International Society of Soil Science (ISSS)
Association Internationale de la Science du Sol (AISS)
Internationale Bodenkundliche Gesellschaft (IBG)

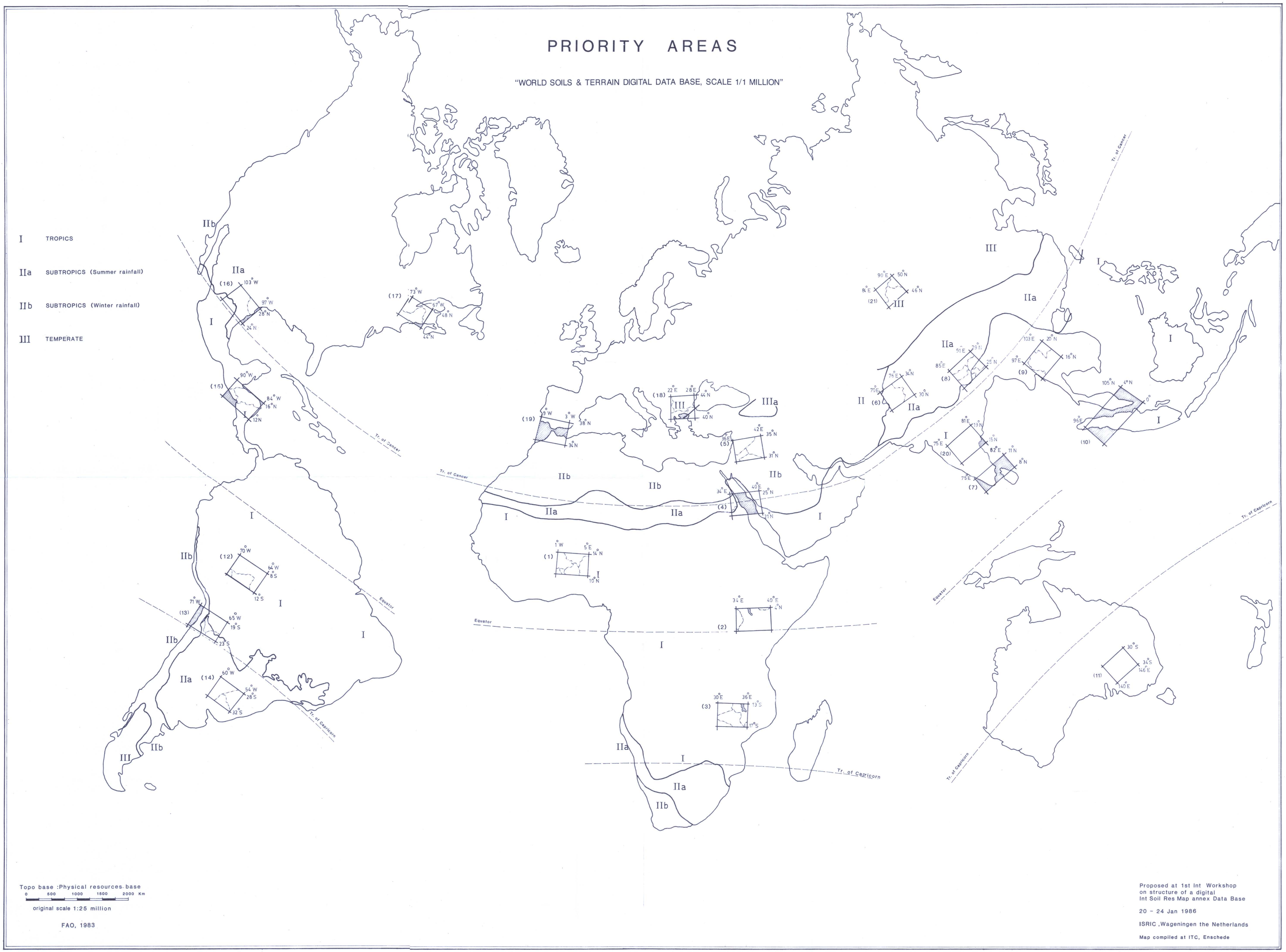
Proceedings of an International Workshop on the Structure of a Digital International Soil Resources Map annex Data Base

20-24 January 1986
at the
International Soil Reference and Information Centre,
Wageningen, the Netherlands

Structure of a Digital International Soil Resources Map annex Data Base

Proceedings of an International Workshop ISSS, Wageningen, January 1986

12801 pdf 54x46



S25 I

International Society of Soil Science (ISSS)
Association Internationale de la Science du Sol (AISS)
Internationale Bodenkundliche Gesellschaft (IBG)

PROCEEDINGS
of an
INTERNATIONAL WORKSHOP
on
THE STRUCTURE OF A DIGITAL INTERNATIONAL SOIL RESOURCES MAP ANNEX DATA BASE

20-24 January 1986
at the
International Soil Reference and Information Centre,
Wageningen, the Netherlands

Inquiries: Secretariat I.S.S.S.
P.O.Box 353
6700 AJ Wageningen
the Netherlands

TABLE OF CONTENTS

ABSTRACT

These proceedings contain the papers and a summary of the deliberations of a workshop which was held in Wageningen, the Netherlands, to consider the feasibility and desirability of preparing a global soils and terrain digital database. A background paper for the Workshop was prepared by Dr. Wim Sombroek and appears in the appendix of the proceedings (Section 7.1). During the meeting at the International Soil Reference and Information Centre from 20 to 24 January 1986, the 40 participants from 19 countries heard and discussed 5 invited papers related to global environmental databases (Sections 3.1 - 3.5), 6 presentations on technical considerations for development and implementation of a world soils and terrain digital database (Sections 4.1 - 4-6), and 9 specific country reports on soil databases (Sections 5.1 - 5.9).

The final 2 days of the Workshop were devoted to the activities of 3 subgroups to consider different issues related to a world soils and terrain digital database, including map and attribute data. The first subgroup defined objectives and suggested 21 priority areas for inclusion in the development phase of a world soils and terrain digital database (Section 6.1). The second subgroup prepared a description of potential uses and users of a world soils and terrain database (Section 6.2). The third subgroup dealt with the conceptualization of such a database and issues related to a "universal" map legend, correlations among national maps and different classification systems, and a minimum set of parameters (physical, chemical, biological) to be included in a soils and terrain database (Section 6.3).

During the discussions on the final day of the Workshop, there was consensus among the participants that a recommendation be made to ISSS Commission V in support of producing a world soils and terrain digital database at an average scale of 1:1 million. A subgroup was named to begin work on a legend for a world soils and terrain map, and a minimum data set for attribute data to be entered into the database. Another subgroup was requested to prepare a draft proposal for a project to develop a world soils and terrain digital database at an average scale of 1:1 million. Reports from both subgroups will be presented and discussed by working groups of Commission V during the International Soils Congress in Hamburg in August 1986.

2

THE WORKSHOP OBJECTIVES

2.1 WELCOME AND STATEMENTS OF PURPOSE

Wim G. Sombroek
Secretary-general
International Society of Soil Science (ISSS)

On behalf of the International Society of Soil Science and its provisional Working Group on Digital Mapping of Global Soil Resources, I welcome you at this first Workshop on "The Structure of a Digital International Soil Resources Map annex Database."

I am happy to note that so many representatives and specialists of national and international institutions engaged in soil resources inventory and evaluation are able to attend, notwithstanding the short time of preparation and the poor weather conditions at this time of the year.

The subject of the meeting has been tabled over the past few years at various international fora, and was discussed in detail between myself, as director of the International Soil Reference and Information Centre (ISRIC), and the Chairman of ISSS Commission V, Dr. Richard Arnold, who is also Principal Investigator of the Soil Management Support Services of USAID-SCS. At his suggestion a first discussion paper was prepared in October 1984, which elaborated on the need to update and expand the soil data base used for the 1:5 million FAO/Unesco Soil Map of the World, this time employing advanced computer processing techniques.

This paper arose substantial interest, and by agreement of the Executive Committee of ISSS, a provisional Working Group for the purpose was established, under the aegis of its Scientific Commission V (cf. ISSS Bulletin 67, page 29).

Encouraging reactions were received from individual soil scientists, from institutions dealing with soil resources, and from international organisations engaged in development cooperation, prompting the convening of this workshop. The timing was set for January 1986, to allow the presentation and discussion of a draft plan-of-action that may emerge from this meeting at three major forthcoming international gatherings, viz:

- An international Workshop on Agro-ecological Characterisation, Classification and Mapping of the Consultative Group on International Agricultural Research (CGIAR), to be held at FAO, Rome, in April 1986.
- The 13th General Congress of Soil Science, to take place in Hamburg, FRG in August 1986, with meetings by several ISSS Working Groups on related subjects such as Remote Sensing for Soil Survey, Soil Information Systems, Land Evaluation, and development of an International Reference Base for soil classification.
- The General assembly of the International Council of Scientific Unions (ICSU) set for Berne, Switzerland in September 1986, where representatives of many disciplines will formulate the details of an International Geosphere-Biosphere research and monitoring Programme.

As indicated in the background paper for the present workshop, entitled "Establishment of an international soil and land resources information base"*), the time would appear to be ripe for a new effort to aggregate up-to-date information on the world's soil and land resources. There are, right now, a lot of initiatives to develop national, regional and global (soil-) geographic information systems. There is a danger that these initiatives develop along different lines and will compete for the same groundtruth data and funds. Compatibility of systems, and thereby the exchange of data - intra and interdisciplinary - may become in yeopardy. Each group may be tempted to jealously guard its own data and to boost the merits of its own system.

It is the duty of a Scientific Union or Society like ours to try to prevent such diverging tendencies, and to bring as many interested parties as possible together on the same approach and line-of-action.

On this ambitious note I wish you a most successful Workshop.

*) See Appendix 7.1 of these Proceedings.

2.2 THE WORKSHOP THEME*

Richard W. Arnold
Soil Conservation Service
Unites States Department of Agriculture

Soil scientists, fellow pedologists, friends and guests,

This Workshop is a good example of what Commmission V of the ISSS and soil science in general, is all about. We are unique and yet we are the same. Let me explain.

We are here today to be part of the First International Workshop on the Structure of a Digital International Soil Resources Map and accompanying data base. Wow! How many times have you personally been involved in an international first? Within this group there are quite a few who have been associated with "international firsts". What a challenge, what excitement - a one and only. The next workshop will have to be the second, not the first. You are privileged - you are unique - both in space and time. Thus we must carry the responsibility for all of our peers and associates who could not be here with us today. On your own shoulder is the burden of more than 10,000 other soil scientists in the world. Don't let them down - they want and they need your support.

But not only are we unique - we are also the same. We are repeating the dreams, the hopes and the frustations of those pedologists who previously led the way and shouldered the responsibilities.
Did they want to share their knowledge about soils? Of course. Did they get excited about improved understanding of soil development and soil behaviour? Of course. And did they have an unselfish dream of a one-world Pedology that would bring together our fragmented pieces of the puzzle and put them

* Adapted from original presentation illustrated by color slides.

together so that mankind could live, and love, and grow into something better and stronger and wiser than ever before? Oh yes, it is a part of our heritage as Commission V pedologists; we have the same dreams and hopes and wishes for a better world.

Uniqueness occurs because of differences and changes in space and in time. Nothing is ever again really quite the same in our physical, chemical, biological world of soils. Yet the concepts, ideas, and goals of the human mind are a common thread that lets each of us contribute to a great oneness - the same great workings of human beings. And a particular similarity of those who are pedologists. This is what Commission V, and soil science in general, is all about.

Some people say that since there are already several soil maps of the world, there is little need for additional work. More details about soils are available in the numerous national soil maps throughout the world and many of them are available here at ISRIC. Many intermediate scale soil resource maps are available for states, provinces, and regions. Some of these are also here at ISRIC. At the level of farms and ranches there often are soil maps available to show the location and distribution of kinds of soils. So why do pedologists want more? Why do we have to hold another workshop?

The world is a busy place and it doesn't have much time or patience to consider soils. Besides, to many people the soil appears to be uniform; it doesn't have much character. Same color, similar texture and structure - what's the big deal? You see one soil, you've seen them all.

As pedologists we know better. On the surface the landscape may convey very little evidence of the fantastic story beneath that cries out to tell you of the prior vegetation and climate. Anyone who has examined a tonguing argillic horizon has observed a soil which gives rise to a lot of local variability.

Soils can also occur as tongues in solution channels in limestone. In such cases, the history of the landscape is vital to an adequate understanding of the history of the soil. The properties are conncected - they are related - and so understanding one soil helps us to understand better the other.

When you describe and interpret soils you integrate many disciplines - geomorphology, pedology, archeology, agronomy, economics, cultural history, art, science, esthetics, reality and the mysterious projections of the future. The joy and sorrow of the past, the pragmatism of today, and a perception of the unknown future become a part of the interpretation. The story of a Plinthic Paleaquult in Thailand is so complex, yet so fascinating, that it could hold us spellbound for years to come. Yet it can be described, and characterized, and classified by its combination of diagnostic soil features regardless of the real story of how it came into existence.

Soils with their many properties and qualities are the basis for sustainable farming systems. It may be extensive grazing when the climate, vegetation, and soils have recognizable and predictable relations. In other locations the use and management of soil resources are brought into a beautiful harmony with the natural and cultural environment. Pedologists bring understanding to such scenes, and they want to share it with others.

A great deal of our expertise is in our ability to characterize and delineate patterns of variability. Systematic variations in space and in time are predictable in the sense that consistent relationships among features are observed again and again. We develop and use many models to prepare maps which show many kinds of variability. When we map, we also classify; thus, we have many classifications currently in use.

We are moving slowly ahead. We are searching for an appropriate structure, a design for working together. We must reach out and touch new ground. We must be aware of the world around us and sense that each one of us is important to the eventual outcome. The world of soil maps has been done at a snail's pace - but it is a good world.

But now the pace should accelerate. There are many concepts to help us move ahead - computerized databases; database management systems to help us integrate, test, and evaluate data; data dictionaries for commonality of definitions; coding schemes for features, properties, and qualities; digitized maps of resource information including soils, climate, geology, land use, and numerous interpretive derivatives; and the extension of soil information systems to planners and implementors of land use decisions.

Yes, we are searching for the beauty that is achievable in this world when all the parts are connected in the right way. We want the pieces to be integrated, to become parts of the same wholeness, and to bring a keener sense of purpose and appreciation to those around us.

From the pedologists' delight with the beauty and charm of soil profiles in the field; to the experience and results of agronomic research done at many locations throughout the world; and the translation and transfer of soil and agricultural technology into meaningful patterns for mankind everywhere - there is the utmost urgency and desirability for cooperation.

The operational aspects of much of our daily lines are closely linked to computers. As we are now in the era of "information handlers", we will increasingly become personally involved in the ways and means of collecting, coding, handling, and packaging soils information so it can be utilized by others. The machines can't do what humans can do. We build models of soils in landscapes. We study, observe, and understand soil behavior. We can come from all over the world, get together, and work for a common goal. Machines will never be pedologists. Pedologists have the serious responsibility to maintain and build and provide the very best scientific basis they can about the soils of the world.

Together we must learn to see beyond the trees of the forest and to focus on the bright goal of developing a world soil resource database that will be able to provide basic information on kinds and distribution of soils, and also on the utilization and performance of those soil resources.

It is not an easy task. Much has already been done - there is much yet to do. But we can go ahead with confidence because we are representatives of Commission V of the International Soil Science Society and we know that the trust and care of the soil is in our hands. We will carry the responsibility, we will help others to make wise use of the soil resources so precious to our survival and well being. This is our challenge and this is our Workshop.

3

GLOBAL ENVIRONMENT DATABASES

3.1 DATABASES AND INTERNATIONAL RESEARCH AND DEVELOPMENT

F.W.G. Baker
International Council of Scientific Unions (ICSU)

3.1.1 History of Global Environmental Databases

When Dr. Sombroek asked me to talk about Databases and International Research and Development and particularly the International Geosphere-Biosphere Programme and activities of the International Union of Biological Sciences (IUBS), I sought help from two main sources: 1) ICSU's Committee on Data for Science and Technology; and 2) the ICSU Panel on World Data Centres (Geophysical and Solar). In the introduction to the "Guide to International Data Exchange through the World Data Centres" I read that the "World Data Centres (WDCs) first came into being in 1957 as part of the International Geophysical Year". Although this is true if one considers the WDCs as they exist today, looking back through the history of science and of international research and development, we find that the WDCs created for the International Geophysical Year (IGY) were fourth in a series of such data centres concerned with one or more aspects of geophysics.

The first was the data centre set up by K.F. Gauss and W. Weber at Göttingen to collect the results of observations made in the framework of the Göttingen Geomagnetic Union. This was a period of international cooperation from 1836-41 when 44 stations throughout the world made standard measurements at standard times during periods of 4-6 days. This was to some extent a follow-up of the measurements made by E. Halley in the 17th Century when maps of the magnetic intensity were particularly important for navigation.

A German geophysicist and polar explorer, Carl Weyprecht, was responsible for the second, which was established at the Central Physical Observatory at St. Petersburg. The final meeting of the International Polar Commission decided that 12-16 copies of the results of the first International Polar Year (1882-83) should be lodged at this observatory. A similar system operated in the second International Polar Year (IPY) when a centre for collecting the data was established in Copenhagen for geomagnetic data and at Hamburg for meteorological data. The third International Polar Year became the International Geophysical Year and so we have a World Data Centre, at least in geophysics, that provides a 150 year sequence of information.

When the WDCs were created, the ICSU Special Committee for the International Geophysical Year resolved that "observational data to be exchanged in accordance with the IGY programme shall be available to scientific institutions in all countries" and authorized "the establishment of at least three IGY World Data Centres of which one (C) will consist of a number of parts. Each centre will be international in the sense that it will be at the service of all countries and scientific bodies". This policy of freedom of access continues. As Dr. Arnold indicated, there is a great desire to share information. The reason for organizing three centres with common basic collections of data was to ensure against catastrophic destruction of a single centre. This was probably stimulated by the fact that part of the data from the second International Polar Year was lost during the 1939-45 war before it could be published.

There are also long sequences of data collection in other areas of science, such as biology, chemistry, crystallography, hydrography, physics, etc. The increased facilities for obtaining data, and as a result the much larger amounts of data collected, have led to the use of computers to handle data mechanically. These have improved greatly our ability to handle the collection, analysis, storage, retrieval and dissemination of data. Practically all of these tasks can be done more efficiently and faster than by hand. In addition, computers allow us to manipulate large data sets, combine or compare different sources of data, and to perform more sophisticated searches for data with specific properties. With collections of data stored in such systems, computer type-setting can be used to prepare camera-ready copy directly and the data bases can be incorporated into on-line networks of rapid accesss and dissemination.

In spite of such facilities data handling and the production of a specialized graphic end product can still be time-consuming and expensive. Some indication of this can be given if we look at the General Bathymetric Chart of the Oceans (GEBCO), which was initiated at the turn of the century by H.R.H. Prince Albert I of Monaco, who believed that the best possible maps are essential for wise and intelligent management of the environment and natural resources. The first edition of GEBCO took 7 months to compile from the existing data and was published in 1903. The fifth edition of GEBCO was completed in 1984 after seven years. Even with the help of computer techniques such a long period of time was necessary to handle the data that had been collected in the period of more than twenty years since the fourth edition.

3.1.2 Global Atmospheric Research Programme (GARP).

The great value of computers in handling large amounts of data was one of the reasons (the other being the development of Earth observation satellites) which led the United Nations in its resolution 1802 to invite ICSU "to develop an expanded programme of atmospheric science research which will complement the programmes fostered by the World Meteorological Organization". This led to the agreement between WMO and ICSU to launch the Global Atmospheric Research Programme (GARP) and within this the First GARP Global Experiment, probably the most complex and ambitious international interdisciplinary study of our environment ever undertaken. Data were collected in real-time and with various periods of delay from ground-based stations of the World Weather Watch, from drifting buoys, ships, balloons, aircraft, polar-orbiting and geostationary satellites and so on. Two main centres for data were created in Sweden for space-based systems data and in the U.S.S.R. for surface-based data. The final data products provide a detailed record of a number of parameters of the entire global atmosphere during the period of the Experiment. These data are accessible to scientists and research workers from any part of the world in the World Data Centre system and are being used widely by scientists from many nations.

3.1.3 International Biological Programme (IBP).

When planning began for the International Biological Programme (1964-1974) - a study of the biological bases of productivity and human welfare - the Special Committee set up by ICSU also considered the possibilities of creating a set of world data centres in biology. Discussions took place about the types biological data that might be collected, processed and stored in data banks but only one was created, for blood data. Although only one data base was created during the IBP, a considerable amount of effort was expended to ensure that the data collected would be comparable. This included not only a comparison of methodology from one laboratory or one instrument to another but also to the problems of sampling. The author of one of the 30 IBP synthesis volumes drew attention to the problems that arise from inconsistencies in existing data. He suggests that it is necessary in such cases "to point the need for further research rather than attempt to draw premature conclusions".

3.1.4 International Geosphere-Biosphere Programme (IGBP).

I now come to an ICSU international programme that is in the stage of a feasibility study - that on Global Change or the International Geosphere-Biosphere Programme. The programme on Global Change, if launched, will be designed to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the changes that are occurring in this system and the manner in which they are influenced by human actions. It is expected that it will be a focused programme of research directed at providing the body of knowledge needed to assess the near term - up to 100 years - future of the Earth. Such a programme should be based on a restricted and well-planned series of observations, models, process studies, and experimental research. It should also include increased efforts to recover a much longer history of the Earth and its environment, from geological records and the records preserved in sediments, trees and ice.

Since this is a meeting mainly of soil scientists, may I draw attention to two suggested studies of:

1) processes of soil formation, functioning and degradation, the salinization and chemical balance of soils and of soil erosion, needed to understand the impacts of modern agriculture on the global soil resource and to specify the function of soil cover in the biosphere;
2) specific aspects of the hydrological cycle - for example, the exchange of water between the troposphere and stratosphere, the investigation of dynamic and radiative feedbacks involving clouds, and studies of the exchange of water between soils, plants and the atmosphere.

The programme would be one of basic science, with the promise of significant practical rewards for the good of all mankind. A deeper understanding of the coupled processes that govern the Earth's environment will provide the basis for a more rational management of resources and improve the reliability of forecasts of significant global change.

3.1.5 Other Global Environmental Research Programmes.

A number of broadly based programmes have been undertaken in the past to study different parts of the Earth's environment. I have already mentioned the IPY's and the IGY, GARP and the International Biological Programme. There have been others, such as the International Indian Ocean Expedition and the International Lithosphere Programme, which may be familiar to some of you. A number of programmes are currently in progress, such as the World Climate Research Programme (WCRP), which is organized jointly by ICSU and the World Meteorological Organization with the participation of the Intergovernmental Oceanographic Commission, the Man and the Biosphere Programme of Unesco, the SCOPE Study on Land Transformation, which brings in strongly the impact of man, the Decade of the Tropics of the International Union of Biological Sciences (IUBS) and the TROPENBOS Programme of Tropical

Forest Research Stimulation launched in Utrecht in 1981. Until now, these organized programmes of research have tended to concentrate on isolated components of the system: the atmosphere, the hydrosphere, the biosphere, or the lithosphere. We know that there are interactions between these component domains, but, in general, we know too little about the physical, chemical, and biological processes that connect them. An IGBP would aim at an improved understanding of the ways in which the various parts of the system interact.

The formulation of the observational programmes should be based on careful analysis of the requirements that arise from the specification of the process studies, modelling efforts and testing as outlined above. Observational data from ongoing programmes, such as the WCRP or from an array of global monitoring efforts, will be counted on to supply many fundamental inputs to an IGBP. Other observations more specific to its goals will also be required. With regard to the data, careful consideration will be given to the problems of handling (for example, collection, validation, analysis, storage, transmission) of the large amounts of information that

3.1.6 Committee on Data for Science and Technology (CODATA).

If I may, I will revert to the activities of ICSU's Committee on Data for Science and Technology, which was established in 1966 to promote and encourage on a worldwide basis the production and distribution of reliable numerical data of importance to science and technology. Although it was initially concerned primarily with chemical and physical data, it has extended its scope to include space- and time-dependent data from the bio- and geosciences. CODATA prepared under contract with Unesco an "Inventory of Data Sources in Science and Technology" to facilitate the access of scientists and engineers to sources of numerical or factual data. One of the topics considered is soil science with a list of institutional sources of data and a list of published sources of data. This Inventory is being revised and published as the "CODATA Directory of Data Sources for Science and Technology". The Committee has produced a Multisatellite Thematic Map based on Tanzania, which was on display at the CODATA Conference in 1984.

A more recent publication of CODATA "The Role of Data in Scientific Progress" contains in a paper entitled "Tools for the Automated Handling of Evaluated Data" by B.B. Molino the following statement: "There are a limited number of automated data files of evaluated, numeric data and, at present, even these are under-utilized". This was confirmed by a conversation I had last week with the manager of one of the largest international data bases, who said that up to the present no organization has managed to recuperate its investment in establishing and maintaining a numerical data base in any subject. Experience with large data bases has shown that even the existence of the required data in the base is not sufficient motivation for the average user to make the effort to obtain it.

3.1.7. User Requirements for a Database.

This brings me to my last point. What are the principal questions that should be asked when establishing a data base - be it for national, regional or international use? The first is what are the potential users' needs? Time and again data bases are established because the data are there or because someone has a bright and convincing proposal for a data base. A survey should be made of potential users and their specific requirements. Such a survey must be exhaustive and take account not only of whether the users would find the data useful but the practicalities of the cost they would be willing to pay and other conditions under which they would be willing to access the data if they were provided.

The second question that must be asked is what are the sources of data already in existence and what are future data sources likely to be? Are there significant differences among the sources of data from the viewpoint of quality, price, preparation, compatibility, etc? What are the problems of maintaining the data base?

3.1.8 Need for Global Cooperation and Compatibility of Data.

These questions apply equally to a data base with graphical outputs, such as the Geological Map of the World, the Digital International Soil Resources Map or the suggested World Digitized Data Base for Environmental Sciences.

It is essential that we cooperate closely in creating data bases to ensure that they provide the information we all need and also to ensure that maximum use is made of them. For one thing is certain, if ICSU decides to launch a study of Global Change it will be essential to improve interactions between scientists of the different disciplines involved and also between data bases that will be necessary to store, process and provide access to the results.

3.1.9 Bibliography.

Glaeser, P.S. (Ed.), 1985. The Role of Data in Scientific Progress, Elsevier - CODATA, Amsterdam.

ICSU, 1985. The International Geosphere-Biosphere Programme (IGBP): A Study of Global Change, Paris (duplicated).

Malone, T.F. and Roederer, J.G. (Eds.), 1985. Global Change, ICSU Press - Cambridge University Press, Cambridge.

Rumble, J.R. Jr and Hampel, V.E. (Eds.), 1984. Database Management in science and Technology, North Holland - CODATA, Amsterdam.

Unesco, 1982. Inventory of Data Sources in Science and Technology, Paris.

3.2 WORLD DIGITAL DATABASE FOR ENVIRONMENTAL SCIENCE

David P. Bickmore
Joint Working Group on Environmental Atlases & Maps
International Geographic Union
International Cartographic Association

3.2.1 Database framework.

Spatial surveys and data collection systems often need a framework to start from - viz. a common base map. This project is about providing a 1:1M global base map in digital form. It is planned in the context of International Geographical-Biophysical Programme (IGBP) as a frame of reference and index for many environmental disciplines and, especially so, for global soil mapping at 1:1M scale.

3.2.2 Proposed specifications for the Database.

The following specifications or attributes for the Database have been defined:

(a) Scale. 1:1M for land areas linked with smaller scales (e.g. GEBCO 1:10M for the oceans) and intermediate scales (e.g. 1:5M for Antarctica).

(b) Content. The following data should be included: relief contours at 300m intervals supplemented by 10'gridded elevation data, river and stream networks categorised by Institute of Hydrology, and coastlines. This physical relief information will be the predominant element (and cost) of the database. It would also provide internal administrative boundaries, built-up areas and place names.

(c) Sources. We assume digitising an existing world map series at 1:1M scale to obtain these data. Part of this work is already complete but contours still require digitising. Note that remotely sensed data, even when available globally, are not a directly useful source for contours, boundaries, names, etc.

(d) Up-dating. We believe there is a need to develop a centre (with a good library) that can provide a continuing up-date and revision service based on user priorities.

3.2.3 Digitization of Base Map.

Completion of the digitising is assumed by 1988 at a cost of approximately $ 500,000. We are considering - with ICSU - the means of raising this money (e.g. from a Foundation) and assuming that the resulting data would be distributed at minimal cost via World Data Centres. Alternatively, we are considering a joint ICSU/commercial arrangement that would sell tapes, optical discs, etc. to individual users on a quasi publishing basis.

3.2.4 World Environmental Database Workshops.

Our recent workshop in Boulder, Colorado, proposed that we now undertake some feasibility studies and demonstrate some pilot areas (Kenya, Sumatra, China) for discussion and assessment at a workshop in July 1986. This should make it possible to submit a proposal to ICSU for consideration at its General Assembly in September 1986. Recently we have been invited by UNEP/GRID to hold the July 1986 workshop at their establishment in Geneva and with a view to mounting our database on their GRID system which does not at present have global topography.

3.2.5 Objectives of Pilot Studies.

The following objectives have been defined for the Database pilot studies:

(a) To substantiate the feasibility and costs of coding map data appropriately before being digitised (e.g. ensuring a logical network and stream ordering for all rivers, lakes, etc. for statistical analysis, generalisation, linkage with names, etc.).

(b) To assess the costs and management problems related to different systems and approaches to the digitization of maps.

(c) To test digital structures for this very large data set and to assess methods to speed up data searches and fast inexpensive retrieval for users. It is assumed that routine adjustment of scale and change of map projection can be made in the system.

(d) To test the use of digitized contour data in combination with gridded data and print data of heights for the preparation of thematic maps required by users.

(e) To conduct a pilot study for the generation of thematic maps from the overlay of various data sets, e.g. soil boundaries, altitude levels.

(f) To select pilot areas which coincide with some of the priority areas selected by the ISSS Commission V Working Group on World Soils & Terrain Digital Database; to digitize a topographic base map for overlay with other digitized map data for testing before and presentation to the July workshop in Geneva. This assumes that there can be efficient assimilation of soil or landscape data with topographic data and its manipulation within a computer system.

3.3 The World Soil Map, Agro-ecological Mapping and Some Related FAO Activities

by Maurice F. Purnell.
Land & Water Development Division
Food & Agricultural Organization(FAO)

3.3.1 Introduction.

This is a brief account of some FAO activities in small scale soil mapping and their linkage with agro-climatic mapping for assessing potential crop productivities and potential human population supporting capacities. It is emphasized that large scale mapping on projects for agricultural development would have other objectives and use different methods of data collection, land suitability evaluation and mapping.

The FAO/Unesco Soil Map of the World is familiar to everyone. It was developed over about 15 years and completed by the 1978 ISSS Congress. Much new information has been collected, and it is desirable to use it to update the map.

3.3.2 Updating the Legend of the Soil Map of the World.

Before the mapping units can be changed it is necessary to update the legend to the map. The objectives of updating are to make use of modern concepts and new data to provide greater reliability for agro-technology transfer, and to introduce standards for 3rd level soil units for use in larger scale, national mapping, such as are being used in Kenya, Europe, Brazil and other places. A working group has prepared a draft Revised Legend which is being circulated for comment and will be presented at the ISSS Congress in 1986 (FAO, 1986)

The World Soil Map has already been digitised using the ARC/INFO system. It will form part of an FAO Geographical Information System (GIS), linking forty internal data bases, for which a feasibility study is in progress. A computer program for using the revised legend may also be produced in the future. Some examples of the changes which are being introduced may be of interest. All shallow soils are being grouped under Leptosols (to include the former Lithosols, Rankers and Rendzinas). The sequence of soils with Argillic horizons is being rationalised. Some additional soil groupings are proposed, for example the Plinthosols (with hydromorphy and plinthite) and Anthrosols (man-made soils).

The soil climate is being eliminated as a criterion for classification, so the Yermosols and Xerosols will disappear. The boundary of the deserts will be indicated by a line showing the zero days length of growing period and another soil grouping will be added, the Calcisols, for soils with accumulation of calcium carbonate, calcium sulphate or both.
The third level sub-units of soils cover two different cases: intergrades between soil units and more closely specified soil conditions. Examples of these are gleyi-Eutric Fluvisols, sali-Eutric Fluvisols and necessarily orthi-Eutric Fluvisols for the soils in the central concept of the unit. Apart from adding the third level the format of the revision will not change fundamentally from the original. The legend remains a practical grouping of soil units for ease of reference and representation on a map. FAO is not trying to do the same thing as the proposed international soil and land resources database.

3.3.3 FAO Activities in Electronic Data Processing.

It is worth recording here that more than a decade ago FAO began to develop a soil databank, based on a punched card system. The coding system is described in the draft document (FAO, 1976). This endeavour was abandoned because it appeared that other agencies were more advanced, and the FAO priorities changed in emphasis.
The subject of another FAO publication is "Electronic Data Processing for Land and Water Data" (FAO, 1981). Volume I describes the principles and concepts for computerised data base design and operation. Volume II gives specific examples for water data, including water data characteristics, coding forms, storage, retrieval and manipulation of data and some examples. Volume III would have been on Soil Data but it was decided to terminate the project. In other words, FAO is not developing a soil databank.

3.3.4 Rationale for Updating the World Soil Map.

An important reason for updating the World Soil Map is the increasing use of the Map. It is being used as a basis for the study of soil degradation and desertification. We also are using the digitised map with a program to convert it to the Fertility Capability Classification (FCC) developed by North Carolina State University to provide rapid printouts of soil condition modifiers such as phosphate fixation, potassium deficiency, and other soil factors affecting crop performance.

A major use was for the agro-ecological zones study for assessing the potential productivity of soils for specific crops, followed by another study of the potential population supporting capacities of the agro-ecological zones (FAO, 1978, 1984). The method, consisted of using the

World Soil Map for soil data overlaid by a specially developed agro-climatic classification to produce agro-ecological zones. These were matched with crop requiremets for climate and soil conditions to assess potential land productivity and subsequently the potential population supporting capacities.

The climatic classification which was developed is based on broad temperature regimes and lengths of growing period (as shown on the FAO 1:25M map of the Land Resources Base). This provides an excellent framework, which has proved very useful for predicting crop productivity. It will be used on the updated World Soil Map and should result in a product of much broader usage. It can be modified and added to, as has been done by FAO for country studies in which patterns of climate have been added, as for Mozambique (Kassam et al, 1982).

3.3.5 Importance of Soils Data for Individual Country Needs.

Experience has shown that each country has different needs and different physical and socio-economic conditions. For example, Bangladesh needs good soils data for better resource management under conditions of flooding. The Yemen Arab Republic can use soils data in their planning for more efficient water harvesting in dry areas. Management of resources in the Philippines must take into account the incidence of hurricanes.
It may be concluded that, at a level of detail equivalent to 1:1M scale mapping, land resource mapping is essentially to be done by countries. Its value for agro-technology transfer will be enhanced by systematic co-ordination of methods at the international level, and the proposed international soil and land resources database could play an important role.

3.3.6 References.

FAO 1976: Guidelines for the coding of soil data (First Draft).

FAO 1978: Assessment of potential land productivity by agro-ecological zones. World Soil Resources Report 48.

FAO 1981: Electronic data processing systems for land and water data. Vol. I General Principles. Vol. II, Water Data. FAO, Rome.

FAO 1984: Land, food and people. FAO, Rome.

FAO 1986: FAO-Unesco Soil Map of the World. Revised Legend. Draft.

Kassam, A.H. et al, 1982: Assessment of Land Resources for rainfed crop production in Mozambique. FAO Project MOZ/75/011 Field Document No. 34.

3.4 UNEP's GLOBAL RESOURCE INFORMATION DATABASE

by Ian K. Crain
Global Environmental Monitoring System
United Nations Environment Programme

3.4.1 GRID, a Global Environmental Data Management Concept.

GRID, the Global Resource Information Database, is a new service for managing environmental data, established by the United Nations Environment Programe (UNEP) as an international co-operative effort involving the specialized agencies of the United Nations (FAO, WHO, WMO, the World Bank), intergovernmental organizations (ILCA, IUCN, ISSS) and national governments. GRID is managed by the Global Environmental Monitoring System (GEMS) Programme Activity Centre (PAC), a part of UNEP.

GRID has four main functions: to bring together key data sets from a number of environmental databanks; to integrate these data sets; to establish an analytical basis which will make it possible to issue a series of assessment statements on key environmental issues; and to make environmental data available to both national and international decision-makers anywhere in the world.

Environmental data are traditionally available only within specialized sectors: these include physical data on such things as climate, geology, geomorphology, hydrology and soils; biological data on vegetation, and animal and human populations; and socio-economic data on human demography, land use and infrastructure. The environment, however, is a composite of such factors. Most of the problems which arise involve interactions among them. Data analysis within GRID uses the latest computer technology to make it possible to take environmental data from a number of sources (such as tables, maps, aerial photographs and satellites), geo-referenced, overlaid and statistically analysed to provide simple inventories, to monitor trends, or to model the functioning or disfunctioning of the environment.

The two-year pilot phase of GRID, which started in April 1985, has been made possible by generous in-kind donations from a number of national agencies and private companies: the Canton of Geneva (Switzerland), the Environmental Systems Research Institute (ESRI, USA), the National Aeronautical and Space Administration (NASA, USA), the Prime Computer Corporation (USA), the Swiss

Confederation, and the University of Geneva. The donations include hardware (super-mini computers with suitable digitizing, graphics and image-analysing peripherals), software (ESRI's ARC/Info and NASA's ELAS), accomodation and running costs, seconded personnel, data processing, training fellowships and bursaries. Other governments and agencies are currently considering participation as in-kind donors. Additional running costs are being met by the Environment Fund of UNEP.

3.4.2 A Distributed System.

GRID will be a distributed system. In the long term it will be accessible via telecommunications networks using low-cost Earth terminals, by participating experts visiting a GRID facility, or through micro-computers in remote locations which have access to selected parts of the software and data. Initially, the system will have two nodes: GRID-Control and GRID-Processor. The GRID-Control facility is at UNEP's headquarters in Nairobi, Kenya. This unit is responsible for overall policy and management, for editing and quality control of data, for demonstration and display, and training and anlysis of limited (for example, regional) data sets.

The GRID-Processor facility located in Geneva, Switzerland, is responsible for main data input and file handling, storage of global data sets, and training.

Regional nodes are envisaged as institutions which already have or are planning to have a GIS capability soon. Such institutions, whilst not compromising their primarily national allegience, will serve as de facto regional centres at which training and the improvement of regional data sets will occur during the early years of GRID development. Institutions have already been identified in Canada (the Canada Land Data Systems of Environment Canada), Kenya (KREMU, the Kenya Rangeland Ecological Monitoring Unit), Norway (the Norwegian Computing Centre) and Peru (ONERN, Oficina Nacional de Evaluacion de Recursos Naturales). The state of Western Australia will identify one soon. The GRID-Control facility at UNEP's headquarters, apart from providing management policy guidance, will also serve as the Africa regional node.

Thematic or sectoral nodes exist within UN specialized agencies which manage their own special data sets (see below), within intergovernmental organizations, such as IUCN and the International Livestock Centre for Africa (ILCA), or, in certain cases, national bodies which manage particular global or regional data sets (such as GEMS/Water at the Canada Centre for Inland Waters, or the World Glacier Monitoring Service at the Zürich Federal Polytechnic) as part of co-operative programmes.

National nodes will develop in appropriate national institutions. The institutions will participate in specific GRID pilot phase projects. As GRID develops and costs of hardware diminish, it is expected that many countries will develop GRID nodes, linked via satellite telecommunications. The GRID pilot project has provision for testing data exchange through commercial PTT links as well as via Intelsat.

There is a need to demonstrate during the two year pilot project the scope, power and usefulness of GRID in dealing with global, regional and national questions. Therefore, a balance of activities through the three scales has to be kept.

Work at the global level will concentrate on obtaining and improving a few key databases which will be of use, for example, in preliminary analyses of global desertification or deforestation.

There already exists a digital soils database at 1:5M. A database for global land-water boundaries has just been obtained by GRID-Processor in Geneva, and GEMS/PAC has recently made contact with a source for a digital database containing climate data from 5000 WMO stations reporting to the regional climate data centres (Melbourne, Moscow, Washington DC). Negotiations are underway to obtain NOAA global climate anomaly data and to activate the global soil data previously digitized in a joint FAO/UNEP project.

Work at the regional scale is to concentrate initially on Africa. A list of priority countries for national case studies is being compiled.

GRID intends to rely on recognized international bodies such as ISSS to assist in locating the best data sources and in identifying limitations in accuracy and utility of all data entered into the systems.

3.4.3 Current Status of GRID.

Progress on developing and implementing the GRID facilities has been very rapid in the last few months. With the exception of some minor peripheral devices all hardware has been delivered and installed in both Geneva and Nairobi. This primarily consists of a Perkin-Elmer mini-computer and Prime microcomputer at each site with associated digitizing tables, plotters and interactive graphics work stations. The Nairobi configuration is less powerful than its counterpart in Geneva because of consideration of maintenance problems and environmental conditions in Africa. These facilities are to use the "ELAS" software of NASA on the Perkin-Elmer computers to perform satellite image analysis and raster-based GIS manipulation along with the ARC/Info package on the Prime. To date all this software is installed and operational with the exception of ARC/Info in Geneva, scheduled for mid-April.

The Geneva GRID-Processor facility has begun to accumulate available digital global data sets, and a wish-list of priority global scale data sets has been drawn up. Negotiations are currently underway with a number of national governents for potential national scale case studies. High priorities are Kenya, Senegal, Peru, Costa Rica, Thailand and Indonesia.

3.4.4 ISSS World Soils and Terrain Digital Database.

With respect to the proposed 1:1,000,000 world soils digital database, it must be noted that this is an extremely ambitious and laudable undertaking. The existence of good soils and terrain data on a consistent basis for the globe is of fundamental importance to any global or continental scale environmental assessment or resource model and is therefore of keen interest to UNEP and the GRID project. GRID therefore would be glad to assist in a pilot project of one or two map sheets to be implemented at either of the GRID facilities in order to test out methodologies, data structures, etc. In that regard, support is given to the concept put forward in the chairman's opening remarks to the effect that one should develop a geographic information system of soils and terrain data, rather than a new "World Soil Map". Then, using GIS facilities, various classification systems and models could be applied to the soils data to produce an infinite number of soil interpretive maps. The data set could be used in conjunction with other data sets for environmental modelling.

It is hoped that further discussions with ISSS and ISRIC will lead to a fruitful pilot project on the GRID system.

3.5 NATURAL RESOURCES DATABASE STRUCTURES

by Peter A. Burrough
Department of Physical Geography
University of Utrecht

3.5.1 The Meaning of 'Structure' in Databases.

The most important aspect of building a database of natural resources is to decide on the ways in which the data to be collected can be organized into coherent units that carry the information required of them. The kind of organization necessary may not be the same throughout the whole database. For example, the field scientist will organize his data into 'phenomenological' units - mountains, terraces, solifluction layers, textural horizons, catchment areas, geotopes, and so on, that he can recognize directly as physical entities having a clear role in the landscape. The representation of these physical entities in a cartographic database will take a different form. Very often these 'phenomenological' units will be represented by graphical constructions such as points, lines or areas and appropriate symbolisation and legend description on a paper map. A computer representation of the same data may be completely different. Although the original phenomenological units should still be reachable through the computer system, the ways in which the data are stored and organized in the computer will have more to do with the constraints of space and efficiency and the requirements for high-speed processing and the ability to handle large amounts of data, than the apparently 'natural' structures recognised by the user. Ideally, the computer database structures should be transparent to the user - that is to say, they should allow a user to pursue his own well-tried methods of data organization without being a hindrance to normal work methods.

