

METHODS OF LAND EVALUATION AND LAND USE PLANNING FOR RURAL AREAS : A REVIEW

MARKUS KAPPEL, Pune.

ABSTRACT: Methodologies and procedures of land evaluations, as integral parts of land use planning for rural areas, were subjected to profound changes during the 1980's. The pressure on land in developing countries as well as in industrialized countries along with the increasing application of computer technology and the development of new data integration and processing systems for land use planning purposes will contribute towards a further rapid development of land use planning methodologies. This paper compares the two internationally common methods: the USDA Land Capability System and the FAO Framework for Land Evaluation and describes the recently developed computer tools for the analysis and integration of data for land evaluation in the context of the "FAO - framework". After an introductory outline, both methods are described separately around the following points: a) aim of the method, b) range of application, c) subject-approach, d) postulated principles, e) procedures and progression, f) range of map scale and level of detail, g) type of mapping units, h) land use, i) criteria of evaluation, and k) evaluation procedures. An assessment of weaknesses, limitations and strong points is given at the end of each description.

INTRODUCTION

Outline of the present international development in land evaluation and land use planning methodologies: There are several aspects of the discussion in the area of land use planning/land evaluation evolved in the last twenty years, that are particularly important for the development of this subject: First, the realization that evaluation on the basis of one factor only (e.g. soil) is not sufficient; second, the demand that land evaluation should present development options and potentials; third, the development of methods for specific land suitability evaluation for defined types of land utilization; and fourth, the realization of the necessity of ecological, social and economic factors to be integrated for planning purposes.

The Land Resources Development Centre

(LRDC) in Great Britain concludes from its project experiences the following requirements for a land evaluation which can be taken as trend indicators.

1. Multi-disciplinary approach

Projects need to have larger teams with a broader specialization and the ability to carry out more comprehensive studies.

2. Ability for a fast transformation

The trend goes for a rapid identification of developmental potentials.

3. Integration

Socio-economic factors influence land utilizations in a decisive way and therefore need to be taken into account.

4. *Quantitative approach*

Stronger emphasis is laid on quantitative evaluation and presentation of the results.

5. *Monitoring*

Aspects of controlling implementation/application of the results of land evaluation gain more importance.

6. *Intensity*

The trend goes for a more intensive and detailed analysis of smaller areas.

7. *Structuring*

An efficient system of data procurement and problem analysis is required which provides a logical step by step approach, able to guarantee a comprehensible procedure.

The following recommendations of a workshop "Quantified land evaluation: need for further methods" are representative and very informative. The conference was organized by the International Society of Soil Science (ISSS) together with the FAO, and the International Institute for Aerospace Survey and Earth Sciences (ITC), in Washington, April 1986.

"(1) To promote the adaptation of land evaluation procedures to variable scales, levels of information and different users.

(2) To promote the incorporation of local and regional expertise in matters such as pests and diseases, workability of land, economics, risks and natural hazards.

These are not adequately accounted for in the present QLE and can be incorporated by using techniques such as expert systems, including local farmers' experience, and statistical models.

(3) To encourage land evaluators to include users, such as planners and farmers, in the establishment of goals,

objectives and relevant LUTs² during the process of QLE.

(4) To encourage the development of methods that effectively use incomplete data bases, while at the same time allowing for and encouraging the acquisition and incorporation of local data.

(5) To foster the development and use of electronic equipment to gather and process data for quick assessment, problem solving and application in the field.

(6) To encourage research on the relationships among land use, farming systems and soils in order to derive knowledge from farmers' experience.

(7) To promote the diffusion of land evaluation procedures and results to target users through education and demonstration.

(8) To establish permanent data collection programmes for (a) continuous testing and feedback of land evaluation results, and (b) monitoring dynamic land characteristics and qualities for updating data bases" [BEEK *et al.* 1987 : 158].

¹ QLE = Quantified land evaluation

² LUT = Land utilization type

³ International Society of Soil Science

⁴ Stichting Bodemkatering, Wageningen, The Netherlands

⁵ International Institute for Aerospace Survey and Earth Science, Enschede, The Netherlands.

⁶ International Soil Reference and Information Centre, Wageningen, The Netherlands

Topics of other conferences on land evaluation, organized by the FAO or ISSS together with relevant organisations read as follows: "Land evaluation criteria for irrigation", 1979, Rome [FAO 1979], "Land evaluation standards for rainfed agriculture", 1980, Rome, [FAO 1980], "Land evaluation for forestry", 1980 Wageningen, [LABAN 1981], "Land evaluation for extensive grazing", 1983 Addis Ababa, [STDERIUS 1984], "Land evaluation for land - use planning and conservation in sloping areas", 1984 Enschede, [SIDERIUS 1984], "Land evaluation and farming systems survey", 1993.

These symposiums have proved to be goal-setters since they are generally organized by several internationally recongized institutions.

One of the more recent conferences organized by ISSS³ workshops in collaboration with the FAO, Agricultural Wageningen, STIBOKA⁴, ITC⁵, ISRIC⁶, and Geographical Institute University Utrecht, took place in Wageningen, 1988, under the title: "Land qualities in space and time" [BOUMA *et al.* 1989]. The thematic focus was on experiences with computer supported land evaluation programmes, Geographical Information Systems (GIS), and issues of levels of scale and detail. Results and recommendations refer to issues of data procurement (guidelines, methods, level of detail, application of remote sensing, and information technology), development of models (simulation), utilization and presentation of soil surveys, variability (of evaluation - criteria), application of information technology (efficiency), training and communication (documentation).

