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A world soils and terrain digital database (SOTER) — An improved assessment of land resources

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ABSTRACT

The soil is a natural resource, non renewable in the short term or very difficult to renew and expensive either to reclaim or to improve following erosion, physical degradation or chemical pollution. The increasing pressure on land and water resources, leading to degradation and pollution of those resources, and a reduced productive capacity calls for a system which can store detailed information on natural resources of all kinds in such a way that these data can be accessed, combined and analyzed from the point of view of potential use, in relation to food requirements, environmental impact and conservation. Such a system is a prerequisite for policy formulation, development planning at all levels, efficient use of both internal and external resources, and for implementation of development programmes.

In a typical case such a system would consist of:

(1) A computerised database containing all available information on topography, soils, climate, vegetation and land use. It should be complemented with compatible databases of socio-economic factors.

(2) Geographical Information System or GIS, which links each item of information to its precise geographical location, but which can display each type of information as a separate layer, or overlay.

(3) A set of crop yield models which can calculate the level of production which could be obtained from each and any combination of soil and climate in the region or country, at a number of different input levels or management systems.

(4) Various environmental impact models, which, for example, allow the calculation of rates of erosion for a given land unit, use, and production system.

Development of computerized natural resource inventory and land evaluation systems especially for use in developing countries has been carried out by FAO since the early nineteen-seventies, notably under the Agro-Ecological Zones programme. In 1987, the International Soil Reference and Information Centre (ISRIC), based in Wageningen, the Netherlands, undertook at the request of UNEP and in close cooperation with the ISSS, FAO and the Land Resources Research Centre in Canada, to develop a Methodology for a World Soils and Terrain Digital Database (SOTER).

This land resource information system was tested in three pilot areas involving five countries (Argentina, Brazil, Uruguay, USA and Canada), using local data and training national staff in operation. Though further up-grading and improvement will continue, this system can now be established as an almost routine operation which mainly involves the provision of equipment, and training.

Most developing countries are quite acutely aware of the need, and many are already attempting to establish computerised natural resource databases of one kind or another. Furthermore, all donors and aid agencies, particularly those such as the World Bank, which seek comprehensive solutions, will become aware that such systems are an essential tool for development, and are also very cheap in comparative terms.

A long term commitment from these agencies is needed 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.

INTRODUCTION

The intense and increasing pressure on land and water resources, leading to degradation and pollution of those resources, and leading to a partial or complete loss of productivity calls for an approach that:

- strengthens the awareness of 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, 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, and engineers.

The World Soils and Terrain Digital Database (SOTER) is an international land resource information system. 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" (G.M. Higgins, pers. commun., 1990).

After a brief description of the historical background of SOTER, the need for a global natural resources information system is discussed from the point of view of an assessment of the productive capacity of the land, of soil degradation, and in relation to global change studies. Then an overview is given of the concept and general approach of the SOTER methodology. In the concluding section the future strategies and implementation of SOTER is discussed.

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 1:5 million 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 1:1 million". 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 1:1 million. Following an international workshop on "The Structure of a Digital International Soil Resources Map Annex Database" held in Wageningen, the Netherlands in January 1986 (ISSS, 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.

SOTER is a computerized information system on soil and terrain attributes. For many of its potential applications SOTER data can only be used in conjunction with data on other land-related characteristics. Nevertheless, in order to be able to obtain a broad characterization of tracts of land in terms of these other land-related characteristics the SOTER database includes files on climate, vegetation and land use.

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 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 immediate desire for a global soil degradation assessment. "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 : 10 million within three years,
- a detailed assessment on the status and risk of soil degradation for one pilot area in Latin America, accompanied by a soil and terrain database at a scale of 1 : 1 million.

The World Map of the Status of Human-induced Soil Degradation was published in 1990 (Oldeman et al., 1990). 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, 1990; Scoppa et al., 1990; Shields and Coote, 1990).

The SOTER project was originally divided in three phases. Each phase had a different set of tasks designed to move as quickly as was feasible 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, 1989), which was tested in the first pilot area, covering portions of Argentina, Brazil, and Uruguay. The enthusiastic support and full commitment of 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 USA). 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, and most recently at an ad-hoc expert consultation in Nairobi (February 1992). During this second phase of the SOTER project, 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 later sections of this paper.

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.

