An overview of land evaluation and land use planning

Land evaluation is formally defined as 'the assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation' (FAO, 1976).

Conceptually, land evaluation requires matching of the ecological and management requirements of relevant kinds of land use with land qualities[1], whilst taking local economic and social conditions into account. Land evaluation provides practical answers to such questions as "What other uses of land are physically possible and economically and socially relevant?", "What inputs are necessary to bring about a desired level of production?", and "What are the current land uses and what are the consequences if current management practices stay the same?".

Depending on the questions that need to be answered, land evaluation can be carried out at different scales (e.g. local, national regional and even global) and with different levels of quantification (i.e. qualitative vs quantitative). Studies at the national scale may be useful in setting national priorities for development, whereas those targeted at the local level are useful for selecting specific projects for implementation. Land evaluation is applicable both in areas where there is strong competition between existing land uses in highly populated zones as well as in zones that are largely undeveloped.

Land evaluation is often carried out in response to recognition of a need for changes in the way in which land is currently being used. The information and recommendations from land evaluation represent only one of multiple inputs into the land use planning process (discussed in a later section of this paper), which often follows land evaluation. In turn, the land use planning process can serve to screen preliminary land use options that should be considered for land evaluation. The two processes are therefore interlinked.

Land evaluation should be distinguished from land valuation (i.e. estimation of the monetary or "market" value of land for the purpose for which it is currently used, e.g. farming). It should also be distinguished from 'land capability' as used, for example, within the context of the Canada Land Inventory[2] or the USDA land classification system. For these systems, capability is based primarily on an assessment of soil conditions to support common cultivated crops and pasture plants. The FAO land-evaluation approach, on the other hand, additionally takes into account specific crops and aspects related to land-management and socio-economic setting. The approach has been applied extensively in

[1] A land quality is a complex attribute of land that acts in a distinct manner in its influence on the suitability of land for a specific use. Examples are moisture availability, erosion resistance, flooding hazard, nutritive value of pastures, accessibility.

[2] http://geogratis.cgdi.gc.ca/cgi-bin/geogratis/cli/agriculture.pl

projects backstopped by FAO in various countries in different parts of the world for over thirty years.

Land evaluation principles

The first FAO publication setting out the principles of land evaluation as well as the broad methodological approach for identifying a range of relevant agricultural land-use options for a given area appeared in 1976, "A framework for land evaluation" (referred to hereafter as the '1976 Framework')(FAO, 1976). Subsequent FAO guidelines on land evaluation concerned detailed application of the 1976 Framework to several specific major land uses, namely, rain-fed agriculture, irrigated agriculture, livestock and forestry production (FAO, 1983; 1984; 1985; 1991 respectively). An example of the application at the national scale of automated approaches to land evaluation (see later section on Automated land evaluation tools and databases) that are based on the original 1976 Framework principles was published in 1993 (FAO/UNEP, 1993). A technical guideline on such approaches appeared three year later (FAO, 1996).

Framework Principles

The principles of the 1976 Framework specify that land[3] should be assessed with respect to its suitability for a range of alternate land uses based on several criteria, in particular

- the requirements[4] of specific land uses
- a comparative multi-disciplinary analysis of inputs vs. benefits
- the physical, economic and social context
- potential environmental impacts and land-use sustainability

Main conceptual steps in land-evaluation

Step 1: Initial consultation on the objectives

The land-evaluation process usually begins with consultations leading up to the setting of objectives (e.g. increased wheat and/or livestock production) and noting of any assumptions (e.g. demography, infrastructure, land tenure, market demand and prices, inputs, location, etc.). *Relevant land-use options* that should be considered in the evaluation are *provisionally* defined at this stage[5]. The outcome of these consultations

[3] Within the context of the 1976 Framework, land comprises the "physical environment, including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use".

[4] Requirements are the specific set of land 'qualities' (e.g. moisture availability; ease of cultivation; resistance to soil erosion, pests and diseases, etc..) that determine the production and management conditions of a kind of land use.

