Working Paper and Preprint 92/06

A World Soils and Terrain Digital Database (SOTER)

An Improved Assessment of Land Resources for Sustained Utilization of the Land

L.R. Oldeman
V.W.P. van Engelen

ISSS/SSSA Conference "Operational Methods to Characterize Soil Behaviour in Space and Time"
Ithaca, New York, 27-30 July 1992

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INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

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1 INTRODUCTION

The intense and increasing pressure on land and water resources, leading to degradation and pollution of those resources, and leading to a partly or complete loss of productivity calls for an approach that:
- strengthens the awareness of the users of these resources on the dangers of inappropriate management;
- strengthens the capability of national soil/land resource institutions to deliver reliable, up-to-date information on land resources in an accessible format to a wide audience;
- and improves the methodology for timely monitoring of changes in soil conditions to halt the further deterioration of the land.

This approach calls for a system which can store at different levels of detail information on soils and terrain resources in such a way, that these data can be assessed and combined (and updated) immediately and easily and can be analyzed from the point of view of potential use, in relation to food requirements, environmental impact and conservation. Such a system will assist international and national environmental agencies to become more customer oriented and to become more involved and active in the distribution of knowledge of the environment to many users, including non-soils specialists such as agronomists, ecologists, engineers, etc.

The World Soils and Terrain Digital Database —SOTER— is a true international system of environmental database information. As stated by the former director of FAO's Land and Water Division: 'only through the development and application of such techniques —SOTER— can we catalyze the required breakthrough in land resource use, which is essential to halt and reverse the current degradation of land resources in developing countries' (Higgins, pers. comm., 1990). After a brief description of the historical background of SOTER, the concept and general approach of the SOTER methodology will be discussed. This is followed by some deliberations on the need for SOTER from the user's point of view. In conclusion the future strategies to implement SOTER are discussed.

2 HISTORICAL BACKGROUND

At an International Symposium on Tropical Soils, held in Madison, Wisconsin in 1960, a resolution was adopted for the compilation of all existing soil survey material. The Food and Agricultural Organisation of the United Nations —FAO— assumed responsibility not only for compiling this information, but also for preparing an integrated world soil map. About 20 years later the FAO/Unesco Soil Map of the World was published at a scale of 1:5M in ten volumes with nineteen map sheets and in four languages (FAO, 1971-1981). This World Soil Map proved to be a useful tool for development, to assess desertification, to establish complementarity between areas with different production potentials, to assess potential population supporting capacities and to develop a framework for land evaluation. It was the first internationally accepted inventory of world soil resources.

The emergence and evolution of the information sciences during the past decades has provided a new set of tools for the soil scientist. In the 1970s a ISSS working group on soil information systems was established. This working group was charged with the responsibility to examine new data acquisition and analysis systems, including computer technology and to report how this new technology could be used effectively as a tool for the soil scientist in the storage, retrieval and analysis of soils data and the subsequent dissemination of soils information.

In 1984 Sombroek prepared a first draft of a discussion paper entitled: "Towards a global soil resources inventory at a scale of 1:1M". In 1985 a ISSS provisional working group was established to consider the feasibility and desirability of developing a world soil digital database at a map scale of 1:1M Following an international workshop on "The Structure of a Digital International Soil Resources Map annex Database" held in Wageningen, the Netherlands in January 1986 (Baumgardner and Oldeman, 1986), a project proposal was developed for a World Soils and Terrain Digital Database —SOTER—, which was presented and endorsed by the International Soils Congress in Hamburg (August 1986). The provisional working group was at that congress approved as the official ISSS Working Group on World Soils and Terrain Digital Database under Commission V.

Recognizing the importance of the SOTER proposal the United Nations Environment Programme —UNEP— convened an ad-hoc expert meeting at Nairobi in May 1987 to discuss the feasibility of producing a Global Soil Degradation Assessment. SOTER would provide the necessary ingredients —soil and terrain attributes— to make a quantitative assessment of the rate and risk of soil degradation at sufficient detail for national and regional planning. A world coverage of SOTER however would take at least 15 years to complete. This approach did not solve UNEP's desire for a global soil degradation assessment now. "Politically it is important to have an assessment of good quality *now* instead of having an assessment of very good quality in 15 to 20 years" (ISSS, 1987). Based on recommendations of this meeting, UNEP asked the International Soil Reference and Information Centre (ISRIC), in Wageningen, to coordinate all activities related to the accomplishment of:

- a world map on the status of human-induced soil degradation at a scale of 1:10M within three years,
- a detailed assessment on the status and risk of soil degradation for one pilot area in Latin America, accompanied by a soils and terrain database at a scale of 1:1M.