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 are still available and suitable to grow crops. However, most of the land has a moderate to low productivity. (Although tropical soils are often acid and infertile, various techniques have emerged, indicating that physical characteristics of these soils can be improved and made more productive, providing they are fertilized.) 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 are very high. 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.

Crop models that take into account physical characteristics of the environment and soils are a very useful 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 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 1:5 million. 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 1:1 million. 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 landform information."

Assessment of soil degradation

Human-induced soil degradation is often 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 highly occupied 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 1:5 million covering Africa north of the equator and the Middle-East were published 5 years later (FAO/UNEP/UNESCO, 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 (Oldeman et al., 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 topographical 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, 1990). The SOTER methodology could be of invaluable assistance to systematically store the required information for land conservation and rehabilitation at national and regional level.

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 (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). Until 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, 1990). Bliss (1990) 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."

THE SOTER APPROACH

General concepts

Basic to 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) Can the methodology be utilized in developing countries?

(e) Can the methodology be used at larger scales?

Mapping areas with homogeneous soil and terrain characteristics

Sources of data

SOTER relies mainly on existing soil information. The data have 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 exist they 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 are entered in the database. Terrain data are derived from local sources and consist of interpretation of geomorphological maps, geological surveys, soil survey reports, etc.

The 1 : 1 million scale Operational Navigation Chart is used as a topographical base map.

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 system of Australia (Christian and Stewart, 1953) and its successors (Gunn et al., 1990; MacDonald et al., 1990). SOTER, in viewing the land as natural divisions made up of terrain and soil individuals, is following this line of thought.

The major differentiating criteria for the SOTER units are applied systematically. Landform or physiography is the first separating criterion between areas (Fig. 1). A further subdivision of these zones can be made on the basis of lithology or parent material. This leads 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, 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".

Each "terrain component" has 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. Characteristics that have an impact on the use

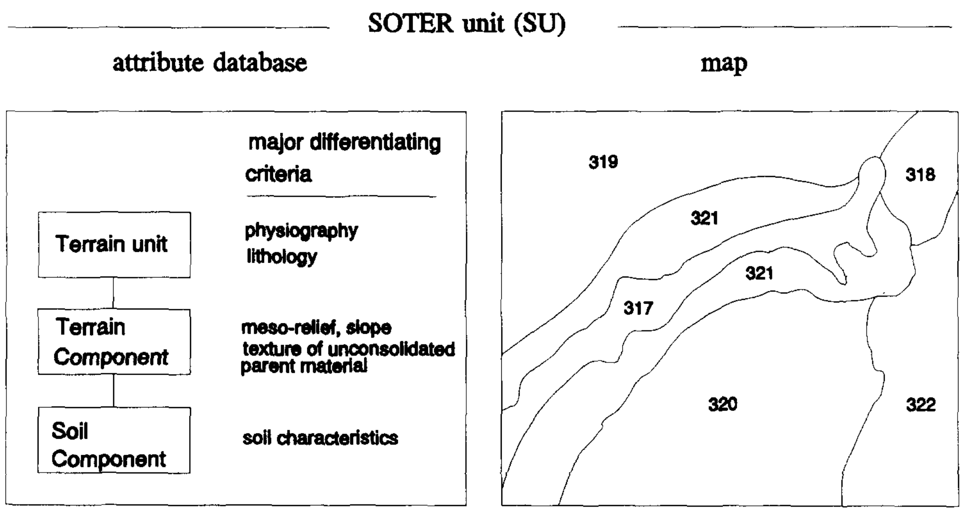

Fig. 1. Relations between a SOTER unit and its composing parts.

of the soil or that are variable through time, like exchangeable cations or soil fertility aspects, are not taken into account as differentiating criteria.

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

- If the mapping units in the source materials are defined only to the second level of the FAO Legend (FAO-Unesco, 1974) or to 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.

Terrain and soil characteristics

Traditional small-scale soil maps are restricted in their level of information by the scale of the map. Such restrictions do not apply to a digital database. 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 1:1 million 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 is extracted from point observations of fully described and analyzed reference profiles. Following judicious selection, one of these reference profiles is designated as the representative profile for the soil component in the SOTER unit. Additionally, the range of each soil property is indicated when such information is available.

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. The first two SOTER pilot areas demonstrated that gaps exist in the availability of certain soil characteristics like soil physical aspects. When data exist, it is not clear how 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 puts limits on 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 Fig. 4. Links

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 maximum 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 of 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.

between tables are maintained through primary keys: identification labels that occur throughout 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.

