SOTER Report 9

Proceedings of the KENSOTER International Workshop

V.W.P. van Engelen (editor)

14 - 17 March, 1995
at
Kenya Soil Survey, National Agricultural Research Laboratories
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Nairobi

Meeting organized in the framework
of the KENSOTER Project of UNEP-ISRIC

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1. INTRODUCTION

In the framework of the United Nations Environment Programme (UNEP) sponsored project for the 'Compilation of soil and terrain database in the Republic of Kenya (KENSOTER) for national and local agricultural planning purposes' (Project No. FP/CD/6101-92-02(3025)), the Kenya Soil Survey (KSS) and the International Soil Reference and Information Centre (ISRIC) have organized an international workshop at the premises of KSS for displaying the results of the project and for raising interest for SOTER activities at sister institutes in the region.

The four days workshop was attended by representatives of soils institutes of 11 southern and eastern African countries, by local (potential) users of the KENSOTER database and some donors. The latter two groups only took part in the first session of the workshop.

The programme of the workshop covered three major subjects:

- an explanation of the SOTER methodology and the implementation in Kenya with a demonstration,
- national reports of all participating countries on the status of soil surveys and GIS,
- discussions on possible SOTER activities in the participating countries.

No report on the explanation of the SOTER methodology will be given here but reference is made to the SOTER Procedures Manual (UNEP/ISSS/FAO/ISRIC, 1995) for a full explanation of the methodology.

As the KENSOTER project is now nearing its completion, a terminal report on the implementation is under preparation.

Demonstrations of SOTER in Kenya were, apart from database input, queries for thematic single value maps, mainly focused on a land evaluation and a soil erosion hazard application. Both have already been published separately (Mantel, 1994; Van den Berg, 1992).

The national reports on the status of soil survey and GIS in the participating countries form the major part of this publication. They give a state-of-the-art overview on soil mapping in Southern and Easter Africa.

The outcome of the discussions are put down as recommendations. Furthermore several countries expressed their willingness to prepare project proposals for national SOTER activities.

2. OPENING

Miriam Schomaker
Representative of UNEP

Mr. Chairman, Ladies and Gentlemen,

Please allow me to start with expressing UNEP's sincere appreciation about the tremendous work ISRIC has done over the years to develop the SOTER methodology. I recall the process started some 8 years ago when the International Society of Soil Science (ISSS) brought up the SOTER idea. ISRIC has since taken the lead in the coordination and development of SOTER, of course with inputs from many scientists all over the world, both within ISSS, in FAO and on an individual basis.

UNEP is proud to have been able to facilitate the SOTER development process by funding the development phase, which started with a pilot SOTER in Argentina/Brazil/Uruguay some 8 years ago, on to the current SOTER project here in Kenya.

Indeed the methodology now has been firmly established and is ready for wider application. UNEP is very pleased to note that the SOTER methodology has been officially endorsed as a very valid approach by the 'creme-de-la-creme' in the soil science community and by institutions like FAO, ISNAR, WRI, etc. Eventually we would want to see the whole world covered by SOTER databases, so providing internationally compatible, detailed and structured soil and terrain related information for use in policy formulation, decision making and action planning.

Time has now come to more actively spread the SOTER message, and this immediately brings me to KENSOTER. On behalf of UNEP I would like to congratulate the Kenya Soil Survey for the excellent job done in setting up the SOTER database for Kenya. With this database we now have the opportunity to illustrate how such SOTER databases can be used. By illustrating a wide variety of applications we should be able to convince others, including the funding agencies and bilateral donors of the enormous added value of a well structured, electronic database like SOTER. As was mentioned earlier this morning, we could compare SOTER with building a bridge. The first half has now been finalized and we are in a good position to build the second half: the applications.