The basic 'phenomenological' unit of a natural resource database usually consists of two kinds of data. These are a) data describing the location and spatial extent of the unit, and b) data describing the attributes or properties of that unit. In many situations, in most soil classifications, for example, only attribute data are recorded. In cartographic databases, the accent is more on the spatial information than on the attributes, which often are only present in summary form.

3.5.2 The Organization of Database Units - Hierarchical Structures.

The idea of a database is not just to record all the varieties of a certain class of phenomenon that might be encountered, but rather to organize knowledge so that coherent patterns of understanding can be derived that transcend the basic data units. That is the whole point of classification. Coherent patterns may exist at many different aggregation levels, and it is probably fair to say that the choice of a given level of aggregation reflects human capabilities for perceiving complexity. Experience tells us that the number of differences that the human mind can cope with at any one time is roughly between 7 and 10; if the number of differences becomes greater, then many persons will want to regroup the data at a new level of aggregation in order to be able to keep a clear overview. For example, many soil classifications recognize 7 to 10 major levels - Soil Taxonomy has ten major taxonomic classes, the Handbook of Australian Soils (Stace et al., 1968) has seven major classes. Each of these classes is split at the next level of aggregation into between 4 and 9 classes, which are in turn split.

This hierarchical approach to data organization has many advantages. It allows complex data to be viewed at many aggregation levels, with at each level a comparable degree of variety. It has a 'natural' quality, in the sense that hierarchical structures have long been accepted in the organization of both primitive and advanced societies. Different levels can be separated on the basis of a single, critical attribute, or 'discriminating criterion'. Any set of discriminating criteria forms a 'key' that defines a unique path through the hierarchy so that each division at each level of aggregation can be quickly located. Botanical keys, based on critical features of plants, are ideal examples of how an individual plant can quickly be located and identified.

Unfortunately, hierarchical data structures also have several major disadvantages. The first is the choice and ordering of the discriminating criteria used to set up the keys. Put another way, the choice of a discriminating criterion at a given level of the hierarchy has very serious implications for the interpretation of the aggregation level that is being recognized. Should kinds of soil be split into groups at the highest level according to the parent material on which they developed, according to the climatic regime in which they are found, or according to the dominant processes occurring within them? Each alternative will have its advantages and disadvantages; each will have its proponents and opponents. In the end, it is very often either a matter of compromise, or of intellectual or physical dominance, which set of discriminating criteria should be used to order the hierarchy. Therefore, the organization of knowledge at any aggregation level may more accurately reflect the opinions of a dominant peer group than the 'natural' divisions of the real world.

The second problem with hierarchical classificaitons is that data can only be easily retrieved if they can be directly referenced via the key. For example, a database of plants organized according to the rules of plant taxonomy will not be of much use if one wishes to know which parts of the world certain plants come from. Geographical location, not being a part of plant taxonomy, is an associated attribute that is unreachable in such a hierarchical system. But very often in natural resources databases, we need to be able to retrieve information about all attributes, not just those used to define the hierarchy. The exact nature of the queries cannot be anticipated in advance. A hierarchical system that could provide pre-set keys for all possible queries is practically quite out of the question.

A third problem with hierarchical classifications is the problem of defining class boundaries so that new individuals can be allotted to an existing class. There is usually not too much difficulty in getting scientists to agree on the central concepts of a class - most soil scientists understand intuitively the concepts of vertisols, podzols or gleysols. The main problem is that for many types of natural resource, and soil in particular, the hierarchically defined classes are multivariate, and overlap each other. Class boundaries are not necessarily orthogonal to the direction of the axis of the discriminating criterion and simple, Boolean logic of the IF..... THEN..... type does not suffice. This problem has been clearly demonstrated by, among others, Webster and Burrough, 1974 and Burrough and Webster, 1976. It is clearly recognized by the exponents of remote sensing (American Society of Photogrammetry, 1983) as a major problem when classifying remotely sensed imagery (Figure 3.5.1).

A fourth problem with hierarchical structures is that it is possible that two almost similar individuals will be separated at one level in the hierarchy because they happen to have slightly different values of a critical attribute that fall on both sides of the value chosen as the discriminating criterion. The reasons for the difference may be real, or the difference may result simply from measurement errors. Once the two individuals have been further allocated in the branches of their respective 'trees', no further cross-referencing is possible.

So, the deficiencies of the hierarchical approach can be summarized in the same terms as those used by Webster (1968) in his criticism of the USDA 7th Approximation. They are:

a) exactly defined, mutually exclusive classes are not in accord with the reality of multivariate soils variation;
b) strict Boolean logic is not appropriate for dispersed, overlapping classes, or situations in which the values of attributes cannot be determined exactly; and
c) the choice of discriminating criteria is arbitrary, and leads to keys that provide insufficient flexibility for data retrieval.

3.5.3 Alternatives: Networks and Relational Database Structures.

The requirements of a data structure are that it should organize data according to accepted modes of understanding, allowing generalization and aggregation as required, while at the same time permitting easy access to all the data present. The allocation of new individuals to the database or the modification of data already present must also be able to be done without difficulty.

There are three basic data structures that can be considered for organizing natural resource data. One is the hierarchical structure just discussed. The second is called the 'network' structure. The network structure avoids the limitations of the hierarchical system that restrict information flow to up and down the main taxonomic pathways by including cross-referencing pointers from one branch to another. Their main disadvantages are that the action of the pointers has to be fully defined, and thus known, beforehand, and that addition or deletion of data usually requires the pointer system to be rebuilt. So, network systems carry extra overheads as a price for speed.

The third alternative is called the relational database structure. In its simplest form, the relational database structure stores no pointers and has no hierarchy, Instead, the data are stored in simple records, known as tuples, containing an ordered set of attribute values that are grouped together in two-dimensional tables, known as relations. Each table or relation may be held in a separate computer file. The pointer structures in networks and the keys in hierarchical structures are replaced by data redundancy in the form of unique identification codes for labelling the records in each file. Data can be extracted from a relational database by defining a request in terms of a given query language. The database management program uses the methods of relational algebra to construct new tables containing the results required.

Relational databases have the advantage that they are very flexible and can meet the demands of all queries that can be formulated using the rules of Boolean logic and mathematical operations. They allow different kinds of data to be retrieved, searched and compared at will. Addition or removal of data is easy too, because this just involves adding or removing a record, or changing a value in a record. The major disadvantage of the relational database in its simple form is that many of the operations involve sequential searches through large files to find the right data. Sequential search, even on large, fast computers, can be very time consuming, because it requires on average $(n+1)/2$ search operations to find a required record among n alternatives. In contrast, a search to find a single individual using a hierarchical system does not have to check more items than are present in the key.

Figure 3.5.2 shows how a simple map, consisting of two linked polygons, each bounded by 4 lines of two coordinate pairs each, can be represented in a hierarchical system, a network system and a relational system. Note that the network system involves the least data redundancy (repeats of the same data) at the expense of the pointer structures, and that the relational database achieves it flexibility through the use of redundant attributes.

3.5.4 Data Structures for Graphical Representation.

In most natural resource databases, the data will have to be analysed and displayed in the form of maps. There are two main ways of recording spatial data from maps. One involves representing all spatial entities as sets of points on a grid or matrix. This method is known as the RASTER approach, and is familiar from satellite imagery and cheap, lineprinter computer maps. The raster method often means that each separate attribute must be recorded as a separate grid or 'overlay' (Figure 3.5.3), so that the raster database is in effect a kind of relational structure. Consequently, raster database structures allow great flexibility for data analysis and modelling at the expense of compactness and, until recently, cartographic elegance.

The second method of structuring graphical data is by linking the boundary lines of polygon nets as shown for the network structure in Figure 3.5.2 (c). This is known as the VECTOR method. It has the great advantage of compactness for storing spatial coordinates, which is to a certain extent offset by the need to create and update complex pointer linkages. Moreover, the data structure is conceptually very similar to that used by most cartographers and map makers, and it allows products of high cartographic elegance to be produced. Both raster and vector systems have their advantages and disadvantages for storing spatial data, and for the ease with which they permit data analysis and aggregation. The two systems can be interconverted, and can be used side by side. A thorough discussion of many of the relevant points will be found in Burrough (1986).

3.5.5 Data Structures Currently Used in Natural Resource Databases.

The alternatives discussed above, should in no way be thought of as being mutually exclusive, but rather as providing a range of opportunities for creating a suitable data structure for a natural resource database that will meet all requirements. Ideally, we need a system that preserves original data as far as possible so that the user is not constrained by any outside classification rules whereby information can be lost. The system must have a quick response, it should not be burdened by unnecessary redundancies, and it should allow the joint handling of spatial and non-spatial data in any way that the user desires.

Current 'state of the art' geographical information systems (i.e. computer systems for storing and processing spatial data) use a mixture of the data structures described above. The first stage is usually the separation of graphic (i.e. coordinate data about the locations of the phenomenologically recognized elements) data from attribute data. Just as in a relational data structure, a link will be maintained through a common code identifying a set of points on the map with a set of attribute values. Because attribute values are usually present in the form of tables, it is natural to use a relational database to handle queries involving atributes alone. These queries can be assisted by having certain data about the spatial aspects of the element in quesion (e.g. its area, perimeter or neighbours) present in the attribute files. The relational searches can be speeded up by defining keys for frequently encountered queries; these keys then function in a similar way to an index in a book. In this way, advantages of flexibility and speed can be combined.

The graphical data are usually stored in a form that occupies the least space while at the same time maintaining locational accuracy. For many applications, the vector network system is very acceptable. Spatial analysis, polygon overlay, modelling and simulation, however, are operations that are easier to program for raster data, and algorithms are available for converting from vectors to that form. There are also compact systems for storing data in raster form, known as run-length codes and quadtrees, which embody certain elements of hierarchical systems (Burrough 1986,). For some operations, it may be desirable to have the spatial data present in both forms (e.g. for clear boundary definition coded as vectors and uniform shading coded as raster). Raster data structures also make it easier to link remotely sensed data (already present in raster form) to soil data on maps and to model dynamic changes in time and space (e.g. the variation of the form of a lake or snowcap with season).

3.5.6 Retrieval Languages and Fuzzy Logic.

It was noted that the use of strict Boolean logic can lead to the separation of like individuals. Also, in some situations, it may not be possible or desirable to define classes that do not in some way overlap.

Solutions to this problem have been suggested using multivariate discriminant analysis or maximum likelihood methods (Webster and Burrough, 1974; American Society of Photogrammetry, 1983), but these are hardly applicable when dealing with qualitatively defined classes. The alternative to strict Boolean logic is called 'fuzzy logic' (Kaufman, 1975; Zadeh, 1965), which is a logic system in which the class boundaries do not have to be accurately specified, nor the rules written expressly for every situation. In fuzzy logic, central concepts remain important, but an answer of "maybe" to a query is just as legitimate as "yes" or "no". In fuzzy set theory, we define a MEMBERSHIP FUNCTION to express the degree to which an individual is a member of any given set. The membership function is a very useful device that allows one to model linguistic vagueness or the class use linguistic quantifiers that are less precise than strict, hierarchical logic allows ('most', 'some', 'a few'), but which are often very well suited to data classification and retrieval problems in resource assessment. Research on the use of fuzzy logic in resource databases is just beginning and the first 'hard-wired' fuzzy-logic electronic 'expert' chips are being developed (Scientific American, 1986). Fuzzy set logic can be used with relational database structures.

3.5.7 Discussion.

In the past, hierarchical classification was very important for reducing complex data to manageable proportions. Given the limitations of the data processing tools available, it was the only sensible way to approach a very difficult problem. The identification of central concepts was never a large problem, but the choice of discriminating criteria and their values for the definition of class boundaries for precisely circumscribing those central concepts was the greatest stumbling block. Under those circumstances, attention was diverted away from the core activity of understanding the workings of soil and soil forming processes towards monumental exercises in attempting to pigeonhole soil profiles according to arbitrarily chosen criteria that often seemed to have little relevance for soil use. The problem was compounded when different scientists used conflicting classification schemes (de Bakker, 1979), making soil correlation and information transfer between different countries (sometimes within a country!) very difficult, if not impossible.

Modern database systems offer us a way out of this impasse, providing we do not make the mistake of simply automating those activities that we used to do before by hand. Given the current state of computer science, the current price/performance figures for computer hardware and software, and the sheer demand for the flexible use of soil information to solve many disparate problems in both the developing and the developed world, it behooves us as soil scientists to equip ourselves with the most powerful and modern tools available. In order to keep up with the problems of the times, we must adopt the work methods and the tools of the age.

3.5.8 References.

American Society of Photogrammetry, 1983. Manual of Remote Sensing, 2nd Edition. Falls Church, Va.

Bakker, H. de, 1979. Major soils and soil regions in The Netherlands. Junk, The Hague/PUDOC, Wageningen. 203pp.

Burrough, P.A., 1986. Principles of geographical information systems for land resources assessment. Oxford University Press.

Burrough, P.A. and Webster, R., 1976. Improving a reconnaissance classification by multivariate methods. J. Soil Science 27: 554-71.

Kaufman, A., 1975. An introduction to the theory of fuzzy subsets. Vol. 1. Academic Press, New York.

Scientific American 1986. Science and the citizen. March 1986, 254:50-1.

Stace, H.C.T., Hubble, G.D., Brewer, R., Northcote, K.H., Sleeman, J.R., Mulcahy, M.J. and Hallsworth, E.G., 1968. A handbook of Australian Soils. Rellim, Glenside, S.A.

Webster, R., 1968. Fundamental objections to the 7th Approximation. J. Soil Science 19: 354-66.

Zadeh, L.A., 1965. Fuzzy sets. Information and Control, 8: 338-353.

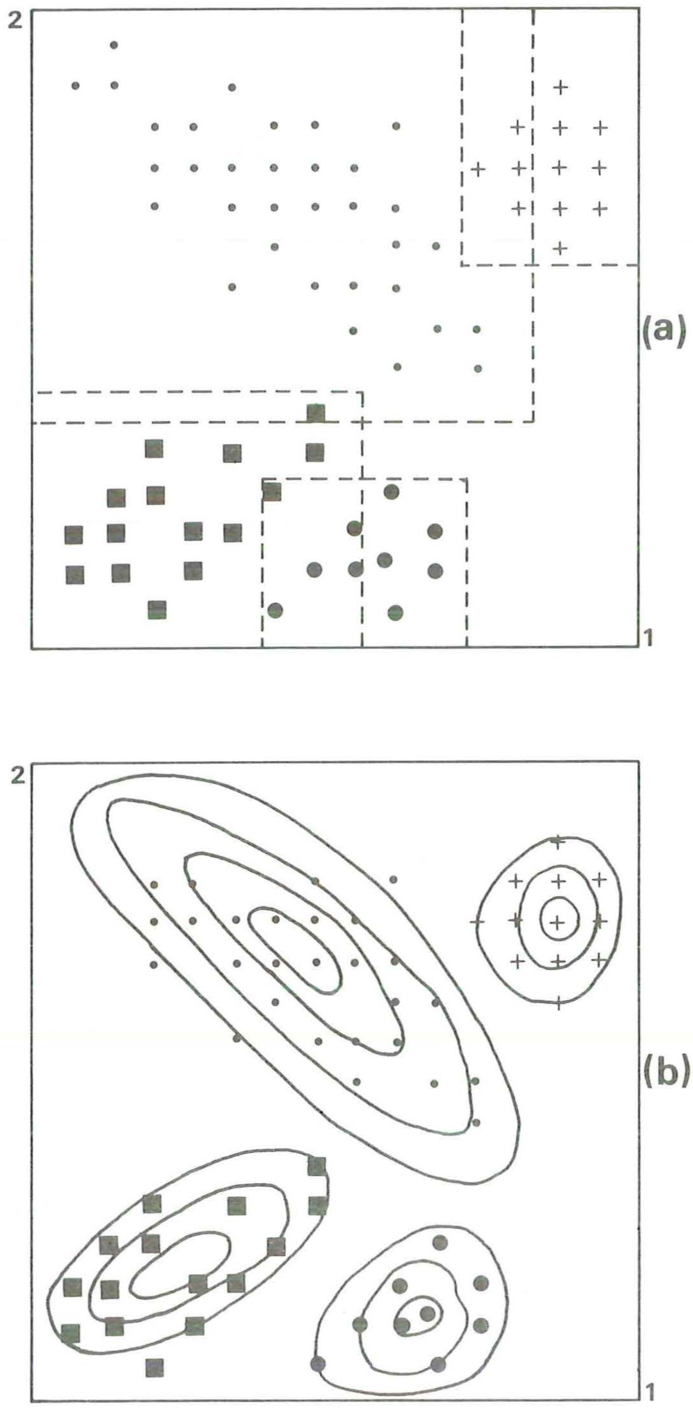
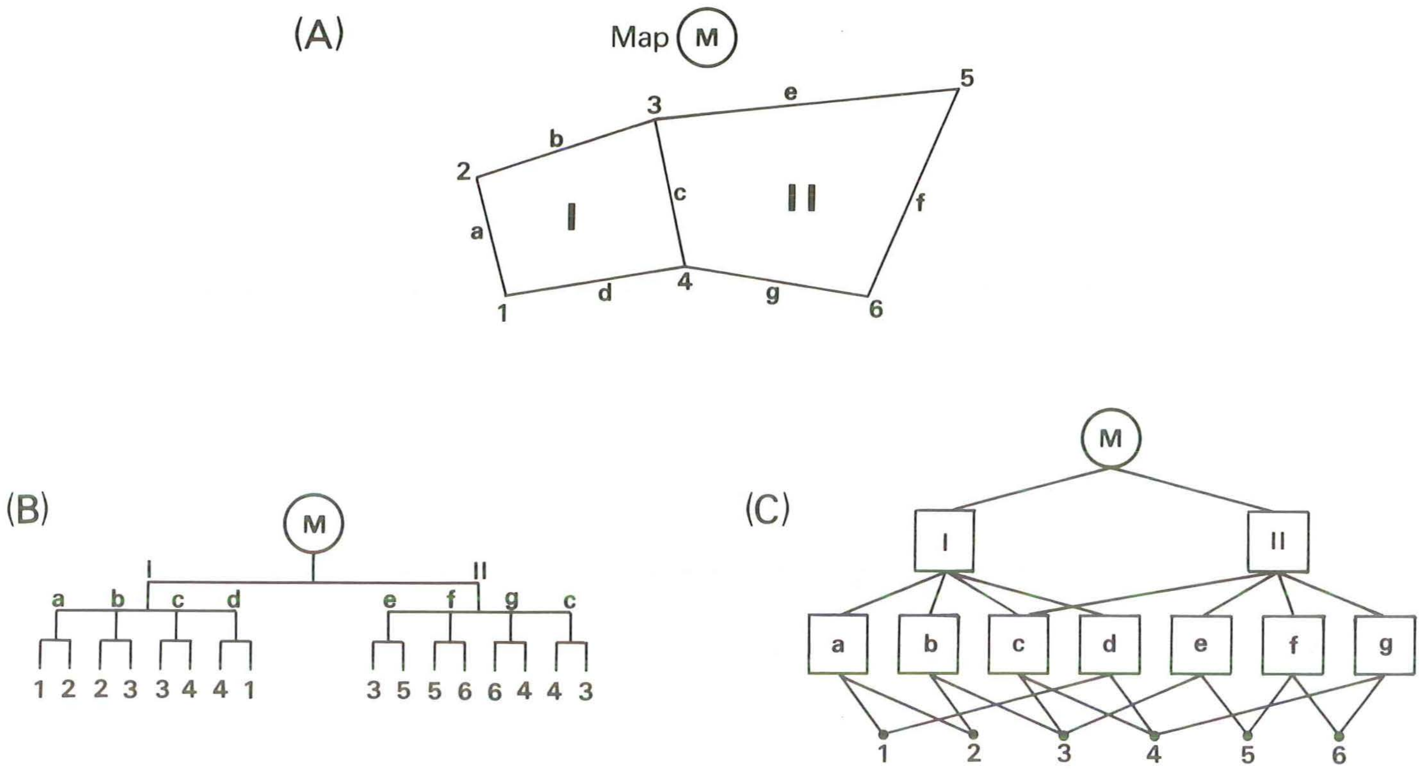


Figure 3.5.1. (a) Class overlap can be a serious problem when attempting to define class boundaries in terms of critical values of single discriminating criteria (axes 1 and 2)

(b) A more realistic approach is to work with levels of membership probability (contour lines). Then the classes are seen not to overlap. Allocation of new members to the classes is also made simpler.



(D)

Map

M	I	II

Polygons

I	a	b	c	d
II	c	e	f	g

Lines

I	a	1	2
I	b	2	3
I	c	3	4
I	d	4	1
II	e	3	5
II	f	5	6
II	g	6	4
II	c	4	3

Figure 3.5.2. Several methods to express a simple map structure.
(a) A simple map comprising 2 polygons bounded by seven lines that are defined by six coordinate pairs.
(b) The same map, expressed in terms of a hierarchical data structure.
(c) Idem, but expressed in terms of a network structure. Note that the limited redundancy of the hierarchical scheme has been replaced by a set of pointers.
(d) Idem, but expressed as a set of simple relations. The data redundancy (repeating of key data) serves to link the tables.
Note that version (c) is most compact and quickest in operation, but that this is at the cost of building and updating the pointers should the map be edited. In contrast, the relational structure is least compact, but is the most flexible.

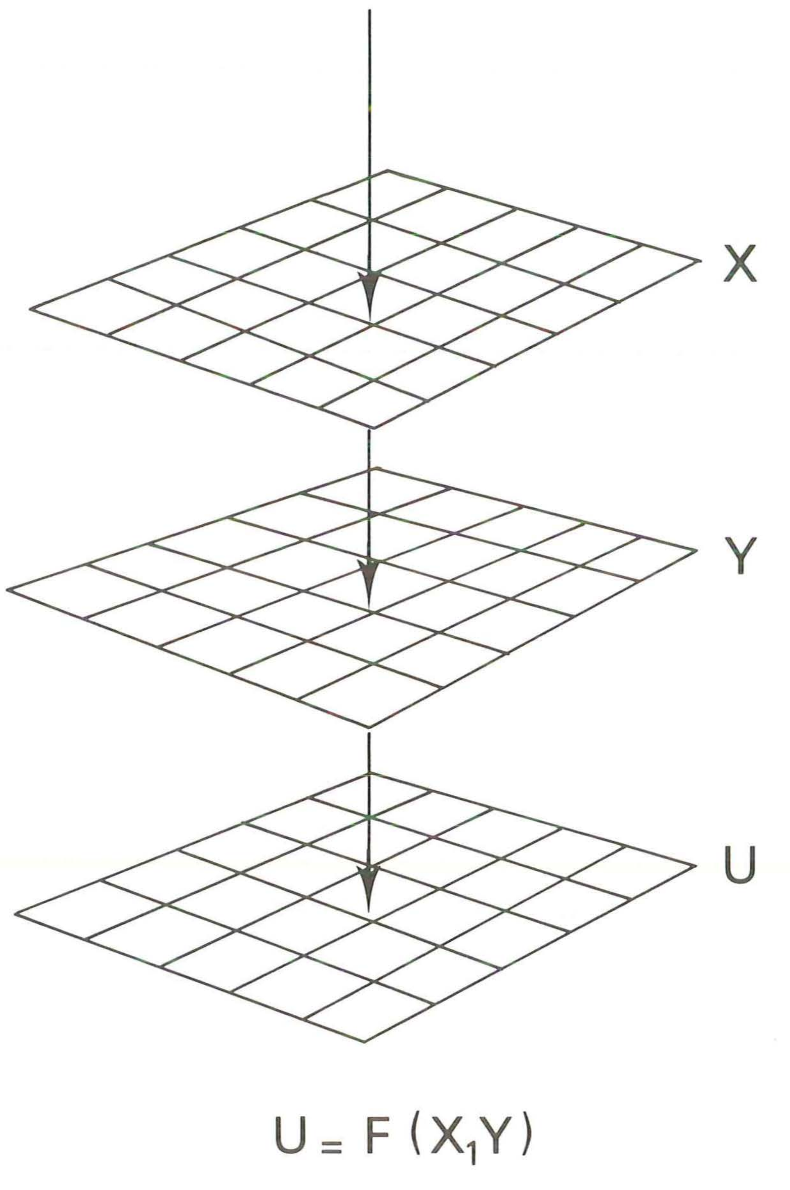


Figure 3.5.3. Spatial data are often structured by frids or rasters. Each attribute is represented by a table or grid that covers the whole mapped area. Data can be manipulated by repeating the same operation for each grid cell over a chosen set of layers.

4

TECHNICAL CONSIDERATIONS FOR DEVELOPMENT AND IMPLEMENTATION OF WORLD SOIL & TERRAIN DIGITAL DATABASE

4.1 LANDFORM GROUPING

Roel F. van de Weg
Netherlands Soil Survey Institute (STIBOKA)

4.1.1 Landforms and Spatial Distribution of Soils.

The spatial distribution of soils is related to landforms at all scales. Soil surveyors make extensive use of landform and relief as a means of recognizing soil patterns, in particular in interpretation of satellite imagery and aerial photographs which are essential tools in soil surveys. Landforms should, however, also play a major role in the presentation of mapping units, as this facilitates the map user's insight into the spatial variation of the soil and landscape concerned.
By the systematic use of remote sensing data, the delimitation of the mapping units is done on a physiographic basis using in particular the characteristics of landforms. It is therefore perfectly logical that these characteristics are reflected in the set-up of the maps and the legend, including codes and database. By not using genetic geomorphological names but rather landform names (with a short description), it is felt that the map pattern is easier to understand for the map user, in particular the non-soil specialist. The map user must be able, by using the data, to grasp the relationship of landform / parent material / soils. It is therefore preferable that the first entry (main headings) of the legend should be on patterns of landforms.

4.1.2 Grouping of Landforms.

Landforms (landform types) can be grouped and described in many ways, as there is no one system that is universally accepted. However, several regional schemes for grouping of landform do exist.
The "landform classification framework" should be developed with the following requirements in mind:
- to provide compatibility and consistency with existing landscape classification systems;
- to be capable of functioning in readily accessible, computer-operated information systems; and
- to be based on measurable or readily inferable features of the land.

The landscape data file, being part of the database, calls for the setting up of a uniform, simple classification of landforms and landscape attributes, which can be used on a global scale taking into account the scale of the map (1:1 million). For the proposals of Working Group III of the Workshop, refer to section 4.1.5.

4.1.3 Prerequisites for Landform Classification.

It is proposed that the following prerequisites be used in the landform classification for a World Soils & Terrain Digital Database:

(a) landform types, i.e. landscape attributes, should be simple to allow them to be derived from existing soil maps and soil descriptions and/or to be derived from satellite imagery;
(b) the classification should be open-ended;
(c) parametric elements should be included and be defined (refer to 4.1.5);
(d) the classification should take into account GIS operations (legends can be rearranged according to attributes);
(e) landform classification preferably should be in descriptive terms in a systematic way, mainly based on form and material, with little consideration of genesis and avoiding complicated geomorphological terms; and
(f) the system should avoid overlapping (parametric) classes by landscape attributes, in view of the GIS data file.

4.1.4 Regional Landform Classification Systems.

Several regional landform classification systems have been selected for presentation here to describe different applications of landform data.

(a) Canada:
The landform classification system is categorical in nature but does not involve any hierarchy. It is intended to be a field classification system rather than a theoretical taxonomic one. Landforms in this system are considered to include materials and form. The system attempts to map comprehensively all landforms rather than to stress prominent features.
Ref.: Landform classification, Ch. 17 in "Project plan: Generalized Soil Landscape Mapping" (Canada, 1985), scale 1:1 million.

(b) Australia:
The system is developed as a method to describe landforms in the field. Two levels are recognized: landform elements are described by the characteristics such as slope, morphological type, etc.; landform patterns are described by relief, geomorphological agent, and component landform elements.
Ref.: Field description of landforms in "Australian Soil and Land Survey Field Handbook", 1984.

(c) USA:
Landform is one of the three constituents within a framework for an ecological land classification system (in addition to soils and natural vegetation). In the absence of a detailed landform classification hierarchy a glossary is presented.
Ref.: An ecological land classification framework for the United States, USDA, 1984.

(d) Indonesia:
Ref.: Catalogue of landforms for Indonesia, 1977.
Ref. Landform classification as used in GIS Sumatra project (ITC, paper A.M.J. Meijerink). The main classification elements are each indicated by codes.
+ origin of landform
+ specific origin-functionality, including short description
+ lithology, materials
+ internal relief (relief amplitude)
+ valley or drainage density

(e) Kenya:
Methodology to visualize the relationship landform - geology (lithology) - soils. Landform classification is pragmatic and descriptive, taking

into account differences of physiography, altitude, slope class, relief intensity, drainage, etc.
Ref.: Exploratory soil map of Kenya, 1982.

4.1.5 Data Input Set for Landscape Data File.

A minimum data set for landscape, with attribute suggestions based largely on Canadian experience, has been proposed for entry into a World Soils & Terrain Digital Database. Attributes within delineated landscape units would be based on areal coverage, i.e. dominant, subdominant, inclusions. A tentative list of landscape attributes for a minimum data set includes:
(a) elevation (mean and range);
(b) Surface form;
N.B. Guidelines of definitions of "landform" should be drawn up; a manual should be prepared describing by example (word and photographs) surface forms.
(c) origin and kind of material;
(d) slope gradient;
(e) slope length;
(f) land use, vegetative cover and degraded lands;
(g) stoniness (at the surface);
(h) flooding;
(i) surface water and drainage;
(j) groundwater; and
(k) permafrost distribution.

4.2 LES MATERIAUX ORIGINELS ET LEUR CODIFICATION

Pierrick Brabant
Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM)

4.2.1 Règles pour la préparation d'une liste des matériaux originels.

Le matériau originel est un des 3 paramètres principaux qui ont été choisis pour définir le contenu des polygones des cartes à 1:1 million, les 2 autres paramètres étant la forme du paysage et la nature du sol. Il est donc nécessaire d'établir une liste des matériaux originels qui sera ensuite codifiée avant d'être numérisée comme les autres données de base.

Pour préparer cette liste, nous proposons de suivre les 3 règles suivantes:
1. Il semble préférable d'établir une liste des roches-mères plutôt que celle des matériaux originels afin de simplifier la procédure de codification.
   La roche-mère est définie comme le matériau, au sens géologique du terme, d'où dérive le sol, et le matériau originel comme le produit d'altération de cette roche. En effet la roche-mère est plus facile à déterminer sur le terrain que la nature du matériau originel qui nécessite parfois des examens de laboratoire. D'autre part une roche-mère de même nature peut fournir des matériaux d'altération différents sous le même climat et dans le même site selon les conditions stationnelles. Un granite, par exemple, peut s'altérer en un matériau à kaolinite sur le versant et en un matériau à argiles gonflantes vers le bas du versant.

2. La liste doit regrouper les roches par catégories de manière la plus simple possible. Elle ne doit pas être une simple énumération des roches, reprise dans un manuel de géologie. Ce regroupement s'effectue, d'une part, d'après les propriétés des roches qui déterminent réellement la différenciation des sols et d'autre part d'après les observations réalisées effectivement sur le terrain qui ont permis d'identifier ces propriétés. Il faut considérer aussi le mode de gisement: roche à diaclases, en dalles compactes, à pendage vertical, à strates horizontales etc... En effet, le mode de gisement a une action déterminante sur les flux hydriques, sur la vitesse d'altération et en conséquence sur l'épaisseur du sol.
3. Cette liste doit être établie en prévision d'une procédure de numérisation qui inclue un grand nombre d'autres variables.
Or les 3 paramètres principaux, la roche-mére, la forme du paysage et le sol ne sont pas des variables indépendantes. Il existe entre eux des niveaux de corrélation plus ou moins élevés dont il est souhaitable de tenir compte durant la mise au point de la procédure de codification. Par exemple, une argile sableuse récente est associée à un modelé de plaine et à des fluvisols. Un sable éolien ancien est associé à un modelé dunaire et à des luvisols. Cette 3ème règle se rapporte donc à un problème technique qu'il est possible de régler par une collaboration entre des pédologues et des informaticiens.

4.2.2 Application à des zones tropicales.

L'application de ces 3 règles permet de dresser une liste des roches-mères pour les zones tropicales (cf tableau 4.2.1). Il faut considérer cette liste comme une première proposition, établie d'après les travaux de l'ORSTOM en Afrique, en Amérique du Sud et en Asie du Sud-Est. Voici quelques brefs commentaires sur le tableau où sont énumérées une trentaine de catégories de roches-mères.

A un premier niveau, nous distinguons les roches consolidées des roches non consolidées. Les roches consolidées correspondent généralement à un modelé de glacis d'érosion, de plateau ou de montagne, avec des sols souvent anciens et bien différenciés. Les roches non consolidées constituent plutôt un modelé de plaine avec des sols récents peu différenciés.

4.2.2.1 Roches Consolidées.

Nous distinguons 6 catégories principales, subdivisées ensuite en sous-catégories d'après la composition pétrographique, la texture ou l'âge de la roche. Chacune d'entre elles peut être corrélée à un type de sol et souvent à une forme de paysage dans les principales zones écologiques: équatoriale humide, tropicale sèche et aride.
Prenons l'exemple des roches cristallines:

- Les roches quartzeuses à texture grossière portent souvent des Luvisols Albiques en zone tropicale sèche, des Ferralsols Xanthiques, des Acrisols et des Podzols en zone équatoriale humide.
- Les mêmes roches, à texture moyenne ou fine, portent des Luvisols Chromiques, des Planosols et des Vertisols en région tropicale sèche; ce sont des Ferrasols Orthiques en région équatoriale humide.
- On distingue encore celles qui sont riches ou pauvres en minéraux ferro-magnésiens. Cette distinction n'est pas toujours perçue par des examens morphologiques et analytiques ou elle n'apparaît pas au niveau des unités taxonomiques des classifications. Mais cette distinction est importante du point de vue agronomique dans les régions équatoriales très humides. En effet, les sols dérivés de roches à nombreux minéraux ferro-magnésiens ont un potentiel agronomique plus élevé et ils se régénèrent plus rapidement sous l'effet de la jachère.

- Les roches métamorphiques à minéraux micacés alumineux résistent à l'altération sous ces climats tropicaux. Les sols qui en dérivent sont peu épais, riches en limons, battants et sensibles à l'érosion dans un modelé accidenté.

La limite à établir entre l'âge des roches anciennes et récentes devra être précisée en collaboration avec des spécialistes; cela concerne les roches volcaniques et les roches calcaires. Les différents modes de gisement seront aussi à définir après consultation des géologues puis à codifier. La 6ème catégorie (notée "autres") est réservée à des roches diverses qui possèdent des propriétés particulières et qui n'occupent souvent que de faibles superficies. Par exemple, les roches ultrabasiques ou les roches nickelifères.

4.2.2.2 Roches Non Consolidées.

Elles sont subdivisées d'après l'âge des dépôts et d'après la granulométrie, limitée à 3 classes principales: sableuse, argileuse et une classe intermédiaire.

- L'âge des dépôts: on constate que les dépôts d'un âge supérieur à 3.000 ans BP ont déjà subi des transformations importantes dues à la pédogénèse. Au-delà de 10.000 ans BP les transformations sont telles que les sols qui en dérivent sont homologues des sols formés sur le socle ancien situé dans la région.
  Ainsi les dépôts de terrasses fluviatiles d'un âge de 8.000 à 10.000 ans BP portent des Luvisols et des Planosols tandis que les dépôts plus récents du lit majeur (de 1.000 à 2.000 ans BP) portent des Fluvisols et des Vertisols.
- Le soubassement des dépôts: une distinction est faite parmi les sables éoliens anciens en fonction de la nature acide ou basique du soubassement. On constate en effet que le potentiel agronomique des sols dérivés de sables éoliens sur roche basique est plus élevée que sur roche acide, bien que la morphologie et la dénomination taxonomique soient les mêmes.
- La 4ème catégorie (notée "autres") est réservée encore à des roches diverses, ayant des propriétés particulières et couvrant de faibles superficies, comme les diatomites, les cendres volcaniques, les sables coralliens etc...

4.2.3 Conclusion.

Cette proposition concerne surtout les roches-mères des sols dans les régions tropicales. Il conviendrait de l'examiner et de l'aménager au cours des réunions qu'il est prévu d'organiser pour des groupes restreints dans le cadre de ce projet.
Cet aménagement pourrait s'effectuer:

- en y ajoutant les roches des zones tempérées et froides (dépôts de moraines, loess etc...), les matériaux d'origine anthropiques,
- en procédant à des regroupements ou à des subdivisions de certaines catégories si cela est nécessaire,
- en précisant quelques définitions: sur l'âge des roches, sur la distinction entre la roche-mère et le matériau originel.

La liste définitive serait ensuite à comparer avec la liste des formes du paysage et avec celle des sols en collaboration étroite avec les informaticiens. C'est seulement après l'examen comparé de ces données et en accord avec les informaticiens qu'il sera possible de procéder à la codification de la liste des roches-mères.

4.2.4 Parent material grouping and coding (Summary)

It is essential to establish a list of parent materials keeping in mind the following three rules. Firstly we suggest to make a list of parent rocks - defined as material from which the soil derives in a geological sense - rather than a list of parent material being the weathered rock material. Secondly this list should not be a simple enumeration of rocks taken from a geological manual, but should be made according to those rock characteristics that lead to soil differentiation. They should be recognized in the field and the stratification of rocks should be taken into account. Thirdly this list should be prepared in anticipation of a numerical coding system, including a great number of other variables on landform and soils, which have strong correlations with parent rock variables.

These rules were applied in a first proposal for a grouping of parent rock for the tropical regions (see table 4.2.1). Parent rock is at the highest level grouped into consolidated rock and non-consolidated rock. Six main categories are recognized in the consolidated rock group: crystalline rocks; effusive rocks; sandstone; schists and shales; limestone; "other rocks". These categories are then subdivided according to petrographic composition, texture or age of the landform in various agro-ecological zones. Age of rock material and type of stratificaion should be defined in consultation with geologists. The non-consolidated rocks are grouped in three textural classes: sand; clay; and an intermediate group. These categories are then subdivided in ancient and recent deposits. The sands and the intermediate textural classes are further characterized on the mode of sedimentation alluvial/colluvial or eolian. With regard to the eolian group the nature of the underlying rock (acid or basic) should be characterized because of its agronomic potential.

Further development of this parent rock grouping should include parent rock of the temperate zone. Better definition of the rock age and the difference between parent rock and parent material is needed. The final categorization of parent rock should then be compared with groupings of landforms and soils in direct collaboration with information scientists in order to develop a proper coding system.

Tableau 4.2.1 Liste provisoire des roches-mères pour les zones tropicales (Tentative grouping of parent rocks for the tropical regions)

I ROCHES CONSOLIDEES

ROCHES CRISTALLINES
(Crystalline rocks)
- quartzeuses
  - à texture grossière
  - à texture moyenne à fine
- feldspathiques
  - à texture grossière
  - à texture moyenne à fine
- à minéraux ferro-magnésiens abondants

ROCHES D'EPANCHEMENT
(Effusive rocks)
- anciennes
  - acides
  - basiques
- récentes
  - acides
  - basiques

GRES
(Sandstones)
- quartzeux
- feldspathiques

SCHISTES ET ARGILITES
(Schists and Shales)
- schistes à muscovite et séricite
- schistes à minéraux ferro-magnésiens
- argilites

CALCAIRES
(Limestone)
- durs
  - anciens
- tendres
  - récents

AUTRES ROCHES
(Other rocks)

II ROCHES NON CONSOLIDEES

SABLES
(Sands)
- anciens
  - alluviaux et colluviaux
  - éoliens
    * sur un soubassement de roche acide
    * sur un soubassement de roche basique ou calcaire
- récents
  - alluviaux et colluviaux
  - éoliens

ARGILES
(Clays)
- anciennes
  - alluviales
- récentes

SABLES ARGILEUS OU LIMONEUX
(Clayey or Loamy Sand)
- anciens
  - alluviaux et colluviaux
- récents

AUTRES ROCHES
(Other rocks)

4.3 SOIL PROFILE RECORDING - AN OVERVIEW

J.Martin Ragg
Soil Survey of England and Wales

4.3.1 Important considerations in recording data.

Many of the soil profile recording forms designed 10-15 years ago inherited features from the now obsolete Hollerith cards and associated data cards with 80 narrow columns. Such forms, some of which required almost exclusively numeric coding, are universally disliked by both users and data typists. Furthermore, as it is very easy to misplace a code by one column to the left or right, they are error prone.

More 'friendly' forms have been used, e.g. by INRA and CanSIS, which contain many aides memoires to help the users. The former, however, still has the disadvantage of 80 columns while the latter is grossly expanded and runs to several pages for a detailed description. The author believes that a more acceptable compromise is both feasible and desirable.

When designing a recording document, which may be a card for completion in the field or office, or an input screen on a computer, there are several stages which should be given full consideration:

(a) What are the data items? (This should be given a lot of thought).
(b) Who will enter the data? (Scientists, students, temporary staff, data typists, etc.) ful headings for data items, group associated items (e.g.
(c) Use universally agreed nomenclature with no overlaps or ambiguity.
(d) Have dialogue with the users and consider their ideas. (This is not only diplomatic but is likely to encourage a cooperative attitude when they s start to enter data.)
(e) Make the form easy to use. Avoid numeric coding whenever possible and use familiar abbreviations. (e.g. use Btg for an horizon code rather than 247 or 853). Use boxes rather than columns.
(f) Provide meaningful headings for data items, group associated items (e.g. matrix and mottle colours) and think carefully about the layout of boxes.
(g) When a prototype form has been designed for field or office use, discuss it with the data typists. (The author learned that they liked well spaced items, boxes about twice the width of the old columns, and pale yellow paper.)
(h) Conduct a comprehensive trial.
(i) Design the final document.
(j) Leave spare boxes for forgotten data items!

4.3.2 A recording form for soil profile descriptions.

An example of a recoding form for brief soil auger-hole descriptions is shown in Fig. 4.3.1 as an illustration of the principles outlined above. It is not suggested that the form for the 1:1M scale International Soil Map Database should be a close likeness. The form has been used successfully for the last 5 years by the Soil Survey of England and Wales and has recently been emulated, together with some data validation, on a hand-held datalogger. Details of this recent development are available from Mr. S. Clarke, Soil Survey of England and Wales, Rothamsted Experimental Station, Harpenden, St. Albans AL5 2JQ, England.

The advantages of this particular field-recording form can be summarised as follows:

(a) Form requires no numeric codes, other than those in daily use;
(b) Familiar abbreviations are used for entering data.
(c) Once completed, the form can be checked by 'reading' (No backward translation).
(d) Data typists like the form.
(e) This format is less error prone than 80 columns forms.

