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Evaluation of the Soil and Land Resource

M. Latham

IBSRAM, PO Box 9–109, Bangkhen, Bangkok 10900, Thailand

Introduction

Warnings about the finiteness of our resource base are not new. Malthus emphasized the limitations of the world's resources in the beginning of the nineteenth century, and regular pleas to adjust our consumption to our resources have since been made, albeit without much success. The difficulty in taking these warnings seriously stems from the fact that emotional reactions and an inadequate grasp of technical progress are too often mixed with real scientific data. In order to avoid emotional judgements, our soil and land resources need to be evaluated in relation to the following assessments: the quantity of land available to secure our food and other needs; the quality of the resources and the potential for improving productivity through proper management; the equality of access to the resources (especially for the poorest part of the population); and the sustainability of the land management systems used to counteract the risk of degradation.

The Soil and Land Resource Base

According to recent figures, out of a total land area of 13 billion ha, about 1.5 billion ha are being cropped, 3.2 billion ha are under pasture, and 4 billion ha are under forest or woodland (WRI, 1990). The same source indicates that between the mid-1970s and the mid-1980s, the percentage of cropland has increased by an average of 2.7% with a major increase in South America, Oceania and Africa; whereas it has stagnated or decreased in Europe and North America. The increases in cropland have been made to a large extent at the expense of forested and woodland areas.

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Table 2.1. Land resources (million ha) (WRI, 1990)

	Land area	Population density (km^{-2})	Cropland		Permanent pasture		Forest and woodland	
			1985–87	% change since 1975	1985–87	% change since 1975	1985–87	% change since 1975
World	13,076	392	1479	2.7	3215	(0.2)[a]	4074	(2.1)
Africa	2963	212	184	4.6	787	(0.5)	689	(4.0)
North–Central America	2137	197	273	2.1	367	2.5	684	(2.2)
South America	1753	166	142	14.1	472	4.0	904	(4.5)
Asia	2678	1139	451	0.8	678	(1.2)	539	(1.5)
Europe	6172	1050	140	(1.0)	84	(3.4)	157	1.3
(Former) USSR	2227	128	232	0	373	0.2	942	(2.6)
Oceania	788	33	50	14	451	(3.8)	156	(6.7)

[a] Figures in parentheses are negative values.

Paradoxically this picture shows that the largest forest clearings happen where population pressure is lowest (Table 2.1). The extensive agriculture practised in Latin America and Oceania, and the shifting cultivation system practised in Africa are probably the main reasons for this state of affairs. The need for food of the poorest part of the population pushes them to the margin of cultivated areas, where the forest stands.

More elaborate figures, such as those prepared by FAO (1985), compare the cultivable land reserves to the cultivated areas, and indicate that the expansion of cropland occurs where there is still some room (Table 2.2). At the other end of the spectrum, in Southeast Asia and in the Near East, farmers are already cultivating lands that are considered to be uncultivable.

The first conclusion that can be drawn from these figures is that the land resources are finite, and that whatever the population pressure is, the tendency is towards an over-exploitation of the resource base, which justifies our fears.

Analysis of the Soil and Land Resources

Beyond these raw figures, a proper analysis of the soil and land resources is needed, because the basis for an evaluation of the land quality rests in great part with soil characteristics and the way soils are distributed.

The most recent global effort to quantify the characteristics and distribution of soil resources dates from the publication of the *Soil Map of the World* at a scale of 1:5,000,000 (FAO/UNESCO, 1971–1981). Further efforts to assess soil resources have been made at the national level, at the regional level, and more recently at a global level (ISSS, 1988). Mapping techniques have evolved through the use of remote sensing, particularly in arid and semiarid areas, through the use of the 'catena' concept to understand soil distribution (Brabant and Gavaud, 1985) and more recently through the use

Table 2.2. Cultivable reserves and cultivated areas (million ha) (FAO, 1985)

	Total cultivable areas	Cultivated areas		
		1975	2000	2025
Africa	789	168	204	248
Near East	48	69	74	79
South-East Asia	297	274	308	346
Central America	74	36	41	46
South America	819	124	166	233

of kriging, a geostatistical method used in mining surveys (Valentin, 1988). Soil classifications have developed, but despite great efforts by the Soil Management Support Service (SMSS) of the United States, *Soil Taxonomy* (SSS, 1975) has not been accepted worldwide. What is more, during the 1990 Soil Congress in Kyoto, new national classifications were proposed. In the meantime, other modes of representation of the soil mantle have been tested – mapping of soil catena or tridimensional representation of soil horizons (Boulet *et al.*, 1982).

