

Implementation of a Spatial Information Systems Unit at the Soil Survey of Pakistan

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1. Abstract

The Soil Survey of Pakistan is currently undergoing a modernisation process. Like many similar organizations it is entering the relatively new world of geo-information technology. To enable this organization to make efficient use of its (in)valuable data resource, collected over the years, the Government of the Netherlands has offered technical assistance under a project titled: 'Strengthening the Soil Survey of Pakistan'.

One of the main activities of the project is to design and develop a Database/GIS and Image Processing facility. The Database will hold all the paper-based information acquired over the years, not only for safeguarding it, but also enabling a much wider and more efficient use. A Geographical Information System (GIS) will be incorporated to use the data in a spatial way offering a wide range of new and more customer oriented products. Practical services require up to date supporting information. Remotely sensed data will be processed digitally, providing information on current developments and insight in a changing natural environment.

This paper describes the first findings and the consequences of implementing a geo-information system in an existing organization. After introducing the receiving organization and outlining the rationale behind the establishment of a spatial information system at the Soil Survey of Pakistan, the paper focuses on the envisaged organization of the spatial Information Systems Unit. No modern project is complete without discussing the sustainable framework for proposed new developments. Sustainability nowadays has evolved from a pure technical matter to a matter of human resources and institutional ability. Due to easy and cheap access to required hardware, financial capacity has become an almost negligible factor. This is evident when evaluating the implementation of specialized and dedicated technical tools in an existing and operational environment.

The paper concludes discussing current practices of data-management and future expectations.

2. Introduction

The Soil Survey of Pakistan has had a glorious past, when during the sixties and seventies most of the country was surveyed and mapped at a reconnaissance level. In the years afterwards large areas of important agricultural land were mapped at greater level of detail.

However, in recent years work in the organization has become somewhat stagnant, mainly due to scarcity in operational funds, limiting the possibilities to do fieldwork and to undertake mapping activities. In order to revitalize the organization, the Government of the Netherlands together with the Government of Pakistan has jointly worked out a plan for technical assistance: the project 'Strengthening the Soil Survey of Pakistan' (SSSP). This Dutch-Pakistani funded project is undertaken in recognition of the need for improved planning and

management of land resources in Pakistan. The project aims at improvement of technical skills and capabilities by introducing new methods of surveying and data processing, improvement of demand orientation and services, increasing financial autonomy and human resource and institutional development.

3. The Soil Survey of Pakistan

The activities of the Soil Survey of Pakistan started in 1962 as a project with funding and technical assistance of the Food and Agricultural Organization (FAO) of the United Nations and the United Nations Development Program (UNDP). Under this "Soil Survey Project of Pakistan", staff were recruited from the Land Reclamation Directorate of the Irrigation Department and from the Provincial Agricultural Department. FAO experts extensively trained them. Two separate Directorates were established, one for East Pakistan ('East Wing Directorate') and one for West Pakistan ('West Wing Directorate').

During the sixties the main charter of the department was the preparation of a comprehensive inventory of the soil resources of Pakistan through reconnaissance soil surveys (1:250,000 and 1:125,000). All findings were compiled in descriptive reports and maps.

After the separation of East Pakistan in 1972 to form Bangladesh, a new organization emerged. It became an attached department under the Federal Ministry of Food, Agriculture and Livestock, having three Directorates each with its own staff. The Directorates of Soil Survey Reconnaissance (DSS(R)), Interpretation (DSS(Int)) and Basic Soil Investigation (DSS(BSI)) covered the new field of soil surveys. In this period semi-detailed and detailed soil surveys were started. Field offices were established in Hyderabad, Multan and Peshawar. Later a field office was opened in Quetta.

The SSP has basically a pyramid structure from the Director General down to Research Assistants. At present there is one Acting Director General/Director, two Directors, one Head Business Development Unit/Deputy Director, three Deputy Directors, sixteen Soil Survey Research Officers (SSROs), twenty-five Assistant Soil Survey Research Officers (ASSROs), five Research Assistants (RAs) and a large resource of supporting staff. All of them are qualified and trained for the tasks they are expected to perform.