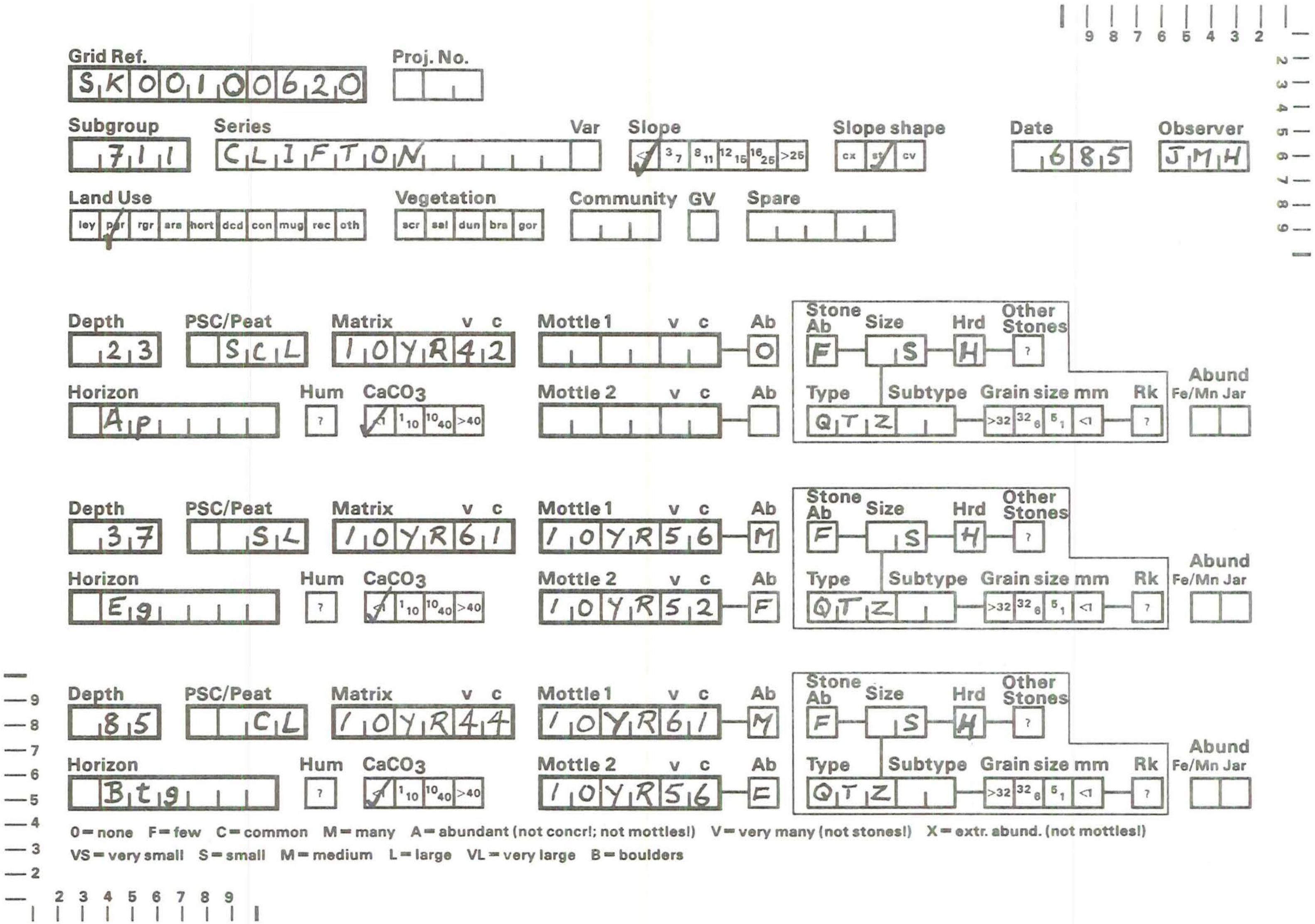


Figure 4.3.1 Example of a field recording card.

site and field horizon data) and laboratory analyses of horizons (sets/records of physical, chemical, mineralogical and other data). While the latter consist of and are stored as integer and real variables, the field descriptions often are coded as literal short cuts of longer terms. Lists of terms and symbols for many national approaches and of the FAO system exist as well as multilingual dictionaries. Many countries and FAO have already built up pedon or profile data banks with primary data of thousands of soils. These data banks are especially used for functional interpretations of soils but can be used for taxonomic evaluations, too.

4.4.3.2 Conclusion.
If a world soil resources data base is initiated, the geometric data of soils (map data bank) has to be supplemented by an International Soil Profile Data Bank (ISPDB). The data consist of different sets (flat tables) of primary site and horizon data, that can be retrieved by a suitable relational data base management system. This system also has to manage the secondary data (translation and en-/decoding tables, file and variable specifications, etc.). The FAO and the US coding systems can be used as a good starting point for an International Profile Coding System.

The collection and amalgamation of heterogeneous profile data from different origins is a tedious task. Methods of correlation have to be developed and applied, for example:
(a) regression algorithms for overcoming analytical differences of laboratory data;
(b) cross reference tables for converting field descriptions from one source into another or into a common base; and
(c) taxonomic conversion tables and reclassification algorithms for translating different horizon designations and profile classifications into each other.
Attention must be given to the new International Soils Reference Base System as a common taxonomic root of ISPDB. These algorithms and tables must also be supported and managed by the relational database system. It is emphazised that a standard commercial system will be implemented. The main system should be distributable to smaller computers working at the data collection sites.

4.4.4 United Nations Collection of Soils Data.

4.4.4.1 Proposition.
Two UN organisations are engaged in the collection and evaluation of international soil data,
(a) FAO, being specialized in practical evaluation for land use purposes, mainly at project level, and
(b) UNEP, using soil data for global environmental impact analyses and monitoring purposes.
An international soil resource information system for scientific studies and educational purposes is missing. Especially, facilities for quantitative pedogenetical and taxonomic evaluations of soil data at a global scale are not available today.

4.4.4.2 Conclusion.
ISRIC is a natural domain for an ISRDB-system that allows soil scientists and advanced students to perform statistical evaluations of soil data at a global scale. Also, fundamental work for the updating of a generic World Soil Map could find at ISRIC a professional background. Members of given ISSS working groups should be prepared to help ISRIC to initiate and organize the International Soil Resource Database as well as to make use of it. It is emphasized that a cooperative agreement should be arranged with FAO, UNEP and ISRIC which brings together the different approaches to evaluating soil data internationally.

4.4 PROPOSITIONS AND CONCLUSIONS FOR THE CREATION OF AN INTERNATIONAL SOIL PROFILE DATABASE

H. Jürgen Lamp
Institut für Pflanzenernährung und Bodenkunde
Christian Albrechts Universität

4.4.1 Creation of a World Soil Resources Database.

4.4.1.1 Proposition.
The creation and updating of an International Soil Resource Database (ISDRB) is an iterative and cooperative task based on two interrelated sources of knowledge:

(a) Concepts about soils concerning the
  - pedogenesis (theories about the causal chain: factors, processes, attributes) and
  - pedofunctions (deductions about the relation of attributes - functions - ecocomponents).

(b) Facts about soils observing and measuring in the field and laboratory mixed-scaled data of
  - soil attributes of the total profile and of single horizons,
  - factors and ecocomponents (inductive analyses of genetic and functional inferences.

4.4.1.2 Conclusion.
With developing soil science the collection of facts about soils into digital databases and inductive-statistical evaluations deserve preference against conceptual and often speculative deductions. The creation and updating of global data- bases for the inventory, monitoring and optimal use of endangered soil resources is urgent.

4.4.2 Nature of Soil.

4.4.2.1 Propositions.
Soil is a continuum, that shows for some attributes high variations in time (moisture e.g.) and for many permanent attributes high variations in space, often reaching more than 50% of the total variance within less than 100 m. This includes taxonomic variables (taxa multistates). Only some genetic features vary at greater distance, but usually trends at global scale are overlayed by strong local and regional sources of variation.

4.4.2.2 Conclusion.
Homogeneous soils, defined by pedogenesis, soil attributes or pedofunctions, can be mapped only at large scales (possibly 1:5,000). For regional, national and global map scales soils must be successively compounded to micro-, meso- and source maps (see fig. 4.4.1). A classification system of soil associations is missing and must be created for global soil maps. Apart from the (inexpensive) creation of generic maps (expensive) special purpose maps can be computed with the help of modern information technology and methodology (showing area of soil productivity for crops, potentials for improvements, ecological capacities, limitations, forecasts of the soil resource, etc.).

4.4.3 Homogeneous Soil Association.

4.4.3.1 Proposition.
Soil associations finally consist of (roughly) homogeneous soil bodies (elementary soil units, polypedons), that can be described by representative soil profiles. These, also called pedons, can be analyzed and defined by field descriptions of the site and single horizons (sets/records of profile/

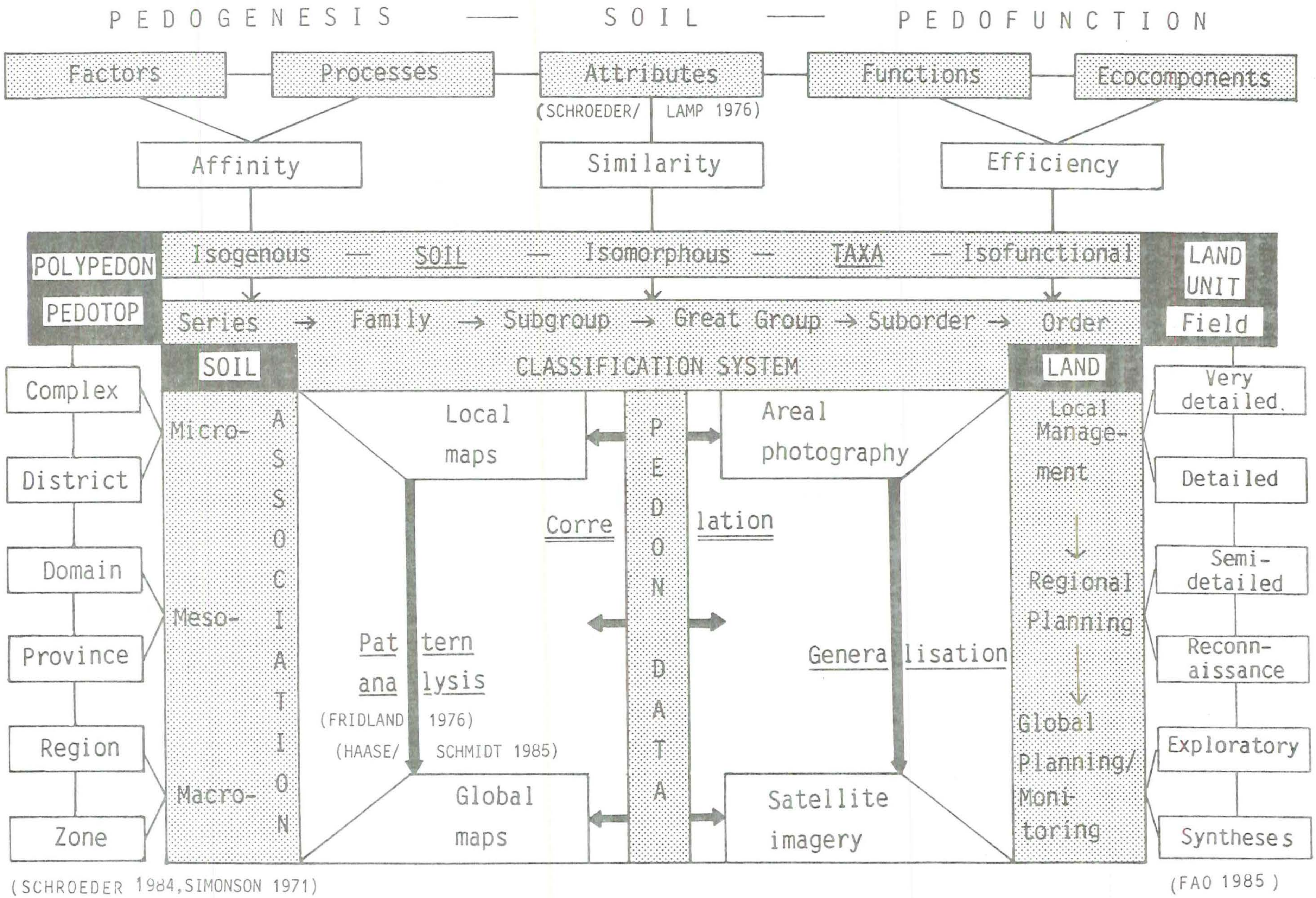


Figure 4.4.1 Basic concepts in soil/land regionalisation.

4.5 APPLICATION OF SATELLITE REMOTE SENSING FOR A WORLD SOILS & TERRAIN DIGITAL DATABASE

Frederik W. Hilwig
International Institute for Aerospace Survey and Earth Sciences (ITC)

4.5.1 Introduction.

The completion of the FAO/UNESCO Soil Map of the World, scale 1:5 million which was initiated in 1961 and completed in 1980, took about 20 years (FAO, 1985). The aggregation was achieved by the correlation of national soil maps to a common base map with limited additional field check. Index maps indicate the sources of information (systematic soil surveys, soil reconnaissance and general information with local soil observations) involved and thus the relative reliability of the delineated mapping units in the various map sheets.

Our question now is how and where and at what cost remote sensing techniques can be applied for a new world soils & terrain digital database (map and attribute data), scale 1:1 million as proposed by ISRIC (Sombroek, 1985). The idea is to incorporate into this digital soil map of the world all systmatic soil resources maps of compatible scales, produced since the mid-seventies and fill the gaps using Landsat type imagery. Two questions have to be adressed: the topographical base map production and the preparation of the soil map annex database using satellite imagery.

4.5.2 Topographical Base.

The only available world wide topographic map coverage is the series of Operational Navigation Charts (ONCs), scale 1:1 million, consisting of approximately 275 sheets of which 257 sheets were completed in 1977 by the US Department of Defense and published by the Aeronautical Chart and Information Center, St. Louis, Missouri, USA.

The multicolour ONC map sheets show contour lines in feet, partly also coloured relief portrayal, forest representation in low land, traffic networks, towns and villages partly depicted without names, numerous spot heights in feet, airfields, aeronautical information, magnetic variations, and is covered with a complete latitude and longitude degree network. The map projection is conform Lambert's conical projection; polar sheets are polar stereographical projection. Format is 145x105 cm. The maps can be obtained from the USA and also through GEO CENTER, Stuttgart, FRG.

4.5.3 Scale and Cost of Satellite Imagery.

The working scale of imagery commonly used in soil and land use surveys is usually a factor two larger than the publishing scale, i.e. 1:500,000 in our case. Both Landsat multispectral scanner (MSS) and thematic mapper (TM) imagery, generated from computer compatible tapes (CCTs) fulfill these requirements. Besides the current Landsat MSS and TM imagery, satellite data from the French SPOT system will become available, at a 10 to 20 meters spatial resolution compared to 80 and 30 for Landsat MSS and TM respectively.

The increased number of map sheets for the World Soils & Terrain Digital Database (SOTER) compared to the limited number of 20 sheets involved in the FAO/UNESCO Soil Map of the World, leads to a large number of Landsat CCTs to support the thematic map production. Calculations for use of satellite images have been made on the assumption that one SOTER map sheet on average covers about 20 Landsat CCTs. (Table 4.5.1)

Table 4.5.1. Landsat data for the World Soils & Terrain Digital Data Base

1. Total land surface of the Earth (Kossina, 1933)	150 million km^2
2. Total number of ONC map sheets covering the world	275 sheets
3. Effective area per Landsat scene(13,000-26,000 km^2)*	20,000 km^2
4. Approximate number of Landsat scenes covering the world	7,500 scenes
5. Average number of Landsat scenes per ONC map sheet	27 scenes
6. Cost of Landsat MSS CCT world cover (US$ 660/scene**)	$ 5.0 million
7. Cost of Landsat MSS FFC 1/500,000 world cover($400/scene)	$ 3.0 million
8. Cost of Landsat TM CCT world cover (US$ 3350/scene)	$ 25.1 million
9. Cost of Landsat TM FCC 1/500,000 world cover ($ 700/scene)	$ 5.3 million
10. Cost of SEASAT, SIR-A and AIR-B or other radar imagery***	$ 5.0 million

* Due to polar orbit, the Landsat image sidelap percentage depends upon latitude; at the equator the sidelap is 14%, the image base is 159 km and the effective area is 26,000 km^2. At 60° latitude the sidelap is 57%, the image base is 80 km and the effective area is 13,000 km^2. Above 60°N and below 60°S half or one quarter of all scenes can be used for a full cover of the world's surface.

** cost EOSAT, Sep 85.

*** estimated at 20% of the land area of the world suffering from cloud problems and budgeted for the same price per unit area as Landsat TM CCTs.

Satellite radar imagery, such as SEASAT with an L-band synthetic aperture radar (SAR), the Shuttle Imaging Radar (SIR-A, 1981 & SIR-B, 1984) with a spatial resolution of 25, 40 and 30 meters respectively offer possibilities to explore areas, that are difficult to study using visible and infrared sensors, e.g. cloudy areas and dense forests. Also, other applications are known, such as penetration of dry sand to discern fossile drainage patterns, geological studies, geomorphological mapping, topography and land use in cloudy areas, irrigation, soil moisture and salinity studies.

A rough estimate of the cost of Landsat TM monotemporal digital data including SIR or similar, amounts to approximately $ 22 million, exclusive of geometric corrections and digital image enhancement techniques to deliver 1:500,000 colour composites for interpretation, field survey and correlation purposes. For change detection (land use, vegetation, soil moisture, etc.) multitemporal data would push up the price for required initial coverage by a factor 2 or 3 to US$ 44 or even $ 66 million, unless substantial rebates could be negotiated with EOSAT and various regional distributors of Landsat TM and/or SPOT data.

If only Landsat false colour composite (FCC) imagery, scale 1:500,000, were used for visual interpretation purposes and map correlation, a full monotemporal cover of the land surface of the world would cost US$ 2.2 million for MSS and US$ 3.9 million for TM imagery.

4.5.4 Availability of Satellite Remote Sensing Data.

With the exception of Central America, central East Africa and parts of the USSR and China, the world is covered by more than 15 receiving stations and distribution centers, which are in various stages of upgrading to handle in addition to Landsat MSS also the 7-channel Landsat TM data. The latest information on the status of various receiving stations and distribution centres can be found in Landsat newsletters published by NOAA (EOSAT) and ESA-IRS.

4.5.5 Selection of Satellite Remote Sensing Data.

During the selection of the most promising satellite remote sensing data for multitemporal studies of land resources, due attention should be given to the following factors affecting the interpretation: cloud cover, image quality, bio-climate (e.g. precipitation/temperature diagrams), vegetation/ landuse practices (crop calendars) and snow cover (Hilwig & Davis, 1980).

4.5.6 Mapping Methods and Techniques Using Satellite Remote Sensing Data.

It is doubtful whether a great number of national soil maps and land resources maps of the world at a scale of 1:1 million or similar can be simply integrated using a Landsat database and mainly cartographic smoothing. To pursue the establishment of a world soils & terrain digital database will mean the preparation of a global correlation model in terms of soil legend, classification and benchmark soils, to be followed by the national soil survey organizations cooperating in the SOTER project.

Then jointly, a common methodology needs to be developed and agreed upon for the interpretation of multi-temporal satellite remote sensing data, of areas which are not yet covered by systematic and/or reconnaissannce soil surveys. Integration of visual and computer-assisted interpretation techniques may be required based upon landforms, lithology, drainage (patterns and condition), vegetation and land use. Application of digital terrain models wherever possible must be pursued. Inaccessible and/or cloudy areas such as rainforests, mountainous terrain, swamps, deserts and polar zones may be poorly covered with aerial photography and thus pose problems as far as digital terrain models are concerned.

The above methodology could be a followup of the low cost procedure for the physiographic analysis of Landsat imagery, developed at ITC (Hilwig, 1980). Visual interpretation of carefully selected multitemporal Landsat imagery for inventories of natural resources should be carried out by integrating static and dynamic image interpretation elements (Figure 4.5.1).

The guiding principle of the proposed multitemporal Landsat image analysis is the use of the best band or combination of bands of the most relevant season(s) for a particular image interpretation element; these elements are then integrated into the final physiographic analysis ready for field investigations and subsequent re-interpretation. Such an analysis may be regarded as an optimum interpretor's map for soil survey purposes.
'Low cost' refers to low input in terms of capital. However, a high input is required in terms of expertise regarding image interpretation techniques, i.e. a specialist well trained in aerial photo-interpretation and Landsat analysis. The interpretation procedure is visual and multitemporal using existing information (topography, geology, etc.) and is carried out with limited photographic and optical facilities, which make this methodology suitable in most developing countries in the world.

4.5.7 Draft Proposal for a Digital International Soil Map.

As a first step, it appears appropriate, that as a result of this ISSS Workshop, a draft proposal shall be formulated with a clear outline on the methods and procedures for data collection, data analysis and archiving. Not only must choices be made with regard to a provisional soil legend and soil classification for the proposed soil map of the world but also a geo-info system has to be designed for general purposes with inputs on soils, topography and climate. Problems have to be solved on point, aerial, multispectral and multidimensional representation. An important aspect for archiving will be the continuity of readibility and the compatibility with other databases. Also, the problem of copyright must be adressed.

With due respect to on-going activities in the field of mapping of global soil and land resources, priority areas (based on a relevant set of criteria) must be proposed for cooperating countries with deadlines for completion of correlation, printing and publishing to be set at the coming ISSS Congress in Hamburg, August 1986.

4.5.8 References.

ESA-IRS, News and views. Information Retrieval Service, ESRIN, Frascati, Rome.

EOSAT, 1985. FAO/Unesco Soil Map of the World, 1:5,000,000, revised legend, 3rd draft World Soil Resources Report, FAO, Rome.

GEO CENTER, 1977. Geo katalog, Band 2, p 45. Operational Navigation Charts of the world. Int. Landkartenhaus, 7000 Stuttgart, FRG.

Hilwig, F.W. & S.M. Davis, 1980. Selecting Landsat Imagery. ITC/LARS minicourse and study guide, Enschede.

Hilwig, F.W., 1980. Visual interpretation of multitemporal Landsat data for inventories of natural resources. ITC Journal 1980-2, Enschede.

NOAA, Landsat data users notes; Landsat Customer Services, Sioux Falls, SD, USA.

Sombroek, W.G., 1985. Establishment of an international soil and land resources information base. Discussion paper ISSS working group DM, Oct 1985.

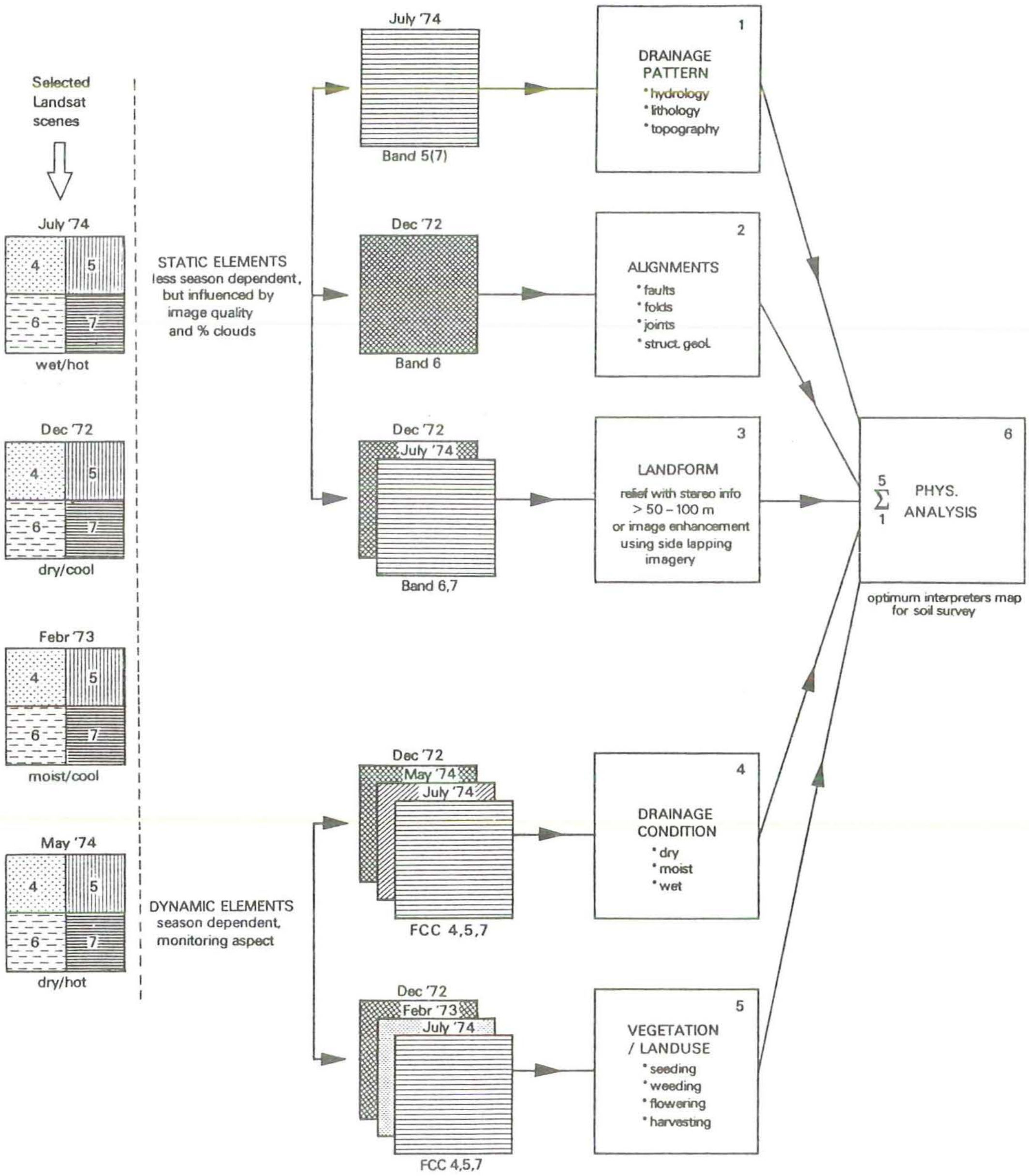


Figure 4.5.1 Elements for the interpretation of Landsat imagery for inventories of natural resources. (An example of multi-temporal and multi-spectral Landsat image interpretation for a physiographic soil survey in Northern India).

4.6 DEVELOPMENT OF A SOIL INFORMATION SYSTEM BY PROTOTYPING

Arnold K. Bregt
Netherlands Soil Survey Institute (STIBOKA)

4.6.1 Introduction.

The development of a large information system such as a global digital land and terrain database is rather complex. Many user requirements need to be integrated into one system.

Prototyping is one method by which information systems can be developed and this was the one used by the Netherlands Soil Survey Institute (STIBOKA) to develop a new soil information system. The concept of prototyping, and our experience of it at STIBOKA, will be discussed in this article.

4.6.2 Development of Information Systems.

Three items must be distinguished when building an information system (IS): user requirements, materials, and methods. All three items strongly influence the other and must all be dealt with at the same time when developing an IS (Figure 4.6.1).

The first essential step is to identify the user requirements, and several questions need to be answered, such as:

- what data do we want to store?
- how much data do we want to store?
- what data do we want to retrieve?
- how do we want to retrieve the data?
- how may people will be using the system?

Secondly, we must choose the appropriate materials (software and hardware) with which to build the IS. Both software and hardware must be chosen carefully. In most cases, it is advisable to develop the IS using a commercial software package that is already available, rather than developing a new database management system. Obviously, there is a close link between the user's requirements and the necessary materials; a global digital soils and terrain database cannot be implemented on a small personal computer.
Thirdly, we need a method for developing the IS. Traditional methods contain detailed written system specifications at the start of a project. These specifications are subsequently translated into programs and procedures. The resulting system is frequently not what the user originally had in mind. So, in order to minimise these mistakes, the prototyping method was introduced for the development of an information system.

4.6.3 Prototyping.

Prototyping can be defined as a method by which examples of (parts of) an information system are developed in close cooperation with the future user(s) (Andrews, 1983). The biggest advantage of using software prototypes is a better definition of user requirements. Traditionally, user requirements are specified by detailed written system specifications. However, they do not serve this purpose well because they are incomplete, often confusing and take a static view of the requirements (McNurlin, 1981). It is very difficult for the user to visualise the ultimate system from these specifications.

In the prototyping process, the user discusses his wishes with the analyst, who then creates a prototype system that performs some of the functions mentioned in their discussions. The prototype system is demonstrated to the user, and actual data entered. Most users then re-define their requirements. The process of building new prototypes, followed by testing, is repeated several times. When the user is satisfied, the final version of the prototype can be used as the production system (Figure 4.6.2).

The building of prototypes is not new. It is commonly used in industry before a product is introduced. It has, however, only just been introduced in software engineering because the appropriate tools were not available until recently. Due to the introduction of relational database management systems and fourth generation programming tools, the prototyping of information systems is now also feasible.

4.6.4 BIS (Bodemkundig Informatie Systeem) as a Result of Prototyping.

The prototyping method was used to develop a new soil information system at the Netherlands Soil Survey Institute (Bregt et al., 1986). The system is called BIS (Bodemkundig Informatie Systeem). BIS was built using the relational database management system ORACLE (ORACLE, 1984). ORACLE includes a complete implementation of SQL (Standard Query Language), plus a set of integrated software tools for application generation and report writing. SQL is one of the standard languages for relational database management systems.

In the resulting system, the following data of both small and large-scale soil survey projects are stored:
- project data;
- augerhole data;
- soil-profile descriptions, including the data of chemical, physical and mechanical analysis; and
- mapping unit information, including land qualities and suitability classes.

Interactive procedures are used during input, and validation and correction is done immediately. The information in the system can be retrieved and presented in different ways. For certain standard questions, a standard overview is programmed. The user can obtain such an overview quite easily. For non-standard questions the user can make use of the ad hoc selector or the query language of ORACLE (SQL).

Some conclusions regarding the use of prototyping for the development of BIS are:
1) It is possible to build an information system in a relatively short time.
2) The building process is a very intense one for both computer specialist and user, and requires their undivided attention.
3) The resulting system is well-tailored to the requirements of the user who can evaluate prototype systems much better than written specifications. This, in turn, also results in a clearer definition of the requirements.

4.6.5 References.

Andrews, W.C., 1983. Prototyping information systems. J. of Systems Management, September, pp 16-18.

Bregt, A.K., J. Denneboom, J. Stolp & J. Vleeshouwer, 1986. BIS, an information system for soil survey and research. XIII International Congress of Soil Science, 1986, Hamburg (in press).

McNurlin, B.C., 1981. Developing systems by prototyping. EDP Analyzer, Vol. 19:9, 1-12.

ORACLE, 1984. ORACLE overview and introduction to SQL. Oracle Corporation, USA.

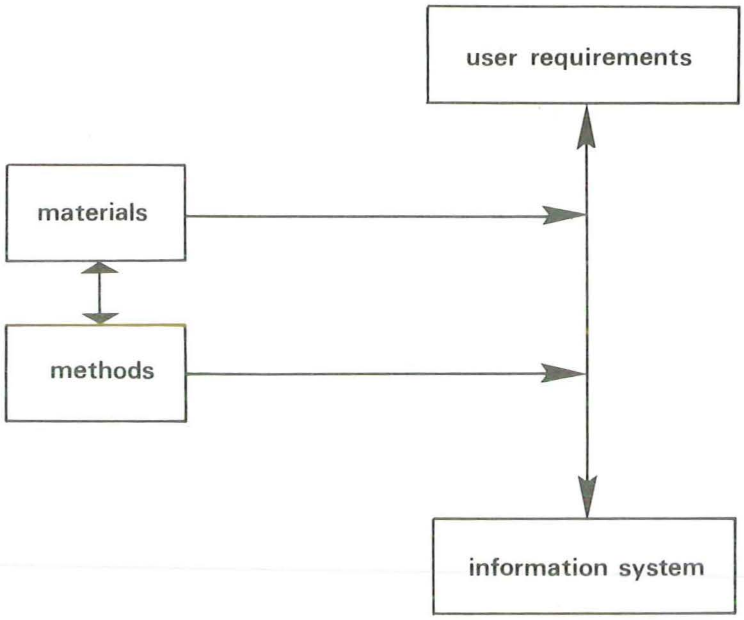


Figure 4.6.1 Development of an information system.

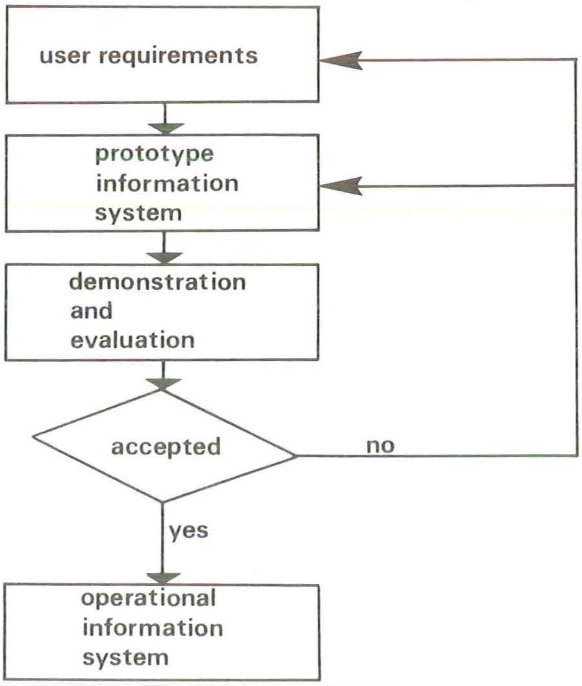


Figure 4.6.2 Flow chart of the prototyping process.

5

COUNTRY REPORTS

5.1 CANADIAN GENERALIZED SOIL LANDSCAPE MAPPING (GSLM) PROJECT

Jack A. Shields
Land Resource Research Institute, (LRRI)
Agriculture Canada

5.1.1 Terms of Reference.

To produce generalized small scale maps of the Canadian land areas based on permanent soil and non-soil landscape attributes complete with a computerized extended legend containing additional data sets essential to interpretations for soil conservation, field crop growth, forest productivity, wilderness terrain sensitivity, land management and regional planning.

5.1.2 Relevant Background.

Concern was expressed by the Director of the Land Resource Research Institute (LRRI) that generalized maps and soil conservation assessments were being made by different federal and provincial governmental agencies with very little dialogue and correlation among them. To achieve consistency in mapping concepts, diagnostic attributes and map legends, it was requested by the Director that maps based on permanent natural soil and landscape properties be prepared by the correlation methodology group in cooperation with unit heads in the provinces and personnel from the Land Use and Evaluations Section including CanSIS.

In 1982 a Working Group was established within the Expert Committee on Soil Survey (ECSS) to select differentiating attributes, construct a map legend, develop the generalization mapping methodology and design an extended legend coding form. The Prairie Provinces were selected as the pilot study area and maps of Manitoba, Alberta and southern Saskatchewan were completed by 1984. More recently, in response to a request by the Eastern Canada Soil Degradation Project, generalized mapping was extended to cover most of the remaining agricultural region of Canada.

5.1.3 Objectives.

The following objectives were defined:
- To compile generalized maps of naturally occurring geographical areas based on permanent soil and non-soil landscape attributes;
- To compile an extended legend table in computer compatible format documenting the dominant and subdominant soil, or non-soil, attribute classes which differentiate one area from another, plus additional attribute classes to characterize further each map polygon for interpreting various causes of soil degradation risk and assessments of wilderness terrain sensitivity;
- To prepare provisional maps and computerized derivative maps available on user request; and
- To publish each map and legend accompanied by a short report.

5.1.4 Scope and Scheduling.

The project is defined by a number of subprojects.

Subproject List	Completion Date
1) Agricultural Region (See Figure 5.1.1)	1985-'86
2) Northern Wilderness (See Figure 5.1.1)	1990-'91
3) Degradation Risk	1986-'87
4) Forestry	(developmental)
5) CanSIS Data Base Management System	1986-'87

5.1.5 Methodology.

Compilation of generalized maps for Subproject 1 where source maps exist as documented in our generalized small scale Mapping Procedures Manual is described below (see 5.1.5.6). Compilation procedures where source maps do not exist and exploratory mapping is required are documented in the Appendix of this paper (5.1.10).

5.1.5.1 Legend development.

Differentiating classes of soil and non-soil landscape attributes as established by the ECSS Working Group for a Prairie Pilot Study (see Fourth ECSS Proceedings, 1982, page 62-74) were used for the project and supplemented as required in other geographic areas. In summary, the attributes used to differentiate one map polygon from another are:

a) Mode of deposition of soil parent material;
b) Texture of parent material;
c) Soil development, generally at the Great Group level of the Canadian System of Soil Classification;
d) Surface form;
e) Slope gradient; and
f) Kind of non-soil (or rock).

There are several reasons for selection of these differentiating attributes. Soil texture influences moisture storage capacity, its availability to plants and in the case of sandy soils, their susceptability to wind erosion. Soil development was selected because it is indicative of natural fertility, drainage, alkalinity and reaction. Surface form was selected because forms with long, continuous slopes influence susceptability to erosion by water particularly when coupled with steep gradients. The mode of deposition of soil parent material provides a linkage to surficial geology and to the mapping methods used on the source maps. Finally, the acid or basic properties of rock (or non-soil) influence drainage water chemistry and plant growth.

Each of the above differentiating attributes was coded into one of a number of classes (Table 5.1.1). For example, the property soil texture was grouped into classes of sand, sandy loam, loam, clay loam and clay with plant available water capacities to 120 cm depth of 50, 100, 150, 200 and 250 mm, respectively. Similarly, the slope gradient range was generalized into classes of 1-3%, 4-9%, 10-15% and 16-30%. Surface forms included level, undulating, hummocky, rolling or dissected. Classes were also documented for soil development.

5.1.5.2 Map symbol explanation.

The map symbol (Figure 5.1.2) is composed of three lines describing only the attributes which are dominant (apply to 40% or more of the polygon area).

a) Top line indicates soil development and texture of the parent material.
b) Middle line indicates origin of parent material, its surface form and slope gradient.
c) Bottom line indicates a unique number which serves as a reference to additional information contained in an Extended Legend.

5.1.5.3 Legend structure.

The map legend (Figure 5.1.2) contains a listing of information describing the dominant soil and landscape attribute classes within a map polygon as follows:

a) Dominant soil development and texture group of parent material;
b) Mineral soil and rock outcrop mode of deposition, surface form and % slope gradient; and
c) Organic soil wetland class and wetland form.

5.1.5.4 Computerized extended legend table.

The Extended Legend contains information on additional dominant properties including:

a) Surface texture,
b) Soil drainage,
c) Calcareousness of parent material,
d) Depth to water table,
e) Regional surface form,
f) Kind of compact layer and depth of occurrence, and
g) Slope length.

The Extended Legend also includes information on similar properties which are subdominant, applying to more than 15% but less than 40% of a polygon; information on other contrasting soil inclusions applying to less than 15% of a polygon is also included. Thereby, a data set for dominant and subdominant properties, and soil inclusions was systematically recorded for each unique numbered polygon (Table 5.1.2) and then input into the CanSIS Computerized data set. Attribute classes and their codes used in the extended legend are given in Table 5.1.1. When in CanSIS, this data set may be merged with other data sets such as the Cartographic File, Soil Names File and the Soil Description File.
Provision is also made to record a map reliability estimate for each polygon.

5.1.5.5 Source maps.

Generalized maps were compiled from the most recently available soil survey maps for each area which ranged from the mid 1940s to the present; in some cases, the source maps were made without the help of aerial photographs. Commonly, mapping scales of the source documents were 1:63,000 or 1:125,000 but ranged from 1:50,000 to 1:250,000. In a few areas there were no soil survey maps available and the generalized maps were compiled from soil capability maps.

5.1.5.6 Generalization procedures.

The following steps were used in generalizing the source maps:

1) Establish the size of area at the source map scale that reduces to 1 cm^2 at a scale of 1:1 million (large enough area to insert a map symbol). There are a few exceptions where a generalized map polygon at 1:1 million may be smaller than 1 cm^2, e.g. narrow elongated features and drainage patterns, and strongly contrasting soil landscapes. Map symbols can be attached to these polygons by use of a leader, assuming the polygon density adjacent to these areas has space for the extra symbol and leader.
2) Overlay and register transluscent matte surface chronoflex to the source soil survey map.
3) Delineate major drainage pattern and other major physiographic features on the source map; care must be taken not to make the drainage patterns too detailed as drainage often bisects soil landscape areas which may greatly increase the number of polygons required.

4) Delineate large, uniform soil landscape areas on the source map; translate the source map symbol and legend information to the generalized map symbol format and assign a unique polygon number. A change in at least one differentiating property class limit on the source map results in a separate generalized polygon.
5) Where necessary, group smaller source map polygons which are most similar, keeping in mind which applies to the dominant portion of the generalized polygon; translate its map symbol and assign a unique polygon number.
6) If necessary, group source map polygons which are dissimilar and proceed as indicated in item 5.
7) Continue the above procedure until most of the source map area is generalized; review remaining small areas and decide to which generalized polygons they should be most sensibly added.
8) Review generalized polygons, their map symbols and source information (map legend and report) required for recording the attribute classes on the extended legend coding form; code attributes applying to the dominant, subdominant and inclusion portion of the generalized polygon on the extended legend.
9) Correlate polygon boundaries along adjacent source maps and also along provincial boundaries.
10) Reduce the generalized maps on the chronoflex overlays photomechanically to 1:1 million scale, process onto clear material, then mozaic and register to an appropriate base map. This mozaic is then recompiled for a provincial area and edited.
11) Input the extended legend into CanSIS, sorting according to map symbol attributes and a map compiled legend.
12) Typeset the map legend and attach to the map to comprise a "Provisional Map" which is processed on clear material that can be readily copied on request by users.
13) Digitize and merge the map with the computerized extended legend to permit generation of single or multi factor maps.

5.1.6 Map Reliability.

Reliability of generalized maps is dependent on:
1) Experience of generalized map compilers. The maps were all compiled by local, senior soil surveyors with sufficient experience to interpret map symbols and related information from <u>all</u> the local source maps and reports.
2) Source documents, their age, inspection intensity and scale of publication. Their age becomes a factor if they were produced prior to the use of aerial photographs during field mapping. Stereo photo patterns greatly enhance extrapolation of site specific data from one traverse to the next.
3) Inspection intensity per unit area mapped which provided general insight to mapping accuracy and was usually related to the scale of publication. The larger the scale of publication, the higher the inspection intensity.

Three levels of map reliability have been established in relation to inspection intensity and publication scale of source documents, and whether aerial photographs were used during field mapping:

Low
- compiled from soil survey maps produced from field traverses at wide intervals (up to 6 miles) and without the used of aerial photographs <u>or</u>
- compiled by maps produced by inspections using fixed wing aircraft or helicopter and aided by interpretation of Landsat imagery.

Medium - produced from systematic traverses by helicopter and by interpretation of stereoscope aerial photographs or
- compiled from modern soil surveys produced from traversing existing accessible roads in wilderness areas and aided interpretation of stereoscopic aerial photographs.

High - compiled from modern soil survey maps produced from field traverses at one mile intervals or less and with the aid of stereoscopic aerial photographs.

5.1.7 Correlation Procedures.

Correlation activities were initiated by translating source map symbols within the generalized polygons in terms of the minimum data set attributes and by coding them accurately on the extended legend table. In the simplest case of a large source map polygon, correlation required only a translation of the map symbol and its appropriate coding. Similar source map symbols were coded similarly on the extended legend.

In cases where the generalized map polygon comprised two or more source map polygons, correlation required consistent translation and coding of attributes which characterized the dominant, subdominant and inclusion portions of the generalized polygon. Decisions became more difficult as the number of source map polygons grouped into one generalized polygon increased and also as the degree of contrast among grouped polygons became stronger.

A second level correlation activity involved resolving differences in both map symbols and generalized polygon boundaries on adjacent source maps within a province, or between provinces. These discrepencies arose due to differences in source map scale and intensity of inspections as well as differences in soil classification systems used. Resolution of differences was time consuming, often frustrating and occasionally irreconcilable. Experience and knowledge of the different mapping and classification systems used was a definite asset for the required translations of these differing source map symbols to the coding document.

