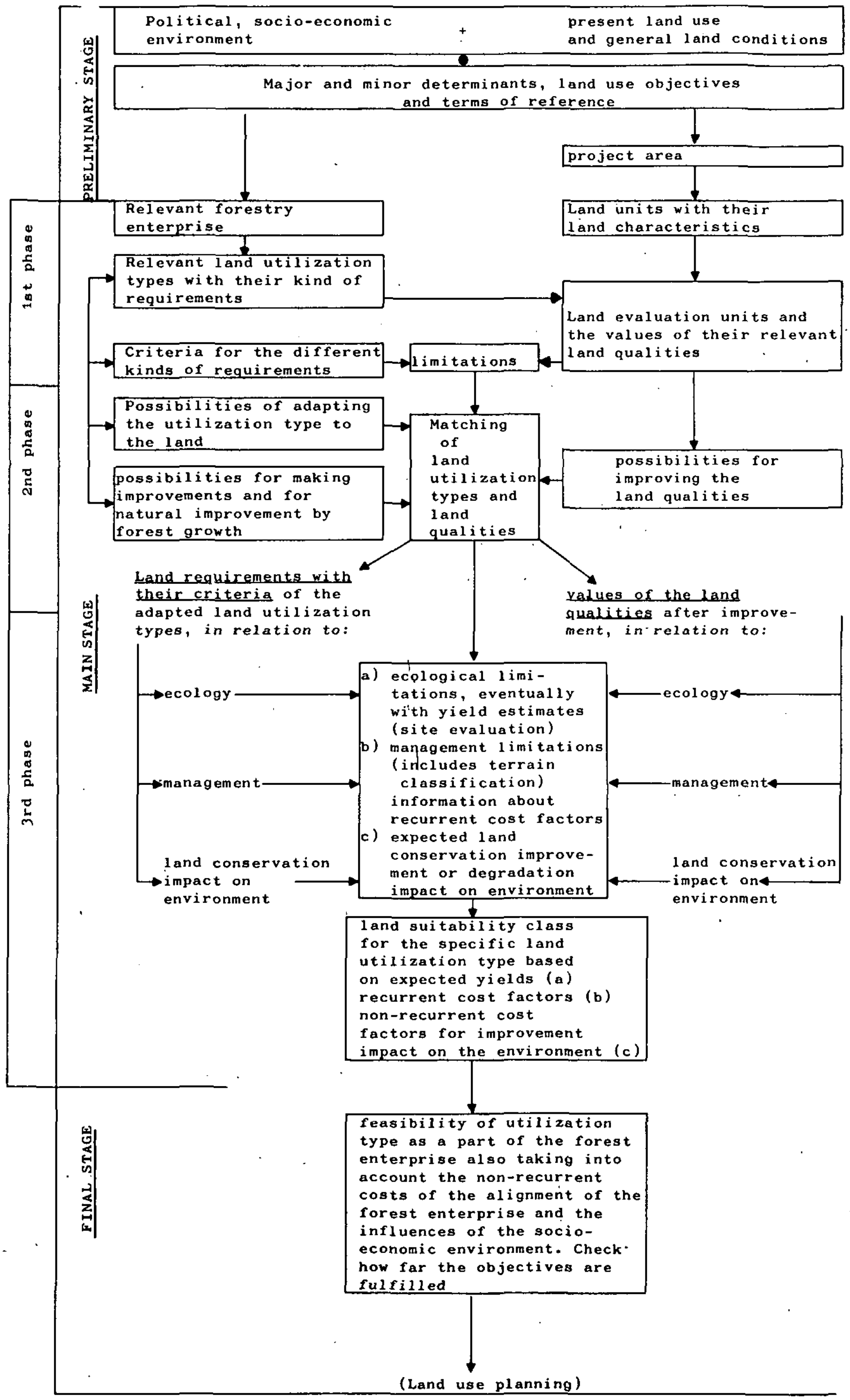
The above points are elaborated further in paper 2.1.2. "Land Utilization Types for forestry". However, it should be emphasized that the terms of reference for a land evaluation in general should include: area limits; general development and land use objectives; constraints in the study area, also those related to the wider environment and to the time period during which the land evaluation results should be relevant. This last point is of major concern in land evaluation for forestry, more than in most other land evaluations.

The main stage

This stage will be briefly described according to the flow diagram in fig. 2. In the flow diagram there are 3 columns.
The left - hand column indicates land use, the right hand column the land and its physical characteristics and in the central column the relation between the two is shown. The main stage is divided into three phases.

The First phase: When the fundamental information of the study area has been assembled as a result of the preliminary stage, it becomes possible to define the forest enterprises and their associated land utilization types that are supposed to fulfil the objectives. The land utilization types are characterized by so-called key attributes, e.g.
1) main produce (timber, firewood, pulpwood, recreational facilities)
2) kind of management (scale of operations, kind of machinery to be used, amount of hand labour etc.)

Fig. 2 Flow diagram indicating the different aspects to be considered during the *land evaluation* study



3) influence on the environment (e.g. regulation of the hydrological regime).

At the same time, land units (mapping units) have to be identified in the project area. The different utilization types have different requirements that the land units must meet. These requirements are partly related to management (e.g. accessibility of the terrain, possibilities for efficient use of machinery etc.), partly related to land conservation, and partly to the growth conditions such as the need for water for plant growth, the need for nutrients etc. The land characteristics that are directly related to these requirements are called land qualities. Establishing the values of these land qualities is an important and often difficult task for the surveyor. Aerial photography can be of great help for a number of qualities. In forestry the ecological land qualities are often combined as the result of a site evaluation and expressed as expected growth or growth class, which can be seen as a kind of ecological super quality.

The land utilization types with their land requirements indicate which kind of land qualities have to be studied. The detail of description of land utilization types also determines at what level of detail the land qualities need to be graded.

Land units that have the same level of relevant land qualities in common can be grouped into land evaluation units (planning units), which are the basic units for the land evaluation study. The rationale of land evaluation units is that they meet the land requirements of a specific land utilization type to the same extent. Logically, land requirements and land qualities need to be defined in the same terminology and dimension.

The requirements of the Land Utilization Types can be fully met by the land qualities, (e.g. possibilities for logging are optimal) or only partly met. Criteria to define classes for each requirement indicating in how far they are acceptable have to be established.

The number of classes defined depends on the detail of the study. For example, the following classes could be defined for a specific requirement:

Requirement classes	Grades of the relevant land qualities
1) near optimal	grades 1 and 2
2) fairly	grade 3
3) acceptable	grade 4
4) problematical	grade 5
5) unacceptable	grade 6

The grades 1,2 etc. may e.g. indicate the ease of logging. These criteria for the classes depend indirectly on the objectives defined (e.g. on acceptable input for logging, acceptable volume of wood production per ha, expected number of people using the woods for recreation per ha etc.).

From the first phase it becomes clear how far the different requirements of the land utilization types are met by the land qualities or, in other words, which limitations of the land prevent the defined land utilization type from achieving its optimal result. In the second phase attempts can be made to remove or reduce these limitations.

The second phase comprises the matching of land utilization types and land evaluation units, or more precisely of land requirements and land qualities. This might be possible by adapting the land utilization type. For instance, it may be intended to use a certain tree species for the land use objective 'production of firewood', because this tree species was originally thought to be the best adapted to the climate of the study area. However, further investigations reveal that certain values of the land qualities related to the soil are not optimal for that tree species. A wider search for tree species that could be used for firewood production leads to the conclusion that another species is better adapted to the site and that the land utilization type can be modified by replacing the originally chosen tree species by the latter.

Another example is that another type of machinery or another method of logging than that originally proposed is more suitable for the land evaluation unit. On the other hand, modification might be possible by improving the land qualities, e.g. by minor drainage works or by fertilization, etc. The extent to which matching is possible depends both on the kind of forest enterprise (the kind of input available) and on the land (whether it is difficult or indeed possible to remove the limitations wholly or partly). A special aspect of improving land qualities is the improvement induced by the forest growth itself, as is e.g. the case with the forest growth on the old heathland in the Netherlands. The growth possibilities for different tree species may improve over time, and other species may be introduced as a second or third generation. The reverse may also be true. Plantation forest might, under certain conditions, degrade certain land qualities. This aspect has to be borne in mind when preparing a land evaluation that has to be the basis of long-term land use planning.

For simplicity's sake we have not considered here the possibility of drastically changing the land unit by expensive major improvements that have a long lasting effect, such as terracing, draining peat soils, etc. This will be discussed in paper 2.3.1. "Physical land suitability classification". But one has to consider the influence of the land conditions on the difficulties encountered when establishing or regenerating a forest. Many land qualities, such as accessibility, topography, depth of soil to rock, present vegetation, play an important role here. If a tropical rainforest was to be transformed into a plantation forest in an area where labour is scarce and expensive, the vegetation itself might even be an unacceptable constraint for this transformation. Non-recurrent costs related to the land conditions are always an important aspect to consider.

In the Third phase, the classes or "suitability criteria" for the different land use requirements are compared with the different grades of the land qualities. They form the basis for a) yield estimations, b) estimations of the main factors determining both the establishment costs and the operational costs (including labour and machinery, c) estimations of cost of land improvements and the ecological effects on the land in the study area as well as on the wider environment.

With this information one can classify the suitability of each land unit for each land utilization type. The result will be the land suitability classification. On the basis of these results it can be decided which combination of land utilization types and land evaluation units are worth further investigation in the final stage. The data obtained during the land evaluation, such as yield expectations, cost factors related to the establishment of the forestry enterprise and those of the management costs are needed again for the final stage.

The final stage

In a physical land evaluation study, inputs, outputs and criteria are expressed in physical terms, although as quantitatively as possible. If the aim is also to produce an economic evaluation of feasible land use, the physical evaluation stage has to be followed up (in a two-stage procedure) or to be accompanied (in a parallel procedure) by a socio-economic analysis, in which outputs and inputs are commensurated as much as possible in monetary terms; in addition, the extent to which the objectives defined in the preliminary stage can be met should be checked.

It should be realized that the final socio-economic analysis should use the forest enterprise as its economic base and that the costs of establishing this forest enterprise and the influences of the socio-economic and ecological environment outside the enterprise should be taken into account. This land evaluation study is therefore called an integral land evaluation study.

It is understood that the emphasis of this workshop is on physical land evaluation and the final stage will therefore not be elaborated further here. However, some remarks can yet be made on this distinction between physical and integral land evaluation.

Although the physical land evaluation described above is mainly a process of finding the most suitable lands in physical terms for the defined land utilization types, important socio-economic background information is also used to define these land utilization types. During the main stage of the physical land evaluation, factors influencing costs and benefits are emphasized.

It is clear that in the final stage where the feasibility is determined socio-economic analysis plays an important role. On the other hand it should be realized that in this rapidly changing world, in which changes are often unforeseeable, a socio-economic analysis can usually only be made for short-term periods. In forestry planning for long-term intervals, the physical information therefore has an important role to play, and in certain cases it may even be decisive.

REFERENCES

Beek, K.J., 1978. Land evaluation for agricultural development. ILRI publication no. 23, Wageningen.

FAO, 1976. A framework for land evaluation. Soils Bulletin no. 32, FAO, Rome. ILRI publication no. 22, Wageningen.

LAND UTILIZATION TYPES FOR FORESTRY

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Summary

This paper will deal exclusively with the concept of land utilization types. The concept is part of the FAO Framework for Land Evaluation (1976) and it is proposed to adopt this concept for forestry purposes too. A land utilization type describes a specific type of land use, specifying the produce as well as other key attributes such as capital input, labour input, levels of technology and management, scale of operations needed to pursue such land use. In this paper the procedure that leads to a detailed description of land utilization types will be outlined. The concept and procedure are illustrated by examples of situations as they may exist in Southeast Asia and Northwestern Europe.

Outline of the paper

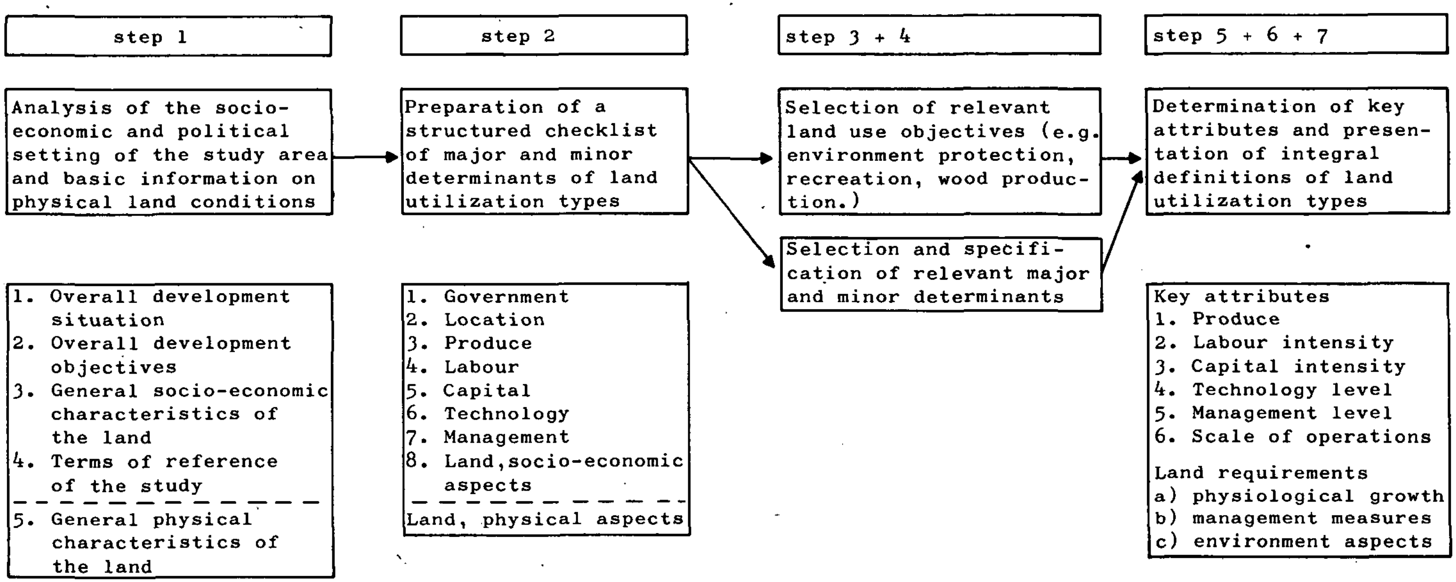
The aim of this paper is to discuss what applications the concept of land utilization types can have in forestry and to show how they can be formulated. This will be summarized below and in the corresponding diagram (Fig. 1), while in following paragraphs the different steps will be elaborated.

0. First, further thought will be given to the concept of land utilization types.
1. A specific land evaluation project will always confine itself to a specific area, region or country. In order to establish relevant land use objectives and land utilization types, information on the socio-economic, political and physical setting of that area has to be analysed.
2. The above can be facilitated by making a checklist, the so-called checklist of major and minor determinants of land utilization types (Appendix 1.), in order to obtain a clear picture of all factors, limitations, etc. affecting land use objectives and land utilization types.
3. Relevant land use objectives can be identified from the socio-economic, political and physical conditions that have been examined (see Table 1).
4. Simultaneously, the determinants mentioned in the general checklist that are really relevant for the selected land use objectives can be identified (see Table 2).
5. The information available on the determinants selected this way will provide the basis for defining the key attributes of specific land utilization types. The key attributes define the means by which land use objectives can be reached (see Table 3).
6. The result will be the description of land utilization types relevant to the land evaluation project and the study area (see Appendices 2 and 3).
7. Each land utilization type will have specific land requirements, which need to be defined in order to match land utilization types with land evaluation units and finally to assess land suitability for such a land utilization type (see Appendix 3).

The concept of land utilization types

In every forest a certain number of different functions, all inhe-

Figure 1. The process of synthesizing relevant land utilization types (adapted from Beek, 1978)



rent to that forest, can be recognized (growth of wood and other products, establishment of a micro-climate, soil protection, etc.). Society's needs for forests, wood and other forest products result in land use objectives being formulated. These objectives can be met, wholly or partially, by one or more of the above functions. In order to ensure that desired objectives are indeed fulfilled, the functions that are expected to meet these objectives can be enhanced by taking management measures.
However, the fulfilment of land use objectives and the execution of management measures may be restricted by socio-economic and political determinants of a study area as well as by the physical characteristics of the land. The land use objectives must be matched with these socio-economic determinants and the physical characteristics to achieve the description of specific types of land use that are considered to be able to meet the desired land use objectives. The description of such specific types of land use will specify outputs (produce) and inputs as regards labour, capital etc. In the FAO Framework these specific types of land use are termed 'land utilization types' and in this paper we propose to adopt this term for forestry purposes too. The term 'land utilization type' can be abbreviated to LUT.

Although general information on the physical characteristics of the study area is also needed to define land use objectives and LUTs (for instance, it would be senseless to contemplate teak production in temperate climates) this paper will be concerned with the definition of land utilization types as far as they are determined by the socio-economic characteristics of a study area. How more detailed information on physical characteristics will determine the selection of relevant land utilization types, will be one of the subjects of paper 2.3.1 "Physical land suitability classification".
A land utilization type is defined more precisely as: "A specific way of using the land, actual or alternative, described for the purpose of land evaluation in the following terms of key attributes: 1) produce, 2) labour, 3) capital, 4) technology, 5) management, 6) scale of operations. It is a technical organizational unit in a

specific socio-economic and institutional setting (Beek, 1978).

In the past, when the suitability of land was assessed for a specific use (e.g. Pinus caribaea for timber production), usually only the ecological relationships between site and woodgrowth or the terrain factors limiting the use of equipment were emphasized. There are, however, also other factors (such as cost of production, labour input, etc.) that determine the suitability. The purpose of defining land utilization types is to take into account all these other factors that also determine the requirements of LUTs in order to be better equiped to assess and compare the suitability of specific land units for different types of land use.

General analysis of a study area

It has been stated above that LUTs can only be identified within the context of a specific setting (e.g. a watershed, a region, a country) defined by its major political, socio-economic and physical conditions. These conditions will provide the scope within which the land evaluation study has to be carried out. Of special interest in this respect will be the following:

- the overall development situation in the area (present land use, industrialization, import-export ratio, level and distribution of income, trends, etc.)
- overall development objectives and policies (employment, production of goods, self-sufficiency, import substitution etc.)
- general socio-economic attributes of the land (land use patterns, land ownership and infrastructure, etc.)
- general physical attributes of the land

  The latter include general information on climate, relief, hydrology, soils, vegetation. Forest has strong interactions with other attributes of land and one should therefore bear in mind that the vegetation is considered to be part of the land. It is the vegetation or the forest (in which this workshop is interested) that performs a whole range of natural functions including protection of the environment and wood production. Some or all of these functions will be given more emphasis, as far as related to the defined objectives.

- terms of reference of the study (focus and purpose of the land evaluation study; time period during which the land evaluation results should be relevant).

Information on the above points is necessary so that the relevant land use objectives and LUTs can be selected. To collect the required data more systematically it may be helpful to organize these points in structured checklists.

The gathering of this information may be considered to be part of the preliminary stage of a land evaluation study, as was explained in the preceding paper 2.1.1. "Principles , basic concepts and procedure in land evaluation, considered from a forestry angle"

Major and minor determinants of land utilization types

What are the factors, limitations, conditions as regards the government structures, capital and labour availability, infrastructure, social and cultural traditions, etc. etc., that may affect the selection of LUTs?. These kind of data which determine the land use in the study area are called major and minor determinants.

To be in a position to make a genuine assessment of all these determinants it is recommended to set up checklists covering most of them in such detail as is needed for the purpose and scale of the land evaluation study.

Such checklists can be structured under the following headings:

1. Government (including government structures, development objectives, politics, targets, etc.).
2. Location (including distances, infrastructure, transport facilities, etc.).
3. Produce (including products, yields, quality, prices, demand, etc.).
4. Labour (including availability, wage level, labour/land ratios, productivity, etc.).

5. Capital (including availability, credit institutions, needs for investment, etc.).
6. Technology (including degree of application and availability of advanced techniques, scale of operations, etc.).
7. Management (including availability of trained staff at different levels of education, experience, know-how, etc.).
8. Socio-economic aspects of land (including man/land ratios, land use patterns, land ownership, size of forest lots, etc.).

In Appendix 1 these eight main groups of determinants are elaborated in further detail with emphasis on forestry. They should not be considered to make up the ultimate checklist; it is one among many possible other examples. Anyone beginning a land evaluation project can set up his own checklist according to the specific project (area). In the example in Appendix 1 the checklist is oriented towards forestry.

Identification of relevant land use objectives

Within the scope of the socio-economic, political and physical context of the study area and the overall development objectives set by the government it will be possible to identify the relevant land use objectives more specifically. In forestry these land use objectives can be indicated in terms of e.g. production of timber, fuelwood, recreation, nature conservation, soil and water conservation. This can be done, of course in varying degrees of detail. In Table 1 some examples are listed in a rather general way. (If the objective mentioned in column 1 is the sole or dominant one the resulting "forest use" can be given a name. These names are shown in the third column, while at the same time these names give additional information on the land use objective). It is obvious that when a forest has to fulfil more than one objective this will result in a combination of such major kinds of forest use and ultimately in a combination of LUTs. The list is far from exhaustive and can certainly be adjusted for any specific situation.

The selection of land use objectives will depend on the overall development objectives and on other determinants of the socio-economic context of the study area. The structured checklist of major and minor determinants will help to provide the criteria needed for this selection.

Selection and specification of relevant major and minor determinants

Not all of the major and minor determinants stated in the checklist will be relevant for the selection of specific land use objectives and LUTs. The selection of relevant determinants depends on the land use objectives, while the selection of specific land use objectives depends on the information provided by these determinants. Therefore the selection of relevant determinants will be done at the same time as the land use objectives are identified and selected.
Table 2 identifies which determinants can be considered to be relevant for several specific land uses (nos 6, 7, 8, 10 and 11 of Table 1). The determinants stated in Table 2, correspond with the major determinants in Appendix 1. The numbers in Table 2 (7a, 7b, 7c, 8, 6, 10 and 11) also correspond with the example descriptions of LUTs (presented in Appendix 2). When land use objectives can be more refined or translated into LUTs, the selection of determinants can become more specific; this is illustrated by the differences between 7a, 7b and 7c. At the same time, the relevant determinants have to be made more specific, in order to provide the information needed to define the LUTs and their key attributes. This should be done in as much detail and as quantitatively as possible given the available data and the level of generalization that the land evaluation study requires.

Defining the key attributes of land utilization types

The relevant major and minor determinants will provide the information needed to define HOW the land use objectives in forestry under consideration can be fulfilled. What different levels of labour and

Table 1. Examples of land use objectives in forestry and major kinds of forest use

Specific land use, objectives in forestry	no.	Major kind of forest use	natural vs man-made conditions *	other specifications
Storage of genes and/or development of knowledge	1	Nature conservation forest	N	no other use
Environment protection	2	Watershed protection forest	i	to limit undesirable effects on air, water and soil inside and outside forest area
	3	'Stop the desertification' forest	i	as 2
	4	Sand dune fixation forest	M	as 2
Foraging	5	Foraging forest	N	for foraging for wood and minor forest products for use or barter by local people without shifting cultivation
Recreation and tourism	6	Recreation forest	i	other uses limited
Wood production	7	(Semi-) natural forest for timber	N + sN	for concession exploitation by commercial firms with natural regeneration or with enrichment with either indigenous or exotic species
	8	Conversion forest	tN	as reserve prior to conversion into either man-made forest or non-forest use
	9	Production forest for fuelwood	M + tM	on a permanent or temporary basis
	10	Production forest for industrial wood (pulp, fibre, chips, etc.).	M + tM	on a permanent or temporary basis
	11	Production forest for timber	M	Plantations in long cycle rotations
Production of other forest products	12	Production forest for resin, game harvesting, etc.	N or M	on a commercial basis
Agro-forestry production	13	Shifting cultivation forest	N	mostly combined with foraging
	14	Agro forest for wood and food crops	M	forestry and agriculture combined on a permanent basis
	15	Agro forest for wood and fodder crops	M	as 14
	16	Range forest	i	forestry and grazing combined on a permanent basis

* N = permanent natural conditions; sN = semi-natural conditions
tN = transitory natural conditions; M = man-made conditions;
tM = temporary man-made conditions; i = indifferent

capital inputs, of management and technology are possible; what are the limitations regarding location and socio-economic structure? The listing and successive selection of major and minor determinants only serve to structure the information needed to answer the above questions. The response to these questions will result in the definition of the key attributes i.e. the technical, cost and other specifications of a specific LUT.

These key attributes can be described in terms of Produce, Capital, Labour, Technology, Management and Scale of operations. They define more precisely under what conditions the objective is supposed to be fulfilled: how much capital is needed, how much labour will be used, what are the precise specifications about produce, what are the requirements as regards sophisticated management, etc. The detail in which key attributes are described depends on the objectives and scale of the land evaluation study, as well as on the detail of information given by the determinants. For instance, at general levels of planning, key attributes can be described in qualitative terms (high, medium, low),while at the planning level of enterprises, key attributes can be considered as operational specifications.
Let us illustrate this using the key attribute "Produce". With the information available on the determinant "Produce" and on other determinants (which produce objectives, e.g. timber production, soil conservation, recreation space, have to be taken into consideration, which produce is naturally possible, what are yield targets, what quality and kinds of seeds and plants are available, what demand for produce exists, what are the market restrictions) it will be possible to define the key attribute "Produce" for a specific LUT. In other words, we can define the specific produce of a specific type of land use (how this LUT will satisfy produce objectives, which products and yields are expected from this LUT, what quality and kind of seeds and plants are needed for this LUT, under what forest conditions this LUT has to perform, how this LUT has to satisfy market demand).
In Table 3 examples of the key attribute "Produce" are presented, as they could be valid for LUTs described in another section of this paper. The numbers of the LUTs correspond with those in Tables 1 and

Table 2. Relevant determinants for specific land use objectives and LUTs

Determinants		LUTs in S.E.ASIA 7a	7b	7c	8	LUTs in N.W.EUROPE 6	10	11
1. Government:	development situation		x		x	x	x	x
	development prospects	x	x	x	x	x	x	x
	labour		x				x	
	production		x	x		x	x	x
	policies	x	x			x	x	x
	status of services		x			x		x
	status of organization		x		x	x		
2. Location:	critical distances	x	x					
	urban influence		x					
	status of infrastructure	x	x	x	x		x	
	transportation means	x	x	x	x	x	x	x
	prices inputs	x	x	x	x			
	locational costs	x	x	x				
	environment factors	x	x	x		x		x
	interdependencies		x			x		x
3. Produce:	removable	x	x	x	x	x	x	x
	non-removable		x		x	x		x
	yields	x	x	x	x	x	x	x
	age and condition of forest	x	x	x	x	x	x	x
	seeds and plants					x	x	x
	scale of operation	x	x	x	x	x	x	x
	destination of produce	x	x	x	x	x	x	x
	marginal distances to markets				x		x	
	specific demand		x	x				
4. Labour:	availability	x	x	x	x	x	x	x
	kind	x	x	x				
	skill and education		x			x	x	x
	income		x			x	x	x
	conditions		x	x		x	x	x
	productivity	x	x	x	x	x	x	x
	other production factors						x	
	trends and prospects		x			x	x	x
5. Capital:	availability		x	x			x	
	present investment		x			x	x	x
	price of capital		x	x			x	x
	prices and policy	x	x	x	x	x	x	x
	capital inputs	x	x	x	x	x	x	x
	investment financing		x	x			x	
	investment incentives		x				x	
6. Technology:	kind	x	x	x	x	x	x	x
	specification implements		x			x	x	x
	supply		x			x	x	x
	scale		x			x	x	x
	hazard prediction					x	x	x
	marketing flexibility		x	x			x	
7. Management:	surveys	x	x			x		x
	planning	x	x	x	x	x	x	x
	operational experience		x			x	x	x
	commercial experience	x	x	x	x			
	social values					x		x
8. Land (socio-economic):	availability				x	x		
	ownership	x	x	x	x	x	x	x
	use				x	x	x	
	physical infrastructure		x		x	x	x	x
	status of institutions	x	x	x	x	x	x	x
	trends		x			x	x	x

2 and in Appendix 1, 2 and 3.

