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SPACE AND TIME DIMENSIONS OF A WORLD SOILS AND TERRAIN DIGITAL DATABASE

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New tools for land resource scientists

Several dramatic developments within the past two decades now make it possible for us to conceptualize land resources spatially and temporally as no previous generation has been able to do. Let me illustrate this point in three ways. First, we are the first generation to see the Earth as a whole. In all previous human generations, the consideration of land and land quality was done in a limited spatial context. Human observations were made on very limited areas. The observer would look at a small area and characterize it. Observations of many small areas were placed in a spatial mosaic in an attempt to show how the Earth might appear if it could be seen as a whole. The enterprise of Earth observation has been turned around. The human observer can now see the broad, synoptic view of the land, choose an area of specific interest, and extract detailed information for a selected area from the big picture.

Second, our view of temporal observations has changed dramatically. We have the capability to acquire data sequentially over the same scene on the Earth surface. Not only can we use this capability as a tool to inventory and characterize land features at a given point in time, we can use this capability to quantify changes which are occurring at the Earth surface at a broad range of temporal resolutions-hourly, daily, weekly, monthly, yearly, multi-yearly.

The third point addresses the data storage and analysis issues. We are the first generation of land scientists to have at our disposal the data storage and computational capabilities to extract useful information from the millions of bytes per second of spatially and temporally related Earth observation data which are being transmitted continuously to receiving stations.

The soil map as a tool for land quality assessment

Perhaps land quality has been a concern related to human survival since pre-history. No doubt land quality and sound management of the soil have been factors in the rise and fall of empires through history. However, the use of scientific data for the assessment of land quality has best been documented in various ways since the development and codification of soil mapping and inventory techniques during the past one hundred years.

It is difficult if not impossible to place a beginning date on the concept of a soil map of the world. However, it has been documented that, at an International Symposium on Tropical Soils held in Madison, Wisconsin, USA in 1960, recommendations were made that led to the establishment in the Food and Agriculture Organization (FAO) Rome of the World Soil Resources Office and, eventually to the Soil Map of the World. At the Madison Symposium, which was sponsored by the

International Society of Soil Science (ISSS), a resolution was adopted which asked for the compilation of all existing soil survey material. FAO, through the World Soil Resources Office, assumed the responsibility not only of compiling the information, but also, of preparing an integrated World Soil Map.

The Soil Map of the World project was an enormous undertaking by FAO from a technical point of view alone. There were problems related to different schools of thought, quality of data to be used, scale to be adopted, nomenclature to be used, and the classification system to apply. A landmark of 1968 was the international agreement on the legend for the Soil Map of the World, obtained at the 9th Congress of the ISSS in Adelaide, Australia.

The World Soil Map by the 1970s proved to be a tool for general assessment of land quality for development, to combat desertification, to establish complementarity between areas with different production potentials, to assess potential population supporting capacities, and to develop a framework for land evaluation.

The FAO/Unesco Soil Map of the World, published at a scale of 1:5M, was the first internationally accepted inventory of world soil resources. It was completed in 1980 and published in ten volumes with nineteen map sheets and in four languages. Recently, a working group of FAO, Unesco and the International Soil Reference and Information Centre (ISRIC) completed and published a revision of the legend for this 1:5M soil map. With the cooperation of the United Nations Environment Programme (UNEP), this map has been digitized using the ARC/INFO system. It is a component of UNEP's GRID (Global Resources Information Database) in Geneva and of FAO's Geographic Information System (GIS), linking forty internal databases.

During the 1970s two new Working Groups under ISSS Commission V were established to explore the applications of new technologies to the management of soils resources. The Working Group on Soil Information Systems was charged with the responsibility of examining new data acquistition and analysis systems, including computer technology, and of reporting on how this technology can be used effectively as a tool for the soil scientist in the storage, retrievel and analysis of soils data and in their dissemination.

The Working Group on Pedology and Remote Sensing was charged with the responsibility of examining the specifications and images of new aerospace sensors and to report on and advise how this new technology can be applied in the inventory and monitoring of soil resources.