[5] It is recommended that preliminary selection of these options should emerge from a participatory land use planning process involving al stakeholders in the future use of the land.

determines the scope and intensity of surveys that may later be required in order to fill data gaps.

Step 2: Determination of the requirements of relevant land-use options

Land-use options and their corresponding requirements may be described with varying levels of detail. In reconnaissance studies, the descriptions correspond to major divisions of rural land use, e.g. rain-fed or irrigated agriculture, grassland or forestry. However, for detailed studies, more information on the management conditions is required since, in practice, these strongly influence the attainable levels of production. In these studies, a land use option is described using the following set of management-related (or "input") attributes (reflecting socio-economic setting) that together define a "land utilization type" (LUT)[6],

- produce, including goods and services
- market orientation
- capital intensity
- labour intensity
- power sources
- technology
- infrastructure
- size and configuration of land holdings
- income level.

A large number of agricultural LUTs is theoretically possible (as a consequence of the possible combinations of products and/or services --- e.g. crops, livestock and forestry products ---- under varying management (or input) conditions. However, only those that are most relevant and acceptable by stakeholders should be retained for further consideration. An example of 3 LUTS for the same set of products but corresponding to three distinct input levels, characterized as 'high, 'intermediate' and 'low', is given in Table 1. An extract from an FAO case study in Kenya illustrating this stage of land evaluation is presented in Annex I.

The requirements (conditions) that would permit efficient, sustainable (long term) functioning of each LUT are determined. In general, for LUTs focussed on rain-fed crop production, the major requirements concern crop physiology, technology of management systems, and avoidance of land degradation. A list of criteria used for assessing requirements in each of these three categories is presented in Table 2.

Step 3: Mapping land qualities

[6] The 1976 Framework defines LUT as 'a kind of land use described or defined in a degree of detail greater that that of a major kind of land use. LUT has more recently been defined as "a use of land defined in terms of a product, or products, the inputs and operations required to produce these products, and the socio-economic setting in which production is carried out" (FAO, 1996).

The spatial unit of analysis for evaluation of suitability is the 'land mapping unit'. The delineation of this unit should, ideally, be based on *land qualities* that have the most influence on the land uses under consideration. Thus, depending on the objectives of the evaluation, relevant 'core' data sets may include soils, landform, climate, vegetation, and surface and/or groundwater reserves. In practice, geographic information systems (GIS) are commonly used to overlay relevant data sets in order to derive land mapping units. Such units are now commonly referred to as 'agro-ecological units' when the original core data sets that are used in the overlay process consist of climate, soils and landform (terrain) data. The set of parameters used for assessing land quality of each land mapping (or agro-ecological) unit are the same as those retained for characterizing the requirements of each LUT (see Table 2). An extract from an FAO case study in Kenya illustrating this stage of land evaluation is presented in Annex I.

Step 4: Interim matching of land-use requirements with actual land qualities

At its simplest level, matching (i.e. suitability assessment) for each land-mapping unit can be made taking into consideration only the physiological requirements of a specific crop(s) and the existing biophysical land conditions (e.g. climate, soils and landform). These sets of information allow prediction of theoretical crop performance (yields). However, such theoretical maximum levels of performance are strongly attenuated by a range of land management factors (as reflected in the list of parameters used to define LUTs --- see previous section on "*Determination of the requirements of relevant land use options*"). Thus, estimates are made of production performance under different operational land-management settings as specified for the LUTs. These 'adjusted' estimates then form the basis for assigning land-suitability ratings for each land-mapping unit.

In earlier non-automated 'qualitative' approaches to matching, estimates of crop performance were based on previous experience or scientific knowledge. In contrast, in more recent automated approaches, estimates are based on computer modeling of crop or animal growth. For non-automated 'qualitative' approaches to matching, land suitability was described using a hierarchic classification structure (ranging from orders, classes, sub-classes to units) that allows the incorporation of fewer or more details on specific land-use limitations (see Table 3). However, in automated approaches, a simplified system based on estimated productivity (% of maximum attainable yield) is often used[7].