Examples of land utilization types

The key attributes thus defined will, when combined, give a detailed description and definition of each specific LUT. In Appendix 2, seven examples of semi-detailed descriptions of LUTs in forestry are presented. Four of them are based on the situation that may exist in the Dipterocarp regions of moderately populated areas in South-east Asia (nos. 7a, 7b, 7c and 8) and on situations that may exist in the densely populated and industrialized areas of North-western Europe (nos. 6, 10 and 11). (The numbers correspond with those in Table 1). As will be noticed, three LUTs, nos. 7a, 7b and 7c, are all examples of the major kind of forest use: (semi-) natural forest for timber. However, they differ considerably in their key attributes and therefore are considered to be different LUTs.

The difference between 7a and 7b is one of scale of operations; the difference between 7a and 7b on the one hand and 7c on the other is one of location (dry land vs swamp).

In Appendix 3 one of the examples given here, i.e. LUT no. 10: "Production forest for short-fibre industrial wood of black poplar plantations in Western Europe" is described in greater detail.

As may be clear from the examples in Appendix 2, in many cases more than one specific land use objective is combined in the same LUT. Such LUTs can be called multipurpose LUTs. In forestry, multipurpose LUTs are more likely to occur than simple LUTs; in Dutch Forestry, for instance, it has even become a policy to give high priorities to forests with multiple use objectives.

One should bear in mind that, as has already been stated in the second section of this paper, in reality a forest serves by its nature a whole range of functions. Some of these functions will be emphasized and given priority, depending on which specific land use objectives are considered to be important. However, in spite of the emphasis given to one function (e.g. wood production) because of a land use objective (production of fuelwood), obviously, other func-

tions (e.g. soil protection) will be realized concomitantly. It should be stressed that in this approach to land evaluation, 'multiple-use objectives' and 'multipurpose LUTs' only refer to the combination of specifically defined land use objectives (e.g. a situation where production of fuelwood and soil conservation are specific land use objectives that can only be combined in the same forest and on the same land unit and where only those functions are enhanced which help to realize these two objectives).
The standard concept of a LUT only takes one specific land use objective into account. LUT no. 10 is such an example. This is more often the case in agriculture than in forestry, facilitating the process of land suitability assessment.

The land requirements of land utilization types

The description of LUTs provides information on the objectives and key attributes: for what reasons and under which technical and socio-economic specifications a LUT is supposed to operate.
However, in order to assess on which unit of land the LUT will perform best, we have to know what requirements the LUT will ask of a unit of land.
For instance, for an optimal performance a certain LUT will require a certain level of fertility, moisture, soil depth, size of the land unit, roughness of the terrain, while also restrictions vis à vis conservation aspects have to be considered. These land requirements are usually grouped as follows:

- land requirements with regard to the physiological growth the LUT is supposed to achieve
- land requirements with regard to the management measures needed for the optimal performance of the LUT
- land requirements with regard to conservation aspects in order to meet the objectives set by the LUT.

Appendix 3 gives, as an example, the land requirements pertinent for LUT no. 10 (Production forest for short-fibre industrial wood from black poplar plantations in Western Europe).

Tabel 3. Examples of the key attribute "Produce".

	LUT 6	LUT 10	LUT 11	LUT 7a	LUT 7b	LUT 7c	LUT 8
Removable produce	5-8m3/ha of forest land of quality timber. Less than 0.5 m3/ha fire wood, per year	20 m3/ha of 1-2 m pulpwood logs/ per year	5-8 m3/ha of quality timber. Less than 0.5m3/ha fire wood per year	40-70 m3/ha log volume of quality timbers ← 10-20% of veneer quality and 80-90% of saw timber quality → game and fish rattan, bamboo, resin	40-80 m3/ha log volume of quality timbers game and fish rattan, bamboo, resin	30-60 m3/ha log volume of quality timbers fish and prawns thatching leaves	20-40 m3/ha log volume of quality timbers 5-10% veneer and 90-95% saw quality > 50 m3/ha in poles and chipwood rattan, bamboo, leaves
Non-removable produce	30% open space for recreation and playground. About 30% water for sailing, rowing and fishing. Scenery	---	Good scenery and healthy environment. Possibilities for extensive recreation	← soil and water conservation →			groundwater regulation
Yields	Mixed forests, mostly hardwoods. In pioneer phase 20 m3/ha/year low quality hardwood timber. No prospects for increase	Pure poplar forests By using better genes production can be increased to ± 25m3/year/ha	Mixed hardwood forests. No potential increase	← mixture of presently commercial and unused species: commercial growth of 2-2,5 m3/ha/yr bole volume, potential increase to 3.5-4 m3/ha/yr →		ditto mixed swamp species, growth 2.5-3 m3/ha/yr. pt. increase to 5 m3/ha/yr	awaiting conversion, growth as 7a, 7b. No increase
Age and overal condition	No risky production. Mainly artificial regeneration. No forest or soil degradation	Since use of clonal material certain risks of diseases or pests. With good soil treatment no degradation	No risky production. Artificial and natural regeneration. Healthy conditions in the site	← highly mixed and uneven-aged heavy and light woods → ← selective tree fellings over minimum diameter limits → risk of reduction of commercially more valuable species in second and future cycles stands; vigorous regeneration of many tree species requiring release treatment of crop trees ← risk of invasion of weed, trees, vines and climbers along logging roads →			salvage fellings risk of soil erosion, loss of topsoil structure and fertility before and after clearing for other use
Scale of operations	Small scale from 0.25 ha; clear felling systems mainly. If possible, selective felling. After a certain time (tree height ± 15m) choice of crop trees and concentration of stand treatment in these trees. Extensive exploitation	Large scale (5-10 ha) operation unit Clear felling. In the area logs are cut into pieces 1 or 2 m long. Intensive exploitation	Small to large scale, depending on species. Clear felling as well as selective felling. Choice of crop trees and concentration of stand treatment in these trees. Extensive exploitation	50-500 ha/year, usually 200 ha/year ← extensive exploitation and silviculture, silvicultural treatments limited to directional felling to minimize damage to crop trees and release treatment of those trees →	500-4000 ha/year usually 1000 ha/year	250-1000 ha/year usually 400 ha/year	50-250 ha/year usually 100 ha/year no treatments exploitation extensive to moderately, intensive in parts

Availability of seeds and plants	Certified seeds and plants to be used. Growing planting material in commercial nurseries under contract	Certified plants of standard quality from commercial nurseries	As with LUT 6 ←	exclusively natural regeneration of local species →----			
Destination of produce	National and local market as standing timber	National market as logs or direct to paper mill	National market or for export mostly as standing timber	local market and export of part of the logs	own mill and subsequent export of (semi)-finished products	own mill and export of part of the logs and mill products	local market, export of part of the logs and local chipmill
Marginal distances	No limitations	Not more than 150 km to pulpwood processing plant	No limitations ←		logs by road; 400 km → saw timber by road: 600 km	logs and mill products by waterways: no limit	logs by road: 400 km industrial wood: 40 km by road. Chips to export harbour: 100 km by road
Demand for specific produce	No knots, regular annual rings, straight stems, price determined mainly by national market	diameter within 28 and 8 cm, 1-2 m length, knots permitted, is delivered to market with bark	as with LUT 6 ←	logs: bole surface free of bumps > 15 cm in height or radius, hollow, brittle or spongy heart, not to exceed 1/4 of log diameter →			

Needless to say, these requirements will not be satisfied by every unit of land.

The process of matching of land requirements with the properties of the land (see paper 2.1.1) and the classification of suitabilities of land for LUTs are in fact the main tasks of the land evaluation project. These subjects will be elaborated in paper 2.3.1 "Physical land suitability classification".

References

Beek, K.J., 1978. Land evaluation for agricultural development. ILRI publication no. 23, Wageningen.

Beek, K.J., and H.A. Luning, 1980. De rol van het landgebruik in de landevaluatie (The role of land use in land evaluation). Landbouwkundig Tijdschrift 92 (2): 43-48.

Bennema, J., 1980. Wat is landevaluatie (What is land evaluation). Landbouwkundig Tijdschrift 92 (2): 35-41.

FAO, 1976. A framework for land evaluation. Soils Bulletin FAO, Rome, no. 32. ILRI publication no. 22, Wageningen.

Appendix 1. Checklist of major and minor determinants of land utilization types (an example oriented to forestry)

1. Government

* Existing development situation: GNP, income/head for different groups of society; general level of education, health, housing, etc.; political system, structure, power relations; present land use.
* Existing development prospects, plans and targets, such as projections for scales of operation, land reclamation, re-afforestation and consolidation, forest inventories and classification (nature reserve, protection forest, other).
* Labour absorption and labour income targets.
* Production targets in relation to export, consumption and import substitution of specific produce such as wood, energy, scenery, watersupply, outdoor recreation and tourism, nature conservation, food and fodder crops.
* Policies, as regards energy, environmental control (e.g. soil conservation, flood control, water and air qualities, buffer zones) and legislation (e.g. felling prohibitions, use of state-owned lands, reafforestation requirements of exploitation concessions, sustained yield); financial policies as regards subsidies, taxation, foreign exchange.
* Status of government services: research, education, extension, management, credit, supply of inputs, output processing, transport, storage, marketing.
* Status of government organization: structure, hierarchy and relationship between ministeries, departments, executive bodies, planning commissions.

NOTE: When reporting on major and minor determinants, a sharp distinction should be made between the present situation and the options for development. Determinants should be assessed as quantitatively as possible and be reasonable, given the scale and terms of reference of the project.

2. Location

* Critical Distances: residence to campsite, campsite to food-market/health service, campsite to working place in the forest, campsite to wood-market/processing point and mill to sales/export point, servicing/repair centre to forest.
* Urban influence: availability of labour, turnover of personnel to urban workshops, distances.
* Status of infrastructure: types of roads, road density, surfacing, maintenance; hazards such as susceptibility to obstructions e.g. snow, flooding and landslides; raftability of rivers in different seasons; number of ferry-crossings; regulations regarding weight of vehicles, speed limits, tolls; capacity of harbours and airports.
* Means and cost of transportation: external (road, rail, river or combinations), internal (dragroads, railways, skidding, cable-yarding); by own, hired or contracted equipment; transport losses due to decay, long transporting time, poaching; cost of transportation (external and internal); cost of intermediate handling, storage.
* Availability and local prices of inputs: cost of new and second-hand equipment; distance to second-hand markets, to fuel-depots; available water-supply (paper); variations in prices compared with other areas.
* Other locational costs: land premiums, land taxes, boundary maintenance.
* Environmental factors: topographical features (steepness and irregularity of relief, roughness of terrain); advantages compared to other areas (healthy mountain areas versus hot tropical coastal swamps).
* Natural interdependencies with other areas (subsurface water storage, water supply, drainage, erosion and flooding impact on down-stream areas; effect of deforestation upstream.

3. Forest produce

* Removable produce: timber, industrial wood, firewood, charcoal, leaves and branches, bark, fruits, resin, game, fish, honey, rattan, bamboo, medical plants, wood-carving products.
* Non-removable produce: healthy environment, soil protection, space for recreation, knowledge about natural ecosystems, gene storage, grazing possibilities, land for shifting cultivation, water supply, scenery.
* Observed and potential yields: from mixed or pure forest, from hard woods or conifers; potential yield increases, trends.
* Age and overall condition of forest in relation to specific produce: defects; possibility for natural or artificial regeneration or coppicing; phytosanitary conditions (required treatment for improvement); environmental conditions (degree of forest degradation); degree of tree stocking; quality of specific produce.
* Scale of operations required in relation to specific produce: felling systems, quality of produce, exploitation intensity.
* Availability of seeds and plants: quality and source of seeds; commercial, certified or selected seeds; existence and quality of commercial, government or other tree nurseries.
* Destination of produce: own saw mill, local or national market, export; raw, semi-final or final product.
* Marginal distances of specific produce to input and output market: dependent on form, size, quality and on prices of semi- and final products.
* Demand for specific produce: on local or national market; quality and quantity required; export prospects; shipping, government export regulations; competition with other countries; income and price elasticities; prices and price structure of outputs, trends.

4. Labour

* Availability: total; labour density: man/land and man/capital ratios per operational unit, e.g. family, farm, cooperative, forest enterprise, communal forest land; differences per region; competition with other sectors; seasonal distribution; mobility of labour.
* Kind: male, female, child, cultural and social restrictions; full-time or part-time; local or migrant; on/off-farm.
* Education and specialization: skills; available and required levels; existence of various levels of education facilities; motivation and work attitudes in government and other institutions.
* Limits to scale of operation due to labour availability and distribution in relation to various forestry activities such as afforestation, road maintenance, harvest and other operations.
* Labour income: in forestry but also in other sectors; per unit of land, time or capital; labour income from forestry activities as a percentage of income derived from other activities.
* Labour conditions: existence of government or other, cultural, regulations; strength and behaviour of labour organizations; preference of labour for specific kinds of work; status of labour in forestry activities; value of leisure as compared to labour.
* Labour productivity per time unit, per unit of land, per unit of invested capital.
* Relationships with other production factors: capital invested per labour unit; available and occupied land per labour unit; effective animal and/or mechanical labour inputs.
* Trends and prospects relating to above-mentioned aspects.

5. Capital

* Available and invested capital per operational unit and per ha.
* Present capital investments in roads, bridges, buildings, in plant and equipment and in drainage/water-regulation; value of these investments.
* Price of capital for investment and financing: interest rates, inflation, alternative investment opportunities; amortization, annuities, taxes; in forest operations, in forest protection, in processing; trends.
* Price structure and policy: free or state-controlled market, control of maximum prices, quota control, import and export regulations; difference between nominal and real exchange rates of foreign currency; shadow prices; price ratios of inputs and outputs; observed trends.
* Availability of capital inputs: non-recurrent and recurrent input; availability for maintenance and repair of machinery and equipment; quality; scarcity; prices, kind of availability (own, hired, contracted, purchased); locally available or to be imported.
* Investment financing: existence and willingness of development banks to invest; existence and status of credit institutions; credit regulations and conditions; alternative investment opportunities.
* Investment incentives: government subsidies, temporary tax exemptions, tax rebates for re-development (planting); soft loans; investment conditions.

6. Technology

* Kind of techniques applied: use of fertilizer, insecticides, herbicides; shortwood, treelength, full and total tree harvesting concepts, at different levels of mechanization; intensity of labour used in forest operations.
* Specification of available traction and implements: manual and animal power (hand tools, horses, oxen); manually operated machinery (brushcutters, power saws, insecticide sprays); tractor-operated mobile and semi-mobile machinery; stationary machinery.
* Supply of readily available and applicable techniques: choice of systems and mechanizational level; availability of implements machinery and spare parts; availability of educational facilities for forest workers and machine operators; physical properties of land; capital/labour situation; status and orientation of research and educational facilities.
* Scale of operations required for the application of specific techniques: technical components: machine manoeuvrability, character of operations (selective vs clearcutting); economical component: machine utilization costs.
* Predictive capacity of climate and other environmental hazards: Presence and sophistication of research and 'routine' institutions; quality and density of network for recording data on climate, soils, vegetation, hydrology, erosion, fire, etc.
* Predictive capacity of market fluctuations and price relationships: access to international and national information sources; sophistication of data handling; flexibility to adapt to changing situations.

7. Management

* Surveying and inventory; experience with survey-flying, aero-photograph interpretation, air-calls, ground-calls, sampling and mapping.
* Planning; necessary know-how and experience at different levels in relation to
  a) formulating goals, ways, time limits as regards: orientation of specific produce components and overall production; harvesting and regeneration methods; tracing and constructing roads; recreation facilities.
  b) determining requirements of:men, machines, buildings, logistics, short-term and long-term credit in relation to time limits and seasonal availability.
  c) degree of centralization of management decisions; communicating systems; freedom of timing of operations.
* Operational experience
  a) capacity utilization of men and machines: efficiency in use of specific inputs; feeling for the use of equipment; degree of specialization; technical experience; feeling for social contacts and stimulating people; care of personnel; bearing isolated living conditions.
  b) processes and network planning: level and organization of product processing; feeling for timing of operations related to climatic variation; feeling for the tolerance for specific operation of trees and forests; feasibility and adoption rate of new techniques; ability to absorb inefficiency.
  c) efficiencies in specific operations such as access and transport system, forest protection against insects, diseases and fire, site improvement (fertilizer use, irrigation/drainage, tree species composition).
* Commercial experience in marketing and storage; capacity utilization of capital and money affairs.
* Specific social, cultural and religious values: individual attitudes and outlook; solidarity and other group attitudes; public relations (information and interpretation).

8. Land (socio-economic aspects)

* available land per inhabitant: man/land ratio
* land/ownership and land tenure; transferability of land titles, security of land titles; land prices and trends; extent and use of community lands, extent of government land and national parks, reserves; ethnic claims on land; land tenure systems; status of unused land and amounts available
* land use: patterns, rotational cycles, shifting cultivation; existence of extensive grazing in forest areas; legislation and rights of local population as regards use of government owned (forest) land; traditional division of tasks between men and women; need for subsistence food crops
* status of physical infrastructure; form and size of land parcels, farm sizes, size of operational units; percentage share of different farm size groups
* status of institutions and legislation; cadastral and extension services, water board, irrigation authority; soil conservation law and services, forestry laws, regulations on grazing; government strength in implementation and execution of laws; credit facilities.
* trends in land prices, farm size, land occupation, land productivity, changes in land use, trends in scale of operations, land use intensity.

Appendix 2. Examples of land utilization type descriptions *

N.B. One should bear in mind that the LUTs presented below are only intended to give more concrete examples of what terms LUTs can be described in. They are not meant to be the precise representation of an existing situation. Furthermore, it should be realized that, although the land use objectives can remain the same, another LUT is defined when one or more key attributes are changed in kind or dimension, as is illustrated for those in example no. 7.

6. Recreation forest in densely populated areas in North-western Europe

A land utilization type of mainly man-made forests near concentrations of population, with as main objective the production of space and agreeable forest environment for leisure and recreation (produce). At the same time this utilization type produces wood from slow-growing hardwood species and of high quality, and wood for industrial utilization and/or fuel. Labour both skilled and not-skilled numbers per ha depending on the type of infrastructure, about 1.5 manyear per 100 ha. Level of capital investment is high, because of costs of structure and degree of mechanization. Level of management 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. Supervision by university-trained foresters requires at least an area of 5000 to 10.000 ha. Since the average area of a recreation forest will rarely be more than 500 ha, combinations have to be made. Technology for establishing and tending is simple and advanced for harvesting and transport. Scale of forest operations is small to promote diversity of the area (0.25 ha). Income from wood and recreation facilities. Costs mainly for maintenance of infrastructure and for a very small part for forest work

* The numbers correspond with those in other tables of this paper.

such as planning and thinning. Wood production on 30% of the area. Wood production in forest areas is about 5 to 8 m^3/ha/year. About 1/3 is open space and another 1/3 is water.

7a. Small-scale Timber Concession in the South-east Asian Dipterocarp forest region

A land utilization type of natural dryland forests with wood production and soil and water conservation as main objectives. Major produce is quality timber for sale as logs on open market, usually in small quantities at a time (less than 100 m^3 as individual sales). Minor produce of rattan, bamboo and stakes is of importance. Labour; semi-skilled under skilled foreman, numbering 10-30 persons. Level of capital investment is moderate: at most US $ 250,000 and substantially less if only secondhand machinery is purchased. Level of management is intermediate without regard for continuity of log production during wet periods.
Forestry Department supervision of the management of applied selective tree fellings only adequate when arranged for a number of smaller concessions combined in one work area. Technology is of intermediate level, operators mostly using secondhand machinery of older type (especially army surplus with winches fitted and adapted for log extraction). The scale of operations is indicated by a concession agreement over 400-4000 ha for a period of 3 to 12 years; the minimum annual felling area is 125 ha for a production of 5000 m^3 logvolume per year. Forest machinery consists of 2-5 vehicles. Forest access roads are of dry-weather use only. There is no river-rafting of logs.

7b. Intermediate scale Timber Concession in the South-east Asian Dipterocarp forest region

A land utilization type of natural dryland forests with wood production and soil and water conservation as main objectives.

Major produce is quality timber for own industrial processing, minimum 25,000 m^3 log volume per year. Minor produce includes rattan, kopal and game individually collected by local people. Labour in forest operations is skilled and semi-skilled, minimum 75 persons. Skilled and semi-skilled labour in processing, marketing and transport outside the forest, totalling at least 200 persons. Level of capital investment is high: at least US $ 1.25 million in forest operations and US $ 4 million in processing. Management is advanced and specialized, particularly for the building of forest infrastructure and the organization of log transport. Forestry Department supervision of the management of applied selective tree fellings requires at least one staff member attached to the concession management of at least 3 staff members in forest operations. Technology is of a high level, forest operations making use of the latest equipment, including articulated wheeled vehicles and cable/winch systems.
The scale of operations is indicated by a concession unit of a minimum of 20,000 ha in a 30-year felling cycle, a permanent forest-road building programme for at least 60 km, and a forest machinery of at least 10 vehicles. Forest machinery workshop constitutes at least a 10% cost component. There is no river-rafting of logs.

c. Swamp Exploitation Forest in South-east Asia

A land utilization type of natural peat-swamp forests with wood production and (ground) water-regulation as the main objectives. Major produce is quality timber, partly for own processing and partly for sale on open log market, minimum 10,000 m^3 log volume per year. Minor produce include thatching leaves (attap) individually collected by local people. Labour in forest operations is semi-skilled to unskilled, minimum 40 persons. Skilled and semi-skilled labour outside the forest in processing and sales, totals at least 50 persons. Level of capital investment is moderate to high: at least US $ 750,000 in forest operations and

US $ 1.5 million in processing.
Management is advanced and specialized, particularly in the operation with movable swamp-rail tracks for log extraction. Technology is of intermediate level, operations involving only diesel rail-locos and tow-boats for pontoon hauling. The scale of operations is indicated by a concession unit of a minimum of 10,000 ha in a 30-year felling cycle and a forest machinery pool of at least 2 locos, 1 tow-boat and 2 pontoons. No permanent access is constructed.

8. Conversion forest in South-east Asia

A transitory land utilization type of natural forests in the process of replacement by other land use over a period of 1-2 decades. Major produce consists of quality timber for sale on open log market and industrial wood (chipwood, stakes and scaffolding poles) for local use. Minor produce includes rattan, bamboo and leaves individually collected by local people. Labour semi-skilled under skilled foreman, numbering 10-75 persons. Level of capital investment is moderate: US $ 250-500,000 mainly in secondhand machinery.
Level of management is low to intermediate, virtually without Forestry Department supervision. Technology is of intermediate level. The scale of operations is indicated by a salvage agreement over 1000-5000 ha for a period of 4-6 years; the minimum annual felling area is 250 ha for a production of 10,000 m^3 log volume per year. Forest machinery pool consists of 4-10 vehicles. Permanent access roads constructed in the area are taken over, after due compensation, by the land development agency. There is no river-rafting of logs.

10. Pulpwood production forest with poplar in Western Europe

A land utilization type of man-made forests with a fibre wood production objective. Major produce is timber for short-fibre

pulp for papermaking. Minor produce of timber for packing. Skilled labour numbering 0.8 man/year per 100 ha. Level of capital investment is moderate to high, because of mechanized harvesting. Level of management is intermediate, because of its simplicity. Supervision by university-trained foresters requires an area of at least 10,000 ha. When suitable land units are not that large, smaller land units have to be combined.
Technology is high level, due to sophisticated harvesting machinery, road maintenance machinery and transport facilities. Scale of forest operations is on a large basis - at least 10 ha per unit - rotation 10 years, production 20 m^3/year/ha. Infrastructure of unpaved, but often sand-improved forest roads at around 200-300 m spacing.

11. Timber production forest in North-western Europe

A land utilization type of man-made forest as well as converted more or less natural forests, with wood production and water- and environment-conserving objectives. Major produce of quality timber from hardwood species (oak, ash, beech, maple, etc.). Minor produce fuelwood, game, fruit. Labour semi-skilled under skilled foreman, numbering 1 man-year per 100 ha.
Level of capital investment is moderate to low, because of long rotations while most work is done by hand, or partly mechanized. Level of management is high to moderate, because of complexity of stand treatment for quality timber. Supervision of university-trained foresters for tree selection and treatment of stands requires a maximum area of 5000 ha. Units of this land utilization type should be at least 1000 ha, so combinations have to be made.
Technology is of intermediate level. Operators use machinery for establishing stands, harvesting and road maintenance.
Scale of operations is of medium scale, units of 1 to 5 ha. Rotation is mostly long: 80-120 years. Production averages 5-8 m^3/ha/year.

Appendix 3. <u>Detailed description of the LUT no 10</u>

<u>Production forest for short-fibre industrial wood from black poplar plantations in W.Europe</u>

N.B. This more detailed description of a LUT is also only hypothetical. It should not be considered to be <u>the</u> representation of such a LUT.

<u>Objective</u>: Maximum feasible short-fibre pulpwood production at lowest possible costs.

<u>Key attributes</u>:

<u>Produce/</u>	species	: Populus euramericana
	removable	: 2 m pulpwood logs, excl. branches and bole wood. Critical diameter 7 cm.
	yields	: minimum 15 m3/Y/ha average 20 m3/Y/ha
	age/condition	: rotation 10 year, full tree stocking, no pruning, no thinning
	scale of operations	: enterprise min. 500 ha operational unit 5 ha, clear-cut
	destination	: pulp and paper mills
<u>Labour/</u>	availability	: about 0.8 man-year per 100 ha, skilled with planting, harvesting and internal transport
	kind	: full-time adult males
	education	: skilled from forestry school and elementary school
	income	: determined by C.A.O.
	conditions	: 40-hour week and vacation regulation, safety regulations
	productivity	: 0.7 man-hours for the production of 1 m3 wood

Capital/	available and invested cap.	: high
	present cap. investment	: high (in equipment)
	price of capital	: average 10%
	price structure	: free market price
	total inputs investment financing	: restricted interest, because of low earning capacity through high wages
	investment incentives	: subsidies for establishment, management and accessibility for recreation. Income-tax exemptions
Technology/	kind of techniques	: fertilization, weed control, short wood harvesting (100 x 200 cm logs), high level of mechanization
	specifications	: manual power (planting) and mechanized (harvesting and road maintenance), tractor-operated fertilization and weed control
	supply of techniques	: training facilities in special courses for forest workers
	climate and hazards	: no special measures needed
Management/	surveying	: preparation of management maps, continuous forest inventory for estimation of increment
	planning	: formulating objectives planning production processes planning infrastructure work planning supervision of decision making
	operation	: high capacity in utilization of men and

experience		equipment, technical experience, specialized in harvesting, transport and road management, capable of cooperating in technical teams.
efficiency transport system	:	much experience in developing transport organizations
efficiency protection	:	familiar with diagnozing diseases and pests, and their control
efficiency site improvement	:	familiar with fertilization, drainage and soil preparation
Scale of operations	:	minimum area for operations 5 ha; internal roads distance 200 m, main roads paved; critical distance from papermill 150 km

Land requirements of LUT no 10

"Production forest for short-fibre industrial wood from black poplar plantations in Western Europe".

Land requirements for growth.