THOMASSON [*et al.* 1989: 239] recognizes major development tendencies during the last ten years as:

1. the recongition of the necessity for simple-to-handle, large cartographic and tabular

sets of data.

2. the acceptance of the general use of "land qualities" like workability or dryness, correlating closely with soil and climate.
3. the change from single to multiple evaluation systems. For example, land potential evaluation is replaced by evaluation of crop suitability and environmental risks.
4. a shifting of the target group or clients from farmer/extension-worker towards political decision-maker.

The most recent developments comprise modelling of complex landscape phenomena; "expert models" for land evaluation using electronic data processing, and their integration in a Geographic Information System (GIS).

Most promising is the integration of farming system anlaysis with land evaluation in the way it has been done by FAO and ITC recently [FAO *et al.* 1990]. This concept could be the basis for a stronger target group and planning orientation.

1. THE USDA LAND CAPABILITY SYSTEM

The concept of land capability was developed during the 1930s in the USA, but the widespread adoption of land capability schemes only began after 1960. The assessment of land capability involves an evaluation of the degree of limitation posed by permanent or semi-permanent attributes of land to one or more land uses. This method has therefore been referred to as a "proscriptive approach" in contrast to a "prescriptive approach", which has the best possible utilization as its goal of evaluation, rather than the determination of land use limitations.

The American work during the 1930s was a response to the serious soil erosion problems which occurred then, especially in the Mid-

West. The aim of the appraisal was to express the risk of erosion and to indicate sustainable land uses. The maps were thus designed to provide an important input to the formulation of soil conservation schemes. The production of land capability map was encouraged by the increasing awareness that conventional soil maps were not being widely used. An early review of American work on land capability assessment is given by HOCKENSMITH and STEELE [1949].

The "USDA - Land Capability System" was published by the Soil Conservation Service (SCS) of the United States Agricultural Department in September 1961 [KLINGEBIEL *et al.* 1961]. The methodology was the result of decade-long experience of the SCS in America, establishing a new development in the field of land evaluation. The procedure is therefore well described in specialist literature [DAVIDSON 1980; DENT *et al.* 1981; HUIZING 1983; HUNDSON 1986; IANSON 1984; LUNDGREN 1975].

The prime aim of the method is to assess the degree of limitation to land use or potential imposed by land characteristics on the basis of permanent properties. The method assists also,

- “(1) to help landowner and others interpret the soil maps,
- (2) to introduce users to the detail of the soil map itself,
- (3) to make possible broad generalisations based on soil potentials, limitations in use, and management problems” [KLINGEBIEL *et al.* 1961 : 1].

The range of application lies in the suitability classification of a given area for cultivation, grazing and forestry. This is done “primarily on the basis of their capability to produce common cultivated crops and pasture plants without deterioration over a long period of

time” [FAO 1974:2].

The USDA method is used worldwide, in India, in the Philippines, Malawi, Pakistan, Venezuela and South-Africa. It's a monodisciplinary soil science approach with emphasis on soil conservation and with consideration of climatic conditions, but without regard to economic and social aspects.

Several specified principles and assumptions form the basis of the evaluation procedure, some of them are outlined below [KLINGEBIEL *et al.* 1961:4]:

- the suitability classification is interpreting the classification based the combined effects of permanent soil, climatic and land characteristics.
- soils of the same capability class are only similar in point of their agricultural limitations.
- a moderately high level of management is assumed on the part of the land user. This level is considered to be ‘reasonable’ for the area in question.
- limiting factors (stones, risk of flooding, soluble salts), technically feasible to remove with justifiable expenditures, are not appraised as permanent limitations.
- soils suitable for cultivation are also appropriate for other land uses like grassland, pasture, forest or wildlife.
- the capability assessment of a soil may be re-evaluated after the adoption of measurements which could help to eliminate factors of limitations durably.
- factors such as distance to market, types of roads, size and shape of the soil areas, location within fields, ability and resources of individual land users, and other aspects of land ownership are not taken into account.

– soils unsuitable for mechanised farming are not to be included in classes I-IV.

“Soil mapping units”, having similar characteristics and factors, are used as spatial reference units. These are consequently soil units. According to FAO [1974:2] the procedure is based on the analysis of intensive soil surveys, published in the US on scales of 1:20,000 and 1:15,840.

The USD method has three levels in its classification structure.

1. Capability class

This is the broadest category and a total of eight classes are defined and labelled I to VIII, indicating degree of limitation.

2. Capability subclass

These subclasses indicate the type of limitations encountered within the classes. Limitations such as an erosional hazard, rooting zone restriction, and problems of climate, stoniness, low fertility, salinity or wetness are indicated by a lettersubscript. For example, class II with major limitations imposed by excess water and climatic characteristics is indicated as IIwc.

3. Capability unit

this is a subdivision of the subclass. Land in one capability unit clearly includes many different soils but has little variation in degree and type of limitation to land use, but in addition is suitable for similar crops under similar farm and management schemes. The yield range of crops within capability units in such circumstances should not be greater than 25 per cent [DAVIDSON 1992:58].

