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EVALUATING LAND EVALUATION

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Abstract

The term "land evaluation" became current in the 1960s, after it became clear that the conventional approaches of soil interpretation based on soil survey needed to be augmented by assessments of economic factors if viable land use alternatives were to be produced for land use planners. Soil survey interpretation had itself developed in the first half of this century in response to the demand for soil investigations to remedy land use failures and to prevent similar mistakes being made in the future. By recounting the procedure followed in this aspect of soil science, and its historical development therefore, it will become clear which inadequacies and problems have led land use planners to rely more on land evaluation rather than on traditional soil survey interpretation. The scene will then be set for an evaluation of land evaluation as prescribed by the Framework for Land Evaluation (FAO, 1976) by presenting a critical review of some of the principles, basic concepts and procedures propagated in the Framework.

Soil survey interpretation: its development and its procedures

During the first half of our century land use failures created a public awareness of the need for soil investigations to remedy disastrous situations and to guide future land use developments. A soil survey has become a prerequisite for the preparation of land development projects. The soil survey provides an inventory of the soil, using concepts of natural soil bodies that enable soil scientists to determine the place of a particular soil among all other known soils. Unfortunately these concepts have little meaning for non-soil scientists. This obliges the soil surveyor to explain the edaphic (soil related) constraints for each unit of the soil map and the resulting implications for land use and soil management, and possibly also to make yield predictions. The appraisal of soils for agricultural uses on the basis of soil inventories is called *soil survey interpretation,* or briefly, *soil interpretation.*

Interpretative methods were first applied in soil science 100 years ago in Russia by Dokuchaev, the father of modern soil science. Since that time, but especially during the last fifty years, numerous soil interpretation systems have evolved in different countries, the best known being the USDA-SCS Land Capability System (Klingebiel and Montgomery, 1961), the USBR Land Classification for Irrigated Agriculture (USBR, 1953), and the Storie-index rating (Storie, 1937), all developed in the United States of America, but also widely used as models for soil interpretation systems elsewhere. These systems differ in the number and kind of soil properties they take into account, and in the logic of the procedures followed to arrive at a suitability rating. A common feature of "comprehensive" soil interpretation systems is that the soil surveyor in his role of soil interpreter has to estimate to what degree a given soil can support a specific farming system. His starting point is the notion that the function of the soil in a farming system is twofold: the soil should be accommodating to the farmer and accommodating to the crop. The farmer requires the soil to be workable (e.g. not stony, not sticky) and accessible. The crop requires good conditions for its roots (e.g. moisture, nutrients, ample rooting space, suitable temperatures, no problems of toxicity, acidity or salinity). The soil interpreter/surveyor bases his judgment on soil characteristics - i.e. features that can be measured directly, such as stoniness, clay content, chemical composition - and on soil qualities - which are learned only by inference, e.g. fertility, productivity, erodibility. He distinguishes between soil qualities that affect management (ploughability, bearing capacity) and those that affect plant growth (availability of water and plant nutrients). Although this approach is inherent to any soil interpretation for agricultural purposes, it lasted until the 1950s that its concepts were explicitly formulated: the term "soil quality" was first used by Kellogg (Kellogg and Davol, 1949) and the distinction between soil qualities and soil characteristics was described in the Soil Survey Manual (Soil Survey Staff) in 1951.

The soil interpreter/surveyor can present his judgment in a descriptive form but, if he is dealing with many soil units he will probably decide to rank them. In this ranking exercise he encounters the problems so typical for the classification of objects (here: soils) on the basis of dissimilar criteria. How do you evaluate the occurrence of temporary waterlogging in one soil against erosion hazard in another? The soil interpreter must somehow establish rating criteria for individual soil qualities and weigh different soil qualities against each other, remembering that sometimes these qualities overlap and interact. The lack of data on relationships between soil performance and soil quality means that the rating is largely intuitive. Indeed, the rating of soil properties and the grading in classes is the Achilles' heel of soil interpretation. Back in 1943 Simonson ans Englehorn warned "the selection of criteria for the grading of soils into classes is one of the most perplexing problems in the present time and promises to remain so in the future".

The rating of a given soil for a defined use proceeds in two steps:

1. A selected set of soil attributes (characteristics, qualities or both) that are considered to be relevant are rated.
2. The soil is assigned to a suitability class by combining the rating of separate soil properties into one class rating or index rating. Usually, multiple entry conversion tables are established for this.