ISSS Working Group on world soils and terrain digital database

As a logical evolution of activities in the ISSS along with that of data acquisition, handling, and analysis technologies, an ISSS provisional Working Group was established in 1985 to consider the feasibility and desirability of developing a world soils and terrain digital database at a map scale of 1:1M. A background paper in support of this concept was written by W.G. Sombroek (1985) and distributed in 1985 to more than 60 soils and terrain scientists around the world for their consideration and comments. This background paper served to focus the discussions of the 40 participants in an International Workshop on the Structure of a Digital International Soil Resources Map Annex Database (Baumgardner and Oldeman, 1986). As an outcome of this Workshop held in Wageningen, the Netherlands, in January 1986, a proposal to develop a World Soils and Terrain Digital Database (SOTER) at a scale of 1:1M was written (ISSS, 1986).

THE SOTER PROJECT

At the 13th International Soils Congress in Hamburg, West Germany in August 1986, the SOTER proposal was endorsed and the provisional Working Group was given formal status and charged with implementing the SOTER Project. During the months which followed the Congress, contacts were made with many potential national and international funding agencies to solicit support for the Project.

Because of their intense interest in global databases for environmental sciences, officials of UNEP expressed an interest in SOTER, especially if the Project could make a significant contribution to the assessment of degradation of global soils and terrain resources.

Fifteen soil scientists representing the SOTER Working Group were invited by UNEP to an Expert Group Meeting on the Feasibility and Methodology of Global Soil Degradation Assessment. This meeting was held at UNEP Headquarters in Nairobi in May 1987. As a result of this meeting a UNEP Project Document entitled "Global Assessment of Soil Degradation" was prepared, and in September 1987 a contract was awarded by UNEP for Phase 1 of the SOTER Project. There are two primary tasks under this contract. The first is to produce a general soil degradation map of the world at a scale of 1:15M. The second is to develop a soils and terrain digital database at a scale of 1:1M for an area of 250,000 sq km which includes portions of Argentina, Brazil, and Uruguay. The remainder of this paper will discuss the objectives and approach to the development of a global soils and terrain digital database at a scale of 1:1M.

Objectives

The long range objective of the SOTER Project is to utilize emerging information technology to produce a world soils and terrain digital database containing digitized map unit boundaries and their attribute database, and supported by a file of chosen point data. In the implementation of the Project an attempt will be made to include in the database some minimum density of ground observation data. The database will have the following characteristics:

a) general average scale, or accuracy, of 1:1M;
b) compatible with global databases of other environmental resources and features;
c) amenable to updating and purging of obsolete and/or irrelevant data;
d) accessible to a broad array of international, regional, and national decision-makers and policy-makers;
e) transferable to and useable by developing countries for national database development at larger scales (greater detail).

This is an exceedingly ambitious project, one which will require sustained, innovative effort over a period of many years.

Specific short range objectives are required in the initial phases of the Project to provide a logical and orderly sequence of activities to produce an operational world soils and terrain digital database. Emphasis will be on research, development and testing of methodologies in the field and in the laboratory and demonstration of the uses of the database. Specific short term objectives are as follows:

a) development of implementation plan;
b) adoption of a universal legend for a World Soils and Terrain Digital Database at 1:1M;
c) development of guidelines for the correlation of soils and terrain

mapping units;
d) definition of soils and terrain parameters and specifications to be included in the database;
e) development of a detailed set of specifications and logic which define the minimum set of capabilities/functions required for the database;
f) selection of three specific areas of 250,000 sq km each in developing countries for initial database construction;
g) acquisition and correlation of all relevant maps and data about the selected areas essential for the database;
h) input of data, including digitized maps, into the database;
i) test and demonstration of the reliability, accuracy and utility of the database;
j) conduct of an assessment of current geographic information systems and development of recommendations on the optimal system for the SOTER Project; and
k) documentation of results, conclusions and recommendations from the initial phase of the SOTER Project.

Approach

1. Implementation Plan. Upon receiving financial support for SOTER Phase 1, an implementation plan was developed which defined specific tasks and assigned responsibilities and a schedule to bring Phase 1 to completion on 31 December 1989. A Project manager for this phase was assigned and the Project officially began in September 1987.
2. Universal Legend. An international committee of soil scientists was appointed in January 1986 to develop a universal legend for soils and terrain data to be entered into the SOTER database. A draft version was distributed in March 1988 entitled "SOTER Procedures Manual for Small Scale Map and Database Compilation" (Shields and Coote, 1988).