The USDA system defines potentials for a range of land uses, rather than specific and exactly defined land uses.

The “better” a land unit the more variable its land use potential. Areas of class (I) are possible for all uses, where class (VIII) is useable for wildlife. Altogether eight land classes are differentiated according to their limitations, described thoroughly in the handbook [KLINGEBIEL et. al. 1961:6]. The brief summary of these classes as provided by YOUNG [1973:14] is given below.

Note that classes I to IV are cultivable while the remaining classes are not.

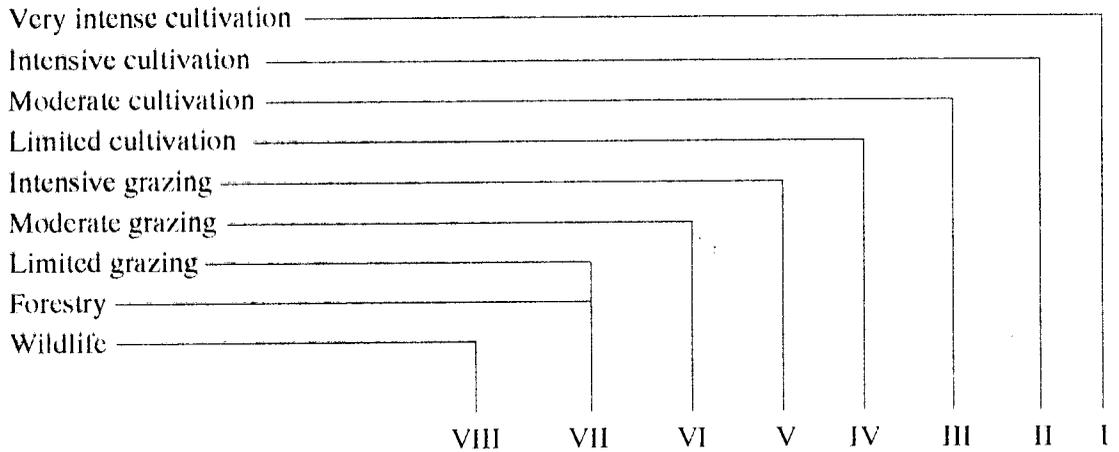
Table 1

USDA CAPABILITY EVALUATION STRUCTURE [DENT ET AL. 1981:131]

Capability	Class	Capability subclass	Capability unit	Soil mapping unit
arable	I			
arable	II	IIe	IIe-1	P series
arable	III	IIw	IIe-2	Q series
arable	IV	IIc	IIe-3	R series
non-arable	V	IIc	etc	
non-arable	VI	IIwc		
non-arable	VII	etc		

Table 2

INTENSITY OF LAND USE AND LAND CAPABILITY CLASSES



Class I	Soils with few limitations that restrict their use.	Class VI	Soils with very severe limitations that make them generally unsuited to cultivation and limit their use to pasture or range, woodland or wildlife.
Class II	Soils with some limitations that reduce the choice of plants or require moderate conservation practices.	Class VII	Soils with very severe limitations that make them unsuited to cultivation and restrict their use largely to grazing, woodland or wildlife.
Class III	Soils with severe limitations that reduce the choice of plants or require special conservation practices, or both.	Class VIII	Soils and landforms with limitations that preclude their use for commercial plant production and restrict it to recreation, wildlife, water supply or aesthetic purposes.
Class IV	Soils with very severe limitations that restrict the choice of plants, require very careful management, or both.		
Class V	Soils with little or no erosion hazard, but with other limitations impractical to remove, that limit their use largely to pasture, range, woodland or wildlife food and cover (in practice this class is mainly used for level valley-floor lands that are swampy or subject to frequent flooding).		Permanent limitations and yield potential are the criteria used to evaluate a given area for its sustainable agricultural suitability. The following limitations in the sense of an impairment to agricultural use are being considered. The procedure begins with a definition and description of land units. For each land unit

Table 3

LIMITATION AND INDICATORS IN THE USDA SYSTEM

Limitation (subclass)	Indicators
e risk of erosion	- erodibility
	- previous damage
w excess of water	- impaired soil drainage
	- water logging
	- high water table
	- flood
s root restriction	- shallowness of soil
	- stones
	- low water holding capacity
	- low fertility (permanent)
	- salinization/sodium
e climatic conditions	- temperature
	- moisture deficiency

In more recent studies additional criteria may be used.

limitation factors are selected and evaluated according to their characteristics. The results are then compared with a conversion table which contains value limits for each land use class. Land units are so assigned to a capability class. The results are presented in maps along with a commentary on soil condition.

The USDA concept has been internationally accepted to the extent that other methods, like the "FAO framework" borrowed large parts of it. A number of countries developed national methods that directly have their origin in the USDA procedure.