Whatever the system followed, the soil surveyor/interpreter ultimately produces a soil map with explanatory reports, including the interpretation results in the form of tables, texts and maps. His work is then itself used for example by land use planners, farmers, fellow soil scientists. This use is not seldom beset by a further array of problems and misunderstandings not only arising from whether the map is complex or oversimplified but also from insufficient awareness of the aims of the original soil surveyor/interpreter when preparing and interpreting the soil map. In this context, Kellogg 1939, p. 258) saw a need for enlightening the procedures of the soil scientists, and called for a closer attention to the general objective of all soil research, i.e. "to determine the capacities of each soil type for secure production under physically defined systems of management".

The need for a clear understanding of the objectives of soil interpretation was repeatedly stressed in the 1940s (Orvedal and Edwards, 1942; Simonson and Englehorn, 1943). The difficulties of extrapolating from one system of interpretation to another, in a different country, further complicated the issue. Not surprisingly, over the years soil interpretations have given rise to many misunderstandings between soil scientists and economists, agricultural engineers and agronomists (Vink, 1960) - let alone between soil scientists of different countries! By 1970 the need for a standardization of terminology and of methodology was acute. The "Framework for

Land Evaluation'', which was developed jointly by FAO and a Dutch working group (FAO, 1976) was hailed as fulfilling this need and as providing a broader base on which to assess the potential of land.

The Framework for Land Evaluation

The ''Framework for Land Evaluation'' sets out concepts, principles and procedures for land evaluation which are ''universally valid, applicable in any part of the world and at any level, from global to single farm''; in short, it supposedly provides the key to the solution of all land use problems. It has met with general approval, notably from international agencies, while Beek (1980), himself a major contributor, describes the Framework as the climax of this quarter century of international methodological reassessment, and as a milestone in the evolution of a realistic approach to land evaluation.

The overwhelming enthusiasm for the new approach needs some comment. First of all, it clearly conveys general dissatisfaction with previous approaches. Secondly, the Framework was conceived by pedologists and enthusiasm among economists has reportedly been less than among resource-minded scientists. Thirdly, while covering virtually all aspects of land evaluation the message of the Framework allows for great flexibility in its applications, to the extent that every pedologist/land evaluator can find supporting statements for his own preferred working method.

However, the proof of the pudding is in the eating and after 10 years of practical applications of the Framework it is perhaps time to attempt an evaluation of the Framework on the basis of its achievements.

A personal observation is that a rigid application of the Framework leads to frustation for the pedologist and leaves the planning economist in despair. Some of the problems find their origin in the concepts and principles underlying the Framework.

Principles of the Framework

The Framework mentions certain principles that are fundamental to land evaluation. They include the following:

Land evaluation is based on *interpretation of physical land attributes in respect to specified kinds of land use.* Agricultural land use, or Land Utilization Type (LUT) implies crop production that can be achieved in a particular farming system *on a sustained basis* (without environmental damage).

Land evaluation provides ratings of relative suitability of land for *two or more relevant land use alternatives.* The relevance of these land use alternatives is dictated by *the physical, economic and social context of the area concerned.*

The suitability classes are defined by economic criteria. This requires *a comparison of the benefits obtained and the inputs needed* for a given land use on different types of land. Such an economic comparison is called *quantitative* evaluation, but if the economic evaluation is not substantiated the land evaluation is called *qualitative.* In fact, most, if not all land evaluations are qualitative in the economic sense. This complicates the comparison of suitability ratings for a given tract of land for alternative uses, as there is no common denominator expressed in monetary units.

From the foregoing it will be clear that a *multidisciplinary approach* is required. The Framework calls for close co-operation between natural resource scientists, land use technology specialists, sociologists and planners.

Difference between land evaluation and soil interpretation

Land evaluation is born out of soil interpretation, but land has replaced soil as the basis for suitability evaluation. The difference is that land comprises climate, relief, hydrology and vegetation in addition to soil. However, more often than not soil units continue to serve as Land evaluation Units (LU), only split by agro-climatic zone if large areas are involved. While the purpose of soil survey interpretation was to make predictions of soil performance to guide profitable management on each kind of soil (Steele, 1976), land evaluation moves much further in the direction of recommending particular uses of land. It aims to provide land use planners with a choice of ready-cooked land utilization types (LUT) for each land unit (LU). According to the Framework the next step after land evaluation is selection of a preferred use for each type of land, i.e. land use planning proper.