Correlation of differing polygon locations across a provincial or national boundary was done in consultation with the appropriate provincial, regional or national correlators. It was best resolved by reviewing the mapping methodology, kind and scale of aerial photographs and quality of satellite imagery. Local knowledge was also a definite asset. However, in some cases, particularly in the absence of definite physiographic features, it was necessary simply to compromise.

The third level of correlation activity dealt with interpretation of extended legend attributes for various purposes. Again, the consistent translation of attribute classes to interpretive algorithms must be emphasized, particularly where similar interpretations were made in adjacent provinces. Resolution of minor differences often required considerable time when dealing with both provincial and federal agencies of adjacent provinces.

5.1.8 Minimum Data Set Requirements.

To this point, I have presented what was done for our Canadian Project. As indicated earlier, Soil Development (or Soil Taxonomy) was used as one of the differientating legend attributes. Soil taxonomy at whatever level you choose, in this case the Great Group level, provides a convenient form of shorthand which includes many defined attributes. However, as stated by Dr. Sombroek in his discussion paper, he would like to downplay the inclusion of soil taxonomy as one of the main legend headings. An alternative to including soil taxonomy as one of differentiating legend headings is to compile a list differentiating attributes which will comprise a "minimum data set" for this International Project. This is definitely a topic which must be further addressed. To initiate this discussion I have prepared an initial minimum data set proposal for landscape and soil attributes. In summary, both landscape and soil attributes are recorded on a spatial basis according to the proportion (dominant, subdominant, inclusion) of the entire map polygon to which they apply. The soil attributes are also recorded according to a maximum of four depths.

The list of landscape attributes includes:

1) climax vegetation
2) elevation (or altitude)
3) relief
4) origin of material
5) surface form
6) slope gradient
7) % cultivated land
8) stoniness
9) % surface water coverage
10) permafrost distribution
11) patterned ground
12) flood hazard

Soil attributes include:

1) organic carbon
2) soil color when dry and moist
3) texture and coarse fragments
4) mineralogy
5) structure
6) bulk density
7) drainage
8) pH
9) kind of diagnostic or contrasting layer
10) electrical conductivity
11) calcareousness
12) organic soil degree of decomposition
13) frozen soil, (mineral or organic)
14) ice content of material
15) saturated hydraulic conductivity
16) sodium adsorption ratio
17) soil name (linkage to soil data file)

Mr. Chairman, this initial compilation of a "minimum data set" for this project will necessarily be reviewed and revised in view of contributions from other international participants.

5.1.9 Closing Summary of Critical Steps Required for this Project.

1) Define objectives;
2) Priorize "prime" interpretations to be made, e.g. soil degradation risk;
3) Document differentiating attribute classes required for interpretations, i.e. minimum data set;
4) Construct extended legend tables for:
   a) Soil landscape attribute class;
   b) Climatic data;
   c) Land use and farming systems;
   d) Soil degradation risk;
   e) Irrigation suitability and aridity;
   f) Forestry land evaluation;
5) Design output products and reports;
6) Design input forms compatible with output products;
7) Design cartographic files;
8) Compile procedures manual (Re: correlation); and
9) Design computerized database management system.

5.1.10 Appendix: Generalized Soil Landscape Mapping In the More Northerly Wilderness Areas of Canada.

Little or no soil information is available for most of the areas in the Territories where soil surveys are to be carried out in the future. In many cases there is also a lack of geomorphological data concerning such features as glacial history, landforms and surficial materials. This lack of information and the inaccessibility of the terrain required the development of survey methodology which provided both detailed information on a site specific basis and general information in the form of small scale soil landscape maps based on Landsat imagery (Tarnocai 1977)*. Thus, the survey methodology used in the Territories is different from that used by the provinces to compile general small scale maps (e.g. 1:M scale). These small scale provincial maps are based on previous and reconnaissance survey information and represent a scaled down and generalized version of these earlier surveys.

5.1.10.1 Methodology for the Horton and Firth river exploratory surveys, N.W.T.

The mapping of the Horton and Firth river map sheets (Figure 5.1.1, map area NW028507) was carried out using 1:1M scale Landsat imagery. The satellite imagery was interpreted manually with the aid of panchromatic photographs. Carrying out the interpretation on this scale enables one to view the terrain on the same scale as on the final soil map. This eliminates many of the small details which would have been identified if larger scale imagery had been used for interpretations.

During these surveys it was found to be important to collect a maximum amount of information from both ground and aerial traverses. Information collected aerially (between stops) was mainly of use in the interpretation of satellite imagery. Landforms, surficial deposits, size and type of water bodies, wetlands, vegetation and patterned ground features were the most important features which are constantly observed. During this process the composition and characteristics of the mapping units were continuously checked and corrections were made if the preliminary interpretation did not satisfy the conditions observed from the air. During the stops, detailed information was collected relating to terrain and vegetation. Soils were also sampled at these stops. This detailed information provided the basis for characterizing the soil associations and vegetation. It is important that a maximum amount of detailed information be collected at these sampling sites and not merely general information since often these are the only data available for the soils, terrain and vegetation for the area. It would also be very difficult to justify the high cost of the flying required in these surveys if only general information were collected, supplemented by a few photographs taken both on the ground and from the air. This work has proved to be achieved most efficiently if the field work and photo-interpretation are carried out by a pedologist experienced in the northern environment.

5.1.10.2 Legend development.

The following information was collected at the stops made in these map areas.

a) Landform (genetic landform)
b) Parent material
    - characteristics of material
    - mode of deposition
    - texture
c) Slope
d) Drainage
e) Surface runoff
f) Seepage
g) Stoniness
h) Rockiness
i) Permafrost description
    - depth to thaw
    - ice content (estimated)
    - type of ice
j) Patterned ground type
k) Soil classification
l) Pedon description
    - color
    - texture
    - mottles
    - structure
    - consistence
    - horizon boundary
    - depth of rooting zone
    - root description
    - pore description
m) Description of vegetation
    - species list
    - vegetation cover

* Tarnocai, C., 1977. Manual interpretation of Landsat data for land classification, Northern Keewatin, N.W.T., Canada Soil Survey, Winnipeg. 15pp.

All information relating to these sites and pedons was recorded on computer input forms. All soil horizons were sampled at every stop.
An uncontrolled, open legend was used. The possibility of using a controlled open legend was examined. All map symbol combinations (single or compound map units) occurring on the map were listed and sorted using a special computer program to generate groups of symbols which were similar in characteristics and could be identified by a single symbol. It was found that the controlled legend generated by this system reduced the number of symbol combinations by only three (the total uncontrolled number was sixty-six). It was also found that the controlled legend was much longer than the uncontrolled one and the descriptions were repetitious. The uncontrolled, open legend was used since the objective was to produce an uncomplicated map, composed of simple map symbols and a short legend.

The soil associations, e.g. Hornday soil association, indicated in the legend are broad soil associations representing a sequence of genetic soils developed on similar parent material. These soil associations could also be called soil association complexes since the distribution of genetic soil types has not been identified precisely; only the most commonly occurring subgroups are indicated. The symbols found on the map (e.g. Ho1, Ho2 and Ho3) have the same soil association (Hornday soil association) but differ in the associated landforms in the size and cover of the associated water bodies.

5.1.10.3 Field procedures and sample density.
The continental portion of the Horton River 1:1M scale map sheet was surveyed in 1980. Only the southwest corner of the map area is forested; the rest of the area lies in the Arctic. This map area is a typical northern survey area with its isolated location, weather problems and lack of previous terrain and soil information. During the survey of this area, a Cessna 185 float plane was used for transportation and for flying the traverses. This aircraft was selected both because of its relatively low cost and because it had been found to be suitable during previous surveys for moving small amounts of equipment and the two surveyors working in the area.

The air traverses were planned in such a manner that they radiated out from the two camp sites. Approximately one and a half days of flying were necessary to cover the traverses from the Sadene Lake camp and two days flying were required from the Bluenose Lake camp. An average day included approximately six stops, which were all detailed soil sites. The locations of these stops were selected using the interpreted Landsat based preliminary soil landscape map. It was necessary that they included suitable lakes on which to land the plane and that as many different polygons as possible were covered. In addition to these aerial traverses, one day was spent at each of the two camp areas carrying out detailed soil-terrain-vegetation work in order to gain a greater understanding of the interrelationsships between these components. This information was collected along foot traverses. The work was carried out by a two-man crew in which both persons were experienced in northern surveys in general and arctic surveys in particular. The total field survey time spent on this map area, including traversing, moving camps, and delays due to bad weather, was approximately seven days. The number of aircraft stops was twenty-four. Soils were described and sampled in detail in the vicinity of the two camps. On the Horton River map all traverses, aircraft stops and camp locations were marked in red to provide some idea of the sampling strategy and sampling density for this mapping methodology.

Table 5.1.1 Generalized Soil Landscape Attribute Classes and their Codes Used in the Extended Legend.

SOIL DEVELOPMENT

A Brown Chernozemic
B Dark Brown Chernozemic
C Black Chernozemic
D Dark Gray Chernozemic or Dark Gray Luvisolic
E Gray Brown Luvisolic
F Gray Luvisolic
G Brown Solonetzic
H Dark Brown Solonetzic
I Brunisolic Gray Luvisol
J Black Solonetzic
K Gray Solonetzic
L Melanic Brunisol
M Eutric Brunisol
N Sombric Brunisol
O Organic Cryosol
P Dystric Brunisol
Q Humic Podzol
R Regosol
S Static Cryosol
T Turbic Cryosol
U Gleysolic
V Ferro Humic Podzol
W Humo Ferric Podzol
X Fibrisol
Y Mesisol
Z Humisol
2 Folisol

Water Occupance (Decile)

Active Layer Depth (CM)

Coarse Fragment (Percentile)

NON-SOIL MATERIALS

R1 Soft Rock Undiff.
R2 Hard Rock Acidic
R3 Hard Rock Basic
R4 Hard Rock Undiff.

ICE CONTENT

L Low
M Med
H High

FERTILITY INDEX

CALCAREOUS CLASSES

0 Non
1 Weakly
2 Strongly
3 Extremely

WATER TABLE DEPTH

1 0-2m
2 2-3m
3 >3m
4 0-1m
5 1-2m

TEXTURE GROUPS AND TEXTURAL CODES FOR PARENT MATERIAL OR SURFACE

SD Sand Group Includes:
S Sand
LS Loamy Sand
FS Fine Sand
GS Gravelly Sand
VFS Very Fine Sand
LFS Loamy Fine Sand
LVFS Loamy Very Fine Sand
GLS Gravelly Loamy Sand
CB Cobbly

SL Sandy Loam Group Includes:
FL Fine Sandy Loam
SL Sandy Loam
GSL Gravelly Sandy Loam
CBSL Cobbly Sandy Loam

LM Loam Group Includes:
VL Very fine Sandy Loam
CBL Cobbly Loam
GL Gravelly Loam
CBGL Cobbly Gravelly Loam
GFL Gravelly Fine Loam
L Loam
SIL Silt Loam
GSIL Gravelly Silt Loam

CL Clay Loam Group Includes:
VCL Very Fine Sandy Clay Loam
CL Clay Loam
SICL Silty Clay Loam
SCL Sandy Clay Loam
GCL Gravelly Clay Loam

C Clay Group Includes:
C Clay
GSIC Gravelly Silty Clay
SIC Silty Clay
SC Sandy Clay
HC Heavy Clay

ROOTING DEPTH

0 0 - 15
1 15 - 75
2 75 - 150
3 > 150

DRAINAGE CLASSES

E Excessive
R Rapid
W Well
I Imperfect
P Poor
V Very poor

COMPACTED OR CONSOLIDATED LAYER

B Basal Till
C Compacted Mat. (Anthropogenic)
D Duric
F Fragipan
O Ortstein
P Placic
R Rock

GENETIC ORIGIN OF PARENT MATERIAL

A Alluvial
B Bog
C Colluvial
D Residual
E Eolian
F Fluvioglacial
H Marsh
L Lacustrine
M Morainal
N Fen
O Organic Undifferentiated
R Rock
S Swamp
T Anthropogenic
U Undifferentiated
W Marine

11 Fibric Sphagnum
21 Mesic Sedge
22 Mesic Woody Sedge
23 Mesic Woody Forest
24 Mesic Brown Moss
25 Mesic Spagnum
26 Mesic Moss Forest
30 Mesic Moss Forest
31 Humic Sedge
32 Humic Woody Sedge
33 Humic Woody Forest
34 Humic Brown Moss

PERMAFROST DISTRIBUTION

D Discontinuous
W Widely Spread
C Continuous

Patterned Ground

DEPTH TO COMPACTED OR CONSOLIDATED LAYER

1 0-50 cm
2 50-100 cm
3 > 100 cm

SURFACE FORM

Mineral Soils:
D Dissected
H Hummocky
I Inclined
K Knoll and Kettle
L Level
M Rolling
R Ridged
S Steep
U Undulating
V Veneer
T Terraced

Organic Soils:
B01 Bog Palsa
B04 Bog Domed
B05 Bog Polygonal Peat Plateau
B06 Bog Lowland Polygon
B07 Bog Peat Plateau
B08 Bog Northern Plateau
B09 Bog Atlantic Plateau
B13 Bog Basin
B14 Bog Flat
B15 Bog String
B16 Bog Blanket
B17 Bog Bowl
B18 Bog Slope
B19 Bog Veneer

F01 Fen Northern Ribbed
F07 Fen Shore
F08 Fen Collapse
F11 Fen Slope
F13 Fen Horizontal

M01 Marsh Estuarian High
M02 Marsh Estuarian Low
M06 Marsh Stream
M11 Marsh Shallow Basin
M14 Marsh Shore

S01 Swamp Stream
S03 Swamp Peat Margin
S04 Swamp Basin
S05 Swamp Flat

SLOPE LENGTH

1 0-100 ft
2 100-500 ft
3 500-1000 ft
4 >1000 ft

Slope %

1 1-3%
4 4-9%
10 10-15%
16 16-30%
31 31-61%
61 61+%

SOIL OR LANDSCAPE INCLUSIONS

A Acid Surface Soil
BL Blanket
BS Bedrock Soft
BR Bedrock Hard
C Clay substrate
CA Calcareous Surface Soil
D Sandy Marine Mat.
E Eroded Knolls
ES Eroded Slopes
G Sandy Lm. Morainal Mat.
GL Gleyed
ID Imperfect Drainage
L Melanic Brunisol
LI Lithic
LM Lm. Morainal Till
M Eutric Brunisol
ML Marine Clay Loam Mat.
MP Moss Peat
N Sombric Brunisol
O Organic
OC Organic Cryosol
OT Ortstein
P Dystric Brunisol
PD Poorly Drained
PP Poorly Drained Peaty
R1 Soft Rock Outcrop - Undifferentiated
R2 Rock OutCrop Acidic
R3 Rock OutCrop Basic
R4 Hardrock Outcrop - Undifferentiated
RD Rapidly Drained
SA Saline
SC Static Cryosol
SG Sandy Glaciofluvial
SP Steep
ST Stoney
T Till Substrate
TC Turbic Cryosol
TE Terric
V Veneer
WD Well Drained
WE Wind Erosion
X Fibrisol
Y Mesisol
Z Humisol
11 Fibric Sphagnum
21 Mesic Sedge
23 Mesic Woody Forest

Table [illegible] Extended Legend for Generalized Soil Landscape Maps.

POLY NUMB	AREA KM SQ	SOIL DEVL	TEXT GRP	ORIG PM	SURF FORM	SLP %	TEXT PM	CALC	DRAINAGE	SURF TEXT	WATR TABL COM LAY	DEP COM LAY	SLP LEN	SUBDOM SOIL DEVL	TEXT PM	ORIG PM	SURF FORM	SLP %	SURF TEXT	DRAINAGE	INCLUSION	INCLUSION	NONSOIL-DOM KIND ROCK	SURF FORM	SLP %	NONS KIND ROCK
105		W	SL	M	M	10	GSL	0	W	GSL	B	2	2	W	GSL	M	U	4	GSL	I	PD	BS				
106		R	CY	A	L	1	SIC	0	I	SICL				U	SI	W	L	1	L	W						
107		W	SD	F	U	4	GS		W	GSL			2	U	GS	F	U	4	GSL	P	ID					
108		W	SL	M	U	4	GSL	0	W	GSL	B	2	2								ID	O				
109		W	SL	M	U	4	GSL	0	W	GSL	B	2	2	W	L	M	M	4	SL	I	PD					
110		W	SD	F	U	4	GS	0	R	GSL			2													
111		W	SD	F	U	4	GS	0	R	GSL			2	R	GS	L	L	1	SL	W	O	I				
112		W	LM	M	M	4	GL	0	W	GL	B	2	2								ID	LI				
113		W	LM	M	M	4	GL	0	W	GL	B	2	2								ID	LI				
114		W	LM	M	U	4	GL	0	W	GL	B	2	2								ID	LI				
115		W	LM	M	M	4	GL	0	W	GL	B	2	2								ID	LI				
116		W	LM	M	M	4	GL	0	I	GL	B	2	2	U	GL	M	M	4	GL	P	WD	O				
117		F	CL	M	U	4	CL	0	I	L	B	1	2	U	CL	M	U	1	L	P	WD					
118		W	CL	M	U	4	GCL	0	I	GL	B	2	2								WD					
119		W	CL	M	U	4	GCL	0	I	GL	B	1	2	U	GCL	M	U	4	GL	P	O					
120		W	SL	M	U	4	GSL	0	W	GSL	B	2	2	W	GSL	M	U	4	GSL	I						
121		W	CL	M	U	4	CL	0	I	L	B	1	2								PD					
122		U	CL	M	U	1	CL	0	P	L	B	1	2	F	CL	M	U	1	L	I	O					
123		W	SL	M	M	10	GSL	0	I	SL	B	2	2													
124		W	CL	M	M	10	CL	0	I	L	B	2	2													
125		W	CL	M	U	4	GCL	0	I	GL	B	2	2	W	GCL	M	U	4	GL	W	PD					
126		W	SL	M	U	4	SL	0	W	SL			2	U	SICL	W	L	1	SICL	P						
127		W	SL	M	M	10	GSL	0	W	SL	B	2	2	W	GSL	M	M	16	SL							
129		W	CL	M	U	4	SCL	0	W	CL	B	2	2													
130				R																			R2	U	4	
131				R																			R2	M	10	
132		W	SL	M	S	16	GSL	0	W	GSL	B	2	2													
133		W	LM	M	U	4	GL	0	W	GL				W	GL	M	U	4	GL	I						
135		W	SL	M	U	4	GSL	0	I	SL	B	2	2													
136		W	LM	M	U	4	GL	0	W	GL	B	2	2													
137				R																			R2	M	10	
138				R																			R2	M	10	
139		W	SL	M	M	16	GSL	0	W	GSL	B	2	2													
140		W	CL	M	M	10	CL	0	W	L	B	2	2	W	GCL	M	M	10	GCL	W	ID	WD				
141		W	SL	M	M	16	GSL	0	W	GSL	B	2	2													
142		W	SL	M	M	10	GSL	0	W	GSL	B	2	2	W	GSL	M	M	10	GSL	I						
143				R																			R2	M	10	
144		F	CL	M	M	4	CL	0	I	L	B	2	2	U	CL	M	U	1	L	P	O	WD				
145		W	SL	M	U	4	GSL	0	I	GSL	B	2	2								O					
146		W	CL	M	U	4	SCL	0	I	CL	B	2	2													
147		W	SL	M	U	4	GSL	0	I	SL	B	2	2	W	GCL	M	U	4	GCL	I	O					
148		W	SL	M	U	4	GSL	0	I	SL	B	2	2								PD	O				
149		W	SL	M	M	10	GSL	0	W	GSL	B	2	2	W	SCL	M	M	10	SCL	W	R2		R2	M	10	
150		W	LM	M	M	10	GL	0	W	GL	B	2	2													
151		W	CL	M	U	4	SCL	0	W	SCL	B	2	2								ID					
152		W	CL	M	U	4	SCL	0	I	SCL	B	2	2													
153		W	LM	M	U	4	GL	0	W	GL	B	2	2	U	GSL	M	U	4	SL	P	R2					
154		W	CL	M	M	10	SCL	0	W	SCL	B	2	2	U	GL	M	U		SL	P	O	ID				
155		W	SL	M	U	4	GSL	0	I	GSL	B	2	2	W	GL	M	U	10	GL	W						
156		W	LM	M	M	10	GL	0	W	GL	B	2	2	W	SCL	M	U	10	SCL	W	PD					

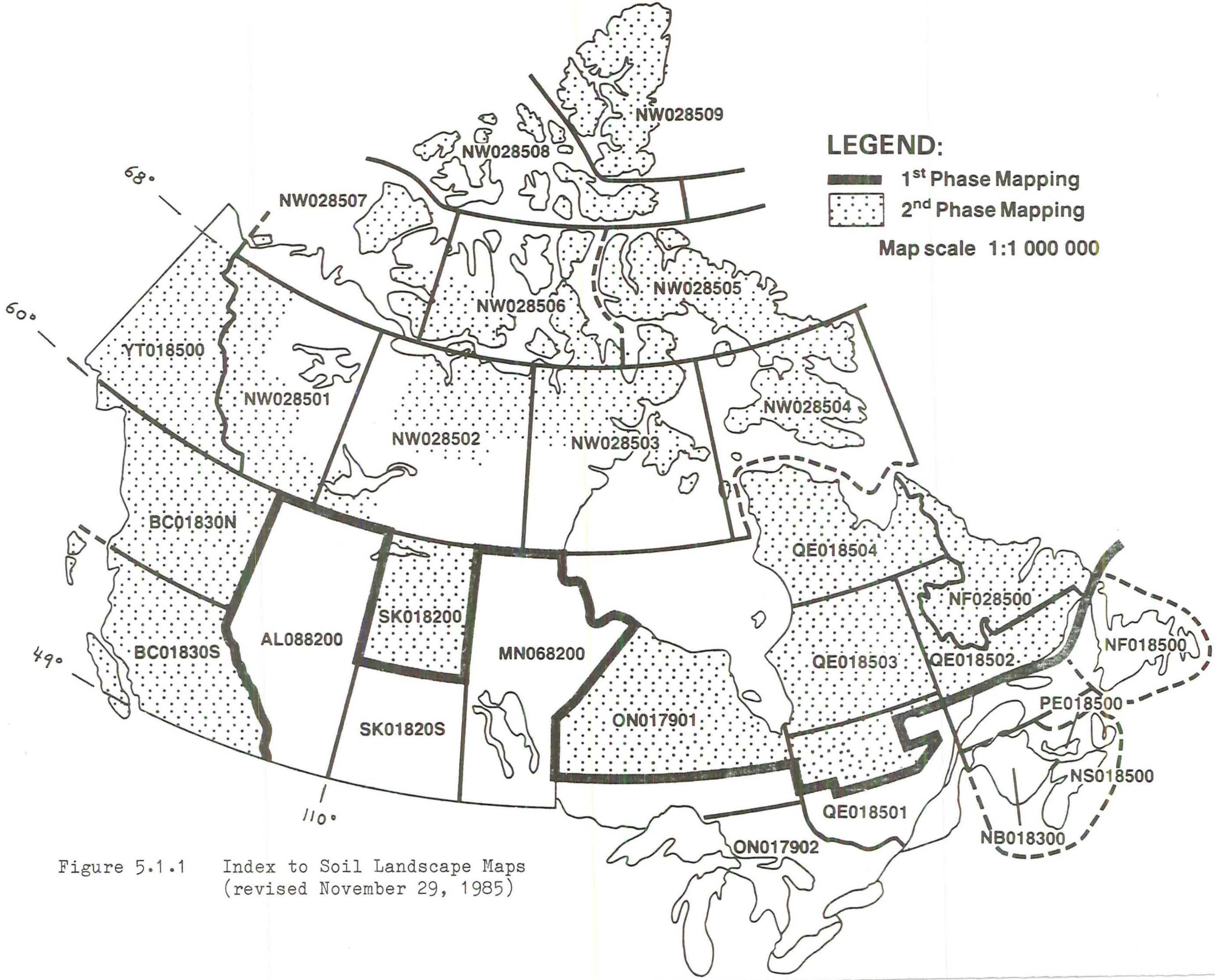


Figure 5.1.1 Index to Soil Landscape Maps (revised November 29, 1985)

MAP SYMBOL

	COMPONENTS		EXPLANATION
TOP LINE	indicates Dominant Soil Development and Texture of Parent Material	Ac1	Brown Soil (A) developed on clay loam (cl) textured material
MIDDLE LINE	indicates Parent Material Mode of Deposition, Surface Form and % Slope gradient	Mh4	Morainal material (M) with hummocky (h) surface form in slope class 4 (4-9%)
POLYGON NUMBER	a unique number for each map polygon (or delineated area)	150	Provides the linkage (or reference) to additional information provided in the Extended Legend of accompanying report[1]

OP LINE: DOMINANT[2] SOIL DEVELOPMENT AND TEXTURE GROUP[3] OF PARENT MATERIAL

A. BROWN CHERNOZEMIC SOILS ON:

Asl	sandy loam parent material
Alm	loam
Acl	clay loam
Acy	clay

B. DARK BROWN CHERNOZEMIC SOILS ON:

Bsl	sandy loam parent material
Blm	loam
Bcl	clay loam
Bcy	clay

C. BLACK CHERNOZEMIC SOILS ON:

Csl	sandy loam parent material
Clm	loam
Ccl	clay loam
Ccy	clay

H. DARK BROWN SOLONETZIC SOILS ON:

Hlm	loam parent material
Hcl	clay loam
Hcy	clay

K. GRAY SOLONETZIC SOILS ON:

Kcy	clay parent material

M. EUTRIC BRUNISOLIC SOILS ON:

Msd	sand parent material
Msl	sandy loam

R. REGOSOLIC SOILS ON:

Rsd	sand parent material
Rlm	loam
Rcl	clay loam
Rcy	clay

IDDLE LINE: MINERAL SOILS

SYMBOL	PARENT MATERIAL MODE OF DEPOSITION	SURFACE[4] FORM	% SLOPE	SYMBOL	PARENT MATERIAL MODE OF DEPOSITION	SURFACE[4] FORM	% SLOPE
Ad1	Alluvial	dissected	1-3	Md1	Morainal	dissected	1-3
Al1	Alluvial	level	1-3	Md4	Morainal	dissected	4-9
Au1	Alluvial	undulating	1-3	Md10	Morainal	dissected	10-15
				Md16	Morainal	dissected	16-30
Ed4	Eolian	dissected	4-9	Mh4	Morainal	hummocky	4-9
Eh4	Eolian	hummocky	4-9	Mh10	Morainal	hummocky	10-15
Eh10	Eolian	hummocky	10-15	Mh16	Morainal	hummocky	16-30
Eh16	Eolian	hummocky	16-30	Mk1	Morainal	knoll and kettle	1-3
				Mk4	Morainal	knoll and kettle	4-9
Fd1	Fluvioglacial	dissected	1-3	Mk10	Morainal	knoll and kettle	10-15
Fd4	Fluvioglacial	dissected	4-9	Mk16	Morainal	knoll and kettle	16-30
Fd10	Fluvioglacial	dissected	10-15	Mm4	Morainal	rolling	4-9
Fh4	Fluvioglacial	hummocky	4-9	Mm16	Morainal	rolling	16-30
Fh10	Fluvioglacial	hummocky	10-15	Mr1	Morainal	ridged	1-3

Figure 5.1.2 Map Symbol and Partial Legend.

5.2 CANADIAN GSLM CanSIS DATABASE: DATA ORGANIZATION AND APPLICATION

K. Bruce MacDonald
Land Resource Research Institute
Agriculture Canada

5.2.1 Introduction.

The GSLM project in Canada consists of a series of similar maps at various stages of completion across the country at scales in the range of 1:1M. It is important to note that there is not a complete consistency, but rather 'similar' maps, legends, and associated data sets, and a partial stage of completion both in terms of the number of maps and of the associated attribute data sets.

In may ways, the concerns and problems encountered in developing the Canadian GSLM project are similar to those which must be considered by this Working Group in developing a world soils & terrain database, and for that reason some of the Canadian experience (and examples both good and bad) may be of value in planning an international soils database project.

5.2.2 CanSIS - Canada Soil Information System.

The organization of data and structure of the map projects are influenced by the data system which will store and manipulate the data. This is particularly true in the case of the Canadian project.

The data system being used, CanSIS, consists of a relational database management system (RAPID) for site and attribute data and a custom developed vector-based cartographic system. The cartographic system currently stores the thematic lines and symbols for approximately 800 maps. The system was established in 1971 and is now an old system. CanSIS has evolved to incorporate some concepts of modern geographic information system, e.g. number labels for polygons and extensive attribute files. It has failed to accommodate such requirements as overlay, edge match, and geographic referencing.

The consequence of not having an overlay capability is that Canadian soil scientists have tended to produce combination map coverages which are detailed and complex. Usually, the analysis consists of simplifying the data to output only the attributes of interest. Because of this, boundaries are dissolved and the map simplified. With this approach there are no sliver areas resulting from the combination of inconsistent boundaries to resolve. Analysis is carried out on the extended legend, or attribute files, and is a database function. The only cartographic decision is whether or not to retain a boundary based on comparison of attributes on opposite sides of the line.

The lack of edge match capability to join adjacent map sheets has meant that the areas covered by map sheets for input must be chosen carefully to be the most useful areal representation possible. It has also been part of the justification for retaining a conventional cartographic unit to compensate for capabilities not present in the computer system.

The current system has, in fact, outlived its usefulness, and upgrades are now being planned to provide geographic referencing, standard transfer formats for output, edge matching, windowing, and overlay capability.

5.2.3 Essential Decisions for Map Computerization.

The following decisions must be considered in the process of computerizing the 1:1M Soil Landscape maps:

- To "freeze" the data at a point in time for the initial computerized form while recognizing that the system must make provision for the fact that
  a) spatial (areal) coverage was not complete;
  b) the attribute list would be increased;
  c) errors will be detected in both the line and attribute data and must be updated;
  d) the computer system is not completely adequate for all tasks and should be upgraded; and
  e) ways and timeframes must be agreed upon to augment or correct the data.

- To define the terminology so that both the conventional and computerized aspects of the project could be discussed unambiguously, e.g. such terms as a "compilation map sheet" were distinguished from a "cartographic data set" and from a published map. Also a legend was differentiated from an extended legend and a polygon attribute file.

- To organize and define computer formats for standard types of data with no redundancy. The data files used in the GSLM project include
  a) cartographic;
  b) standard soil properties and linkage keys (or indices) to associated data files;
  c) interpretive data sets which have less than complete coverage and, in some cases, do not use consistent definitions for all areas; and
  d) associated properties (e.g. census) to provide a non-cartographic overlay link to other data.

5.2.4 Application and Output Considerations.

Data requirements for soil geography interpretations and survey applications are familiar to the personnel compiling the maps. Consequently, these data must be incorporated into the attribute files to the extent possible. Nevertheless, it is important to ask questions about the probable types of data to be output. For example, questions relating to the distribution of dominant surface textures in a region are straightforward. But a question about the area associated with the various soil properties is more complicated since area is determined for the polygons but properties are usually defined on dominant and subdominant components of the polygons.

For many other applications, the soil landscape data will be used in combination with other types of information either in statistical summaries or in models. One of the main requirements of the data will be reliable information on the properties which affect crop growth frequently in conjunction with land evaluation studies. The properties required for modelling and land evaluation in a Canadian context may be summarized as follows:

a) National coverage of attributes describing land quality and availability (current and potential);
b) Photosynthetic variables, consistent with the FAO/LRRI crop productivity model;
c) Workability parameters, - probability of timely seeding and successful harvest;

d) Moisture stress factor, - extent to which agro-climatic and edaphic conditions restrict crop yields; requires data on:
   - crop sensitivity to water stress,
   - crop moisture requirements,
   - moisture deficit,
   - available water holding capacity, or
   - soil texture, coarse fragments, bulk density, depth to water table;
e) Topography - slope length, steepness and type of slope for estimating losses from erosion and effectiveness of conservation measures; and
f) Administrative units - census districts or groups of census districts.

For modelling and land evaluation the requirement is for actual soil properties rather than taxonomic groupings. Frequently, for crop modelling and land evaluation types of applications, the data will be used and manipulated at the level of the map polygon and then aggregated by other boundaries (political or administrative) for output. Consequently, it is important that the quality and reliability of soil landscape data be clearly documented because the user group may not be particularly familiar with the data and its appropriate applications.

5.2.5 Levels of Output.

In practical terms a soil database must be capable of output as follows/
a) in cartographic form (at various scales) or tabular form;
b) output on a subpolygon basis;
c) output at the polygon level;
d) output at administrative or political boundaries (implying capability to overlay with other boundaries);
e) aggregations of polygons by groupings of similar properties; and
f) broad single-valued regional summaries based on summation of polygon by polygon assessment.

5.3 SOIL RESOURCE INVENTORY OF PUNJAB USING REMOTE SENSING TECHNIQUES

Jawahar L. Sehgal and P.K. Sharma
National bureau of Soil Survey and Land Use Planning, India
R.L. Karale
Punjab Agricultural University

5.3.1 Abstract.

Landsat multispectral scanner (MSS) data in the form of black and white imagery were used to generate a soil map of Punjab covering an area of about 5 million ha. MSS bands 2 and 4 were interpreted singly and combined to form a composite interpretation map which, with field observations, was translated in terms of soils. The abstraction level attained was Great Groups of Soil Taxonomy.

The distribution of soils of Punjab, with Aridisols in the SW through Inceptisols in the Central zone, to Alfisols in the NE sectors suggests a strong geographic bias in their evolution. The major soils of the Aridic zone (SW sectors of the State) are: Camborthids, Calciorthids,

Torripsamments and Torrifluvents. The major soils of the Ustic zone (central Punjab) are: Ustochrepts and Haplustalfs (the most productive soils of the State), Ustipsamments and Ustifluvents. The salt affected soils are found interspersed with these soils. In the Udic zone (NE fringe), Hapludalfs, Eutrochrepts, Udifluvents, Udorthents and Hapludolls are the major soil formations.

The soil map reveals that about one-third of the total area of the state suffers from various soil problems, such as soil salinity and sodicity, water logging, and soil erosion. For increasing agriultural production, these soils need to be brought under the plough. The study leads to the conclusion that for precise macro level land use planning, the use of Landsat imagery is imperative.

5.3.2 Introduction.

Recent advances in remote sensing technology have opened new vistas in the mapping and monitoring of natural resources. Westin and Bradner (1980) successfully employed this technology for drawing a soil map of Pennington county, South Dakota, involving a total area of about 4000 km^2. Karale, Rao and Singh (1978) presented evidence to show that computer-aided remote sensing technology affords 10 times more efficiency for reconnaissance level mapping than does conventional survey methods.

In India the need for dependable soil maps of different states and the country as a whole has long been realised, but the progress made so far, based mostly on conventional techniques, calls for accelerating the pace of mapping with the help of modern efficient techniques. Sporadic attempts have been made to employ remote sensing techniques for soil mapping (Venkataratnam and Rao, 1977; Teotia, d'Horre and Gombeer, 1980; Manchando and Iyer, 1983; Karale, Bali and Rao, 1983). Experience suggests that this technology holds great promise for the preparation of a reliable soil map of the country in an highly efficient and cost effective manner.

5.3.3 Study Area.

The state of Punjab situated in the north-west of the country between 73°50' to 77°E longitude and 29°30' to 32°30'N latitude and covering a total of 50,330 km^2 forms a study area. It is a vast alluvial plain of recent age built up by the deposits of the Indus river system. It is bordered by the Shiwalik hill ranges in the North-East composed of Tertiary sedimentary formations, comprised mainly of sandstone. Varied physiographic processes seem to have been operative in the evolution of the landscape as expressed in the formation of Shiwalik hills, piedmont plain, river terraces, sand dunes, cover plain and flood plains.

The area is drained by rivers of the Indus system. The drainage density is high in the northeastern strip bordering Shiwalik, whereas it is moderate to low in the central and southwestern portions with subparallel and subdendritic patterns. The natural drainage in the southwestern sectors has been seriously obstructed by a number of man-made canals leading to problems of flooding, waterlogging and salinity. Climatically the area manifests zonality from moderately humid to arid qualifying for Udic, Ustic and Aridic moisture regimes in the northern fringe, Central region and southwestern plain adjoining Rajasthan, respectively (Sehgal, 1970). The rainfall and mean annual temperature variations in the State are 250 to 1200 mm and 21 to 25°C, respectively.

5.3.4 Materials and Methods.

Multidate (March/October 1984) black and white (BW) imagery in MSS bands 2 and 4 (Landsat 4) and false colour composites (FCC), generated from MSS bands 1,2,4, at a scale of 1:250,000, were employed for visual interpretation aided by magnoscope and hand-lens. Image interpretation was carried out following a stratified approach based on moisture regime. Three strata, viz. Aridic, Ustic and Udic, were first delineated on the imagery with the help of climatic data. Image manifestations in each stratum, though similar, may have different connotations in terms of soils, especially at Suborder/Great Group levels where moisture regime forms a criterion for differentiation. The relevant Landsat Path-Row numbers are 147-038, 147-039, 148-038, 148-039, 149-039. Colateral data in the form of published soil survey reports and maps, geological maps, Survey of India topographic maps and research papers were used as reference materials. Five sample areas representing most of the pedo-climatic zones and covering 10% of the State, fully illustrative of the various image manifestations, were chosen for field survey and investigations. Individual pedons were classified at the Subgroup level, and mapping was carried out at the Association of Subgroups/ Great Groups of Soil Taxonomy (Soil Survey Staff, 1975)

5.3.5 Results and Discussions.

5.3.5.1 Soil Map of Punjab.
Six main land forms viz., Shiwalik hills, piedmont plain, terraces (upper, middle, lower) sand dune complexes, channels and flood plains were delineated on BW, FCC and imagery. These were further subdivided based on the image characteristics. The physiographic units, their image characteristics and associated dominant soil groups are given in Table 5.3.1. The soilscape of each of the three strata (Arid, Ustic, and Udic zones are discussed hereunder.

1) Soils of the Arid Zone:
Typic Camborthids and Typic Calciorthids are the dominant soils in the upper terraces. Soils in the lower terraces and Satluj flood plain, which have fluctuating water table conditions, are salt affected and show prominent aquic properties in the subsoil; terrace soils qualify as Salorthids (Fluvaquentic) and Camborthids (Natraquic), whereas flood plain soils mostly qualify as Fluvaquentic Salorthids. Sand-dune soils are classified as Torripsamments (Typic, Thapto, Camborthidic) and Camborthids (Psammentic). The terraces with sand cover show Torrispsamments associated with Camborthids/Calciorthids.

2) Soils of the Ustic Zone:
The soils of the upper and middle terraces show the development of Cambic or Argillic subsurface horizons. Sodic soils occupying lower terraces have Cambic/Natric/Calcic horizons. These soils are classified as Ustochrepts (Typic/Udic/ Natraquic), Haplustalfs (Typic) and Natrustalfs (Aquic). In the dunal areas Typic Ustipsamments and Psammentic Ustochrepts are the dominant soil formations. However, in the interdunal areas and terraces with sand cover, in addition to these groups, Ustochrepts (Typic/Udic) are also encountered. The soils in the flood plains are highly stratified and qualify as Ustifluvents (Aquic/Typic) and Haplaquents (Aeric). Locally sandbars have Ustipsamments (Fulventic). In the salt-affected flood plains dominant soil formation is Natraquic Ustifluvent.
The soils in the piedmont plain are also young and stratified. Ustipsamments (Fluventic) represent dominant soils adjoining the hills. In the piedmont plain away from hills, Ustifluvents (dominant) associated with

Ustipsamments are common. In the hills the dominant soil groups are Ustochrepts (Typic/Udic) and Ustorthents (Typic). Locally, in the inter-hill areas Ustifluvents are observed.

3) Soils of the Udic Zone:
The soils in the hill tops/summits classify as Eutrochrepts with some Hapludalfs and Hapludolls. The eroded soils on the hill slopes are Udorthents. The soils in the flood plain and piedmont plain are Udifluvents/ Udipsamments.

5.3.5.2 Problem Inventory.
The BW imagery in conjunction with FCC facilitated precise demarcation of problem soils in the State. The arid zone is found to have problems of cover-sand, waterlogging and salinity related to a fluctuating, brackish ground water table. These are expressed in the soil formations of Torripsamments and Salorthids. In the Ustic moisture zone waterlogging and salinity-sodicity on lower terraces are clearly observed in the FCC. Erosion in the Shiwalik region is manifested both on MSS2 and FCC. The udic moisture zone shows a problem of soil erosion. The extent of the different problematic soils in the State as derived from the interpretation of satellite imagery, and comfirmed by field observations, is summarized in Table 5.3.1.

Table 5.3.1. Assessment of nature and area of problem soils of Punjab from interpretation of satellite imagery and confirmed by field observation.

Problem soils	Hectares (10^6)	Percent of total area of Punjab
Saline-sodic soils	0.784	16
Waterlogging areas	0.423	8
Salinity + waterlogging	0.336	7
Moderate to severe erosion	0.593	12
Sandy soils	1.019	20

From this study it may be concluded that the major salt affected pockets identified on 1965 BW Air Photos in the Kapurthala and Sangrur districts have diminished from 36475 ha to 22250 ha possibly attributable to reclamation programmes in the State. However, the overall area of salt affected soils, especially salinity, in the State has increased because of the development of salinity and sodicity in the SW districts in the past three to four years. This appears to be caused primarily by blockage of natural drains by man-made canals.

5.3.5.3 Efficiency of Mapping.
Time spent on different operations for preparation of the soil map of Punjab involving a total geographic area of about 5.03 million ha. is given below:

a) Imagery interpretation — 20 man days
- MSS bands 2,4, FCC
- Two seasons

b) Cartography — 40 man days
- Drawing of base maps
- Transfer of interpretation units
- Fair drawing
- Area measurements

c) Field work 250 man days
   - Sample areas
   - Random field checks

A total of 310 man days were needed to generate a reliable soil map of Punjab at a broad reconnaissance level. This corresponds to about 1.5 field party years assuming 200 days effective work in a year.
A conventional approach of field work for this area would necessitate 12.6 field party years with national norms of 400,000 ha per field party per year even at rapid reconnaissance level. Remote sensing technology, therefore, offers about eight times the efficiency of a conventional reconnaissance mapping system. This gives promise for a more efficient preparation of a soil map of India. The study also leads to the conclusion that for efficient data acquisition, particularly, for use in macro level planning, remote sensing technology is a most valuable tool.

5.3.6 References.

Karale, R.L., K.V. Seshagiri Rao and A.N. Singh. 1978. Evaluation of Landsat imagery for reconnaissance soil mapping. A.P. Appreciation Seminar, New Delhi.

Karale, R.L., Y.P. Bali and K.V. Seshagiri Rao. 1983. Soil mapping using remote sensing techniques. Proc. Indian Acad. Sci. (Engg. Sci.) 6:197-208.

Manchanda, M.L. and H.S. Iyer. 1983. Use of Landsat imagery and aerial photographs for delineation and categorization of salt affected soil of part of NW India. J.Ind. Soc. Soil Sci. 31:263-71.

Soil Survey Staff. 1975. Soil taxonomy, U.S. Dept. Agric., Agr. Handbook 436. U.S. Govt. Printing office, Washington, D.C.

Sehgal, J.L. 1970. Influence of climate on morphology, mineralogy and classification of the soils of Punjab. D.Sc. Thesis, State University. Ghent, Belgium.