Database construction

In SOTER, the geometric data are captured and managed by a Geographic Information System (GIS) while the attribute data are stored and handled by a Data Base Management System (DBMS), as illustrated in Fig. 2.

The SOTER project uses two of the many GIS that are on the market: PC ARC/INFO and ILWIS. The attribute data of the SOTER units are stored in a relational database system (Pulles, 1988). The scheme of constituents of a hypothetical SOTER unit is illustrated in Fig. 3. The database structure as shown in Fig. 4 is derived from that scheme. 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.

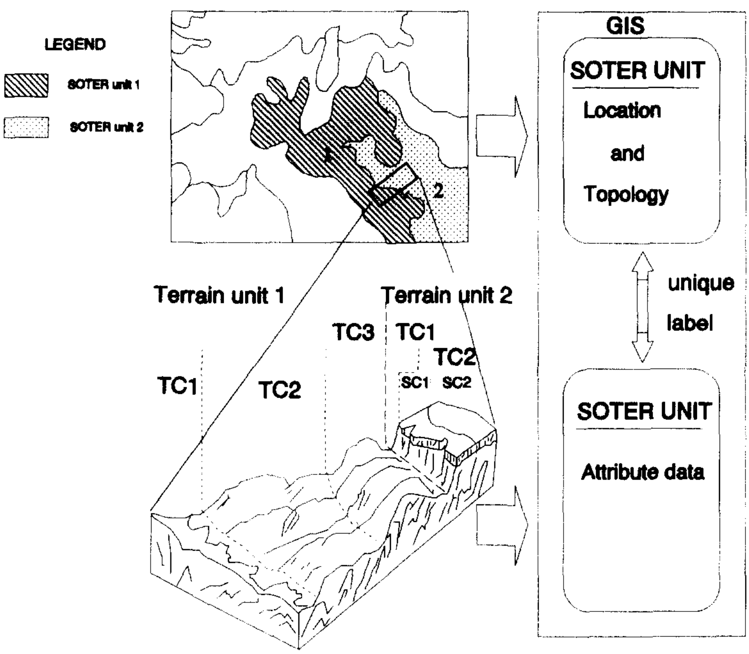

Fig. 2. SOTER units and their components (terrain units, terrain components and soil components).

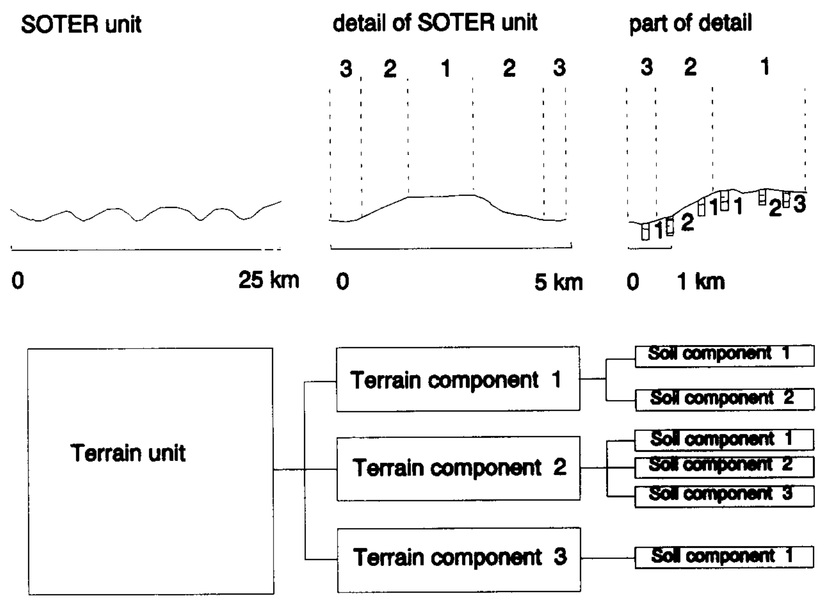

Fig. 3. Schematic representation of a SOTER unit.