The method is not up to date any more. The USDA has already developed a new system, "Agricultural Land Evaluation and Site Assessment System" (LESA), though it is used so far only in the USA. In this context DAVIDSON [1982:G2.6] says the following:

"In essence the system lacks a firm ecological foundation in contrast to more recent schemes of land evaluation". The pure mono-disciplinary approach together with a confined objective towards arable and non-arable areas without consideration of cultivable plants considerably restricts the meaningfulness of this method. McRAE [et.al. 1981:83] presents an informative list of advantages and disadvantages:

Advantages of the USDA method:

- classification is relatively easy to understand;
- qualitative approach corresponds with today's limited knowledge about soil/environment/plant interaction;
- versatile, because easy adjustments to local conditions possible;

- easy applicability by experts as well as technicians;
- general suitability evaluation with clear differentiation of cultivable and non-cultivable areas;
- emphasis on possible negative land use effects supports soil conservation aspects;
- results can be represented easily and clearly in maps;
- broad application in industrialized and developing countries.

Disadvantages of the USDA method:

- encourages subjectivity;
- interactions between factors are not taken into account;
- differentiation into eight classes is too inaccurate;
- classification portrays an unreflected evaluation of the true value of an area;
- suitability for specific crops is not taken into account;
- socio-economic factors are not considered;
- negative evaluation may discourage involved farmers;
- taking over soil unit from available soil maps as area units is insufficient.

Due to the large scale, requirements on data acquisition may be quite high, although criteria are possible to be assessed in the field without too many technical requirements. The procedure itself is described in detail and relatively easy to handle so that time is not an important factor for the immediate evaluation procedure. One person trained in soil science is sufficient to carry out an evaluation.

The easy differentiation of the suitability groups in cultivable and non-cultivable areas

is sufficient only for strategy planning. Alternative forms of land utilization are not taken into account hence planning options are not provided.

DENT [*et al.* 1981:137] views the USDA system as very appropriate for farm planning. He divides the procedure into seven steps:

- (1) decide upon the arable land
- (2) add land for grazing, woodland etc.
- (3) if not already there, locate the central service point
- (4) locate water supplies (wells, boreholes, channels, weirs)
- (5) set out the farm service road
- (6) set out major conservation work (storm drains, waterways)
- (7) identify in outline bunds or other soil conservation works which the farmer constructs himself."

The USDA method is certainly used for this purpose, but that does not mean that it is necessarily destined for it. Especially for farm planning as the most intense form of land use planning exact statements about field crops, crop rotation, their water requirements, etc., are needed. On this level of planning economic considerations are obligatory, since for the farmer profit maximization will be an important maxim of choice. The basic question should therefore be which cultivable plants and farming systems are ecologically and economically suitable, rather than which areas are generally suitable for arable agriculture.

2. THE FAO FRAMEWORK FOR LAND EVALUATION

In the early 70s under the overall control of the FAO and with international cooperation, especially the Netherlands, Great Britain, and

the USA, efforts were undertaken to consolidate methods of land evaluation [BRINKMAN *et al.* 1973]. This work led to a framework concept named "Framework for land evaluation" [FAO 1976].

Meanwhile the Framework might be the most used land evaluation procedure.

The range of application possibilities is very broad and covers many areas of human resource demands. Many examples of applications can be found in the literature, although it is often not clear if the postulated use of the FAO procedure has always been followed according to its principles. Likewise there are a good number of descriptions of the procedure in its different variations available: BEEK [*et al.* 1987] BENEMMA [1978], BOUMA *et al.* 1979], YOUNG [*et al.* 1977], BOHLIN [*et al.* 1981], DAVIDSON [1980:36], FAO [1975:79], SIDERIUS [1984/1986], SYS [1986], LANDON [1984] and THALEN [*et al.* 1985].

The Framework aims at a suitability evaluation of different (alternative) land uses for an area. Thereby prevailing interactions and level of technology are taken into account. A multidisciplinary approach is propagated.

The methodology is based on six principles: DAVIDSON [1992:80]

"1) Land suitability is assessed and classified in relation to particular land uses.

This principle recognizes that land uses vary in their requirements so that a field highly suitable for one crop may be unsuitable for another.

2) Evaluation requires a comparison of the inputs and outputs needed on different types of land. This could be done by comparing the costs of production with the economic returns of different types of land.

3) A multidisciplinary approach is required. Contributions from such specialists as crop ecologists, agronomists, pedologists, climatologists, economists and sociologists are necessary in order to make a comprehensive and sound assessment of land suitability for a specified use.

4) The evaluation is made with careful reference to the physical, economic and social context of the area under investigation. It is fairly obvious that any land use proposals have to be realistic for an area. It is important to take into account such factors as cost of available labour and skills of the labour force.

5) Suitability refers to use on a sustained basis. The proposed use of land must not result in its degradation through processes such as wind erosion, water erosion or salinization.

6) Different kinds of land use are compared on a simple economic basis. This means that the suitability for each use is assessed by comparing the value of the goods produced to the cost of production."

The Framework distinguishes two different strategies: In the parallel approach, acquisition and analysis of bio-physical and socio-economic data may be done simultaneously, while in the two stage approach, a qualitative land suitability classification is followed by an economic and social analysis. Figure 3 shows these two approaches. The dotted line from "Qualitative land classification" to "Planning decision" indicates a short cut often used in practice.

The procedure is outlined by the following main activities:

- deciding on the objective of the study and on data and assumptions on the basis of which the evaluation is made.