UNEP wishes you all much success with building this second half of the bridge and will in its modest way try to continue its support to the SOTER process. We can for instance assist in developing and supporting proposals for the 'big guys', in promoting the SOTER approach through the Capacity Building and Servicing Component of UNEP's Environment Assessment Programme and in finalizing regional SOTER activities.

One of the reasons for UNEP's interest, apart from the obvious one (having good, well structured, electronic and therefore easily 'up-datable' and extendable soil and terrain databases in place on a national level for national and local level applications), is that the world is 'internationalizing' rapidly. Many issues are not confined within national boundaries. There is a need for standardized information so that policies can be formulated, decisions and action can be taken at an international level, based on sound information for an entire (sub-)region.

This is where UNEP comes in. One of UNEP's main mandates is to report on the state of the environment in a global and, more and more, a regional context, so providing sound information for international policy setting, decision making and action planning. In our experience so far it has proven extremely difficult to compile data and information from national levels into regional and or global pictures, exactly because of this lack of compatibility. Every attempt to try and standardize environment related data and information therefore has UNEP's full support.

This is one of the reasons why I am very pleased to see that there are so many different countries from the Eastern and Southern African region represented here in this SOTER workshop. I sincerely hope that this first step towards spreading the SOTER message in this part of the world will prove fruitful and I wish you lots of success in achieving this.

Thank you.

L.R. Oldeman
Director, International Soil Reference and Information Centre

Mr. Chairman, Ladies and Gentlemen,

Exactly two years ago a project for the establishment of a Soils and Terrain Database Information System for the whole territory of the Republic of Kenya (KENSOTER) was implemented by the Kenya Soil Survey under a grant provided by the United Nations Environment Programme. Today these activities have been accomplished by the Kenya Soil Survey with provision of training and backup technical assistance from the International Soil Reference and Information Centre in Wageningen, the Netherlands. We are very pleased that UNEP made it possible to organize this international workshop to demonstrate the results and usefulness of KENSOTER to a broad forum of delegates from many Eastern and Southeastern African countries.

Why do we need a SOTER database?

So far, soil survey institutions have collected a wealth of information, which is provided in the form of soil survey reports, often accompanied with voluminous reports and appendixed tables on soil characteristics. However, this very useful and valuable information is often not very user friendly. A soil map is a necessary generalization of information collected by soil survey institutions and soils are classified and given names using a jargon, that is difficult to interpret even by soil scientists. Users of soil information are more interested in derived products. What is the erosion hazard in a certain area under specified land use? What is the suitability for a certain crop; what is the impact of soil degradation on food productivity? etc. etc. Therefore a methodology is needed that can store this wealth of data in a well organized database, linked to delineated map units.

The emerging information technology that is now available in the form of database management systems and Geographic Information Systems makes it possible to assist policy-makers and resource managers in providing answers to these and many other questions.

The SOTER programme is an initiative of the International Society of Soil Science. The methodology, developed by ISRIC, in close cooperation with UNEP and FAO, was thoroughly tested and is now operational. It is a powerful tool that is internationally endorsed and can be implemented at what can be considered insignificant cost.

International endorsement for SOTER came from different user groups.

To cite the Director General of ISNAR (International Service for National Agricultural Research): *"According to me, SOTER is a service which the donor community should provide to most developing countries. SOTER will be able to develop the tools useful first and foremost by national research systems but also by the donors and others".*

The former Director of FAO's Land and Water Development Division stated: *"We intend to assist our member countries in appreciation of the value of the SOTER methodology and the potential of it use. Only through development and applications of such techniques can we catalyze the required breakthroughs in land resource use, which are essential to halt and reverse current degradation in developing countries".*

The former President of the World Resources Institute indicated: *"The WRI supports your plans to create a Soils and Terrain Database system. There is a critical need for further study to more* *accurately portray soil degradation problems at national and local level. WRI urges you to continue this work and encourages UNEP and other funders to support it".*