Teotia, H.S., J.D'Horre and R. Gombeer. 1980. Soil and land use distribution over a part of North plains (Indo-Gangetic Plains9 of India, based on the optical interpretation of Landsat MSS Imagery. Pedologie 30:19-42.

Venkataratnam, L and K.R. Rao. 1977. Application of remote sensing techniques for soil studies; NRSA Document No. 22.

Westin, F.C. and T.M. Bradner. 1980. Use of Landsat data for soil and agricultural land use studies. Proc. 14th Int. Symp. on Remote Sensing of Environment of San José, Costa Rica. Env. Res. Ins., Michigan.

5.4 THE USE OF LANDSAT IMAGES AND SYSTEMATIC FIELD OBSERVATIONS IN PREPARING A SOIL MAP OF SYRIA

Mohammed K. ILAIWI
Soil Science Division
Arab Centre for the Study of Arid and Semiarid Lands

5.4.1 Introduction.

The soil map of Syria was completed by interpretation of satellite image followed by a systematic soil survey. Satellite images have been used extensively in the last ten years as base maps for national land resour inventory. Liang and Philipson (1977) stated that "in many areas for wh general maps are unavailable or poorly done, Landsat images provide excellent base maps". Landsat images were used in this study for the following reasons:

1) The lack of a complete airphoto coverage of the country;
2) The time required to interpret Landsat images is much shorter than that needed to interpret airphotos; and
3) Each image covers an extensive area (185 x 185 km) in which large physiographic regions are easily and completely traced.

5.4.2 Procedures.

The methodology used in preparing the soil map of Syria, is described under three categories: office, field and laboratory.

5.4.2.1 Office procedure

a) Images of 18.5 x 18.5 cm, black and white transparencies composed of bands 4, 5, 6 and 7 at a scale of 1:1,000,000 were simply interpreted by using a back lighted table. Whenever it was necessary, they were enlarged up to 4 times by using a scale changing overhead projector.
b) Visual interpretation was performed by using a colour additive viewer, 5.58 x 5.58 cm, black and white transparent Landsat images were available in four bands at a scale of 1:3,369,000. Each band was projected in one of the four colours by using flip-in colour filters to create a colour composite image. They were projected at a scale of approximately 1:1,000,000 onto a tracing glass surface. Colour intensity was adjusted by rotating the filter holders.
c) Overlays of clear plastic were prepared for each image where different units were delineated and numbered.
d) A transparent overlay for each image was prepared from a topographic map of the same scale, indicating towns, roads and other guiding features.
e) A table consisting of information about soils, geology, geomorphology and rainfall for each delineation was prepared from maps of the same scale (1:1,000,000).

5.4.2.2 Field procedure

The procedures described below were used for the field operations of the soil survey.

a) Aside from few bare rock localities and water bodies all units were traversed regardless of their accessibility.
b) The soils were examined in widely distributed observations along the conducted transects. The observations were made in vertical cross sections of pits. The depth to which the pits were examined generally ranged from 1 to 1.5 m. Shallower observations were made where there was bedrock at a shallower depth, and where experience had shown that a certain soil material has a regular pattern of vertical deposits and thus not necessary to be repeatedly and deeply exposed in the same unit. This case is particularly related to gypsiferous deposits of flat landscapes where compacted gypsum occurs below a shallow epipedon and extends to a great depth.
c) While the number of transects was determined by size and shape of units, the number of observations is rather governed by the complexity of the soil pattern.
d) Profile sites were chosen on the basis of soil variation (mainly toposequences). In many cases, where the relief changes rapidly in the same unit, the observations were duplicated or triplicated to represent the soils of different slope components.
e) The guidelines given by FAO (1977) were used to describe the soil profiles.
f) All horizons of the observed profiles were sampled for laboratory analysis. In addition, many other single samples were collected for classification purposes (e.g. organic matter, carbonate, gypsum, thin sections, etc...).

g) The soil association name was given to each unit in the field, immediately after having the work terminated. The area occupied by each member of the association was estimated. Their location in the landsape was also determined.

h) Notes on vegetation, land use, parent rock, physiography, slope, soil surface characteristics (e.g. stoniness, sandy layers, etc...) were recorded in the course of soil survey.

5.4.2.3 Laboratory procedure

Physico-chemical analyses were completed for 97 profiles. Sixty-three of these and 40 individual samples were analysed in the laboratories of the Soil Directorate, Damascus. Samples from the other 34 profiles were analysed in the Lincoln Laboratories of the U.S. Department of Agriculture. Mineralogical and micromorphological investigations were done mainly at the University of Ghent. Mineralogical analyses of 12 profiles were carried out at the laboratories of ORSTOM. These analyses and investigations were done according to the conventional methods used in the aforementioned laboratories.

5.4.3. References.

F.A.O., 1977. Guidelines for Soil Profile Description. Soil resource Development and Conservation Service, Land and Water Development Division, FAO, Rome.

5.5 THE CONCEPT OF AN INTEGRATED SOIL INFORMATION SYSTEM IN BELGIUM

J.F. Maes
Laboratory of Soil and Water Engineering
Katholieke Universiteit, Leuven

5.5.1 Introduction.

Experience in the field of soil science in Belgium goes back to the previous century. It started in 1849 with a comprehensive soil classification which was mainly based on geomorphological features. Later the soil research in Belgium extended to the domains of soil fertility, soil survey and soil cartography. The major break-through of soil research in Belgium occurred in the late 1940s with the survey of the soil patrimony of Zaïre and the establishment of a National Centre for Soil Survey in 1947. The objectives of the Centre were fourfold (1) the elaboration of a national soil mapping legend, (2) the characterization of the physical and chemical properties of the soil units, (3) a systematic and detailed soil survey (scale 1:5,000), and (4) the publication of a soil map at a scale of 1:20,000.

This ambitious project, which started in the beginning of the fifties is now almost completed. Ninety-seven percent of the Belgian territory is surveyed, with an augering density of around one per hectare. More than 3,000 maps on a 1:5,000 scale are available and 400 soil maps are published. The published maps are of high cartographic quality. Nearly 12,000 soil profiles have been described, sampled and analysed, and these data are on record.

During this period the understanding of the genesis, the geography and the morphology of our soil resources has grown. A considerable volume of this knowledge is published in articles, reports, fieldbooks and notes, and is available for future processing. Unfortunately a great part of the knowledge is constituted by the personal experience of soil scientists and surveyors, and is not stored in a lasting form. This information may be lost soon when most of those experts will retire with only a few being replaced because of the current economic situation.

Thanks to the survey of the Belgian territory at a very detailed scale an impressive amount of information and knowledge about our soils has been acquired. However, the basic inventory is now completed, and it is the challenging task of the coming generation of soil scientists to preserve this knowledge and to make it suitable for the ever changing needs of our society.

5.5.2 The need for automatic information processing.

Despite the efforts spent in the national survey the published soil maps are not being used as widely as would be desirable. The reasons are many.

The accessibility of the 1:20,000 soil maps for non-soil scientists is limited. This is due to the pronounced scientific and technical nature of the map legend and the limited ability of potential users to interpret detailed soil maps. Users need practical information about the behaviour of the soil resource for different types of land use and utilization potentialities. However, this information can not easily be derived from the existing maps.

The step following the inventory and systematization of the soil data is the interpretation. This phase was started at the time of the surveys. In recent years, it has been applied to establish soil suitabilities for some specific crops. The approach so far has been mostly empirical and the derived soil suitability classifications depend strongly on location and management. The results do not show causal relations and as a consequence results are difficult to extrapolate.

The use of soil data may also have been limited by the lack of a campaign to promote the use of the soil map, the non-existence of institutionalized soil consulting services and the scale of the publication, which does not correspond with the scale of other natural resource maps.

The Belgian soil survey was set up in the fifties, long before the availability of the computer. Today several generations of computers have evolved, and digital information processing has been introduced in geo-sciences. Simulation programs, data bases, statistical software packages and geographic information systems are becoming more widely available for soil scientists. In addition, techniques such as knowledge processing are quickly coming of age. Furthermore, new land evaluation methodologies, more analytical in nature, have been developed. They offer new perspectives for the interpretation and more intensive use of the existing source of valuable soil data.

The realization of the value of the soil survey data requires the use of new techniques and interpretation procedures. Only then can restrictions in the current use of soil survey data be overcome and the way paved for new multidisciplinary land evaluation approaches. However, integrated information processing is necessary to achieve this goal.

5.5.3 Statistical Analyses.

In the framework of the soil survey of Belgium, about 12,000 soil profiles were described, sampled and analysed. The individual data are stored in a data base which contains over 2 million figures. The data have been summarized and analyzed using available statistical packages. For example summary statistics have recently been used to characterize the soil series texturally, physicochemically and chemically. Combined with continuous ongoing field research, the analyses of the data base open the perspective to correlate the soil series with soil physical characteristics such as hydraulic conductivity, moisture content and soil moisture curves which were not previously measured. Preliminary results do indicate that a considerable proportion of the total variability in soil parameters (between 50 and 70%) is explained by the soil units.

5.5.4 Geographic Information Processing.

Historically two different approaches for the processing of geographic information developed almost simultaneously. In the vector approach geographic entities are located by the coordinates of characteristic points in a continuous defined space. Vectorial data bases consist mainly of lists of coordinates linked to attributes. The vector approach dates from the early 1960s (e.g. The Canada Geographic Information System). Vector processing was predominant in Computer Aided Cartography (CAC). Vectorial approaches have been shown to be useful for simple digitization methods and the drawing of thematic maps based on generalization and reclassification techniques.

The second geographic information processing method, raster-processing, is more recent and developed mainly in the field of remote sensing and pattern recognition, partly as a result of the rapid growth of raster hardware. A map or picture is divided into a large number of grid cells, pixels (picture cells). The use of these systems, called image processing systems, is increasing rapidly. Especially the overlay, the superposition of different geographic resources, is relatively easy to perform in raster format. In addition many raster based algorithms are straight forward and easy to program.

The specific advantages and disadvantages of raster and vector processing make the conversion between raster and vector format interesting. Without going into detail it can be stated that the raster to vector conversion, the rasterization, is quite simple and can be fully automated. The inverse way, the vectorization, is much more complicated. Extensive software is often needed, the computer time required is voluminous and manual interaction of an operator is frequently necessary. With regard to the Belgian soil maps, automatic geographic information processing offers several possibilities: (1) automatic drawing of generalised as well as thematic maps, (2) correction and updating of the soil inventory, (3) correlation and combination of soil data with other natural resources maps for integrated and multidisciplinary land approaches. Both raster and vector methods are highly complementary to achieve these goals.

5.5.5 Simulation.

Many simulation models, such as water balance models and plant growth models, are operational and often validated for specific conditions. These models are important instruments for defining land qualities (assessment factors), which are considered as the keys for evaluation procedures.

Simulation models will become increasingly important in soil suitability and land evaluation research. Therefore a flexible access to geographic information data bases for both soil scientists and users is highly recommended.

5.5.6 Expert Systems.

Expert systems are knowledge based computer techniques for consultation and problem solving. They accomplish tasks for which human expertise normally is necessary and help the user in solving specific problems. In an expert system, knowledge is transformed into a digital form. In contrast with 'classic programming', knowledge is not incorporated into the program structure but stored in a separate 'knowledge base'. By this the degree of complexity can be avoided and difficulties in adding information (knowledge) are overcome. The knowledge base can be further used for interpretation and problem solving, by applying inferential techniques. Expert knowledge of soil surveyors and scientists is suitable for storage in a knowledge base, after which it will be preserved and available for future applications. Even if that does not entirely meet all our expectations, the potential capability of expert systems should be a stimulus for synthesizing and recording expert knowledge. Nevertheless, it is expected that expert systems will be an interesting technical tool in the field of soil science and land evaluation.

5.5.7 The Necessity of an Integrated Soil Information System.

When evaluating these new information processing tools and techniques it is realized that many of those will be very suitable for the validation of existing, not yet used soil information. Moreover, they seem to be very complementary. Statistical techniques will always be necessary for summarizing the vast amount of available soil data but will also, together with the output of simulation models and expert knowledge, be useful to upgrade land characteristics to land qualities. The matching of land qualities to crop requirements finally will result in land evaluation for a specific kind of land-use. Results of this land evaluation can be graphically represented by making use of geo-information processing. Vector based procedures can be used for relatively simple digitizing work. The resulting vectorial database can be used for cartographic purposes and/or converted into a raster format, making the overlay of the soil data with other natural resources feasible. This approach allows for an interdisciplinary and dynamic evaluation of our land by which the impact of certain decisions can be tested.

To realise these objectives work should be directed toward the physical and logical integration of the different techniques and interpretation methodologies described above.

5.6 UNE BANQUE DE DONNEES DE SOL DE LA TUNISIE

Mohamed C. Derouich
Direction des Sols
Ministère de l'Agriculture de Tunisie

5.6.1 Introduction.

Les principales activités de la Direction des Sols en matière de cartographie pédologique se traduisent par des études à des échelles différentes (variant du 1:500.000ème au 1:10.000ème) et ce pour cause d'inventaire des sols du pays ou pour répondre à des projets d'aménagement agricole.

Au cours de leurs études et projets, les pédologues collectent des données descriptives et des observations relatives à un grand nombre de sites dans de nombreuses zones où l'environnement est différent. Ces données représentent par conséquent la plus large base de données orientées systématiquement et scientifiquement.

Cependant, le mode de présentation et de conservation de ces données sous forme de rapport et de carte n'est pas de nature à faciliter la tâche des utilisateurs et ce, tant au niveau de la recherche qu'à celui de la planification ou de la vulgarisation. En effet, une grande quantité de données sont égarées ou laissées de côté au cours des transferts ou lorsque le volume de données devient considérable.

C'est en prenant conscience de ces problèmes que la Direction des Sols a jugé nécessaire d'établir un système de banque de données-sols.

5.6.2 Historique.

C'est à partir de l'année 1976, après une visite des banques de l'ORSTOM, de l'INRA et de la SOGREAH que Messieurs Ahmed Souissi et Abderrahman Mami ont pensé à la création d'une banque de données de sol.

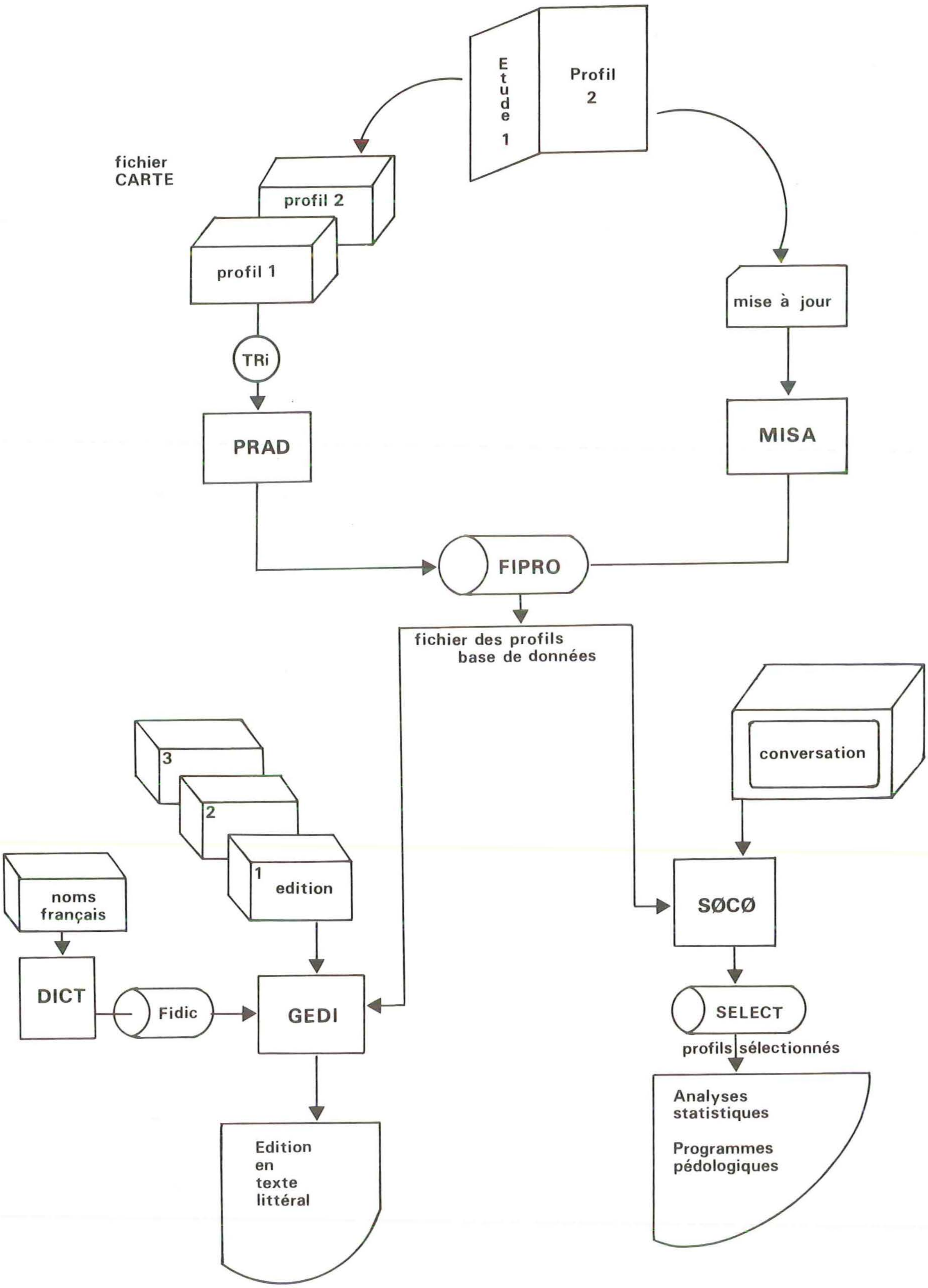
Le projet a démarré avec la collaboration de l'ORSTOM, puis avec celle d'Informatique et Biosphère. Cette dernière travaille, comme nous, dans le cadre du projet RITDS (Réseau International de Traitement des Données de Sols).

Sans décrire les différentes étapes de la constitution de la banque, on se limitera dans ce qui suit à évoquer les principales fonctions de cette banque.

5.6.3 Principales Fonctions d'une telle Banque.

Toute banque de données commence par une analyse de l'existant, de ce que l'on veut faire et des buts que l'on se propose d'atteindre.
Les principales fonctions de cette banque de données-sols sont (cf fig. 5.6.1):

a) L'acquisition des données-sols:
   Elle se fait à l'aide d'une fiche de terrain et un glossaire et d'une fiche de laboratoire. Ces fiches permettent une saisie immédiate des informations sans que le pédologue n'ait à les retranscrire sur bordereaux.



PRAD - Programme d'enregistrement des descriptions de sols.
FIPRO - Constitution du fichier de profils.
DICT - Constitution du dictionnaire des mots utilisés.
GEDI - Edition en français de la description des profils

MISA - Mise à jour de FIPRO.
SØCØ - Programme d'interrogation du fichier de profils FIPRO.

Figure 5.6.1. Schéma général de la Banque.

b) La gestion de l'information:
Elle se fait grâce à un ensemble de programmes:
- Deux programmes d'enregistrement des descriptions sur disque:
  1.PRAS: Profils Accès Séquentiel. Ce programme lit les cartes de description des profils dans l'ordre croissant de leur numérotation. Il décode les signes perforés et enregistre sur disque les valeurs des variables décrites. Ce programme n'est utilisé qu'une seule fois, lors de la création de la base de données.
  2.PRAD: Profils Accès Direct. Ce programme joue le même rôle que PRAS. Il enregistre les profils, non pas séquentiellement, mais par un accès direct sur disque.
- Un programme de mise à jour MISA, qui permet de rectifier les erreurs, d'ajouter ou de retrancher de l'information.
- Un programme de vérification des données VERI, qui teste aussi la validité de remplissage de la fiche.

c) Exploitation des données:
Les programmes d'exploitation se composent essentiellement d'un programme d'édition en texte français clair de l'information contenue dans la banque et d'un programme de sélection de cette information. Un programme préliminaire permet la constitution des dictionnaires nécessaires à l'édition.
- DICT (programme dictionnaire). Ce programme permet de lire les cartes, les noms français et crée deux fichiers séquentiels indexés;
- FIDIC pour les noms figurés usuels;
- FICØ D pour les noms propres.
Chaque mot est associé à un code numérique qui permet de le retrouver facilement.
La constitution de ces fichiers, indépendamment de tout autre programme, permet de transformer la fiche sans changer la logique des programmes (ex: édition dans d'autres langues).
- GEDI (General Edition). Ce programme compose l'édition d'un sol à partir des données qui ont été introduites dans la banque de données. L'utilisateur de ce programme peut choisir les profils qu'il désire éditer, les chapitres (ensemble de variables se rapportant à un même thème) qui le concernent, le format de sortie et la composition de l'édition.
- SØCØ (Sorties Conditionelles). Ce programme se propose de répondre aux questions les plus variées des pédologues. Il permet d'établir la conversation avec l'ordinateur. En effet, il ne suffit pas de collecter des données, mais il faut pouvoir ensuite tirer ces données pour en extraire des informations. Il ne faut pas s'attendre à résoudre toutes les questions des pédologues, mais néanmoins, une grande partie de celles-ci pourrait être résolue. Ce programme est en cours de réalisation.

En plus de ces programmes fonctionnels (sauf le dernier SØCØ qui est en cours de réalisation) déjà sur deux systèmes différents, on pourrait imaginer d'autres très utiles tels que la cartographie automatique, positionnement des échantillons sur le triangle de texture, sortie d'un schéma de profil, etc...

5.6.4 La Banque de Données Cartographiques.

Cette option n'est, pour le moment, qu'un désir et nous comptons beaucoup sur la collaboration des pays participants avec la Tunisie pour pouvoir créer cette banque.
La création d'une telle banque est d'un intérêt incontestable. En effet, elle va nous permettre non seulement de sauvegarder les cartes

(pédologiques, de ressources en sols, d'aptitudes culturales, etc.) qui constituent un potentiel scientifique important, mais aussi de répondre rapidement à des projets d'aménagement et d'évaluation des ressources agricoles à l'échelle nationale ou internationale.
D'autre part, nous savons que la réalisation d'une telle banque est étroitment liée à la nature de l'information contenue dans la base des données pédologiques. Cette dernière étant fonctionnelle en Tunisie ce qui va faciliter la création de cette banque cartographique.

5.6.5 Conclusion.

Les avantages que présente la création d'une banque de données de sols sont évidents. Elle permet en effet une collecte des données par l'intermédiaire des fiches de terrain et de laboratoire.
Ces données, une fois stockées, peuvent constituer un potentiel scientifique important: un certain nombre de tâches pratiques telles que les annexes des rapports pédologiques, peuvent être faites automatiquement et rapidement.

Cependant, certaines difficultés apparaissent au fur et à mesure qu'on avance dans ce domaine.
Tout d'abord, la banque est implantée sur du matériel informatique n'appartenant pas à la Direction des Sols, ceci implique certaines restrictions: espace ou capacités insuffisantes, absence de certains logiciels de traitements particuliers, manque de spécialistes etc...
D'autres difficultés ne valent pas moins notamment le temps à mettre pour le remplissage des fiches de terrain ou la nécessité d'employer un personnel spécialisé.

Malgré cela, notre banque de données est fonctionnelle et elle nous rend beaucoup de services. Nous espérons la développer encore et la rendre plus utile.

5.6.6 The Soil Data Bank for Tunisia. (Summary)

Realizing the wealth of information on soils being collected from a large number of sites in various environmental zones in Tunisia, and also realizing the danger of loss of information in the process of transfering this information into reports and thematic maps for a non-specialised public, the Soil Department of the Ministry of Agriculture of Tunisia intitiated late 1976 the establishment of a soil data bank within the framework of an International Network on Soil Data Treatment (Réseau International de Traitement des Données de Soil, RITDS).

The Soil Data Bank at present allows for rapid acquisition of soil data with the help of specially prepared record forms for field descriptions and laboratory data. Profile descriptions can be input sequentially or directly on disc. Errors, adjustments or deletions of data can be handled as well as data verification of already stored as well as newly added information. In order to use the stored information from the above mentioned records, programmes have been prepared to edit the data into clear french language. Sequential files are created - one with popular names, one with proper names - which allow transformation of a record without changing the logic of the programme. The user can select from the data bank those soils he is interested in, but also certain combinations of variables among soils he is concerned with. Presently a new programme is being developed that permits direct conversation between the user and the computer on various soil related questions.

The Soils Department realizes the undeniable value of a digitized cartographic database. It will not only safeguard existing maps of various kinds, but this database will also allow rapid response to questions from agricultural development and evaluation projects. Despite the evident advantages of the creation of a soil data bank certain difficulties should be mentioned, partly affairs which are not directly related to the activities of the Soils Department, such as lack of space, computer capacity, and unavailability of information specialists, partly a direct concern of our Soils Department, such as time required to update the special recording forms and the need to employ personnel for this job. Despite these difficulties our data bank is operational and provides us lots of services. We hope to develop it further to make it even more useful.

5.7 STATUS OF SOIL RESOURCES INVENTORY IN ARGENTINA. FACILITIES TO IMPLEMENT THE WORLD 1:1,000,000 SOIL RESOURCES INVENTORY

Carlos Scoppa
Instituto Nacional de Technologia Agropecuaria
Argentina

5.7.1 Introduction.

In Argentina the soil survey and classification work began in the 40s as a set of observations. Small surveys were carried out with different intensity on various regions of the country. The result was a map of the whole territory performed at a scale of 1:2,500,000 in 1962 and brought up to date in 1967. The soils were classified according to the 7th Approximation in use at that time. However, the real development of soils inventories through systematic survey began in 1965 when the National Institute of Agri-Livestock Technology (INTA) launched the semi detailed (1:50,000) soil survey of the most important agricultural region of the country. In a first step an aerophotographic survey of the whole area (55,000,000 hectares) was performed, an important number of specialists were trained and the required facilities and equipment were prepared.

5.7.2 Classification System Used.

The taxonomic system of classification adopted was the 7th Approximation and further amendments, and later on the Soil Taxonomy which is now the official classification system applied to all the inventories in the country. The support given by the laboratory work is also significant (35,000 samples analyzed) including all the determinations required by the taxonomy.

5.7.3 Range of Scale of Argentina Soil Survey.

Later on and jointly with the Pampean Region inventory other important inventories were and are being performed at different intensities over wide areas of the country. These range from detailed soil surveys (>1:50,000) up to 1:500,000, the scales being selected according to the ecologic characteristics and the agricultural importance of each area.

The detailed and semi-detailed surveys (generally >1:500,000) include only the soils inventory as others at lower intensity ($\leq$ 1:500,000) also include other natural resources (climate, geomorphology, vegetation, hydrology, etc.). This type of integrated inventories are carried out in regions showing evident limitations (generally extreme aridity or strong topography) and where the planning and management of the environment as a whole and not of a single resource becomes necessary.

5.7.4 Status of Soil Survey in Argentina.

The surface surveyed at different scales of intensity is shown in Table 5.7.1 and the growth (in hectares) through the years in figure 5.7.1. It can be observed that of the total surface of Argentina, including agricultural land, a significant part is already inventoried. Besides, in 1976 the determination of moisture and temperature regimes of the soils was done using the Neshall's model on the basis of the records of some 300 meteorological stations. Figure 5.7.2 is an example of data recorded at each meteorological station.

The great amount of knowledge and information available and the delay in publication demand the use of computers to develop a geographical information system capable of updating and rapid information delivery to meet present requirements for information. The facilities indicated in Table 5.7.2 are available and could be used for the project of the digitized world map at a 1:1,000,000 scale and the annex data base.

On the other hand, these facilities jointly with the aerophotographic materials, imagery, CCT, etc. support the task in the region corresponding to the southern portion of South America as expressed in the discussion paper prepared by Dr. Sombroek.
Argentina would then aspire to receive qualified advice through well known specialists to develop its own system of geographical information which must include digitized mapping.
As the need for global soils and terrain digital data base no doubt exists, it has to be done, and this project could be an opportunity to develop and implement a system to meet the present requirements in the whole world.

Table 5.7.1. Status of Soil Resource Inventories (SRIs) in Argentina.

I: Argentina. Total Land Surface ha	Area covered by SRIs at different scales: *) (1983 estimate) 1:1,000,000	1:1,000,000 to 1:500,000	> 1:100,000	
279,181,000	75,347,000	190,213,000	44,263,913	ha
(100)	(27)	(78)	(16)	%
II Agricultural Land.				
77,350,000	-	-	44,263,913 ha(=57%)	
Pampean region				
55,000,000	-	-	30,000,000 ha(=55%)	
Other regions				
22,350,000	-	-	14,263,913 ha(=63%)	

*) Total area covered by SRIs at different densities as of late 1985: 439,797,200 ha.

Table 5.7.2. Facilities in Argentina available to support an international project.

Hardware

Image processor IP 8.500 "Gould":	Computer VAX 730:
- 5 memories 512 x 512 x 8 bytes and with capacity until 20 memories.	- Memory 2 megabytes
- 2 video output controls.	-2 dick storage of 205 megabytes; possibilities 24 disks.
- Video signal digitizer.	- Floating tape drive point processor.
- TV monitors. Color and b/w.	- Terminals.
- Trackball.	- Printonix of 600 l.p.m.
- TV camera (50 mm vivitar).	

Software

LIPS (Library of Image Processing Software)
ELAS (Earth Resources Laboratory Applications Software).

Staff

- Pedologist, Cartographers, Chemists, etc., seniors and juniors in different experimental stations and universities around the country.
- 2 Senior computer scientists.
- 1 Pedologist with training (MS) in digital image processing.
- Computation Department: 20 specialists, 6 of them could work supporting the program.

Organization

Building, laboratories, technicians around the country. 35 Experimental stations and 250 Extension agencies.

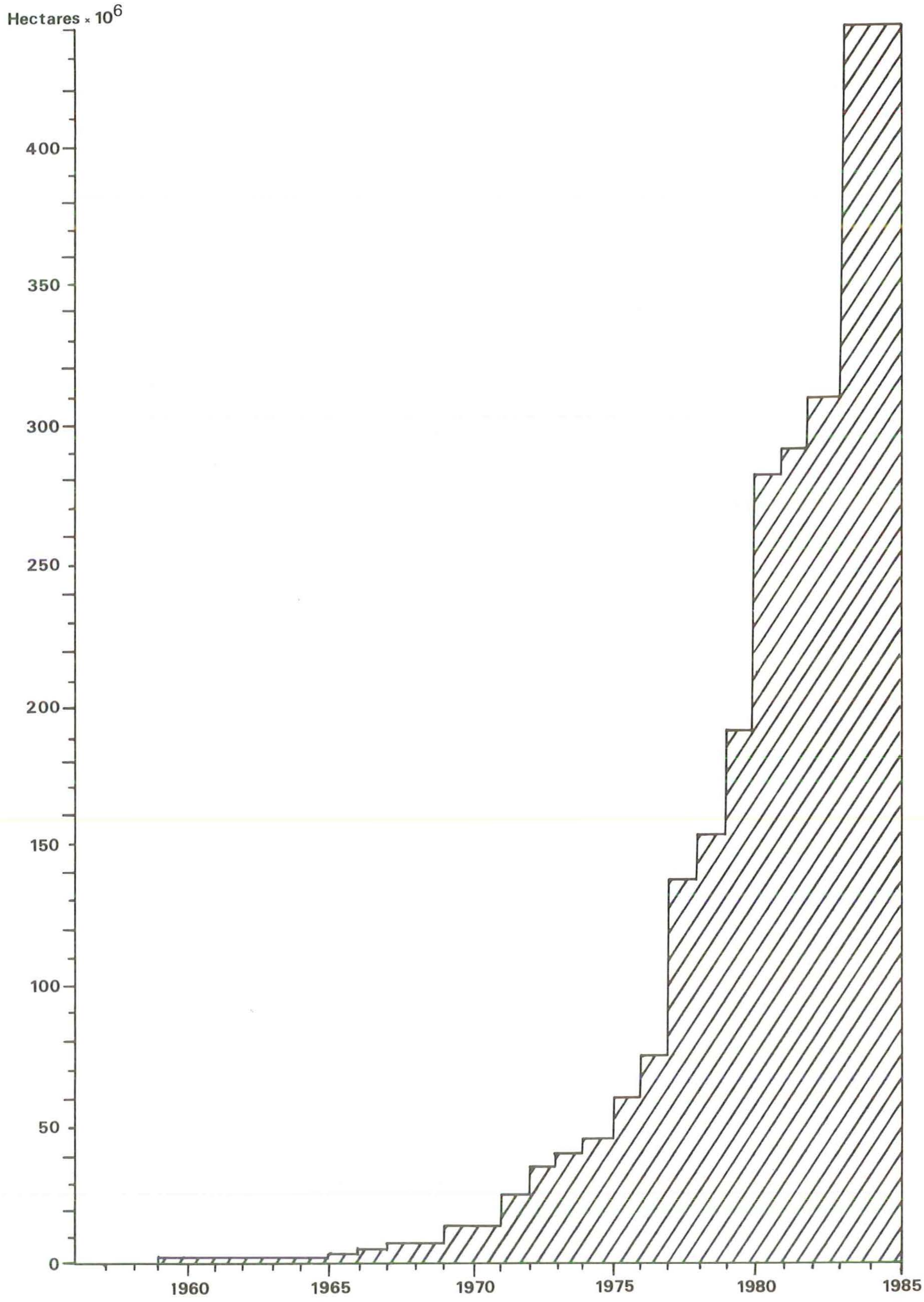


Figure 5.7.1. Growth of the Soil Resource Inventory in Argentina, since 1959 (foundation year of the Institute Nacional de Technologia Agrapecuaria).

STATION: BALCARCE HEMISPHERE: S

INPUT DATA:	JAN	FEB	MAR	APR	MAY	JUL	JUL	AUG	SEP	OCT	NOV	DEC
PRECIPITATION:	78.0	87.0	95.0	74.0	54.0	52.0	50.0	54.0	62.0	67.0	64.0	81.0
EVAPORATION:	115.0	94.0	81.0	50.0	35.0	20.0	21.0	26.0	37.0	56.0	80.0	107.0
TEMPERATURE:	20.7	19.7	18.0	13.3	10.5	7.8	7.5	8.4	10.3	13.2	16.5	18.4

ANNUAL RAINFALL: 818.0 mm ANNUAL EVAPOTRANSPIRATION: 722.0 mm.

SOIL TEMPERATURE REGIME AT 50 cm DEPTH ESTIMATED FROM AIR TEMP.DATA
BY ADDING 2.5 c TO ANNUAL MEAN AND REDUCING AMPLITUDE BY A FACTOR 0.66.

```
***************************************************************************
*  MEAN SOIL TEMPERATURES  *  SEASONS WHEN SOIL TEMPERATURE *             *
*  (DEGREES CENTIGRADES)   *       IS HIGHER THAN           *             *
****************************  FIVE DEGREES * EIGHT DEGREES  *  REGIME     *
*                     DIF- *               *                *             *
*ANNUAL SUMMER WINTER FEREN*************************************************
*                      CE  * BEGIN  LENGTH * BEGIN LENGTH   *             *
*                          *        (DAYS) *       (DAYS)   *             *
*                          *               *                *             *
* 16.2   20.1   12.4   7.7 *           360 * 16 AUG  312    *   THERMIC   *
***************************************************************************
```

SOIL TEMPERATURE CALENDER (-: T<5 ; 5: 5<T<8 ; 8: T>8) DAYS 1-------- 11-------- 21-------30	MONTH	MOISTURE CONDITION CALENDER (1=DRY 2=PARTLY DRY 3= MOIST) DAYS 1-------- 11-------- 21-------30
8888888888 8888888888 8888888888	JAN	3333333333 3333333333 3333333333
8888888888 8888888888 8888888888	FEB	3333333333 3333333333 3333333333
8888888888 8888888888 8888888888	MAR	3333333333 3333333333 3333333333
8888888888 8888888888 8888888888	APR	3333333333 3333333333 3333333333
8888888888 8888888888 8888888888	MAY	3333333333 3333333333 3333333333
8888888888 8888888888 8888888555	JUN	3333333333 3333333333 3333333333
5555555555 5555555555 5555555555	JUL	3333333333 3333333333 3333333333
5555555555 5555588888 8888888888	AUG	3333333333 3333333333 3333333333
8888888888 8888888888 8888888888	SEP	3333333333 3333333333 3333333333
8888888888 8888888888 8888888888	OCT	3333333333 3333333333 3333333333
8888888888 8888888888 8888888888	NOV	3333333333 3333333333 3333333333
8888888888 8888888888 8888888888	DEC	3333333333 3333333333 3333333333

```
***************************************************************************
*NUMBER OF CUMULATIVE DAYS THAT * HIGHEST NUMBER OF CONSE- *              *
*THE MOISTURE CONTROL SECTION   * SECUTIVE DAYS THAT MCS IS*              *
***********************************************************               *
*DURING ONE YEAR*WHEN SOIL TEMP.* MOIST IN *  DRY  * MOIST *  MOISTURE    *
*     IS        * ABOVE 5 DEG.  *SOME PARTS* AFTER * AFTER *              *
***********************************************************   REGIME     *
* DRY MOIST MOI * DRY MOIST MOI * IN   WHEN* SUMMER* WINTER*              *
*      OR    ST *      OR    ST * ONE  TEMP*  SOL- *  SOL- *              *
*     DRY       *     DRY       *YEAR    8 * STICE * STICE *              *
***************************************************************************
*  0    0   360 *  0    0   360 * 360 * 312*   0   *  120  * UDIC         *
***************************************************************************
```

COMPUTED BY FORTRA PROGRAM VW08, MARCH 1976 DATE: 14/05/76
NOT FOR PUBLICATION

FIGURE 5.7.2. DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA,1974) USING FRANKLIN NEWHALL SYSTEM OF COMPUTATION

5.8 THE COMPUTERIZED LAND RESOURCE INVENTORY OF TROPICAL AMERICA

Thomas T. Cochrane
Centro de Pesquisa Agropecuaria dos Cerrados (CPAC)
(Convenio EMBRAPA-IICA)

5.8.1 Introduction.

In the past, scant attention was paid to the influence of environmental (soil-climate) differences on food crop production in the tropics. Recently Metz and Brady (1980) stated "The Green Revolution has failed to fulfill expectations in most areas of the world. Yields and production levels are only a fraction of those predicted when the new high-yielding varieties were released in the 1960s. There is a growing recognition that environmental factors are largely responsible for this failure of new crop varieties to live up to expectations." In other words, many cultivars of crops which performed well in one tropical soil-climate environment, often did poorly in another.

CIAT[1] in collaboration with EMBRAPA-CPAC[2], and with the goodwill of the Ministries of Agriculture of most Latin American countries, started a continental-wide land resource inventory in mid-1977 to meet the growing concern expressed by many scientists, with the apparent anomalies in performance of so-called "improved" varieties of tropical crops when grown in locations away from where they were originally developed. Consequently from the outset, the inventory was to provide a geographical agroecological base to guide crop selection and breeding priorities, and choose representative field sites to test potentially higher yielding or disease-resistant crop cultivars. Further, it was to help identify areas where germ plasm-based agrotechnology specific to, or advantageous in, given climate, landscape and soil conditions, might successfully be transferred. By mid-1981 the inventory in a computerized database form, covered some 1000 million hectares, including a large part of the lowlands of tropical South America, parts of Central America and the Gulf Coast of Mexico. It had satisfied CIAT's immediate needs. The South American portion of the survey covering the Amazon, Andean Piedmont, Centra Brazil and Orinoco regions has since been published by CIAT and EMBRAPA-CPAC in book form (Cochrane et al., 1985).

5.8.2 Methodology.

The methodology used for the inventory is modeled on the land system approach so successfully developed by Christian and Stewart (1953), in assessing land resources of the Katherine-Darwin region of Northern Australia. It reduces the information to a common base, redefining land systems as repetitive patterns of climate, landscape and soils. These are delineated directly onto satellite and, or radar imagery following field work and climatic analyses.

---

[1] Centro Internacional de Agricultura Tropical, Cali, Colombia
[2] Empresa Brasileira de Pesquisa Agropecuaria-Centro de Pesquisa Agropecuaria dos Cerrados, Planaltina, D.F., Brazil

The principal parameters used to define a land system are:
1. Climate
   a. Radiant energy received
   b. Temperature
   c. Potential evapotranspiration
   d. Water balance
   e. Other climatic factors
2. Landscape
   f. Landform
   g. Hydrology
   h. Vegetation
3. Soil
   i. Soil physical characteristics
   j. Soil chemical characteristics

After the land resource information is collected and collated, it is summarized in a computerized data storage, retrieval and map printout system to facilitate speedy and comprehensive analyses. As noted by McQuigg (1979), "There is an astonishing amount of information available in most countries on climate, soils and other factors important to agricultural success."

In essence, the methodology facilitated the speeded appraisal and systematization of vast readily available information in Tropical America. Its use of satellite and radar imagery enabled cartographic information to be reduced to a common geographical base in terms of land systems. Nevertheless, a strategic amount of field work was carried out to verify the soil descriptive work available in the literature, using a small STOL (Piper PA-18) aeroplane flown by the author to reach back areas. The climatic work to complement the study was subcontracted to Prof. G.H. Hargreaves and his associates at Utah State University. It included monthly estimates of potential evapotranspiration and the water blanace. Since 1980, this work has been continued at CIAT.

Paradoxically, the delineation of land systems was effective not only to describe the land resources of regions where little or no information was available, but also to condense and summarize the copious amounts of literature occasionally available for some regions of lesser geographical extent. The land systems maps were digitized using a grid method (raster-hierarchical), and completely integrated with the relational data base containing the climate, landscape and soil information.

5.8.2.1 Climate.
Long-term meteorological data for over 1,100 stations throughout tropical America were assembled on a monthly basis and include:
- Mean temperature,
- Mean relative humidity,
- Percent possible sunshine,
- Mean solar radiation (Langleys per day),
- Mean precipitation,
- Potential evapotranspiration,
- Precipitation deficit,
- Dependable precipitation (75% probability level of occurrence), and
- Moisture Availability Index according to Hargreaves (1972).

Potential evapotranspiration was calculated to assess the amount of energy availabe for plant growth and determine the water balance and growing seasons. To provide a common yardstick for estimating potential evapotranspiration throughout the region, Hargreaves' equation (1977a) based on solar radiation and temperature was used, as it gives consistently reliable estimates when compared with other equations (Hargreaves, 1977b).

The work completed by Hargreaves and his associates is available from EMBRPA-CPAC on computer tape, or in printout form with explanatory text (Hancock et al., 1979).

5.8.2.2. Landscape.

Land systems were mapped to illustrate analogous areas of land, insofar as practical farming is concerned. These land systems are physiographic units, based on repetitive patterns of topography, vegetation, and soils, within a given climate circumstance. (See figure 5.8.1. for area coverage of the Land system maps in Tropical America).

Native vegetation classes were identified following the physiognomic criteria of Eyre (1968) for tropical forests and Eiten (1972) for tropical savannas.

The mapping of land systems provided a common base for bringing land resource information together. After delineation, maps were collated and drawn at the scale of 1:1M and numbered according to the International Chart of the world at the millionth Scale (Kerstenetsky, 1972). They were then digitized in 5 by 4 minute units (approximately 6,800 ha at the equator), to serve as the basis for thematic map production. The field work provided on-the-ground control to help standardize descriptive criteria, and to distinguish the variation in landscape features within the land systems. These variations, although not mapped because of scale limitations, were described as "land facets", and the proportion of each land facet within the land systems estimated. In this way, selected landscape features and soil descriptions and properties were computed on the basis of the land facet subdivision. A maximum of three land facets were defined for any one land system, to simplify computerization.