Figure 3: Two-stage and parallel approaches to land evaluation**INITIAL CONSULTATIONS**Two - stage approach

Basic survey
Qualitative land classification

Economic and social analysis
Quantitative classification

Source : FAO 1976:7

Parallel approach

Basic survey
Qualitative and Economic
quantitative and social
classification analysis

Planning decisions

- describing land utilization types, to be studied, the land use requirements and limitations
- describing land unit and selection of relevant land qualities (attributes of land which can be measured or estimated).
- comparison of the proposed land utilization types with present land use.
- economic and social analysis.
- presentation of results.

Their stages of intensity are distinguished which usually also indicate the mapping scales [source:FAO 1976:52].

- Reconnaissance level (1:500.000 - 1:120.000)
Surveys of land resources and development potentials at national level belong to this degree of detail. The economic analysis remains very general. The land suitability classification is a qualitative one. The study is mostly based on satellite data.
- Semi-detailed level (1:100.000 - 1:30.000)
More accurate objectives like feasibility studies are possible. Economic analysis are

far more important than in the previous level. The land suitability classification is generally expressed in quantitative terms. Mostly air photographs are utilized with a greater fieldwork component.

- Detailed level (1:25.000 - 1:30.000)
Here precise field surveys are essential, often on farm-level or for project implementation.

Results of the physical resource survey which is commonly a soil or soil-landform survey is presented in the form of "Land mapping units" as spatial references. Theoretically possible is also the selection of mapping units which more closely refer to the kind of land utilization, like "management units".

Because the Framework is a procedure for specific land suitability classification the description of the type of land use to be evaluated, is considered as an essential element of the study. A distinction is made between two types of land use:

- **Major kind of land use :** Major subdivision of rural land use, for example rainfed agriculture, irrigated land, pasture land, forestry or recreation.

- **Land utilization type (LUT):** Form of land use described in greater detail [FAO 1976].

The decision which type is used depends on the objectives and level of detail. Land utilization types are described not only in terms of actual land uses or crops, but also with reference to such factors as type of market orientation (subsistence or commercial production), capital intensity, labour intensity, technology employed, infrastructure requirements, size and configuration of land holdings, land tenure and income levels. An example of a land utilization type as given in the FAO Framework [1976:10]

is rainfed annual cropping based on groundnuts with subsistence maize, by small holders with low capital resources, using cattle-drawn implements, with high labour intensity, on freehold farms of 5-10 ha.

It is also possible to describe multiple land utilization types with different uses co-existing together and compound utilization types with uses different areas of land within the same functional unit—a mixed farm with both arable and pasture.

Another peculiarity concerns the criteria of evaluation, for which complex factors are preferred. They are in general more meaningful for an evaluation as they are also able to represent interactions between single parameters. The Framework distinguishes

- **Land quality** (site factor)

A complex attribute, directly related to a specific kind of land use and assessed by land characteristics (e.g. risk of erosion, water availability, risk of flooding).

- **Land characteristics**

A parameter (and attribute) which can be measured or estimated, used for mapping of

land resources (e.g. slope, precipitation, soil texture, salt content).

For evaluation, the land use requirements are compared with the land qualities whereby various description and evaluation tables (conversion tables) are used:

- tabular description of land mapping units;
- tabular arrangement of LUT - definitions;
- tabular description of land qualities per land mapping unit;
- tables where LUTs are graded in terms of degree of limitation posed by a particular land characteristic;
- tables of the results of evaluation per land mapping unit

The FAO Framework does not give any recommendations concerning weighting of evaluation factors. Limit values are only mentioned exemplarily in some guidelines [FAO 1983/1984/1985].

The Framework recommends a quantitative or at least semi-quantitative presentation of results preferred are economic dimensions. It is important to differentiate between current suitability and potential suitability. The former describes the suitability for a defined land use under the current condition of the site without greater improvements. The second variant takes effects of investments or other measurements (terracing, drainage) into account. Necessary specifications of suitability for planning purposes are thereby possible.

The results of the land suitability classification are given in four categories, representing levels of decreasing generalization [FAO 1976:21]:

- 1 Land suitability orders reflecting kinds of suitability
- 2 Land suitability classes reflecting degree of

suitability within orders

- 3 Land suitability subclasses reflecting kinds of limitation, or main kinds of improvement measures required, within classes
- 4 Land suitability units reflecting minor differences in required management within subclasses

At the order level an assessment is made as to whether the land is suitable (S) or not (N) for sustained use of the kind under consideration and yielding benefits which justify the inputs. Classes indicate the degree of suitability-up to a maximum of five. Subclasses indicate the type of limitation and are represented by lower-case letters, for example S2M for suitable land of class 2 with the specific limitation of moisture availability. The most detailed level in the classification hierarchy is the unit. Units vary in their production characteristics or in minor aspects of their management requirements. This level in the structure is designed to be applicable to individual farms. Units are indicated by arabic numerals, eg S2m-1, S2m-2, etc.

A land suitability report based on the FAO Framework should give details about the following points:

- 1 the physical, social and economic context as well as background data and assumptions in the approach
- 2 description of land utilization types or major kinds of land use
- 3 maps, tables and explanatory text showing degrees of suitability of land mapping units
- 4 management and improvement specifications for each land utilization type with respect to each kind of land use considered, together with the diagnostic criteria
- 5 economic and social analysis of the consequences of the various kinds of land use considered

6 the basic data and maps from which the evaluation was estimates.