Constraints arising from the principles enshrined in the Framework

Less concern for people than for land

The Framework allows for simultaneous land evaluation for LUTs of different levels of technology, from primitive to modern, acknowledging differences in social and economic conditions between farmers in the evaluation area. This represents an innovation of the Framework in relation to previous evaluation systems that paid only attention to mechanized farming. To judge by the emphasis on socio-economics in the principles and by the meticulous analysis of LUTs in some applications of the Framework, land evaluation seems to be oriented to people and social change. However, all this tends to obscure the notion that land evaluation is primarily concerned with land to benefit land use planning, which is but a part of overall development planning. The Framework attaches certain values to the productivity and conservation of the land, but is neutral with regard to people. The latter is not stated explicitly in the Framework; on the contrary, it suggests that what is good for the land is good for the people. But whereas the beneficial and adverse consequences for environment are compared, the social consequences of the relevant kinds of land use are always assumed to be beneficial, and there seem to be no losers. In fact, land evaluation is oriented to natural resources, not to people. It considers land resources in terms of physical and economic factors, but only considers people insofar as they participate in the relevant kinds of land use within the boundaries of the area to be evaluated. Other economic activities, and other people, not to be involved in land use within the are, are mentioned incidentally in the land evaluation in a socio-economic context, but are not a target of the land evaluation procedure.

Because of its politically neutral foundations, the Framework can either be applied to support land allocation to small farmers, or to evict them. This means that land evaluation could be abused to justify denying certain groups of people access to land resources, or even to justify blatant land grabbing. Such political goals could be easily brought into the land evaluation procedure, e.g. by considering subsistence farming to be an inappropriate land use alternative, or by classifying the land as unsuitable for subsistence farming and at the same time declaring it suitable for large-scale export crop plantations. Thus a preselected land use alternative may receive the lustre of scientifically proven viability. But the question, who will gain or lose as a result of planned development is not answered by the land evaluation procedure, but is decided upon in the political field of force.

Sustained use

Another field where the bias towards land resources becomes apparent lies in the statement: "that the kind of land use proposed will be *sustained,* that is capable of being continued over an *indefinite* period of time". In the practice of land evaluation, environmental degradation (soil erosion, soil salinization, pasture degradation) only concerns the land within the evaluation area. Although the Framework refers to off-site effects, it is not geared to the incorporation of comprehensive environmental impact statements.

To date, land evaluators have condoned land use systems that sacrifice many tons of oil, but no soil, and at the same time they advise against land use systems that sacrifice many tons of soil, but no oil (e.g. flower production in hot houses versus subsistence food production on hillsides). Also the reference to "an indefinite period of time" is made from a conservationist's viewpoint, but the duration of eternity is not compatible with the time spans commonly applied by economists, which cover periods of 5 or 10 years, and rarely exceed 30 years.

As far as sustained use is concerned, it may be more realistic to regard it not as a principle, but as a possible option in land evaluation, thereby specifying what kind of pressures on environment would be tolerated and to what degree.

No categorical distinction between economy and ecology

The crucial problem in land evaluation is that it deals concurrently with plant growth conditions, environmental aspects and economic considerations. The Framework approach leads to blending ecological and economic systems, rather than keeping them apart. It proposes measuring ecological factors by economic standards. For example, the Framework approach implies that if the price of cotton doubles, much more land will become suitable for cotton growing. But the construction of a new road will affect the economic suitability of land in a similar way. Thus land evaluation results soon become invalid, or need frequent revising. Because ecology and economy are amalgamated the land evaluator has to be prepared to adapt his edaphic suitability criteria to fit changing economic situations. If a purely ecological land evaluation is applied, the edaphic criteria will only need to be changed if the knowledge about edaphic conditions changes.

The great advantage of a separate ecological land evaluation rather than the uneasily amalgamated Framework approach is that it generates information of longerlasting value. For that reason soil survey organizations usually apply ecological approaches to land evaluation, resulting in a combined rating for crop growth, management and conservation aspects. However, they use the *normative* (good-bad) classes recommended by the Framework. This is inconsistent. A more logical solution for a rating system would be to use *indicative* (high-low) productivity class ratings, based on yield level for a specific LUT. This could be supplemented by separate ratings for special management inputs (insofar as these are not included in the average LUT under consideration) and for intensity of desirable soil conservation measures. The productivity classes could be defined as very high, high, medium, low, very low. This is more concrete than the Framework classes of highly suitable, moderately suitable, marginally suitable, currently not suitable, permanently not suitable land. The application of neutral-value, indicative classes leaves open the question of what productivity level corresponds to the lower economic limit of suitability.

Related to the lack of a categorical distinction between ecological and economic systems are the definitions of qualitative and quantitave land evaluation. According to the Framework they differ in the specification of economic. If a land evaluation presents land/land use combinations with pricetags, it is called quantitative; without price-tags it is qualitative. However, the Framework does not make a distinction on the basis of the quality of the data on which the calculations or guesses are based. It would be much clearer to distinguish between physical and economic evaluations, thereby allowing the results to be expressed either in precise terms or as estimates. The distinction between qualitative and quantitave is not helpful, because a general study may present its results numerically and would therefore be quantitative, whereas the results of a detailed study may be presented descriptively, and the study would therefore be "qualitative", in spite of its greater precision.