5.8.2.3 Soils.

The subdivision of land systems into land facets was particularly useful to bridge the gap between land systems and soil units. Clearly, land facets will contain soils with a variation in properties; but some level of generalization must be made in inventorising land resources.

The most extensive soils in each land facet were classified as far as the Great Group category of Soil Taxonomy (Soil Survey Staff, 1975); the soils were then described in terms of their main physical and chemical properties. This was because Soil Taxonomy does not provide for the grouping of soils "having similar physical and chemical properties that reflect their response to management and manipulation for use" until the soil Family category is reached. The amount of soil survey work needed to classify soils to the Family level throughout the region was far too great. In addition to a classification of soils according to Soil Taxonomy great groups, the soils were classified according to the FAO-Unesco legend (FAO-Unesco, 1974).

Apart from describing the soil properties inherent in soil classification (Eswaran, 1977), key physical and chemical properties of the topsoil (defined as the layer from 0 to 20 cm depth) and subsoils (21 to 50 cm depth) of the individual land facets were recorded, tabulated and coded when the information was available.

Soil physical properties coded include slope; texture; presence of coarse material; depth; initial infiltration rate; hydraulic conductivity; drainage; moisture-holding capacity; temperature regime; and presence of expanding clays.

Soil chemical properties coded include pH; % Al saturation; exchangeable Al, Ca, Mg, K, Na; total exchangeable bases; effective cation exchange capacity; organic matter; available soil P; P fixation; available soil Mn, S, Zn, Fe, Cu, B and Mo; free carbonates; salinity; % Na saturation; presence of Acid Sulphate clays; X-ray amorphism; and elements of importance to animal nutrition.

It shoud be noted that the quantity and quality of data varied considerably from region to region, that minor and trace element information was seldom available, and that there were often large distances between sampling sites, all of which compounded the problems of generalizing data. Consequently, a small scale "reliability" map was drafted to help judge the variability in the quality of the data base.

5.8.3 The data management system - Computerization.

Science starts with systematization. Because of the quantity and complexity of data available for the study, it was decided from the start to choose what was then considered a minimum of essential data and code all information on computer-compatible formats. These, together with the detailed methodology of computerization, have been described by Cochrane et al. (1979). The rational data base technology developed by Statistical Analysis System (Barr et al., 1976) was selected for computing the data; this contains procedures for statistical analyses and data reporting. Thus storage, analysis and retrieval of information was achieved without the help of sophisticated computer expertise, and the information made available to interested institutions on computer tape.

5.8.3.1 Data input.

The geographical subdivision of the region into land ystems provided a minimal unit for map making; further subdivision of the land systems into land facets provided the building blocks for describing and comparing topography, vegetation and soils. Consequently, much of the information was summarized as data sets that refer to units or units within units, which facilitates programmer access to data and the revision of the database.

The land system information is currently organized in four computer files; the Climate file, Land-System file, Land-Facet file and Map file.

The Climate file records data for individual meteorological stations. These are indexed by geographical coordinates, altitudes and reference numbers to facilitate assignment to land systems and land facets within land systems.

The Land-System file records generalized landscape characteristics of the land systems and the subdivision of the land systems into land facets.

The Land-Facet file records the coding of the land facets of the land systems and includes the following headings:

- General description,
- Percentage of Land Systems,
- Topographic class,
- Altitude,
- Original vegetation class percentage,
- Induced vegetation percentage,
- Soil classification,
- Soil physical properties,
- Soil chemical properties,
- Elements of importance mainly to animal nutrition and fertility capability classification.

The Map file indexes the Land System Map units by geographical coordinates. Grids subdividing the 1:1M land systems maps into 5-minute latitude by 4-minute longitude areas were placed over the 1:1M land system maps and each 5 by 4 minutes area identified by the coordinates of its northwest extremity. Each one of these areas was identified as belonging to a given land system. This method of indexing the maps facilitates thematic mapping as computer printouts. It also facilitates the construction of maps according to various projections.

5.8.3.2 Data output.

The basic output includes:

- Printouts of the land resource information for individual land systems and land facets within systems;
- Meteorological data and;
- Map construction including thematic and single-factor maps.

However, the true value of computerization lies in the speed and flexibility of analyses to help define soil-climate limitations and advantages for the growth of crops, and to define analogous geographical areas for the more effective transfer of cultivars growing well in any given environment. A series of convenient programs have been developed to facilitate these analyses.

5.8.4 Results

The systematic coding and computerizing of the climate, landscape, and soil information throughout tropical South America has permitted an objective assessment of the land resources. As noted by Cochrane (1981), many conflicts and myths relating to both the savanna and Amazonian forest regions have now been dispelled. A much more optimistic picture of the nature of the land resources of those regions and their development possibilities, has emerged.

Perhaps of equal importance is that the work has furnished the basis for CIATs and EMBRAPA-CPACs ongoing efforts to develop and transfer ecosystem compatible food production technology. The survey's separation of the region into land systems provides a manageable comparison of agro-environments. The use of satellite and radar imagery has made quantification to a common geographical base a reality. And computerization has provided a powerful tool not only for data storage and retrieval, but also for map making and the analyses of the inter-acting factors of climate, landscape, vegetation and soils. The net result is a merging of soil and climate expertise and an interdisciplinary approach to land resource assessment for tropical agriculture planning and development.

Use of the computerized land system database has profoundly affected CIAT activity. It has led to the strategic location of regional trial networks for testing promising pasture-plant accessions (Toledo et al., 1982), and is shaping the development of cost effective, ecosystem compatible, germ plasm-based agrotechnology. Its use in locating test sites representative of the major soil-climate environments of potential production regions, has enabled CIAT to focuss scarse resources more effectively. This approach is a quantum leap over the "wonder plant" philosophy of plant development prevalent in the early days of the Green Revolution.

5.8.5 Discussion

The computerized land system approach has demonstrated the feasibility of making a continental-wide inventory of tropical land resources, both quickly and cheaply. In fact, only three scientists were directly involved in the work during a four year period, apart from those involved in the University of Utah subcontract; the latter was completed during the first two years.

The resultant computerized data base has been put to good use, especially for the development and transfer of new pasture plant and food crop cultivars. It has also proven to be a novel and effective way of investigating basic climate-landscape-vegetation-soil relationships per sé. Notwithstanding, with the advent of improved satellite imagery and the steady accumulation of climate and soil knowledge over the past five years, the data base could profitably be updated, revised and even restructured to accommodate greater detail.

It has long been recognized that crops often do as well, if not better, in continents away from their center of origin (Purseglove, 1974). This would imply that substantial mutual benefits lie in store for all tropical countries if a common land resource assessment could be extended throughout the whole of the tropics. With a tropic-wide land systems base, improved crop varieties and successful agrotechnologies developed in one tropical ecosystem could then be transferred to other environmentally compatible areas with a much greater degree of success than is currently possible. This is not to infer that production difficulties will not arise. Every continent has specific biological (pest and disease) problems that could affect the successful transfer of technologies. Nevertheless, considerable time and effort will be saved by ensuring compatible matches between germ plasm-based agrotechnologies and soil-climate environments, rather than the "hit or miss" methods still largely in vogue today.

Many additional benefits would be derived from such a global information system. Not the least would be the progressive build-up of information concerning cultivars well adapted to the many soil-climate environments of the tropics, enhancing the ability of nations to better plan and manage production problems in environmentally, socially or economically fragile regions. In short, a tropic-wide land systems database would be an invaluable resource for individual nations now striving to meet the escalating need for food in an ever-changing world.

5.8.6 References.

Barr, H.J., T.M. Goodnight, J.P. Sull, and J.T. Helwing 1976. A users guide to SAS 76. Statistical Analysis System Inst. Inc., Raleigh, North Carolina, U.S.A.

Christian, C.S. and S.A. Stewart 1953. Survey of Katherine-Darwin region, 1946. Land Resource Series 1. CSIRO, Melbourne, Australia. 126 p.

Cochrane, T.T. 1981. Tropical climate/soils resources. An assessment. In: Food and Climate Review 1980-81, Aspen Inst. for Humanistic Studies, Boulder, Colorado, U.S.A., p. 18-28.

Cochrane, T.T., J.A. Porras, L.G. de Azevedo, P.G. Jones, and L.F. Sanchez 1979. An explanatory manual for CIAT's computerized land resource study of Tropical America. CIAT, Cali, Colombia, 131 p.

Cochrane, T.T., L.F. Sanchez, L.G. de Azevedo, J.A. Porras, and C.L. Garver 1985. Land in Tropical America. A guide to climate, landscapes and soils for agronomists in Amazonia, the Andean Piedmont, Central Brazil and Orinoco. CIAT, Cali, Colombia and EMBRAPA-CPAC, Planaltina, D.F., Brazil. Vol. 1. 144 p., Vol. 2. 38 maps, Vol. 3. 441 p.

Eiten, G. 1972. The cerrado vegetation of Brazil. Botan. Rev. 38 (2): 201-341.

Eswaran, H. 1977. An evaluation of soil limitations from soil names. In: Soil resource inventories. Agron. Mimeo 77-23. N.Y. State College of Agric. and Life Sci., Cornell University, Ithaca, N.Y., U.S.A., p. 289-314.

Eyre, S.R. 1968. Vegetation and soils. A world picture, 2nd ed. Edward Arnold Publishers, Ltd., London, England, p. 195-258.

Hancock, J.K., R.W. Hill, and G.H. Hargreaves 1979. Potential evapotranspiration and precipitation deficits for Tropical America. CIAT, Cali, Colombia, 398 p.

Hargreaves, G.H. 1972. The evaluation of water deficiencies. Age of changing priorities for land and water, irrigation and drainage specialty conference. A.S.C.E., Spokane, Washington, U.S.A., p. 273-290.

Hargreaves, G.H. 1977a. Consumptive use of water and irrigation water requirements. J. Irrigation and Drainage Division. Proc. ASCE 103 (IR2): 287-290.

Hargreaves, G.H. 1977b. World water for agriculture. Climate, precipitation probabilities and adequacies for rainfed agriculture. Utah State University, Logan, U.S.A., 272 p.

Kerstenetsky, I. 1972. Carta internacional do mundo ao milionésimo: Brazil. Fundaçao Instituto Brasileiro de Geografia. Rio de Janeiro, Brazil. 46 maps.

McQuigg, J.D. 1979. The promise of information systems. In: Food and Climate Review, 1979. Aspen Inst. for Humanistic Studies, Boulder, Colorado, U.S.A., p. 58-62.

Metz, J.F. and N.C. Brady 1980. Priorities for alleviating soil-related constraints to food production in the tropics. Int. Rice Res. Inst. and N.Y. State College of Agric. and Life Sci., Cornell University, U.S.A., p. V.

Purseglove, J. 1974. Tropical crops: dicotyledons. (Reprint 1977). Longmans, London, England, p. 9-17.

Soil Survey Staff 1975. Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Handbook 436. S.C.S., USDA, Washington, U.S.A., 754 p.

Toledo, J.M. (ed.) 1982. Manual para la evaluacion de pastos tropicales. CIAT, Cali, Colombia, p. 23-44.

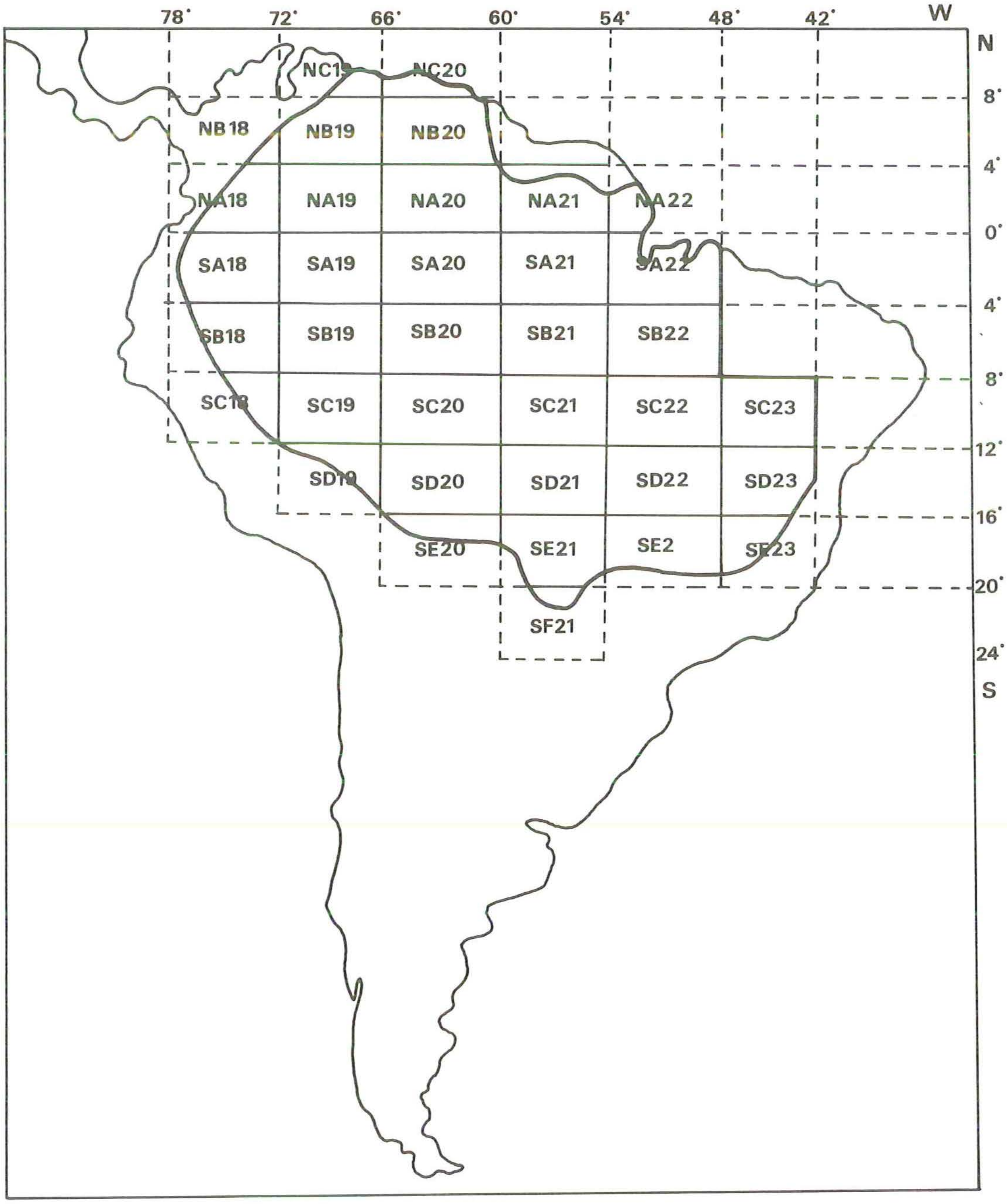


Fig. 5.8.1 Schematic summary of individual 1:2,000,000 Land System Zone maps in Tropical America.
(Shaded area indicated the actually mapped region).

5.9 INFORMATION EXTRACTION FROM A SOILS AND TERRAIN DIGITAL DATABASE

Carlos R. Valenzuela
International Institute for Aerospace Survey and Earth Sciences (ITC)
and Marion F. Baumgardner
Purdue University

5.9.1. Introduction.

The complexity and increasing volumes of available information, and the demand for the storage, analysis and display of large quantities of environmental data, has led in recent years to rapid development in the application of computers to environmental and natural resources data handling, and the creation of sophisticated information systems (Tomlinson et al., 1976). Increasingly data of all types are being collected and converted to digital format. Extensive digital geographically oriented databases are being developed, and automated spatial information systems are used for storage, retrieval, manipulation, analysis and display of information (Tom and Miller, 1975; Knapp, 1978; Jerie et al., 1980; Marble and Peuquet, 1983). Effective utilization of large spatial data volumes is dependant upon the existence of an efficient geographic handling and processing system that will transform these data into usable information. The major tool for handling spatial data is the geographic information system (Marble and Peuquet, 1983).

A digital geographic information system (GIS), is a computerized system designed to store, process and analyse spatial data and their corresponding attribute information. Advances in computer technology and techniques have made it possible to integrate a wide range of information (Gribbs, 1984). Technological advances have increased input techniques, storage, analysis and retrieval capabilities. Furthermore, there has been a reduction in costs and an increase in accessibility, so that a larger user community has developed (Moellering, 1982). Geographic information systems have provided planners with a readily accessible source of objective earth-science-related facts and an inexpensive, rapid and flexible tool for combining these facts with various other products to create decision alternatives (van Driel, 1975; Stow and Estes, 1981; Stoner, 1982).

Basic information on the location, quantity and availability of natural resources is indispensable for planning more rationally their development, use and/or conservation. The demand for specific, accurate, and rapid soil information is growing in our modern society. Soils, because of their importance in agricultural and non-agricultural matters, and their inherent relationships with other environmental resources are a basic and fundamental component of any complete geographic information system. Johnson (1975) points out that the conventional preparation of soil interpretive maps combining information of the soil resource with other resource information are excessively expensive, especially if various source maps have to be converted to a common scale, and if the interpretive requirements are complex. Automatic data processing systems have created immense opportunities for storing and disseminating soil data (Bertelli, 1979). As the demand for interpretive maps increases, computers are used to speed up and cut down costs of the processes (Bertelli, 1966; Shields, 1976; Bertelli, 1979; Bie, 1980; Valenzuela, 1985). The national Soil Handbook of the USDA Soil Conservation Service (1983), indicates that computer generated interpretive maps are encouraged where the soil survey has been digitized, because they cost less than maps perpared by other means.

5.9.2 Methodology.

The digital geographic information system used for this study basically consists of five major subsystems: 1.- Input subsystem; 2.- Database subsystem; 3.- Management subsystem; 4.- Modelling and analysis subsystem, and 5.- Output subsystem.

The soil association map of Indiana, U.S.A., was prepared by the Indiana soil survey staff of the United States Department of Agriculture Soil Conservation Service and Purdue University Agricultural Experiment Station and made available to users as publication AY 209, at a scale of 1:500,000 in 1980.

The soil association map was digitized using the Purdue/LARS digitizing system. The system is composed of a Talos table digitizer and an APPLE II Plus microcomputer. A complete documentation of this menu-driven system was prepared by Phillips (1983). The data capture consisted of the transformation of three (3) map primitives, i.e., control points, boundaries (limits of soil units), and centroids, into a format compatible with digital computers. After the process of data capture was completed, the computer compatible data were transferred from the APPLE II Plus microprocessor to the host (main) computer (IBM 360/158), where the data were stored and the activities of editing, coordinate transformation and rasterization were performed. Editing the data was accomplished by manual and automatic editing routines using a Tektronics 4054 graphics terminal. Twelve (12) control points were used to derive statistically a biquadratic regression model required to transform the digitized X and Y values into longitude and latitude geographic coordinates. These data were subsequently transformed into an Albers equal-area cartographic projection.

The final step in the map input procedure was the rasterization process. During this process, the boundary and centroid files stored in addresses corresponding to the Albers cartographic projection, were converted into an image file. The map units were filled-in cells according to a predefined grid (500 m x 500 m on the ground, or, 1mm x 1 mm on the map), and subsequently each cell was assigned with a class code (0 to 255) associated with the centroid file. The codes (fill characters) assigned to each of the 55 soil associations present in the map and to the portion of Lake Michigan in Indiana are shown in Table 5.9.1.

For the construction of the attribute database (hierarchical), extensive use was made of the available information generated for the state soil associations of Indiana (Galloway et al., 1975). Other information not readily available in tables or maps, were obtained by generalization of the information present in the description of the soil series forming each soil association (Galloway and Steinhardt, 1981; Franzmeier and Sinclair, 1982). Information generated by visual and digital interpretations of LANDSAT data from Indiana were also used. Figure 5.9.1 illustrates a LANDSAT mosaic covering the whole state.

For display purposes and generation of color outputs of the computer generated interpretive soil maps, the rasterized image file was transfered to the image processing device IBM 7350 (HACIENDA).

5.9.3 Results.

Once the input of the data is completed and the rasterized data set and their attribute information are stored in the database, this spatial information can be easily retrieved, handled, analysed and displayed. The degree of the analytical capabilities implemented in a system depends on the nature, purpose and objectives of the principal user. However, a well thought-out system will be one that is flexible enough to respond to the needs for input, analysis and display of different kinds of data required by the user.

In almost every digital geographic information system currently operational, one element appears to be present to satisfy the requirements of the main user. It is the element soils, depicting soil types as obtained from soil surveys. This is the result of its relation to the fauna, vegetation and climate, and its strong interaction with other natural resources elements. The nature and type of information available from a soil survey enables the generation of several interpretive soil maps. These maps can be used as new variables for analysis or modelling of resources to predict changes that may occur through time.

The soil association of Indiana in digital format displayed in the High Level Image Processing System (HLIPS) device IBM 7350 are shown in Figure 5.9.2. The area estimates and percentage of occurance of each soil association in Indiana are presented in Table 5.9.1. Soil association Crosby-Brookston present on nearly level surfaces of Wisconsin age glacial till plains in Central Indiana, constitutes the largest association covering an area of approximately 703,050 ha or 7.4% of the state. Figure 5.9.3 illustrates the parent materials from which Indiana soils were developed. It depicts the various kinds of materials, including old sedimentary rocks in the southern part of the state; different thickness of loess deposits over glacial till; alluvial, lacustrine and eolian deposits from which the soils were developed.

The potential soil erosion was calculated using the Universal Soil Loss Equation (USLE). The factors of the USLE for each soil association were estimated by Brentlinger et al. (1979). This information was used to reclassify the digital soil association map into four (4) potential soil erosion groups; Low, Medium, High and Very High. The potential soil erosion map is illustrated in Figure 5.9.4. This interpretive information can be used in conjunction with landuse/landcover data to predict the erosion hazard or gross erosion in the state. It can also be related to slope, landuse and proximity to streams to determine agricultural pollution due to erosion and to estimate sedimentation hazards, and the related dangers of floodings. The dominant drainage, as determined by the characteristics of the soil associations, is shown in Figure 5.9.5. This information is very important for the planning, design and construction of septic systems in the state.

Soil maps in Indiana are used in the assessment of agricultural potential. The basic aim of any assessment activity is the equal treatment of all individual land owners. Yahner (1979) described the procedures employed in agricultural land reassessment using stimates of corn yields. Each soil association has been assigned an estimated corn yield value. Figure 5.9.6 illustrates the corn yield estimate map of Indiana. Table 5.9.2 presents the corn yield values for each soil association. Because of the resolution (scale) of the data and the generalization involved in the creation of the soil associations, some problems and difficulties exist in the assessment of individual farms. However, it can be used to obtain rapid information on the approximate value of agricultural land. Figure 5.9.7 illustrates the soil associations depicting organic matter levels for the state of Indiana. This figure shows weighted averages of organic matter content, which were calculated taking into consideration the relative occurrence of soil series forming the soil associations, as tabulated by Galloway et al. (1985).

Figure 5.9.8 shows the digital county map of Indiana. This information was combined with the digital soil information and it was used to calculate the areas of soil associations present in each county, which is very important for planning the allocation of resources at county level. Table 5.9.3 includes the soil associations and their corresponding areas for some counties in the state.

Table 5.9.4 presents all the soil associations in the state with their respective information used to generate the interpretive maps and tabular information. The production of digital interpretive maps does not involve any changes in the original data set. It uses atribute files to regroup the original units into interpretive classes in real time. These new data (interpretive) can be used in analysis and modelling with other data sets available in the database. Figure 5.9.9 illustrates the county boundaries and the soil association original data sets, and the interpretive information generated using the analysis capabilities of the GIS.

5.9.4 References.

Bertelli, L.J., 1966. General soil maps: a study of landscapes. Journal of soil sciences and water conservation, 21(1).

Bertelli, J.L., 1979. Interpreting soil data: planning the use of management of land. ASA-CSSA-SSSA, 677 South Segoe Road, Md.

Bie, S.W., 1980. Computer assisted soil mapping: the computer in contemporary cartography. Edited by D.R.F. Taylor, John Wiley and sons Ltd.

Brentlinger, J.L., J.B. Hays, R.L. Lauster and C.S. Pierce, 1979. Agricultural assessment for the non-designated and designated 208 planning areas of Indiana. State soil and water conservation committee, Indiana Department of Natural Resources.

Driel van, N., 1975. Geological information in a computer mapping system for landuse planning. Proceedings of the international symposium on computer assisted cartography. Bureau of the census and ACSM, Auto Carto II.

Franzmeier, D.P., and H.R. Sinclair, 1982. Key to soils in Indiana: showing the relationships of soils to each other and their environment. AY-249, Cooperative Extension Service, Purdue University, West Lafayette, Indiana

Galloway, H.M., J. Yahner, G. Srinivasan and D. Franzmeier, 1975. User's guide to the general soils map and interpretive data for counties in Indiana. Supplement to AY-50 series. Cooperative Extension Service, Purdue University, West Lafayette, Indiana.

Galloway, H.M. and G.C. Steinhardt, 1981. Indiana's soil series and their properties. AY-212, Cooperative Extension Service, Purdue University, West Lafayette, Indiana.

Gribbs, W.J., 1984. The combining of geographic and other information systems to create a new type of information system. Technical papers of the 44th annual meeting of the American congress on surveying and mapping. ASP/ACSM convention, Washington DC.

Jerie, H.G., J. Kure and H.K. Larsen, 1980. A system approach to improving geo-information systems. ITC journal 1980-4, Enschede, the Netherlands.

Johnson, C.G., 1975. The role of automated cartography in soil survey. Proceedings of the meeting of the ISSS working group in soil information systems, Wageningen, the Netherlands.

Knapp, E., 1978. Landsat and ancillary data inputs to an automated geographic information system: application for urbanized area delineation. Goddard Space Flight Center and Computer Science Corporation.

Marble, D.F., and D.J. Peuquet, 1983. Geographic information systems and remote sensing. Manual of remote sensing, vol 1, chapter 22.

Moellering, H., 1982. The challenge of developing a set of national digital cartographic data standards for the United States. Proceedings ACSM/ASP, spring meeting, Denver.

Phillips, T.L., 1983. Operation of the Purdue/Lars digitizing system. Laboratory or Applications of Remote Sensing, Purdue University, West Lafayette, Indiana.

Shields, R.L., 1976. New generalized soil maps guide for land use in Maryland. Journal of soil and water conservation, vol 32, No.6.

Stoner. E.R., 1982. Agricultural land cover mapping in the context of a geographically referenced digital information system. Report No 205, NASA, Space Technology Laboratories, Earth Resources Laboratory, NSTL Station.

Tom, C. and L. Miller, 1974. A review of computer-based resource information systems. Land use planning information report 2, part 2, Colorado State University, Fort Collins, Colorado.

Tomlinson, R.F., H.W. Calkins and D.F. Marble, 1976. Computer handling of geographical data. The Unesco press.

USDA, 1983. National soils handbook. USDA, Soil Conservation Service. U.S. Government Printing Office, Washington DC.

Valenzuela C.R., 1985. The element soil as a basic component in a digital geographic information system. Ph.D. Thesis, Agronomy Department, Purdue University, West Lafayette, Indiana.

Yahner, J.E., 1979. Use of soil maps in Indiana's farmland reassessment. Agronomy guide AY-216, Cooperative Extension Service, Purdue University, West Lafayette, Indiana.

Table 5.9.1 Area estimates and percentage of occurence of soil associations in Indiana.

CODE	SYMBOL	SOIL ASSOCIATIONS	AREA IN HA	PERCENT
1	A1	GENESSE-EEL-SHOALS	202,050	2.13
2	A2	FOX-GENESSE-EEL	187,825	1.98
3	A3	SLOAN-ROSS-VINCENNES-ZIPP	44,225	0.47
4	A4	STENDAL-HAYMOND-WAKELAND-NOLIN	400,000	4.23
5	A5	WHEELING-HUNTINGTON-LINDSIDE	65,800	0.69
6	B1	HOUGHTON-ADRIAN	70,600	0.74
7	B2	MAUMEE-GILFORD-SEBEWA	333,350	3.51
8	C1	RENSSELAER-DARROCH-WHITAKER	131,450	1.39
9	C2	SEBEWA-GILFORD-HOMER	30,150	0.32
10	C3	LYLES-AYRSHIRE-PRINCETON	15,600	0.16
11	D1	MILFORD-BONO-RENSSELAER	23,900	0.25
12	D2	PATTON-LYLES-HENSHAW	51,350	0.54
13	D3	ZIPP-MARKLAND-MCGARY	38,275	0.40
14	E1	TRACY-DOOR-LYDICK	91,475	0.96
15	E2	ELSTON-SHIPSHE-WARSAW	77,325	0.82
16	E3	OSHTEMO-FOX	219,100	2.31
17	E4	FOX-OCKLEY-WESTLAND	208,825	2.20
18	E5	PARKE-NEGLEY	22,175	0.23
19	F1	OAKVILLE-ADRIAN	19,450	0.21
20	F2	PLAINFIELD-MAUMEE-OSHTEMO	198,475	2.09
21	G	PRINCETON-BLOOMFIELD-AYRSHIRE	98,100	1.03
22	H	ALFORD	173,350	1.83
23	I1	RAGSDALE-RAUB	45,225	0.48
24	I2	SABLE-IPAVA	17,300	0.18
25	I3	FINCASTLE-RAGSDALE	273,700	2.88
26	I4	REESVILLE-RAGSDALE	99,050	1.04
27	I5	IVA-VIGO	62,200	0.66
28	J1	BROOKSTON-ODELL-CORWIN	155,300	1.64
29	J2	CROSIER-BROOKSTON	135,300	1.43
30	J3	CROSBY-BROOKSTON	703,050	7.41
31	K1	BLOUNT-PEWAMO	517,925	5.46
32	K2	HOYTVILLE-NAPPANEE	28,375	0.30
33	L1	PARR-BROOKSTON	102,700	1.08
34	L2	RIDDLES-TRACY-CHELSEA	13,500	0.14
35	L3	MIAMI-CROSIER-BROOKSTON-RIDDLES	387,700	4.09
36	L4	MIAMI-CROSIER-BROOKSTON	493,400	5.20
37	L5	MIAMI-HENNEPIN-CROSBY	72,475	0.76
38	L6	MIAMI-RUSSEL-FINCASTLE-RAGSDALE	490,425	5.17
39	L7	RUSSEL-HENNEPIN-FINCASTLE	67,700	0.71
40	M1	MARKHAM-ELLIOT-PEWAMO	42,950	0.45
41	M2	MORLEY-BLOUNT-PEWAMO	636,825	6.71
42	N1	BARTLE-PEDGA-DUBOIS	72,000	0.76
43	N2	WEINBACH-WHEELING	43,325	0.46
44	N3	AVONBURG-CLERMONT	135,850	1.43
45	O1	HOSMER	152,575	1.61
46	O2	ZANESVILLE-WELLSTON-TILSIT	125,100	1.32
47	O3	CINCINNATI-VIGO-AVA	246,575	2.60
48	O4	CINCINNATI-ROSSMOYNE	383,950	4.05
49	P	WELLSTON-ZANESVILLE-BERKS	461,950	4.87
50	Q1	CRIDER-BEDFORD-LAWRENCE	25,675	0.27
51	Q2	CRIDER-HAGERSTOWN-BEDFORD	284,925	3.00
52	Q3	CRIDER-BAXTER-CORYDON	63,125	0.67
53	R1	BERKS-GILPIN-WEIKERT	185,675	1.96
54	R2	CORYDON-WEIKERT-BERKS	56,725	0.60
55	R3	EDEN-SWITZERLAND	138,525	1.46
60		LAKE MICHIGAN	62,500	0.66

Table 5.9.2 Weighted average corn yield estimates for soil associations in Indiana.

SOIL ASSOCIATIONS	MAP SYMBOL	CODE	CORN*
GENESSE-EEL-SHOALS	A1	01	115
FOX-GENESEE-EEL	A2	02	106
SLOAN-ROSS-VINCENNES-ZIPP	A3	03	119
STENDAL-HAYMOND-WAKELAND-NOLIN	A4	04	116
WHEELING-HUNTINGTON-LINDSIDE	A5	05	116
HOUGHTON-ADRIAN	B1	06	120
MAUMEE-GILFORD-SEBEWA	B2	07	109
RENSSELAER-DARROCH-WHITAKER	C1	08	128
SEBEWA-GILFORD-HOMER	C2	09	109
LYLES-AYRSHIRE-PRINCETON	C3	10	121
MILFORD-BONO-RENSSELAER	D1	11	122
PATTON-LYLES-HENSHAW	D2	12	138
ZIPP-MARKLAND-MCGARY	D3	13	105
TRACY-DOOR-LYDICK	E1	14	112
ELSTON-SHIPSHE-WARSAW	E2	15	099
OSHTEMO-FOX	E3	16	091
FOX-OCKLEY-WESTLAND	E4	17	106
PARKE-NEGLEY	E5	18	082
OAKVILLE-ADRIAN	F1	19	076
PLAINFIELD-MAUMEE-OSHTEMO	F2	20	083
PRINCETON-BLOOMFIELD-AYRSHIRE	G	21	099
ALFORD	H	22	103
RAGSDALE-RAUB	I1	23	141
SABLE-IPAVA	I2	24	142
FINCASTLE-RAGSDALE	I3	25	132
REESVILLE-RAGSDALE	I4	26	130
IVA-VIGO	I5	27	126
BROOKSTON-ODELL-CORWIN	J1	28	131
CROSIER-BROOKSTON	J2	29	118
CROSBY-BROOKSTON	J3	30	117
BLOUNT-PEWAMO	K1	31	109
HOYTVILLE-NAPPANEE	K2	32	118
PARR-BROOKSTON	L1	33	123
RIDDLES-TRACY-CHELSEA	L2	34	094
MIAMI-CROSIER-BROOKSTON-RIDDLES	L3	35	107
MIAMI-CROSBY-BROOKSTON	L4	36	100
MIAMI-HENNEPIN-CROSBY	L5	37	090
MIAMI-RUSSELL-FINCASTLE-RAGSDALE	L6	38	104
RUSSELL-HENNEPIN-FINCASTLE	L7	39	086
MARKHAM-ELLIOTT-PEWAMO	M1	40	103
MORLEY-BLOUNT-PEWAMO	M2	41	097
BARTLE-PEOGA-DUBOIS	N1	42	107
WEINBACH-WHEELING	N2	43	107
AVONBURG-CLERMONT	N3	44	110
HOSMER	O1	45	093
ZANESVILLE-WELLSTON-TILSIT	O2	46	068
CINCINNATI-VIGO-AVA	O3	47	087
CINCINNATI-ROSSMOYNE	O4	48	079
WELLSTON-ZANESVILLE-BERKS	P	49	058
CRIDER-BEDFORD-LAWRENCE	Q1	50	086
CRIDER-HAGERSTOWN-BEDFORD	Q2	51	085
CRIDER-BAXTER-CORYDON	Q3	52	086
BERKS-GILPIN-WEIKERT	R1	53	041
CORYDON-WEIKERT-BERKS	R2	54	042
EDEN-SWITZERLAND	R3	55	022
LAKE MICHIGAN		60	

* = Bu/acre

Table 5.9.3 Soil associations and area estimates for some counties in Indiana.

COUNTY	CODE	SYMBOL	SOIL ASSOCIATIONS	AREA IN HA
BENTON	4			
	8	C1	RENSSELAER-DARROCH-WHITAKER	10,500
	28	J1	BROOKSTON-ODELL-CORWIN	68,725
	33	L1	PARR-BROOKSTON	24,225
	36	L4	MIAMI-CROSBY-BROOKSTON	2,700
CARROL	8			
	1	A1	GENESSE-EEL-SHOALS	8,650
	17	E4	FOX-OCKLEY-WESTLAND	18,625
	25	I3	FINCASTLE-RAGSDALE	33,800
	30	J3	CROSBY-BROOKSTON	975
	35	L3	MIAMI-CROSIER-BROOKSTON-RIDDLES	175
	36	L4	MIAMI-CROSBY-BROOKSTON	25
	37	L5	MIAMI-HENNEPIN-CROSBY	25
	38	L6	MIAMI-RUSSELL-FINCASTLE-RAGSDALE	34,125
CLINTON	12			
	23	I1	RAGSDALE-RAUB	8,100
	25	I3	FINCASTLE-RAGSDALE	17,225
	30	J3	CROSBY-BROOKSTON	28,525
	36	L4	MIAMI-CROSBY-BROOKSTON	46,600
	38	L6	MIAMI-RUSSELL-FINCASTLE-RAGSDALE	4,100
FOUNTAIN	24			
	1	A1	GENESSE-EEL-SHOALS	5,650
	15	E2	ELSTON-SHIPSHE-WARSAW	10,600
	17	E4	FOX-OCKLEY-WESTLAND	23,825
	23	I1	RAGSDALE-RAUB	7,850
	26	I4	REESVILLE-RAGSDALE	17,375
	37	L5	MIAMI-HENNEPIN-CROSBY	25
	39	L7	RUSSELL-HENNEPIN-FINCASTLE	41,625
JASPER	37			
	1	A1	GENESSE-EEL-SHOALS	200
	6	B1	HOUGHTON-ADRIAN	6,100
	7	B2	MAUMEE-GILFORD-SEBEWA	59,900
	8	C1	RENSSELAER-DARROCH WHITAKER	35,125
	20	F2	PLAINFIELD-MAUMEE-OSHTEMO	15,200
	28	J1	BROOKSTON-ODELL-CORWIN	10,350
	33	L1	PARR-BROOKSTON	19,000
MONTGOMERY	54			
	17	E4	FOX-OCKLEY-WESTLAND	18,950
	23	I1	RAGSDALE-RAUB	6,700
	25	I3	FINCASTLE-RAGSDALE	19,600
	26	I4	REESVILLE-RAGSDALE	2,950
	33	L1	PARR-BROOKSTON	3,325
	36	L4	MIAMI-CROSBY-BROOKSTON	5,475
	37	L5	MIAMI-HENNEPIN-CROSBY	7,825
	38	L6	MIAMI-RUSSELL-FINCASTLE-RAGSDALE	64,225
	39	L7	RUSSELL-HENNEPIN-FINCASTLE	1,650

Table 5.9.4 Soil associations and corresponding interpretive information in the State of Indiana.