As a result, a large amount of soil data has been obtained. This has often been stored in 'geographical information systems' (GIS), such as the UNEP GRID System, to provide easy access to the user. At a time when we are witnessing a trend towards sophistication of the information provided, we can also see divergent approaches in obtaining the data, and different formats in which it is presented, which confuse the non-specialist.

Is Available Soil Information Adequate for the Users?

Despite efforts to provide soil information, and partly because of the confusion created by different approaches and formats, little of the information obtained has been used by agronomists, environmentalists, or other potential users. Farmers, who should be the main end-users, have hardly benefited at all from soil surveys, and the soil information that they do use consists of very simple soil fertility tests.

The main reasons advanced by non-specialists for not using soil data are that the scales of the maps are not convenient, that the information provided is too complex, and that the definitions of the soil units are not practical enough.

The question of scale is a major one, as large-scale maps have hardly any other use than for general planning, and all too few small-scale maps exist. Agronomists and farmers are mostly looking for microvariations (often considered as randomly distributed) at the farmers' field level, the environmentalist prefers the watershed level, and economists/planners prefer the farm or the regional level; the soil scientist, however, is more at ease at the regional or country level (Table 2.3). Understandably, then, there is no unanimity of approach.

The complexity of available information as viewed by non-specialists derives from a similar divergence of interests. Agronomists develop models of crop growth according to varieties or inputs, and would like to take the soil as a random variable, but economists/planners look at the potential productivity of the land. There are more than 100 basic units in the FAO/UNESCO *Soil Map of the World* – quite a formidable number for a non-specialist, who is looking for simplicity so as to extend his models. Soil scientists, on the other hand, will find that these hundred or so units give

Table 2.3. Interest of soil users in relation to the scale of the soil information

	Scale				
Users	Farmers' fields	Farms	Watersheds	Regions	Country/ world
Soil scientists	–	+	++	+++	++++
Agronomists	++++	+++	+	+	+
Farmers	++++	+++	–	–	–
Environmentalists	+	+	++++	+++	++
Economists/planners	–	+++	–	+++	+++

an over-simplistic representation of the soil mantle. Non-specialists often have difficulties with the concept of 'map unit', defined as 'the aggregate of all soil delineations which are identified by a unique symbol' (Van Wambeke and Forbes, 1986).

The definition of the map unit is another source of divergence. Agronomists want information on soil fertility, which is concentrated in the topsoil and can be modified with time, whereas soil scientists would rather have more permanent information on major soil characteristics, which are essentially found in the subsoil. Much of the information introduced by soil scientists in their maps has no specific relevance for crops, and some of the essential variables, such as those related to soil fertility, are not represented in the soil maps.

An attempt has been made to correlate soil units, defined at the family level of *Soil Taxonomy*, to productivity indices (Swindale, 1978). Experiments were conducted on two major soil families throughout the world in what was called the 'benchmark project'. Despite some encouraging results (Silva, 1985), the project has had little practical application. The complex socioeconomic constraints which prevail in agricultural production in the developing world, together with the huge soil diversity – at the family level 4500 soil families have been identified in the United States alone (SSS, 1975) – greatly limit the possibilities of some convenient unit-based linkage between soil and productivity.

Soil information as such, therefore, is not a direct tool for agronomic evaluation of soil and land resources.

Towards a Practical Agroenvironmental Classification

IBSRAM, since its inception in 1983, has taken the point that too strict a definition of soil units will limit the value of the agronomic results obtained.

The board even changed the name of a proposed network on the management of Oxisols and Ultisols (Panabokke, 1984) to that of a network on the management of acid tropical soils (IBSRAM, 1987). The scope was slightly changed, as upland acid soils cover the major occurrence of Oxisols and Ultisols, and also some other related soils; essentially, however, the title of the network was supposed to be more attractive to agricultural scientists. In a way, by making this change the board took the responsibility of indicating that taxonomic units were not always the best basis for the establishment of a soil management network. By creating broad agroenvironmental units such as acid tropical soils, the board assumed that these units could be derived easily from existing documents. The board further chose an approach by which the general recommendations obtained in the network would need to be adapted case by case to different agroenvironments, and the variations were expected to be recognizable by critical indicators easily identifiable in the field.

These broad agroenvironments are defined by soil qualities, climatic conditions, slopes, and other such parameters. They correspond essentially to the FAO definiton of land: 'The physical environment including climate, relief, soil, hydrology and vegetation to the extent that these influence potential for land use' (FAO, 1976).