If the purpose of quantification is to work with a common denominator for comparing alternative land uses, some standards that could serve this purpose in ecological land evaluation are: dry matter increment or nutritive value in terms of energy or of proteins. It depends on the political priorities, which one is selected.

Parallel evaluations are not comparable

The Framework states (section 1.1) that the function of land evaluation is to present comparisons of the most promising kinds of land use. The comparison of several alternatives is even proposed as a basic principle. Elsewhere (section 3.4), however, the Framework states that suitability classes for different uses cannot be compared, because suitability class limits are defined separately for each use. This means that if a given piece of land is rated highly suitable for LUT 1 and moderately suitable for LUT 2, LUT 2 may yet give a higher net return than LUT 1, and thus be the most preferred land use on that particular piece of land. Thus, land evaluation would allow land units to be ranked according to their suitability for a given use, but not according to different use possibilities for a given piece of land.

In fact, it is even disputable whether the suitability ranking of different land units for a given use (LUT) is theoretically possible, because a LUT is partly defined by the properties of the land. If the land differs, the LUT must differ too. For example, dairy farming on excessively well drained sandy soils is different from dairy farming on moderately well drained clay soils, even if the socio-economic context is exactly the same. The dependence of LUTs on land units is most pronounced if the LUTs are specified in much detail in terms of key attributes such as use of fertilizers or machinery.

Its inability to present results that can be compared means that land evaluation inevitably betrays its very principle of comparability.

Parallel evaluations are not always needed

The Framework approach to land evaluation is likely to be most successful for land use planning where there is great freedom in choice to implement alternative land use options. This is especially the case in frontier areas to be reclaimed or ortherwise opened up by governments, or in situations where the decision-making about land use is strongly centralized. In such cases land evaluation comes up with the comprehensive specification of a set of alternative land utilization types for each land unit or combination of land units.

In areas with an established land use and with many decision makers, the relevance of land evaluation in the sense of the Framework is debatable. In such cases the questions that land evaluators are required to answer are much less comprehensive, and do not involve specifying entire farming systems, or classifying land for different uses. Instead, the questions involve specifying alternative land improvement measures that can be taken for a land use that has already been decided. For example, the question may be to ascertain the repercussions of lowering a shallow water table, which would increase the soil's bearing capacity, but render it more sensitive to drought. Contrary to popular belief, answering such practical questions is not land evaluation in the sense of the Framework. Similarly, many a soil surveyor, scouting around for land that is suitable for growing a crop e.g. cacao, is unaware of the fact that he violates a principle of land evaluation by considering only one kind of land use.

Multidisciplinarity is difficult to achieve

Land evaluation can be thought of as an attempt to reconstruct "rational" farmers' decisions to grow something in a certain place in a certain way in current or projected situations. If done in the sense of the Framework, land evaluation is multidisciplinary teamwork aiming to reconcile the findings of experts on land and on land development, on crops and on cropping, on environmental issues, and on economics. A synthesis should be made out of the various expert contributions. This involves more than compiling section papers in one report. The complex action of synthesizing dissimilar information is called matching.

The Framework (section 4.5.1) explains that:

> Matching represents the essence of the interpretative step following the resources surveys in the land evaluation procedure, and is based on the functional relationships that exist between the land qualities, the possibilities for land improvement and the requirements of the land use. In its simplest form matching is the confrontation of physical requirements of specific crops (or grasses, trees, etc.) with the land conditions to give a prediction of crop performance. Matching becomes more complex when the production factor is complemented by other performance conditioning characteristics of the land utilization type, including non-physical aspects like labour intensity and capital intensity.

Basically, matching is a kind of optimalization procedure. However, the Framework does not prescribe a methodology for matching, not even for matching in its simplest form, the purely physical matching, let alone for the more complex variant of matching. Beek (1978) proposes to apply systems analysis in specific purpose land evaluation but does not back this up with guidelines of how to achieve this in practice.

In the absence of prescribed matching techniques, land evaluators follow their intuition. They arrive at a synthesis straight away. This is much the same way that farmers assess land. Farmers take a holistic view of the land, and a group of farmers can quickly reach a consensus on the productive value of a piece of land, when they are asked to classify it using a scale with 10 or even 20 grades (the Framework recommends the use of only four grades of suitability). The farmers base their judgment on their experience, but the factors that play a role in their minds are not always easy to translate in terms of land properties.

The Framework stipulates that the land evaluator should base his judgment on matching, i.e. he must somehow reconstruct his judgment on the basis of the few land characteristics that happen to have been inventoried systematically. In practice, it is very difficult to construct a consistent set of rating and conversion tables for each LUT to substantiate the initial intuitive judgment. This results in discrepancies between the intuitive and the reconstructed suitability ratings.