The World Map of the Status of Human-induced Soil Degradation was published in 1990 (Oldeman, Hakkeling and Sombroek, 1990, 1991). Results related to activities for the development of a World Soils and Terrain Digital Database with testing in two pilot areas in South and North America were discussed during the International Soil Congress in Kyoto, Japan (Baumgardner M.F.; Shields J.A. and D.R. Coote; Scoppa C. *et al.*, 1990).

The SOTER project was originally divided in three phases, each phase with a different set of tasks designed to move as quickly as is feasible and possible towards an operational system easily accessible to the user community.

The first phase was mainly concerned with the development of an applicable methodology for SOTER and with testing the SOTER approach. A SOTER Procedures Manual was developed (Shields and Coote, 1988), which was tested in the first pilot area, covering portions of Argentina, Brazil, and Uruguay. The enthusiastic and fully committed partners in these three countries resulted in a Latin American SOTER database. Simultaneously, the methodology was tested in another pilot area in North America (portions of Canada and the U.S.A.). The method was also used in an area in Central Brazil.

The second phase was based on the results of these two test areas. The SOTER Procedures Manual was restructured and refined. The manual has been discussed at various international workshops, most recently at an ad-hoc expert consultation in Nairobi (February, 1992). During this second phase of the SOTER project also a SOTER training manual was developed and a training course was held in Montevideo (March 1992).

Following the completion of SOTER pilot area studies in South and North America requests for technical assistance to implement SOTER were received by ISRIC from a number of countries in West and East Africa, in Central America, Central and Eastern Europe and from individual countries in South America and Asia. the number of requests to date is indicative of the demand for, and the importance attached to the land resource database, land evaluation and land use planning system which SOTER is capable of providing.

The third, operational, phase of SOTER is further discussed in chapter 5.

3 THE SOTER APPROACH

3.1 General concepts

Basic in the SOTER approach is the mapping of areas (SOTER units) with a distinctive, often repetitive pattern of landform, surface form, slope, parent material and soils. From this general definition more specific rules can be derived which should answer the following questions:

a) What are the criteria for delineating areas with homogeneous soil and terrain characteristics?
b) Which soil and terrain data should be collected?
c) How should the data by organized (database construction)?
d) How is the transferability of the methodology to developing countries?
e) Can the methodology be used at larger scales?

Question (a) will be answered in chapter 3.1. The data to be collected are treated in chapter 3.2, while the database construction is dealt with in chapter 3.3. Transferability of the methodology to developing countries and use of SOTER at larger scales is discussed in chapter 3.4.

3.2 Mapping areas with homogeneous soil and terrain characteristics

3.2.1 Sources of data

SOTER will not repeat soil mapping exercises worldwide - it has neither the funds nor the manpower - so it has to rely heavily on existing soil information. The data has to be extracted from various published and unofficial sources by local experts and coded according to a globally valid system. Where no appropriate soil survey data exists it can be completed with remote sensing data. It is assumed that soils information will be extracted from most recent soil surveys. Attributes from representative soil profiles, characterizing SOTER units will be entered in the database. Terrain data will be derived from local sources too and will consist of interpretation of geomorphological maps, geological surveys, soil survey reports, etc.

As a topographical base map the 1:1M scale Operational Navigation Chart is used. In the near future the digital version (Digital Chart of the World) will replace it.

3.2.2 Differentiating criteria

The mapping of soil and terrain characteristics has evolved from the idea that land in which terrain and soil occur incorporates processes and systems of interrelationships between physical, biological (and social) phenomena evolving through time. This idea was initially developed in the former USSR and Germany and was later accepted throughout the world. Similar integrated concepts were used in the land systems of Australia (Christian and Stewart, 1953) and its successors (MacDonald *et al.*, 1990, Gunn *et al.*, 1990). SOTER is following this line of thought in viewing the land as natural divisions made up of terrain and soil individuals.

The major differentiating criteria for the SOTER units are applied in a step-by-step way. Landform or physiography is the first separating criterion between areas (see fig. 1). A further subdivision of these zones can be made on the basis of lithology or parent material. This will lead to units with a particular combination of landform and lithology: the "terrain unit" in the SOTER methodology.

It is clear that these units are not homogeneous throughout as they possess a typical combination or pattern of terrain surface forms and soils. By means of the surface form or meso-relief, slope and texture of non-consolidated parent material it is possible to further subdivide the "terrain unit" into smaller homogeneous "terrain components".