The relevance and quality of the Framework is unquestionable. Renowned institutes like ITC, STIBOKA and LRD are using the Framework in their projects as well as for training purposes. Many examples of applications can be found worldwide and in the meanwhile it may represent the most recognized methodology for an objective-oriented land suitability classification. The method is widely spread in eastern and southern Africa (Botswana, Ethiopia, Kenya, Mozambique, Tanzania and Zambia) [FAO 1986] and in southeast Asia (Indonesia, Philippines) [HUIZING 1986:1.10].

Advantages of the Framework are:

- clear and relatively conclusive concept of principles and procedure;
- flexibility of the approach allowing and even requiring regional adjustments;
- wide application for different kinds of land use and various mapping scales, until the evaluation of the actual land use;
- orientation towards an evaluation of complex factors with respect to specific land utilization types;
- (at least theoretically) integration of all land use aspects but also technological and social influences;
- spacious and further expanding documentation with many examples is available;
- altogether, approach and procedure very relevant for planning purposes;

Although theoretically provided for, social and economic considerations are often left out with the explanation that this is a task of a following further step of analysis. It is questionable if this weakness should be attributed

to the method itself or to a deficient application.

The procedure seems to be unsuitable for the selection of natural reserves (ecologically endangered or other natural areas to be protected) because of its production orientation.

The concept is principally designed for application in developing countries although industrialized countries are also included by the FAO [BEEK 1984:279].

Requirements on time and finances depend essentially on accuracy and scale of the study. No reliable details can be given but it may be stated that a relatively high level of expertise is required that usually involves higher costs.

3. RECENTLY DEVELOPED COMPUTER TOOLS FOR DATA ANALYSIS AND INTEGRATION FOR LAND USE PLANNING PURPOSES

Relational Databases

The necessity to handle great amounts of data, to set up voluminous tables and to do many recurrent calculations lead to the logic development of electronic data processing. With relational databases for example it is now possible to store, retrieve and manipulate land resource, land cover/use, farming systems and socio-economic data. A database structure with base tables linked by "common fields" facilitates substantially the analysis and integration of data with information that is of direct relevance for the development of land use systems. Data can be stored without prior aggregation (original data e.g. slope steepness, soil depth or farm size as obtained in the field are stored rather than slope class, soil depth class or farm size class). If necessary, aggregation of the original data into classes can be done in the database itself and new more relevant classes can easily be made, in case standard classifications are not satisfactory. This is

possible because the original data is directly accessible in the database [HUIZING 1992:42].

GEOGRAPHIC INFORMATION SYSTEM

In the recent past there has been considerable scientific and commercial development of geographic information systems (GIS). The advantages of GIS are its capability to permit easy update of information and to present results in forms required by users. It can eliminate data integration problems that are caused by the different geographic units to which different data sets are related. Crossing and overlaying of maps with different mapping units becomes an easy task (e.g. soil, agro-climate, land use, watershed, and district/village maps). Distance modules allow the assessment of interactions of (potential) land uses, physical infrastructure and markets. Prime advantages of GIS are also its rapidity and quality, e.g. by Digital Terrain Models (DTM), of its display and map production facilities.

MODELS

In the field of land evaluation various crop predicting models have been developed. Two main types of models are available:

- Empirical or expert models; and
- Simulation, dynamic or process models.

Empirical or expert models use decision rules based on general and local expert knowledge. Examples of such models are:

- LECS (Land Evaluation Computer System) was developed in 1983

by WOOD [*et al.* 1983] within the FAO project "Land resources evaluation with emphasis on outer islands project Indonesia." It contains decision rules based on local conditions and may need substantial modifications when

LECS is used in other areas.

- ALES (Automated Land Evaluation System) was developed at the Agricultural Department Cornell University, Ithaca, New York by ROSSITER [1988] with cooperation of WAMBECKE and TOLOMEO. This computer program allows to create an expert system for land evaluation on project and regional level. It is based on decision trees that structure local and expert knowledge and can be described as an "empty box" with menus through which this knowledge can be stored, retrieved and edited. ALES from version 2.1 onwards is available as commercial software.

Simulation or dynamic models are based on known (plant growth, soil, hydrological) processes. These models are, in general, more universally applicable than expert models. They contribute to a better evaluation of the impact of dynamic (seasonal or fluctuating) characteristics of land on plant growth. However, before their application in a certain area, they still require often substantive data for their calibration and validation. Examples of such models are:

- ALMANAC was developed at the Grassland Soil and Water Research Laboratory at Temple, Texas [ALLAN JONES *et al.* 1987]. This model simulates such processes as soil temperature regime, hydrology, erosion, nutrient cycling, and crop growth and yield. The overall package is designed to assist with general agricultural management.

The simulation of crop growth based on geno-type specific coefficients which describe differences in growth of various crops and crop cultivars.

- WOFOST (acronym for World Food Studies) has been developed at the Centre for World Food Studies in Wageningen, The Netherlands [KEULEN VAN *et al.* 1986].