At present approximately 87% of the country has been surveyed at a reconnaissance level. Only some agriculturally unimportant areas remain unsurveyed. However, to make the services of SSP more customer-oriented and meeting current demand for soil and land resources information, a project was formulated in 1995 to strengthen the organization.

Besides a new Business Development Unit (BDU), trying to market new products and services, the project aims at giving SSP financial independence and establishing an Information Systems Unit (ISU), offering a land resources Database/GIS and Image Processing facility.

4. The Rationale of Spatial Information Systems in Soil Survey

The important role SSP could play in supporting improved land resource management, project planning and environmental protection has been recognised by many. There is however, a wide gap between the role SSP could play and the role that it actually plays. In the last decade, SSP activities have been constrained and in some cases even stagnant. As a result of this, SSP has not been able to keep abreast with the latest developments in data gathering, processing, storage and retrieval, cartography and presentation. Most procedures and methodologies date from the sixties and are done manually, without the help of new technology. This results in a slow supply and limited information generation capability.

For optimal management of national resources, soil information and related spatial and attribute data play a vital role. Easy and rapid access to these data is essential for efficient planning. Data availability is not much of a problem. Large quantities of data are available in the form of the soil survey area reports and maps.

However, this information is neither easily accessible, nor available in a user-friendly format and, most important, no information is available in electronic form. There is a potential risk of losing the invaluable information if no measures are taken.

The objective set out by SSP in developing a Spatial Soil Information System for Pakistan - *SISPAK* - is to contribute to improved management of natural resources by providing easily retrievable soil information. To establish *SISPAK*, while paying respect to the present centralized organization, an Information Systems Unit (ISU) will be set-up at SSP headquarters. This should promote easy access to soil data, increase efficiency of work, facilitate interpretation of the data, stimulate computer modeling, develop new applications, create new uses for the traditional data and generate revenue for the organization.

Central theme in *SISPAK* is the organization of data. The valuable data of SSP requires a safe and efficient storage and Data Base Management Systems (DBMS) appear to be the logical solution. Having soil information available in a digital format, preferably held in a relational database, easy access and efficient use of this data is guaranteed. Through pre-defined indicators a link with its spatial extent can be made, supporting the defined mapping units on the map. This capability forms one of the principles of geographical information systems (GIS).

Operations that previously were time-consuming, can now be performed in a relatively short period of time, producing output in a retrievable way (any one can make the same product using a set procedure). Integrating tabular and spatial data generates new products that can satisfy customer needs.

5. Implementation of a Spatial Information System

The introduction of a computerized system in a traditional environment has many implications for the receiving organization. Technically it is not difficult to set-up a computerized unit in an organization nowadays. Computers and other hardware have become relatively cheap, while software is easily obtained and installed. A period of testing and improvement often proves sufficient to make the unit operational. It then seems only a matter of acquiring the spatial data and entering attribute data into a well-structured database.

Often neglected in the past, the development of the organizational infrastructure of the receiving party is crucial for the success of the technical implementation. This especially is true for the use of spatially related data since not only use is made of new computer technology, but also close co-operation and exchange of (natural resource) data is required of many levels in the organization. The new information unit should be well positioned in the organization, which is often strictly hierarchically organized. Furthermore, the organization should cater for the recruitment of new disciplines into the new unit, e.g. information systems management. For available staff with a relevant background, structural training programs in the various -spatial- subjects have to be arranged.

6. A Framework for Sustainability

Bringing advanced tools in a traditional organization, working with procedures and methodologies mainly designed during the sixties, has great implications for an organization.

In this respect sustainability nowadays has evolved from a pure technical matter to a matter of human resources and institutional ability. Technically nearly everything is possible and this first layer for implementation of the ISU is relatively easily laid.