CODE	SYMBOL	AREA IN HA	EROSION	SLOPE	DRAINAGE	FARM	CORN	%O. M.
1	A1	202,050	1	1	1	2	3	2
2	A2	187,825	1	1	1	2	3	2
3	A3	44,225	1	1	4	1	3	2
4	A4	400,900	1	1	1	2	3	1
5	A5	065,800	2	1	1	2	3	2
6	B1	70,600	1	1	4	2	3	4
7	B2	333,350	1	1	4	1	3	2
8	C1	131,450	1	1	4	1	4	3
9	C2	30,150	1	1	4	1	3	2
10	C3	15,600	1	1	4	1	3	1
11	D1	23,900	1	1	4	1	3	3
12	D2	51,350	1	1	4	1	4	3
13	D3	38,275	2	1	3	1	3	2
14	E1	91,475	1	2	1	1	3	2
15	E2	77,325	1	1	1	1	2	2
16	E3	219,100	1	2	1	2	2	1
17	E4	208,825	2	1	1	2	3	2
18	E5	22,175	4	3	1	3	2	1
19	F1	19,450	1	3	1	3	2	1
20	F2	198,475	1	2	1	3	2	1
21	G	98,100	2	3	1	2	2	1
22	H	173,350	3	3	1	2	3	1
23	I1	45,225	1	1	4	1	4	3
24	I2	17,300	1	1	4	1	4	4
25	I3	273,700	1	1	3	1	4	2
26	I4	99,050	1	1	3	1	4	2
27	I5	62,200	1	1	3	1	4	2
28	J1	155,300	1	1	4	1	4	3
29	J2	135,300	1	1	3	1	3	2
30	J3	703,050	1	1	3	1	3	2
31	K1	517,925	1	1	3	1	3	3
32	K2	28,375	1	1	4	1	3	3
33	L1	102,700	1	2	1	2	3	3
34	L2	13,500	1	3	1	3	3	1
35	L3	387,700	2	3	3	2	3	2
36	L4	493,400	2	3	1	2	3	2
37	L5	72,475	3	3	1	3	2	1
38	L6	490,425	3	3	3	2	3	1
39	L7	67,700	3	3	1	3	2	1
40	M1	42,950	2	3	3	1	3	3
41	M2	636,825	2	3	3	2	2	2
42	N1	72,000	2	2	3	1	3	1
43	N2	43,325	2	1	3	1	3	2
44	N3	135,850	2	1	3	1	3	1
45	O1	152,575	3	3	1	2	2	1
46	O2	125,100	3	3	1	3	1	2
47	O3	246,575	3	3	3	3	2	1
48	O4	383,950	3	3	1	3	2	1
49	P	461,950	4	4	1	3	1	1
50	Q1	25,675	3	3	1	2	2	1
51	Q2	284,925	3	3	1	3	2	1
52	Q3	63,125	3	4	1	3	2	1
53	R1	185,675	4	4	1	3	1	1
54	R2	56,725	4	4	1	3	1	1
55	R3	138,525	4	4	1	3	1	2
60		LAKE MICHIGAN						

where:

Erosion 1(low), 2(medium), 3(high); 4(very high)
Slope 1(nearly level), 2(undulating), 3(rolling), 4(hilly)
Drainage 1(well), 2(moderately well), 3(somewhat poorly), 4(poorly)
Prime farm 1(>75 %), 2(25-75 %), 3(<25 %)
Corn yield 1(low), 2(medium), 3(high), 4(very high)
Org. Matter 1(<1.5%), 2(1.6-2.5%), 3(2.6-3.5%) 4(>3.6%)

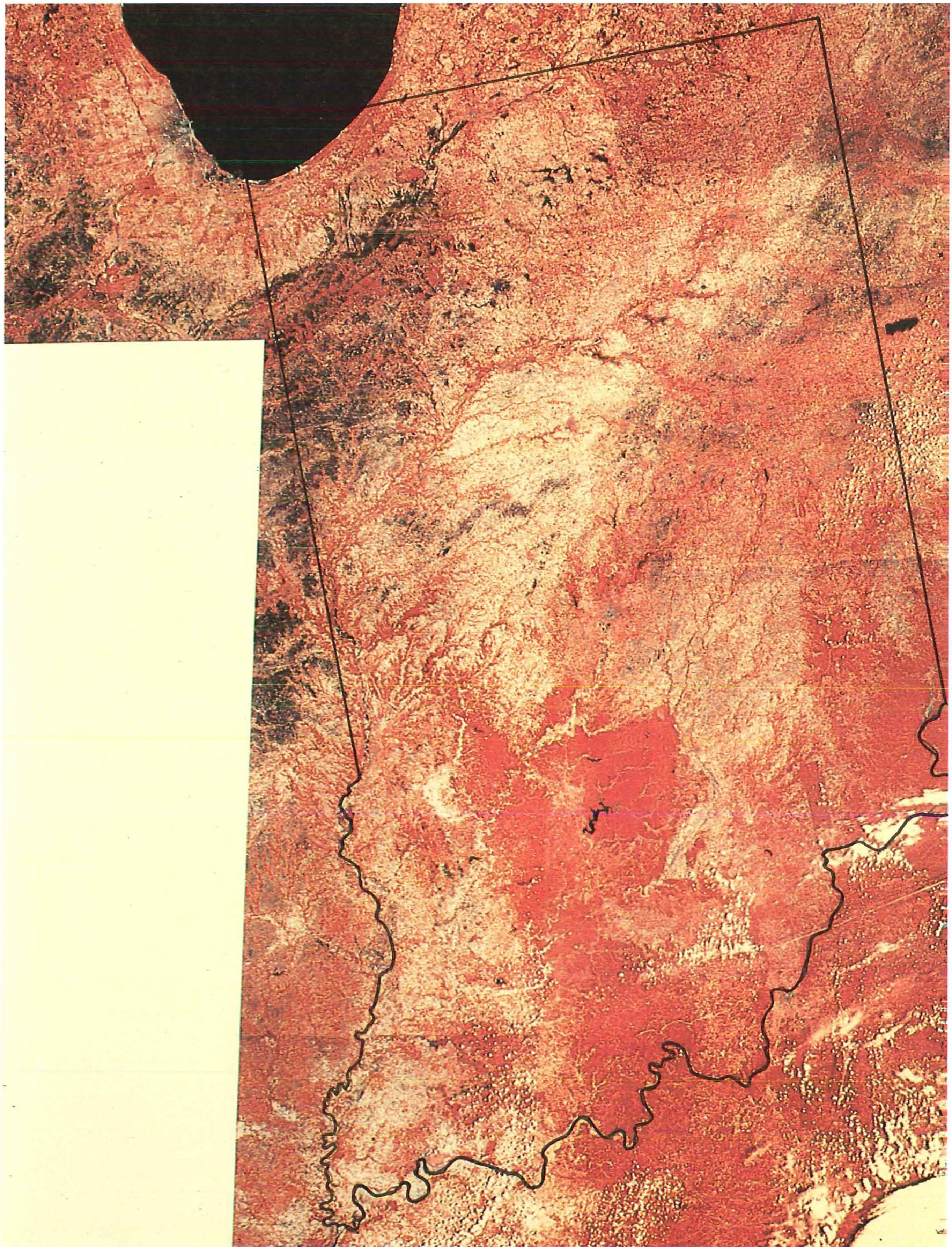


FIGURE 5.9.1 Landsat mosaic

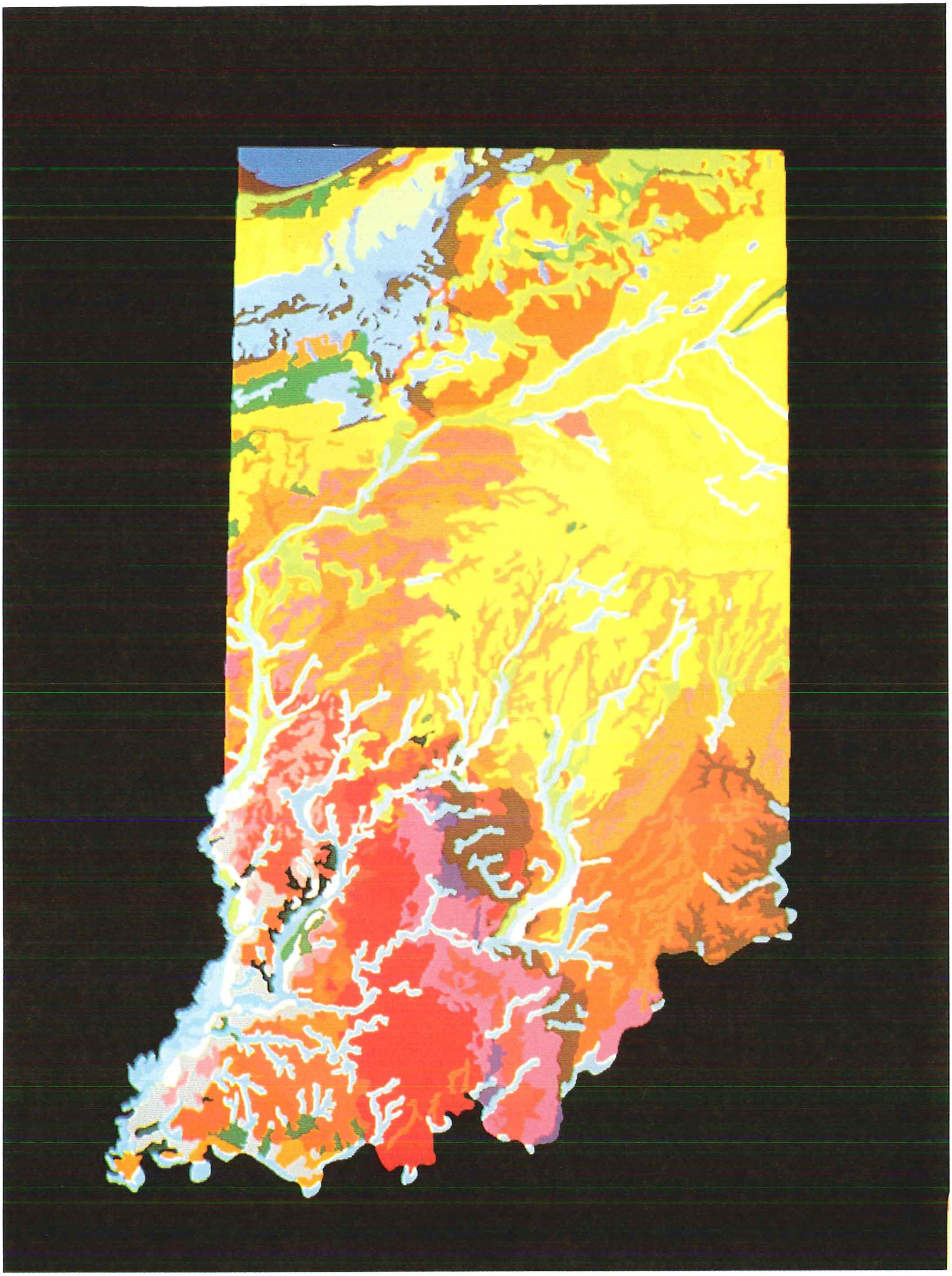


FIGURE 5.9.2 Soil associations

FIGURE 5.9.3 Parent materials

FIGURE 5.9.4 Potential erosion hazard

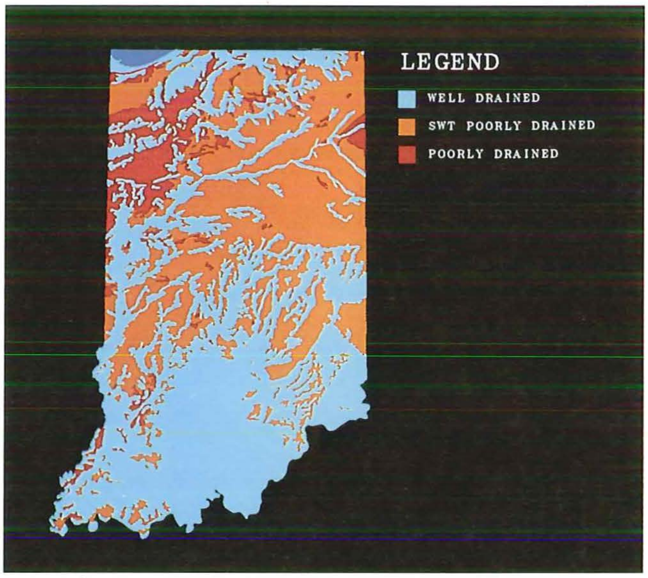


FIGURE 5.9.5 Dominant drainage

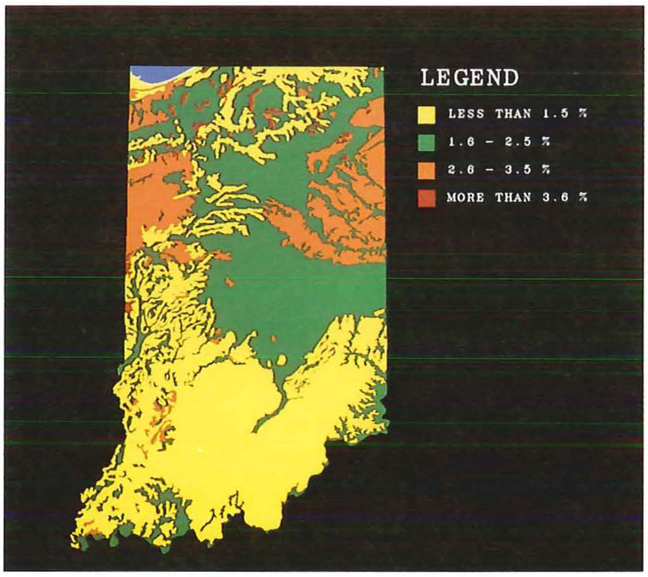


FIGURE 5.9.6 Organic matter content

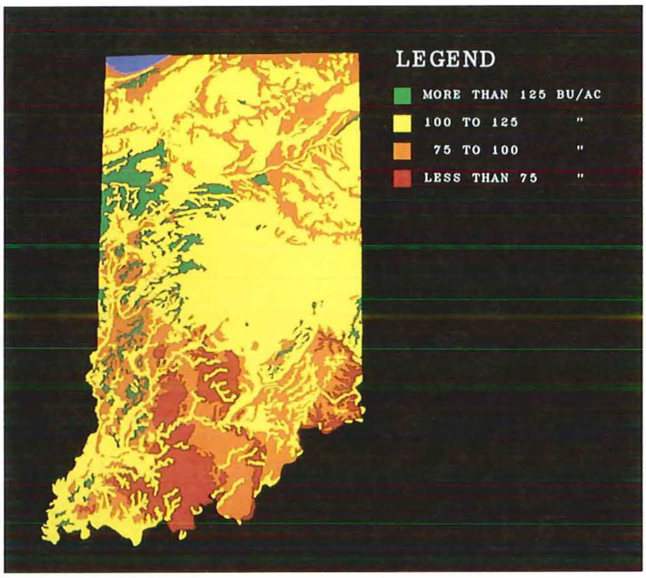


FIGURE 5.9.7 Estimated maize yields

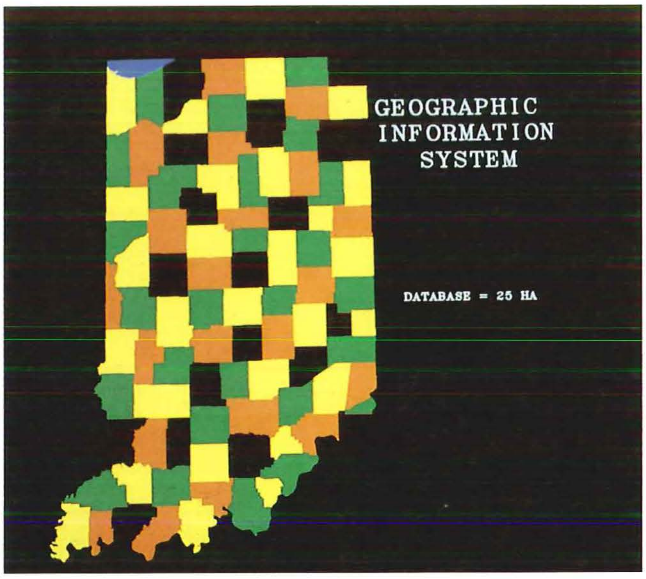


FIGURE 5.9.8 Administrative (county) units

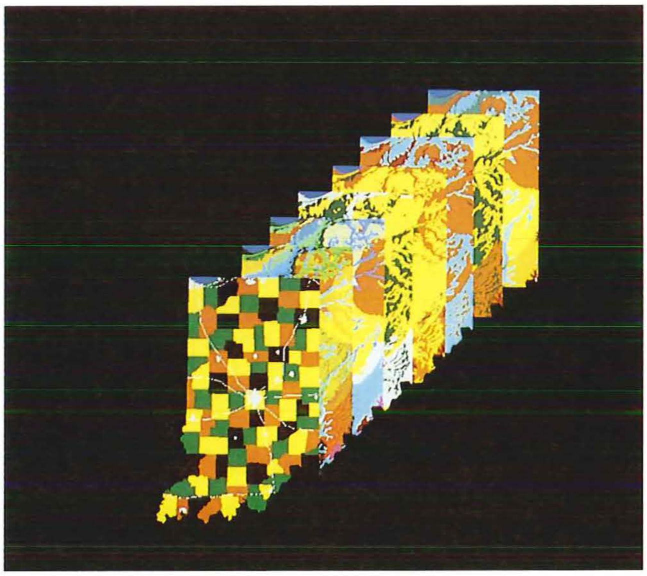


FIGURE 5.9.9 Image database

6

REPORTS FROM WORKING GROUPS

6.1 WORKING SUBGROUP I: PROPOSAL OBJECTIVES FOR A WORLD SOILS & TERRAINS DIGITAL DATABASE.

6.1.1 Working Subgroup Participants.

R.W. Arnold (Chair)
G. Del Rio
F.W. Hilwig
A. Hoekstra
J.L. Labrandero
M.F. Purnell
C. Scoppa
J.L. Sehgal (Rapporteur)
W.G. Sombroek

6.1.2 Guidelines for Subgroup I.

1) Assumptions:
- The primary objective is to develop a global digital database (map) for soil & terrain resources at a scale of 1:1M.
- The database will be accessible to and utilized by a broad community of users, including decision-makers and policy-makers with reponsibilities in development, management and conservation of land and water resources.

2) Items to be addressed:
- definition of specific proposal objectives;
- action plan: duration and phasing of project;
- priority areas: specific criteria for selection of pilot/demonstration areas; identification of candidate areas (national, regional);
- data sources: consideration of a scheme for inventory and acquisition of existing data (maps, data sets, aerial photos, satellite images) which would be useful to the project;
- other burning issues.

6.1.3 Proposal Objectives for a Global Soil & Terrain Digital Database (SOTER).

Our goal is to further the well being of mankind in relation to the environment as we all know "De natuur is duur", i.e. nature is dear, by:
- creating and maintaining a social awareness of soil and land resources;
- providing a global overview of the value and potential of soils;
- supporting the concept of a World Soil Policy and fostering cooperation among nations;
- assisting countries in their own soil inventory activities;
- promoting international correlation of methods of collecting, handling and presentation of soils information;
- providing a link among numerous scientific disciplines concerned with the global environment; and
- providing information to assist with the interchange of agro-technology.

6.1.4 Action Plan.

A tentative action plan is presented in Table 6.1.1.

6.1.5 Priority Areas.

Tentative priority areas have been defined and indicated on a map of the world (Figure 6.1.1, inserted). A more complete description of the 21 priority areas and their priority rating is presented in Table 6.1.2.

6.1.6 Suggested Activities Essential to Realize Objectives.

Subgroup I identified a number of items which must be considered in the initiation and development of a soil and terrain digital database project. It was suggested that the project must provide the following:

1) Social awareness of soil and land resources by
   - publicizing the project;
   - completing pilot areas by working with ISSS, UNEP, etc.
2) Global overview of value and potential of soils by
   - preparing examples from pilot areas, interpret and correlate soils;
   - ensuring global interest;
   - helping people by providing in-country seminars;
   - creating international awareness.
3) Concept of World Soil Policy by providing (additional) information as to how the soil information can assist a country with problems of
   - degradation, pollution;
   - desertification;
   - productivity, sustainability.
4) Encouragement/assistance to countries in their own inventories by
   - offering counsel on various aspects to different countries, nations, etc. to help produce their maps (involvement of local staff);
   - encouraging information exchange.
5) Promotion of international correlation by preparing
   - Guidelines and manuals on:
     - soil correlation,
     - map-unit description (Polygon) - where are they; what is correlated - central concept, average properties,
     - minimum data sets - what is the minimum to produce a product + feedback,
     - auxiliary info: climatic data; soil data.
   - Training material such as slide set, video tapes, methodology softwares.
6) Link with other scientific disciplines concerned with environments by
   - exhange of proposals;
   - interchange of newsletters;
   - sharing costs of materials, etc.

Table 6.1.1 Tentative action plan.

	Aug.'86 Congress	March	Aug.'87	March	Aug.'88	March	Aug.'89
Activities:							
- Select pilot areas.	xx						
- Prepare standards for maps of data base	xx						
- Hold meetings to review standards/manuals;	xx						
- Collect existing materials for pilot areas;	xxxxxxxxxx						
- Provide base maps for pilot areas;		xxxxx					
- Countries recompile new maps (of the pilot areas);		xxxxxxxxxx					
- Countries provide supporting data sets;				xxxxxxxxxx			
- Pilot area correlations; define problems, minimum data sets (guide for correlation e.g. FAO);				xxxxxxxxxx			
- Prepare and distribute publications.			xxxxxxxxxxxxxxxxxxxx				
Languages: English, French, Spanish.							
Authorization:							
Pilot Areas							
-recompilation		xxxxxxxxxx					
- correlation		xxxxxxxxxx					
National Go-Ahead							
- Guideline preparation	xxx						
- Pilot studies		xxxxxxxxxx					
- Computer study (for pilot)			xxxxxxxxxxx				
- Country map preparation			xxxxxxxxxxxxxxx				
- Digitization					xxxxxxxxxx		
- Recompilation						xxxxxxxxxx	

Table 6.1.2 Tentative Priority Areas for the World Soils and Terrain Digital Data Base (ISSS Commission V Working Group on World Soils Data Base)

10 April 1986

Area No	Priority Rating(1)	Cooperating Countries	ONC Sheet No. (2)	Long./Lat of Specific Area (3)	Suggested Individuals /Organisations to review Specific Area Selection	Remarks
1	**1	Benin, Burkina Faso, Ghana, Niger, Nigeria, Togo	K2	1°W- 5°E; 10°-14°N	Brabant, Esu	
2	20	Ethiopia, Kenya, Uganda	L5	34°- 40°E; 0°- 4°N	Crain UNEP	
3	** 8	Malawi, Mozambique, Tanzania, Uganda, Zambia, Zimbabwe	N5	30°- 36°E; 13°-17°S	Samki SADCC	
4	** 4	Egypt, Saudi Arabia, Sudan	J5, J6	34°- 40°E; 21°-25°N	Ilaiwi, ACSAD	moved from N to SE (Ilaiwi)
5	17	Iraq, Jordan, Lebanon, Saudi Arabia, Syria	G4, H5, H6	36°- 42°E; 31°-35°N	Ilaiwi, ACSAD	moved from NE to SW (Ilaiwi)
6	21	Afghanistan, India, Pakistan	G6, H7, H8	70°- 76°E; 30°-34°N	Sehgal, ICRISAT	
7	* 8	India, Sri Lanka	K8	75°- 82°E; 8°-11°N	Sehgal, ICRISAT	Area extended per Bickmore request for oceanographic interests
8	14	Bangladesh, Bhutan, China, India, Nepal	H9, H10	85°- 91°E; 25°-29°N	Sehgal	
9	19	Burma, Laos, Thailand	J10, J11	97°-103°E; 16°-20°N		
10	** 1	Indonesia, Malaysia, Singapore	L10	96°-105°E; 0°- 4°N	Soekardi	Area extended per Bickmore request for oceanographic interests
11	* 7	Australia	Q14, R13	140°-146°E; 30°-34°S		
12	* 8	Bolivia, Brazil, Peru	N25, N26	64°- 70°W; 8°-12°S	Cochrane, IICA, CIAT	
13	16	Argentina, Bolivia, Peru	P26	65°- 71°W; 19°-23°S	Scoppa, Cochrane, IICA	
14	** 1	Argentina, Brazil, Uruguay	Q27, Q28	54°- 60°W; 28°-32°S	Scoppa, Cochrane, IICA	
15	14	El Salvador, Guatemala, Honduras, Nicaragua	K25	84°- 90°W; 12°-16°N	IICA	
16	12	Mexico, USA	H23, H24	97°-103°W; 24°-28°N	Arnold, IICA	
17	13	Canada, USA	F9	67°- 73°W; 44°-48°N	Shields, Arnold	shifted from west to east coast (Sombroek, Baumgardner)
18	* 8	Bulgaria, Greece, Romania, Turkey, Yugoslavia	F3	22°- 28°E; 40°-44°N	Garbouchev	
19	* 4	Morocco, Portugal, Spain	G1	3°- 9°W; 34°-38°N	Labrandero	
20	* 6	India	J8, J9, K8	75°- 81°E; 15°-19°N	Sehgal	Later proposed (Sehgal)
21	18	China, Mongolia, USSR	E6, E7, F7	84°- 90°E; 46°-50°N		Later proposed (Sombroek)

(1) In the determination of levels of priority, * designates high priority areas; ** designates high priority with potential early funding; the numbers are the weighted ratings produced by the formula used by Working Subgroup 1 of the Workshop; the lower the number the higher the rating; criteria used in rating: availability of 1:1M maps, interest of donor countries/agencies, political feasibility; interest of users, multinational aspects.

(2) Operational Navigation Chart series produced by the US Defense Mapping Agency, scale 1:1M.

(3) In all cases specific coordinates have been given for land areas of 250,000 km^2 or less.

6.2 WORKING SUBGROUP II: USE OF GLOBAL SOILS & TERRAIN DIGITAL DATABASE

6.2.1 Working Subgroup Participants.

M.F. Baumgardner
D.P. Bickmore
J.P. Garbouchev
I.E. Esu (Chair)
B.K. MacDonald
K.M. Matungulu
J.M. Ragg (Rapporteur)
R.F. Van de Weg

6.2.2 Guidelines for Subgroup II.

1) Assumptions:
- The primary objective is to develop a global digital database (map) for soil (landscape) resources at a scale of 1:1M.
- The database will be accessible to and utilized by decision-makers and policy-makers with reponsibilities in development, management and conservation of land and water resources.

2) Items to be addressed:
- Identification of users of 1:1M map (database) of soil resources, national and international.
- Information requirements of users of databases: what management of policy decisions require information about soil (Landscape) resources? What specific information about soils and related resources is required?
- Information (data) delivery: most effective methods and formats for transmitting data or information from the database to the user.
- Information utilization: scheme for making potential users aware of the database; training users to use database
- Other pertinent issues.

6.2.3 Potential Users.

The proposed international Database will be new and unique , and will generate uses and users that the experience of our Working Group are unable to predict. Those users we have been able to identify - in general terms - are:
1) The International Agricultural Research Development and Planning Institutions,
2) National Agricultural Research Institutes,
3) International Agro-Development organisations (e.g. World Bank, and regional development banks),
4) Academic establishments,
5) Multi-disciplinary global and regional bodies (WMO, WHO, UNEP, UNESCO, FAO, EEC, ICSU, others).

6.2.4 Main Topics of Interest to Users.

Under this heading, the Subgroup believed it would be useful to categorize this subject in two ways: a) whether the requirements are of national or international significance and b) whether the topics are suited mainly for assessment purposes and/or policy decisions.
Five broad topic headings were identified, namely: Land Degradation, Agro-economic Production, Agro-ecological potential, Pollution and Land Use. The results of our considerations are all contained in the following table:

Table 6.2.1. Topics of national and/or international interest for users of the proposed Database ant its suitability for assessment purposes and/or policy decisions.

Topic		Assessment	Policy
Land degradation	I	v	v
	N	v	
Agro-economic production	I	v	v
	N	L	L
Ecological potential and stability	I	v	
	N	L	
Pollution and environmental protection	I	v	v
	N	R	
Present and potential Landuse	I	v	v
	N	R	

I= International N= National
v= generally applicable
L= Only applicable to large nations or regions
R= Restricted use.

6.2.5 Information requirements.

When considering the requirements for various uses , Subgroup II was continually being side-tracked by the need for links with other databases. In order to 'clear the log jam' it was agreed that it would be assumed that access to the following external databases would be possible:
.Climate*: Agro-climatological database used in Agro-ecological zone maps
.Geology
.Hydrology
.Topography*
.Natural vegetation
.Present Land Use
.Socio-economic
.Administrative*
(*= high priority)

N.B. Many of these global databases are either not available or only partially complete. If these external data are not available to us, then the potential of the soil database will be restricted.
The most extensive requirements are those of the International Agricultural Research Institutes. They are:
.Soil category and areal extent;
.Chemical properties of soils;
.Physical properties of soils;
.Moisture relationships; and
.Relief and land form.
In contrast, the main requirements of the Agro-development organisations will be for interpretations. The following have been identified: Suitability or productivity for crops, forest and other as yet unidentified uses. These organisations are also likely to require assessments of pollution risk - given certain criteria. The multi-disciplinary global organisations will in all probability, also require interpretations to be made for them, but they may also need limited access to raw data.

6.2.6 Format for Information Delivery.

The Subgroup suggested that there should be two forms of output: i) standard and ii) customized.
Standard output will provide a large part of users' needs and should include
- Maps
- Tabular output
- Machine readable tapes, disks.

A limited number of interpretations (as maps, files, or tables) will be needed to establish priorities for specific kinds of interpretation. The range of these output forms will necessarily be restricted at first but wil increase in scope and style as users' requirements become known. When the database becomes well established and users realise its full potential, customized output will be required in the form of:
- Thematic maps;
- Additional regional or topical interpretations; and
- Subsets of adata tailored to specific requirements.

6.2.7. The Need for Publicity.

During the creation stage of the database by many nations, a sense of involvment will be developed world-wide and a degree of publicity will be generated automatically. Nevertheless, when completed, the potential of the database will require promotion. Subgroup II regards this as a high priority and recommended that funds be set aside at an early stage of the project for this purpose. We also believe that, in general, scientists make poor salesmen and that professional advice on 'marketing' should be sought when appropriate.

Attention will also have to be devoted to the need for training. How will scientists, advisors and planners be able to get the information they require?

Regional seminars will be required to provide a general overview of what is available and to indicate what potential exists within a new global database capable of being manipulated automatically. More specifically, there will also be a need to train key members of staff in many countries on how to interrogate or request data (a) from a remote centre or (b) on their own hardware.

6.3 WORKING SUBGROUP III: CONCEPTUALIZATION OF GLOBAL SOIL RESOURCES DATABASE STRUCTURE

6.3.1 Working Group members.

J.A.A. Brabant
A.K. Bregt
T.T. Cochrane (Chair)
M.C. Derouich
I. Heyse
M.K. Ilaiwi
E. Klamt
G. Lamp
F.J. Maes
L.R. Oldeman (Rapporteur)
J. Shields
M. Soekardi
A. Stein
L. Venkataratnam
J.A. Zinck

6.3.2 Guidelines for Subgroup III.

1) Assumptions:
- The primary objective is to develop a global digital database (map) for soil (landscape) resources at a scale of 1:1M.
- The database will be accessible to and utilized by a broad community of users, including decision-makers and policy-makers with responsibilities in development, management and conservation of land and water resources.
- Hardware/software technology questions will be addressed by specialists at an appropriate time (not during this workshop).

2) Items to be addressed:
- Data inputs: minimum data inputs into the global digital database (soils, landscape, other environmental resources)
  * georeferenced data
  * attribute data
- Assessment of data quality: consideration of methods to assess quality o input data (maps).
- Development of legend: approaches, guidelines for developing legend.
- Coding systems: criteria for selecting existing system or developing new system.
- Correlations: ideas for establishing guidelines to translate and correlate data/maps from multiple sources, multiple scales, different classification systems.
- Other pertinent issues.

6.3.3 Summary of Subgroup III Discussion.

1) It was concluded that the digital database consists of interactive cartographic and landscape, soil and meteorological attribute data files.
2) Tentative minimum data input sets for these files were drawn up and reviewed.
3) Wherever feasible correlation of soil information should be conducted at the national level and tested across international boundaries in selected pilot study areas.

6.3.4. Minimum Data Inputs.

1) Landscape attributes:
   Attributes within delineated landscape units would be based on areal coverage i.e. dominant, subdominant and inclusions. The tentative list of the landscape attributes is as follows:
   - elevation (medium and range);
   - surface form (e.g. level, inclined, steep, undulating, hummocky, rolling). A manual should be prepared describing by example (word and photographs) surface forms;
   - origin and kind of material (e.g. colluvial, eolian illuvial, volcanic, marine; sandstone, limestones, igneous);
   - slope gradient (e.g. % 0-3, 4-8, 9-15, 15-30, 30);
   - slope length (m);
   - land use, vegetative cover and degraded lands;
   - flooding;
   - stoniness;
   - patterned ground (e.g. permafrost, polygons, mounds, gilgai);
   - permafrost distribution and ice content;
   - surface water and drainage;
   - ground water;
   - substratum.

2) Soil attributes:
It was suggested that these might be recorded for at least 3 layers (surface, subsurface, subsoil).
- organic carbon;
- CEC, effective CEC, AEC;
- base saturation, exchangeable cations;
- pH;
- electrical conductivity;
- texture and coarse fragments;
- available water capacity;
- bulk density;
- drainage (wetness);
- structure and consistance;
- rooting depth and biological activity;
- presence of gypsum and calcium carbonate;
- color and mottling;
- diagnostic horizons and compacted layers (e.g. natric, mollic, hard pans).

3) Climatological attributes (at least monthly):
- precipitation (inc. reliability);
- minimum and maximum temperature;
- mean radiation;
- potential evaporation;
- relative humidity;
- wind humidity;
- wind speed;
- climatic hazards.

It was recommended that an international inventory of available digital meteorological data be drawn up.

4) Georeferenced data
It was suggested, that the 1:1 million cartographic base use the UTM projection. The landscape maps should be digitized.
A file containing the boundaries and topology of the digitized landscape polygons. This file should contain pointers to a series of "flat files" on:
a) landscape
b) soil attributes
c) climatic attributes
and a record pointing to an access point in the relevant national soil data base.

6.3.5 Assessment of Data Quality.

It was recommended that each national map is to be accompanied by a map indicating the relative reliability of data.

6.3.6 Development of Legend.

It was suggested that a simple number system should be used on the map and be linked to the map legend.

6.3.7 Coding Systems.

It was suggested that the coding systems shoud be user friendly. An international glossary of terms and coding symbols shoud be prepared.

6.3.8 Correlations.

1) Where possible, national maps should be correlated before submission.
2) In areas where correlation is a major concern, field correlation is recommended.
3) Pilot areas were suggested for the testing of preliminary methodology and correlation procedures in areas that cross international boundaries.

6.4 FOLLOW-UP ACTIVITIES

6.4.1 Working Group Subcommittee on Legend.

The following persons were named to serve as a subcommittee on legend: P. Brabant (France, Africa), J. Sehgal (India), T. Cochrane (South America), J. Shields, secretary (Canada), W. Sombroek, chair (Kenya).

The Legend Subcommittee was charged with the responsibility of initiating an effort to develop a suitable legend for a World Soils and Terrain Digital Database and the design of a data records format with a systematic sequence of regional landform, regional lithology (materials), soil surface characteristics, soil surface/profile compound properties, diagnostic horizons, and classification.

It is intended that the early results of legend development and format design can be tried and tested on one or two small scale mapping units / 1:1M level polygons in an area of interest of each member of the Subcommittee. The Subcommittee is requested to prepare a report for consideration at a meeting of the Working Group during the International Soils Congress in August 1986.

6.4.2 Questionnaire Distribution and Response.

One of the Workshop follow-up activities was the development of a mailing list which includes approximately 130 institutions, organizations, professional societies, and individuals who are perceived to have a special interest, for a variety of reasons, in a world digital database of soils and terrain resources. A letter (6.4.2.1) was prepared for distribution according to this mailing list. The primary objective of the letter was to inform a particular "worldwide" group of recipients of the Workshop and the preparation of a proposal for a World Soils Database. A questionnaire (6.4.2.2) was designed for inclusion with the letter and to provide recipients an opportunity to respond by indicating an interest in receiving a copy of the Workshop Proceedings and the Proposal and to designate specific kinds of environmental resource data of most importance to them.

international society of soil science
association internationale de la science du sol
internationale bodenkundliche gesellschaft

ISSS-AISS-IBG

Secretariat general
Secrétariat général
Generalsekretariat

c/o ISRIC, 9 Duivendaal
P.O. Box 353
6700 AJ Wageningen, Holland

tel.: (31)-(0)8370-19063
telegram: Sombroek,
ISOMUS, Wageningen

6.4.2.1 Letter sent to selected mailing list.

Subject : Questionnaire on International Environmental Data Bases.

Dear ,

An International Workshop on the Structure of a Digital International Soil Resources Map annex Data Base was held in Wageningen from 20 to 24 January 1986. Cosponsored by Commission V of the International Society of Soil Science (ISSS) and the International Soil Reference and Information Centre (ISRIC), the Workshop was attended by 35 participants from eighteen countries.

Presentations on the state-of-the-art in digital data handling and processing, landscape data acquisition systems, georeferenced information systems, and global data bases helped to focus attention on the kinds of technical and administrative problems which must be addressed. Presentations on digital data bases of soil and physical terrain resources of specific countries helped Workshop participants to grasp the operational aspects and potential uses of a global soils data base.

During the final two days of the Workshop there were intense discussions about the feasibility, need and potential use of a global digital soils data base at a scale of 1:1 million. The Workshop participants reached concensus on the desirability to proceed with plans to prepare a proposal for the development of such a data base.

It is anticipated that such a data base would be accessible to a broad community of users (international and national agricultural research institutions, international development organizations, universities and research institutes, funding institutions, and others) and that there would be linkages and overlay capabilities with other environmental data bases such as topography, hydrology, vegetation, climatology, land use, geology and administrative boundaries. Global data bases are expected to become available for several of these discplines within the next decade.

It is envisioned that these global data bases will become invaluable tools for a wide community of decision-makers and policy-makers at the international, regional and national levels. These data bases will be useful in deriving quantitative information about potential soil productivity, land degradation assessment, land use capability, and stratification of land resources for many different objectives.

Further, a strong argument can be made for the creation of such a georeferenced data base at a scale of 1:1 million to serve as a model for educational purposes and the future development of more detailed (1:10,000 - 1:100,000) in-country data bases with sufficient detail for use in local planning and decision-making.

With this brief background statement as an introduction to the concept of a global soils data base at a scale of 1:1 million, you can contribute to the task of the Working Group on the Global Soil Data Base if you could provide your response to these ideas by completing the enclosed information questionnaire. I would appreciate having your response no later than 25 March 1986.

If you wish to have a copy of the proceedings of the Workshop and a copy of the Proposal for an International Soils Data Base, please indicate your interest on the questionnaire.

I look forward to hearing from you.

Sincerely,

W.G. Sombroek
Secretary-General

6.4.2.2. Questionnaire.

GLOBAL DIGITAL SOIL AND TERRAIN DATABASE AT 1:1 MILLION SCALE

INFORMATION QUESTIONNAIRE

YOUR NAME:

ORGANIZATION:

CONTACT PERSON:

ADDRESS:

TELEPHONE: TELEX:

Please check the appropriate column for each item below.

	Yes	No	Uncertain
1.0 I would like to receive			
1.1 The proceedings of the Jan.'86 International Workshop on a Global Soils and Terrain Digital Data Base.			
1.2 The "follow-on" project proposal to develop a Global Soils and Terrain DigitalData Base.			
2.0 My organization is:			
2.1 A user of soil and terrain data/information			
2.2 A user of information about soil productivity			
2.3 A user of information about land degradation			
2.4 A user of information about environmental pollution			
2.5 A user of information about land use			
2.6 A user of information about agroclimatology			
2.7 A user of other environmental information (Please specify)________			
3.0 My organization is:			
3.1 A potential user of a Global Soil and Terrain Digital Data Base			
3.2 A potential supplier of data to a Global Soil and Terrain Digital Data Base			
4.0 As a potential user of Global Soils and Terrain Data Base, my organization would wish to overlay soils/terrain data with data from the following data bases:			
4.1 Topography			
4.1.1 Contour lines only			
4.1.2 Other topo parameters (please specify) ________			

Yes No Uncertain

4.2 Geology
- 4.2.1 Age of bedrock
- 4.2.2 Nature of bedrock
- 4.2.3 Other (please specify) ______________

____

4.3 Hydrology
- 4.3.1 Surface drainage
- 4.3.2 Flooding conditions
- 4.3.3 Ground water
- 4.3.4 Other (please specify) ______________

____

4.4 Climatology
- 4.4.1 Time and length of growing season
- 4.4.2 Climate hazards such ad typhoons, extreme temperatures
- 4.4.3 Other (please specify) ______________

____

4.5 Surface cover
- 4.5.1 Patterns of present land use
- 4.5.2 Vegetation types (managed and non-managed)
- 4.5.3 Other (please specify) ______________

____

4.6 Administrative boundaries

4.7 Other (please specify) ____________________

____

5.0 As a potential user of a global soils/terrain digital data base, my organization would wish to have access to the following kinds of output:
- 5.1 Raw digital data (tape, disk)
- 5.2 Printed thematic maps
- 5.3 Tabular data
- 5.4 Other (please specify) ____________________

____

6.4.2.3 Results of the questionnaire.

With responses from 54% of the recipients of the questionnaire, there is an almost unanimous indication of interest in the development of a World Soils and Terrain Digital Database at 1:1M. More than 90% of the respondents would like to receive the proceedings of the January 1986 International Workshop on a Global Soils and Terrain Digital Database as well as the "follow-on" project proposal. Around 75% of the respondents indicated that their organizations would be potential users of a World Soils Digital Database, and 15% was uncertain, while half of the respondents would also be potential suppliers to such a database. With regard to the question on the type of databases a potential user would wish to overlay on a soil/terrain database. The response was variable as indicated in table 6.4.1.

Table 6.4.1. Response (as percentage of total questionaires received) on the question: "As a potential user of the global/soil/terrain database my organization wishes to overlay soil/terrain data with data from the following data bases".

Databases	Yes	No	Uncertain	No response
Topography (contourlines only)	53	28	13	6
Geology (age of bedrock)	31	47	11	11
(nature of bedrock)	42	37	8	10
Hydrology (surface drainage, flooding, groundwater)	67	15	8	10
Climatology (length of growing season)	71	11	9	9
(climatic hazards)	58	21	12	9
Surface cover (present landuse, vegetation)	75	8	8	9
Administrative boundaries	58	28	3	11

The last question related to the kind of output a potential user would like access to. There was a preference for thematic maps (71% said yes and 9% no), while around 60% indicated they would like either raw digital data or tabular data with 16% indicating they were not interested in that type of output. A relatively high percentage (15%) was uncertain at this stage on the type of output.

6.4.3 Work on Draft Proposal.

During the two months following the Workshop Marion Baumgardner developed a tentative proposal for the development of a World Soils and Terrain Digital Database (SOTER). The consideration of this draft proposal will be a major agenda item for the meeting of the Working Group during the International Soils Congress in Hamburg. An abstract of the draft proposal is presented below.

6.4.3.1 Proposal Abstract.

Information is a valuable commodity! Accurate, timely information about soils and terrain resources is essential for rational decision-making related to the development, management, and sustainable productivity of these resources. Of the 14.9 billion hectares of land in the world, approximately 10.5% is currently cultivated and another 11.5% is potentially arable, leaving 78% of the land as non-arable. According to estimates of Buringh (1982), of the total land area, only 3% is inherently highly productive, 6% is of medium productivity, and 13% of low productivity. Such global statistics are at best rough estimates with the possibility of sizeable errors at local and country levels. Not only that, the conditions and uses of soils and terrain resources are subject to rapid local change in many countries.

The increasing pressure on the land, the often indiscriminate destruction of forests and woodlands, and the spectre of land degradation resulting in decreased productivity with dire social consequences provide a strong argument for 1) improved mapping and monitoring (of changes) of world soil & terrain resources, and 2) development of an information system capable of delivery of accurate, useful, and timely information about soils and terrain resources to decision-makers and policy-makers.

In response to this argument this Proposal is designed to utilize current and emerging information technology to produce a world soils and terrain digital data base (map and attribute data) with the following characteristics: 1) average scale of 1:1 million, 2) compatible with data bases of other environmental resources, 3) amenable to updating and purging of obsolete and/or irrelevant data, and 4) accessible to a broad array of international, regional and national decision-makers and policy-makers responsible for the development, management, and conservation of environmental resources, 5) and transferable to developing countries for national data base development in greater detail.

The Technical Proposal describes the technical approach, divided sequentially into three phases and utilizing the most effective information technology (hardware and software) for developing, testing and implementing the following tasks: 1) creation of a "universal" legend for a world soils & terrain survey at 1:1M; 2) definition of soils & terrain parameters for entry into the data base; 3) selection, prioritization, and scheduling of land areas to be added sequentially to the data base; 4) acquisition and input of all data essential for inclusion in the data base; 5) implementation of updating capability and the capability to overlay with other global environmental data sets; 6) transfer of the technology to the user community.

The Facilities Proposal describes the basic requirements for space (type, size), computers (hardware, software), communications network, and other equipment.

The Administrative Proposal outlines a suggested basic staff and administrative structure for supervising and coordinating all activities essential to the accomplishment of the Project objectives. Relationships among the administrative units and responsibilities of each unit are described. Project operations, Project review, and Project reporting are discussed.

The Budget Proposal provides a detailed budget for Phase 1 (years 1 and 2) for each of the following budget sub-headings: 1) personnel (salaries, wages), 2) communications, 3) travel, 4) data acquisition, 5) computer support, 6) reporting, and 7) supplies and expenses. Budget projections are made for Phase 2 (years 3, 4 and 5).

6.4.4 Plans for Working Group activities during the ISSS Congress in Hamburg, 13-20 August 1986.

A meeting of the Working Group has been scheduled during the Congress on 19 August 1986 in the Congress Centrum from 10.30 to 12.30. However, the following important agenda items make it essential to schedule other periods during the Congress so that adequate attention may be given to them:
1) Legend/data recording format for SOTER
2) SOTER proposal.

7

APPENDIX

7.1 Establishment of an International Soil and Land Resources Information base 1)

Discussion paper
W.G. Sombroek
Working Group on Digital Mapping of Global Soil Resources
International Society of Soil Science

7.1.1 Aim.

To produce a digital map of soil and other physical land resources at average accuracy of 1:1 million, accompanied by tabular information on soil properties per politico-administrative entity ("digital soil map" + "soil database management system"). The effort will concentrate on soil and land resources of Latin America, Africa, the Middle East and Asia, starting with some regions of urgent development need and fragile ecosystems. The product will be an international soil database that can be updated regularly and can be interfaced with similar databases on other natural resources such as (agro) climates, surface hydrology and vegetation/land use/farming systems, in a global resources information data base.

7.1.2 Background.

The only available document on the geography of the world's soil resources is the FAO/Unesco/ISSS Soil Map of the World at 1:5 million scale (1 cm^2 on the map representing 250,000 ha.), which was prepared by conventional cartography (though it has been recently digitized). It was the result of a major international action programme and it achieved an aggregation of all soil survey information that was available about 15-20 years ago. In the meantime - and often stimulated by the FAO/Unesco effort - many countries in all continents have embarked upon systematic soil resources mapping at national scale, combining new ground truth with remote sensing imagery of several kinds, resulting in maps ranging in scale from 1:250,000 to 1:1 million. These national soil geographical data sets not only give much more detail, but in many cases also modify the earlier estimates that were incorporated in the 1:5 m. FAO/Unesco map (the Amazon region and Eastern Africa being cases in point). But these national soil maps are produced with different levels of ground truth, in different languages, with different legend structures, and with different systems of soil classification and land capability evaluation.

---

1) A first draft of this discussion paper was prepared in October 1984 under the title "Towards a global soil resources inventory at scale 1:1 million" (Working Paper and Preprint Series 84/4 of the International Soil Reference and Information Centre (ISRIC), Wageningen - the Netherlands).
The author gratefully acknowledges the comments and suggestions for improvement of the earlier text by: Burrough - Utrecht, Ragg - Rothamsted, Lamp - Kiel, Jones - Cali, Bickmore - Oxford, Flach - Washington, Maes - Leuven, Croze - Nairobi, Millington - Australia, Van de Weg/Bouma - Wageningen, and many others.