Such a classification of the land resources was presented for Asia and the Pacific by Dent (1990) who identified 12 major units, including steeply sloping lands, poorly drained soils, acid sulphate soils, or constraint-free lands. A similar effort was made by Sanchez *et al.* (1982) when they presented their 'fertility capability classification' (FCC). Such classifications based on soil and other environmental constraints for agriculture give agronomists practical land units, with similar edaphic constraints and a sufficiently large field of application. These land units provide them with a proper basis for breeding varieties adapted to the constraints and for developing appropriate agrotechnologies.

The Productivity of the Land Resource Base

As indicated in the 'scheme for land evaluation' (FAO, 1976), land quality in terms of productivity can hardly be disconnected from its use. Some lands, however, have a narrower spectrum of use than others. A good paddy soil is unsuitable for upland crops unless expensive drainage systems are established. On the other hand, 'constraint-free soils' have a much broader spectrum of use. Nevertheless, on the whole the value of land is a function of the agriculture or other exploitation envisaged.

Remaining in the agricultural field, the value of land is also a question of scarcity and demand. The value of a paddy field in Japan is worth many times the price of good farmland in the American Mid-West. In developing countries, the situation is even more acute, as food is generally not a simple cash commodity but a means of survival. A piece of land in Burundi, where the population density is very high, is much more valuable than a comparable piece of land in neighbouring Zaire, where the population density is low. Political boundaries, ethnic groups, and land appropriation often push poor farmers to cultivate marginal lands where the economic return is low and the environmental risks are high.

In this regard, land management techniques can improve the intrinsic quality of the land for agricultural production. As indicated by Larson and Pierce (1991), the quality of the soil and land resource derives from a combination of natural and management-induced soil properties. Goedert (1987) and others have shown that poor acid soils could be very productive soils for soyabean growing when properly managed.

Some sloping lands, which would have been considered as unsuitable for agriculture in conventional land assessment systems (Klingebiel and Montgomery, 1961) can, with appropriate soil and water conservation practices, be quite productive (Anecksamphant *et al.*, 1990). In fact, any land can become productive if the inputs and management brought to it are suitable. The bottom line concerns economic questions and also environmental risks.

In the FAO scheme for land evaluation (FAO, 1976), some of these issues are integrated in a hierarchical manner by production systems. Computerized evaluation systems derived from the FAO scheme such as ILWIS (ITC, 1988) have formed the basis of land use planning systems, and have undoubtedly been a very useful tool for planners. Their present limitations should not, however, be overlooked. Three main handicaps remain in these systems:

1. The evalution is based on existing soil, climatic, or socioeconomic data, which are not always very accurate.
2. The evalution is mainly for monocropping, whereas multicropping is the rule in the traditional systems of developing countries.
3. The techniques of land management, and not only fertilizer inputs, tend to evolve rapidly and need to be integrated in the systems.

Land evaluation systems based on the FAO scheme are certainly a very promising tool for planners. However, they need to be regularly revised and upgraded in order to include the latest information on the resource base and on management techniques.

The Sustainability of Land Management Systems

Considerable concern has been aired of late about the sustainability of land management systems. The pollution of groundwater by the overuse of chemicals, wind and water erosion encouraged by clean tillage, and the resistance of pests to pesticides favoured by monocropping production systems have been some of the issues which gave birth in the developed world to such movements as alternative agriculture (NRC, 1989). In developing countries the question of sustainable land management has also raised serious concerns. The overuse of irrigation has led to the salination of many of the good lands in the Middle East and in East Asia (El Ashry *et al.*, 1985); the reduction of the fallow period and the use by poor farmers of marginal lands has led to severe erosion (Stocking and Peake, 1985); and the mining of nutrients by crops, without nutrient replacement, has put strains on traditional slash-and-burn systems.

Land management systems and the quality of the land resource need therefore to be evaluated not only in terms of productivity but also in terms of sustainability. One alarming aspect of this necessity is that if we have difficulties in evaluating the productivity of lands, an assessment of sustainability in the context of land management practices seems even more problematic. Sustainable agriculture would seem to be more of a slogan than a subject for serious research. Realizing this situation, IBSRAM, together with FAO and others, has recently taken the initiative in developing a framework for the evaluation of sustainable land management (FSLM) (IBSRAM, 1991). The goal of this framework is 'to identify and evaluate sustainable land management practices, as a prerequisite for agricultural land development, research planning, and agrotechnology transfer'. The objective, aims, approaches, and action statements were defined during a preliminary workshop held in Chiang Rai in 1991. One of the options is to develop a fully computerized evaluation system in which land management policies (approaches) would be evaluated by production systems according to physical, agronomic, environmental, economic, and stewardship criteria, and in accordance with the different scales involved (Fig. 2.1). Critical indicators at these different levels need to be defined.