Similar to ALMANAC it models the growth and production of annual crops according to crop species, soil type, hydrologic conditions and weather during the growing season from emergence to maturity. Although WOFOST is generally recognized as a scientifically elegant crop simulation model, DIEPEN [*et al.* 1989] point out the limitations of the assumptions and simulation procedure, for example the time resolution of one day is inadequate in dealing with infiltration of runoff.

Another negative point is the tremendous data requirement of the programme.

- CRIES (Comprehensive Resource Inventory and Evaluation System) developed at Michigan State University, has two main menus, a geographical information system and an agro-economic information system. The merit of this package is the integration of GIS capabilities with modelling. Use of the yield module within CRIES allows prediction for thirty different crops. Data requirements include temperature, precipitation, relative humidity, wind velocity, solar radiation, sowing dates, crop selection, length of growing stages, soil texture and slope gradient, soil moisture characteristics in the root zone, and root development over various growing stages [SCHULTINK *et al.* 1987:187].

- DSSAT (Decision Support System for Agrotechnology Transfer) developed by the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) [THORNTON *et al.* 1991]. Part of this package is a database of soils, weather and crops so that users can run models which simulate the outcomes of alternative management practices. The system allows the prediction of agricultural yields according to different climatic change scenarios. In

the early versions of DSSAT, models are included for predicting yields of maize, peanuts, soybean and wheat. Applications are not limited to yield prediction, but can also be used for impact assessment of environmental change. Other possibilities of the package are to explore yield outcomes from intercropping of different crops using varying management strategies and also to translate yield figures into economic terms for individual farms. For this, farming systems are simulated with yield predictions as one important input. An integral minimum dataset on soils, crops, weather, management and yields allows the immediate validation of crop yield models for one or more areas in order to be applied further for analogous areas.

INTEGRATED LAND USE MODELS

Information on land resources are acquired to be incorporated into land use management or planning decisions. In practice, managers or planners have to make decisions on the basis of a wide range of considerations. The physical suitability of land need to be compared with the societal goals as expressed in priorities such as those given to economic returns, need for new housing, and landscape or habitat conservation. To provide such a synthesis of land resource information with goals and objectives for land use an integrated approach of land evaluation may be adopted. Land use options are identified for each land unit and the extent to which such uses are critical in the land units. The following approach represents a methodological development of the FAO Framework for Land Evaluation and is given

as an example:

LUPLAN has been developed in Australia by the Division of Wildlife and Ecology, CSIRO (IVE and COCKS 1983; IVE et al. 1985). The package application consists of three inherent components. First, information it acquired for the study area, subdivided into mapping units or planning zones. These zones are then rated in terms of their attractiveness for a range of land uses on the basis of different policy guidelines. These ratings express the relative contribution which each mapping unit can make to the achievement of each specified policy. In the third step the relative importance of the different policy guidelines is assessed. Each policy is assigned a relative preference to ensure that those considered more important are given higher votes than those deemed of less importance. The LUPLAN package includes a database on the mapping units (inventory capability) and has the ability to provide attractiveness ratings for each potential land use (evaluation capability). On the basis of the ratings the most attractive land uses can be determined for each mapping unit (allocation capability). Results of LUPLAN are given in the form of percentages which express the extent to which individual land use plans achieved the guiding policy. A review then follows and assigned votes to policies may be changed. Further runs of LUPLAN are then necessary until acceptable results are achieved. In Australia, LUPLAN has been used as an aid to rural and conservation planning. This approach has the merit of being able to assess the extent to which particular land use plans meet policy objectives.