The flimsiness of the matching procedures often creates friction in multidisciplinary teams. Instead of uniting the various disciplines, matching pits them against each other. The place of the land evaluator as team coordinator is contested, because his working procedures are not stipulated and give irreproducible results that can be revised in any direction. Precisely because it is so permeated with subjectivity, the place of land evaluation among other disciplines is difficult to define. The question is, whether it is a part of another discipline or disciplines (and, if so, of which), a discipline in its own right or even a superdiscipline? Ideally, a land evaluator should be familiar with all the contributing disciplines. Sound judgment requires him to view the land through the eyes of the farmer, and for the matching exercise he must be as lucid as a mathematician, as conciliative as a diplomat and as flexible as a politician. Theoretically, such a person may originate from any discipline, but in practice land evaluation is the domain of pedologists. But as long as certain concepts and procedures of land evaluation are defined ambiguously a true multidisciplinary effort cannot be realized. The concluding thoughts on matching in a paper on data analysis in land evaluation (Beek et al., 1980) are revealing:

We consider it of great importance to reach an agreement on matching procedures with economists, particularly in relation with detailed and semidetailed land evaluation, to avoid overlap between the work that is done by physical scientists and the economists.

On the other hand, we must confess to a certain concern that economists tend to draw their conclusions after synthesizing such a variety of social, economic and political factors that the role of the physical land variables may be underrated.

The question is whether we have progressed far enough with our methods of physical land evaluation to present the economists with acceptable proposals that can be incorporated in their established working methods. Are these land evaluation methods good enough to convince economists that they should reconsider some of their working methods? In our opinion the successful applications of land evaluation and its link with systems research and rural development depend on such cooperation.

It is probably unrealistic to expect economists to reconsider their working methods to incorporate ill-defined matching procedures that are unlikely to answer their questions. On the contrary, economists try to convince land evaluators to ponder matching procedures as a first step towards true multidisciplinary cooperation.

Basic concepts of the Framework: land qualities and land characteristics

The basic consepts of the Framework include land, land use, land utilization types, land characteristics, land qualities, diagnostic criteria, land use requirements and land improvements. Of these, the definitions of land characteristics and qualities differ slightly from the old American definitions for soil characteristic and soil quality:

- a land characteristics is an attribute of land that can be measured or estimated. Examples are slope angle, rainfall, soil texture, available water capacity, biomass of the vegetation, etc.:
- a land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use. Examples are moisture availability, erosion resistance, flooding hazard, nutritive value of pastures, accessibility.

Crop yield is considered to be an aggregate land quality. Land qualities are frequently described by means of land characteristics. However, a land quality can sometimes be measured directly, and would be a land characteristic as well.

The Framework recommends comparing land with land use in terms of land qualities, and not in terms of land characteristics, because of interaction between characteristics. This recommendation is largely invalidated by stating that either land qualities or land characteristics may be used as a basis for assessing the suitability of a given area of land for a specified use.

Constraints related to the concepts of land qualities and land characteristics

The suggestion in the Framework that the problem of interaction can be avoided by applying land qualities is an oversimplification. Many interactions and complementarities between land qualities give problems similar to those arising from the application of single characteristics. In the practice of land evaluation a land quality is often replaced by the land characteristic that is considered to have the greatest differentiating influence of all characteristics on that particular land quality. Furthermore, land characteristics that simultaneously influence many land qualities are used instead of the qualities themselves.

The concept of land quality is extremely useful to highlight why a particular land characteristic is important for a given land use. But once such a land characteristic has been identified, it becomes easier to work with it than with the land quality, because a quality cannot be measured and is therefore not an operational concept. Other arguments for working with land characteristics are that land mapping units are described in terms of land characteristics and that remedial action to improve the land is implemented by manipulation of land characteristics, not of land qualities.

The mapping unit as basis for suitability evaluation

Remember that a function of land evaluation is to bring about an understanding of mutual relationships between land and the use to which it is put. Suppose that a land evaluator must explain why a given land mapping unit is marginally suitable for arable farming. Compare the following descriptions of this mapping unit, the first in terms of land characteristics, the second in terms of land qualities:

- a shallow sandy soil on a hillside
- a soil having low moisture availability, high oxygen availability, low nutrient availability, low resistance to erosion, low trafficability, with respect to the requirements of arable farmings.

If the audience possesses a little more than rudimentary understanding of agriculture, it will probably accept the explanation that the land is marginally suitable for arable farming because the soil is shallow and sandy and on a hillside. But would an explanation of the suitability rating in terms of land qualities add much information to the first explanation?