Finally, I like to stress that the United Nations Conference on Environment and Development (UNCED) in Rio strongly underlines the need for data and information. From Chapter 10 of Agenda 21, which deals with an integrated approach to the planning and management of land resources, I quote: *"Governments at the appropriate level, in collaboration with national institutions and with the support of regional and international organizations, should strengthen the information systems necessary for making decisions and evaluating future changes on land use and management. To do this they should strengthen information, systematic observation and assessment systems for environmental, economic and social data related to land resources at global, regional, national and local level".*

Similar statements are repeated in Chapter 11 (combating deforestation), Chapter 12 (managing fragile ecosystems), Chapter 13 (sustainable mountain development), Chapter 14 (promoting sustainable agriculture and rural development).

In conclusion, I like to congratulate the Kenya Soil Survey for their enthusiasm and full commitment to establish this georeferenced soil and terrain database for Kenya within a period of two years. I am fully convinced that the KENSOTER database will be a tremendous step forward in making a better and sustainable use of the fragile natural soil resources of Kenya. The wealth of information now stored in KENSOTER will be a powerful tool for making a Land degradation assessment and mapping of Kenya, a project formulated by UNEP with financial support of the Dutch Government. We hope that this workshop, attended by delegates from many East African countries, will stimulate the development of SOTER activities in their respective countries and that donors can be found to support these activities.

W.K. Ngulo
Director of Research Development
Ministry of Research, Technical Training & Technology
Republic of Kenya

Distinguished guests, ladies and gentlemen.

May I take this opportunity to welcome all of you and especially those from overseas and other countries in Africa to Kenya. Please feel comfortable here in Nairobi and take time to sample the hospitable leisure in the city.

It is our great pleasure to see such a congregation of intellectuals and researchers gathered here to review one of the very successful collaborative initiatives of the Kenya Agricultural Research Institute and the International Soil Reference and Information Centre (ISRIC), on the soil resources inventory.

I am informed that this is a global project and Kenya is the only Country in Africa that was selected to be one of the pilot countries.

I am convinced that Kenya will benefit from such a project as it is one of the first countries in the region to have completed Exploratory Soil Survey in 1982. We are also very keen to develop a comprehensive soil resources database and management based on a good knowledge of their characteristics and quality.

I am informed that this project is a culmination of an initiative of ISRIC which was born way back in 1984. A paper by ISRIC on Global Soil Resources Inventory at a scale of 1:1 M led to the formulation of digital mapping of Global Soil Resources within the International Society of Soil Science (ISSS) which proposed the world Soils and Terrain Digital Database, acronymed SOTER. Later joint efforts of FAO, ISRIC, UNEP, and ISSS resulted in the SOTER procedures manual which was tested in some South American Countries.

It was after this pilot project that UNEP proposed and supported a similar project in Kenya under the collaborative auspices of KARI and ISRIC. The Kenyan Soils and Terrain Digital Database (KENSOTER) at the scale of 1:1 M was initiated in 1993 with the following objectives:

1. To improve the National capabilities to deliver accurate and timely information on soils and terrain for the national environmental planning.

2. To assist the Government of Kenya in developing development plans that ensure integrated management of land resources.

3. To help control land degradation and stimulate land reclamation through appropriate conservation of the land resources.

KARI, through the Kenya Soil Survey undertook to assemble all the available data on soils, terrain, climate, vegetation and land use. The data was entered into a computerized database and thematic maps and tabular data have been prepared to elucidate potential use of land in relation to environmental impact.

The efforts which have gone into this endeavour, including the computer hardware and software, person hours and brains are enormous. Kenya is now lucky to have a comprehensive database and interpretation system of all soil resources facets and this is a unique achievement.

I am informed that the experience of Kenya will be a basis for the other countries in the region to learn from. We shall be very willing to share this knowledge with our neighbouring countries, as we deepen our knowledge on the utilization of the database.