SOTER unit (SU)

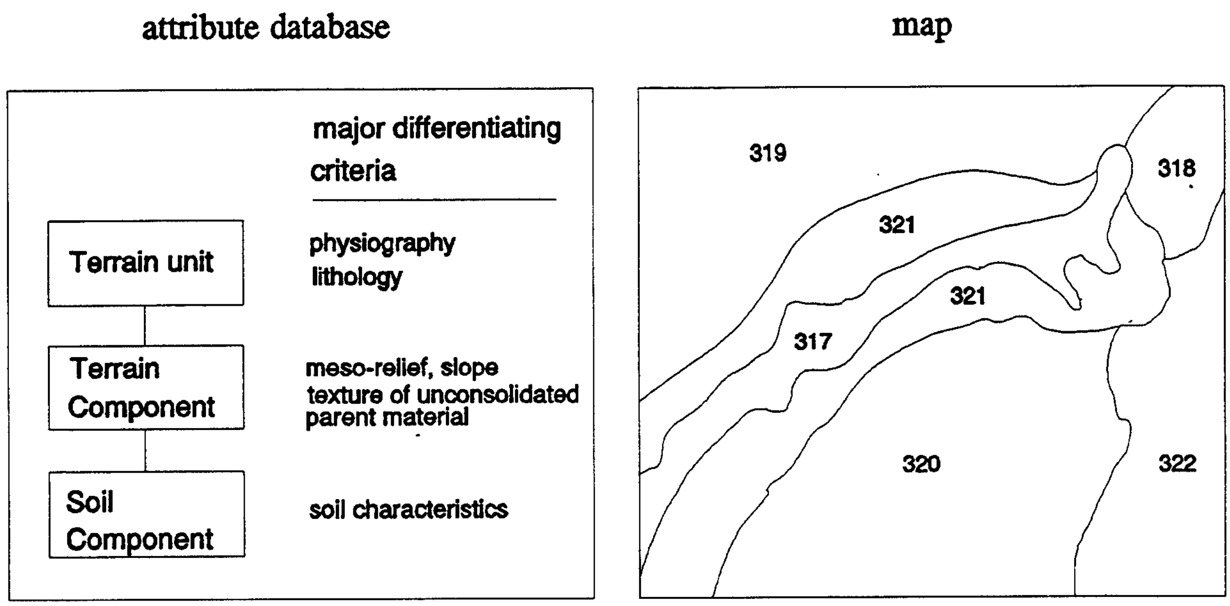

Figure 1: Relations between a SOTER unit and its composing parts.

Each "terrain component" will have one or more soils which are distinguished on the basis of differences in soil forming processes reflected in major soil characteristics, such as the thickness of the major horizons/layers, texture, pH, CEC and organic carbon. Differences in other characteristics that do have an impact on the use of the soil or that can be considered as variable through time usually do not justify the definition of a 'new' soil. In this respect soil properties like exchangeable cations or soil fertility aspects are not taken into account.

Existing soil information will in most cases be used for the compilation of SOTER units. The following rule of a thumb can be used whether soils are to be considered similar or dissimilar:

- If the mapping units in the source materials are defined only till the second level of the FAO Legend (FAO-Unesco, 1974) or till the third level of Soil Taxonomy (Soil Survey Staff, 1975), i.e. Great Group, soils should be considered as dissimilar in the SOTER context. Soils should be further distinguished on the basis of additional information and separate entries have to be made for each soil within the terrain component.
- If the classification is given down to the equivalent of the Soil Taxonomy Subgroup level or comparable, e.g. the third level of the revised FAO Legend plus phases (FAO, 1988), then soils can be considered as similar. No further separation is necessary and reference to one entry elsewhere in the database is permissible.

3.3 Terrain and soil characteristics

Traditional small-scale soil maps have limits to what extent information can be stored or displayed. A digital database does not have such strong limitations as the physical storage by computers is nowadays hardly unlimited. Nevertheless not everything can be stored and thus a selection of terrain and soil data that should be put into the database is necessary.

SOTER, being a general purpose database, has to collect as many terrain and soil parameters as possible that could be of use for future interpretations. The scale, or better said the resolution, of 1:1M set limits to what can be delineated on the map. However, the number of attributes that can describe the geo-referenced area is manyfold. Within the database there are hardly any physical restrictions on the number and amount of attribute data.

Soil information can be extracted from point observations (viz. profile pits of representative profiles). In addition the range of each soil property may be indicated when such information is available. The extrapolation of soil profile characteristics to the extent of the soil in the SOTER unit should be carried out with caution.

Constraints in obtaining correct soils and terrain data are set by the availability of data, its representativeness and by the efficiency of the database management system. It appeared from the first two SOTER pilot areas that gaps exist in the availability of certain soil characteristics like e.g. soil physical aspects. When data does exist it is not clear how the measurements from a single point can be extrapolated towards the rest of the mapping unit. Even with powerful computing facilities the amount of data to be handled can put limits on the efficiency. Table 1 shows all non-spatial attributes (101 fields) that are stored in SOTER. The table names (in capitals) correspond to the ones used in figure 4. The links between the tables are maintained through primary keys: identification labels that occur throughout the tables and printed in bold in table 1. It should be noted that soil classification alone does not characterize a soil unit although a reference to the FAO revised legend (1988) and other national and internationally accepted soil classifications can be made in the database.