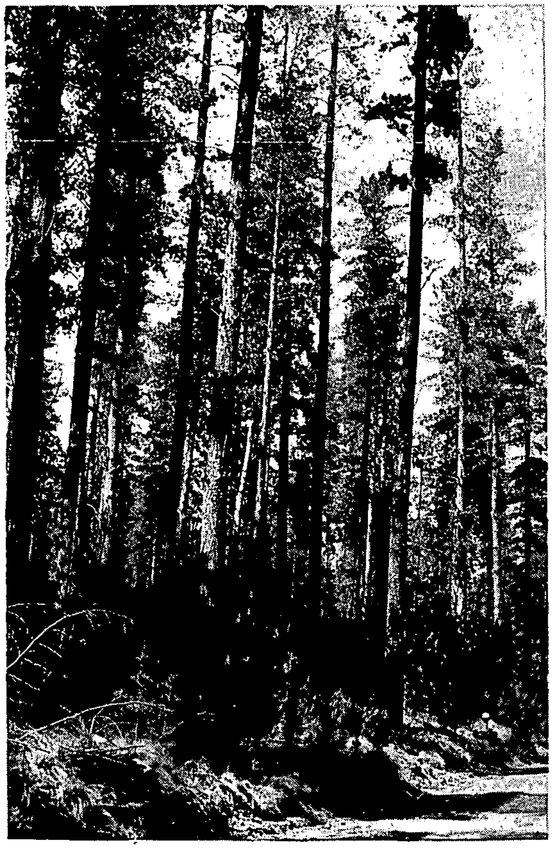
1. Mineral soils
2. organic matter $\geqslant$ 3%
3. lutum ($<$ 2 micron) $> 3\%, < 40\%$
4. available water $\geqslant$ 125 mm
5. groundwater table $\geqslant$ 100 cm
6. rooting depth $\geqslant$ 80 cm
7. total $P_2O_5 \geqslant 40$ mg/100 g of soil
8. total N $\geqslant$ 0.10%
9. N organic matter $\geqslant$ 3.00%
10. adequate K supply

Land requirements as regards forest operations
(exploitation with power saws or harvesting machines; forwarders)

1. Ground roughness: smooth-rough (average distance between obstacles $>$ 3 metres)

2. steepness $< 20\%$
3. capacity for traction/flotation: on friction and cohesion soils (excluding uphill transport on cohesion soils)
4. Opening-up of forests: possibility for constructing unpaved, but in many cases sand-improved forest roads at around 200-300 m spacing; stands with temporary strip roads 4 m wide at 20 m spacing or less; provisions for forwarder passing over ditches, drainage systems, etc.
5. land unit homogeneity: > 500 ha

No restrictions as regards conservation aspects.



Stand of Pinus radiata in Southern Australia.

3.2 Papers on "Land evaluation, a new approach"; Session 2, November 11, Tuesday

"Land qualities and their relationships with the land use requirements of land utilization types"

Chairman: W. Kilian; Rapporteur: R. van der Weg

- B. Lundgren
  Land qualities and growth in the tropics
- H. Löffler
  Land qualities and forest operations
- D.O. Nelson
  Land qualities and conservation

LAND QUALITIES AND GROWTH IN THE TROPICS

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Summary

The characteristics of the land available for forestry development in the tropics differ in many important aspects from those of temperate regions. Nutrient and water availability, i.e. the land qualities most directly related to growth, depend to a considerable extent on instable land characteristics such as organic matter, pH, porosity, etc. Since these are very sensitive to management it is not advisable to try to base land quality/growth predictions on pre-management survey data only. Equally essential is to assess the dynamic long-term interaction between growth, land qualities and management. This will require, among else, continuous monitoring of land characteristics and systematic trials to an extent that is unknown in tropical forestry today.

Introduction

Trees require water, nutrients, light, suitable temperatures, carbon dioxide, oxygen and anchorage to grow. The relative importance of these factors vary with species and geographical location. Land qualities related to growth, "ecological qualities" according to BENNEMA and van GOOR (1975), may be defined as mechanisms and processes by which these factors are made available to plants.

It is hardly feasible to try to make a comprehensive review of land qualities important to growth of all types of forests in all environments - it would only lead to generalised restatements of well-known, fundamental physiological and ecological growth relations.

The scope of the discussion below has therefore been limited to:

- tropical environments in which rainfed forest growth is possible,
- forest land use for bulk production of wood,
- climatological and pedological land qualities influencing water and nutrient availability and, thereby, growth.

Finally, emphasis is rather on highlighting some important and specific dynamic interactions between land qualities, growth and management in the tropics and how to evaluate these interactions, than to produce an exhaustive catalogue of important land qualities.

Forestry land use in the tropics

Forestry in the tropics

The demand for wood increases reapidly in tropical developing countries as a result of an increased use of firewood and other household wood by an increasing population, and also as a result of an increased demand of industrial wood. At the same time, the area of tropical forests decreases, in some countries and regions at an alarming rate. In the drier tropics it is mainly the increased wood use that causes the retreat of tree vegetation, in the moister tropics it is the clearing and burning of forests for agriculture.

Over the last century many silvicultural attempts have been made to manage natural forests on a sustained yield basis. Most of these attempts have failed economically, and today practically all systematic utilization of natural forest wood for industrial purposes in the tropics is exploitive in the sense that none or very limited efforts are made to secure a high value natural regeneration.

Instead, government forest departments, private companies, international aid organizations, and even farmers, rely increasingly on forest plantations for the long-term supply of wood. This is a rather recent development and it is only during the last two decades that manmade forests have started to play a role in the economies of some tropical countries. The expansion is rapid, however, and today some 90 tropical countries possess smaller or larger areas of plantations of tropical pines, eucalypts, valuable and/or fast-growing hardwoods and wood legumes.

Still, the total area is comparatively small - around 8 million hectares, all types of plantations included - but it has been estimated (LANLEY & CLEMENT, 1979) that by the year 2000 there will be 16 million hectares of industrial plantations alone in the tropics. If it is assumed that the rate of increase of non-industrial plantations (mainly for firewood) will be of the same order as that of industrial plantations, the total area of plantations in the tropics will be between 25 and 30 million hectares at the turn of the century.

The need for developing land evaluation methods, including methods of assessing short- and long-term land quality/growth relations, is therefore urgent. Today, plantation establishment, even on a very large scale, is rarely preceded by a systematic land evaluation.

Types of forest land

Although there are important local exceptions it is permissible to make two generalisations on the types of land presently under forest and potentially available for plantation establishment.

One is that closed forest today mainly remains on land with low potential for permanent agriculture, either due to low soil fertility, to steep slopes or to seasonal flooding. This is because human settlements and agricultural development and, consequently, the removal of forests, in the past have been largely decided by land potential.

The other is that in most developing tropical countries, food and cash crop agriculture takes precedence of forestry in practically all land development considerations. This means that large scale expansion of plantation forestry will mostly take place on land with more or less pronounced physical limitations to permanent agriculture. This is partly in contrast to the conditions where plantation forestry was first introduced, e.g. in the high potential uplands of East and Central Africa and in South Brazil. The success of these early plantations has been a major source of inspiration to governments and companies now embarking on large schemes.

The most important implication of these generalizations is that land evaluation for tropical forestry, be it for intensified utilization of natural forests or for afforestation, must concentrate on, generally speaking, low potential land.

Forestry-specific land use characteristics

It is often claimed that plantation forestry in general is a suitable form of land use on low potential tropical land because forests and woodlands normally constitute the natural and ecologically well adapted vegetation on these lands. In reality there is only one significant similarity as regards the interaction between the physical environment and vegetation/ management - a plantation which has closed its canopy creates a microclimate similar, but not identical, to that of a natural forest. In all other respects they are different and not more similar to each other than a savanna is to a wheat-field.

Compared to agricultural forms of land use intensive forestry operations for wood production are often on a larger scale (area-wise), the end products are bulkier and more heavy, the time between investment and harvest is longer, leading to larger economic risk, and the profitability per unit area is lower. These differences normally lead to three important implications with regard to land management and land evaluation:

- heavy input in soil management is apparently unattractive,
- it is not economically possible to adapt management methods to too small-scale and subtle variations in land qualities,
- use of heavy machinery is more or less necessary in land clearing and logging/extraction operations.

Thus, intensive forestry in the tropics, involving either entirely man-made plantations or regularly clearfelled and regenerated natural forests, is a form of land use clearly distinct from both natural forest cover and from agriculture.

Land characteristics in the tropics

Typical features

Land characteristics of the tropics, and thereby land potential and land quality/growth relations, differ in many important ways from those of temperate regions. For reasons of land use history and priorities intensive forestry is likely to be developed on a large scale only on land where:

- rainfall exceeds 500 mm,
- where soils do not impose serious, immediately apparent restrictions (too shallow, too saline, water-logged), and
- where soils do not have a high potential for agriculture.

The remaining areas, which cover well over 60% of the total area of the humid (>2000 mm rain), sub-humid (1000-2000 mm) and semi-arid tropics (500-1000 mm), have got many land characteristics in common, most of which seriously restrict their land potential:

- temperatures are high and uniform throughout the year resulting in high potential photosynthesis rates, in rapid decomposition or organic matter, in intensive weathering of rocks (in the presence of moisture), and in high evapotranspiration rates,
- the variation in annual rainfall is high, normally with a range of 50% - 150% around the mean over a 30-year period, often much higher,
- the variation in monthly and seasonal rainfall is extreme; droughts often occur in "wet" seasons and torrential rains in "dry" seasons;
- rain intensity (i.e. amount of rain per time unit) is very high (also in the dry tropics), consequently the erosivity of rains is very high in the tropics,
- with a few exceptions, soils in these areas have a very low inherent fertility due to long and intensive weathering and leaching, and to the low nutrient retention capacity of kaolinitic clays,
- with a few exceptions, the combination of structural instability of the topsoils and the high intensity of rains makes erosion a primary limiting factor to land development,

- the water retention capacity of many soils is low, which, in combination with high evaporation rates and uncertain rainfall make drought damage a major limiting factor, also in the humid tropics,
- fertility, structure (i.e. infiltration capacity) and water retention of topsoils are all highly dependent on the organic matter content of the soil, and, since organic matter is easily lost, they are highly sensitive to mismanagement.

Land with these characteristics coincide well with areas where shifting agriculture is the dominant form of subsistence land use. In no such regions of the tropics (except on nitosols) has it yet been possible to introduce high-yielding forms of sustained agricultural production outside well equipped and staffed research institutes. Only with very high inputs of soil and crop management has it been possible to profitably produce such plantation crops as rubber, oil palm, tea, coffee and cocoa.

Stable and instable land characteristics

As a result of the rapid biological and chemical processes, the high intensity rains, and the organic matter-dependent topsoil structure and fertility of tropical "forest land", it is much more essential in the tropics than in temperate regions to assess the dynamic interaction between management and land qualities in land evaluation. In order to systematize this assessment and the interpretation of survey data on land characteristics, it is a useful approach to distinguish between stable, or unmanageable, and instable, or manageable, land characteristics. This is exemplified in table 1. It should be emphasized that this is only a generalized subdivision - a characteristic which is listed as instable/manageable is not necessarily easy to manage, or one that is stable/unmanageable in forestry may be manageable in other forms of land use.

Land qualities and growth

General relations

For reasons of clarity one may distinguish between three groups of land qualities influencing growth:

TABLE 1. Examples of stable and instable physical and biological land characteristics

	1. Stable, unmanageable characteristics	2. Intermediate	3. Instable, manageable characteristics
Climate	Macroclimatic features, e.g. gross rainfall, temperatures, winds, evaporation	Some local climatic features, e.g. temperature, throughfall transpiration	Some microclimatic features, e.g. soil surface temperatures, wind, rainfall energy impact
Geology	All geological features		
Topography	All topographical features depending on geology	Meso- and microtopographic features depending on soil deposits	
Soils	Profile texture, mineralogy, total soil depth, hardpans at depth, internal drainage	Topsoil texture, subsoil fertility and organic matter, shallow hardpans, subsoil water holding properties, subsoil toxicities	Topsoil organic matter and nutrient levels, CEC, structure, infiltration rates, topsoil water-holding properties, porosity, topsoil toxicities, pH
Biotic features vegetation & animals			All biotic elements and ecological features related to them
Hydrology	Drainage pattern, flow characteristics of larger rivers originating outside land area	Groundwater levels and fluctuations, discharge pattern in smaller rivers originating outside land area	Water quality, quantity and seasonal flow pattern of smaller streams originating within land area

- those influencing the supply of nutrients,
- those influencing the supply of water,
- those providing a rooting medium and anchorage.

Individual land qualities can sometimes be estimated or measured directly, e.g. the amount of plant available moisture in the root zone or the rate of nitrogen uptake by the trees at any particular time. However, such measurements are often timeconsuming and complicated why land qualities are often described by means of more easily measured land characteristics, e.g. rainfall and soil porosity values or amount of nitrogen in the soil.

The influence of any particular ecological factor on growth follows a four-phase relation:

- below certain levels they totally prevent growth,
- at sub-optimal levels they limit but do not prevent growth, i.e. an increase in the level will positively affect growth and vice versa,
- at optimal levels increases or decreases will not significantly affect growth,
- at high levels the factors again limit and eventually prevent growth (e.g. by toxicity, water logging, etc).

Not only nutrients and water influence growth in this principal way but also light, temperature and CO_2, but these are of less practical importance in land evaluation since they are stable, not manageable and, in the tropics, rarely growth-limiting characteristics of the land.

The assessment and rating of land qualities in relation to growth is very close to, or even identical with, site evaluation and site classification in conventional forestry terminology. With the development of computer techniques site/growth research has advanced tremendously over the last decades. An almost unlimited amount of data on land characteristics can now be statistically analysed, and complicated multiple interaction and principal component growth relations can be established. However, these techniques, as well as systematic site evaluation in general, have mainly been developed in northern temperate regions of the world and are, consciously or unconsciously, based on the assumption that site/land characteristics are stable. This assumption is basically correct for temperate land normally used for forestry. Fertility, for example, is mainly dependent on mineralogy and the rate of release of nutrients from the mineral reserves, which are "unlimited" in the time perspective of economic forestry, and on the rate of decomposition of humus. The form of humus and its rate of decomposition depend as much on stable climate/mineralogy-factors as they do on vegetation/management-factors. Humus-dependent fertility may indeed change as a result of management (cf. the "spruce problem" in Europe) but the change is slow and, more important, it is not irreversible. Erosion is seldom a problem in temperate forestry, partly because most forest soils are not erodible, but mainly because rainfall is not erosive.

On the type of land where intensive forestry is likely to expand in the tropics, the basic assumption of stable site characteristics and site growth relations, is not valid. It is not advisable to use site-growth relations based on a "before-management-survey " uncritically for the prediction of yield in land evaluation. Important land qualities may change quickly and drastically, and sometimes irreversibly, as a result of management.

Evidence from studies and trials

Though the number of reported site/growth studies and fertilizer trials in the tropics proper is still rather small, it is rapidly growing (for comprehensive reviews see LUNDGREN, 1978 & 1980, and SCHUTZ, 1976). It is apparent that land qualities/growth relations are as complex in the tropics as they are anywhere wlse. The interaction between climatic, soil and topographic factors in making nutrients and water available to plants may be comparatively easy to analyze statistically with modern computer techniques but it is not always easy to interpret such relations ecologically and draw relevant management conclusions from them.

A statistically significant correlation between growth and a particular land characteristic may only represent part of the true land quality/growth relation. It is only valid as long as other characteristics influencing the same quality remain unchanged. A mathematical regression between rainfall and growth, for example, is only valid as long as water infiltration into the soil and soil porosity conditions are not significantly changed.

Likewise, an established correlation between a complex soil characteristic such as pH and growth may reflect the influence of many land qualities, e.g. Al-toxicity, P-availability, availability of cations, etc., and since these are limiting growth at different pH-ranges the correlation with growth is rarely linear.

Some relations which are statistically significant may be ecological nonsense. Om many soils in the drier tropics it is, for example, perfectly possible to prove a significant <u>negative</u> correlation between the level of available cations and growth. The ecological reality is of course that with decreasing rainfall growth, but also leaching of cations, decrease.

Even if generalizations are dangerous, some patterns stand out:

- growth in the humid tropics is very often correlated with instable soil characteristics affecting both nutrient and water supply, such as contents of various nutrients, pH, organic matter, CEC and porosity,
- in the subhumid tropics, land characteristics affecting the availability of water are normally well correlated with growth, e.g. rainfall, length of rainy season, depth to groundwater, drainage, water holding capacity of the soil and porosity,
- correlations between growth and stable, "compound" land characteristics, i.e. those which are affecting several land qualities, are often reported, e.g. altitude, soil texture, soil type, depth of A-horizon, rooting depth, slope and aspect.

The latter type of correlations are convenient to work with since they are often easily surveyed in the field but they are dangerous in that they normally conceal the true ecological cause and effect mechanisms.

Further evidence of growth in relation to land qualities are provided by the increasing number of fertilizer trials in tropical plantations. On latosolic soils in the subhumid and humid tropics the following relations often seem to apply:

- most plantations respond to P applications and to compound NPK and NP fertilizers,

- N applied alone is generally ineffective and sometimes even depresses growth;
- K, and sometimes Ca and Mg, often result in improved growth, particularly of Pinus spp.,
- applications of B produce very big responses on some soils,
- liming of acid forest soils is only beneficial up to the point when Al is neutralized - too high pH will cause P-fixation and nutrient imbalances.

Management, land qualities and growth

One important conclusion can be drawn from what has been said above:

land evaluation for tropical forestry is not only a matter of assessing how various land qualities affect growth, but also how different management practices affect land qualities in the short and long run.

With the "static" approach common in land evaluation today the short and long term influence on land qualities, and thereby growth conditions, are rarely or ever systematically evaluated. To the author's knowledge there is not one single case reported where this has been done in connection with tropical forestry development schemes. Still, there is a convincing body of evidence based both on field experience and research that many growth-related land qualities change negatively as a result of management practices.

The best known such evidence comes from studies on shifting agriculture. It has been shown beyond doubt that clearing of natural vegetation, burning of slash and keeping the soil unprotected under cultivation for as short time as two-three years in humid climates on kaolinitic soils result in significant nutrient losses (mainly through leaching), structural deterioration and compaction of topsoil, erosion and rapid loss of organic matter, and thereby lower water and nutrient retention capacity. The same dynamics of course apply when a tract of land is cleared, burned and planted with trees up to the time when the plantation closes its canopy.

Similarly, the very negative effects caused by use of heavy machinery in land clearing and logging operations have been demonstrated. Not only will the compaction of the topsoil cause a decrease in infiltration capacity and an increase in run off and erosion, but it may also seriously restrict the rootability of young seedlings.

The biological and physical influence on the soil of a monoculture tree crop will vary with the characteristics of the species grown, e.g. its rooting habit, litter quality, crown density and nutrient and water requirements. Some tree crops, particularly evergreen leguminous species will have a beneficial influence on soil structure and organic matter. Many other fast growing species, however, and unfortunately those most widely used (e.g. pines, eucalypts, teak), generally seem to affect the soil in a negative way when grown on short rotations (LUNDGREN, 1978). Decrease in fertility levels, due to build up of nutrients in the vigorously growing crop, and decline in soil organic matter (litter fall and breakdown in young stands are not enough to compensate for the natural rate of decomposition), are the main causes. When logs are removed in harvests a substantial amount of nutrients are lost to the site - this is a major difference to the use of tree and bush fallows in shifting cultivation with which timber tree plantations are often erroneously compared.

It can be concluded that management practices in intensive tropical forestry - complete clearing, burning, use of machinery, short rotation, monoculture crops, etc. - will affect land characteristics which in turn determine growth-related land qualities - fertility, porosity, organic matter, water and nutrient retention. In most cases these influences will be negative and there are strong scientific indications that the long term productive capacity of the site will deteriorate under many combinations of soil, climate, management regimes and species. So far, few reports have been published where such site deterioration has been observed (EVANS, 1980). This however depends on the fact that there are very few, if any, studies where site/management dynamics have been related to growth in tropical forestry.

Approaches to land quality assessment

General approach

Integrated land evaluation deals with both yield (physical and biological aspects) and cost of production (social, economic and technical aspects) in a wide sense. One may envisage a four-step approach where the steps should answer the following questions respectively:

1. What land is suitable for forestry?

2. What type of forestry (species, management) is best?

3. What will be the expected yield?

4. What risks are involved?

The answers to the first two questions will be based on combined assessments of economic potentials and restrictions on the one hand and general land suitability on the other. The land is sub-divided into units based on surveys of stable land characteristics and the limitations these impose on the economically desired form of forestry, e.g. topography, climate, accessibility, groundwater depth, flooding, soil depth, stoniness, etc.

The answer to the third question will require survey data on both stable and instable land characteristics and matching of these against known requirements of the species to be grown. This is site classification in the traditional sense and will only differ in practice from site classification in temperate forestry by the fact that land use requirements are generally less known in the tropics.

The risk assessment will involve an identification of those land qualities that are likely to change under management, quantifying the likely effect on growth of these changes, and suggesting means of minimizing negative effects. This work will be based on the same survey data as used in answering the other questions but must, in addition, involve a dynamic approach when evaluating the data in relation to management.

Important land characteristics and qualities

It has been emphasized above that growth in the tropics is often limited by the availability of nutrients and water, and that the capacity of the land to supply these depends to a large extent on instable land characteristics. In land evaluation it must therefore be a primary objective to identify those land characteristics. Fertility of a site depends, for example, on the availability of nutrient ions in the soil solution in the root zone over the rotation period. This is determined by the following three factor complexes:

1. Input of nutrients, via weathering of rock minerals, which is affected by geological origin, texture, soil moisture and soil temperature; release of nutrients in organic matter decomposition; rainfall.

2. Exchange and retention characteristics, determined by colloidal properties of clay minerals, amount and quality of humus colloids, pH of soil solution.

3. Output of nutrients, via leaching; immobilization.

Similarily, <u>water availability</u> in the root zone is determined by:

1. Input, which is the part of rainfall infiltrating to the root zone; capillary water from the ground water level.

2. Water retention properties, determined by pore size distribution; amount of organic matter; type of clay minerals.

3. Output, via deep percolation; capillary evaporation.

Although <u>erosion</u> basically is a problem of nutrient and water supply - it decreases both by removal of fertile topsoil and by reducing water infiltration - the irreversible nature of its effects always warrants a special assessment of land characteristics affecting it. These are, apart from the more obvious topographic features: rainfall intensities; degree of soil protection; infiltration capacity, determined by texture, structure and biological activity.

In practical land evaluation operations, it will rarely be feasible to quantify in detail all individual land characteristics affecting nutrient and water availability and erosion. What is important is to quantify the permanent "frame" characteristics, such as: <u>topography</u>, <u>rainfall pattern</u>, <u>soil texture</u> and <u>mineralogy</u>, <u>soil depth</u>, <u>drainage</u> and <u>groundwater conditions</u>.

Instable land characteristics should not only be quantified prior to forest establishment, they must be continuously monitored and the result of this should be correlated with growth measurements. Important land characteristics that should be monitored are <u>soil organic matter</u>; <u>pH</u>; <u>topsoil structure</u>; <u>infiltration rate</u>, and <u>porosity in the root zone</u>.

By relating these to the permanent frame characteristics of the site on the one hand and growth of the trees on the other, it will eventually be possible to establish land quality/growth relations and how these are affected by management. Simple trials may considerably speed up the results. It is, for example, quite unnecessary, as is done today, to speculate over the influence of many management practices on land characteristics and growth.

The influence of machinery on infiltration rate, porosity and rootability can be established simply by driving with a machine on different soil types and at different moisture contents of these soils (various moisture contents can easily be artificially created so there is no need to wait for rain). After this is done, porosity and infiltration are measured, seedlings are planted, and after only one year very important results can be obtained which may prevent enormous misjudgements in the choice of management methods in land clearing and logging.

Similarly, the question of long term fertility decline can be partly answered by simple analysis and trials - measure leaching of nutrients in the clearing phase with simple lysimeters, fell a few trees and analyse them for nutrient contents to establish how much is lost in harvest, collect rainfall and analyse it, sample the soil and determine reserves of nutrients, and, if possible (in the laboratory), the rate of release from mineral weathering. Within a year it would be possible to have 75-90% of the facts needed to answer the question of long term fertility maintenance of the particular site or land unit.

Finally, with the help of runoff plots, infiltrometers and rainfall simulators it is possible to establish erosion risks of any conceivable combination of land characteristics and management methods.

What is lacking in tropical forestry today is an appreciation of the dynamic aspects of the land quality/growth/management - relations. Land evaluation must be a permanent feature of any large forestry development scheme. Monitoring and reevaluations of land characteristics should be continuous, leading to improved soil management. Only by doing so will it be possible to develop sustained and high yielding forestry land use systems on the land available for forestry.

References

BENNEMA, J. & VAN GOOR C.P., 1975. Physical land evaluation for forestry. in Report on the Ad Hoc Expert Consultantion on Land Evaluation. World Soil Resources Report 45. FAO, Rome. p 103-117.

EVANS, J., 1980. Long-term productivity of tropical plantations. Paper to IUFRO Symposium on Genetic Improvement and Productivity of fastgrowing tree species in Sao Paulo, Brazil, August 25-30, 1980. 11 p.

FAO, 1976. A framework for land evaluation. FAO Soils Bulletin 32. Rome.

LANLY, J.P. & CLEMENT, J., 1979. Present and future natural forest and plantation areas in the tropics. Unasylva, No. 123, p. 12-20.

LUNDGREN, B., 1978. Soil conditions and nutrient cycling under natural and plantation forests in Tanzanian highlands. Reports in Forest Ecology and Forest Soils No. 31. Dept. of Forest Soils, Swedish Univ. of Agric. Sci. Uppsala, Uppsala. 426 p.

LUNDGREN, B., 1980. Plantation forestry in tropical countries. Physical and biological potentials and risks. International Rural Development Centre, Swedish Univ. of Agric. Sci. Uppsala. 123 p.

SCHUTZ, C.J., 1976. A review of fertilizer research of the more important conifers and eucalypts in subtropical and tropical countries. Bulletin No. 53. Dept. of Forestry, Pretoria.

LAND QUALITIES AND FOREST OPERATIONS

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Abstract

During the past three decades several concepts of describing and classifying forest land have been developed for the purpose of recording systematically the influences of the physical conditions of terrain on forest operations, especially on timber harvesting. Efforts to make these terrain classification systems comparable, at least with reference to the characteristic features, and to elaborate a common classification language have failed so far. The vocabulary used in the context of land evaluation is unknown within the scope of terrain classification.

One of the most important findings referring to terrain classification is the fact, that one has to distinguish between a primary or descriptive and a secondary or functional terrain classification. According to the type mentioned first, terrain classes or land units are formed independent of the limitations of machines and operational methods, whereas in the latter type the respective technical possibilities are taken into account. International uniformity or at least comparability can only be reached on the level of the descriptive terrain classification. This should be considered when developing a land suitability evaluation concept.

Land qualities relevant to the various forest operations are: Accessibility (with the components terrain trafficability and infrastructure), engineering properties, climate (and weather), susceptibilities (with the components

erosion hazard and risk of soil compaction) and size of working tracts. The land characteristics and the basic or elementary factors, which determine the land qualities, are discussed. The possibilities of forming terrain classes are shown by the examples of the land characteristics "slope" and "ground conditions".

In the author's opinion a forest management, which pursues both the sustained yield principle and the objective of an optimal relation between cost and revenues, requires above all an ecologically based site classification as well as a technical-economically oriented terrain classification. One should try to integrate these approaches to describing, classifying and mapping forest land.

Introduction

Information on the interactions of the physical conditions of land and forest operations is not only required in the case of a land suitability evaluation concept, e.g. for the comparison of different land utilization types, but in general for:

- long-termed planning of management activities including road network planning and development of operational methods and equipment,
- short-termed planning of operations including road construction and the choice of optimal methods and equipment,
- fixing of wage rates,
- comparison and interpretation of the results of operations performed under different terrain conditions, and for
- supervision and controll of time consumption and cost of operations.