Suitability ratings of a given land mapping unit may change over time as a consequence of improvements which modify existing land qualities[8] or as a consequence to changes in one or more of the underlying assumptions (e.g. a change in input level).

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[7] Very suitable: > 80% of potential maximum yields, Suitable: 60-80%; Moderately suitable: 40-60%, Marginally suitable: 20-40%; Very marginally suitable: 5-20%; Not suitable: 0-5% (FAO, 1993)

[8] A minor improvement is temporary in nature and lies within the technical capacity of an individual farmer (e.g. fertilizer application). On the other hand, a major improvement is a large, non-recurrent input which

Step 5: Final matching

The interim suitability classifications produced in the preceding step may be re-evaluated taking into consideration a range of additional factors, e.g. potential land improvements, environmental impacts, economic and social analysis.

Since a given land use could have important on-site and/or off-site environmental impacts (e.g. soil erosion, salinization, pasture degradation), such potential impacts should be assessed and subsequently considered in modifying the results of the interim matching process. A specific modification for mitigating environmental impact may be, for example, the exclusion of certain areas from agricultural development.

Economic and social analyses help to identify problems (e.g. labour shortages, adverse tenure conditions, poor access to markets, etc) in relation to potential land uses. These analyses consequently focus on government development objectives, macro-economic tools and data, the rural economy, infrastructure, demographics, land tenure, labour availability and educational level, etc.

It is worth noting that a preliminary selection of acceptable land-use options to consider during land evaluation (see Section on *"Initial consultation on the objectives"*) is often made as part of the land-use planning process. This helps to reduce the number of land-use options that may have significant adverse environmental and/or socio-economic impacts.

Automated land evaluation tools and databases

Since the FAO Land Evaluation Framework was published in 1976, a number of technological developments have facilitated the implementation of its principles. One of the most significant developments has been the advent of affordable PC-based (vs. mainframes) geographic information systems (GIS). GIS facilitate the storage and analysis of a wide range of spatial data. Computerized databases and modeling programs are now inter-faced with GIS in order to facilitate the computational intensive aspects of land evaluation (e.g the stage of matching potential LUT requirements with land qualities). In particular, rather than qualitative matching, complex computer models of crop growth and development can now be used to provide estimates of yields corresponding to the soil, climate and landform characteristics of each land mapping (agro-ecological) unit under the three different land-management scenarios of low, intermediate and high input levels. Moreover, the feasibility and the impact of different cropping patterns on productivity can be analyzed.

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causes a permanent change in the land qualities and which lie usually outside the technical capacity of an individual farmer (e.g. a regional drainage scheme) (FAO, 1983).

With GIS, the analyses of alternate scenarios could be output as maps (e.g. showing how would land suitability would change if land improvements were made or if more drought resistant crop varieties were introduced). This graphic capability allows ready communication of the outcome of land-evaluation in formats useful for guiding decision making at various administrative or technical levels.

Automated AEZ (agro-ecological zoning) methodologies for land evaluation were initially developed by FAO in 1978 using main-frame computers, in response to widespread interest in assessing global human carrying capacity (FAO, 1978-81). AEZ is based directly on the 1976 Land Evaluation Framework (FAO, 1996). The latest implementations of AEZ take notable advantage of GIS databases and models for assessing land suitability. A PC-based AEZ software program is available at no cost from FAO[9]. Models included in AEZ allow the calculation of length of growing period, irrigation requirements, crop biomass, land suitability, and land productivity. A schematic of the information systems used in an AEZ study of Bangledesh is shown in Annex II.

The AEZ methodology and models have been applied to global data sets in order to determine land suitability and productivity for about 154 different crop types. Results can be viewed on-line via the Internet[10].

FAO has also developed a software/ database package, ECOCROP[11], that allows users to identify plant species whose most important climate and soil requirements match the information on climate and soil entered by the user.

Since 1986, FAO in collaboration with external partners has also been spearheading an international effort aimed at creating, using a standardized methodology, national to regional databases on soil and terrain (SOTER)[12]. These databases contain information, among others, on landform, morphology, slope, parent material and soils. They are thus useful for the purposes of land evaluation.