3.4 Database construction

In SOTER, like in every discipline involved with mapping of spatial phenomena, two types of data can be distinguished:

a) geometric data: location and extent of a SOTER unit are represented by a delineated area. The relation to other units is also recorded.
b) attribute data: characteristics of the SOTER unit.

The geometric data are captured and managed by a Geographic Information System (GIS) while the attribute data is stored and handled by a DataBase Management System (DBMS). The relation between the two parts of the database is illustrated in figure 2.

The SOTER project is making use of two of the many GIS that are on the market. The final choice will depend on the GIS's capabilities and financial implications (Van Engelen, 1989). Sofar no definite choice of a GIS tool has been made but in this stage of the project two packages have been used: PC ARC/INFO and ILWIS.

The attribute data of the SOTER units are stored in a relational database system (Pulles, 1988). The database structure as shown in figure 4 is derived from the scheme of the constituents of a SOTER unit of figure 3. For reasons of database efficiency the components of a SOTER unit have been split, resulting in two separations for the terrain components and three for the soils part.

Table 1: Non-spatial attributes of a SOTER unit

TERRAIN UNIT		
1 SOTER unit ID	6 relief intensity	11 permanent water surface
2 year of compilation	7 depth of incisions	12 map ID
3 major landform	8 slope of incisions	
4 minimum elevation	9 coverage of incisions	
5 maximum elevation	10 general lithology	

TERRAIN COMPONENT	TERRAIN COMPONENT DATA	
13 SOTER unit ID	**17 terrain component data ID**	24 surface rockiness
14 terrain component number	18 slope gradient	25 depth to parent rock
15 proportion of SU	19 length of slope	26 surface drainage
16 terrain component data ID	20 meso-relief	27 frequency of flooding
	21 parent material	28 start of flooding
	22 texture group of non-consolidated parent material	29 duration of flooding
		30 high groundwater
	23 surface stoniness	31 low groundwater

SOIL COMPONENT	HORIZON	
32 SOTER unit id	**55 profile ID**	81 EC_e
33 terrain component number	**56 horizon number**	82 $CaCO_3$
34 soil number	57 lower depth	83 gypsum
35 proportion of SU	58 abruptness of boundary	84 coarse fragments vol%
36 position in terrain component	59 moist colour	85 coarse fragments size
37 micro-relief	60 dry colour	86 total sand%
38 rootable depth	61 form of structure	87 very coarse sand%
39 profile ID	62 size of structure	88 coarse sand%
40 number of reference pedons	63 grade of structure	89 medium sand%
	64 carbon content	90 fine sand%
PROFILE	65 nitrogen content	91 very fine sand%
	66 P-total	92 silt%
41 profile ID	67 CEC-soil	93 clay%
42 latitude location	68 ECEC-soil	94 natural clay%
43 longitude location	69 AEC-soil	95 texture class
44 lab ID	70 exchangeable Ca	96 clay mineralogy
45 sampling date	71 exchangeable Mg	97 SM% at various pF
46 national profile database	72 exchangeable K	98 bulk density
47 internal drainage	73 exchangeable Na	99 hydraulic conductivity at various pF
48 infiltration	74 exchangeable Al	
49 soil development	75 Fe-dithionite	100 diagnostic horizon
50 soil classification	76 Al-dithionite	101 diagnostic properties
51 thickness O.M./litter on surface	77 Fe-oxalate	
52 decomposition O.M.	78 Al-oxalate	
53 sensitivity to capping	79 pH-H_2O	
54 material below pedon	80 pH-KCl	

N.B. Primary keys are printed in bold.