This Manual describes and contains procedures for compiling and coding the following kinds of data for entry into the SOTER database (Figure 1):

Polygon file	(15 attributes)
Terrain component file	(28 attributes)
Soil layer file	(73 attributes)
Soil degradation file	

The Manual also presents coding forms on which to enter all the attribute file data which have been translated into the universal legend from whatever soil classification system that is being used.
3. Correlation Guidelines. The Procedures Manual in a sense serves as the primary guideline for the correlation of soils which have been mapped under different classification systems. Further refinement of correlation procedures must be developed during the actual testing of the procedures and legend during field and compilation operations.
4. Definition of Soils and Terrain Parameters for Entry into the Database. Careful attention has been given to the amount and kinds of data to be included in the SOTER database. The tendency is to include more data than can be used or is necessary for a map scale of 1:1M. The legend committee has given tentative definitions in the Procedures Manual. The adequacy of these definitions is being tested during Phase 1.
5. Definition of Detailed Set of Specifications and Logic to Define Minimum Capabilities/Functions of Database. In general, the SOTER

Proposal specifies that the SOTER database should be accessible to a broad base of users for a wide array of uses. During Phase 1

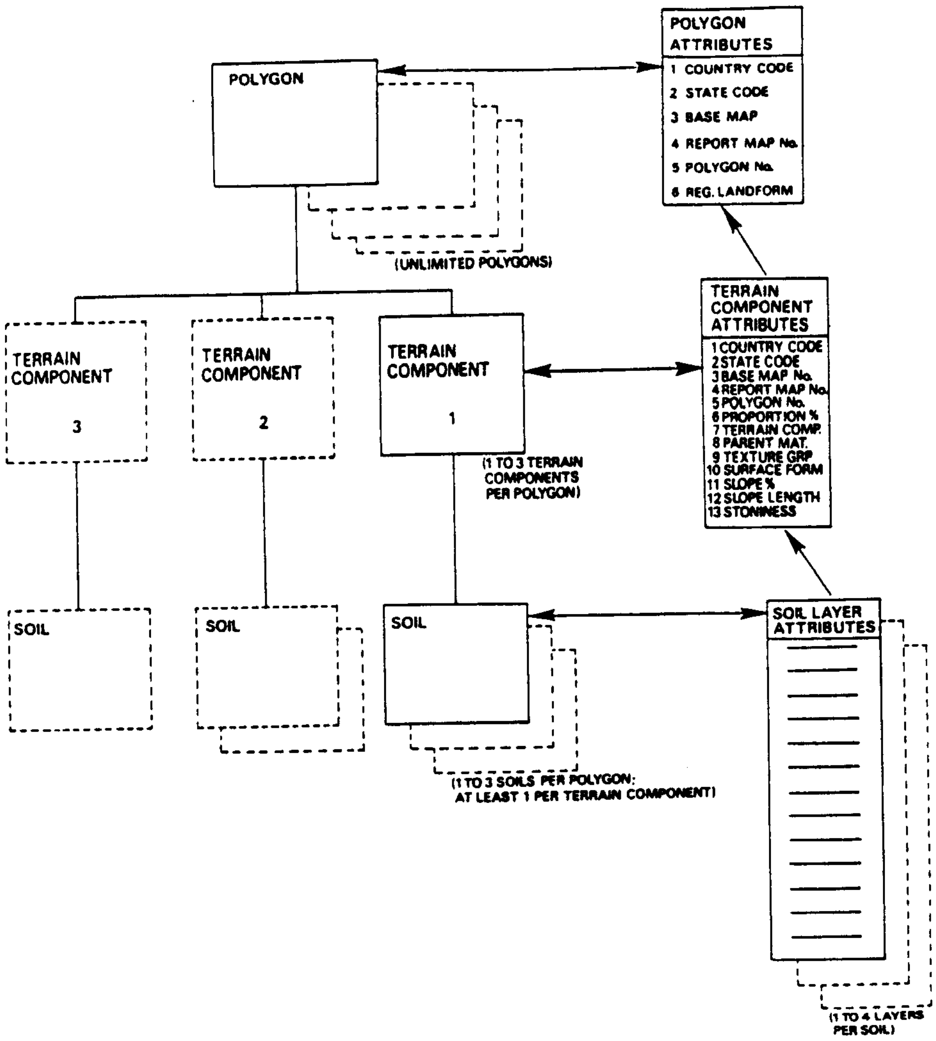

Fig. 1. Relation between Soter attribute files.

the potential users and uses of the Database must be more clearly defined so that the minimum capabilities and functions of the Database can be specified.

6. Selection of Pilot Areas of 250,000 sq km each in developing countries. During the International Workshop in Wageningen in January 1986, approximately twenty areas of 250,000 sq km were suggested as potential pilot or demonstration areas for SOTER. These were prioritized in terms of availability of data and interest of potential funding agencies. These priority areas included regions in South America, East Africa, West Africa, and Southeast Asia.