At SSP introduction of the ISU affects the three Directorates, which through the newly established unit will obtain an efficient and transparent medium to exchange information and to produce combined output. A shift in responsibilities of staff and management is the logical result of these new activities.

Another result of the implementation of such new unit is an increased efficiency and staff motivation.

With the introduction of a modern computer system land resources information will be available within a very short time scale. The products will also be of a higher standard than those generated using traditional methods. The progressive build-up of revenues from the sale of services and products will lead to a stronger resource base in both manpower and equipment. An increase in staff moral and effectiveness is expected. Staff motivation also will accrue from a decentralization of activities which results in more freedom for research officers to work on projects.

Externally, integration of data from other organizations will increase efficiency through hitherto unachievable analyses of combined data sets. Facilitating data exchange between SSP and external organizations enhances the performance of SSP in satisfying clients. In turn, this has effect on internal affairs, for prospects for staff training will encourage loyalty and career aspirations.

Increase of the quality of the SSP product will enhance customer demand and expectations. As in any other productive environment, SSP needs to innovate its products and services. This will be the innovation layer in the envisaged model (see figure 1.).

In this 'multi-layer' model, also to be referred to as the '*sandwich model*', relevant aspects can be related to one another, indicating their inter-relationships and their sustainability.

Aspects of ensured sustainability include:

- Technical Input
- Human Resources
- Institutional Development
- Financial Implementation
- Innovative Stage

Each layer of the sandwich has a strong relationship with both adjacent ones. Sequential interaction of these layers and their ingredients provides a strong basis for the project's sustainability.

Elaborately discussed by Campbell and Masser (1995), innovation (and its successive diffusion) is a fundamental process in an organization. At the innovative stage, all previous aspects should be in temporal balance. However, innovations are necessary to respond to client demands and to ensure sustainability in the future. The innovative phase is dynamic, as indeed is the entire model.

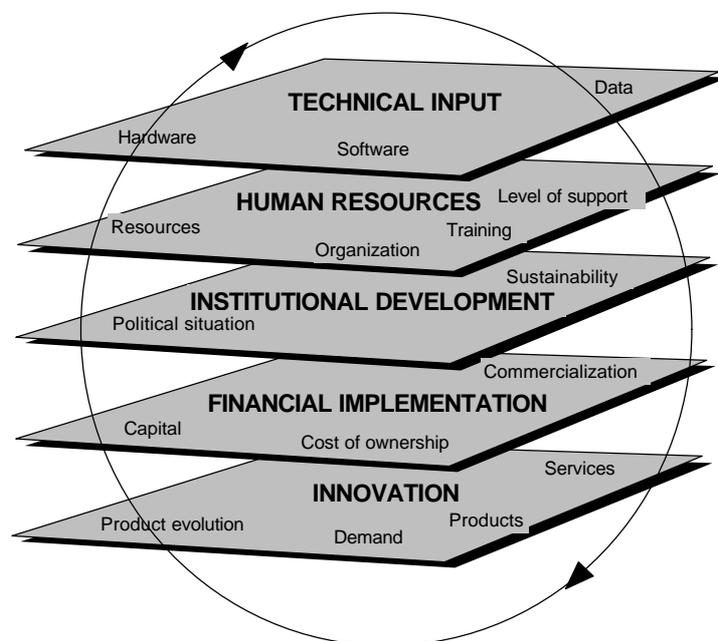


Figure 1 The 'sandwich' model for sustainable information systems

Each of the layers can change over time in response to external effects. Because of their strong inter-relationship, all layers will be subsequently affected (e.g. technical innovations will have a strong effect on the human resources and both will influence the economic situation). The innovative stage will then change again so the whole model becomes iterative.

In the ISU two of the described layers of the sandwich model can be recognised. These refer to the technical aspects and the human resources of the unit.

In view of the limitations in computer skills, the project installed a relatively simple but powerful PC network in a dedicated facility at SSP headquarters during autumn 1996. A PC-platform was considered appropriate, as it is commonly found in research institutes and commercial organizations throughout Pakistan.