The ALES[13] (the Automated Land Evaluation System) developed at Cornell University follow the principles of the 1976 Framework. In ALES, expert users can describe proposed land uses as well as the geographical areas to be evaluated, using their own set of criteria based on their local knowledge, and subsequently allow the program to automatically do the matching.

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[9] http://www.fao.org/ag/agl/agll/aez.htm
[10] http://www.fao.org/ag/agl/agll/gaez/index.htm
[11] http://www.fao.org/catalog/book_review/giii/w9692-e.htm
[12] http://www.fao.org/ag/agl/agll/soter.stm
[13] http://www.css.cornell.edu/landeval/ales/ales.htm

Land use planning

Land-use planning has been defined as "the systematic assessment of land and water potential, alternative patterns of land use and other physical, social and economic conditions, for the purpose of selecting and adopting land-use options which are most beneficial to land users without degrading the resources or the environment, together with the selection of measures most likely to encourage such land uses" (FAO, 1999-b).

This subject that has been addressed in several recent FAO publications (e.g. FAO, 1993-a, -b; 1995; 1997, FAO/UNEP, 1995; 1997; 1999-a). These publications emphasize the appraisal processes for selecting the most appropriate, sustainable land-use from among the ones considered relevant within the physical, economic and social context of an area under consideration.

The earliest of these publications refer to a need for social acceptability of selected land use options (FAO, 1993-a). The issue of sustainability of land uses was specifically addressed in the formulation of FESLM (Framework for Evaluating Sustainable Land Management) (FAO, 1993-b). This conceptual framework evaluates whether the current land use (deemed suitable on the basis of a preceding land evaluation) will remain 'suitable' in the future. The evaluation is based on the estimated future stability of a range of selected factors (physical, biological, economic and social) that either individually, or in combination, exerts a significant influence on the suitability of a defined land use within a given local context (FAO, 1993-b).

Concepts for more integrated, interactive approaches to land use planning that involves all stakeholders (not just planners in a top-down process) and that would produce viable land-use options while alleviating land degradation were initially outlined in 1995 (FAO, 1995). Following a series of regional workshops, these concepts were further developed in the latest FAO guidelines for integrated planning for sustainable management of land resources (see FAO/UNEP, 1999-a). These guidelines underscore the importance of stakeholder participation in the land-use planning/ negotiation process[14]. The guidelines also recommend consideration of factors related to sustainability (viz. social acceptance, economic viability, physical suitability and environmental sustainability), as well as social impact (access to land resources, nutritional status, health status, and education) in the appraisal of land use options.

Seven key factors are associated with successful integrated planning for sustainable management of land resources (FAO/UNEP, 1999-a).

- clear formulation of the objective and problem to be solved (i.e. it should be a demand-driven process)

[14] "Planning of land use should not be a top-down procedure, but a decision support mechanism intended to guide the land user or decision-maker through the process of choosing the best land use option or range of options consistent with his or her objectives. It should be integrated, interactive and demand driven" (FAO/UNEP, 1999-a).

- the recognition of stakeholders and their differing objectives (e.g. competition for resources and land uses)
- an enabling environment and regulatory policy (e.g. consistent policies and plans at all levels of decision making)
- effective institutions at local, sub-national, and national level which are linked (i.e. the devolution of decision making to the lowest possible level that is consistent with the ability of implementation,)
- a platform for negotiation (i.e. fair representation and effective participation of stakeholders in negotiations).
- an accessible and efficient knowledge base, and
- a set of planning procedures that are applicable at different scales (e.g. land evaluation, participatory techniques, analysis of stakeholder objectives, monitoring and evaluation.)