Experience has shown, that this information becomes increasingly important as a decision aid

- with rising degree of mechanization, i.e. with rising input of capital and energy,
- with the extension of forest operations to hitherto inaccessible areas and/or to areas hardly explored up to now,
- with decreasing density of trained personnel, i.e. with growing extension of the area to be treated by one forester, and finally
- under growing urgency of the demand that operational methods and equipment should guarantee high economic efficiency as well as environ-

mental harmlessness.

With the intention of recording systematically the interrelations between land and operations for large areas in a comparable way, several systems of terrain description and terrain classification have been developed after World War II. Although they partially differ to a large degree as to methodical approach, terminology and application, I shall in the following subsume the various systems under the term "terrain classification" (from an operational point of view).

Hitherto, several attempts to make the various systems internationally uniform or at least comparable, did not score any success worth mentioning. A group of experts formed by the Joint FAO/ECE/ILO Committee on Forest Working Techniques and Training of Forest Workers and IUFRO will tackle this task again in the near future. I am sure the present workshop can give useful advices and recommendations to this working group. On the other hand, one should not neglect the methodical and practical experience made with the terrain classification up to now, when a land suitability evaluation concept is to be elaborated. It would be regrettable, if a separate system of describing and classifying the physical land conditions was developed for the purpose of land use planning.

Although research in and practical application of terrain classification systems have been done since about three decades, numerous problems have not yet satisfactorily been solved. Well considered concepts are those of Skogsarbeten, Sweden (CARLSSON et.al., 1969), of Norway (SAMSET, 1975) and the British Forestry Commission (Forestry Commission, 1975). They are, however, oriented to logging and adapted to the terrain conditions of the respective countries.

Land qualities

Up to now the glossary of the terrain classification does not include defined terms like land characteristic, land quality or diagnostic criterion. So far, a unique terminology does not exist at all, which complicates mutual understanding even amongst experts. Henceforth we also lack a common notion, which land attributes should be defined by the above mentioned terms. My attempt to integrate the methodical basics of the various terrain classification systems into the terminological concept of a land evaluation, can thus only be considered as a proposal for further discussion.

According to BENNEMA and van GOOR (1975), the main land qualities related to management are:

"- possibility for mechanization;
- ease with which an adequate infrastructure can be constructed and maintained;
- potential efficiency in relation to freedom of choice of size and shape (of working tracts; supplemented by the author);
- cost levels related to controll of endemic diseases and pests;
- cost levels related to fire controll.".

I presuppose that it should be possible to apply guiding rules or recommendations for land evaluation under the most varying conditions and that they should be valid for a certain period of time. Experience made with the terrain classification shows, that this objective can only be reached if the diagnostic criteria and the suitability are not based on a topical technology but strictly on the physical conditions of the land. Today we distinguish two levels of terrain classification: The descriptive or primary terrain classification, which is developed (almost) completely independent of the respective machines and operational methods, and the functional or secondary terrain classification, which is derived from the primary one and classifies the terrain by exact consideration of the limitations of the available machines and operational methods. ROWAN (1977) says: "... functional descriptions become obsolete as machine characteristics change and new machines appear with limitations quite unlike those known at present. Functional descriptions inevitably mean different things to different people and lack a permanency of basic information on ground conditions, roughness and slope." I belief this experience should also be taken into consideration in the case of the land suitability evaluation.

The suitability grades exemplarily proposed by BENNEMA and van GOOR (1975) for the land qualities, are in my mind to closely related to the prevailing technical standard. According to the terminology of the terrain classification this must be called a functional classification.

I should like to suggest to form suitability grades for the descriptive level by means of the following land qualities:

- Accessibility, with the two components or sub-qualities terrain trafficability and infrastructure,
- engineering properties (roadability),
- climate and weather,
- susceptibilities, with the components erosion hazard and risk of soil compaction,
- size of working tracts.

The important land quality "stand" (kind and size of tree species) is not discussed here.

Table 1 shows the relevancy of each of these land qualities for certain activities. Relevant in this context means on the one hand influence of the physical land conditions on the applicable operational methods and the cost, on the other hand influence of the management activities on the land attributes.

The determinants of the land qualities - some examples

A land quality can be considered as the function of a larger or smaller number of land attributes with a lower degree of aggregation. Some examples may illustrate these connections. A complete survey is not possible within the scope of this contribution.

Accessibility

In agreement with SAMSET I tend to apply the term accessibility in a broader sense than most experts of the land evaluation do. In the opinion of the latter accessibility characterizes the possibility of the construction and maintenance of access roads (cf. for instance BRINKMAN and YOUNG, 1976). According to my understanding, accessibility is the description of the infrastructural conditions as well as the terrain conditions, i.e. the terrain trafficability in the area between the forest roads.

		KIND OF OPERATION *)				
		site preparation and planting	harvesting (incl. extraction) and tending	protection against biotic deseases and pests	protection against fire	road construction and maintenance
LAND QUALITY	accessibility (terrain trafficability and infrastructure)	x	x	x	x	
	engineering properties (roadability)	x				x
	climate (and weather)				x	x
	susceptibilities (erosion hazard, risk of soil compaction)	x	x			x
	size of working tracts	x	x			

*) comprising planning, performing and supervision

Table 1 Relevancy of Land Qualities to Forest Operations

(land quality "stand - kind and size of tree species" out of consideration)

Table 2 shows the main determinants of accessibility. The trafficability of a terrain depends on and can therefore be characterized by the factors ground conditions - which are finally identical with the supporting capacity of the ground -, ground roughness and slope. One would have to discuss whether the macrotopography or - as MAZIÉR (1976) words it - the "fragmentation of terrain" ought to be taken into consideration. This is certainly depending on the degree of intensity and the infrastructural conditions. In the case of a broad land inventory and low road density, this factor is likely to be important. For surveys at a detailled level and in regions with good accessibility and high road density, slope and microtopography will presumably be sufficient for characterizing the surface geometry.

The land quality or sub-quality infrastructure describes on the one hand the state of the forest road network, on the other hand the state of the public infrastructural utilities.

Whether the factors ground conditions, gound roughness and slope etc. may be understood as land characteristics in the sense of the terminology of the land evaluation, is to be discussed. Apart from a few exceptions, however, these terrain features cannot yet be measured immediately, but result from a synthesis of several single attributes in each case.

Table 3 shows these interrelations for ground conditions, ground roughness and slope. The terrain parameters indicated as basic factors are measurable variables and facilitate a sufficiently exact and objective characterization of the land characteristics. A certain defect of these schematic representations is that the basic factors mentioned do not have the same degree of aggregation. The soil type, for instance, is a parameter composed of several elementary variables, whereas height and frequency of obstacles or slope angle represent elementary qualities which cannot be subdivided again.

Engineering properties

It should be made possible by the land quality "engineering properties" to judge a terrain as to the technical practicability and the relative cost of its treatment, especially in the context of road construction and road maintenance. Therefore one could also speak of the land qual-

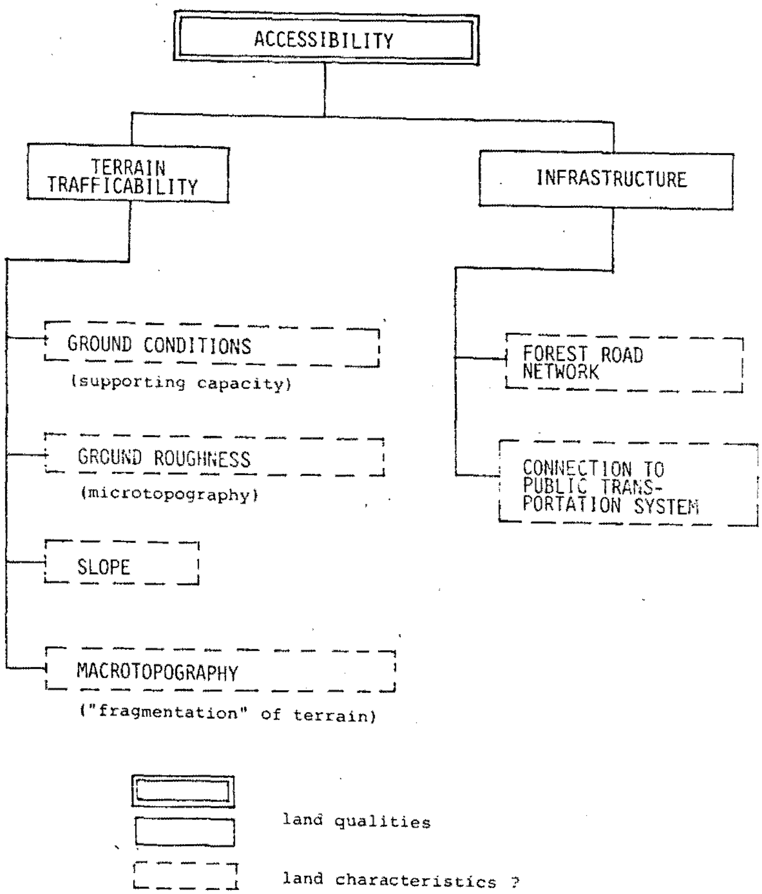

Table 2 Determinants of Accessibility

Land Characteristics	Basic Factors
GROUND CONDITIONS	soil type (group)
	moisture conditions
	strengthening factors
	snow conditions
GROUND ROUGHNESS	height of obstacles
	frequency of permanent obstacles
	slash (and vegetation) cover
SLOPE	slope angle
	shape of slope
	length of slope

Table 3 Determinants of Ground Conditions Ground Roughness and Slope

(within terrain trafficability)

ity roadability and/or workability.

If road standard and traffic load are given, the technical possibilities of and the expense for road construction depend mainly on:

- The necessary earth mass movement,
- the dimensioning of the pavement,
- the necessary drainage measures, and
- the necessity of bridges, walls etc.

The specific earth mass movement is a function of the incline, the angle of internal friction and the macrotopography. The dimensioning of the pavement is determined by the bearing capacity of the subgrade and the engineering properties of the grade material.

The kind and amount of necessary drainage measures are influenced by the rainfall conditions and the drainage patterns. The kind and proportion of walls etc. finally depend above all on the incline, the soil conditions and again on the drainage system.

At a given road standard and traffic load the technical possibilities and the cost of road maintenance are dependent on

- the rainfall conditions (average and heavy precipitation), and
- indirectly on the slope angle, which determines the incline conditions of the road network to a certain degree.

The result of summarizing systematically the various influences and determinants is shown in the interrelations of table 4.

Susceptibilities

"Susceptibilities" is meant to be a term for the degree of resistance of a terrain or soil respectively to

- erosion (surface erosion and slope failures) and
- compaction.

There are several reasons for dividing susceptibilities into two separate land qualities: in "erosion hazard" and "risk of soil compaction". I shall treat them as sub-qualities.

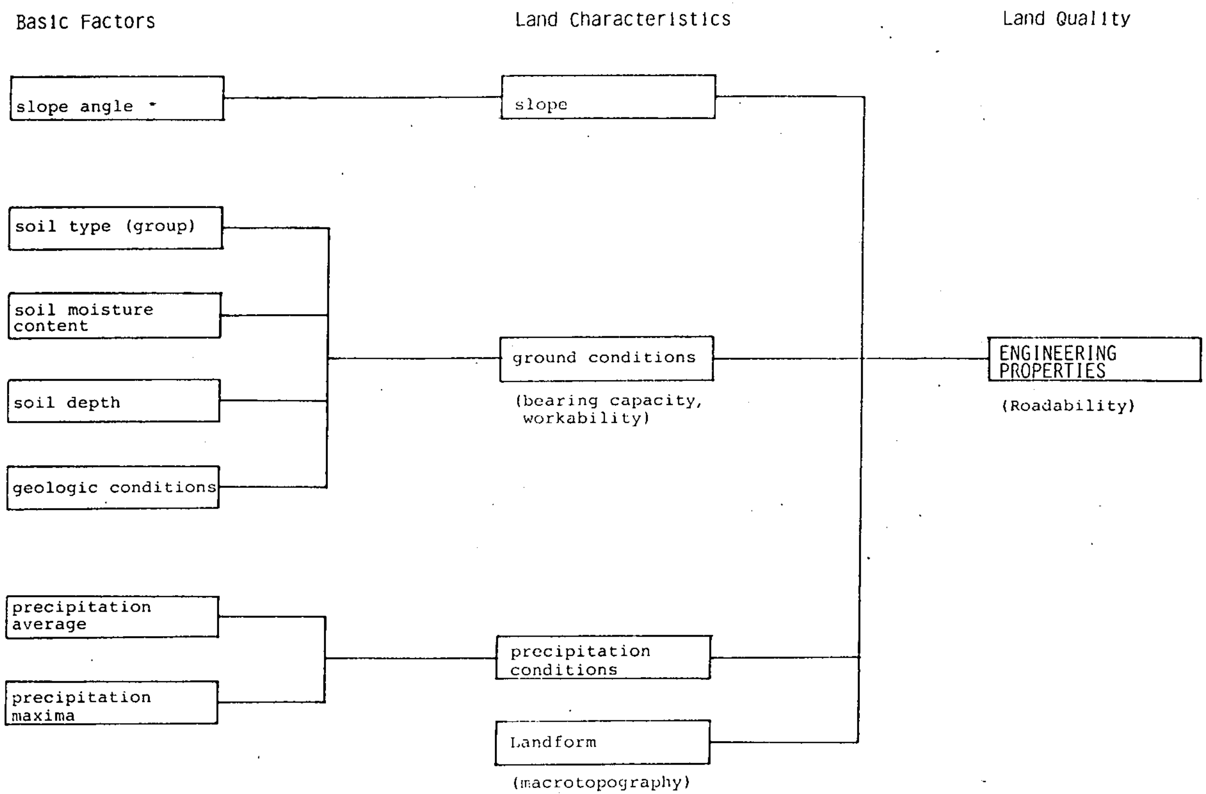

Table 4 Determinants of Engineering Properties (Roadability)

During the last few years proposals for judging the erosion hazard have been worked out in various parts of the world (e.g. MOSER, 1973; LAATSCH und GROTTENTHALER, 1973; BOYDELL and WALMSLEY*, 1975; KRAG, 1980). In spite of differing methodical concepts of these "erosion hazard ratings" or "slope stability assessments", these classifications are largely based on the same land properties in order to evaluate the erosion and/or slope failure potential. Such properties are:

- Incline and shape of slope (slope morphology),
- parent material as to kind (mineralogical) and bedding,
- soil texture including grain size distribution,
- soil depth,
- hydrogeological conditions (soil moisture regime),
- rainfall maxima.

Referring in particular to BOYDELL and WALMSLEY as well as KRAG, a scheme for the sub-quality soil erosion hazard can be established as outlined in table 5.

With rising degree of mechanization of forest operations, closer attention than hitherto has to be paid to soil compaction or reduction of pore volume, especially the proportion of air pore volume. According to the present state of knowledge and with given traffic load, soil compaction depends on soil texture, soil dry density in undisturbed state and soil moisture content. If these factors, which can be summarized as ground conditions, are known, the compaction risk can be prognosticated to a sufficiently exact degree.

The chosen examples show that the various land qualities are determined by the same or at least by similar basic factors. Therefore it seems obvious to try to establish a common foundation for the land qualities relevant to management operations on the level of the basic factors. As far as I know, a well considered and practicable concept of this kind does not yet exist. Neither am I able to make a respective proposal today. In the following disputation on the establishment of classes I can only make a few suggestions by way of example. Principally, the proposals made by ERIKSSON, NIELSSON and SKRÅMO (1978)

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*) I wish to thank the two authors for leaving their manuscripts to me.

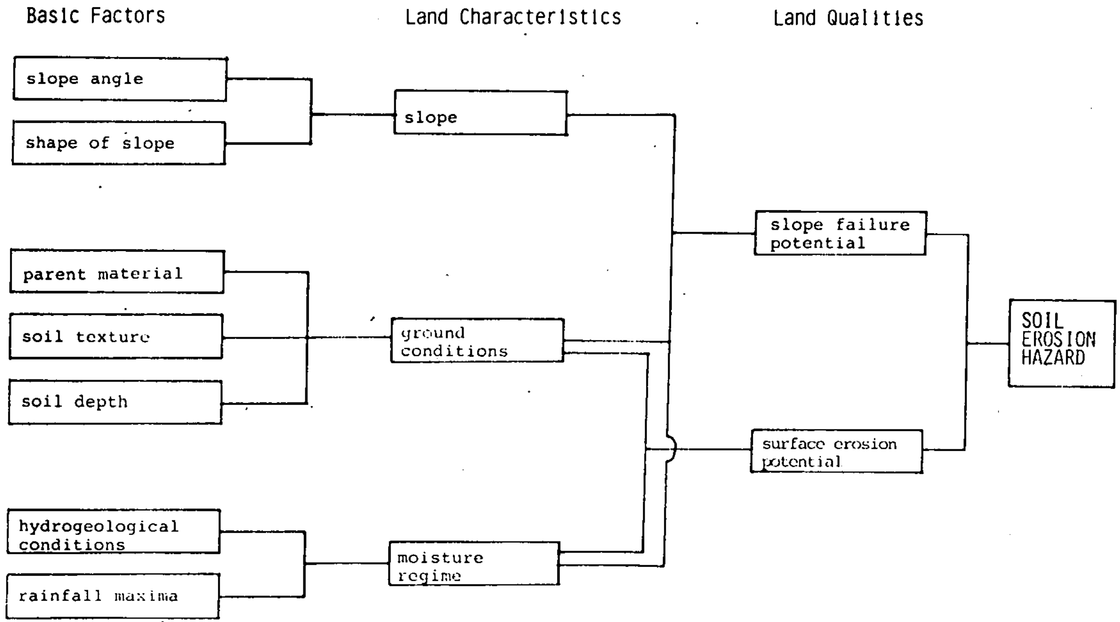


Table 5 Determinants of Soil Erosion Hazard

point in the same direction. At our present state of knowledge, however, we have to realize that further research could prove it impossible or unpracticable to find a common classification system for all land qualities and all kinds of operations.

Formation of groups or classes

The principle

As mentioned before, I recommend a differentiation between land qualities, the classes of which are formed as independent as possible of machines, operational methods and the cost of operations, and land qualities, the classes of which are oriented to the technical possibilities and the input levels. I should like to term the former descriptive and the latter functional land qualities.

The classes of the descriptive land qualities are as a rule the result of a triple classification process with the levels: Basic factors, land characteristics, land quality. Concerning the formation and terming of the classes on the upper two levels, I tend to use the method applied in the Swedish terrain classification and the terrain classification of the British Forestry Commission: Classes in a strictly taxonomic sense are formed only on the level of the basic factors. The higher level classes are the result of a combination and/or addition of the numbers and symbols of the respective lower level classes. The main advantage of this system is, that no further loss of information occurs after the classes have been formed on the lowest level. Its disadvantage is a certain clumsiness of the class terminology, because each class consists of several numbers, suffix letters, symbols and bracket notes.

The high information content of the descriptive land quality classes facilitates the derivation of numerous functional land quality classes.

The demand and recommendation respectively to neglect operational limitations and cost in the class forming process, is naturally and consequently valid also for the class formation on the level of the basic factors. The respective variation range of the basic factors is not divided into classes according to "critical values" as a result of technical possibilities, but according to the principle of the similarity and homogenization respectively of the physical factors. Two examples may help to explain this.

Land characteristic "slope"

It has been said before that the land characteristic "slope" should at least integrate the following basic factors in order to possess a sufficiently broad information content: Angle of slope, shape of slope (type of hillside) and length of slope. The slope angle, however, plays the dominating rôle.

The slope angle is primarily expressed in percent, i.e. the tangent of the incline angle multiplied by 100. The following classification is widely spread all over the world: ≦ 20 %, 21 - 33 %, 34 - 50 %, 51 - 70 %, 71 - 100 %, > 100 %. In some classifications the class limit is not 33 but 30 %.

A uniform grouping or nomenclature for shape of slope or type of hillside does not exist up to now. The British Forestry Commission (1975) distinguishes as follows in its terrain classification: Regular (R), stepped (S), moundy (M), gullied (G). SAMSET uses the terms: Uniform hillsides, basin-shaped hillsides, closed valleys, cone-shaped hillsides, plateaus. ERIKSSON, NILSSON and SKRÅMO (1978) suggest: Even or sloping less than 2 %, undulating or hilly, evenly sloping, terraced. The terminology used in the proposal of a terrain classification submitted to the European Communities (1977) is: Regular or even slope, stepped slope, corrugated form of terrain, slope traversed by rills and ditches or gullies. It should be attempted to characterize the shape of slope by an unambiguous, if possible numeric parameter.

Concerning the classification of the slope length, there are even less proposals hitherto. SAMSET (1975) uses the classes: < 300 m, 300 - 700 m, > 700 m. This grouping is influenced by the reach of the off-road transportation systems, especially the winch- and cable-systems. Thus it is a functional grouping. One could just as well conceive of a classification as follows: $\leqq$ 100 m, 100 - 200 m, 200 - 300 m, 300 - 500 m, 500 - 750 m, > 750 m.

Land characteristic "ground conditions"

The land characteristic ground conditions is part of all land qualities, only the focus of information changes. The following factors should be characterized: Bearing or supporting capacity, engineering properties (workability), applicability as road base material, erosion potential. For a wide range of application it is therefore insufficient to use criteria only for the factors bearing capacity or shear strength as for instance modulus of elasticity, California bearing ratio or cone index. On the level of the basic factors one rather has to find criteria, which are as closely as possible correlated with all target variables.

The study of the relevant literature as well as practical experience with soil classifications indicate, that the following characteristics ought to be taken into account:

- Soil class or soil group, formed on the basis of soil texture (including grain size distribution), soil structure, plasticity and content of organics.
- Moisture content; for purposes of long-termed planning one should use the moisture content at defined weather conditions (e.g. summer dry).
- Parent material (origin of soil) and its geogenesis.
- Soil dry density in undisturbed state.
- Soil depth.
- Stoniness.
- Strengthening factors (like stumps and roots) and slash cover.

  In certain cases also:
- Snow conditions.

It has to be examined, whether addional qualities must be considered for a satisfying characterization of the ground conditions. In areas, where organic soils (muskeg, peat) play an important rôle, it will presumably be necessary to describe in detail kind, proportion and depth of the organics.

The terrain classification systems, which are in use or have been proposed, are primarily concentrated on terrain trafficability and therefore confined to less characteristics. Consequently they are also easier to handle. Nevertheless, I take it worth trying to provide a broader basis for the classification of ground conditions. Similar recommendations were recently made by ERIKSSON, NILSSON and SKRØMO (1978). Another possibility would be to fall back on proved soil and site classification systems (e.g. the Unified Soil Classification System, 1953; the Soil Taxonomy of the Soil Survey Staff, 1975) and adopt their classification principle.

A methodical question not yet thoroughly discussed is, whether on the level of ground conditions classes ought to be formed by mere addition of the class symbols of the basic factors, or whether the large variety of possible combinations of the classes of basic factors should be subsumed under a limited number of ground condition classes. Most of the terrain classification systems in use (especially those of Sweden, Norway and the Forestry Commission) apply the latter method and generally use five up to maximally ten ground condition classes. This approach is undoubtedly more suitable for practical purposes. Disadvantages are on the one hand the unavoidable loss of information and additionally the necessity to take a functional orientation in the process of forming the ground condition classes. In the case of the terrain classification systems mentioned, the bearing capacity is the decisive criterion, which determines the aggregation of the basic factors in ground condition classes. Thus, the latter have only a reduced value in their statement for example on the engineering properties, the erosion potential and the risk of soil compaction.

From my standpoint, the recording and classification of ground conditions is particularly important for the terrain classification or the classification of land qualities; this process, however, involves also great problems. Difficult, too, is the verification of the correlations between the previously mentioned basic factors and the finally interesting variables like bearing capacity, workability, erosion resistance or erosion potential respectively; such correlations are assumed and taken for granted, but they are not yet sufficiently proved in all cases. Promising attempts in this direction are, for instance, the research works by SCHOLANDER (1973) and ERDAS (1976). Further fundamental research in this field is urgently required. Only the results of such studies may enable us to decide, whether a classification considering every case of application is possible at all, which basic factors have to be recorded and how they have to be grouped, and finally which method ought to be chosen for classifying the ground conditions.

Integration of the ecological and technical type of land description and classification.

Foresty and forest management, which pursue the objectives

- high productivity in volume and value,
- high stability of stands,
- preservation of soil fertility, and also
- optimal relation of input (cost) and output (revenues),

require according to my view an ecologically oriented site classification as well as a technically oriented terrain classification. This is valid both for the case that the suitability of an area is to be examined for various types of land use and the question, which kind and level of management is respectively optimal, if the type of land use is given.

Besides the elaboration of a "common classification language including terminology and definitions" (BAILEY, PFISTER and HENDERSON, 1978) I consider it an urgent task to examine the possibility of an integration of the ecologically and technically oriented types of land description and classification. It is true, according to GILMOUR (1951), that "different fields of generalization call for different classifications". The enormous expenditure for data collecting, however, and the similarity of some of the data required in both types of classification suggest at least an attempt at integration.

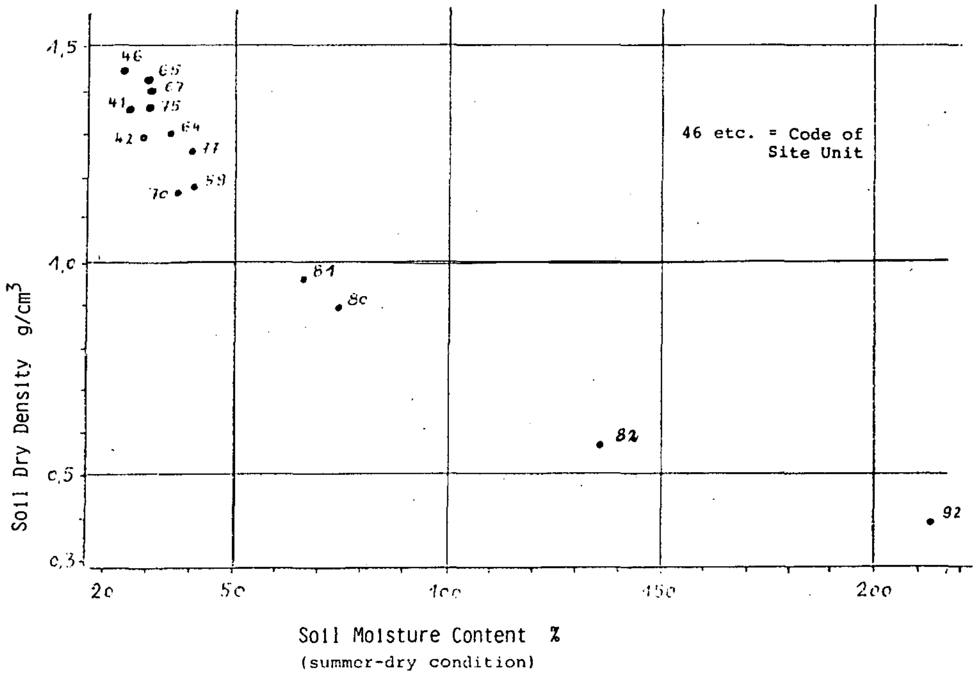
Today, for example, this question is very intensively discussed in the Federal Republic of Germany. A detailled site mapping based on the principle of regionalization, is already available for a considerable part of the forest area in the FRG. Main criteria for the delimitation of site units are parent material, type of soil, water regime of the terrain and terrain morphology. At present we investigate the homogenity of the site units with reference to those basic factors required for the characterization of the ground conditions within the scope of a technically oriented terrain classification.