In consultation with UNEP, the area selected for Phase 1 is an area in excess of 250,000 sq km which includes a portion of Argentina, Uruguay, and Brazil (Figure 2). In March 1988 a SOTER Workshop was held in Montevideo, Uruguay, for soil scientists of the three participating countries and selected members of the SOTER Working Group. The purpose of the Workshop was to present and discuss the concepts of SOTER, to report on the availability of data for the SOTER Database, and to present and discuss thoroughly the Procedures Manual and universal legend for coding data (Peters, 1988).

During April and May 1988 soil scientists of Argentina, Brazil, and

Uruguay tested the Procedures Manual in a relatively small area within their portion of the Pilot Area. The Procedures Manual was used as a

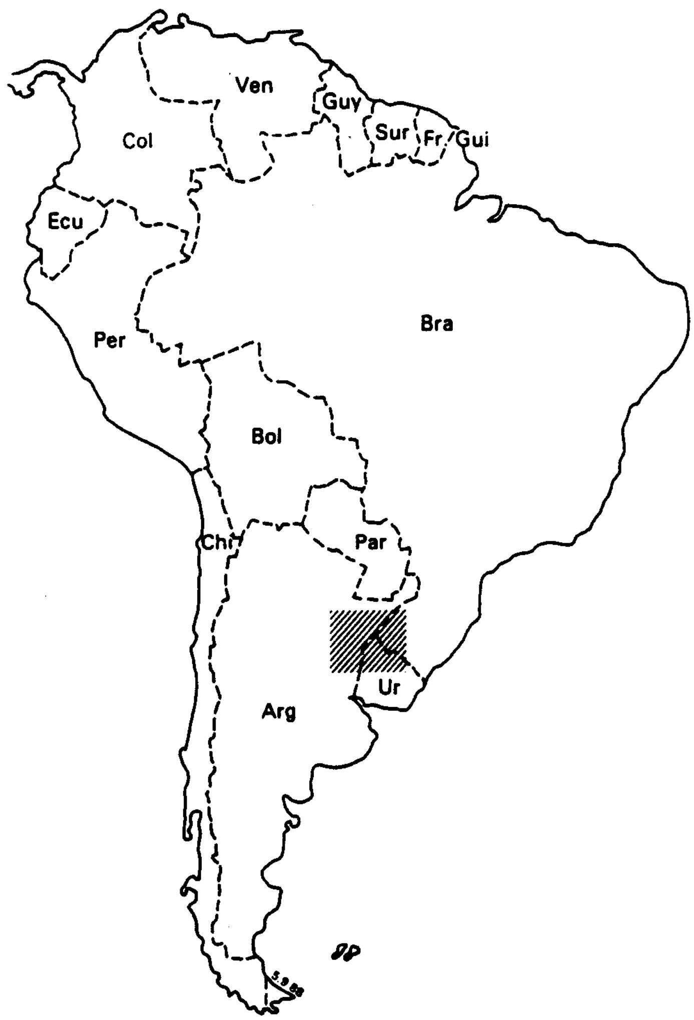

Fig. 2. Pilot area 1: South America.

guide for translating soils and terrain data from their systems to the SOTER legend and for coding the data for input into the SOTER Database.

In June 1988 three external SOTER soils correlators joined participating soil scientists of the three countries for correlation studies. They traveled together to each of the small study areas in each country and discussed the problems which they had encountered with the use of the Procedures Manual. The purpose of this exercise was to refine and improve the Manual and correlation procedures. Each country has appointed a country correlator to work closely and as necessary with the external correlators in order to arbitrate correlation differences.

7. Acquisition and Correlation of Relevant Maps and Data. The Soil Survey organizations of Argentina, Brazil, and Uruguay will be responsible for acquiring relevant map and attribute data and translating the data to the SOTER legend.
8. Entry of Data into the SOTER Database. At this stage of the Project a final decision has not yet been made about this task.

Several possibilities are being considered. It has been agreed that once the Database has been established, one of the places it will reside is UNEP/GRID.