Following land evaluation, stakeholders usually have to select one or more land-use options from those that meet the minimum recommended selection criteria, namely, physical suitability, economic viability, socially acceptability, freedom from significant adverse environmental impacts, manageable implementation constraints). A legitimate forum in which negotiations can take place and conflicts due to differing stakeholder objectives can be resolved in order to arrive at consensus decisions is essential. All stakeholders should have fair representation in such a forum and be adequately informed in order to effectively participate. An adequate knowledge base, appropriate for the local setting, is therefore crucial to the land use planning process. Key items of information for this knowledge base relate to

- Land resources (as described previously for land evaluation)
- Appropriate technologies for improved productivity and reduction of environmental impacts (e.g. WOCAT[15])
- Problems, needs and objectives of all stakeholders
- Institutional and legal framework (e.g. land tenure, access to resources)
- Economic conditions (e.g. prices, interest rates) (FAO/UNEP, 1999-a)

Automated land use planning tools and databases

As discussed above, stakeholders often need therefore to make trade-offs in deciding on final land-use options. A multi-criteria decision analysis (MCDA) software tool that helps to identify such 'compromise' solutions has been developed by IIASA in collaboration with FAO. The MCDA tool was applied in Kenya to determine population supporting capacity taking into consideration the desirability of simultaneously achieving multiple objectives of maximising revenues from crop and livestock production, maximising district self-reliance in agricultural production, minimising costs of production and environmental damages from erosion[16].

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[15] http://www.fao.org/ag/agl/agll/wocat/index.stm
[16] http://www.fao.org/ag/AGL/agll/infotech.htm#mcda

Adequate information on present land uses, including management aspects, is a necessary pre-requisite for elaborating policies and plans that would help bring about specific desirable changes in the environment (e.g. alleviation of land degradation). A software package, the LUDB (Land Use Data Base)[17] that allows the structured storage and retrieval of information on actual land use data (including land management) was developed several year ago by FAO in collaboration with external partners. Work is currently in progress at FAO on the development of a simplified, more user-friendly, update to LUDB. This update, provisionally termed Agri-LUCS (Agricultural Land Use Correlation System) allows description of land uses using a parametric, hierarchic approach using combinations of selected land-use parameters that are amenable to GIS processing. The parameters selected for characterizing agricultural land use are the nature of the product(s) from the land use under consideration, and the nature of the inputs, including land management actions. Parametric description "strings" can be interactively reclassified allowing one to map (and hence, correlate) areas of similar products and land management.

As outlined earlier, land evaluation assesses the suitability of land for one or more specified 'sustainable' land uses, taking into account, among others, aspects of the associated land management (see parameters used in defining LUTs - *"Mains steps in land evaluation"*) that would prevent land degradation. Useful insights could therefore be gained if data on actual land use management could be compared to the results from land evaluation[18]. In particular, differences in land management practices could help pinpoint areas where such practices may be considered inappropriate if they lead to land degradation. In order to facilitate such analyses, FAO, in collaboration with IFPRI (International Food Policy Research Institute) and SAGE (Centre for Sustainability and the Global Environment), is currently building regional to global databases on current land use. At present, the data concern mainly crop-production statistics aggregated by sub-national administrative district[19].

Summary and conclusions

FAO has developed approaches to land-evaluation and land-use planning that have been successfully applied in various parts of the world for over 30 years. These approaches are essentially frameworks that can be modified to suit local conditions.

Evolving technologies (e.g. data processing), as well as increased awareness of the important influence of a wider range of factors (e.g. institutional, social and environmental)

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[17] http://www.itc.nl/ha2/ace/debie/index.htm
[18] This requires explicit linkage of suitability ratings with the required land management practices.
[19] http://www.fao.org/ag/agl/agll/globalmap/default.jsp

on the sustainable use of land and the livelihood of land users, has in the past triggered enhancements to existing approaches.

The process of enhancement in response to topical issues continues. Today, there is significant international awareness and concern over the adverse consequences of human activities on the local and global environments, as reflected in several international conventions and agreements[20]. Mismanagement of agricultural land resources, often linked to increasing demographic pressure, contributes significantly to environmental degradation[21]. It has therefore become increasingly appropriate that decisions concerning the potential uses of land include explicit consideration of environmental impacts and of sustainability[22].