The results achieved so far are encouraging. An example may explain this. Figure 1*shows one of our testing areas in the ground moraine region with a dimension of about 70 hectares. As stated earlier, soil moisture content and soil dry density are important basic factors for the characterization of the ground conditions. Figure 2 shows the position of the site units in the moisture - density - diagram. According to statistical tests and in additional consideration of the kind of soil and the plasticity properties, six groups of site units which are significantly different in their technical behaviour, can be discerned. They are evident in the overlay to figure 2. It can be seen that the site classification provides a very good stratification of the soil according to technical aspects.

Therefore we have a justification to assume, that by means of our site classification at least the ground conditions are recorded in a way which also meets the demands of a terrain classification from the operational point of view. Climate, precipitation and geological conditions are essential factors of regionalization and thus automatically considered in the case of the site units. Only the land attributes ground roughness, slope and perhaps land form have to be recorded additionally.

I suppose that also the site classifications of other countries offer similarly favourable preconditions for an integration with a descriptive terrain classification. To me this seems to be so in the case of the biophysical land classification in Canada (LACATE, 1969; GIMBARZEVSKY, 1978) and the various versions of the ECOCLASS-Classifications in the USA (CORLISS, 1974; DAVIS and HENDERSON, 1976). Comparative international studies and generally a cooperation of the experts working in the diverse fields of land classification, would be of great interest. If this workshop made a contribution to such cooperation, it would have achieved quite a success.

*) Coulored slide, not suitable for print.



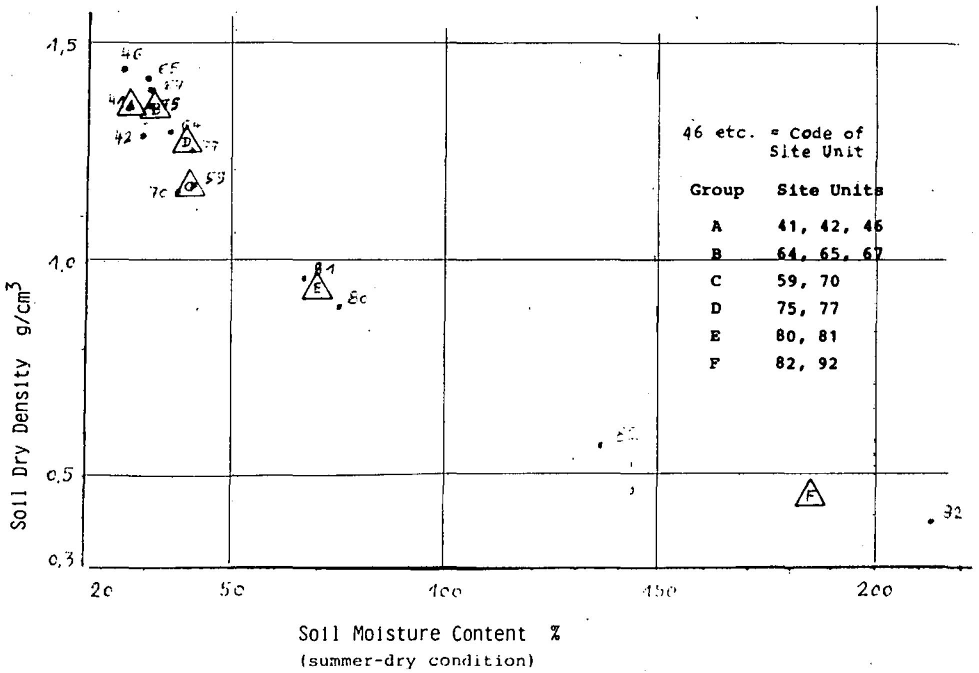


Figure 2: Moisture Content - Dry Density Relation of the Site Units in the Testing Area "TIEFENBACH"

Literature

BAILEY, R.G., R.D. PFISTER and J.A. HENDERSON, 1978: Nature of land and resource classification - a review; Journal of Forestry, October, pp. 650-655.

BENNEMA, J. and C.P. van GOOR, 1975: Physical land evaluation for forestry (in particular relation to wood production); World Soil Resources Reports No. 45. Report on the ad hoc expert consultation on land evaluation, Rome, Food and Agricultural Organization of the United Nations.

BOYDELL, A.N. and M.E. WALMSLEY, 1975: Landuse operation classification for optimal logging management practices on difficult terrain; Surficial Geology and Soils Division, Resource Analysis Unit, Environment and Landuse Committee Secretariate.

BRINKMAN, R. and A. YOUNG, 1976: A framework for land evaluation; FAO Soils Bulletin No. 32, Rome.

CARLSSON, B. et.al., 1969: Terrängtypschema för svenskt skogsbruk; Forskningsstiftelsen Skogsarbeten, Redogörelse Nr. 9, Stockholm.

CORLISS, J.C., 1974: ECOCLASS - A method for classifying ecosystems; Foresters in Land-Use Planning, Proceedings 1973, National Convention, Society of American Foresters, Washington, D.C.

DAVIS, L.S. and J.A. HENDERSON, 1976: ECOSYM - A classification and information system for management of wildland ecosystems: The conceptual framework; Utah State University, Logan.

ERDAS, O., 1976: Bodenmechanische Probleme der Befahrbarkeit, der Bodentragfähigkeit und des Holzrückens in natürlichen Böden des schweizerischen Mittellandes; Dissertation ETH Zürich.

ERIKSSON, T., G. NILSSON and G. SKRÅMO; 1978: The Inter-Nordic Project of Forest Terrain and Machines 1972-1975; Acta Forestalia Fennica, Vol. 164, Helsinki.

FORESTRY COMMISSION, 1975: Terrain description and classification; Commissioner for Harvesting and Marketing, File H 13/6, Edinburgh.

GILMOUR, J.S.L., 1951: A development of taxonomic theory since 1851; Nature 168, pp. 400-402.

GIMBARZEWSKY, Ph., 1978: Land classification as a base for integrated inventories of renewable resources; Proceedings Workshop Integrated Inventories of Renewable Natural Resources, Tucson, Arizona, USDA, Forest Service, Gen.Techn.Rep. RM-55, pp. 169-177.

KRAG, R.K., 1980: A method to estimate risk of soil erosion to logging sites in the Kootenay area of British Columbia; Forest Engineering Research Institute of Canada, Technical Report No. TR-38.

KOMMISSION DER EUROPÄISCHEN GEMEINSCHAFTEN, 1977: Forstwirtschaftliche Probleme und deren Auswirkungen auf die Umwelt in den Mitgliedstaaten der EG; Mitteilungen über Landwirtschaft Nr. 32, Brüssel.

LACATE, D.S., 1969: Guidelines for bio-physical land classification - for classification of forest lands and associated wild lands; Can.For.Serv. *) Publ. No. 1204.

MAZIÈR, D., F. BAUMGARTNER and C. LEPITRE, 1976: Terrain classification for the harvesting of tropical forests; Unasylva Vol. 28, No. 114, pp. 10-19.

MOSER, M., 1973: Vorschlag zu einer vorläufigen Hangstabilitäts-Klassifikation mit Hilfe eines Gefährlichkeitsindex; in: 100 Jahre Hochschule für

*) See last reference on next page.

Bodenkultur in Wien, Band IV Studienrichtung Forst- und Holzwirtschaft, Teil II, Technik in der Forst- und Holzwirtschaft, pp. 159-168.
ROWAN, A.A., 1977: The terrain classification; Forestry Commission, Forest Record 114, Edinburgh.
SAMSET, I., 1975: The accessibility of forest terrain and its influence on forestry conditions in Norway; Reports of the Norwegian Forest Research Institute 32.1, ÅS, Norway.
SCHOLANDER, J., 1973: Skogsmarks tryckhållfasthet; Institutionen for Skogsteknik, Skogshögskolan, Rapporter och Uppsatser, Nr. 59, Stockholm.
SOIL SURVEY STAFF, 1975: Soil taxonomy - a basic system of soil classification for making and interpreting soil surveys; Agricultural Handbook 436, USDA Soil Conserv. Serv., Washington D.C.
"THE UNIFIED SOIL CLASSIFICATION SYSTEM", Corps of Engineers, U.S. Army, Technical Memorandum No. 3-357, Vols. 1 and 3, March 1953.

*) LAATSCH, W. und W. GROTTENTHALER; 1973: Labilität und Sànierung der Hänge in der Alpenregion des Landkreises Miesbach; Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, München.

LAND QUALITIES AND CONSERVATION

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Summary

Conservation qualities express the land's sensitivity to land use pressures. They are generally given as risks or hazards related to application of a land management practice to a specified area. Conservation qualities needed in a planning area can be selected on the basis of experience in similar kinds of land or systematically by matching potential management objectives and methods with known features of the land. Four methods of determining conservation qualities for an area are by direct studies, extrapolation-classification, interpretation of a single natural resource, and by synthesis of several natural resource characteristics. The character of forested lands often imposes unique obstacles to the collection of data needed to develop conservation qualities. An important challenge is to improve our understanding of vegetation communities from a conservation quality perspective.

Introduction

Man's use of forest land can cause changes in the site which jeopardizes the accomplishment of his long-term goals. Conservation qualities are estimates of the land's inherent resistance to negative change when it is used. They are predictions of the land's reaction to use. The predictions enable the planner to choose management objectives, methods and locations to minimize site damage. Beek (1978) defined conservation qualities as "the land's unique capacity to maintain the status of (ecological and management) land qualities (in particular its productive capacity) at pre-established levels."

Conservation qualities, as stated, are features of the land, but for application and for discussion purposes they are considered here the land evaluator's interpretation of the land's innate sensitivity to various uses.

The land evaluator faces several tasks in developing a meaningful set of land qualities. The first question he faces is, "Which land qualities should he have?" This question may not be asked or if asked, answered in a routine way that responds to his information needs more by accident than design. The second question he has is, "How can the quality be estimated?" There are some stock answers to this question, but much innovation is required to make land quality interpretations. The unique features of forest land often require an original approach to quality evaluation.

This paper discusses these tasks and the special character of forest land in the development of conservation qualities. The scope of variabilities in conservation quality development is far too broad to treat here in an exhaustive manner. The methods and examples used here were selected on the basis of the author's experience in the United States and Asia, and although appropriate conceptually, all may not be meaningful to many forest land evaluation situations. The intent is to provide additional insights into one link in the planning process.

Which Conservation Qualities?

The selection of conservation qualities to be determined is a vital part of the land evaluation process. The omission of a conservation quality may lead to unexpected site deterioration, and the unnecessary conservation qualities add to costs of land evaluation. As the linkages between the natural resources and the planning process, conservation qualities take on additional significance as the principal means to define the information need and the data collection activities of the land evaluation process. Knowledge of land quality needs should be used to avoid making surveys for the sake of making surveys.

A standard list of conservation qualities does not exist nor is a standard method of identifying the conservation quality information need established. The conservation qualities to be estimated for a project are usually selected using a subjective "trial and error" approach. Experience in the planning area or its vicinity enables the land evaluator to choose conservation qualities which are appropriate to the planning area and potential management activities. His list of conservation qualities can be revised as his experience in the area increases. Conservation qualities related to road construction for example are known to be important in the mountainous forest lands of Western United States. Soil compaction hazard is a major concern in part of Western United States. Soil erosion hazard has particular importance in tropical forest areas being cut over.

If this subjective approach is not possible or if its results are question-able, a more systematic method of choosing conservation qualities can be devised. Figure 1 outlines the logic of a thought process that can be used for this task. The main tasks in following this process are:

1. Describe the salient features of the land, and establish tentative management objectives and methods.
2. Identify the desired conditions for each objective and the management activity associated with each method.
3. Relate objectives, conditions, methods and activities to the land to identify probable threats and impacts.
4. Restate threats and impacts into conservation qualities.

Knowledge of the land, management objectives, and management method is usually tentative early in the planning process. The selection of objectives and methods that are ultimately part of the management plan would be influenced by the conservation qualities. Some assumptions about objectives and methods however can be made to guide this process. A feedback loop bringing changes in the method and objective factors is assumed. Much detail of information is not expected in this process. Table 1 is an example application of this process for a hypothetical situation in Western United States.

Table 1 shows an orderly way to make a checklist of conservation quality needs. By asking different questions, other kinds of qualities can be identified. Additional columns that could be added to guide data collection include those for scale of each conservation quality, location within the planning area where the conservation quality should be made, and the resource data needed to make the conservation quality. This information

Figure 1.

Process for CQ Selection

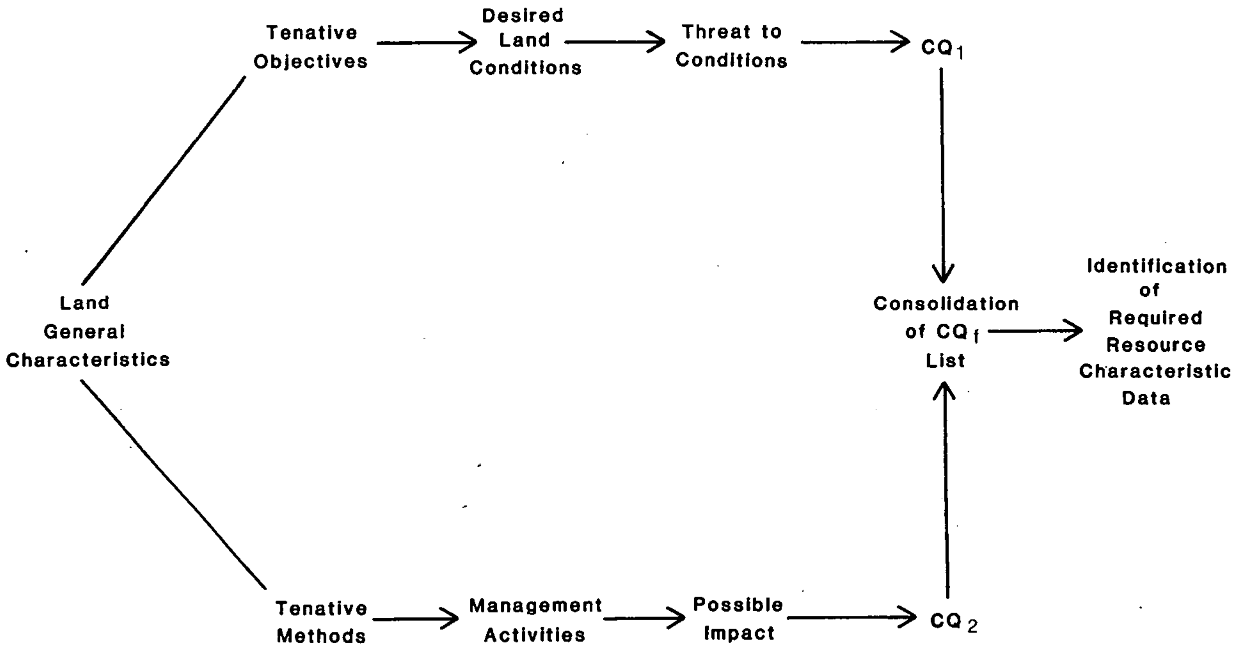

Table 1. Hypothetical Example of Conservation Quality Requirement Determination
Land: Dissected mountain lands, slopes 40-70 percent; soils shallow to moderately deep, gravelly loam to loamy sand; open pine with perennial grass ground cover; elk and deer major game animals.

Objectives	Desired Condition of Land	Threat	Conservation Quality	Consolidated CQ Hazard List
Wood production	High tree growth	Loss of fertility	Soil erosion hazard Fire hazard Insect hazard Windthrow hazard	Soil erosion Fire Insect Windthrow
Forage production	High grass growth	Fire Drought Vegetation composition degradation	Fire hazard Plant community stability	Landslide Sediment delivery
Wildlife habitat	Habitat diversity	Vegetation diversity loss	Diversity trend	
High water quality	Minimal sediment	Surface runoff	Sediment delivery rate	
Methods	**Activities**	**Impact**		
Even Age Management	Road building	Road cuts, exposed soil	Soil erosion hazard Landslide hazard Sediment delivery hazard	Soil compaction Brush Drought
	Log skidding	Exposed soil compaction	Soil erosion hazard Soil compaction hazard	Fertility loss Diversity loss
	Felling all trees	Vegetation loss Drying of site	Brush hazard Drought hazard	Plant community degradation
	Slash burning	Organic matter loss	Soil fertility loss hazard	
	Tree planting	Exposed soil	Drought hazard	Herd damage
	Grazing	Trampling Vegetation loss	Sod breakage Erosion hazard	
	Hunting	Game animals killed	Herd reduction sensitivity	

1

would be a basis for planning the inventory program.

How are the Conservation Qualities Determined for a Site?

This question is answered under the headings of Methods, and Operational Considerations.

Methods of Quality Development

Four general approaches are possible to the identification or development of land qualities:

1. Direct measure. It is possible to observe the reaction of an area of land to a particular use as a basis for projecting that impact into the future with the same use. It is used when existing information or models are lacking and when the information needs are unique. This approach is most commonly used in experimental areas where trial plots are used. Knowledge thus gained can be extrapolated to similar situations in other locations.

2. Extrapolation/Classification. Experience in one area is carried to another location where the same taxonomic unit of a resource or land unit occurs. One of the purposes of classification is to permit accumulation and extrapolation of knowledge, including land qualities. This approach assumes that there is a taxonomy established and that units can be identified using that taxonomy. By classifying a resource or land unit in an established system, much information can be attached to the classified unit. The best known scheme along this line is soil taxonomy. In the United States there is a large amount of interpretive data stored by each soil series as shown in the paper by McCormack, et.al., 1980. Knowledge of a

particular geologic formation also permits statements about the stability of the earth mantle associated with that formation. The Wasatch Formation in the Colorado Plateau is generally linked to high mass movement hazards for example. The Siwalik ridges in Nepal, an ecological zone identified in a recent inventory (Nelson, et.al., 1980), is notorious for its high landslide hazard.

3. Single resource interpretation. Soil, vegetation type, geologic formations and climatic regimes can be interpreted independently to yield land quality information. Soil erosivity, brush hazard, and landslide hazard are examples of possible conservation qualities produced in this manner. Table 2 is an example using soil texture to identify wind erodibility.

Table 2. Soil Conservation Service wind erodibility potential of bare soils by soil groups

Group	Soil Classes	Hazard
1	Sands	High
2	Loamy sands	High
3	Sandy loams	Medium
4	Silty clays and clays	Medium
5.	Loams, sandy clay	Slight
6	Silt loams, clay	Slight
7	Silty clay loams	Slight
8	Wet or stony	Slight

This approach has probably been the most widely used of the four because of the tendencies toward individual resource data collection. The basic data requirement is for an inventory of the individual resources. The rationale for this method is that a single resource may account for most of the variation in hazard occurrence in a given environment. Roose (1977) pointed out the over-riding significance of Factor C, cultural and vegetal cover from the Universal Soil Loss Equation (Wischmeier and Smith, 1965) in the rates of erosion in West Africa. In mountainous areas slope gradient is usually the most significant factor in predicting potential erosion.

4. Synthesis of resource data. Data from two or more resources are combined to produce the land quality. The synthesis can take place in stages. The general pattern of integration is shown in Figure 2.

CHARACTERISTICS ⟶ **MODEL METHOD** ⟶ **SITE QUALITY**

Figure 2. Relationship between resource characteristics and site qualities

The principal task in this approach is to develop the method, model or rationale used to combine the resource data. The combining of information is generally based on well recognized cause-effect relationships which have been studied in field plots and simulations. The model may be an equation accompanied by appropriate tables or nomograms to assist application. The Universal Soil Loss Equation is an example of this type of model. Beek (1978) reviews the Universal Soil Loss Equation to illustrate its application in establishing the soil erosion hazard conservation quality. A similar widely applicable equation is available for wind erosion.

The synthesis of resource data to form conservation quality estimates has great appeal because a hazard is rarely a function of just one resource characteristic. Conservation qualities developed by this approach should be more accurate and consistent than by alternative methods. The function relating an output to a series of factors is a good checklist for the variables causing a problem. The most critical factors can be identified and treated if needed. The Universal Soil Loss Equation is used in this manner to guide management of lands with erosion problems (Wischmeier, 1976).

Under ideal circumstances, a person responsible for conservation quality estimation would systematically identify the conservation qualities needed for his project, select an appropriate method for each quality, accumulate the data necessary to the operation of the method, and arrive at the conservation qualities needed for the planning task.

As most people with field experience know, the actual process is seldom that smooth or complete. The ideal often cannot be realized because of obstacles in the forest environment. The kind, magnitude, and rigidity of these obstacles are variable, but a few generalities about the forest environment as it affects quality estimation are possible. The most obvious feature unique to forest land is the trees. Along with this feature often goes ruggedness of terrain, large extent, remoteness, wide elevational range, and sparse development. Access is often limited, requiring arduous effort to move across the land. Land values are comparatively low, and future investment, if the land is to continue to be forested, is normally comparably low also. Forested lands are usually the last part of a country to be developed, and pressure for conversion to agriculture land or other uses may be high. Data on resources is commonly limited or lacking. Whatever data collecting methods and interpretation models are available are usually developed for agricultural lands. A wide range of resource management objectives usually further complicates the task of the forest land evaluator. There are many exceptions however in industrialized countries, but the picture holds true for most developing countries.

There are several implications of these aspects of forest land. Investment in data collection is roughly proportional to potential investment in management. Consequently, forest land data collection programs are often on a low budget when calculated on a per unit of land basis. The lack of accessibility and difficulty of travel pushes data collection costs up. The result is usually a low density sampling pattern and heavy reliance on extrapolation and remote sensing techniques.

The following items are some additional effects of the forest environment on development of conservation qualities:

1. There is little quality control through field checks and correlation, making accuracy of data and resultant interpretations unverified.
Integrated natural resource inventories on National Forest lands in the United States and other places make quality control difficult because methods of quality assessment of these kinds of inventories have not been developed. This problem is being alleviated somewhat in the United States by requiring that the soil element of these inventories be classified and correlated under the National Cooperative Soil Survey program.

2. The number of conservation qualities is limited. The scope of hazard and other interpretations are kept to a minimum.
Only key conservation qualities are usually identified. There could be several reasons for this including problems related to the above described characteristics of forest land. Lack of analysis of information need and

insufficient knowledge of an area or the effects of management practices also have a role in limiting the scope of conservation qualities selected for assessment. This latter problem has sometimes been stated as, "We don't know enough about the area to know what questions to ask."

3. Methods to make interpretations needed for forested lands are lacking or must be modified to fit the forestry applications. There is little standardization of methodologies, nomenclature, or class values.

The Universal Soil Loss Equation is the best example of the need to modify a model designed primarily for agricultural lands to fit into a forest environment. The father of this widely used analytical tool, W.H. Wischmeier, has warned against the tendency to missapply the equation and gives advice on steps to adapt it to situations beyond its standard environment (Wischmeier, 1976). Osborn, et.al., 1977, found its lack of handling of gully erosion a severe deficiency and recommended that a channel factor be added to the equation. Tryon and Miller (1973) adapted the equation to a forested situation in southern Missouri in the United States by using monthly precipitation rates and by recognizing changing vegetation cover percentages following logging. Moldenhauer and Onstat (1977) point out that there is a need for, "predictions...for entire watersheds, both large and small, for long time periods, and for single storm events," rather than for long-term estimates for single fields for which the equation was designed. The major problem in the use of the equation in developing countries is the lack of data. Fetzer and Jung (1979) concluded from their trials with the equation in Nepal that, "...there is...a great lack of data concerning the factors which affect the erosion process in the Nepal Midlands."

The Universal Soil Loss Equation is valuable as a foundation for assessment of erosion potential. We are not so fortunate in other areas, particularly for conservation qualities related specifically to the forest or mountain environment. Here the land evaluator has the tasks of defining the conservation qualities, describing a method of evaluation and setting up classes for the specific area being planned. The result is a pragmatic method which fits the conditions of the planning area. The following example is from the White Mountain National Forest Ecological Landtypes Report by Alvis (1976):

Deep Slump Hazard

> Deep slumps refer to earth failures with failure planes more than six feet deep and are chiefly associated with silty lacustrine deposits on scarps.
>
> Deep slump hazard ratings evaluated by (1) approximations of potential shearing stresses acting on the soil mass, and (2) approximations of shearing resistance of the soils minus potential pore water pressures. These theoretical evaluations are tempered by field observations of existing stability conditions. Approximations of potential shearing stress (roughly equivalent to gravitational forces) are based on natural slope gradients, bulk density of the soils, depth to bedrock, and hydrologic characteristics of the land types. Estimates of the lowest internal strengths likely to occur are based on evaluation of soil grain size distribution (texture, which approximates gradation curves), grain shapes, arrangement of grains, degree of induration (if any), and plasticity (durability of remolded ribbon) which approximates

plasticity index.

The hazards are rated by three qualitative classes relative to the White Mountains only.

Smalley (1979) developed the following definition and class limits for windthrow hazard on the Southern Cumberland Plateau in Eastern United States:

Windthrow Hazard measures how soils affect root development and how firmly soils hold trees. The hazard is slight if rooting depth is more than 20 inches and trees withstand most winds, moderate if effective rooting depth is 10 to 20 inches and some trees are blown down during excessive soil wetness and strong winds, and severe if effective rooting depth is 10 inches or less and trees will not stand alone in strong winds.

Gott (1975) devised this definition and classes for predicting plant competition for the Mark Twin National Forest in the United States:

Plant competition - Plant competition is rated according to the degree of competition from other plants and the rate at which undesirable species invade when openings are made in the canopy. A rating of slight indicates that unwanted plants are no special concern; a moderate rating indicates that competition delays the establishment of a fully stocked stand; and a severe rating indicates that competition prevents natural or artificial regeneration unless intensive control is used (Gott, 1975).

The following table was used for classifying landslide hazard in a reconnaissance inventory in Nepal (Nelson, et.al., 1980). The characteristics used to estimate this hazard were visible on aerial photographs and from overflights. It is an example of an expedient method and reflects the very limited amount of natural resource data available in a developing country.

Land Characteristic	Landslide Hazard Class				
	1	2	3	4	5
Slope gradient class	1	2	3	4	5
Bedding plant/substratum	Dip is away from slope surface		Dip is with slope surface		
Landslide occurrence (Number per square kilometer)	Absent	3 or more	4-8	9 or more	

Landslide hazard is lowest for Class 1 and highest for Class 5. Slope gradient classes increase in steepness as one moves from Class 1 to 5. The most restrictive characteristic was used to identify hazard class.

Three Forestry Conservation Quality Needs

The following is a rather brief overview of three forestry problem areas that involve conservation qualities:

1. Basic information must be collected. An inventory made in support of a forest land evaluation project must be supplemented by long-term research and inventory programs in a forest environment. Fetzer and Jung (1979) noted this problem for Nepal. Research is a weak link in forestry in developping countries. Equally troublesome is the need for the systematic, long-term accumulation of climatic, hydrologic, and erosion plot data in forested

areas. Such data and relationship findings are needed to make conservation quality estimates possible.

2. Greater attention must be given to the biological components of the ecosystem in regard to conservation qualities. The soil and earth mantle are usually the focus for making conservation quality estimates. Changes in vegetation is also a cause of loss of site productivity. If the potential management objectives include wildlife management, esthetic qualities, or maintenance of seed sources of desired species, greater heed must be givèn to diversity of vegetation. Many forest land management practices lead to loss of diversity. Brockelman (1976), speaking of tropical forests, said, "Everywhere around us the ecosystem is becoming more simplified, less sustaining without unrealistic energy subsidies and uglier." In the United States, attention to plant diversity is required by regulation for federal forest land management planning. Loss of diversity is a hazard in the sense that it threatens or makes more expensive the accomplishment of legitimate forest management objectives in wildlife management or esthetics. The decision maker should be warned of potential loss of vegetation density. Although diversity is an issue in forest planning, in the United States, no method has been developed to routinely predict the impact to diversity that would be caused by a proposed management practice.