Such differences are also apparent in recent efforts to produce regional soil resources maps at 1:1 million scale (e.g. CIAT for tropical South America; ACSAD for the Arab Countries; EEC for Western Europe; FAO for West Africa; etc.). In order to take full advantage of the various efforts and to stimulate international cooperation, there is an urgent need to collate and correlate these national and regional geographical soil databases, and to bring them under a common denominator that can serve as a legend for a new and more precise soil map of the world. Only in this way will it be possible to use this information about the worldwide distribution of soils for a number of important applications.

7.1.3 Approach.

The geographic density of the new soils information now becoming available at national level; the availability of satellite imagery of ever better resolution and frequency; and the advance of new, computeraided cartographic techniques make a global soil mapping effort, at substantially larger scale than before, a feasible proposition. A 1:1 million level (1 cm^2 representing 10,000 ha.) would normally imply about 350 printed, coloured sheets for Latin America, Africa and (sub)tropical Asia, at astronomic costs. New techniques, viz. digital storage and reproduction of soil cartographic information provide the answer.

Initial costs of application of digitizing techniques may be relatively high too, especially as regards base map preparation. One can however produce computer-printed sheets on demand only. Moreover, once all data have been duly processed and fed into the computer system, a continuous or periodic updating by incorporation of new national mapping data should be far cheaper than updating by conventional cartographic printing techniques. When the digital topographic base map includes country, province and district boundaries, then the digital map sheet production can be accompanied by tabular information for planning purposes.

The use of interactive mapping systems also opens up the prospect of combining soils information with information on other aspects of the physico-biological environment in one geographic information system - which would be available to all scientists, all countries and all international institutions/organizations concerned with natural resources and their use.

The 1:1 million level of accuracy mentioned here is an average. Computer processing of the now available data implies a flexibility of scale: For those regions where there is as yet a scarcity of information and/or where the development potential is very limited (e.g. the Sahara, High Mountain Zones) one can do with smaller accuracy /scale, say 1:2.5 million. On the other hand, for areas on which more detailed information exists and where development planning will have to be quite intensive (e.g. potentially irrigable plain lands in sub-Saharan Africa), one can feed or update the data base at larger scale, say 1:500,000[1)], without disrupting the system.

1) At minimum size delineations, or "basic soil mapping units" of about 0,5 cm^2 on the map, this amounts to smallest areas of 5000 ha at 1:1 million scale, but to 1000 ha at 1:500,000 scale.

7.1.4 Use.

A digitized map of soil resources of the world at average accuracy 1:1 million, and of the developing countries in particular, will serve a number of purposes, especially when accompanied by a soil database management system and an agroclimatic data base:

- It will benefit the rural population in developing countries by providing planning committees with a better insight in the land resources potential at provincial level and by improved possibilities for agrotechnology transfer, because of a compatibility of land resource data bases between countries and continents.

- It will provide the necessary land resource data for international agricultural research centres of the CGIAR system, supporting the extrapolation of their findings on site-dependent agricultural production factors to areas of similar physical land conditions. Factual information on the geography, the characteristics and the properties of the soils and other physical land parameters such as agro-climate will also allow these centres better to formulate guidelines for their commodity-oriented research programmes to the breeding of crop-cultivars suitable to soil-related constraints, especially in marginal land zones: areas of acid red and yellow tropical soils, tropical wetland soils, tropical black clays and clay-pan soils, crusting soils of semi-arid zones, shallow mountain soils, etc.
  Research networks that are to study soil-related constraints specifically (e.g. IBSRAM) will need to have access to the best possible data on the spatial distribution of such soils, their average characteristics and properties, and the degree of variation thereof.

- It will allow a more precise estimate to be made of the agricultural production potentials at different levels of input and management. Theoretical production models, or farming systems research data, can then be reliably extrapolated to delineated land areas and thereby the future population carrying capacities per country and per state/province can be quantified. This, in turn, would provide guidelines for bilateral and international Food Programmes, especially those that are directed to increasing the food, fuel and fodder production as a longer-term means to prevent chronic famine in a number of developing countries.
  In combination with a climatic and surface hydrological database, the soil resources data base will, for instance, allow the assessment of irrigation potential per country and state/province, and hence form a guide for the allocation of funds for development of that potential in relation to expected population growth.
  These country or province-level estimates and assessments could also be made on the basis of a national map, but then one has to study time and again the particulars of each different national approach to resources mapping.

- It will provide the soils input of an integrated and updatable global resources information base, that is required for monitoring the earth's life support systems (Global Environmental Monitoring Systems). This will signal trends in land degradation (desertification, deforestation, salinisation, erosion and downstream accumulation) and provide clues for sustainable use of the land resources, at the same time safeguarding essential nature reserves and particularly fragile ecosystems.

- It will allow a better insight to be obtained on the spatial distribution of the different physical and biological elements of the land. This, in its turn, will provide guidelines for more basic multi- and interdisciplinary scientific research on interactions between biomass production; biological processes and nutrient cycling per major resource-geographic region; global carbon cycling; climatic changes, etc. Detailed studies on sites chosen carefully with respect to the distribution of soils will permit more quantified and more reliable spatial assessments of rates of soil formation and loss or gain of carbon, nutrients, etc. than the subjective assessments in current use.

- The methodology to be developed and employed can be taken as the starting point for the establishment of detailed soil resources databases per individual country, in those cases where a national system is not yet operational.

7.1.5 Data Sources.

Guidance on the collection, quality control, and the collation into a suitable legend of the soils ground truth can be given by ISSS Commission V (which deals with soil genesis, classsification and cartography). ISSS, with its 7500 individual members (about 2000 of them Commission V adherents) in all countries of the world, and its 65 affiliated national soil science societies, is in fact in a unique position to obtain the effective cooperation of soil cartographic institutes and individuals everywhere.

Major collections of small-scale soil maps and related thematic maps are already present at FAO in Rome (the former World Soil Resources Office) and at the International Soil Reference and Information Centre (ISRIC) in Wageningen. Sizeable collections, often with regional emphasis, exist at CIAT (Cali-Colombia), at the Asian Institute of Technology (AIT, Bangkok), at the Arab Centre for Studies of Arid Zones and Drylands (ACSAD, Damascus), at ORSTOM (Paris), at the Land Resources Development Centre (LRDC, Tolworth - London), at the World Soil Geography Office of the USDA (Lanham, USA) etc... It may be advisable to create some additional regional support centres for the assembling of new soil cartographic information, e.g. at regional mapping centres or at some UN Regional Offices (Nairobi, Dakar, Montevideo). The data of these collection centres should be supplemented with a comprehensive collection of remote sensing imagery from all relevant space vehicles (Landsat, Spot, SLAR).

7.1.6 Structure of the Soil Database.

A hierarchical system of the soil database is envisaged. It is however suggested not to use soil classification proper as a major entry of the base structure ("legend") that will have to be developed. This is not only because as yet there is no one such a system that is universally accepted, but also because it may obscure other useful information on the physical aspects of the land units, and thereby reduce interchangeability with other thematic mapping efforts that may want to use the same computer outfit (whether or not with the same 1:1 m. accuracy). Priority to soil classification aspects would also imply a less than maximum use of information that can be extracted from remote sensing imagery (satellites, radar).

Preferably, the first entry (main headings) of the legend should be on patterns of landforms (geomorphic units) and the second level on (soil parent) materials (surface lithology), and only the third one on soils information proper.

Several regional schemes for grouping of landforms and of surface materials do already exist, and it is expected that international working groups of geomorphologists and geologists will render advice as to the elaboration and collation of these schemes.

The entering of information on the soil in a strict sense can best be done by a system of coding of diagnostic surface and subsoil characteristics and features - on which there is already a large degree of agreement the world over. The combinations of these coded diagnostics, with texture, slope and drainage classes as additional characteristics, can then be "translated" optionally into any particular soil classification system by the user of the computer print-outs.

Much attention should be given to the quantification of the composition of mapping units (associations, complexes, or inclusions of soils), through a system of major and referral coding. A separate file of extended legend information can contain the properties of each coded unit in relation to plant growth, to engineering use, to hazard of degradation, etc. For interpretative purposes these properties should be presented as estimates within a limited number of classes, rather than as actual figures of field- and laboratory analysis (though representative example pedons should be available for consultation, in a computerized "pedon file").

Advice on the details of the soil data structuring will be sought from the standing Working Group on Soil Information Systems of ISSS, the members of which have close ties with major national soil research institutions that employ such systems or are considering introducing it (Norway, Canada, France, USA, FRG, the Netherlands, Brazil, Indonesia, Thailand).

Major altitudinal zoning, overhead (eco)climatic parameters and flooding conditions, which usually have less detailed patterns than that of the landforms and soils, can be fed into the computer as an overlay. This should be done in consultation with climatologists and hydrologists (c.f. the agroclimatic zones approach of FAO at 1:5 M. world level and at 1:1 M. for some countries; the moisture and temperature regimes as calculated by the Newhall method of Cornell University).

A number of examples exist at national level that are in accord with the approach sketched above. They are the 1:1 M. Canadian Land Inventory; the Soil and Land Survey of CSIRO in Australia; the Indonesian/FAO Land Capability Appraisal project; the "Life System" zoning of Holdridge-Tosi as in use in Central America; the "Cartes Morpho-pédologiques" of the Institut de Recherches Agronomiques Tropicales (IRAT) in France, using the geomorphology-lithology concepts of Tricart; the physiographic-synoptic soil mapping of the Kenya Soil Survey, etc. Also the legend of the USDA World Soil Geography Office at Lanham uses the sequence: landform-materials-soils.

7.1.7 Staffing.

To organize the soils input, the functioning of a multilingual group of (tropical) soil-cartography and information systems specialists will be required. These specialists can be drawn from, or seconded by a number of major national soil cartographic institutes with experience in small-scale mapping of soils and subsequent machine processing. Because the members of this group will have to work very closely together, they should be stationed at one place during the project period, for instance at one of the major soil map collection centres (see above), with easy access to the central computing centre. Some active gathering of soil map data of countries of difficult contact may have to be carried out by this group, as well as the organization of some regional workshops. The actual digitizing work can be subcontracted to a private company specialized in graphical data processing. The total costs may well be in the order of $ 2-3 million, as a very rough estimate.

One may want to start, also for testing purposes, with one or more subregions where the need for organizing an over-all soil geographic data-base is felt most urgently, e.g. Southern Africa (through SADCC?), Western Africa (through FAO?), South-East Asia (through ASEAN?), the Amazon region (through PACTO AMAZONICO?). Such a pilot programme may require funds in the order of $ 0.5 m.

7.1.8 Hardware

The hardware and associated peripheral devices to be chosen should, as far as possible, be independent of manufacturers. Compatibility with simple systems in individual countries should receive major attention.

The hardware for a computer-aided 1:1 M. soil resources data base should consist of a centrally located main computer with a memory of at least 2 megabytes, with a number of subsystems in a network configuration (located at major cooperating international institutions and/or main geographic regions). The connection could be on-line (expensive), or by physical transfer on magnetic media.
Input to a powerful interactive mapping system with a layer structure and a high-resolution scanning device will be required. There are two alternatives for the interactive graphics systems: raster-based or polygon/vector based. The vector-based one would probably facilitate links with national Geographical Information Systems in developing countries, and is relatively simple to operate if only one set of geographical data, such as soils, is to be dealt with. If, however, several thematic data sets need to be combined for interpretative purposes, then the merging of different thematic polygons is cumbersome and highly demanding of computer processing. A raster-based system does such combining more easily, and can also accommodate remote sensing data with few soft- and hardware problems, and may therefore be preferable. Raster techniques are expected to be further developed in the forthcoming years, especially with regard to improved resolution. Tape transfer from a vector-based system to a raster-based one and vice-versa is possible in principle, but in practice there are many problems. Therefore an early decision on the type will be required.

The total costs of hardware and peripheral devices will be in the order of US$ 1.0 million or more, depending on the number of input and output subsystems and the mode of data transmission. Its upkeep and management would require another $ 1.5 M or so. The total cost of $ 2.5 M. would be excessively high if used for the soil database only.

One possibility however is to avail of the services of the equipment that has been acquired recently by UNEP-GEMS for development of its Global Resources Information Base (GRID). It is being installed in Geneva with Swiss Government support on management expertise. From correspondence it is understood that this equipment will be "open for anybody to use, at cost". If the centre for soil data collating and software development is not at the same site as this GRID computer, then at least one on-line connection will be required.

7.1.9 Topographic Base.

A topographic base map will have to be prepared and digitized, in such detail as required for adequate orientation at 1:1M thematic sheet output. Unfortunately there is no convential cartographic base- map at that scale with complete global coverage available (an international/UN series of 1:1M topomapping was started already in 1910, but covers only 60-70% of the world's land surface, at variable quality). There exists however a good-quality world topographical base map at 1:2.5 M scale, prepared and maintained by a consortium of Eastern European countries. Its average resolution (1 km), the details of the topo patterns, and the thinness of lines of altitudes, rivers, roads and administrative boundaries would permit to blow it up to a 1:1 M scale as a basis for soil and land resources digitizing as discussed above.

A joint Working Group on Environmental Atlasses and Maps of the International Geographical Union (IGU) and the International Cartographic Association (ICA) is considering to digitize the said 1:2.5 million map. This is likely to be executed with financial support of the International Council of Scientific Unions (ICSU) through its World Data Centre A (Boulder-CA, USA). Tapes of the digitized maps can be made available to the soils programme per region of interest, "at cost". The IGU-ICA working group is still looking for a Centre where this digitized topobase can be kept updated, and the estimated costs of this updating is $ 25.000 per year (ITC - Enschede, Holland has been approached for this).

7.1.10 Organisational Aspects and Funding.

In view of the likely use to be made of the digitized world soil database as outlined in section 4, it may be expected that several of the major international and bilateral donors as already cooperating in the CGIAR system will be found prepared to provide the necessary funding. Also institutes like the World Resources Institute and resources for the Future Inc, both in Washington, the International Institute for Applied System Analysis (IIASA) in Vienna,and the International Institute for Environment and Development (IIED) in London, may be prepared to participate in the funding. Individual donor countries may be prepared to finance the development of the methodology, and/or to adopt the actual processing work for one or two priority areas of their development cooperation programmes.

A logical umbrella for receiving and administering funds would be the recently created International Board for Soil Research and Management (IBSRAM), which already receives funds for its networking activities from some of the donors of the CG group. This board may want to carry out the programmme under its own direction, or to delegate it to a UN organization like FAO, an international soil resources information center like ISRIC, a major national soil cartogrpahy institute, or a consortium of these.

An alternative is to tie the project to the International Geosphere-Biosphere Programme (IGBP) as proposed by the International Council of Scientific Unions (ICSU) at its recent "Global Change" symposium in Ottawa, September 1984.

On the basis of an earlier version of this discussion paper, many organisations and individuals have shown a varying degree of interest in participating in an undertaking as outlined above. In the technical field, they are national and international soil or land survey and evaluation institutions such as:

- the Canadian Land Resource Research Institute in Ottawa
- the Soil Survey Staff and the Soil Management Support Services of the USDA in Washington
- the ORSTOM organisation in Paris
- the Land Resources Development Centre in Tolworth - UK and the Soil Survey of England and Wales in Rothamsted
- the Dutch Soil Survey Institute in Wageningen and the Cartographic Centre of Utrecht University
- the SADCC Food Security Project Team in Harare - Zimbabwe
- the Division of Water and Land Resources of CSIRO in Canberra - Australia, and
- CIAT's Agroecological Studies Unit in Cali - Colombia.

Encouraging signs of potential support have already been received from FAO's Land & Water Development Division, Unesco's Division of Ecological Sciences, UNEP's Global Environmental Monitoring System (GEMS) section, the Scientific Secretariat in Washington of the Consultative group of international agricultural research (CGIAR), the World Bank's Geographical Services Department, IDRC in Canada, and others.

In view of these first reactions the Executive Committee of ISSS decided to form a provisional Working Group specifically for the purpose. This Group will organize a first workshop on the subject from 20 to 25th January 1986 at ISRIC, Wageningen, with the aim to discuss the structure of an international soil and land resources information base and to prepare a feasibility study for its implementation. A further discussion on the scientific-technical aspects is envisaged to take place at the 13th International Congress of Soil Science in Hamburg - FRG, 13-20 August, 1986, at a joint session of the Working Group with those on Soil Information Systems, on Remote Sensing for Soil Survey, and on Land Evaluation.

7.2 PRIMARY SOURCES OF DATA FOR USE IN PREPARATION OF A WORLD SOILS AND TERRAIN DIGITAL DATABASE

7.2.1 Landsat Worldwide Receiving System-Data Distribution Centers.

The Landsat receiving stations and Landsat orbital tracks for one day of coverage are illustrated in figure 7.3.1

7.2.1.1. Stations and locations with MSS reception only:

Argentina: Station Mar Chiquita, located at 37.4°S and 57.3°W
Commision Nacional de Investigaciones Espaciales (CNIE)
Centro de Procesamiento
Avenida Dorrego 4010
1425 Buenos Aires, Argentina
Tel. 772-5108/5474
Telex 17511 LANBA AR

Australia: Station Alice Springs, located at 23.8°S and 133.9°E.
Australian Landsat Station,
14-16 Oatly Court
P.O.Box 28
Belconnen, ACT 2616, Australia
Tel. 062-515411
Telex 61510

Indonesia: Jakarta, located at 6.3°S and 106.8°E.
Indonesian National Institute of Aeronautics and Space (LAPAN),
JLN Pemuda Persil No 1
P.O.Box 3048
Jakarta, Indonesia
Telex 49175

South Africa: Johannesbourg, located at 25.9°S and 27.7°E.
National Institute for Telecommunications Research,
Attn. Satellite Remote Sensing Center,
P.O.Box 3718
Johannesburg 2000, South Africa
Tel. 27-12-26-5271
Telex 3-21005 South Africa.

Thailand: Bangkok, located at 13.7°N and 100.8°E.
Remote Sensing Division,
National Research Council of Thailand (NRCT),
196 Phahonyothin Road
Bangkok 10900, Thailand
Tel. 579-0117
Telex 82213 NRCTRSD

United States of America: Goldstone, located at 35.3°N and 116.9°W.
EOSAT,
c/o Landsat Customer Services,
EROS Data Center
Sioux Falls, SD 57198
Tel. 605-594-2291 / 800-367-2801
Telex 910-668-0310 EDC SFL

7.2.1.2. Stations and locations with MSS and TM reception:

Brazil: Cuiaba, located at 15.5°S and 56.1°W.
Instituto de Pesquizas Spaciais (INPE)
Departamento de Producao de Imagens
ATUS-Banco de Imagens Terrestres
Rodovia Presidente Dutra, Km 210
Cachoeira Paulista - CEP 12630
Sao Paulo, Brazil
Tel. 0125-611507
Telex 0122-160 INPE BR

Canada: Prince Albert, located at 53.2°N and 105.3°W.
Canada Centre for Remote Sensing (CCRS)
User Assistance and Marketing Unit
717 Belfast Road
Ottawa, K1A OYT, Canada
Tel. 613-995-1210
Telex 053-3777

Peoples's Republic of China: Beijing, located at 40.5°N and 116.9°E
Academia Sinica
Landsat Ground Station
Beijing, People's Republic of China
Tel. 284861 (Beijing)
Telex 210222 ASCHI CN

India: Hyderabad, located at 17.2°N and 78.3°E.
National Remote Sensing Agency
Balaganar, Hyderabad 500 037
Andhra Pradesh, India
Tel. 262572/ext. 67
Telex 0155-522

Japan: Hatoyama, located at 35.6°N and 139.8°E
Remote Sensing Technology Center of Japan
7th floor Uni Roppongi Building
7-15-17 Roppongi Minoto-ku
Tokyo 106, Japan
Tel. 03-403-1761
Telex 02426780 RESTEC J

Europe: Fucino, located at 41.9°N and 13.6°E.
(Contact address for all European countries except Italy and Sweden):
EARTHNET User Service
Via Galileo Galilei
100 44 Frascati, Italy
Tel 39-6-9401360 / 39-6-9401216
Telex 610637 ESRIN I

Italy: Fucino
European Space Agency (ESA)
Telespazio
Corso d'Italia 42-43
Rome, Italy
Tel. 39-6-8497306
Telex 610654

Spain: Maspalomas, located at 27.8°N and 15.7°W (Limited reception only).
European Space Agency (ESA)
contact address: see Europe.

Sweden: Kiruna, located at 67.9°N and 20.3°W.
European Space Agency (ASE)
Swedish Space Corporation (SSC)
Tritonvagen 27
S-171 54 Soina, Sweden

United States of America: Goddard Space Flight Center Greenbelt, Maryland, located at 39.0°N and 76.9°W.
EOSAT
c/o Landsat Customer Services
EROS Data Center
Sioux Falls, SD 57198
Tel. 605-594-2291 / 800-367-2801
Telex 910-668-0310 EDC SFL

7.2.1.3 Stations and Locations about to become operational:

Bangladesh: Dacca, located at 23.6°N and 90.5°E.
Bangladesh Space Research and Remote Sensing Organization (SPARRSO), Dacca, Bangladesh.

Pakistan: Islamabad, located at 33.5°N and 73.2°E.
Pakistan Space and Upper Atmospheric Research Commission (SUPARCO)
Islamabad, Pakistan.

Saudi Arabia: Riyadh, located at 24.7°N and 46.8°E.
Saudi Arabian National Center for Science and Technology (SANCST)
Riyadh, Saudi Arabia.

7.2.2 Spot World List of Distributors.

7.2.2.1 Africa:

South Africa:
Council for Scientific and Industrial Research (CSIR)
Foundation for Research Development
P.O.Box 395
Pretoria 0001, South Africa

Tunisia:
Office de Topographie et Cartographie
13, Rue de Jordanie
Tunis, Tunisia

7.2.2.2 North America:

Canada:
Canada Center for Remote Sensing (CCRS)
2464 Sheffield Road
Ottawa K9A OY7, Canada

United States of America:
SPOT Image Corporation
1150 17th Street N.W.
Suite 307
Washington DC 20036, U.S.A.

7.2.2.3 Latin America:

Argentina:
Centro Nacional de Investigaciones Espaciales (CNIE)
Centro de Teleobservacion
Av. del Libertador 1513
Vicente Lopez 1638
Buenos Aires, Argentina

Brazil:
SENSORA
Rua Bertolomeu Portela
25, S/Lojas Botafogo
Rio de Janeiro CEP 2290, Brazil

Bolivia:
Centro de Investigacion y Aplicacion de Sensores Remotos (CIASER)
Casilla de correos 2729
La Paz, Bolivia

Chile
Servicio Aerofotogrametrico de la Fuerza Aerea (SAF)
Casilla 67, correo de los Cerillos
Santiago, Chile

Mexico:
Instituto Nacional de Estadistica Geografia e Informatica (INEGI)
San Antonio Abad 124
Mexico 8, DF, Mexico

Peru:
Oficina Nacional de Evaluacion de Recursos Naturales (ONERN)
355 Calle 17, Urb. E1
Palomar, San Isidro
Peru

Venezuela:
Fundacion Instituto de Ingenieria
Edo. Mirando Apartado 40200
Caracas 1040 A, Venezuela

7.2.2.4 Asia:

People's Republic of China
Space Science and Technology Center
Chinese Academy of Sciences
Beijing, People's Republic of China

India:
National Remote Sensing Agency
Department of Space
Balaganar, Hyderabad 500 037 AP
India

Japan:
Remote Sensing Technology Center (RESTEC)
Uni Roppongi Building
7-15-17 Roppongi, Minato-ku
Tokyo 106, Japan

Malaysia:
Terra-Control Technologies Sdn Bhd.
No 26 Jalan Syers
Kuala Lumpur, Malaysia

Nepal:
National Remote sensing Center (NRSC)
P.O. Box 3103
Kathmandu, Nepal

Philippines:
Natural Resources Management Center (NRMC)
P.O.Box AC
Quezon City 493, Philippines

Republic of China
Center for Space and Remote Sensing Research
National Central University, Chung-Li
Taiwan 320, China

7.2.2.5 Europe:

Austria:
Beckel Satellitenbilddaten
Marie-Louise Strassse
Bad Ischl 4820, Austria

Denmark
Plancenter Fyn A/S
Overgade 32
5000 Odense C, Denmark

Spain:
Instituto Geografico Nacional (IGN)
General Ibanez de Ibero 3
Madrid 3, Spain

Finland:
National Board of Survey (NBS)
Pasilan Vimastukeskus
Opastinsilta 12
Helsinki 52 00521, Finland

France:
SPOT IMAGE
16 bis, Rue Edouard-Belin
BP 4359
31030 Toulouse Cedex, France

United Kingdom:
Nigel Press Associates Ltd.
Edenbridge
Kent TN8 6HS, United Kingdom

National Remote sensing Center
Department of space
Farnborough
Hantz GU14 6TD, United Kingdom

Hungary:
Foldmeresi Intezet
Guszev. 19
Budapest H 1051, Hungary

Italy:
Telespazio
Via Alberto Bergamini 50
Rome 00159, Italy

Norway:
Fjellander Wideroe A/S
P.O. Box 2916
Trondheim 7001, Norway

The Netherlands:
National Lucht- en Ruimtevaartlaboratorium (NLR)
P.O. Box 90502
BM Amsterdam, The Netherlands

Poland:
Geokart
2/4 Rue Jasna
Varsovia 00-950, Poland

Portugal:
Geometral
Av, Cons. Barjona de Freitas
No 20-A
1500 Lissabone, Portugal

Federal Republic of Germany:
Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR)
Oberpfaffenhofen
Wessling 8031, Federal Republic of Germany

Sweden
SATIMAGE
P.O. Box 816
28 Kiruna S-981, Sweden

7.2.2.6. Middle East

Egypt
Remote Sensing Center
101, Kasr El Eini Street
Cairo, Egypt

Israel
Interdisciplinary Center for Technological analysis and Forecasting (ICTAF)
Ramat-aviv
Tel-Aviv 69978, Israel

7.2.3 Countries where a Direct Spot Receiving Station is Being Installed

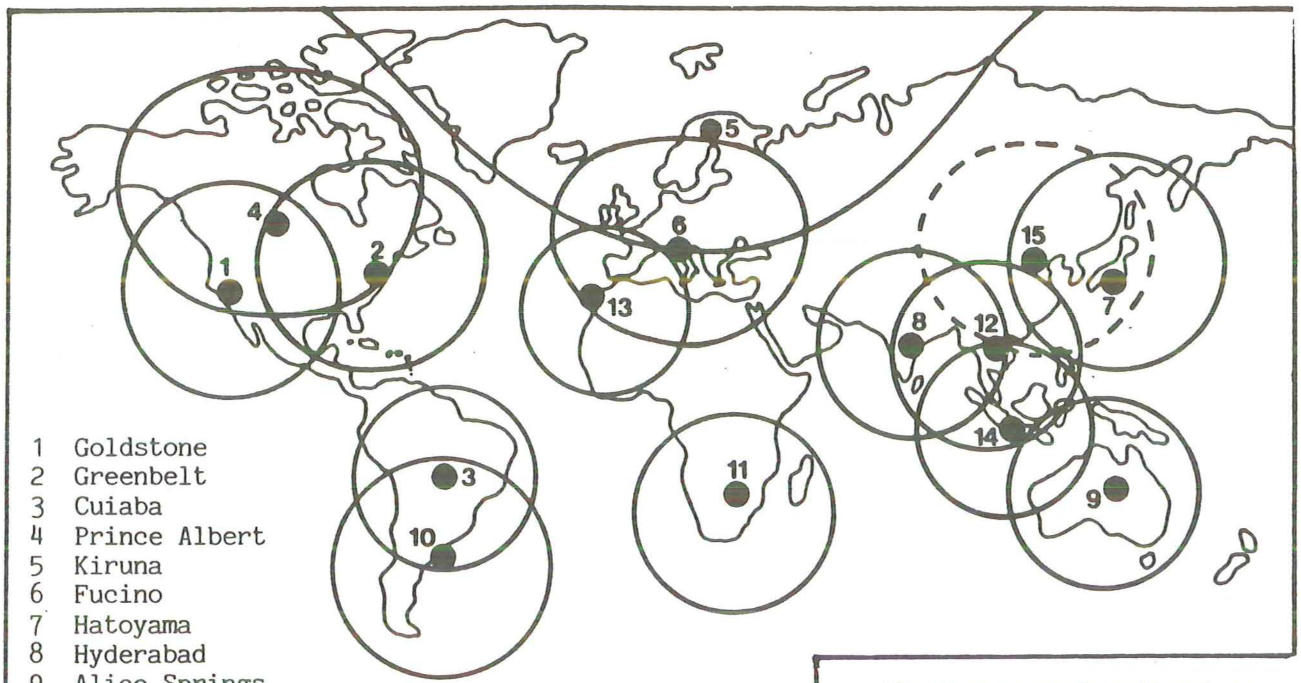
Canada
Canada Center for Remote Sensing (CCRS)
2464 Sheffield Road
Ottawa K9A OY7, Canada

People's Republic of China
Space Science and Technology Center
Chinese Academy of Sciences
Beijing, People's Republic of China

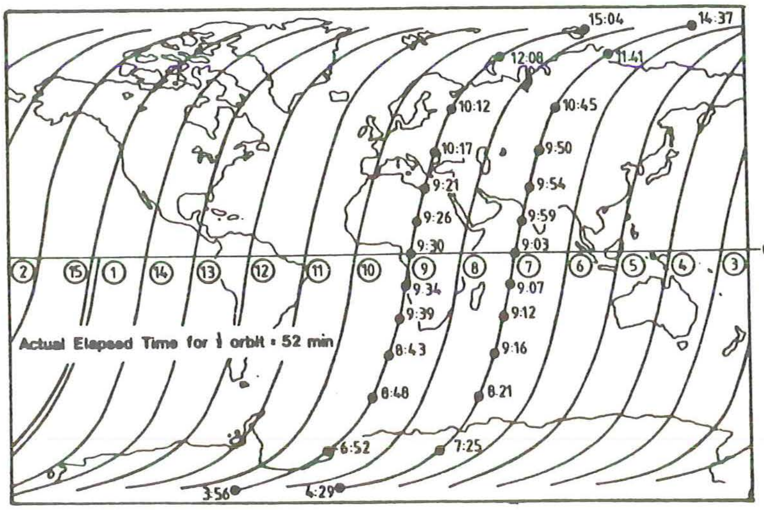
India
National Remote Sensing Agency
Departement of Space
Balaganar, Hyderabad 500 037 AP
India

France
SPOT IMAGE
16 bis, rue Edouard-Belin
BP 4359
31030 Toulouse Cedex, France

Bangladesh
Bangladesh Space Research and Remote Sensing Organization (SPARRSO)
Dacca, Bangladesh



The first generation of Landsat satellites were launched into a sun synchronous, near-polar orbit, at an altitude of approximately 900km. The angle between the Sun, the centre of the Earth and the satellite was maintained at 37.5° as the Earth orbits the Sun, and the orbital plane is inclined at 99° to the equator. This type of orbital configuration ensures repeatable sun illumination conditions, aiding the comparison of yearly changes in vegetation and mosaicing of adjacent tracks.



The satellite crosses the equator every 103 minutes. During this time, the Earth rotates a distance of 2760km under the satellite at the equator. When the satellite has completed 14 orbits, 24 hours has elapsed and the next westward track of data is acquired. In 18 days one satellite obtained coverage of nearly the entire Earth's surface, weather conditions permitting. The coverage pattern and overhead crossing time of one Landsat satellite during the period 1972 to 1983 are shown on the adjacent map. When two satellites were operational they were positioned nine days apart to allow a regular and more frequent data acquisition capability.

Fig. 7.2.1 Land receiving stations and landsat orbital tracks for one day of coverage indicating variations in local time of data acquisition

7.3 MEETINGS SPONSORED OR COSPONSORED BY WORKING GROUPS OF ISSS COMMISSION V TO CONSIDER SOIL INFORMATION SYSTEMS DIGITAL DATABASES AND RELATED SUBJECTS

7.3.1 Working Group on Soil Information Systems (DP).

DATE	PLACE OF MEETING
September 1975	Wageningen, the Netherlands
March 1976	Canberra, Australia
May 1977	Varna, Bulgaria
June 1980	West Lafayette, USA
September 1981	Paris, France
March 1983	Bolkesjo, Norway

7.3.2 Working Group on Remote Sensing (RS).

DATE	PLACE OF MEETING
August/September 1977	Rome, Italy
June 1980	West Lafayette, USA
May 1981	Warsaw, Poland
March 1985	Wageningen/Enschede, the Netherlands

7.4 REFERENCES ON GEOREFERENCED DATABASES FOR ENVIRONMENTAL RESOURCES

American Photogrammetric Society 1983. Manual of Remote Sensing, 2nd Edition. Am. Photogram. Soc., Falls Church, Virginia.

Burrough, P.A. 1986. Principles of geographical information systems for land resources assessment. Oxford University press, 202 pp.

Burrough, P.A. and S.W. Bie, 1984. Soil Data Technology. Proceedings of the 6th Meeting of the International Society of Soil Science Working Group on Soil Information Systems, Bolkesjø, Norway. 28 February - 4 March 1983. PUDOC, Wageningen.

Burrough, P.A. and A.A. de Veer, 1984. Automatic production of landscape maps for physical planning in The netherlands. Landscape planning 11: 205-226.

Chidley, T.R. and S.R. Wood, 1981. Electronic data processing systems for land and water data. Vol. I. General principles. Vol. II. Water data. FAO, Rome.

Dueker, K.J., 1979. Land resource information systems: a review of fifteen years experience. Geo-Processing 1: 105-128

Parameter	Current Coverage	Source	Geo-reference*	Projection	Available
Elevation: (10 min. grid)	Global	National Geophysical Data Center US-NOAA (Developed by US Navy)	No	LAT.-LONG.	No
Soils:	Africa	FAO/Unesco 1.5M soils map	Yes	LAT.-LONG.	Yes
Vegetation:	Africa	From DMA 1.2M Topo Maps (Digitized by ESRI for UNEP/FAO)	Yes	LAT.-LONG.	Yes
"	Africa	White's Unesco/AETFAT map (Being digitized by GRID-Processor)	No	LAT.-LONG.	No
Vegetation Index (4 seasons 1982)	Africa	NASA-GSFC (from AVHHR 4 Km Data)	No	MERCATOR	Yes
Watersheds:	Africa	From FAO data 1.5M scale (Digitized by ESRI for UNEP/FAO)	Yes	MILLER OBL.	No
"	SE Asia	FAO (under discussion)	No	UTM	No
Rainfall: (Mean annual)	Africa	From FAO Data 1.5M scale (Digitized by ESRI for UNEP/FAO)	Yes	LAT.-LONG.	Yes
Number of Wet Days (Mean annual)	Africa	From FAO Data 1.5M scale (Digitized by ESRI for UNEP/FAO)	Yes	LAT.-LONG.	Yes
Wind Speed: (Mean annual)	Africa	From FAO Data 1.5M scale (Digitized by ESRI for UNEP/FAO)	Yes	LAT.-LONG.	Yes
Rainfall Anomalies (Monthly 1985)	Africa	Climate Anal. Center US-NOAA/WMO (Digitized by GRID-Processor)	Yes	LAT.-LONG.	Yes
Temperature Anomalies: (Monthly 1985)	Africa	Climate Anal. Center US-NOAA/WMO (Digitized by GRID-Processor)	Yes	LAT.-LONG.	Yes
Surface Temperatures	Global	Climate Anal. Center US-NOAA/WMO	No	LAT.-LONG.	No
Species	Africa	From IUCN/CMC (20 endangered plants and animals)	Yes	LAT.-LONG.	Yes
Protected Areas	Africa	From IUCN/CMC (centre points and areal extent)	Yes	LAT.-LONG.	Yes

* Adjusted to standard geographic base.

7.6 NAMES AND ADRESSES OF WORKSHOP PARTICIPANTS

Prof.Dr. R.W. Arnold
USDA-SCS
P.O. Box 2890
Washington, DC 20013
U.S.A.
Tel. (1) 202 382-1825

Dr. F.W.G. Baker
ICSU
51 Bd. de Montmorency
F-75016 Paris
France
Tel. (33) 1 45250329
Telex ICSU 630553 F

Dr. M.F. Baumgardner
Agronomy Department
Purdue University
West Lafayette, IN 47907
U.S.A
Tel. (1) 317 494 6305
Telex 276147 AGAD-PULAF

Mr. J.A.A. Berkhout
c/o SOW/CABO
P.O. Box 14
6700 AA Wageningen
The Netherlands
Tel. (31) 8370-19012
Telex 45371 IBVL NL

Dr. D.P. Bickmore
Int. Geographical Union
International Cartogr. Ass.
28 Northmoor Road
Oxford OX2 6UR
England
Tel. (44) 865 513100
Telex 83147 via OR

Dr. P. Brabant
ORSTOM
74 Route d'Aulnay
93140 Bondy
France
Tel. (33) 48473195
Telex SSS BY 215203 F

Ir. A.K. Bregt
Soil Survey Institute
(Stiboka)
P.O. Box 98
6700 AB Wageningen
The Netherlands
Tel. (31) 8370-19100
Telex 75230 VISI NL

Prof.Dr. P.A. Burrough
Vakgroep Fysische Geografie
Geografisch Instituut
R.U. Utrecht
P.O. Box 80115
3508 TC Utrecht
Tel. (31) 30-532766
Telex 40087 VLUUT-NL

Dr. T.T. Cochrane
SHIS Qi-17, Conj.10, Casa 15
Lago Sul
71.600 Brasilia, D.F.
Brazil
Tel. (55) 248 4851
Telex 611858 XPBS BR.

Dr. I.K. Crain
UNEP, GEMS
P.O. Box 47074
Nairobi
Kenya
Tel. (254) 2 333 930
Telex 22068 UNEP KE-I

Dr. G. del Rio
Centro de Calculo
C.S.I.C.
Pinar 19
28006 Madrid
Spain
Tel. (34) 2-6250-20
Telex 42182 CSICE E

Dr. M.C. Derouich
Direction des Sols
Ministere de l'Agriculture
32 Avenue de la Republique
Tunis Port
1001 Tunisia
Tel. (216) 01-242184

Dr. I.E. Esu
Dept. of Soil Science
Faculty of Agriculture
Ahmadu Bello University
P.M.B. 1044
Zaria, Nigeria
Telex 75241

Prof. I.P. Garbouchev
Publishing House of Bulgarian
Academy of Science
acd. "G. Bonchev" Str., Bt 6
1113 Sofia
Bulgaria
Telex 23132 IZD BAN BG

Dr. I. Heyse
State University of Ghent
Lab. Phys. Geogr., Reg.Pedol.
Krijgslaan 281 - S8
B-9000 Ghent
Belgium
Tel. (32) 91-225715

Ir. F.W. Hilwig
ITC
P.O. Box 6
7500 AA Enschede
The Netherlands
Tel. (31) 53-320330
Telex 44525 ITC Enschede NL

Ir. A. Hoekstra
Sectoral verband Land & Water
Ont. Samenwerking Landbouw
P.O. Box 88
6700 AB Wageningen
The Netherlands
Tel. (31) 8370-19040
Telex 45888 NL

Dr. M. Ilaiwi
ACSAD
P.O. Box 2440
Damascus
Syria
Tel. (   ) 755713
Telex 412697 ACSAD SY

Prof.Dr. E. Klamt
Dept. of Soil Science
UFRGS
Av. Bento Gonçalves 7712
90000 Porto Alegre, RS
Brazil
Tel. (55) 512-362011
Telex UFRGS 0511055 dept. solos

Dr. J.L. Labrandero
Instituto de Edafologia y
Biologia Vegetal
Serrano 115 Dpdo
28006 Madrid
Spain
Tel. (34) 2-6250-20
Telex 42182 CSICE E

Dr. J. Lamp
Institute of Soil Science
University
Olshausenstraße 40
D-2300 Kiel
Federal Republic of Germany
Tel. (49) 431-8803256

Dr. K.B. MacDonald
Land Resources Research Inst.
Agriculture Canada
Neatby Building
Ottawa, Ontario
Canada K1A 0C6
Tel. (1) 613-995-5011
Telex AGRICOTT oag2956

Dr. J.F. Maes
Fac. of Agricultural Sciences
K.U. Leuven
Kardinaal Mercierlaan 92
B-3030 Leuven
Belgium
Tel. (32) 16-220931 (ext. 1465)
Telex 25715 KULBIB B

Ir. K.M. Matungulu
U.C.L.
P.O. Box 2224
Kinshasa I
Zaïre

Dr.Ir. L.R. Oldeman
ISRIC
P.O. Box 353
6700 AA Wagenigen
The Netherlands
Tel. (31) 8370-19063
Telex via IAC: 45888 INTAS NL

Mr. H.F. Purnell
AGLS
FAO
Via delle Terme di Caracalla
00100 Rome
Italy
Tel. (39) 57973192
Telex 610181 FAO I
Cable FOODAGRI, Rome

Dr. J.M. Ragg
Soil Survey of England & Wales
Shardlow Hall
Shardlow
Derby, DE7 2GN
England
Tel. (44) 332-792313

Prof.Dr. Carlos O. Scoppa
Centro de Investigaciones de
Recursos Naturales
INTA
1712 Castelar
Argentina
Tel. (54) 621-1448/1873
Telex 17518 INTA AR

Prof.Dr. J.L. Sehgal
National Bureau Soil Survey
and Land Use Planning
Amravati Road
Nagpur 440 010
India
Tel. (91) 32385/23264
Telex 0715-262 or 3162249 ICAR IN

Mr. J. Shields
Land Resource Research Inst.
K.W. Neatby Building, C.E.F.
Ottawa, Ontario
Canada K1A 0C6
Tel. (1) 613-995-5011
Telex 21533283 CANAGRIC OTT

Dr. A.J. Smyth
Land Resources Dev. Centre
Tolworth Tower
Surbiton, Surrey KT6 7DY
United Kingdom
Tel. (44) 1-3995281
Telex 263907 ODMLDN G

Dr. M. Soekardi
c/o Pusat Penelitian Tanah
Jl. H. Juanda 98
Bogor
Indonesia
Telex 48572 CSR IA

Dr.Ir. W.G. Sombroek
ISRIC
P.O. Box 353
6700 AJ Wageningen
The Netherlands
Tel. (31) 8370-19063
Telex via IAC: 45888 INTAS NL
Cable ISOMUS, Wageningen

Ir. A. Stein
Dept. of Soil Sci. and Geology
Agric. University Wageningen
P.O. Box 37
6700 AA Wageningen
The Netherlands
Tel. (31) 8370-82420
Telex via IAC: 45888 INTAS NL

Dr. C.R. Valenzuela
ITC
P.O.Box 6
7500 AA Enschede
The Netherlands
Tel. (31) 53-320330
Telex 44525 ITC Enschede NL

Dr. C.S. Valverde
ISNAR
P.O. Box 93375
2509 AJ Den Haag
The Netherlands
Tel. (31) 70-472991
Telex 33746
Cable ISNAR, The Hague

Dr. L. Venkataratnam
Nat. Remote Sensing Agency
Balanagar
Hyderabad 500 037
India
Tel. (91) 262575
Telex 0155-6522 NRSA IN
Cable REMOSEN, Hyderabad

Drs. R.F. van de Weg
Soil Survey Institute
(Stiboka)
P.O. Box 98
6700 AJ Wageningen
The Netherlands
Tel. (31) 8370-19100
Telex 75230 VISI NL

Dr. J.A. Zinck
Urbanizacion la Soledad
Ave. Principal, Quinta Grazia
Maracay, Edo. Aragua
Venezuela
Telex 85166 cvgCB VC

Note: Telephone numbers are arranged as follows:
Country code: First group of numbers in parenthesis
City code: second group of numbers underlined