Notably, however, while the latest FAO guidelines on integrated planning for sustainable management of land resources (FAO/UNEP, 1999) cite the importance of including environmental and social consideration in final land use choices, operational details of the required approaches/ methodologies are largely missing. Several internal meetings held in 2000 at FAO on this subject indicate that revised land evaluation and land-use planning tools and approaches should include methodologies that explicitly allow consideration of the following issues in screening land-use options:

- Environmental impacts, including goods and services, in relation to both land and water (e.g. soil and water degradation; bio-diversity; carbon sequestration; greenhouse gases; sustainable development)
- Effective participation by multiple stakeholders[23] and the incorporation of gender considerations[24]
- Market and other driving forces (e.g. food, population, income, urban expansion)
- Economic and policy issues (e.g. globalization, liberalization, policy harmonization,..)

Explicit consideration of some of these issues is already possible using the MCDA analytical tool mentioned above in which plausible complex alternate scenarios of land use can be

[20] Agenda 21 of the UN conference on environment and development, 1992; Statement of forest principles, 1992; UN convention on biological diversity, 1993; UN convention to combat desertification, 1994; UN Framework convention on climate change, 1994; Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997

[21] The human-induced land degradation (severe and very severe classes) due to agricultural activities has been estimated as follows (as percentages of total degraded areas): North Africa and Near East (34); Sub-saharan Africa (25%); South and Central America (27); Asia and Pacific (29); Europe (48); North America (16); North Asia - east of Urals (21) [Source: FAO Terrastat database: http://www.fao.org/ag/agl/agll/terrastat/]

[22] Ironically, the need to consider concurrently social, economic and environmental impacts in assessing land suitability was also emphasized in the original 1976 Framework (FAO, 1976).

[23] Stakeholders could include the following groups: Regional international cooperation entities, national or federal governments, state or provincial governments, non-governmental organisations, individual title deed or concession holders, long-existing rural communities, landless people and autonomous groups of migrants, urban communities or tourists, and any original inhabitants of the region (FAO, 1995). See also http://www.fao.org/participation/

[24] http://www.fao.org/sd/seaga/1_en.htm

formulated. Notwithstanding, a commissioned study is currently underway (October, 2002) to examine the feasibility of having the full range of issues better 'integrated' into the land-evaluation/ land use processes.

Source: George, H. Adapted from An overview of land evaluation and land use planning at FAO. FAO, 2005.

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Table 1: Classification of attributes of land utilization types (LUTs) for crop production - Kenya. (after FAO, 1993)

Attribute	Level of input		
	Low	Intermediate	High
Produce & production	Rainfed cultivation of barley, maize, oat, pearl millet, dryland rice, wetland rice, sorghum, wheat, ... Sole and multiple cropping of crops in appropriate cropping patterns and rotations.		
Market orientation	Subsistence production	Subsistence production plus commercial sale of surplus	Commercial production
Capital intensity	Low	Intermediate with credit on accessible terms	High
Labour intensity	High, including uncosted family labour	Medium, including uncosted family labour	Low, family labour costed if used
Power source	Manual labour with hand tools	Manual labour with hand tools and/or animal traction with improved implements; some mechanization	Complete mechanization including harvesting.
Technology	Traditional cultivars; no fertilizer or chemical pest, disease and weed control. Fallow periods. Minimum conservation measures	Improved cultivars as available. Appropriate extension packages including some fertilizer application and some chemical pest, disease and weed control. Some fallow periods and some conservation measures	High yielding cultivars including hybrids. Optimum fertilizer application. Chemical pest, disease and weed control. Full conservation measures.
Infrastructure	market accessibility not necessary; inadequate advisory services	some market accessibility necessary with access to demonstration plots & services	Market accessibility essential. High level of advisory services and application of research findings.