A second vegetation related conservation quality concerns the hazard of permitting or accelerating the establishment of undesirable plant communities. Shrubs or low-value hardwoods often invade sites following logging. Such communities can cause a decline in site productivity in terms of long-range objectives because they impede the establishment of commercially valuable tree species. The possibility of this happening is estimated on some forests as brush hazard. This conservation quality is a function of soil, climate and land use factors. Fire hazard is a conservation quality based on vegetation, climate, and topographic considerations. A more detrimental impact occurs if the site is so altered by a forest practice that no vegetation or only patches of low-value shrubs can occupy the site. Destruction of tropical and subtropical forests sometimes leads to this situation. Land evaluators need to be able to predict the occurrences of these changes. A conservation quality here would have to be based on a knowledge of plant succession.

Wildlife communities can also be negatively affected by forest management practices. A conservation quality alerting the planner to this possibility needs to be developed. Wetland areas are often damaged by forestry causing the loss of a valuable ecosystem component. A conservation quality could be used to guide management practices where this possibility exists.

3. Additional work is needed to develop conservation quality models to predict the impact of several silvicultural practices. The potential for site damage increases as silvicultural practices become more sophisticated. Use of chemicals, fire, and particularly heavy equipment can cause site damage that needs to be predicted. The need for these predictions will become more important as forest technology advances. Heavily mechanized site preparation practices on national forests in the United States are responsible for decline in site productivity in places because they severely disrupt the O and the A1 horizons. A model predicting this loss would be helpful.

Controlled burning is being more widely accepted as a professionally applied silvicultural tool. Conservation qualities here would help the land manager to avoid sites which are likely to be negatively affected.

Use of herbicides as silvicultural tools is one of the most controversial public issues in the National Forests in the United States. The most common use is the application of chemicals to reduce brush competition to permit more rapid tree growth. Models for conservation qualities are needed to predict the possible long-term damage to animals, vegetation, soils, and ground water.

Soil compaction by equipment used in logging causes loss in tree growth. It has been studied by a taskforce in the U.S. Forest Service (1978) which concluded that, "Currently there is no simple method to determine when or where excessive compaction might occur."

Conclusions

Conservation quality estimates speak to the need to protect the site. These qualities, with the qualities which convey the site's productive capacity and its limitations to operational practices, form the foundation of knowledge upon which land use decisions must be made. These qualities are the linkages between the many variables of the land and the multitude of potential uses of the land.

The discussion of conservation quality identification and kinds of methods to estimate the conservation qualities provides a framework for answering vital land evaluation questions. The brief discussion of application experiences illustrates the challenges imposed by the forest environment upon the land evaluator.

Land evaluation is a dynamic process that must be tailored to the unique conditions and information requirements of each project. Although many principles and methods are applicable across the board, considerable sensitivity and ingenuity on the part of the land evaluator are required to use those principles and methods effectively.

REFERENCES

Alvis, R. 1976. Ecological Landtypes, an example extracted from the Evans Notch Unit Plan. White Mountain N.F., Laconia, New Hampshire. 37 pp.

Beek, K. J. 1978. Land Evaluation for Agricultural Development. International Institute for Land Reclamation and Improvement. Pub. 23. Wageningen, The Netherlands. 333 pp.

Brockelman, W. Y. 1976. Economics of the Decline of Diversity. Tigerpaper III, No. 3, 7/76. p. 2-4.

Burkhart, L. J. and G. J. Wigger. 1978. A Guide for Land Use Allocation and Management. Hiawatha National Forest. Escanaba, Mi., U.S.A. 115 pp.

Fetzer, K. D. and L. Jung. 1979. Factors Affecting Soil Erosion by Water Within a Research Area of Northwestern Mountain Ridge of Kathmandu Valley. Jour. of Nepal Res. Centre. Vol 2/3 (Sciences) 1978/1979. Kathmandu. p. 219-236.

Gott, J. D. 1975. Soil Survey of Mark Twain National Forest area. Missouri. USDA Soil Conservation Service and Forest Service in cooperation with Mo. Agri. Exp. Sta., Univ. of Mo., Columbia. 56 pp.

McCormack, D. E. and R. E. Hartung and K. N. Larson. 1980. Evaluations of Forest Lands in the United States. International Workshop on Land Evaluation for Forestry. IUFRO - ISSS. Nov. 1980. Wageningen.

Nelson, D. O., P. Laban, B.D. Shrestha, and G. P. Kandel. 1980. In manuscript. A Reconnaissance Inventory of the Major Land Units and Their Watershed Condition in Nepal. FAO NEP 74/020. Department of Soil Conservation and Watershed Management. Kathmandu, Nepal. 368 pp.

Onstad, L. A. and W. C. Moldenhauer. 1975. Watershed Soil Detachment and Transportation Factors. Jour. of Environmental Quality 4 (1), 29-32.

Osborn, H. B. and J. R. Simanton and K. G. Renard. Use of the Universal Soil Loss Equation in the Semiarid Southwest (1977). Proc. of a conf. on soil erosion, May 24-26, 1976. West Lafayette, Ind. Soil Cons. Soc. of Am., Ankeny, Iowa.

Roose, E. J. 1977. Use of the Universal Soil Loss Equation to Predict Erosion in West Africa. In Soil Erosion: Prediction and Control, p. 60-75. Proc. of a conf. on soil erosion, May 24-26, 1976. West Lafayette, Ind. Soil Cons. Soc. of Am., Ankeny, Iowa.

Smalley, G. W. 1979. Classification and Evaluation of Forest Sites on the Southern Cumberland Plateau. USDA, Forest Service. Gen. Tech. Report 50-23. 57 pp.

Tryon, C.P. and M.R. Miller. 1973. Keeping Soil Erosion Losses to Environmentally Tolerable Minimums on Site Preparation Areas in Southern Mo. Clark and Mark Twain National Forests, Rolla, Mo. 35 pp.

U.S. Forest Service. 1978. Report of the Findings of the Soil Compaction Study Taskforce, Regions 5, 6 and PSW. San Francisco, Calif. 35 pp.

Wischmeier, W. H. and D. D. Smith. 1965. Predicting Rainfall-Erosion Losses from Croplands East of the Rocky Mountains. Agr. Handbook No. 282. USDA. Wash. D.C. 47 pp.

Wischmeier, W. H. 1976. Use and Misuse of the Universal Soil Loss Equation. Jour. of Soil and Water Conservation. Vol. 31, No. 1, p. 5-9.

3.2 Papers on "Land evaluation, a new approach"

Session 3, November 12, Wednesday

<u>"Important aspects and applications"</u>

Chairman: J. Bennema

Rapporteur: D.O. Nelson

<u>Papers</u>:

- K.J. Beek and P. Laban
  Land evaluation, a systematic approach
  Presented by K.J. Beek
- R. Plochmann
  Problems of land suitability classification for forestry
  in Central Europe
- M.F. Purnell (FAO)
  Application of the framework for land evaluation to forestry
  in developing countries

LAND EVALUATION, A SYSTEMS APPROACH *

K.J. Beek and P. Laban

Summary

This paper emphasizes the need for integrated approaches in land evaluation for forestry. Land should be assessed not only for its suitability for timber production but simultaneously for other types of land use. Due consideration should be given to physiological growth, forest operations and environmental protection, important aspects affecting the suitability of land for a certain land use.

The paper describes a systems approach to land evaluation, selecting, integrating and analysing relevant data. This is done by simulating the real situation through models called land use systems. Emphasis is given to inputs, improvements of the land qualities, as well as to the matching of land qualities with land use requirements and to the definition of land suitability criteria.

The paper recommends integration of land evaluation in land use planning procedures and development of land evaluation guidelines oriented to specific regions and problems.

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* *This paper reflects the result of discussions in a Dutch working party consisting of Prof.Dr. K.J. Beek (International Institute for Aerial Survey and Earth Sciences, ITC, Enschede); Ir. C.P. van Goor and Ir. P. Laban (Dorschkamp Research Institute for Forestry and Landscape Planning, Wageningen); Prof.Dr. A.P.A. Vink (Physical Geography and Soil Science Department of the University of Amsterdam).*

Introduction

First of all, land evaluation is not a completely new technique. On the contrary, it is a further development of land classification systems already often used.
As other land classification systems, land evaluation has a proper task of simplifying the complex data base through a process of interpretation and integration of the many data that result from many component studies.
Secondly, land evaluation should arrive at an as simple as possible relevant analysis of these data, finally resulting in a set of recommendations usable for socio-economists, land use planners, etc.
There are many examples of land classification systems, e.g. terrain and site classifications in forestry, land capability classifications and others having an important function regarding data simplification. However, in many cases they are single-factor oriented, emphasizing only one kind of land use and/or neglecting environmental and other important aspects of land use. A next section in this paper will elaborate on these and other points which could be given more attention in land classification approaches.
The land evaluation approach discussed here is systematic. First of all, to understand the functions of existing or future land uses and their interactions with the land on which they perform or have to perform, we have to simplify these functions and interactions. This can probably best be done by building dynamic land use models. Therefore the term Land Use System is introduced, consisting of two main components or subsystems: the land use and the land itself. Land evaluation is then concerned with predicting the behaviour of such Land Use Systems.
The land evaluation approach is not meant to be a precise manual in which one has to adhere to fixed procedures. On the contrary, such an approach can and has to be used at different levels of detail and generalization, with very different mapping scales, for very specific purposes or for a wide range of alternative land uses at the same time. For each application the land evaluation approach has to be adapted properly. In general, such adaptations will depend mainly on the available data, the purpose and the expected detail of the results of the land evaluation.
Furthermore, a land evaluation procedure is part of a more complex process of land use planning. It will be very difficult to draw a sharp boundary

between land evaluation and land use planning. This will be even more so in studies with greater detail and larger scales, where the need for an integrated approach with the socio-economic disciplines becomes larger and the boundary between land evaluation and land use planning becomes still more vague. In such cases how complex land use problems are handled will depend largely on the composition and quality of the team.

Shortcomings of currently used approaches to land classification for forestry

In the history of forest research many systems and methods to show and predict relations between land (site/terrain) and forest productivity have been designed. Most of the work done so far, however, has been specific-purpose or single-factor studies (e.g. the growth potential of a specific tree; the limitations of terrain factors for a specific type of logging equipment). In several countries general classification systems (mostly land capability classification) have also been developed. These are, however, not very specific with regard to different types of possible forestry land use. The current state of the art has been presented in three other papers of this workshop. Some pertinent shortcomings of existing systems are as follows.

1) In many cases only one aspect of forest use has been considered. Usually this is timber production. In classification systems developed thus far, other aspects and objectives have only received cursory attention. One aim of this workshop is to emphasize that there are other land use objectives in forestry, e.g. recreation, environment protection, nature conservation, production of fuel wood, etc. This has already been elaborated on in another paper on Land Utilization Types for forestry (more specifically in Table 1). This emphasis is considered important for a more systematic approach to land evaluation in which it should also be possible to compare the suitability of the same land unit for different types of forestry land use.
2) In current forestry practice, classifications by tree growth on the one hand (site classification) and forest operations on the other (terrain classification) are still strictly segregated. Aspects of environmental protection are rarely taken into account; if they are considered, they

are mostly evaluated independently from tree growth and forest operations. We are convinced that a land evaluation study will only have value if these three aspects are combined when assessing land suitability. One aim of this workshop is obviously to stress the need for this integration by emphasizing it in the choice and content of other papers. One of the tasks of land suitability classification will be to stimulate an integrated discussion of these different aspects.

3) In many cases the land classification systems developed for forestry are indeed classifications of the land. They provide descriptive information on how land can be divided into units on the basis of properties that affect growth or management. Mostly this is done irrespective of the specific requirements of a specific Land Utilization Type. In fact, the result is a classification of land qualities. Examples are given by the preliminary stages of Scandinavian terrain classification systems. In the Swedish example, for instance, several factors or land qualities are considered, including ground condition, slope, incidence of slash and stumps, each divided into 5 classes and defined in rather fixed terms. They provide an objective general system to describe terrain characteristics uniformly. In addition to this primary classification system, a secondary system has been developed in Sweden applying the general information from the primary system to the prevalent LUTs, whether or not the latter are explicitly mentioned. Although this is a good example of land qualities being related to the land use requirements of a specific LUT, it has to be realized that such a secondary classification system is only applicable to that specific LUT, while it only gives information on aspects important for forest operations and not for wood growth or environment al protection. It may be clear that other forest management systems, such as those with only a few machinery inputs or with a recreational function, will require other interpretations of the land characteristics. Thus, in land evaluation the land use requirements have a strong influence on the classification and interpretation of land qualities.

4) In the past many capability systems have followed the examples given by the USDA land capability systems. They resulted in different land classification systems for different types of land use. Well-known examples are the USDA Land Capability System for Rainfed Conditions and the

Canadian Land Capability Classification for Commercial Forest. This often makes it difficult to make suitability comparisons with other types of land use. It has been the practice within the U.S. capability classification systems to assess land suitability according to the presence of limitations, but without specifying for which land use the limitations are indeed limiting.

In these systems, land suitability is basically assessed for agricultural purposes, implying that lands suitable for agriculture are also suitable for forestry and other uses. The result is a classification in which classes 1 to 4 are suitable for agriculture, while classes 5 to 8 are suitable for other uses. In such a system it is not evident if and why land in class 2 would be more suitable for agriculture than for forestry, or vice versa.

The Canadian system makes use of index species to indicate potential productivity of the land corresponding with capability classes. Thus, in Alberta, Canada, white spruce is the principal index-species, because it has the highest potential production in most of the area. If the highest capability class is assigned to a land unit, this indicates that on that land unit white spruce has the highest potential production relative to the study area. However, it is not evident what capability class this land has for another species, e.g. jack pine. It might well be that the same land unit would have a lower capability class if instead of white spruce jack pine were taken as index-species. With this classification it is not possible to assess the difference in suitability for the two species on the same land unit; in addition, no information is given on other relevant factors such as possible differences in limitations for forest operations. When it comes to classifying the suitability of land for a certain LUT it is important that this be done individually, but with the same approach for each relevant LUT. Only then will it be possible to compare suitabilities of different LUTs on the same land unit and to decide which LUT should be given preference.

5) Most land classification systems used in forestry deal with the actual (existing) conditions of land. A land capability classification, by its nature, indicates the productivity of the land as it is. It is often also of interest to know how much land suitability will change when land

conditions are improved or when limitations are made less serious. Such improvements and their respective costs and effects on the operations of LUTs can be important enough to bring about changes in the ultimate suitability classification. Several categories of improvements can be distinguished, which are discussed further in a subsequent section: Inputs and improvements.

6) There is also the question of the recurrent costs involved in the operations of a LUT, therefore affecting the suitability of land for a LUT. There are, in fact, no or few examples of classification systems considering this aspect, except in very detailed studies, where the evaluation is predominantly economic.

Costs (and benefits) do not necessarily have to be expressed in monetary terms. They can be expressed in physical terms. In this case, the different "costs" and "benefits" of different combinations of LUTs and land units are compared with each other in the land suitability assessment. For instance, the amount of fertilizer needed to improve natural fertility of a land unit, or the extra labour needed for weeding or fire protection can be compared when comparing two LUTs on the same land unit, while at the same time the increase in wood growth of the trees in these LUTs is compared.

It may be noted that the aspect of related cost is important, especially when improvements are involved; necessary costs for management, protection, etc. can differ among different LUTs and therefore influence the suitability of the LUT.

7) Many suitability or classification systems are weak in the sense that norms and standards for the distinction between suitability classes are not clearly defined. When suitable, marginally suitable and unsuitable land is identified, it must also be known why and how the distinctions between these suitability classes are made. This becomes even more important and more difficult when types of land use are more specifically defined. In fact we have to assess the suitability for every land utilization type, for every land use system we consider relevant. In the land evaluation approach discussed we call these norms and standards land suitability criteria. This subject will be discussed elaborately in a subsequent paragraph of this paper.

Land evaluation, a systems approach

General concepts

As has already been indicated in the introduction of this paper, we have to understand the complex relationships between land use and the land on which these land uses perform. Therefore we try to simulate these relationships by building dynamic land use models and by studying their behaviour. Such models have to be dynamic because they change with time. For the purpose of land evaluation the term "land use system" has been developed to give concrete form to such models.

The term "system" has many meanings, varying from sets of interacting physical elements (e.g. the "land system", describing a mapping unit in some reconnaissance resource surveys) to relationships between land and user (e.g. the land tenure system) and to land cultivation techniques (e.g. the management system). Toebes (1975) observes that most systems have three things in common:

- a collection of elements,
- relationships between these elements,
- a rationale for selecting elements and relationships.

Toebes also gives the following definition of the concept system.

- A system is a collection of elements and their relationships, selected for their bearing on the questions asked or the goals pursued and related to similarly selected systems in its environment.

This concept of a system is also valid for the "land use system" introduced here. Such a land use system can be divided into two main components or subsystems, as shown in the diagram below. This division is, of course, an arbitrary one; it only serves the purpose of land evaluation.

Land Use System	
Land	Use

We have to realize that the above land use system is in fact a model, (LUS)m, of the real land use system and that by analysing such land use systems for

the purpose of land evaluation we are really simulating real situations. Furthermore we have to be aware that, as in general, the whole (of the LUS) is more than the sum of parts (here land and use), while it should also be recognized that a LUS is in itself part of a larger system: the environment, the universe.
The rationale for this land use system approach, however, is that we have to arrive at a study of the whole system rather than of the components which are difficult to integrate afterwards.

The application of land use systems in land evaluation

The above diagram can be made more specific in terms of land evaluation:

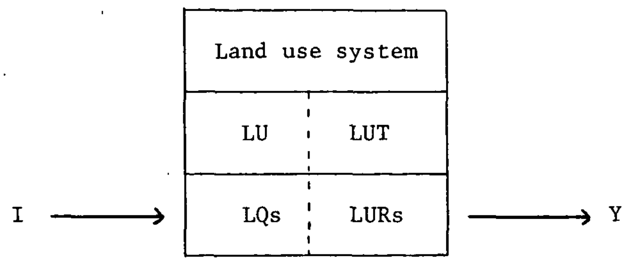
Land use system	
Land unit	Land utilization type

This diagram shows the whole land use system (LUS), divided into its two main components: the land unit (LU) of which we want to evaluate the suitability for a selected relevant land utilization type (LUT).
The main purpose of land evaluation is to predict the behaviour of such a LUS.
When considering the above definitions on the concept of systems (Toebes, 1975), we also have to know:

- what elements are relevant to define the system,
- what relationships exist between these elements
- what rationale is used to select elements and relationships,
- what goals are pursued by evaluating this system,
- what relationships exist between this and other systems.

In the first place, we want to know what the outputs (Y) are of the land use system (outputs in the form of goods (like timber, fuel wood, fruit) as well as in the form of services (soil conservation, recreation, etc.). At the same time we want to know what inputs (I) are needed. Secondly, to understand how inputs interact in the system and how outputs are derived from the system, we have to know which elements define the two subsystems: the land unit and the land utilization type. For the land unit these elements are the land qualities (LQ); for the land utilization types they are the key attributes determining the land use requirements (LUR) of each LUT. With this information we can draw up a more detailed diagram of the land use system (Fig. 1).

Fig. 1. A diagrammatic representation of the major elements of the land use system.



Of course the dimensions expressing land qualities and land use requirements should be similar, otherwise we cannot compare them. To predict the behaviour of this land use system we also need information on the relationships between I, LQ, LUR and Y. Although this information should preferably be as quantitative as possible, this will often be impossible, in which case qualitative information will have to be satisfactory. LUR and LQ are variable and dynamic in time; therefore, we also have to describe what the above relationships are expected to be at various stages in the future.
The main rationale for selecting elements and relationships is the understanding that we cannot handle too much data in such a land use system. A selection of LQs and LURs has to be made so that only necessary data is included.
Basically the goal of evaluating these land use systems is to facilitate the decisions on optimal land use: those land use systems that together reach the goal of optimal land use are selected.
As each land use system is again part of a larger system (e.g. the whole environment, a watershed, a geographic planning unit), the interactions of each land use system in its larger system also have to be known.

The relation structures of the land use system

In other papers ample attention is given to land use requirements and to land qualities. This paper will emphasize the relationships between inputs, land qualities and land use requirements, and outputs.

There are many studies done on the relationships between land qualities and outputs (e.g. soil characteristics and wood growth in many site classifications in forestry). There are certainly also examples of the studies of the effects of inputs on land qualities (e.g. the effect of irrigation on water availability, of basic phosphate dressings on nutrient availability). And there are many studies where inputs and outputs are directly compared. However, these three relationships are very rarely studied within the same model. One of the purposes of land evaluation is to give proper attention to all three relationships. Many of the studies dealing with only one of these relationships can be called black box models. This might especially be true for studies comparing inputs and outputs directly, as in many economic evaluations. You add something and you get an output, you add some more fertilizer and you get some more output. In land evaluation it is attempted to make the needed data analysis more functional, to understand the interacting processes in the (land use) system between inputs and land qualities and land qualities and outputs and so between inputs and outputs. In other words, an attempt is made to open the above mentioned black boxes.

Knowing the fundamental rules of a land use system consisting of a structure of relationships, it may be easier to predict the effect of the inputs on the outputs. Therefore, having knowledge of the three relationships and having good information on two of the elements (e.g. land qualities and outputs), can make it possible to better predict the third element: inputs. In the end such an integrated study of elements and relationships will save time and money, and it may also increase the possibility of transfer of knowledge.

There is a fourth relationship interfering with the first three: the relationship between land qualities and land use requirements or better the degree of adaptation between them. This relationship has its effect on the level of outputs and the need for inputs. This will be discussed in a subsequent paragraph of this paper.

As has been stated before, it must be kept in mind that these relationships are dynamic. Their nature will change with time. Although this aspect might be especially important in forestry, it is also important in land evaluations for agriculture requiring long-term predictions. In forestry the land use requirements of a tree stand, the inputs and outputs and even the land qualities may change due to the maturing of the stand. In agriculture over longer periods of time, desalinization, irrigation and drainage may influence the land qualities, the need for other inputs, outputs and cropping patterns.

Monitoring the elements, in this respect, is a very important means to update our knowledge on the relevant relationships in a land use system, e.g. to measure modifications within a shifting cultivation system.

A summary of the land evaluation procedure

Before discussing several aspects of land use systems and land evaluation in more detail, a short summary of the land evaluation procedure is presented, emphasizing the simulation processes within. The whole cycle of simulation consists roughly of the following:

I. Problem analysis: At the outset of a land evaluation study there is the present situation with one or more kinds of land use and one or more different land units. In short, the existing land use systems have to be studied and their limitations indicated. At the same time the socio-economic development situation has to be assessed.

II. In an abstraction phase descriptive models are made of newly proposed land use systems, thus combinations of land units and land utilization types. Abstraction because of the descriptive nature of these models of "real" systems. Only those data on land and land use, which are needed in the further evaluation procedure, are considered.

III. Deduction: Through deduction we try to select optimal land use systems. This deduction is done in two separate steps (Beek, 1978):

   a. Descriptive analysis.

      Input-output analysis: comparison of physical inputs that will ameliorate constraining land conditions, their management and conservation, with the effects or "outputs" to be expected from such inputs. Each input-output combination is handled as a separate option.

      This information is needed for the next step.

b. Prescriptive analysis.

Land suitability classification: classification of the suitability of a particular land unit for combination with a particular land utilization type.

Land units of comparable suitability are combined in the same land suitability class.

During the land suitability classification the best input-output combination for each LU, LUT combination is selected.

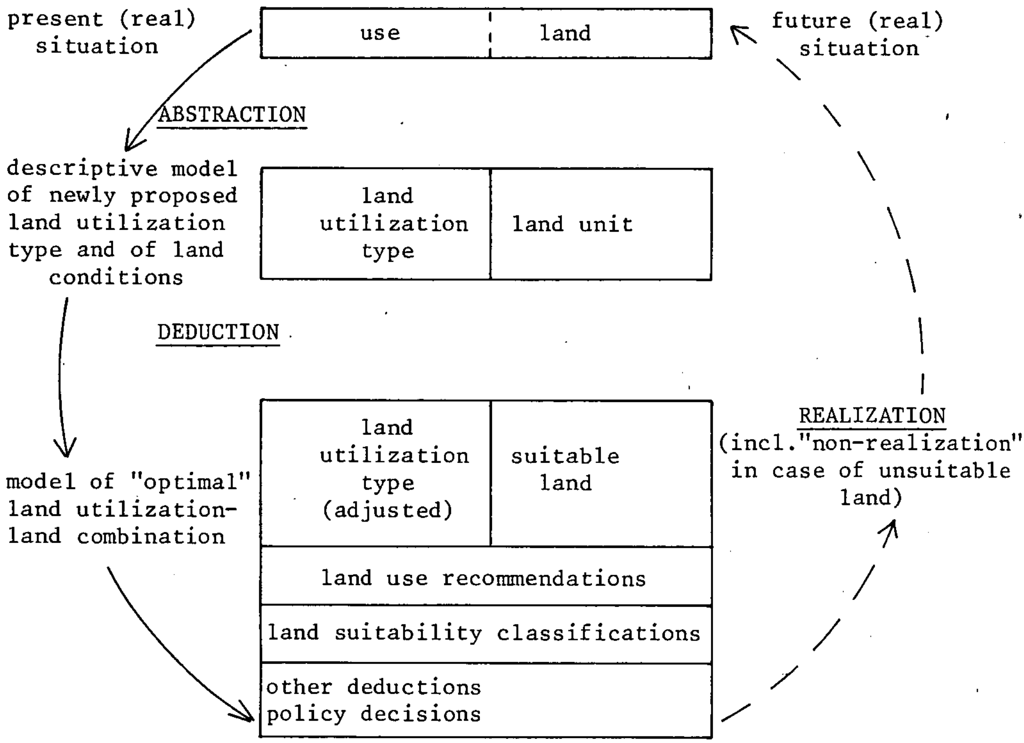
This is the combination that places the land unit in the highest possible suitability class if operated by the land utilization type in question. Thus land suitability classification is a type of optimization process.

Many of the deduction processes can also be called a kind of "matching", in which inputs and outputs, land qualities and land use requirements are combined in an optimal way. "Matching" will be elaborated on in subsequent paragraphs.

IV. The last step of the cycle is the realization of recommendations. This cannot be done, however, before the entire land use planning process (of which land evaluation only forms a part) has been completed and the necessary policy decisions have been made.

Figure 2 (Beek, 1978) summarizes the cycle followed in a systems approach to land evaluation.

Fig. 2. The cycle of a systems approach to solving land use problems.



Important aspects related to a systems approach to land evaluation

What are the main questions asked in land evaluation?

In view of the points made in the above paragraphs, we can underline the main questions to be answered by a land evaluation study. These questions relate to:

- Productivity (output), Y,
- Inputs, I,
- status Land Qualities, LQ,
- status Land Utilization Types (LUT) and Land Use Systems (LUS),
- location and extension of Land (evaluation) Units, LU.

Of course, we want to know what the products of the land use systems we propose will be in terms of goods (wood, fruit) as well as in terms of

services (clean ground water, recreation). We certainly also want to know which and how many inputs are needed to acquire these outputs.
However, we also want to monitor and predict what will happen to the land qualities, with or without inputs, for better or for worse. What irreversible changes may occur in natural fertility level, in soil structure, in microclimate, in drainage conditions, in erodibility, etc. It is a very important task of land evaluation, and one of the main tasks in physical land classification, to predict these environmental impacts for the medium and the long term.
The status of land utilization types and land use systems might be less important in agriculture. In forestry, however, this is probably a most important point requiring information because of the often long rotations, the difficulty to change decisions made earlier, and the mere fact that forest vegetations are almost always ecosystems with a very complex set of interactions.
It might be underlined here that we can often answer these questions descriptively, without saying if it is good or bad. An important part of the land evaluation task has probably already been fulfilled if we can provide descriptive answers to the above questions as well as information on the location and extension of land units and their grouping into land evaluation units. Descriptive here means providing information without indicating relative suitability compared to other possibilities, as opposed to a prescriptive approach.