9. Test and Demonstration of Reliability, Accuracy and Utility of the SOTER Database. During 1989 after entry of data into the Database, attention will be given to the testing of the Database.
10. Assessment of Current Geographic Information Systems. As yet no decision has been made on the system to be used for the SOTER Database. The major concern is that whatever system is finally selected, it be compatible with GRID and other global environmental databases. Many different commercial hardware/software systems are available today, and no doubt others will emerge in the future. It is essential that the system selected for SOTER be flexible and economically feasible.
11. Documentation of Results, Conclusions and Recommendations. Phase 1 of SOTER is scheduled for completion on 31 December 1989. The results, conclusions, and recommendations of this phase of the Project will be documented and provide valuable guidelines and experience for the next phases of SOTER.

Expected Results

In general, the overriding objective of the SOTER Project is to improve the capability to deliver accurate, timely, useful information about soils and terrain resources to decision-makers and policy-makers. It is expected that a World Soils and Terrain Digital Database will provide this improved capability of information delivery. There are other, perhaps more specific, results which are expected from the Project.

1. Orderly arrangement of resource information. All endeavors involved in the development, management, and conservation of environmental resources require information about those resources which is normally available from a variety of sources, at different levels of detail, including format and scale. An important outcome of the operational Database is to bring into being an orderly arrangement of descriptive and quantitative data about soils and terrain, easily accessible to the user community and compatible with other environmental databases.
2. Improvement in standardization and compatibility of reporting soils and terrain data/information. Inherent in the conceptualization of the Database is the requirement for a "universal" legend and a standard system for both input and output. Another requirement of SOTER is that the Soils and Terrain Database be compatible and have overlay (registration) capabilities with world databases of other environmental resources.
3. Improvement in accessibility of soils and terrain and related resource information. An important component of the Project is that of technology transfer, especially in the provision of training in the access to and utilization of the Database for easy extraction of a broad array of interpretive maps and information essential to resource managers and policymakers. Different methods will be explored for improving communications between the Database and the user community.
4. Dynamic resource information system with updating and purging capabilities. One of the significant benefits of the Database, not possible with previous soils and terrain information systems, will be the instantaneous capability to add new data whenever such data

become available and to delete incorrect, obsolete and irrelevant data.

5. Information service for national resource planning in developing countries. Another of the expected results from an operational database is the valuable resource information service which can be made available to a variety of agencies and organizations involved in national and regional resource planning in developing countries.
6. System model for technology transfer. As the world is being caught up in the "information revolution," there is an increasing need to find innovative and useful methods for transferring this technology. The SOTER Database Project can provide an excellent vehicle for training a cadre of specialists, especially in developing countries, for using the Database, providing new data, and developing new uses of the Database. The operational World Database can also serve as a model for the design and construction of incountry databases with sufficient detail and scale (accuracy) for local and provincial use.

A Supporting Research Agenda

The ultimate test and assessment of any soils and terrain database, at any scale, is the degree to which useful interpretive information can be extracted from the database. Two broad areas of interdisciplinary research must be pursued to bring accurate, useful, and timely soils and terrain databases into operation. The first is the development of the database itself. The second but closely related research area is the development of analysis and interpretive techniques.

1. Development of the database. In this discussion it is assumed that state-of-the-art hardware/software systems will be available commercially. The research to be addressed does not include those aspects of basic geographic information system technology. The following items related to database development should be included in the research agenda:
   a. minimum data quality standards for all map and attribute data for entry into the database;
   b. development and refinement of techniques for using remotely sensed data as a tool for delineating meaningful soil boundaries at different map scales and characterizing soils and terrain where current data are inadequate or non-existent;
   c. development of better methods for generalizing soils and terrain maps from scales 1:10K to 1:50K; from 1:50K to 1:250K; from 1:250K to 1:1M;
   d. improvement of methods for translating, correlating, and coding soils and terrain data (map and attribute) from different classification systems to a uniform legend and standard database.

2. Development of analysis and interpretive techniques. Some current GIS systems have excellent query and information extraction capabilities. However, there are areas of research and development which could contribute significantly to the benefits to be derived from soils and terrain databases.
   a. development of modeling algorithms which would be used to derive maps from the database related to erosion hazard, trafficability, potential biomass production, optimal application rates of herbicides;
   b. using temporal data in the database, development of algorithms to estimate amounts and rates of change in the soil as a source and

sink of materials related to carbon dioxide increase, acidification, nutrient decline, erosion, alkalization, salinization, desertification and other processes.

We live and operate in a multidimensional environment. The effects of human activity in this environment play an increasingly important role in global change. Today, we have a remarkable set of tools with which to observe, monitor and model in space and time the Earth system and global processes. May we have the wisdom to use these tools for the benefit of all humankind for all time to come!

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