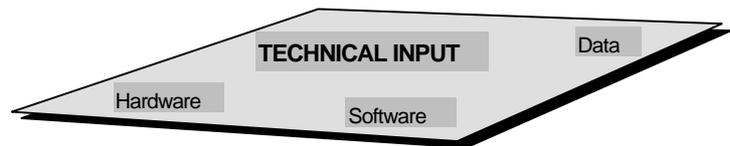


Figure 2 Technical Information layer in an effective functioning organization

A Novell network connecting five Pentium PC's and peripheral equipment such as two printers, an inkjet plotter and a scanner was installed. In the near future, WindowsNT will be made available to link the supporting field offices to the system, giving them access to centrally held data.

Dedicated software is used in the ISU to accommodate the various needs. For capturing and processing the (soil) attribute data, the DBMS software Visual FoxPro is in use. All spatial related data is handled by PC Arc/Info software. Image Processing is the activity that will be taken up by the ISU in the near future and for this the software ER Mapper will be used. To bridge any discrepancies between the GIS and Image Processing/Remote Sensing (IP/RS) software and to facilitate effective dual use of data, the hybrid GIS software ILWIS is expected to prove effective.

Establishing and operating an ISU capable of developing SISPAK will require suitably qualified staff trained in systems management, data entry, computer modeling, DBMS, GIS and IP.



Figure 3 Human Resources layer in an effective functioning organization

Human resources clearly are the most important factor for success of any planned activity.

In the so-called "Human Resources Layer", the rate of success strongly depends on the availability of qualified human resources, a supportive organization, in-depth training and a high level of support of all involved.

True for any unit, but perhaps even more for an information technology unit, it is not so much the number of the people involved in land resources management, but more the quality and its approach to new developments.

The human resources required for a functional ISU at SSP are much related to the activities of the unit. As these currently are growing, the demand for more, and more qualified, personnel increases with time.

The other layers recognized in the model are more an integral part of the entire organization. Managing an effective unit depends on many factors. Internal aspects within the organization will determine what is possible with respect to the posts required. External developments

strongly influence internal management decisions. Changing local and/or national policies, strong customer demand, economic fluctuations, etc. will influence developments. Nevertheless, a more or less basic structure with clearly defined functions can be recognized. In SSP a structure as depicted in Figure 4 is proposed. With increasing activities of the unit this structure obviously changes.