How does vegetation fit into the land use system model?

Whether vegetation belongs to the land unit or to the land utilization type when considering the land use system model is indeed debatable. In many land inventories, vegetation is certainly considered to be an integral part of any land unit. In forestry, vegetation is often an important component of the environment in which wood is produced. This is very clear in mixed tropical high forest, where vegetation is essential, for without it the high-quality wood species cannot be produced. In this case there are certainly reasons to associate vegetation with the land unit subsystem. But this can also be true in other forestry situations. Another case is lifestock breeding where vegetation, the grass, could also be associated with the land. In agriculture, however, vegetation is mostly completely identical with the crop, the produce of the land utilization type. It will probably remain an arbitrary decision, depending on the purpose and the expected produce. Summarizing we might say that vegetation is often produce as well as the medium to that produce.

Land Use Requirements versus Land Qualities

As mentioned earlier, in the abstraction phase of the land evaluation process a list is made of relevant land utilization types, which combined with the land units can form an optional set of land use systems. Afterwards a process called "matching" is started, corresponding with the first step of the deduction phase. In principle, this matching process has to be done for all the combinations of relevant land utilization types and land units. For each combination, a proposed land use system, the matching consists basically of the following:

- an analysis to deduce to what extent the land unit is suited to the land utilization type;
- an analysis to explore how land unit and land utilization type can better be adapted to each other. This can be done by improving the land qualities of the land units with inputs and/or by modifying the land utilization type and therewith its land use requirements.
- a prediction of the effects of these inputs on the land qualities;
- an input-output analysis comparing the inputs with the outputs resulting from the effects of the inputs on the land use system.

The result will be a list of possible combinations of modified land utilization types and land units with improved or unimproved land qualities, together with specifications of inputs and necessary costs to achieve these modifications, of impact of inputs on land qualities and of outputs expected from these combinations.

Although inputs and outputs are important elements of this matching process, its main focus is the confrontation of land qualities with land use requirements. They are the ultimate abstractions of land unit and land utilization type. It is by them that land and land use are compared to select optimal combinations. It is therefore imperative that both LQ and LUR be formulated in the same dimension. If a land use requirement is "high moisture

availability", it is preferable that this be expressed in the same physical terms as the land quality "moisture availability", for instance in mm.
In reality, this matching consists of an iterative process of a series of approximations. At the outset of a land evaluation project only general information on LUTs and land units will be available. In the course of the project more detailed data becomes available and the more one knows, the more one can adjust. Therefore, mostly in a project taking several years, this matching and adjustment of inputs and outputs, of land qualities and land use requirements will be repeated several times before a final recommendation is reached. It is a process requiring experience, a high reference level and much common sense.
It might be underlined here that this matching process indeed makes up a very important part of a land evaluation project. It is this matching of land use requirements with the land qualities for a specific combination of land utilization type and land unit (LUT-LU combination or land use system, LUS) which indicates the suitability of a given tract of land for a certain use.

Inputs and improvements

We can distinguish between recurrent and non-recurrent inputs. Recurrent inputs are applied to the land in regular time intervals, once a year, every month or even every week. Examples are yearly fertilizer applications, daily water gifts by irrigation; they can also consist of other minor land improvements as yearly ditching to improve field drainage.
Non-recurrent inputs are applied only once. They will often have the nature of major land improvements, being permanent and irreversible and requiring important capital investments. Examples of major land improvements in forestry are the opening up of forests, breaking of hard-pans, deep ploughing, drainage of swamps and peat soils, installation of irrigation systems for tree plantations in semi-arid regions, terracing, soil conservation measures and also establishment of plantation forest (as is the case in the Dutch Flevopolders, where poplar plantations on recently reclaimed soils in Flevoland are irreversibly changing soil conditions). However, non-recurrent inputs are not necessarily always major land improvements, as in the case of clearing of stumps or the one-time application of a basic phosphate

dressing, which do not require a high capital investment or are not of a really permanent nature.

In general, when speaking of inputs and improvements in the context of land evaluation, we are speaking of inputs to and improvements of the land and more specifically of the soil or land surface. There are, however, cases in which inputs are applied directly to the crop or the vegetation, e.g. spraying of insecticides or fertilizers directly onto the leaves, as is indeed the case in forestry and horticulture. The input does not go into the soil, soil fertility remains the same, the land quality availability of nutrients is not improved, but nevertheless a higher output will be produced. Still, in the case of fertilizer, a relationship between this input and soil fertility can be conceived: the spraying of fertilizer onto the leaves might prevent a further decline of the soil nutrient level.

The problem here touches in fact the point discussed earlier: is vegetation to be considered as part of the land or part of the land utilization type. If vegetation is part of the land, there is no problem: the input is an input to the land.

Another debatable case is for instance the intersowing with lupins. Is this to be considered as a modification of the land use (LUT) or can it also be seen as an improvement of the land (improving soil fertility)?

In general, however, to keep our model of a land use system (LUS) as simple as possible, inputs to and improvement of land should be distinguished from modifications of the LUT (such as other exploitation techniques, change from hand to power saw, thinning practices, spacing of trees).

Information on inputs is important for our understanding of two important relations: Inputs/Land Qualities and Inputs/Outputs. In the first case, I/LQ, we need information specifically on kind and quantity of inputs. In the second case, I/Y, information on cost of inputs is most useful. The information on and understanding of these relationships is not only important for a descriptive land evaluation, but also for a more prescriptive evaluation in which the suitability classification has an important part. Although in the descriptive part it can already be concluded if the application of an input is technically possible and desirable, in the prescriptive part it must be concluded if the application is really suitable in view of other alternatives and in view of the costs related to the value of the outputs.

Of course, there can also be different levels of inputs and improvements corresponding with lower or higher levels of technology, requiring cheaper or more expensive inputs.
In the context of irreversible changes of the land one should also consider negative changes, especially measures such as clearfelling of natural forests which can cause e.g. the formation of hard plinthite layers or the loss of the upper soil horizons by erosion. Also, such changes involve costs that have to be included in a land suitability assessment.

Goals pursued with land evaluation

The overall goal of land evaluation is, of course, to arrive at recommendations for optimal land use. This rather abstract formulation can be made more precise by defining realistic land use objectives.
Examples of general land use objectives can be:

- adequate food supply for rural population,
- agricultural production for export,
- sustained production of the land,
- conservation of the environment,
- recreation,
- high labour employment in agricultural production.

More specific examples of land use objectives geared to forestry can be:

- adequate supply of fuel wood,
- timber, pulpwood production,
- conservation of natural forests,
- protection against erosion,
- combined production of food and wood; agroforestry,
- storage of genes,
- provision of local household materials.

The selection of one or more of these land use objectives in a study area depends also on the socio-economic and political context of that study area, i.e. on the overall development situation, on labour and capital constraints, on government policies and objectives, on the objectives of the local population. This political, social and economic environment imposes constraints on the land use making one land use objective more relevant than another. Information on these objectives is necessary to know the range within which technically and physically possible types of land use are confined. In other words, the political and socio-economic context of an area provides important references for setting the standards for a physical suitability classification, here called land suitability criteria. In the paper "Land Utilization Types for Forestry" ample attention is given to defining land use objectives.

Once these land use objectives are defined it will be a further task of land evaluation to decide how these land use objectives can be met optimally, thus fulfilling the goal of optimal land use. This to be recommended optimal land use also depends on the land conditions and the relevant land utilization types or in short, on the relevant land use systems.

To achieve these recommendations on optimal land use, the following deductions are made, corresponding with step 2 of the deduction phase discussed earlier. The proposed "possible" models of land use systems, resulting from the matching process described before, are now matched with the land use objectives. This is done by a land suitability classification for which land suitability criteria are necessary. In other words, although we know, as a result of the matching process, which land unit can be combined to what extent with which land utilization type, the suitability of such a combination in view of the defined land use objectives still has to be assessed. If, for instance, one of the land suitability criteria is that "only a very low level of soil loss is tolerable" because "protection against erosion" is an important land use objective, then the land use system in question that cannot meet this criterion is unsuitable.

The above is illustrated in Fig. 3.

Criteria for land suitability classification

The paper "Land Utilization Types for Forestry" explains how land utilization types are defined. An important step is the selection of relevant land use objectives. The same land use objectives are equally important for the preparation of standards for land suitability classes or land suitability criteria. To this end the same sources of information, the same major and minor determinants of land use, are relevant.

The essence of a land suitability classification is to judge to what extent land use objectives are met by the proposed "possible" land use systems; the

Table 1. Land suitability criteria (Beek and Bennema, 1972).

(A) BIOLOGICAL CRITERIA

choice of adapted crops (wide/limited)
yield (high/low)
performance reliability (regular/irregular)
multi annual yield trend (marginal net return rising/sustained/falling)

(B) SOIL MANAGEMENT CRITERIA

timing of field operations (flexible/fixed)
choice of adapted field equipment (wide/limited)
performance of field equipment (high/low)
seedbed quality (high/low)

(C) CONSERVATION CRITERIA

trends in land degradation (improving/sustained/falling)
change in landscape situation (improving/sustained/falling)
hazards for the introduction of endemic diseases (absent/present)

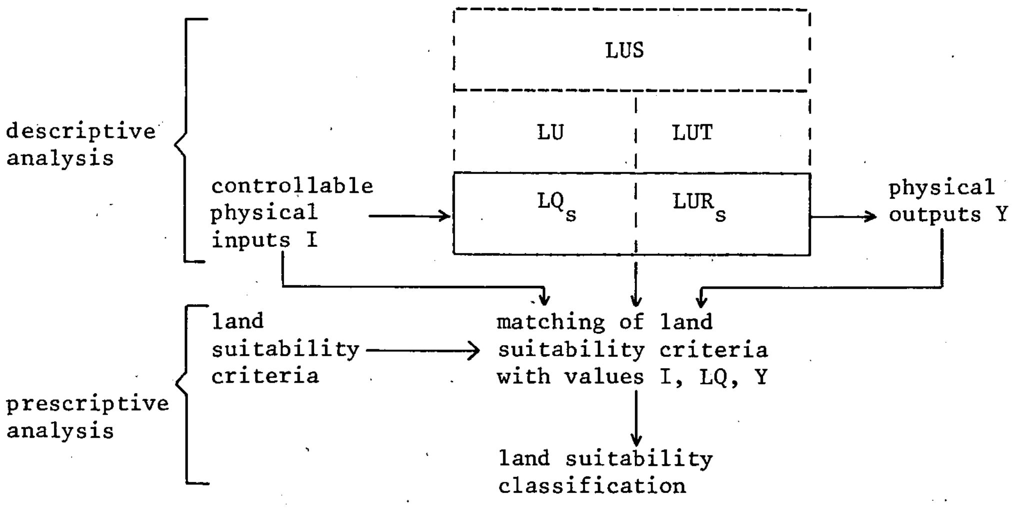
(D) DIVERSIFICATION CRITERIA

land resource allocation (enterprise proportions fixed/limited)
degree of land use intensity (intensive/extensive)
carrying capacity (close/far from proposed utilization)
resource use alternatives (many/few)
elasticity in selection of plot/farm size and shape (free/limited)

(E) ECONOMIC CRITERIA

employment absorption (high/low)
production costs (high/low)
benefits (high/low)
cost of land improvement (high/low)
repayment capacity of investments (high/low; short/long term)

Fig. 3. A diagrammatic representation of systems analysis in land evaluation (from Beek, 1978).



latter have to be assessed for their relative suitability. Each of these land use systems will meet to a certain degree a land use objective. For practical reasons the resulting scale of degrees to which a land use objective is met can be divided into suitability classes, e.g. ranging from low to high suitability.

However, land use objectives and land use systems cannot easily be compared as such. For this purpose land use objectives are translated into land suitability criteria, which are more precise reflections of land use objectives, expressed in the same dimensions as the inputs, land qualities, land use requirements and outputs, the elements defining the land use systems.

While we have been dealing with land evaluation mainly in a descriptive way until now, land suitability classification has a prescriptive nature. The definition of and agreement on land suitability criteria is then of crucial importance. On the basis of these criteria it will be decided if a land use system is considered suitable.

For each land suitability criterion the values of the land suitability classes correspond with the different degrees to which the land use objectives are met. To define the differences and the boundaries between suitability classes, critical levels have to be established. Examples of land

suitability criteria are given in Table 1.
The final land suitability classification has to take into account more than one land suitability criterion, rarely expressed in the same dimension. Land suitability classes are therefore mostly verbal descriptions, dealing separately with the different land suitability criteria and the degree to which these classes meet the respective land use objectives.
When all these different criteria have to be taken into account in the same final land suitability classification, such a classification may become too complex and unpractical and therefore meaningless for land use planners.
To avoid squeezing too many criteria in the land suitability classes it is recommended to separate conclusions related to the different criteria, for instance in tabular form, and not to pay too much attention to aggragating multi-dimensional variables. Table 2 gives a very simple example of four land suitability classes defined separately for yield and soil loss. Another possibility is to present an environmental hazard map and separate tables with inputs and outputs for the land use systems concerned.

Table 2. Specification of land suitability classes.
An example.

CLASS	c_1 -yield kg/ha	c_2 -erosion losses kg/ha
I	> 5000	0 - 100
II	4000 - 5000	100 - 200
	3000 - 4000	0 - 100
III	3000 - 4000	100 - 200
IV	< 3000	> 200

Distinctions in land evaluation approaches

Depending on purpose and expected detail of the results, different aspects of the land evaluation can be emphasized. Three important distinctions are the following:

Internal versus overall land evaluation

Internal land evaluation means evaluation of the suitability of each land use system without considering its external effects. However, the selection of such a land use system or combination of land unit and land utilization type will also have repercussions on other land units or on the selection of other LUTs on other land units. For instance, an erosion-conducive LUT in the upper parts of a watershed can have downstream effects. The evaluation of such impacts and effects has to be part of an overall land suitability assessment.

Descriptive versus prescriptive land evaluation

The field studies and surveys, the definition of land utilization types, t rating of land properties and land qualities, the expression of the land u requirements, all are of a descriptive nature. Also the description of lan use systems, the matching of land qualities with land use requirements, th analysis of necessary inputs and expected outputs, the identification of e fects of inputs on land qualities are part of descriptive land evaluation. No qualification is given on suitability.

For a prescriptive or normative classification we need norms to distingui between good and bad land, between class 1, 2, 3, 4 and 5. In land evaluation these norms are expressed by the land suitability criteria.

It is, of course, an important goal of land evaluation to provide recomme dations on suitability. However, a good descriptive evaluation with a precise analysis of land limitations and land use requirements is already an important result.

Physical versus integral land evaluation

Physical land evaluation concerns the bio-physical aspects of land and la use. In this classification, inputs and outputs are expressed in physical terms, distinct from an integral land evaluation in which the variables a commensurated and expressed as far as possible in monetary terms. An inte gral land evaluation includes the physical as well as the socio-economic evaluation. Often the socio-economic evaluation will follow the physical evaluation; in other cases the two can be done synchronously.

Conclusions and recommendations

An important aim of this land evaluation approach is to select, integrate and analyse the relevant data systematically, presenting the results as simple as possible. It is a continuous exercise fitting well in other modern concepts of data analysis, of modelling multi-dimensional components in environmental planning, of monitoring dynamic system modelling, of simulating land use processes, etc.

There are tendencies in the world towards strong specialization of disciplines and mono-disciplinary studies of the components of land and land use. The authors of this paper, however, want to emphasize the need for more integration and more interdisciplinary teams in land evaluation and generally in land resource studies. This may not always be possible, but the more surveys become problem oriented, especially on detailed, implementary scales, the stronger the need for cooperation between physical scientists, economists, sociologists and planners.

An important question is still unanswered: How detailed must the land evaluation results be for use by economists and land use planners, at different scales and purposes. Physical scientists tend to include too many factors, paying too much attention to the detailed aspects of their disciplines, making it difficult for economists and planners to absorb and use the necessary results. Therefore it is indeed necessary to simplify the data base, to select only those data relevant for the purposes of the study by presenting results as clear and simple as possible.

There are good arguments for integrating land evaluation in a broader scheme of land use planning. It has to be realized, then, that land evaluation makes up only a small part of the whole land use planning process. To what extent economists, planners and investors are indeed interested in such an integration of land evaluation in their planning procedures must be investigated.

A more consistent dialogue with planners and economists, who are to apply the land evaluation results, is necessary. Such a dialogue could be structured by identifying in an early stage the kind of problems to be solved together with these disciplines. In this respect, deciding on the desired mapping scale is one important problem.

An important recommendation to make the land evaluation approach more specific is to develop separate guidelines for land evaluation/land use planning at different levels of details, for different broad development issues as well as for different agro-ecological zones.

FAO has already prepared draft documents on land evaluation for rainfed and irrigated crops. This could also be done for forestry and grazing.

Different guidelines could also be made for different broad agri-ecological zones as the semi-arid, sub-humid, humid, tropical, subtropical and temperate environments or even more specific for the Sahel zone, tropical Southeast Asia, mountainous monsoon regions in Asia, the Amazone Basin.

REFERENCES

BEEK, K.J. (1978). Land evaluation for agricultural development. ILRI publication no. 23, Wageningen.

BEEK, K.J. (1980). From soil survey interpretation to land evaluation. In Land reclamation and water management. ILRI publication no. 27, Wageningen.

BEEK, K.J. and J. BENNEMA (1972). Land evaluation for agricultural land use planning. An ecological methodology. Dept. Soil Sci. and Geology, Univ. of Agric., Wageningen.

BEEK, K.J. and H.A. LUNING (1980). De rol van het landgebruik in de land-evaluatie (The role of land use in land evaluation). Landbouwkundig Tijdschrift 92 (2): 43-48.

BENNEMA, J. (1980). Wat is landevaluatie (What is land evaluation)? Landbouwkundig Tijdschrift 92 (2): 35-41.

FAO (1976). A framework for land evaluation. Soils Bulletin FAO, Rome, no. 32. ILRI publication no. 22, Wageningen.

HAANS, J.C.F.M. (ed.) (1977). De interpretatie van bodemkaarten (Soil map interpretation). Stiboka, report no. 1463, Wageningen.

MCCORMACK, R.J. (1972). Land capability classification for forestry. The Canada Land Inventory Report no. 4, Ottawa.

SCHALKWIJK, J.A. Land capability for forestry, sheet Tawatinaw 83 I. The Canada Land Inventory no. REG 4/3 - 83 I, Ottawa.

Terrain classification for Swedish forestry (1969). Skogsarbeten (Logging Research Foundation), report no. 9, Stockholm.

TOEBES, G.H. (1975). Lecture notes of a course on systems analysis. Spring 1975. Agricultural University, Wageningen.

PROBLEMS OF LAND SUITABILITY CLASSIFICATION FOR FORESTRY IN CENTRAL-EUROPE

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Summary

The problems of a land suitability classification for forestry in Central Europe are represented. After a short historical review the situation of the today prevailing multiple-use forestry in Central Europe is described in detail. It is characterized on the one hand by the fact that the choice of a specific forest utilization type does not so much depend on internal suitability factors of a certain forest land unit, as on external factors like private and especially public demands and objectives. On the other hand the situation is marked by unsufficient planning informations, a fact that impedes a meaningful suitability classification at present. This is especially true for forest site determination, terrain classification, forest inventory and forest function-planning. The opinion is held that the evaluation of the suitability of certain forest land units in Central Europe is only possible after an differentiated evaluation of the potential suitability has been done, considering the given multiple forest untilitation type, the land characteristics, the potential land development as well as the social and economic conditions. Due to the lack of the respective planning-data and -techniques such a suitability classification will not be conducted in Central Europe in the near future.

Introduction

Ever since forestry on a sustained basis was first developed and applied in Central-Europe (defined here as Austria, the Federal Republic of Germany, and Switzerland), efforts have been made to classify the suitability of land for growing timber. Forest utilization types, such as coppice or age-class-systems, and types based on tree species, such as beech, spruce, or mixed forests, were usually classified by their capacity for volume growth. The physical criterion of volume growth could be used in economic calculations to determine the rate of return on invested capital or the total net return. Such classifications and calculations made it possible for forest owners to decide which of a number of alternative forest utilization types would best meet their individual goals.

This system was no longer satisfactory after public goals became most important in determining how forest land should be used. The necessity for intensive land use planning in densely populated and highly industrialized Central-Europe made it imperative to evaluate the characteristics and qualities of forest land. The almost universal competition between individual and public goals, and between different public goals on one forest land unit, create problems for determining forest utilization types, appraising the suitability of land units for each type, and developing a land suitability classification system for forestry. This paper will discuss those problems.

Conditions Affecting Land Suitability Classification in Central Europe

The conditions that affect the evaluation and classification of forest land for specific uses in Central-Europe are easier to understand if one knows something of their history.

The natural forests of Central-Europe are estimated to have occupied over 80 percent of the land area. The difference between that and the present one third of the land area, shows the loss of forest through clearing. This clearing process took place in the Middle Ages, mainly between 1100 and 1350. The uses of some lands have changed several times since then through repeated clearing and natural reforestation or artificial afforestation. But the general process had these results:

i) On most land units, forests were restricted to sites that could not be used for agriculture, at least not with the means and techniques of the times. On the bulk of the remaining forest area forestry was and still is the economic and ecologically optimal use of the land.

ii) The intensive clearing had made forests a scarce commodity by the end of the Middle Ages, not only in terms of timber supply but at least locally and regionally for their protection functions. This led to the preservation of forest land through legal means and government actions from the end of the Middle Ages on. The conversion of forest land to other land uses is no longer one of the rights of ownership. Any conversions are subject to governmental decisions in which private benefits from a change and public interests in forest preservation are carefully considered.

iii) As a result, the physical or "internal" factors of a land unit do not always decide its optimal private use, and the demands of the public for services and the effects of the forest or "external" factors must be considered.

The remaining forests in Central-Europe have been intensively used over hundreds of years. Devastation of the forests by overgrazing and overcutting and degeneration of the soils by shifting cultivation, coppice forestry and litter raking led to losses in forest productivity and soil fertility. The redevelopment of productive forests could only be achieved through a change in forest composition from natural hardwoods to evergreen species. With rare exceptions, Central-European forests are "man made", though they vary in how far they have departed from natural conditions. The susceptibility of these forests to damage (and even catastrophies) from biotic and abiotic factors is high. In spite of this, intensive planning and management for over a century have resulted in well-stocked and productive forests with a nearly normal age class distribution.

These remaining forests, already heavily modified by human utilization, have had to assume new roles as a result of the development of society during the last quarter century. Protection, recreational and ecological functions of forest land have become equal to timber production, and locally or regionally may even rank higher. The consequences can be summed up in the following points:

i) The preservation of the forest area has become one of the highest ranking goals. Changes in land use were restricted by government control to relatively small areas. Losses of forest area by unavoidable clearing have, until recently, usually been compensated for by the afforestation of submarginal agricultural land. Regional disparities in the amount of forest are large, especially between urbanized and rural areas. Current changes in land use are made through complicated planning processes on regional and/or local levels.

ii) Forest lands managed under a single-use concept for public goals are rare and on insignificant areas, such as those under full nature protection. Their suitability has to be given. Forest lands that are managed exclusively for timber production and yield social services without special expenditures do exist in rural areas but have decreased lately. Their suitability for economic timber production varies widely, but the legal management obligations of a forest owner hold for marginal and even sub-marginal forest land.

iii) Because of the scarcity of forest land and the diversity of the expected products and services, the great majority of forest lands must be managed on a multiple use concept. This means that expenditures for different uses must be made within the normal management. Multiple use can be established by free will in the management plans of a forest owner or can be enforced through legal declaration of a forest land unit as a protection or recreation forest by the government. Such a declaration can be combined with impositions and prohibitions for the management of the unit.

Whether a multiple use concept is followed and a particular forest utilization type is therefore chosen, depends not so much on the characteristics and qualities of the forest land unit - especially around concentration areas - or the given situation of the forest as on society's demand for protection and recreational services. It is not the suitability of a land unit, nor its internal factors, but rather the pressure of demand, the external factors, that force the selection of specific forest utilization types. In the vicinity of large cities, for example, forests are often intensively used for recreation in spite of unsuitable soil types, low erosion resistance, high fire hazard, steady noise level, and large monocultures.

A further special problem of land suitability classification is found in Central-Europe where two or three kinds of land use overlap on one forest unit. This is true for hunting on most forest land and for grazing on much of it in the Central European Alps. In many cases the people who use the land for hunting or grazing are not identical with the land owner and forest manager. The goals of the different users are competitive, the coordination is poor, the responsible government agencies are in controversy, and the results are detrimental for the forest. Very often proper relationships do not exist between the characteristics and qualities of the land, the chosen forest utilization type, and the grazing and/or hunting use.

The Situation of Land Evaluation for Forestry in Central-Europe

Until about a decade ago, land evaluation for forestry in Central-Europe was restricted to management planning for single units of various sizes. Planning concentrated mainly on decisions about the management system - such as coppice, selection, or age class - species composition, rotation length, and silvicultural treatment. The criteria for such decisions were not exclusively economic but took intangible benefits such as erosion protection, nature conservation, and aesthetic values into consideration.

In contrast to the economic criteria, benefits were not assessed in phyysical terms. Until the middle of this century, alternative use types were based on expected volume growth rates derived from a comparison of the height of tree species at a given age on the ground and the existing yield tables for that species. Only since then has the assessment of land characteristics and their transformation into so-called "site maps" become an important instrument of planting. Such site maps, which show the suitability of different forest utilization types on the given site types, actually exist for less than half of the total forest area.

A forest terrain classification that would assess land qualities related to management and working conditions is not yet available at all. Such a terrain classification with its information about travel conditions and accessibility - and therewith possible working systems, needed investments and expected expenditures - would complement most effectively the more biologically oriented information on site maps. A descriptive forest terrain classification system based on soil conditions, microtopography, and degree and form of slope, that would not be limited to Central-Europe was proposed by Loeffler (1979). There are no clear indications that the Central European forests will be classified by such a terrain classification system within any reasonable period of time.

The compilation of such a forest terrain classification could be combined with a mathematical/statistical forest inventory without difficulties. The inventory would be an important supplement to the site classification. It would allow us to judge to what degree the current forest resource is suitable to its land base and to compare the present situation with a potential one that showed a better or even an optimal suitability. The necessary improvements could be deduced and their realization planned in long term programs. It may be surprising that in Central Europe, the cradle of modern sustained forestry, only Austria has such an inventory available (Braun, 1974). In the Federal Republic of Germany, the state of Bavaria is the only one that has run a statewide inventory and compiled a forecast of its timber resources (Franz, 1973, 1976). A federal forest inventory is only in the planning stage. Switzerland too is still in the discussion stage of a national forest inventory, despite the fact that the preparatory work for such an inventory has been completed.

This short review of the existing situation shows what restricted and poor data and material were available for a land and resource evaluation for forestry at the time that land use planning started on national, state and regional levels in Central-Europe. This was regrettable because the modern forest legislation passed during the 1970s in Austria and the Federal Republic of Germany ordered the responsible public forest services to furnish forest planning contributions to the state and regional planning processes. That planning had to be done on the basis of the public objectives and goals that the forest legislation had laid down.

The handicap of such planning stems from the fact that these general goals and objectives do not allow one to determine the regional or local goals and objectives for individual forest land units with consideration of their external and internal factors, or to draw the consequences for their management.