In this regard, we are very grateful to UNEP for funding this project and according us the opportunity to have such a valuable tool. I also acknowledge the efforts of ISRIC, specifically Ir Van Engelen who has been very keen to train our scientists and to ensure that the project is implemented within scheduled time. It is because of the efforts of these organizations that this workshop has come to being. The aim of this workshop are mainly to demonstrate the utility of KENSOTER and the capability of SOTER in general. This will be useful not only to KARI in expanding the utility of KENSOTER but also to all the participants in developing their own SOTER.

Finally, ladies and gentlemen, I am convinced that you will find this workshop exciting and useful. I hope you will join hands with us in increasing the knowledge on the soil resources and conserving the environment so that its resources can be highly useful to us and future generation, which I believe is the ultimate purpose of KENSOTER.

I now would wish to declare the International KENSOTER Workshop officially open.

3. RECOMMENDATIONS

The participants of the workshop have agreed upon the following recommendations:

1. The scale-independent SOTER methodology is a useful tool for making data on soil and terrain resources quickly accessible to resource managers, policy makers and the scientific community at large for various types of interpretations. In all participating countries data are available for the creation of a 1:1 M soil and terrain database. In some countries data collection has advanced towards a larger resolution and consequently these countries aim at a larger scale.

2. One of the advantages of the SOTER methodology is the provision of applications/interpretation methods that can be used with minor adaptations in most countries. Another is standardization with the possibility for data exchange between neighbouring countries.

3. Several participating countries have already invested largely in the creation of soil profile databases (point observations), e.g. FAO-ISRIC Soil DataBase and local varieties, while part of the soil maps is in digital form. However, a linkage between the two systems has not yet been established. If the countries will implement SOTER an easy transfer of profile data into SOTER is absolutely necessary. Such a transfer is currently under development at ISRIC.

4. The development of application software using the SOTER database, implemented with user interface, is required for an optimal use.

5. For countries having already a profile database and digital soil maps, an establishment of a pilot programme for testing the ease and costs of transfer of data is necessary.

6. The SOTER methodology should be promoted to soil scientists, natural resources managers and other national authorities by means of demonstrations of applications (water erosion assessment, land suitability).

7. The recognized national soil survey authority should be consulted to approve the proposed methods to ensure that minimum soil survey and database standards be applied throughout the SOTER project.

8. Training in database management and GIS is needed in all participating countries.

9. When a SOTER activity will start in one of the represented African countries, it is advised that experiences of the Kenya Soil Survey will be shared by these countries.

10. Donor support to implement national SOTER activities is needed.
    At the national level:
    Participants agreed to encourage their respective ministries to approach potential donors.
    At the international level:
    Participants urged UNEP, ISSS, FAO and ISRIC to promote SOTER at international funding agencies such as UNDP, World Bank, African Development Bank, Global Environmental Facility, etc.

APPENDIX 1. COUNTRY REPORTS ON THE STATUS OF SOIL SURVEY AND GIS

A1.1 Botswana

Boago G. Moganane

Introduction

Botswana lies between latitudes 14° - 27° S and longitudes 20°-29° E in the central part of Southern Africa. The country covers a surface area of 582,000 km^2 and has a population of about 1.4 million.

About 70% of the country is covered by Kalahari sands in the north and west and the basement complex of mostly pre cambrian rocks such as granites and gneiss in the east and south. The climate is semi arid with summer rainfall occurring between November and April with the highest peak in December and January. The average annual rainfall increases from below 200 mm in the south west to about 650 mm in the north. It is however, very erratic and very unreliable for agricultural operations. Average summer temperatures easily reach 40%t in many parts of the country. In winter sub-zero temperatures are common at night, particularly in the southern part. Day temperatures however, rise to about 20°C to 25°C in most parts of the country.