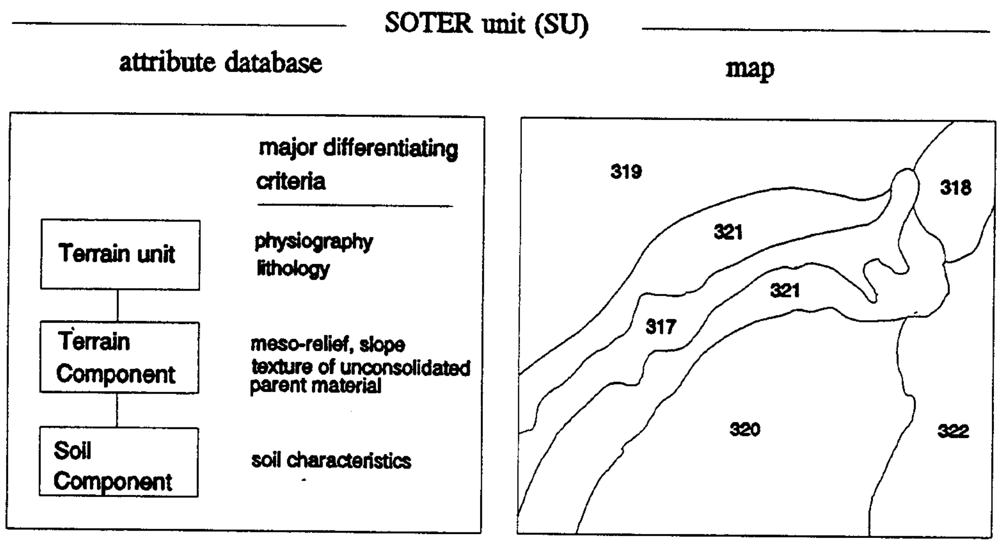

Figure 2: SOTER units and their components (terrain units, terrain components and soil components).