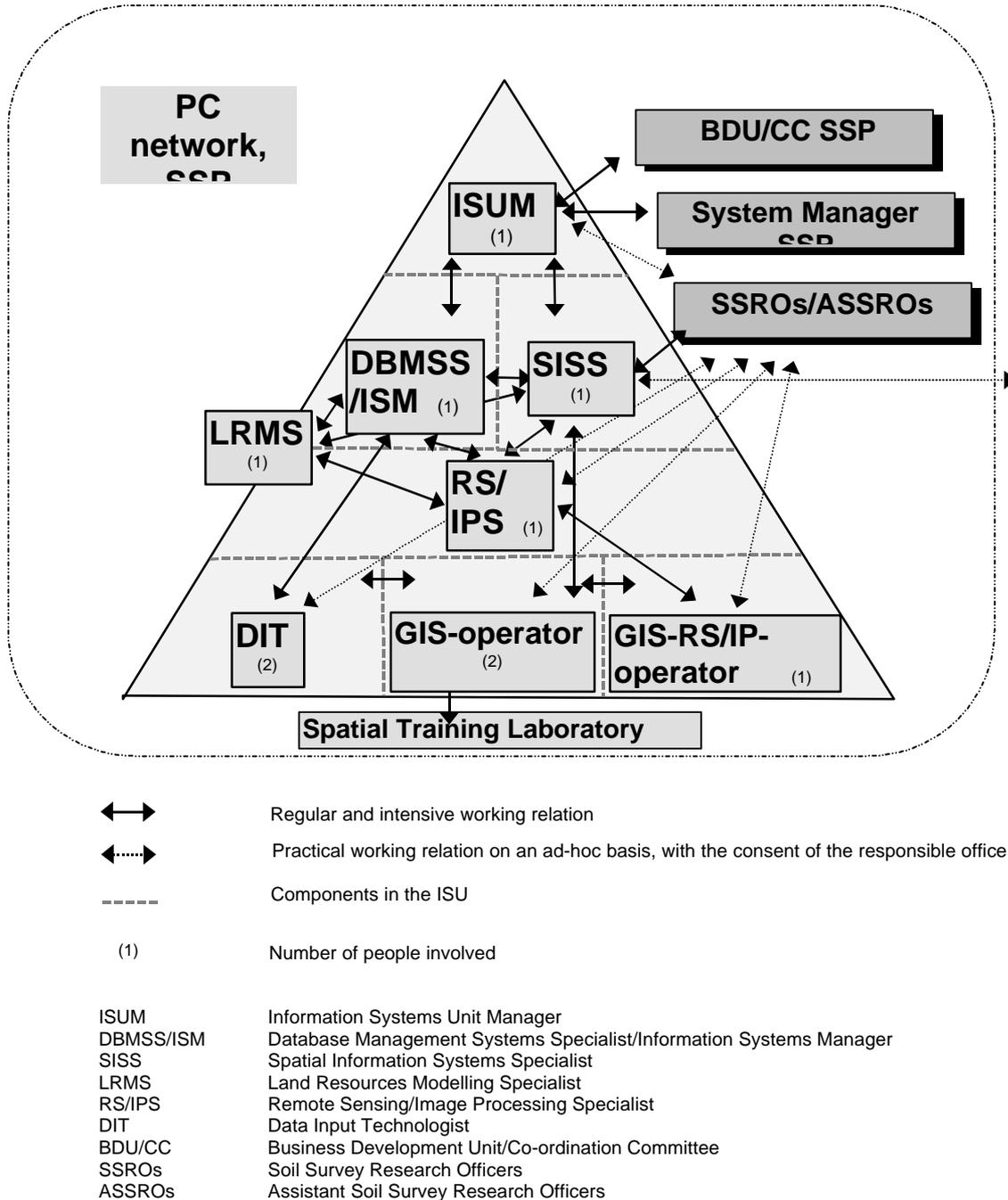


Figure 4 Organization of the Information Systems Unit and internal and external relations

Nine to ten people will ultimately work in the unit. The structure for the ISU is planned as follows.

Two *Data Input Technologists* (DITs) are responsible for entering error free and verified paper based information into the database system.

Two *GIS operators* are considered sufficient at present and they will be responsible for all GIS operations, analysis and applications. They will have profound theoretical and technical knowledge of GIS, i.e. in Arc/Info. To cater for image processing at SSP, a third Operator is required. Though also involved in GIS activities, emphasis of his or her work will be on RS/IP aspects, supporting the *Remote Sensing/Image Processing Specialist* (RS/IPS).

The RS/IPS will perform actual image processing of digital satellite data and integrate the results with GIS. He/she will work in close consultation with the senior staff of SSP with respect to RS/IP issues.

A *Spatial Information Systems Specialist* (SISS) will supervise the GIS-Operators. The SISS is responsible for the overall productivity of the unit. He or she will be in regular contact with senior staff of the organization and translates specific requests into GIS operations and be responsible for planning and output. Furthermore, he/she will design the specific procedures in GIS and technically support the operators.

For specific applications of related computer models, i.e. land use models, erosion risk models and the like, a *Land Resource Modeling Specialist* (LRMS) will be attached to the unit. Although also active outside the unit, the LRMS will be linked to the ISU whenever a digital spatial component is involved. Together with the SISS, GIS Operators and database specialist the LRMS will produce specialized output.

The *Data Base Management System Specialist/Information System Manager* (DBMSS/ISM) is responsible for the overall management of data flow within SSP, i.e. data integrity, security, analysis and programming. He also will be responsible for the overall network facilities.