Soil survey activities

Soil survey Section housed in the Ministry of Agriculture, was established in 1981 by a tripartite project of the Botswana government, the United Nations Development Programme (UNDP) and the Food and Agriculture Organisation (FAO) . The main objective of the project was to make an inventory of Botswana Soils at a reconnaissance scale of 1:250,000 as well as to develop local manpower. That project came to an end in 1990 after achieving its goals. Subsequent to that, soil survey is been continued at various scales by the local experts. At the moment the Soil Survey Section is engaged in systematic mapping of selected areas at a semi-detailed scale of 1:50,000. This work is going on in conjunction with some projects's appraisal activities which are done on ad hoc basis and at larger scales than the systematic 1:50,000 currently on going.

Coverage

Botswana is fully covered at 1:1 million scale. This coloured soil map based on the revised legend of the FAO-UNESCO Soil map of the World was completed in 1990.

About 65% of the country is covered at 1:250,000 scale. Scales larger than 1:100,000 were executed on ad hoc basis at selected areas earmarked for some specific developments such as irrigation. These constitute a very small percentage of perhaps less than 2. The soil survey section is currently undertaking some systematic semi-detailed surveys of some of the areas which were covered at 1:250,000. This work started in earnest, in March 1994. The first sheets are now almost ready for cartography.

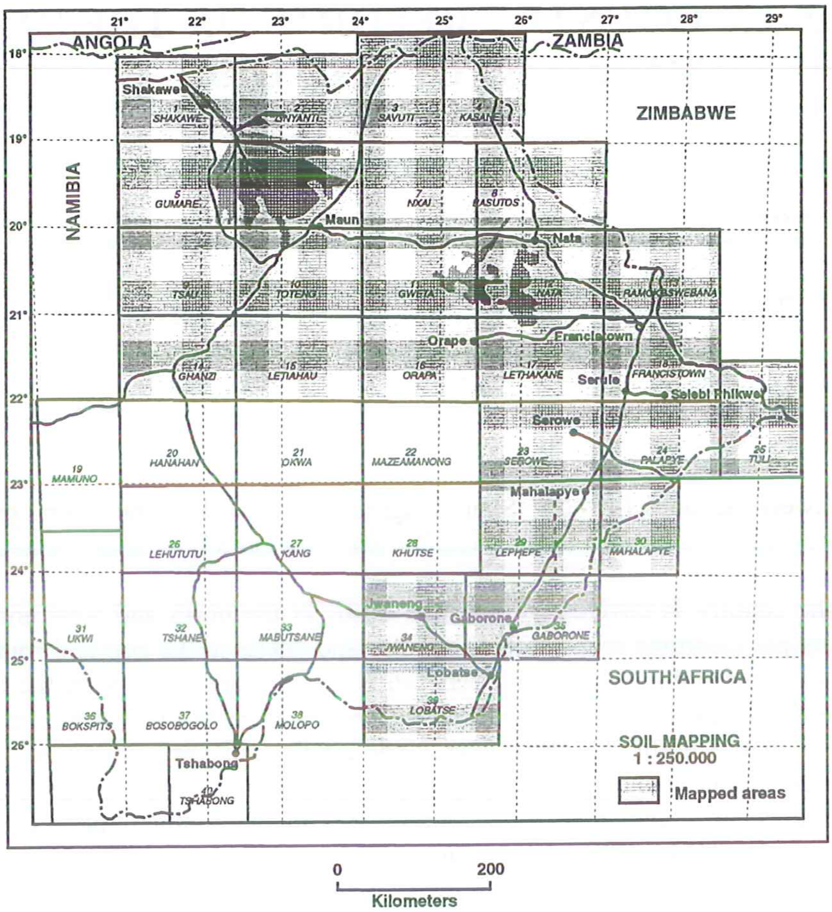

Figure 1 Status of soil mapping at scale 1:250,000.

The establishment of the GIS in the Ministry of Agriculture is therefore a positive step because the final drafts of the soil maps will be digitized and stored in the computer. This will enhance the speed with which maps are produced as manual cartography is put in the background.