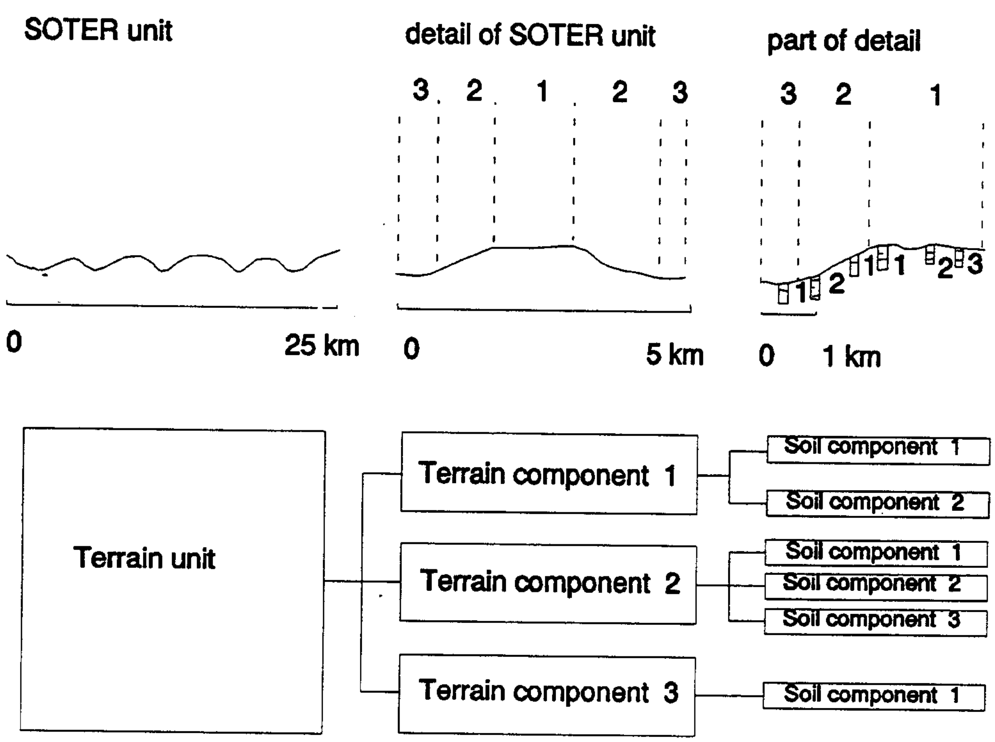

Figure 3: Schematic representation of a SOTER unit

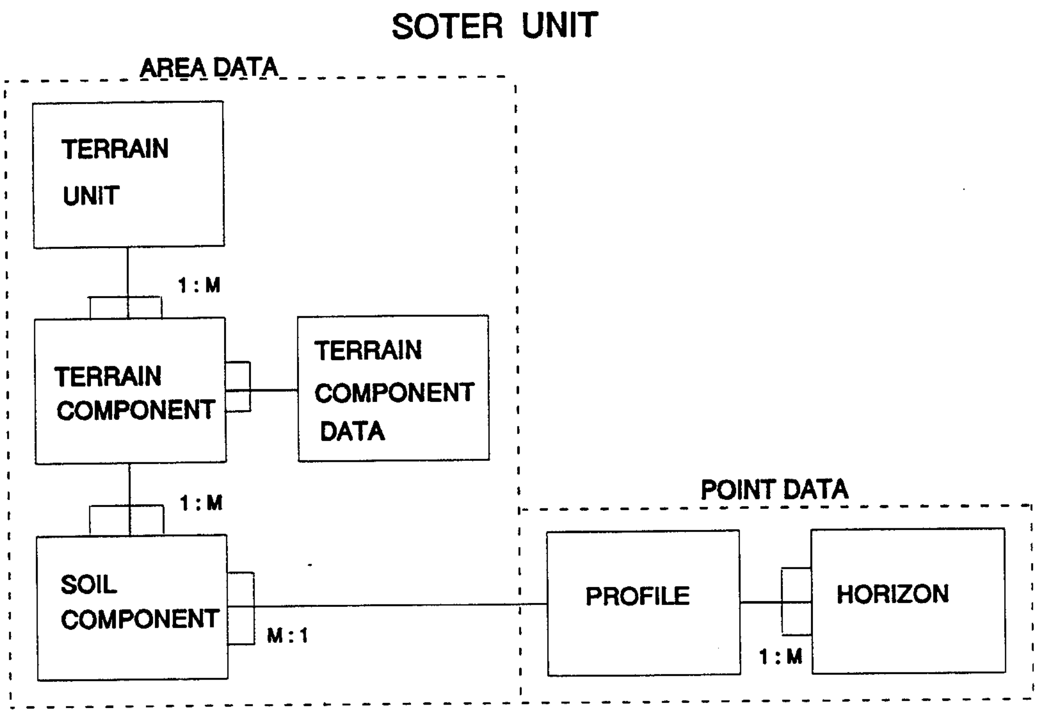

Figure 4: SOTER attribute database structure

3.5 Transferability of SOTER

The SOTER concept has been developed for application at small scales (basically 1:1M). However, it is thought that the methodology is more or less scale independent. Application of the SOTER methodology at larger scales will require some adaptations. Subdivisions of an area according to the physiography, the main separating criterion at the terrain level of a SOTER unit, might result in very extensive units. A subdivision into smaller sub-units, not defined in the current methodology, might be necessary. This was the case in an application of the methodology at a scale of 1:100,000 in Sao Paulo State in Brazil (Oliveira and Van den Berg, 1992). Also at the lower end of the database, the profile data, more detail could be necessary.

With a SOTER approach at scales of 1:100,000 or 1 :250.000 it will be possible to use the data for quantitative modeling. Countries in the pilot area in Latin America are planning to use the methodology at scales of 1:250,000 or 1:100,000 to assess quantitatively soil degradation.

4 THE NEED FOR A GLOBAL NATURAL RESOURCES INFORMATION SYSTEM

The development of a natural resources information system capable of providing accurate, useful and timely data on soils and terrain resources is a prerequisite for policy-makers, decision-makers and for the scientific community in their assessment of the productive capacity of the land, of the status, rates and risks of soil degradation, and of global change.

4.1 Productive capacity of the land

The rapid growth of the world population leads to the key question whether the supply of the land will accommodate a doubling of global agricultural demand in 40 years time. Crosson (1992) states that the supply of the land is reflected by the physical characteristics of the soil, which affects its productivity and by the area that can be brought economically into production. The present supply of the land can be increased by improving the physical soil characteristics, by expansion of the agricultural land, and by investment in new yield-increasing technologies for use on current farmed land.

Buringh and Dudal (1987) indicated that specialists in various countries and international organizations have estimated that around 1800 million hectares of land not yet used for agricultural food crops is still available and suitable to grow crops. However, most of the land has a moderate to low productivity, the spatial distribution of available land is not in proportion to the population density, the infrastructures needed to transport the produce to domestic and foreign markets from this potential available land is often very poorly developed or absent, the potential hazards for soil erosion and degradation once these forest and grasslands are transformed into cropland are threatening, conversion of tropical forests into cropland is a hotly debated issue. Therefore Crosson (1992) concludes that the realisable potential for increasing the agricultural land is far less than the 1800 million hectares suggested.

Although tropical soils are widely referred to as acid and infertile and many observers have concluded that the potential for increasing the productivity of these soils is low, various techniques have emerged, indicating that the physical characteristics of these soils can be improved and thus become more productive. Crop models that take into account the physical characteristics of the environment and the soils are a very important tool to assess the potential productivity of the land. In order to make these models applicable in space and time an accurate up-to-date geo-referenced resources information system is urgently needed.

FAO has developed the concept of Agro-ecological zoning as a sequel to its world inventory of soil resources. This concept was applied to determine the potential population supporting capacities at three levels of input (Higgins, Kassam *et al.*, 1987). These global assessments of the productive capacity of the land have been based on the FAO/Unesco Soil Map of the World, prepared by conventional cartography over a period of 20 years at a scale of 1:5M. Soil characteristics, important to assess productive capacity of the land are however difficult to retrieve. Many countries in all continents have embarked upon systematic soil resources mapping at national scales, resulting in maps ranging in scale from 1:250.000 to 1:1M, but these soil maps are produced with different legend structures, in different languages, and with different systems of soil classification. Therefore, there is an urgent need for an update of the FAO/Unesco Soil Map of the World. As stated by Sombroek (1992): "There is a need for geo-referenced, quantified, computer-driven and compatible databases on natural resources, both at global/continental level and at national level. In such databases hydrological and soils information should preferably be linked systematically to land form information".