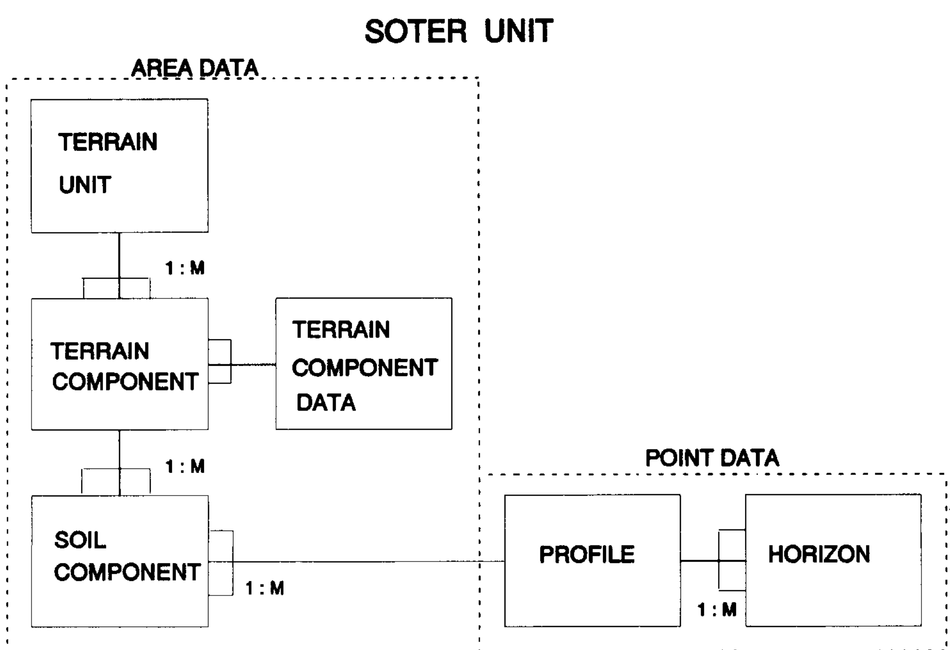

Fig. 4. SOTER attribute database structure.

Transferability of SOTER

The SOTER concept has been developed for application at small scales (basically 1 : 1 million). However, the methodology can also be applied at other scales. This may require some adaptations. At larger scales, 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 Saõ 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.

While the SOTER database at a scale of 1 : 1 million provides sufficient information for global change modelling and for an assessment of the main land qualities a SOTER database at larger scales (1 : 250,000 to 1 : 100,000) can be used for quantitative crop growth modelling and for quantitative assessment of soil degradation rates and risks.

CONCLUSIONS

There is an urgent need for a systematic global inventory of the Earth's natural resources. As of today, the most comprehensive available world inventory of soils is the FAO/Unesco Soil Map of the World. Since this inventory is based on data available in the sixties and seventies, an updating of the World Soils Map is envisaged by FAO (Van Velthuizen, 1992). As topographic base map FAO proposes to use the Digital Chart of the World which is largely based on the 1 : 1 million Operational Navigational Charts (ONC). The soils inventory will be linked to a geomorphological classification, indicating landform, surface geology and parent material. This would be of particular interest to SOTER, making the updated version of the World Soils Map compatible with SOTER. A close cooperation between these efforts by FAO and SOTER's operational phase is required for the development of a continental SOTER framework, 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.

The need for an accurate, useful and timely land resource information system which is accessible to a wide array of users calls for an approach which must be customer-oriented. Every new soil survey report 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. SOTER has 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.

The lack of a system that can store and analyze natural resource information has been one of the most important constraints to the solution of fundamental problems in many countries 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. The increasing number of requests for the implementation of SOTER in various regions of the world and in individual countries is indicative of the demand for, and importance attached to the land resources database, land evaluation and land use planning systems which SOTER can provide. Also the World Bank (1992) has indicated the need for environmental databases: "Ignorance is a serious impediment to finding solutions. Countries can reap large returns from investments in basic environmental data collections." Internationally, scientists 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 information systems.

This view was recently expressed at an international workshop on "New Challenges for Soil Research in Developing Countries: A Holistic Approach" (Stoops and Cheverry, 1992). 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 (FAO/CGIAR, 1986). This recognition in itself is not a guarantee for the success of SOTER. As stated by Mathews and Tunstall (1991), "collecting, storing and reporting data can be expensive, but investments in data collection more than pay for themselves." Similarly one can conclude that the speed at which worldwide coverage in SOTER can be achieved is directly proportional to the financial support from donor agencies. A long term commitment from these agencies is needed 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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