REFERENCES

- Allan Jones, C. / O'Toole, J. C. (1987). Application of crop production models in agro-ecological characterization : simulation models for specific crops in: Bunting, A. H. (Ed.) "Agricultural Environments" CAB International, Farnborough, pp. 199-209.
- Asian Productivity Organization (APO) (1993). Development of marginal agricultural land in Asia and the Pacific. *Report of an APO Seminar*, 20-29 April, 1992. 245p. Bangkok.
- Beek, K. J. / Burrough, P.A. / McCormack, D.E. (Ed.) (1987). Quantified land evaluation procedures. *Proc. of the intern. workshop on quantified land evaluation procedures held in Washington, DC 27, April - 2 May 1986*, ITC Publ. No. 6, 166p. Enschede.
- Benemma, J. (1978). *Land evaluation for agricultural land-use planning* in: Swindale, L.D. (Ed.) (1978). 130-140. Honolulu (USA)
- Bohlin, F. / Messing, I. (1981). Ways of appraising land and a proposal on how to apply the information gathered from a land evaluation. *Swedisch Univ. Agr. Sc., IRDC Working Paper* 20. 49p. Uppsala.
- Bouma, J. / Bregt, A.K. (Ed.) (1989). Land Qualities in space and time : *Proceedings of a symposium organized by the IASS, Wageningen*. The Netherlands, 22-26 August 1988. 355p. Wageningen.
- Brinkman, R./Smith, A. J. (1973). Land evaluation for rural purposes. *Summary of an expert consultation*, Wageningen 6-12.10.72. ILRI Publ. No. 17 (2.ed. 1983), 116p. Wageningen.
- Davidson, D.A. (1980). *Soil and land use planning*. 129p., London.
- Davison, D.A. (1992). *The evaluation of land resources*. 198p., Essex
- Dawson, J.A./Doornkamp, J.C.(Ed.) (1973). Evaluating the human environment. *Essays in applied geography*. 288p., London.
- Dent, D.A. /Young, A. (1981). *Soil Survey and Land Evaluation*. 287p., London.
- Diepen, C.A. van /Wolf J./Keulen, H. van /Rappoldt, c. (1989). WOFOST : a simulation model of crop production. *Soil use and Management* 5 : 16-24.
- Fao (1974). Approaches to land classification. *Soils Bulletin* 22, 120p. Rome.
- Fao (1975). *Report of the expert consultation on methodology for planning of rural areas*. Held in Geneva Switzerland 22-24 July, 1975. 66p. Rome.
- Fao (1976). A framework for land evaluation. *FAO Soils Bulletin*, No., 32. 87p., Rome.
- Fao (1979). Land evaluation criteria for irrigation. *Report of an expert consultation*. World Soil Resources Reports No. 50. 219p., Rome.
- Fao (1980). *Report on the FAO/SIDA/GOI seminar on forest resources appraisal in forestry and land-use planning (Asia and Pacific region)* New Delhi and Dehr Dun, India (27 Nov.-15 Dec. 1978), 112p., Rome.
- Fao (1983). Guidelines : Land evaluation for rainfed agriculture. *FAO Soils bulletin* No. 52. 237p. Rome.
- Fao (1984). Land evaluation for forestry. *FAO Forestry Paper* No. 48s. 123p. Rome.
- Fao (1985). Guidelines : Land evaluation for irrigated agriculture. *FAO Soils Bulletin* No. 55. 231p., Rome.
- FAO/ITC/IAC (Fresco, L./Huizing, H. /Keulen, H. van et. al.) (1990). Land evaluation and farming systems analysis for land use planning. *FAO Guidelines Working Document*, 205p. Rome. Enschede.
- Hockensmith, R.D. and Steele, J.G. (1949). Recent trends in the use of the land capability classification. *Proceedings of the Soil Science Society of America* 14 : 383-8.
- Hudson, N. (1986). *Soil conservation*. 324p, London.
- Huizing (1986). Land evaluation—*lecture notes for the N.11 specialisation*. ITC. 100p. Enschede
- Keulen, H. Van. (1986). Modelling of Agricultural Production : Weather, Soil and Crops. *Simulation Monograph*, nr. 25. PUDOC, Wageningen.
- Klingebiel, A.A. / Montgomery, P. H. (1961). Land-capability classification. US-Dept. of Agr., *Soil Conserv. Service, Agric. Handbook* No. 210. 21p. Washington D.C.
- Laban, P. (Ed.) (1981). *Proceedings of the workshop on land evaluation for forestry*. ILRI Publ. No. 28. 345, Wageningen.
- Landon, J. R. (Ed.) (1984). *Booker tropical soil manual : a handbook for soil survey and agriculture*. 450p., Harlow Essex.
- Ive, J.R. / Cocks, K.D. (1983). SIRO-PLAN and LUPLAN : an Australian approach to land use planning. 2 The LUPLAN land-use planning package. *Environment and Planning B: Planning and Design* 10 : 347-55.
- Ive, J.R./Davis, J. R./Cocks, K.D. (1985). A computer package to support inventory, evaluation and allocation of land resources. *Soil survey and Land Evaluation* 5:77-87. Norwich.

- Lundgren, B. (1975). *Land use in Kenya and Tanzania. The physical background and present situation and an analysis of the needs for its rational planning*. Swedish Univ. Agr. Sc. IRDC, Royal College of Forestry, (2. edit. 1981), 354p., Stockholm.
- McRae, S.G./Burnham, C.P.(1981). Assessment of agro-ecosystems production potential in developing countries: the CRIES agro-economic information system yield model. *Soil survey and Land Evaluation* 7(3), pp. 187-197. Norwich.
- Siderius, W. (Ed.)(1984). *Proceedings of the workshop on land evaluation for extensive grazing* (LEEG). International Workshop on Land Evaluation for Extensive Grazing (LEEG) Addis Ababa, Ethiopia. 31.10 - 4.11.1983. ILRI Publ. 36. 343p. Wageningen.
- Siderius, W. (Ed.)(1986). *Land evaluation for land-use planning and conservation in sloping areas*. Intern. Workshop, Enschede, The Netherlands, 17-21 Dec. 1984. ILRI Publ. 40, 334p., Wageningen.
- Sys, C. (1986). Approach to soil survey interpretation for rice cultivation. *Pedologie*, 36(2)), p. 199-217. Ghent.
- Rossiter, D.G./Tolomeo, M./Wambecke, A.R. Van (1988). *Ales Version 1.0 User's Manual*. Cornell University, 120p. Ithaca NY.
- Thalen, D.c.P./Smiet, A.c. (1985). Quantified land use policy options in forest land evaluation for watershed management. *Netherlands J. of Agric. Sc.* 33(2), p. 89-103, Wageningen.
- Thomasson, A.J. / Jones, R.J.A. (1989). *Land evaluation at regional scale* in Bouma, J. *et al* (1989) 231-240. Wageningen.
- Thornton, P.K./Dent J. B. /BACSI, Z. (1991). *A framework for crop*.

ADDRESS OF THE AUTHOR

Markees Kappel,
Spicer Memorial College,
Pune - 411007