GIS status

The idea of setting up a GIS user facility in the Ministry of Agriculture has been floating around for a number of years in the past. To many people however, it sounded just an idea because they could not quite conceptualize what the whole idea of GIS was all about. Through the assistance of the Remote Sensing and Cartography (RSC) and the Land Use Planning (LUP) sections on the importance of GIS user facility, the noble idea eventually became a reality in 1994.

Most of the procurement of hardware and software has been done. The LUP started first by setting up ILWIS GIS configurations in most of the agricultural regions. There are currently six of such configurations based in the following centres; Gaborone, Francistown, Serowe, Maun, Kanye and Kasane. Although the LUP started first through an FAO project, the mandate of setting up a Remote Sensing and GIS user facility for the Ministry of Agriculture rests with the Remote Sensing and Cartography Section.

The following are the respective hard/software of the above mentioned sections of the Ministry of Agriculture:

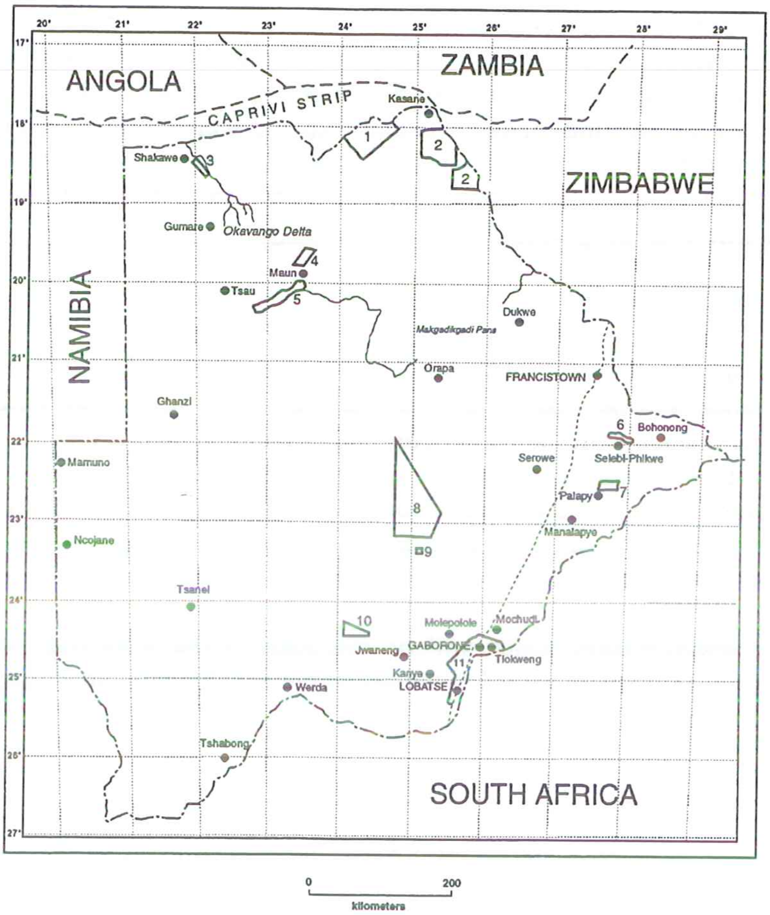

Figure 2 Status of large scale soil mapping in Botswana (scales 1:50,000 to 1:250,000).

The LUP-GIS configuration:

1 x 486/33
1 x 386/25
1 x 8MB
1 x 4MB
4 x B/W Printer
1 x A6 size Digitizing Table

1 x 540MB HD
1 x 340MB HD
1 x HP x L300 Colour Printer
1 x HP Laser Jet
1 x A2 Size Digitizing Table
ILWIS Software

The RSC-GIS configuration:

Hardware

1 x 846/33
2 x 486/66
200/1 GD HD
Canon A3 Size Colour Printer
A0 size Pen Plotter
A1 size Inkjet Plotter
A1 size 300 dpi Scanner
A0 size digitizing table