The ISU will become an important hub at SSP and will have relations with both management and staff of all directorates of the organization. The unit should be headed by a capable manager: the *Information Systems Unit Manager* (ISUM), who is responsible for the long-term development of the unit. His/her responsibility includes strategic development and planning, and control of financial/economic aspects of the ISU. The latter post is more an administrative than a technical one, although in-depth knowledge of spatial information systems, database development and remote sensing is an asset.

7. Pilot project: an example of spatial and tabular data management

After establishing the ISU a pilot project was started in the District of Kasur. GIS was used to produce new thematic maps and demonstrate improved mapping facilities (Figure 5).

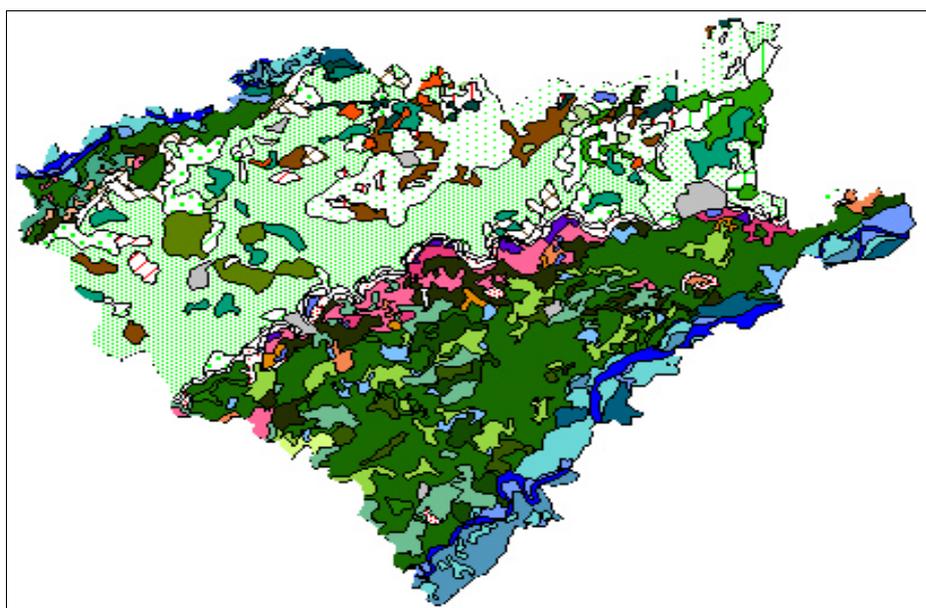


Figure 5 Example of the soil map of the District of Kasur

The existing soil map 1:100,000 was digitized and mapping units assigned. Together with basic infrastructure taken from 1:50,000 topographic map sheets of the Survey of Pakistan, a reference grid and an explanatory legend, an attractive and much better readable map was produced. Although no attribute data was available in digital form, through interpretation several derived thematic maps could be produced, e.g. maps showing waterlogging, high salinity/sodicity or a combination of the two.

Later, present land use and landform maps were produced.

Another major activity was the design and programming of a comprehensive soils database. Based on various international criteria a tailor-made database was designed, capable of storing soil data. The classification was partly taken from the '*Global and National Soils and Terrain digital databases*' (SOTER; FAO, 1993), the '*Guidelines for Soil Description*' (FAO, 1977), the '*Soil Profile Analytical Data Base for the European Communion*' (H. Breuning-Madsen, R.J.A. Jones, 1995) and the '*Guidelines for the description and coding of soil data*' by ISRIC (E.J. van Waveren and A.B. Bos, 1988).

The '*Guidelines for Soil Description*' were extensively used during past and present fieldwork of the Soil Survey of Pakistan.