Another mapping unit with a predictable set of land qualities would be a clay soil in an embanked flood plain with shallow groundwater table. This proves to be a soil having high availability of moisture and nutrients, low oxygen availability, high resistance to erosion, low trafficability, with respect to the requirements of arable farming.

The point to be made here is that a mapping unit represents tracts of land with a coherent set of land characteristics that *jointly* influence the land use potential. Therefore, an insight in this whole complex of land characteristics plus knowledge of the farming practice, can quickly provide an insight into the possible land/land use combinations. The Framework, however, suggests that such an insight can only be obtained by analyzing different land qualities that act *distinctly* on the land use potential. This suggestion opens the way to considering single land qualities separately from all other land qualities, and forms a justification for assessing land suitabilities on the basis of just one (rarely two) land qualities. These one or two land qualities that determine suitability class are singled out because they represent the most severe limitations that adversely affect the given kind of land use.

Still, the question remains whether this analytical splitting up of land use systems in the Framework approach does generate better and more useful information than can be obtained more simply by taking a holistic view of them. The two examples given above seem to indicate that analysis tends to blur the view of the land instead of clearing it.

Specification of improvements and management practices

One of the purposes of land evaluation is to permit specific management and improvement measures to be systematically determined for each land utilization type on each land mapping unit to which it is suited. The Framework gives a fine example of the use of land qualities and land characteristics in land evaluation for soil conservation (section 2.4):

> If land characteristics are employed directly in evaluation, problems arise from the interaction between characteristics. For example, the hazard of soil erosion is determined not by slope angle alone but by the interaction between slope angle, slope length, permeability, soil structure, rainfall intensity and other characteristics. Because of this problem of interaction, it is recommended that the comparison of land with land use should be carried out in terms of land qualities.

And in relation with the assessment of physical inputs (section 4.5.1):

> Maize cultivation, for example, is a form of land use involving periods in which the soil surface is bare. Erosion resistance is therefore a relevant land quality. The optimum conditions include level land, requiring no soil conservation works. Using such land characteristics as slope angle, soil permeability, structural stability and rainfall intensity, a parameter representative of erosion resistance is calculated for each relevant land unit. In a qualitative study, the erosion hazard might be divided into classes such as nil, slight, moderate and severe, and at least the last of these classed as Not Suitable.

This rating of the land quality "erosion resistance" should serve as a basis for specification of soil conservation works.

Suppose that in a land evaluation for farm planning a suitability unit S3e is distinguished. This unit represents a piece of land that according to land evaluators is only marginally suitable for the specific farm type, because of the hazard of severe erosion. If further explanation is not given in an accessible way, as is common practice in land evaluation, the only message of this evaluation to the farmer is that he should not expect much benefit from erosion control measures (the expenditure will be only marginally justified). This kind of evaluation does not propose any solution for the erosion problem. From erosion handbooks it may be learned that a severe erosion hazard requires measures to increase water uptake by the soil and to reduce and regulate surface runoff. But there are so many different ways of achieving erosion control that it is important to identify the most appropriate measures for each particular situation. The appropriateness of these measures, however, cannot be deduced from the severity of the land quality "erosion hazard", but will depend on the relative contribution of the interacting land characteristics to the erosion hazard, and on the ease of correcting them. Depending on the local situation, the remedy for the erosion problem may be sought in modifying slope angle, slope length, or soil surface configuration, or in protecting the surface against rainfall impact. These measures can be taken alone or in combination. If the land evaluator wants to convey a clear message to the farmer, he should make his judgment more explicit, even if this judgment is preliminary, and specify the kind of measures he has in mind for each suitability unit, for example: contour ploughing, vegetative strips, mulching, terracing, gully control. The Framework does recommend to make such specifications, but in no way does it make clear how these can be derived from land quality ratings.

The conclusion is that if the purpose of a land evaluation is to permit specifications for management and improvement to be systematically determined, then mapping units need not be expressed by rating the most limiting land qualities, because a straightforward description in terms of relevant land characteristics serves the purpose better.

Land evaluation procedures according to the Framework approach

Generation and reduction of data

The Framework is not very clear on *how* to carry out a land evaluation. But two important points deserve attention, one procedural and the other concerning the presentation of results. The Framework (section 4.1) states:

> It is important to note that there is an element of iteration, or a cyclic element, in the procedures. Although the various activities are here of necessity described successively, there is in fact a considerable amount of revision to early stages consequent upon findings at later periods.

This iteration makes land evaluation a very time-consuming activity.