4.2 Assessment of Soil Degradation

Human-induced soil degradation is also directly linked to the rapidly increasing population, and to the increasing expectations of the population for higher living standards. In many cases however standards of living are actually falling, especially in rural areas in the developing countries. The poor are both victim and agent of environmental damage. Alleviating poverty is both a moral imperative and a prerequisite for environmental sustainability (World Bank, 1992).

Since its establishment in 1972, UNEP has been preoccupied with the assessment of soil degradation. An expert consultation on soil degradation convened by FAO and UNEP in 1974 recommended that a global assessment be made of actual and potential soil degradation. The results would be compiled as a World Map of Soil Degradation. A provisional methodology for soil degradation assessment was developed and maps at a scale of 1:5M covering Africa North of the equator and the Middle-East were published 5 years later (FAO. 1979).

In 1987, UNEP developed a new project: Global Assessment of Soil Degradation —GLASOD— which was implemented by ISRIC. The World Map of the Status of Human-induced Soil Degradation (L.R. Oldeman, R.T.A. Hakkeling and W.G. Sombroek, 1990) revealed that about 2 billion hectares were degraded in the past

40 years worldwide, which is about 15% of the total land surface. However, this study also revealed that about 40% of the world's agricultural land is affected (Oldeman, 1992). The compiled geo-referenced information on soil degradation is a qualitative assessment, based on the experience of a world wide group of soil and environmental specialists. It does not indicate areas of potential risk nor does it give a quantitative assessment of the rate of soil degradation. This study cannot be used for action plans to conserve or rehabilitate degraded lands. A geo-referenced natural resources information system, such as SOTER, would provide the necessary ingredients —soils and terrain attributes linked to a topological database via a Geographic Information System— to make a quantitative assessment of the rate and risk of soil degradation at sufficient detail for national and regional planning. In the words of FAO: "If sound land use and land conservation policies are to be developed, reliable data on land resources —including soil, climate, vegetation and topography— are needed. Some of these data are more widely available then is recognized. However these data are usually fragmented, at different scales and reliability, and are archived in different ministries, libraries and universities" (FAO, 1991). The SOTER methodology could be of invaluable assistance to systematically store the required information for land conservation and rehabilitation at national and regional level.

4.3 Global Change

Soils are also important sources and sinks for a number of radiatively active trace gases, popularly known as "greenhouse gases", while they also play an important role in the Earth's hydrological cycle and surface energy balance (e.g. Bouwman, 1990). Thus the role of soils in the so-called "greenhouse effect" and global change cannot be neglected. An understanding and description of the interactive physical, chemical and biological processes that regulate the Earth's system forms the main objective of the International Geosphere-Biosphere Programme —IGBP—, established in the 1980s. Most of the coordinating panels, working groups and scientific steering committees within IGBP have indicated the need of worldwide data on present soil and landscape conditions and their liability to change (Oldeman and Sombroek, 1990). Modeling forms a useful and powerful tool for conceptually studying the possible consequences of a wide range of processes of global change. Widespread application and testing of global change models only becomes possible when appropriately scaled, attribute-oriented databases with the main controlling factors become available in a widely accepted and accessible format (Batjes, 1992). Up till now, global change modelers are using very scattered data on soil related factors, unevenly distributed over the main soil-, agroclimatic-, and vegetation zones of the world. Although many of the relevant soil properties for modeling global change can be retrieved from existing soil maps, a potential problem is the correlation of soils if multiple classification systems are used within a region of interest (Lee and Lammers, 1989). Bliss (1989) reports that several of the databases currently used to characterize the effect of soils in the General Circulation Models have been developed by manual interpretation of the FAO/Unesco Soil Map of the World.

From the foregoing discussion it can be concluded that there is an urgent need for an up-to-date description of the land surface, which can best be provided by digitized soil geographic databases. As stated by Sombroek (1986, 1992) and also voiced by the international community active in modeling global change, assessing global soil degradation or estimating potential productivity of the land: "The advance of digitizing techniques and computerized data storage offers revolutionary possibilities for comprehensive geo-referenced soil and terrain attribute databases, with an adaptable level of spatial resolution and updating capacity, which would in fact side-step the problems of attempting to interpret soil properties from soil maps with different legend structures and different soil taxonomic systems".

5 FUTURE STRATEGIES

The urgent need for a systematic global inventory of the Earth's natural resources calls for action at various levels. There is no doubt that what is needed at global level also applies at regional and national level.

As of to-day, the most comprehensive available world inventory of soils is the FAO/Unesco Soil Map of the World. Is it possible to use the digitized version of this map as an "editing template" and improve it with SOTER and other sources of expert input? This question was raised by UNEP at an ad-hoc expert meeting in Nairobi (March 1992), convened by UNEP to discuss SOTER and global modeling: a global strategy and agenda.