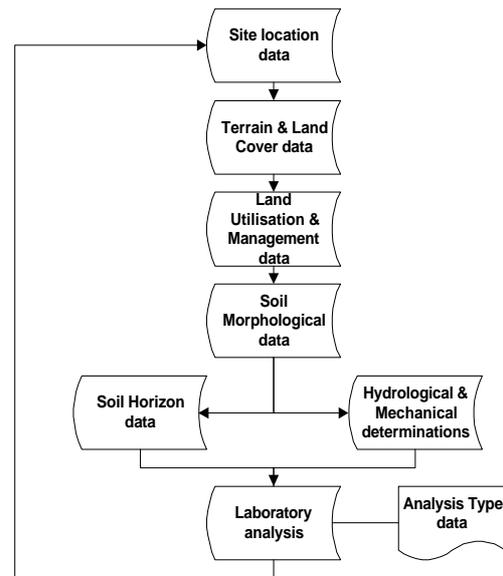
In the integrated soil database, eight separate data components were recognized, each in close relationship to another. They are linked through a common denominator, the observation identity number or, in case of the laboratory data, through the sample number. If desired, the individual databases can be used on their own.

The eight components in itself store various information and in this way serve as separate databases. Their logical position with respect to one another allows efficient flow of data. To reduce occupied space in the database, as well as to enhance speed, the database storing information on analytical determinations in fact is a database *table*, having a descriptive table attached. This descriptive table contains all analyses performed in the laboratory of SSP.

The eight databases identified are:

- Site location data
- Terrain & Land cover data
- Land utilization & management data
- Soil morphological data
- Soil horizon data
- Hydrological & mechanical
- Determinations (field data)
- Laboratory analyses
- Analysis Type data;
- this effectively is a descriptive database table

The components stored in each database are described through a code. A comprehensive key has been developed to describe the various parameters used in these databases.



8. Key to Future Developments

Using spatial data in a digital format facilitates efficient use of information and provides opportunities for new products. Through intelligent linkages, data from various sources can be connected to produce output previously thought impossible. Computerization will replace traditional operations in a quick, efficient and retrievable manner. Tabular data can be linked to spatial information through geo-referencing, allowing traditional mathematical and statistical operations to be displayed in a spatial way.

Having effectively covered the first steps in GIS, SSP is ready for the next phase. Because SSP deals with many point observations, information systems capable of capturing and relating these point data will become more useful. For effective use, these point observations need to be related to a co-ordinate system. Data collected in the past will be given precise X and Y co-ordinates, while new data immediately will be geo-referenced using Global Positioning Systems (GPS). The use of field computers will promote direct data entry in the soil database and efficient update of existing digital maps.

For most effective use, GIS software using the raster data model will prove useful. Such software also allows effective integration of remotely sensed satellite data. Image processing will provide new and more extensive information. Monitoring changes in land use, observation of salinity patterns and acquiring the actual situation of waterlogged areas are just a few of the new possibilities. Integration of RS data with available soil information using GIS will rapidly provide informative products, serving customers dealing with natural resources management.

A most promising development is the integration of digital spatial data and newly developed non-spatial land use planning models. At present, many models are under development, simulating expected plant or animal growth and resulting yields under varying circumstances. Examples are models developed by the FAO, (CYSLAMB; APSRAMB; 1994/1995), the Crop Growth Monitoring System (CGMS) by the Joint Research Center of the European Union or the model described by Driessen en Konijn (1992).

These models allow easy comparison of different land use by using common denominators and enable graphical output in the form of maps. SSP has most of this baseline information, but at present is only limited by the absence of yield response data. Whenever this becomes available, which should not be a much time consuming effort, SSP could produce valuable information for various planning institutes and related organizations. This would open a new

and promising market, now SSP follows a more pragmatic approach as compared to earlier times and has ventured into a more commercial market approach.

9. Conclusions

Implementing a spatial Information Systems Unit at the Soil Survey of Pakistan is more an organizational problem than a technical problem. Good human resources and a supportive management are a prerequisite for success. All such has been recognized and now a sound and continuous planning is required to keep up with current and future developments

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