The second point refers to how land evaluation should be presented. The Framework recommends minimizing the number of suitability classes and also using as few limiting land qualities as possible in the symbols that indicate the kind of limitations. One (rarely two) letters should normally suffice. This means that in land evaluations that follow the Framework, the tremendous amount of information generated by the interpretation of relevant land qualities is largely unused for the final suitability assessment. For example, suppose that fore a given LUT ten different land qualities are considered relevant. Then, for each land unit to be evaluated for this LUT, each of the ten land qualities must be rated individually. After this analysis of land qualities the most limiting is used for the suitability class rating, and the other nine are placed on the reserve list. The proportion of generated data actually used is definitely low; in the preceding example, a person with a feeling for land could reach the same conclusion as a person who follows the Framework, but by using only 10% of the data.

The circular arguments of matching

Matching is the pivot on which land evaluation turns. The process of matching has been most extensively discussed by Beek (1978), who proposes applying systems analysis in land evaluation. The system to be analyzed is the land use system (LUS) consisting of two subsystems: the land mapping unit (LU) and the land utilization type (LUT). Beek (1978) states:

> The systematic breakdown of the land use system into measurable land qualities, land requirements, inputs and outputs is the foundation for a systems approach to land evaluation.

He gives the following relation structure of the land use system (p. 280):

Land quality - output relations (1)
input - output relations (2)
input - land quality relations (3)

In a multidisciplinary land evaluation team, the planning economist is only interested in the second type of relations, the I/Y relations. These relations (2) can be directly obtained from surveys of farm economics or from productivity figures from trial sites located on representative types of land within the land evaluation area, or in similar areas.

The physical scientist in the team, however, also wants to know the two other types of relations for his matching procedures. As neither the functional relationships between land qualities and output (1) nor those between input and land qualities (3) are known, they are estimated by establishing rating and conversion tables.

These tables are then verified on the basis of productivity ratings (relations (2)). This leads to the curious situation that productivity ratings initially used to calibrate the system are presented as calculated output of the system in a later stage. As Beek (1978, p. 282) puts it: "Productivity ratings can provide a useful check on the weights attributed to the land qualities that condition productivity". And as one of this author's colleagues put it: "This guarantees that you are always able to recover the egg you have hidden yourself".

Veldkamp (1979) goes only half that way. By matching he determined a "calculated ecological suitability" of land for a crop by going through a large number of rating and conversion tables established by himself. He then compared this "calculated ecological suitability" with the expected yield for the same land/crop combination, established on the basis of direct yield measurements. Then, he continues (p. 110):

> If the difference is too large, the average value is considered to represent the ecological crop suitability. In this way, the available yield date are used to check the calculated suitability value.

In fact he did not take the average value, since further explanation (p. 140) reveals that after expressing the calculated ecological suitability and the expected yield in a four-class system in which 1 = high, 2 = moderate, 3 = restricted and 4 = low, the final ecological crop suitability was determined according to the formula:

1/3 (2 x calculated ecological suitability + 1 x expected yield)

By using this formula, a greater weight is given to the evaluator's intelligent guesstimate than to directly measured yields, because it is argued that the calculated suitability would be of a more fundamental nature than the directly measured value.

Not surprisingly, his conclusion is (Veldkamp, 1979, p. 178) that the evaluation revealed that the most suitable land use was almost identical with the current land use, and that it might be stated, therefore, that the study was done in the context of the present conditions.

Veldkamp's work is fundamental in the sense that it exposes the empirical foundations that underly qualitative physical land evaluation, but it does not give a fundamental explanation of the role of basic physical processes. For example, he assessed the availability of water in the rooting zone per season by adding, subtracting and multiplying the subratings of four aspects: groundwater class, height of capillary rise, available water holding capacity and seasonal specific overall wetness. But no attempt was made to find a quantitative expression of the availability of water by estimating the water balance in terms of inflow and outflow, which would require additional data on rainfall regime, evaporation regime, and hydraulic properties of the soil.

A great merit of Veldkamp's work is that it uncovers each step of a physical land evaluation procedure, recombining land characteristics into land quality ratings, comparing these with ratings of land requirements of specific crops, arriving at an ecological suitability index, and correcting the latter on the basis of a field check. In many land evaluation projects, underlying reasonings are not stated explicitly in the published reports and the suitability ratings appear out of the blue, although it is claimed that they have been calculated. Often the reason that the supporting evidence is omitted is that the rating rules are not consistent (i.e. are open to criticism) and are under continuous revision.

In the practice of land evaluation the results of a first round of matching may serve as a basis for identifying sites and subjects for research and development action. However, it is rare for the subsequent research results and development experience to be fed back to the original evaluation study for a next round of matching, because neither research nor development projects care for a retrospective refinement of land suitability classifications.