Land holding	small, fragmented	small, sometimes fragmented	large, consolidated
Income level	low	moderate	high

Table 2: List of parameters used for assessing the (1) requirements for LUTs for rainfed crop production, and (2) land qualities of land mapping (agro-ecological) units (after FAO, 1983)

Crop Requirements	Management Requirements	Conservation Requirements
Energy	Soil workability	Erosion hazard
Temperature	Potential for mechanization	Soil degradation hazard
Moisture	Conditions for land preparation and clearance	
Oxygen(soil drainage)	Conditions affecting storage and clearance	
Nutrient availability	Conditions affecting timing of production	
Rooting conditions	Access within the production unit	
Conditions affecting germination or establishment	Size of potential management units	
Air humidity as affecting growth	Location: existing/ potential accessibility	
Conditions for ripening		
Flood hazard		
Climatic hazards		
Excess of salts		
Soil toxicity		
Pest and diseases		

NOTE:

1. Not all parameters listed above are required for every land-evaluation study. The parameters that would be considered significant for a given land-evaluation study are (a) those that have a known effect upon the various kinds of land use under consideration, for which critical values (adverse/ favourable) occur within the study area, and (b) those for which practical means of data collection exist.
2. In later automated approached to land evaluation, computer modelling of crop growth and development has replaced qualitative matching of requirements. Nevertheless, the above table includes parameters that need to be considered in such models.

Table 3: Land suitability classification for rain-fed agriculture (after FAO, 1976; -1983)

Order: Suitable				
S1 class			High	no or non-significant limitations
S2 class	S2e sub-class	S2e-1 unit	Moderate	moderately severe limitations which reduce productivity or benefits or increase required inputs
		S2e-2		
		etc..		
S3 class			Marginal	overall severe limitations; given land use is only marginally justifiable
Order: Not Suitable				
N1 class			Currently not suitable	limitations not currently overcome with existing knowledge within acceptable cost limits
N2 class			Permanently not suitable	limitations so severe that they preclude all possibilities of the given use

Note: Sub-class reflect different kinds of limitations. Letter symbols for some commonly encountered limitations are

1. Temperature regime c
2. Moisture availability m
3. Oxygen availability to roots (drainage) w
4. Nutrient availability n
5. Rooting conditions r
6. Flood Hazard f
7. Excess of salts z
7. Toxicities x
8. Potential for mechanisation q
9. Erosion hazard e

Different units of a sub-class reflect minor differences in production characteristics or management requirements.

ANNEX I:

Extracts from selected stages of land evaluation in Kenya (from FAO, 1993)

Step 2: Determination of the requirements of relevant land-use options

LUTs were differentiated on the basis of level of inputs/ management, into three broad input categories, namely, low, intermediate and high. Land evaluation focussed on crop, livestock as well as fuelwood production. Consideration of crop production alone, yielded a total of 174 LUTs due to 58 different crop types (different cultivars, crop phenology and growth cycles) at the 3 different input levels. The ecological requirements of the various crop LUTS related specifically to climate, soils and landform:

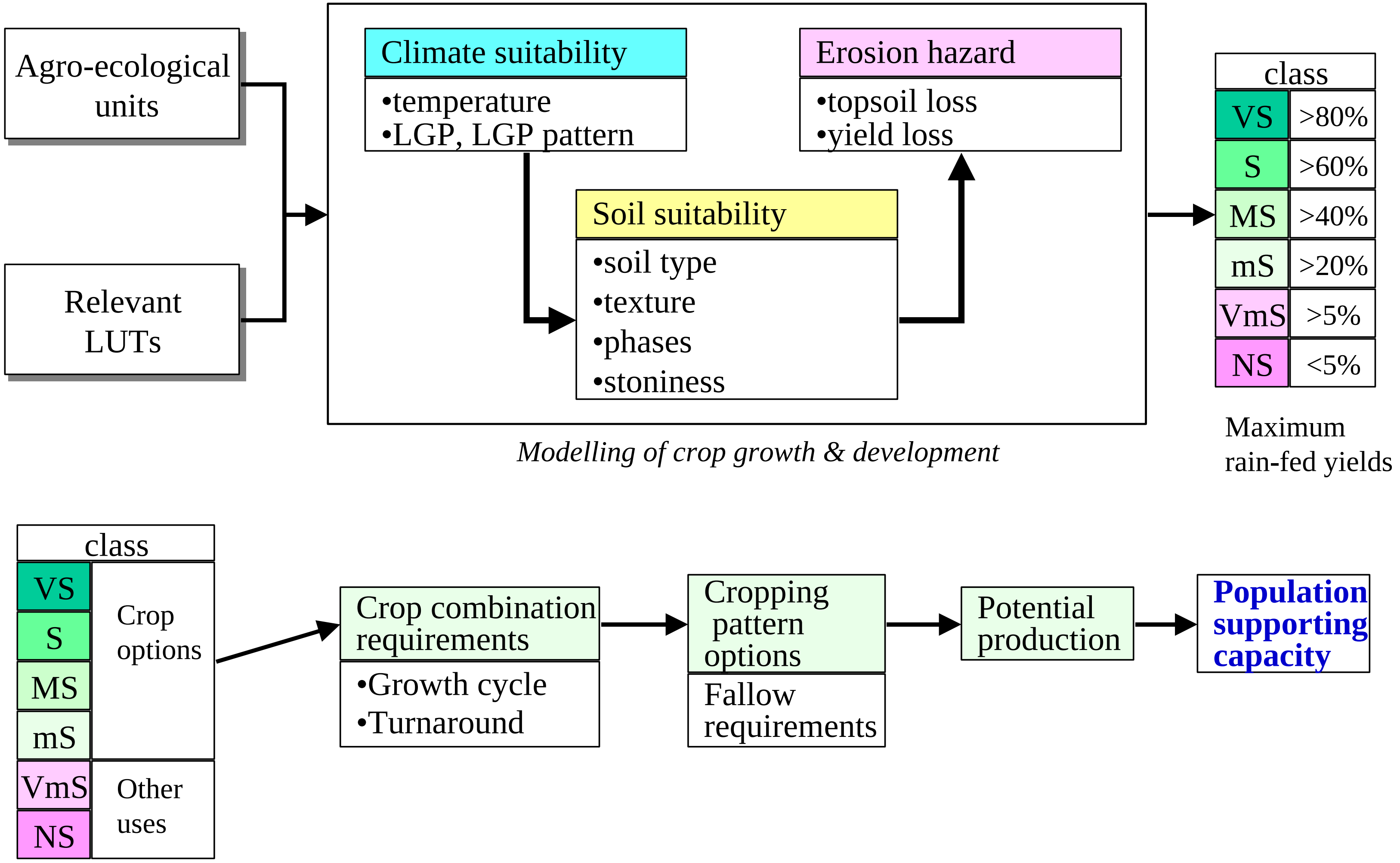
- The temperature and radiation (needed for plant growth)
- The length of the growth cycle, (related to plant phenological development), and
- Soil and landform qualities (e.g. moisture availability; nutrient availability; oxygen availability; foothold for roots; salinity; toxicity; accessibility & workability; tilth; micro/macro relief; soil erosion resistance).

Step 3: Mapping land qualities

A major objective of land evaluation was to identify areas that, under rain-fed conditions, would produce the largest or most desired quantities and qualities of edible calories and protein. The 'suitability assessment' procedure consisted first of comparing the land qualities of each agro-ecological unit with the ecological requirements of all relevant LUTs. Suitability was assessed sequentially on the basis of climate suitability, soil-type suitability and erosion hazard. The output of this assessment was a ranking given to each LUT based on the estimated percentage of maximum crop yield. All LUTs for which the expected crop yields were greater than a pre-selected threshold of 20 percent were considered as possible options and retained for further consideration. Finally, the potential yields for different crop combinations were calculated, taking into account the feasibility of cropping patterns as well as associated fallow requirements. The information was subsequently used to estimate the present and future potential supporting capacity, taking actual and predicted population levels into account (see Figure I-1).

ANNEX I: (cont'd)

Figure I-1: Schematic outline of steps involved in the application of the AEZ methodology in Kenya (after FAO, 1993)



ANNEX II: Case study of application of AEZ in Bangladesh