5.1 Updating of the 1:5M FAO/Unesco Soil Map of the World

The updating of the World Soils Map as envisaged by FAO (Van Velthuizen, pers.commun., 1992) would involve the use of the 1991 revised legend classification system in the recently released digitized version of the soil map which is still based upon the 1974 classification system. The map is based on data available in the sixties and early seventies, while for many countries new or updated soil maps have become available. There is also the need for an up-to-date topographic base map. The World Soil Map is drawn on topographic base maps, which were produced in the early forties. A new digitized topographic basemap (the Digital Chart of the World), which is largely based on the 1:1M worldwide Operational Navigation Charts (ONC) will be used. This topographic base will also be used by SOTER. Finally, it is proposed to link the soils inventory to a geomorphological classification, indicating landform, surface geology and parent material. This would be of particular interest to SOTER: it would make the updated version of the World Soil Map compatible with SOTER.

5.2 Development of Continental SOTER Shells at 1:1M Scale

The first phase of an operational approach for SOTER would be the development of a SOTER shell, which would provide and guarantee a standardized, uniform soil and terrain database linked to a topological database with the input of readily available soil and terrain data. This initial task for a continent —South America is suggested— could be completed within a time frame of 4 menyears. In a second phase, the shell will be complemented and completed with the cooperation of national soil agencies. The SOTER project would provide technical assistance .

5.3 Regional/National SOTER Studies

An increasing number of requests have been received for the implementation of SOTER in various regions of the world (West Africa, East Africa, Central America, Central Europe, the Balkan States) as well as in individual countries (e.g. China, India, Ecuador, Peru, Bolivia, Mexico, Russia). Projects proposals have been developed in cooperation with national agencies and several have been submitted to potential donors. In these cases it is essential to get the support of the national governments expressing their willingness to cooperate and indicating that the project activity is among their national priorities.

5.4 SOTER Application Projects

At global scale, ISRIC has implemented a project for a World Inventory of Soil Emissions. This project aims to arrive at a geographic quantification at global level of the soil conditions and soil processes which regulate the emission of CO_2, CH_4, and N_2O from soils and the hydrological cycle and surface energy balance.

At European level, a proposal is developed for an assessment of the capacity of European soils to absorb, hold and release chemical compounds through a geo-referenced inventarization of significant soil-environment parameters. This project aims to strengthen the awareness of policy-makers and decision-makers on the dangers of soil degradation and soil pollution to the well-being of the human and animal population of Europe from the Atlantic to the Ural.

Eventually, the 1:1M Soils and Terrain Digital Database would form the basis for an improved and comprehensive global assessment of soil degradation.

At national level, SOTER will provide a sound basis for land resource management and for land use planning on a sustainable basis. It would also provide the basis for non-agricultural purposes, such as building of dams, urbanisation, infrastructural developments and others.

6 CONCLUSIONS

With sustainable management of natural resources as the fundamental goal for the 1990s, major changes will have to be made in the environmental information to be collected and communicated. Environmental information must become customer-oriented. Every new soil survey report published is more complex and technically more difficult than previously published reports. However, the majority of potential users of soil and terrain information are not technically trained in soils. Consequently they either will not or cannot extract the specific information they need from a modern soil survey report. One of the major reasons for the development of SOTER is to provide the capability for real time extraction of single value maps or data in response to the specific information and data needs of a wide diversity of decision-makers and policy-makers. Collecting, storing, analyzing and reporting data can be expensive, but investments in data more than pay for themselves (Mathews and Tunstall, 1991).

The lack of a system than can store and analyze natural resource information has in many countries, until now, been one of the most important constraints to the solution of fundamental problems and to the efficient use of resources. This has been felt both by the countries themselves, and by aid donors frustrated at the meagre results from their contributions. As stated by the World Bank in its World Development Report 1992: "ignorance is a serious impediment to finding solutions. Countries can reap large returns from investments in basic environmental data collections" (World Bank, 1992). Internationally, scientists and decision-makers increasingly recognize that land resources must be preserved for future generations. By implication, this means that due attention and support must be given to the development of improved environmental systems. The applicability and usefulness of SOTER has been confirmed by international organizations such as UNEP, FAO and the International Agricultural Research Systems of the Consultative Group of International Agricultural Research (Bunting, 1986). This recognition in itself is not a guarantee for the success of SOTER. The speed at which a worldwide coverage in SOTER can be achieved is directly proportional to the financial support received from donor agencies. A long term commitment of these agencies is needed now so that SOTER can rapidly provide the key soil and terrain attributes, which are needed to assess the potential productivity of the land, the status, risk and rate of soil degradation, to develop action to conserve or rehabilitate the land, and to improve our understanding in global change.

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