The importance of field checking as the final step of the matching procedure is confirmed by the Framework (section 4.7.1):

> A field check of the land evaluation is essential in order to ensure that the suitability classes arrived at by the above procedures are in accord with experienced judgement. Field checking is particularly important where a conversion table has been employed in the matching process, since rigid application of such tables can occasionally produce results at variance with common sense. The field checking should normally be carried out by a party including a natural scientist and one or more people experienced in the types of land use concerned, e.g. a farmer, agriculturalist, forester, engineer.

Here, the Framework seems to acknowledge that a holistic approach to land evaluation would give more consistent results than the analytical approach. The question remains whether matching serves as a check on field observation, or conversely, whether field observations should serve as a check of the results of matching. In this respect it is perhaps important to distinguish between the methodological needs of land evaluation research and the need for sound judgments and working speed in the practice of land evaluation.

Additional problems

Two problems in land evaluation that have received almost no attention in the Framework are the dynamic nature of land qualities, and the complexity of the land quality "nutrient availability".

The dynamic nature of land qualities may be illustrated by the availability of water. The amount of available soil water usually changes according to the seasons, depending on the climate. The influence of available water on crop performance also depends on the growing stage of a crop, and differences occur between crop types and between planting dates. If the Framework approach were strictly applied this would require that in a land evaluation separate comparisons must be made between water availability and water requirements for all land units, all management levels, all crops, all planting dates, all development alternatives. The proliferation of land conditions/crop growth combinations leads to large data bases that can only be managed with the aid of a computer. For the time being, computerization of comprehensive land evaluation in the sense of the Framework is still a research option. It should be kept in mind that computers can only do what they are told to do, and that methodological problems first have to be solved by the scientists themselves.

The second problem of nutrient availability has to do with the way that land mapping units are defined. The criteria for distinguishing mapping units are related more to stable subsoil properties than to the topsoil properties, which are variable in time and in space. Temporal variations are mainly seasonal, spatial variations are often related to differences in land use history. The result is that within a mapping unit there may be a large variation in topsoil properties. Yet soil fertility is affected more by the topsoil than by the subsoil. While it is already risky to predict fertilizer requirements on the basis of measured topsoil properties, because of uncertain interactions, it becomes even riskier to predict them on the basis of mapping units. This constraint is not inherent in the Framework, but concerns the general problem of linking the sciences of soil fertility and soil geography. Perhaps the fertility capability soil classification system (Sanchez et al., 1982) may help to bridge the communication gap between the two branches of soil science.

Conclusions and suggestions for further research

It is time for a thorough revision of the principles, concepts and procedures of the Framework for Land Evaluation. The best way to achieve this is probably by evaluating the applications for which the Framework has been used since its conception. The evaluation should reveal discrepancies between what is advocated in the Framework and what is done in practice. This should be followed by an assessment of whether the Framework approach or its so-called applications serve the intended purpose better, and finally, whether a completely different approach would be needed under the specific conditions of each application. Thus a kind of matching procedure should be set in motion, aiming

- to check the relevance and refine the rules of the Framework
- to permit a systematic determination of the necessary amendments to the rules of the Framework
- to estimate the efficiency of the Framework approach in each particular situation vis-à-vis other approaches.

Much information on land evaluation projects is contained in the FAO World Soil Resources Reports from no. 44 onwards. The European Commision is at present promoting Framework-based pilot studies in western Europe. Many development projects and soil survey organizations in the third world have also adopted the Framework approach, so that examples of land evaluations are amply available.

The subjects selected for an evaluation of land evaluations on methodological aspects should ideally range over a wide scale and could, for example, include the following studies: FAO Agro-ecological Zones Project (FAO, 1978) at continental scale, Kenya Soil Survey reports (e.g. Van de Weg and Mbuvi, 1975; Wielemaker and Boxem, 1982) at reconnaissance scale, the Leziria Grande project study in Portugal (Beek et al., 1980) at semi-detailed scale, a smallholder settlement scheme in Jamaica (Andriesse and Scholten, 1983) at detailed scale, and a case study in Nigeria (Veldkamp, 1979) at farm level.

But not only methodological aspects should be investigated. Other aspects that warrant special research is, firstly, to assess the impact of land evaluation studies on decisions on land use, and, secondly, if decisions on land use have been taken on the basis of land evaluation, to assess the predictive value of land evaluation by comparing the productivity after implementation with the land evaluator's original judgment of land suitability.

Anticipating the results of further research into land evaluation procedures it may be stated that the Framework is over-ambitious in aiming at multidisciplinarity, and that for physical land evaluation the prediction some 40 years ago by Simonson and Englehorn (1943) that the selection of criteria for the grading of soils into classes was to remain one of the most perplexing problems in the future, is still true in the current state of knowledge.

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