Software

PC Arc/Info
Erdas VGA
Map Info
Idrisi
Cadcore
Auto CAD
Arc CAD

The basic idea after setting up all the configurations is to have the RSC as the centre and the regional configurations as the nodes. Some projects have been carried out with the assistance of GIS applications. These however, can be viewed more as learning stages. One of the ongoing-programmes is the digitization of all the existing topographic and thematic maps in the Ministry of Agriculture. Through this programme, all the existing reconnaissance soil maps (1:250,000) of Botswana have been digitised. The full implementation will show that a GIS is an organisational undertaking, mobilizing the resources of the whole ministry at all its levels of management.

SOTER activity in Botswana

Botswana already has a computerised Soil Data Base containing all available attributes on topography, soils, climate, vegetation and land use. This coincides very well with some characteristics of the SOTER Program. The linkage with the Geographic Information System is the only thing that is still missing. However, with the establishment of the GIS in the Ministry of Agriculture, it is hoped that the linkage will be established. It is therefore, an opportune moment for the Botswana Soil Survey to have been invited to come and share with the Kenya Soil Survey, its experiences about the SOTER program, having been fortunate to lay their hands on it.

The advantages and disadvantages which will be discussed in the workshop, will certainly help Botswana with its way forward with regard to the use of the SOTER program in particular and in the resources data base linkages with the GIS in general.

Conclusion

The SOTER Program seems to have moved towards the direction which was always advocated by the Division of Land Utilization of the Ministry of Agriculture. The Soil Survey Section,therefore is in no doubt that this program will certainly be a useful tool to policy makers, resource managers and the scientific community at large.

Acknowledgements

The Botswana Soil Survey, the Ministry of Agriculture and indeed the Government of Botswana is indebted to the Government of Kenya through the Kenya Soil Survey for hosting such a potentially useful workshop. The United Nations Environmental Programme (UNEP) is very much thanked for the financial support of the KENSOTER project as well as its generous sponsorship of the workshop participants.

A1.2 Ethiopia

Gizachew Abegaz

1 Introduction

This paper gives a brief review on the current status of soil survey in Ethiopia. Additionally, the current application of GIS and its potential use is discussed. Through not complete, a list is given of major institutions which are using a variety of GIS software programmes for their sectoral activities. Finally, a general and broad proposal is made on the potential use of SOTER in relation to environmental impact assessment and crop production in the context of the existing natural resources related data in Ethiopia.

2 Status of soil survey

Identification of soil resources, among others, is one of the major useful factors to assess problems and potentials in relation to crop production and natural resources conservation and development. To this end, the first national geomorphology and soil data was inventoried at a scale of 1:1 M by the ex-Land Use Planning and Regulatory Department (ex-LUPRED) in 1983. The basic mapping units for geomorphology and soil were groups of land systems (dominant) or individual land systems where these were mappable. Mapping was achieved through the use of Landsat satellite images interpretation, available survey data, field traverses and agroclimatic data. At 1:1 M scale, a total of 71 Landsat scenes covering the whole country were used for the mapping and interpretation purposes.

Landscape units formed the basic mapping units and morphologic criteria were developed for separating landscape units on the imagery. These criteria included the degree of dissection, drainage pattern and density, relief, land cover and, more particulary, evidence of landform genesis (such as pattern indicating volcanic, structural or alluvial origin). Thus a hierarchial classification system was used for geomorphology and soil mapping. At the highest level the general physiographic character of the landform was used (12 subdivisions). Within each broad landform class a further six subdivisions were made on the basis of landform genesis. Using these two levels of classification, 70 geomorphic type/units were identified for the whole country. Geomorphic units were further subdivided on the basis of soil associations which occur within them, into final landscape units. Finally, about 380 landscape units were identified for the whole country on the Geomorphology and Soils map.

