

LAND EVALUATION, A SYSTEMS APPROACH *

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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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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 environmental 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.

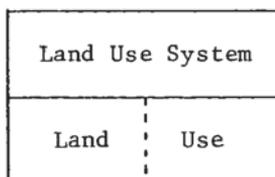
The term "system" has many meanings, varying from sets of interacting physical elements (e.g. the "land system", describing a mapping unit in some reconnaissance resource surveys) to relationships between land and user (e.g. the land tenure system) and to land cultivation techniques (e.g. the management system). Toebe (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.

Toebe 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.



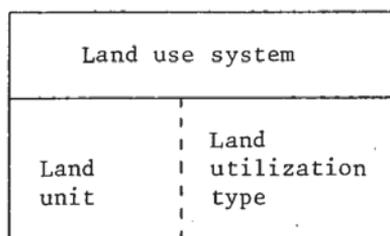
We have to realize that the above land use system is in fact a model, (LUS)_m, of the real land use system and that by analysing such land use systems for

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:



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 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.

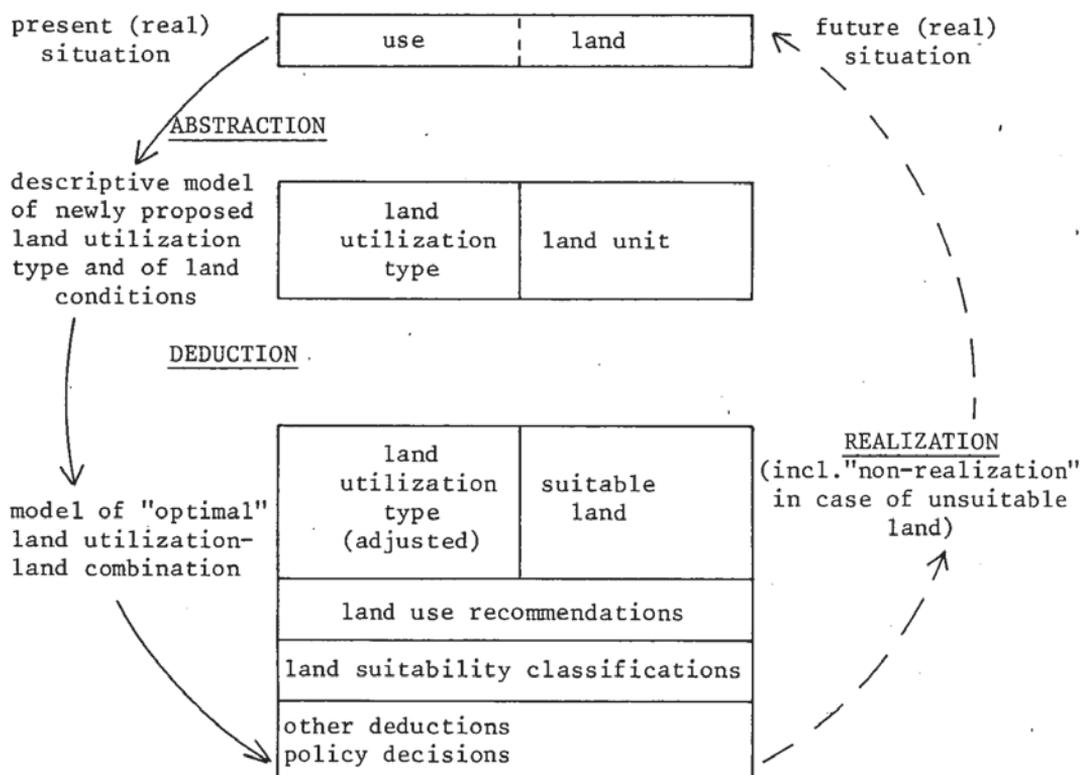
This is the combination that places the land unit in the highest possible suitability class if operated by the land utilization type in question. Thus land suitability classification is a type of optimization process.

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 life-stock 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)

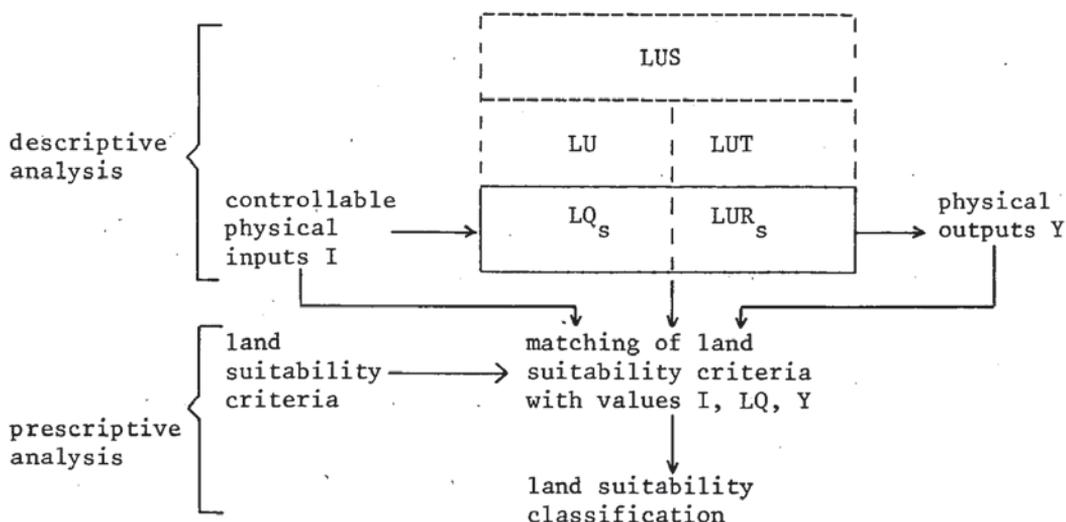
(D) DIVERSIFICATION CRITERIA

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 aggregating 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 3000 - 4000	100 - 200 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, the rating of land properties and land qualities, the expression of the land use requirements, all are of a descriptive nature. Also the description of land use systems, the matching of land qualities with land use requirements, the analysis of necessary inputs and expected outputs, the identification of effects 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 distinguish 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 recommendations 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 land use. In this classification, inputs and outputs are expressed in physical terms, distinct from an integral land evaluation in which the variables are commensurated and expressed as far as possible in monetary terms. An integral 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.

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