An interesting aspect regarding these critical indicators is the frequent lack of convincing data on some of the most common parameters. An increase in soil organic matter was considered as desirable, but to what level? What are the minimum contents in relation to major land units? No one could give a definitive answer to this question. One of the advantages of such a framework will therefore come from the identification of knowledge gaps, which can then be made the objects of research. One thing is certain: a proper land evaluation process needs to incorporate an assessment of land management practices in terms of sustainability in order to prevent further degradation of the resource base.

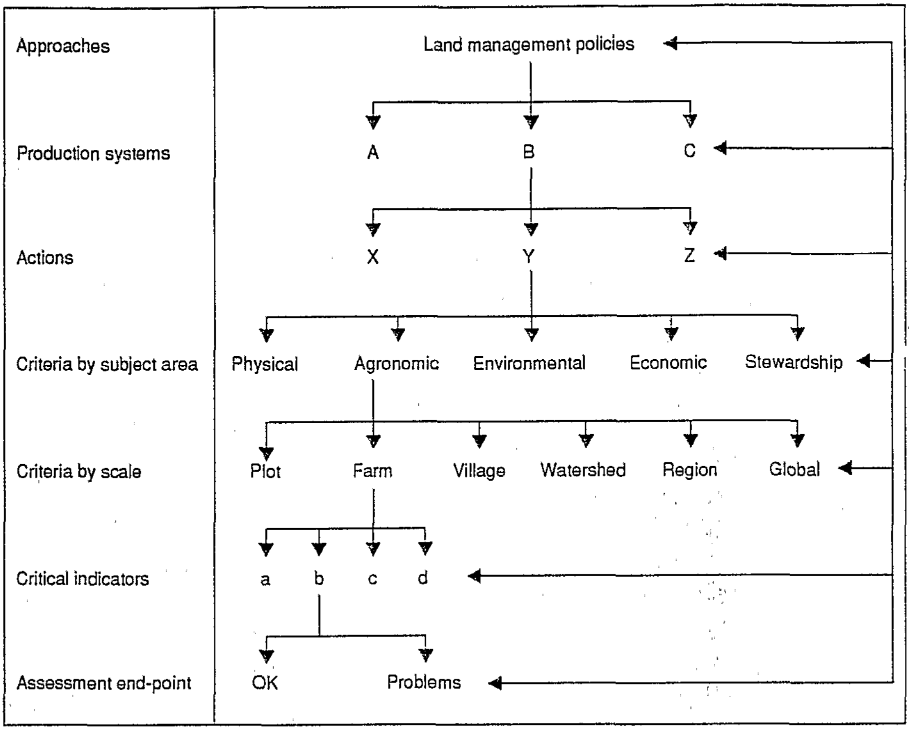

Fig. 2.1. Proposed subdivisions of the framework for the evaluation of sustainable land management (FSLM).

Conclusions

The question of the evaluation of soil and land resources raises both a quantitative issue and a methodological one. On the quantitative issue the present situation is unfortunately bleak, and it will be difficult to break the vicious circuit of poverty, overuse of marginal lands, degradation then more poverty, if some proper economic redistribution of wealth is not attempted. Hungry farmers do not care about the sustainability of human life on the planet; they have more immediate needs.

The situation is, however, not desperate if it is looked at objectively with the new land use planning and management techniques which have been developed. A better knowledge of our resources through basic data, such as soil characteristics and distribution, and through more elaborate concepts, such as agroenvironments or land complexities, should allow better planning and hopefully more sensible use of soil and land resources. A better understanding of the impact of new land management techniques on the productivity of the land and an aggressive policy of dissemination of this information to farmers should also ease the pressure on the land. At the same time, land management practices, whether traditional or modern, have an impact on the sustainability of production. Research on the sustainability of such systems should help to prevent further degradation of the resource base. It is hoped that a proper evaluation will be the first step to a more sound use of soil and land resources in the future.

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Edited by

J.K. Syers* and D.L. Rimmer

Department of Agricultural and Environmental Science
University of Newcastle upon Tyne
UK

(Presently Director of Research, International Board for Soil Research and Management, Thailand)*

Centre Documentation
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CAB INTERNATIONAL
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British Society of Soil Science

CAB INTERNATIONAL
Wallingford
Oxon OX10 8DE
UK

Tel: Wallingford (0491) 832111
Telex: 847964 (COMAGG G)
E-mail: cabi@cabi.org
Fax: (0491) 833508

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