Austria and all of the states of the Federal Republic of Germany have developed different, but basically similar methods, to integrate forestry into the general land use planning process. Surveying crews studied on the ground which social services and/or effects have to be rendered by each treatment unit of a forest enterprise. Forests were classified as different types of protection forests against natural dangers like erosion, avalanches and water draining, protection of forests against civilization dangers like noise, emissions, water pollution, and recreation forests. One treatment unit can belong to a number of such types, which can be brought into a hierarchical order. It is not the land characteristics or qualities or the stand conditions, and therefore not the actual supply of services and effects that are decisive for such a classification, but rather the given demand situation, which means the external factors. The survey results in a type map showing the mosaic and overlapping of types and in a textual part which includes guidelines and proposals for the further management of one type or certain type mixes under given site conditions. The classification has been finished for the Federal Republic of Germany. It is under way in Austria.

The methods used have raised a series of questions and problems which are yet unsolved. They are mainly:

i) Physical terms to assess a number of services and benefits were not available or could not be investigated. The classification could therefore not be based on limiting values but had to follow estimations and subjective criteria.

ii) An assessment was also impossible because of the lack of cost-benefit analyses. The monetary value of services and benefits cannot be calculated in most cases. None of the many proposed evaluation methods has proven to be satisfactory and been accepted. There are no signs that this will change in the near future. Only in Germany has an attempt been made to investigate the higher costs and lower returns of forest enterprises per hectare and year that result from production of forest recreation and other services (Kroth, 1976). That investigation was only able to show the average burden and its variation in certain regions like concentration areas or rural areas without tourist industry. It could not relate the costs to classification types. The social costs and benefits of different classification types, which can also be considered as utilization types, are therefore not available now and will not be in the foreseeable future.

iii) A suitability evaluation was not part of the forest planning process for land characteristics and qualities nor for the actual forest conditions. Although such evaluation methods have been developed theoretically and tested practically for recreation forests by Gundermann (1972) and by Ruppert (1971) as well as for erosion protection forests by Gundermann (1974), they have not been applied in practical work. The planning of an optimal forest condition and the evaluation of a potential suitability classification is therefore just as impossible as the calculation of the necessary investment and the optimal allocation of the always limited funds.

iv) Central European multiple use forestry has to overcome yet another handicap. The classification of a certain treatment unit in one or a number of forest protection or forest recreation types does not determine what would be the optimal production mix of goods and services. Such an optimization is a basic requirement for management planning following such a classification. But methods and techniques to accomplish that task have not yet been developed. Goal programming and linear programming with combined optimization - two methods now used in the USA - have not yet been adopted in Central Europe (Sinden and Worrell, 1979, Bell, 1977).

Consequences for a Land Suitability Evaluation for Forestry in Central Europe

A classification of land by suitability orders which indicate whether it is suitable or not for major kinds of land use is no longer needed on national, regional or even local bases in Central Europe. Through a historical process of one thousand years the present pattern of major kinds of land use has been formed. Today that pattern is rather strictly set and offers only minor opportunities for deviation. Where the land use is changed, the reason is more likely to be public demands than private interests. Moreover before any change can take place, the case must pass through a planning or investigation and permission process by government authorities. The suitability evaluation is therefore case bound and not an object on larger land units. A classification system in these respects is not necessary.

That leads to the question of whether a land suitability evaluation is adequate or necessary where forestry is the present as well as the future land use. The intensive utilization of practically all forest land over hundreds of years and the management of forests on a sustained basis for 100 to 200 years has in itself served as a suitability evaluation for the proper kind or type of forest use, at least in respect to timber production. Allowing for some exceptions, the question has already been answered whether a particular forest land unit is more suitable for a coppice or an age class management respectively for beech or pine forests. Only the social development in Central Europe during the last quarter century and the concomitant new demands for forest services has produced a need for a new planning and evaluation process. Society expects that large areas or proportions of forest land will be managed for multiple use, if one defines this as: "more than one kind of use simultaneously undertaken on the same area of land, each use having its own inputs, requirements and produce" (A Framework for Land Evaluation, ILRI 1977).

Because multiple land use requires inputs in non-timber uses which produce mostly "unpriced values", such use is mainly in the public and not the private interest. The consequence is that multiple land use places restrictions on the private forest land owner in the free use of his property. These can either be considered as his social obligation or as an expropriation with the right to public compensation. But any such restrictions must have a legal base. So a land suitability evaluation in Central Europe only makes sense if it can be based on forest utilization types that are classified according to the respective forest or nature protection laws. A unique classification scheme for Central Europe is therefore impossible.

Multiple forest utilization types normally combine timber production and hunting with one of the protection uses, the recreation use, or a combination of them. Nature conservation or the maintenance of close-to-natural forest situations can be another kind of use, which grows in importance as forests become more valuable as regeneration areas for nature (Haber, 1972, Odum, 1973). The classification of such multiple use forest types must be based not on internal factors but on social demand or external factors such as protection against dangers caused by civilization, recreation, or even protection against natural dangers.

The services and intangible benefits produced by such multiple use types do not depend primarily on the land's characteristics, but on the situation of the forests growing on it. This means that an evaluation of the current suitability of forest land units is only possible after an evaluation of their potential suitability has been made, which considers the multiple use type, the land characteristics and qualities, the potential stand development, and the social and economic conditions. In other words, under the given circumstances in Central-Europe, a determination of the optimum multiple forest use type is a basic prerequisite to the evaluation of its current land suitability. Only such an optimization would allow one to calculate the opportunity costs, any required compensation, and the needed investments, and to allocate the available funds according to their maximum effectiveness.

The forests in the Federal Republic of Germany have been - and the ones in Austria are on their way to being - classified by multiple forest use types which are based mainly on external factors. An accompanying evaluation of the current land suitability was not possible, because

i) land characteristics and land qualities are surveyed by site classifications on only part of the forest land; a terrain classification is not undertaken;

ii) Forest inventories are available only for Austria and Bavaria;

iii) an optimization is not undertaken because optimization techniques and methods for practical application have not yet been developed.

Even to the extent that classification of multiple forest land use types has so far been completed in Central-Europe, the work has not been carried on to an evaluation of land suitability, and this will not be done for some time. The lack of such an evaluation of current and potential suitability is a handicap for a goal-oriented forest policy.

References

ANN., 1974. Arbeitsanweisung für den Waldfunktionsplan. Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, München, 49 S.

ANN., 1977. Leitfaden zur Forstlichen Rahmenplanung FRP. Arbeitskreis Zustandserfassung und Planung der Arbeitsgemeinschaft Forsteinrichtung, Arbeitsgruppe Landespflege. Sauerlaender's Verlag, Frankfurt a.M., 64 S.

ANN., 1978. Forstliche Standortsaufnahme. Arbeitskreis Standortskartierung in der Arbeitsgemeinschaft Forsteinrichtung. Landwirtschaftsverlag GmbH., Münster-Hiltrup, 183 S.

ANN., 1975. Forstpolitisches Programm des Schweiz. Forstvereins (SFV), Eidg. Technische Hochschule, Zürich, 23 S.

ANN., 1974. Leitfaden zur Kartierung der Schutz- und Erholungsfunktionen des Waldes (Waldfunktionenkartierung) WFP. Arbeitskreis Zustandserfassung und Planung der Arbeitsgemeinschaft Forsteinrichtung, Arbeitsgruppe Landespflege. Sauerlaender's Verlag, Frankfurt a.M., 80 S.

BELL, E.F. 1977. Mathematical Programming in Forestry. Journ. of Forestry, vol. 75 (6): 317-319.

BRAUN, R. 1974. Die methodische Entwicklung der österreichischen Forstinventuren. In: 100 Jahre Forstliche Bundesversuchsanstalt Wien: 173-222.

FRANZ, F. 1973. Einführung in die Methode der Waldinventur und Darstellung der Auswertungsmöglichkeiten. In: W. Kroth, R. Plochmann. Ergebnisse der Bayerischen Waldinventur 1970/71 -: Folgerungen für die Forst- und Holzwirtschaft - Forschungsberichte FFA München (16): 1-25.

FRANZ, F. 1976. Verfahrensgrundlagen der Holzaufkommensprognose für Bayern. In: W.Kroth, R.Plochmann. Die Holzaufkommensprognose für Bayern - Folgerungen für die Forst- und Holzwirtschaft - Forschungsberichte FFA München (29): 2-10.

GÖTSCH, H. 1977. Grundlagen der österreichischen Forstwirtschaftspolitik. Wagner'sche Universitätsbuchhandlung, Innsbruck, 139 S.

GUNDERMANN, E. 1978. Die Beurteilung der Umwelteinwirkungen von Forststrassen im Hochgebirge. Eine Delphi-Studie. Forschungsberichte FFA München (41), 453 S.

HABER, W. 1972. Grundsätze einer ökologischen Theorie der Landnutzungsplanung. Journ. Innere Kolonisation Jg. 21 (11): 294-298.

HENNE, A. 1976. Ziele, Zielgewichte und Nutzwertanalyse in der mittelfristigen forstlichen Planung. Journ. Allgemeine Forstzeitschrift Jg. 31: 675-681.

ILRI INTERNATIONAL INSTITUTE FOR LAND RECLAMATION AND IMPROVEMENT, 1977. A framework for land evaluation. Publication No.22, 87 p.

KOELLE, H.H. 1975. Zur Berücksichtigung von Interdependenzen bei Entscheidungsprozessen. Journ. Analysen und Prognosen über die Welt von morgen (38): 19-22.

KROTH, W. 1976. Beitrag der Forstwirtschaft zur Infrasturktur. Journ. Der Forst- und Holzwirt Jg. 31 (21): 433-436.

KURTH, A. 1967. Ein forstliches Landesinventar als Grundlage schweizerischer Forstpolitik. Journ. Wald und Holz Jg. 49 (4): 94-100.

LÖFFLER, H. 1979. Forsttechnische Geländeklassifikation. Journ. Forsttechnische Informationen Jg. 31 (12): 89-92.

ODUM, E.P. 1973. Ökologie 3. Auflage, BLV Verlagsgesellschaft München, Basel, Wien.

RUPPERT, K. 1971. Zur Beurteilung der Erholungsfunktion siedlungsnaher Wälder. Mitteilungen der Hessischen Landesforstverwaltung (8) 142 S.

SCHROEDER, M. und K.-H. GÜNTHER, 1979. Wald und Grundwasser, in: K.-H.Günther. Wald und Wasser. Schriftenreihe des Deutschen Verbandes für Wasserwirtschaft und Kulturbau (41): 71-84.

SINDEN, J.A. and A.C. WORRELL, 1979. Unpriced Values Decisions without Market Prices. "A Wiley-Interscience Publication", John Wiley & Sons, New York, 511 p.

ULRICH, B., MAYER, R. and P.K. KHANA, 1979. Deposition von Luftverunreinigungen und ihre Auswirkungen in Waldökosystemen im Solling. Schriften aus der Forstlichen Fakultät der Universität Göttingen und der Niedersächsischen Forstlichen Versuchsanstalt Bd. 58, 291 S.

WULLSCHLEGER, E. und F. MAHRER, 1976. Der Informationsgehalt des Schweizerischen Landesforstinventars (LFI), in: Festschrift Alfred KURT Beiheft zu den Zeitschriften des Schweizerischen Forstvereins (57): 234-245.

APPLICATION OF THE FRAMEWORK FOR LAND EVALUATION TO FORESTRY IN DEVELOPING COUNTRIES

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Summary

The Framework for Land Evaluation was developed by international collaboration to facilitate the classification of land suitability for specific uses particularly in the developing countries. Some of the main objectives, principles, features and shortcomings are outlined in relation to their significance for classifying land units for multipurpose forestry. The Framework is well adapted to plantation and intensive forestry and can be used for existing forests and savanna woodland. Preparation of a practical manual of land evaluation for forestry is proposed.

Introduction

FAO has for many years been involved in classifying land suitability for various forms of development. The Framework for Land Evaluation was developed, by international consultation and collaboration over a period of years, in order to reduce duplication of effort and to facilitate transfer of technology by a degree of standardization in working methods. The principles embodied in it are intended to be universally applicable, and the methods proposed are sufficiently flexible to be suitable for most situations. The Framework has mostly been used as a basis for interpreting national land resource inventories and for agricultural development projects.

The classification of land suitability for specific uses is an essential preliminary to rational land use planning, both on the macro-scale at national, regional or project level, and on a micro-scale for village or farm planning. It would be an aid to land use planning to develop an internationally acceptable system for evaluation of land suitability for different kinds of forestry use, and preferably a system compatible with those used for rainfed and irrigated agriculture.

Land evaluation for forestry

The main methods used to evaluate the suitability of forest lands can be divided into two kinds:

1. forest mensuration, the site index, and the use of vegetation types as a guide;
2. evaluation of suitability of the environment by either selected diagnostic features or by a holistic approach using land units, site types or environmental ordination (Jones, 1969) as the basis.

The first group aims at a measurement or estimate of the existing forest productivity, and are analogous classifications (if used to indicate land suitability) which assume that if growth is the same the suitability is the same. This may not be very reliable when it comes to regrowth or response to management, but such methods have their value for their own specific uses, and also serve as an input into the second kind of evaluation.

The second group is site-factor or "matching" classification. That is to say, that the characteristics of the site are matched with the requirements of the forest use in order to predict the suitability, and hence the productivity, of the site for that use.

The objectives of land suitability classification depend on whether it is for a natural forest or a plantation or proposed plantation, and on the scale at which the work is to be done. They can be summarized as:

1. to make the best use of the land (particularly when forestry competes with other uses);
2. to justify proposed uses, including multipurpose use such as for soil and water conservation, recreation and timber production;
3. to help predict the results of forest management under various conditions for specified uses (for example, cutting practices or selection of species to be planted);
4. to quantify the costs and benefits as an aid to selection of the best

land use. (These may include economic and other criteria such as provision of employment, energy balance etc.)

To achieve all these objectives a site-factor land evaluation is needed. To promote transfer of forest technology requires a systematic standard methodology for such land evaluation. Because of the large areas and the commonly low unit value of the land, an acceptable system evaluation needs to be rapid and simple and at the same time give reliable results. In so far as these are conflicting ideals the system must be flexible enough to encompass both rapid reconnaissance evaluations and detailed investigations where the predictions must be reliable.

The Framework for Land Evaluation

The Framework for Land Evaluation is now sufficiently well known that no complete description is required here, but some salient features may be emphasized particularly as they concern forestry.

The limits of land evaluation

The whole process of land evaluation can be summed up as

a) inventory of the land resources;

b) determining the (forest) land use requirements;

c) matching the requirements to the resources in order to determine land suitability for a specific use;

d) presentation of the resultant land suitability classification.

These may be regarded as stages but the process is cyclic or iterative: for example the land use requirements and the matching procedures affect the way the inventory is done and vice versa. Nevertheless, it is important to appreciate the distinction between land resource inventory and land evaluation. Methods for the former are well documented (soil survey, climatology, forestry, etc.) and can be taken as available for use in land suitability evaluation. For example, the fact that topography or land facets may be easily determined by remote sensing does not affect the evaluation of their significance for forest land use, though naturally it is desirable to evaluate using features which are easily mapped provided that they give reliable predictive results.

It is also important not to confuse land suitability evaluation with land use planning or project evaluation. The land classification is an essential prerequisite for rational land use planning or for the economic evaluation and planning of project implementation, but both of those activities involve much more than land evaluation.

The principles of land evaluation

The Framework gives guidelines to systematize the principles and procedures of land evaluation while recognizing that no standardized evaluation system could cope with all environmental and socio-economic conditions. The principles on which reliable site-factor land evaluation rest can be summarized as follows:

1. *The evaluation is of land* and not just soil conditions (nor just forest growth). All aspects of the environment need to be considered though their significance will vary (climate, soil, water, vegetation, location, etc.).
2. *Land suitability must be for a specific use* which must be defined (i.e. in terms of the kind of forestry operation, species of trees, management level, etc.).
3. *Evaluation must be in terms of benefits obtained in relation to inputs needed on different kinds of land.* This commonly means economic values (the degree of quantification varying with the data available) but can equally well be employment provided, energy balance, pollution, etc.
4. *Evaluation must be related to local physical and socio-economic conditions.* Assumptions often implicit in assessments of suitability should be explicitly stated. This applies especially to such features of the economic context as the marketability of the forest products or community attitudes (FAO, 1978).
5. *Evaluation requires comparison of different uses.* This may be between present use and potential use after stated improvements for one or more forms of forest management, or it may be a comparison between different species for plantation, etc.
6. *Suitability is for use on a sustained basis.* This normally means without soil degradation or declining productivity. (However, such deleterious effects as acidification by conifers in the tropics or the

"specific replant problem" after clearing a first stand may have to be accepted.)

7. *A multidisciplinary approach is required.* Specialist contributions are needed, from foresters, soils scientists, climatologists, economists, etc. Qualitative evaluation of physical conditions in a general economic context may be possible by an experienced person with good technical backstopping, but quantitative economic evaluation requires a team of specialists to produce reliable results. There is no need to labour this point at a joint IUFRO/ISSS meeting.

Features of the Framework

Some of the main features of the methodology which the Framework recommends can be summarized as follows:

1. Specific land use types must be defined. Examples might be: protection forest (hills in water catchments, sand dunes), production forest, plantations and irrigated forests, with definitions of species, management, etc. Such definition of the forest use envisaged, can in itself be a valuable product of land evaluation.
2. The classification can be for present conditions or for potential suitability after specified inputs. The difference is clear when forest planting is envisaged. For standing forest the difference refers to predictions of responses to management including logging or clearing. If no change at all is envisaged there seems to be little point in classifying suitability (for what?) and this may be the case of some areas of tropical forest.
3. The Framework distinguishes between qualitative and quantitative classification. The former mainly has regard to physical features but in relation to the local economic context; the physical aspects should be quantified as much as the data permit. The latter means that distinctions between suitability classes are made in numerical terms, usually economic, which permit objective classifications between different classes in relation to different kinds of forest use. Except for a few intensively managed plantations, forest evaluations in the developing countries are mostly qualitative.
4. Either land characteristics (generally physical features) or land

qualities (relationships between physical features and plant growth, etc.) can be used to evaluate suitability, but the two should not be confused or used together. In general, forestry evaluations have used simple land characteristics, or selected diagnostic features, for speed and simplicity. The use of land qualities is more complex and requires reliable information on the requirements of forest uses (species responses to environment, critical factors for management, etc.) which are usually lacking. However, for research or for intensive forestry, the use of land qualities seems more rational and more likely to lead to advances in understanding of the factors that control land suitability.

5. The classification proposed has two *orders*: suitable and non-suitable land; *land classes* which distinguish degree of suitability; *subclasses* which differ in the nature of the limitations; and *units* which have only minor differences in management requirements (for intensive detailed work). For forestry, as for agriculture, the most important critical values to establish are those separating non-suitable from suitable land and those separating first class land, with few limitations, from more problematic lands.

Presentation of results

The results are commonly presented as land suitability classes which are usually shown on a map. Tabular presentation of the legend as described in the Framework (FAO, 1976; FAO, 1977) permits a large amount of information on different uses and management inputs to be shown without drawing more than one map (important where drafting facilities are limited).
It should be noted, however, that one does not have to use land classes - results can be presented as input-output requirements for the different land units or mapping units if that is preferred, as it may be, by economists.

The usefulness of land suitability evaluations for forestry depends on them providing what the user requires in a form which is readily understandable. This aspect requires as much attention as the methodology of making the evaluation.

Application to forestry

The principles and procedures of the Framework have been adapted and applied for the past few years in many countries for classifying land suitability for forestry, sometimes on projects where forestry is the main component (e.g. Gaddas, 1976) and more commonly where forestry is just one of a number of potential land uses (e.g. Indonesia, Sierra Leone, Sudan). Such classifications have almost all been very general without much attempt to quantify either the relation of forest growth response to environmental features or the differing inputs required, and benefits expected, on different land classes, though attempts have been made to define critical limits for management practices (e.g. slope, stoniness and flooding subclasses).
Some criticisms have been made of disadvantages said to be inherent in the methodology of the Framework:

1. It is said to be *too complex* and therefore too time consuming and expensive. However, it need not be; the complexity largely depends on the definition of the (forest) land use types according to the scale of the work and the degree of specificity and reliability required. Having a ready made methodology may well save much time wasted in developing a land suitability classification. It must be recognized, however, that there is a trade-off between simplicity and reliability: if the system is too simple it is less reliable (even misleading): increased reliability can only be purchased at the cost of greater complexity.
2. *Cost-benefit* analysis is said not to be suitable for all forest purposes. Nor is it suitable for all agricultural development purposes. Cost-benefit analysis is not an essential feature of the Framework and should only be used where it is appropriate.
3. *The long growth period* of forests makes it difficult to judge the reliability of the evaluation. Much the same thing applies to crops like rubber, but by systematically attempting to classify suitability of environmental conditions in different circumstances the reliability improves and also there is a spin-off in better understanding of management requirements (Chan, 1978).
4. *Failure to achieve the multidisciplinary approach* puts in question the realism of the methodology. It is probably true that failure to obtain collaboration between the various disciplines, often in different

ministries, is one of the commonest causes of unreliable or unusable land classifications. It can be observed, however, that the larger land resource survey agencies, both governmental and private contractors, are increasingly fielding multidisciplinary teams. In any case, the existence of a relatively standardized, internationally accepted method of land evaluation can only help to increase cooperation between the disciplines. Even where interdisciplinary teams cannot be fielded the results of single specialist evaluations are likely to be more acceptable to other specialists if based on a standard method.

5. *Evaluation of off-site* (e.g. downstream) *effects and multipurpose use* are not adequately covered. This is indeed a technical problem but not confined to users of the Framework. The same problem arises with land evaluation for irrigation where suitability of land for irrigation depends on hydrological conditions in the whole catchment, riparian rights up and downstream, downstream pollution effects, etc. Likewise, suitability for pasture land may depend on distant dry season grazing, etc. It is important to distinguish land evaluation from project evaluation and macro-planning of land use. By using the Framework mutual benefit would be derived from sharing attempts to deal with this problem.

In general there is little disagreement that the methodology of the Framework is suitable for classifying land for plantations and for intensive forest management. However, its relevance to the tropical rainforest or tropical savanna woodland or scrub is more problematical. The value of low intensity survey and evaluation is unquestioned for the cases where land is to be zoned for forestry and other uses, and where costly management is to be introduced (for example in Nicaragua very small applications of phosphates can double rates of forest regrowth on suitable soils). But where the expected land use is a continuation of unmanaged forest or woodland anything but the most general and inexpensive "guesstimates" of suitability may not be justified.

Future developments

To complement the concepts and guidelines set out in the Framework, a practical manual of land evaluation for rainfed crops is being produced by FAO. A similar manual for irrigated agriculture is being developed in association with the US Water and Power Resources Services. A manual could be produced for forestry by collaboration among foresters, soil scientists, land evaluation specialists, land use planners, etc.

Such a manual might well include the sections mentioned below.

1. An introductory outline of the system for land evaluation for forestry to make clear the guiding principles, the (limited) objectives, the stages of the evaluation process (resource inventory, requirements of forest use, matching of requirements to resources), etc.
2. A brief account of inventory methods, for climate, soils, forest production, etc., which are all adequately covered in other standard publications, with suggestions on their interaction with the interpretative methods of evaluation.
3. Instructions for the selection and description of relevant forest land use types (with examples of the major ones).
4. An account of the land characteristics and land qualities which affect the suitability of land for forest uses. As a guide to the field worke this should include:
   i. a checklist of diagnostic features (to avoid overlooking any);
   ii. some examples of sets of critical values of the land qualities fo specific uses (e.g. for species or for forest types), followed by warning that any such critical values may not be universally appl cable and must be confirmed for each site.
5. An account of the matching procedure, for predicting the results of specific uses in an identified and described environment.
6. Instructions for methods of presentation of the results, that is as la suitability classes shown on maps, or as economic input-output predictions, or in other ways.

Conclusions

The main argument of this paper is that the Framework for Land Evaluation describes a system which is flexible enough to provide a basis for evaluating the suitability of land for the numerous and varied forest uses. There are obvious advantages in using a system which is compatible with that use for agricultural land suitability evaluation, and which is already widely known and used.

If this meeting decides that the moment is opportune to develop a more systematic approach to land evaluation for forestry and that the Framework is a suitable basis, the next step might well be to work towards producing a practical manual to provide guidelines for land evaluation for forestry. Such a manual would facilitate the transfer of silvicultural technology, and the better integration of multipurpose forest land into land development programmes devised by land use planners, development economists, agricultural development agencies, etc. It could have universal use, but it is particularly needed in the developing (mostly tropical) countries to which we particularly refer.

REFERENCES

CHAN, H.Y. (1978). Soil survey interpretations for improved rubber production in peninsular Malaysia. In soil-resource data for agricultural development. pp. 41-66. University of Hawaii.

FAO (1974). Tree planting practices in African savannas. Forestry Development Paper No. 19, FAO. 185 p.

FAO (1974). Heathland and sand dune afforestation. Report of the FAO/DANIDA Inter-regional Training Centre. FAO/DEN/TF 123. FAO. 239 p.

FAO (1976). A framework for land evaluation. FAO Soils Bulletin No. 32, 72 p.

FAO (1978). Expert consultation on land evaluation standards for rainfed agriculture. FAO World Soil Resources Report No. 49, 116 p.

FAO (1979). Land evaluation criteria for irrigation. Report of an expert consultation. FAO World Soil Resources Report No. 50, 219 p.

FAO (1978). Forestry for local community development. Forestry Paper 7. FAO/SIDA. 114 p.

JONES, J.R. (1969). Review and comparison of site evaluation methods. USDA Forest Service Research Paper R.M.-51. Rocky Mountain Forest and Range Experimental Station Fort Collins, Colorado. 27 p.

APPENDIX

1. Organizing committee of the workshop

Members	Dr. Ir. K.J. Beek Rector of the International Institute for Aerial Survey and Earth Sciences (ITC) P.O.Box 6, Enschede, The Netherlands (Chairman Land evaluation working group of ISSS)
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	Ir. C.P. van Goor Deputy-Director Dorschkamp Research Institute for forestry and landscape planning P.O.Box 23, 6700 AA Wageningen, The Netherlands (Deputy-Coordinator of Division 1 (Site and Silviculture) of IUFRO)
Secretary	Ir. P. Laban Dorschkamp Research Institute for Forestry and Landscape Planning (expert in forestry, soil science and land evaluation)
WORKSHOP SECRETARIAT	J. Drijver (IAC), Mrs. G.H. Jansen (Dorschkamp) and P. Laban

2. Official invitations

Dr. ir. W.M. Otto	- Director-General of the Directorate-General for land development and forestry of the Ministry of Agriculture
Dr. Ir. W.G. Sombroek	- Director International Soil Museum (ISM) Secretary-General International Society of Soil Science (ISSS) (P.O.Box 353, 6700 AJ Wageningen)
Ir. J. van den Bos	- Director of the State Forest Service

Ir. W. Oosterberg	- Deputy-Director of the International Agricultural Centre (IAC)
Ing. A. Brands	- Representative of the Directorate of N.V. Heidemaatschappij Beheer Nederland
Dr. Ir. J. Schelling	- Deputy Director of the Soil Survey Institute (Stiboka)
Ir. F.E. Schulze	- Director International Institute for Land Reclamation and Improvement (ILRI)
Mr. T. Beekman	- Publications Department ILRI
Ir. A.J. van der Poel	- Director Dorschkamp Research Institute for Forestry and Landscape Planning
Prof. Dr. H.C. van der Plas	- Rector magnificus of the Agricultural University, Wageningen
Ir. F.W. van Tuyll van Serooskerken	- State Forest Service (Gelderland Province)
Dr. Ir. J.H. van Kampen	- Vice-Director Lake IJssel Polders Development Authority
Ir. A. Schotveld	- State Forest Service (Lake IJssel Polders)

3. Participants

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