Based upon the Geomorphology and Soil Map (1:1 M scale) and incorporating some new information after finalization of the map, a soils association map of Ethiopia was produced at a scale of 1:2 M. This was an attempt to further update the Ethiopian part of the 1:5 M FAO-Unesco Soil map of the World (1974).

The map and legend follow the format of the FAO/Unesco Soil Map of the World. The result of the geomorphology and soil study showed 18 dominant soil associations in Ethiopia (see table 1).

Table 1. Dominant soil associations in Ethiopia.

dominant soil type	area in %	dominant soil type	area in %
Acrisols	3	Lithosols	16
Andosols	1.0	Luvisols	6
Arenosols	0.5	Nitosols	12
Cambisols	11.5	Phaeozems	2
Chernozems	0.07	Vertisols	10
Regosols	4.0	Xerosols	8.5
Rendzinas	2.0	Yermosols	3
Solonchaks	7.0	swamp and marsh	0.5
Fluvisols	6.0	rocks and stones	4.5
Gleysols	0.5	sand	<0.2
Histosols	<0.3		

3 Status of Geographic Information System

A GIS is a computer-assisted system for the acquisition, storage, analysis and display of environmental data. The use of GIS started in Ethiopia in the mid 1980's. Since then many organizations have started to use GIS while some others have a great interest to establish a GIS. Indeed, the first national conference on the use of GIS for natural resources conservation and development was held in 1990 which, amongst others, aimed to establish a national natural resources database.

Several natural resources development institutions pioneered in the application of either GIS or modification of GIS for multi-sectoral activities related to natural resources management. The Ex-Land Use Planning and Regulatory Department (currently the Land Use Study Division) developed its own GIS referred as Geographical Information and Land Evaluation System (GILES) around 1984. It is a custom-oriented software and combines most GIS functions with land evaluation modules developed by the Land Use Planning Project using the FAO land evaluation approach. In the late 1980's the ex-LUPRED has digitized most of the national land resources maps which are either at a scale of 1:1 or 1:2 M. They included:

I. National land resources maps digitized using GILES:
- soil map at scale 1:2 M
- altitude map, V.I. 200 m
- precipitation map
- length of growing period map

Apart from the above, there are numerous national land resources data within the Ex-LUPRED but not yet digitized. They include the following:
- geomorphology and soils map at scale 1:1 M
- soil management units map at scale 1:1 M
- land use and natural vegetation map at scale 1:1 M
- sheet and rill erosion rate map

- agro-ecological map

II. Digitized project-based studies using GILES:

Soils, altitude, precipitation, land use and natural vegetation, agro-ecological zones, planning zones and length of growing period maps were digitized for the following project areas at scale 1:250,000:

- Menagesha
- Hykoch and Butajira
- Yerer and Kereyo
- Borkena
- Bichena
- Hossaina

The data format of GILES is not compatible with any other GIS and could not be transferred to other systems. However, the data attributes of GILES can be transferred to common spread sheet and database systems like Lotus and dBase. Apart from the incompatibility of GILES towards other systems, lack of trained personnel (especially after restructuring of the ministry) has remained a bottleneck to digitize and analyze the past and current national and various project-based land use planning studies

In addition to Ex-LUPRED the following institutions have started to use GIS in various degrees in their respective areas:

- Woody Biomass Inventory and Strategic Planning Project (WBISPP) within the Ministry of Natural Resources.
  Its aims are to digitize existing nation wide land resources maps and inventorize and digitize land use and natural vegetation data at scale of 1:250,000 for a significant proportion of the country. It employs PAMAP for GIS and PCI for data analysis and image processing.

- Ethiopia Valley Development Studies Authority (EVDSA) within the Ministry of Natural Resources. It has established a GIS system to inventorize and analyze land resources information as per major river basin in the country. The project installed SPANS as a GIS and ERDAS as image processing software.

- Ethiopia Mapping Authority (EMA).
  They have plans to establish a GIS centre and to digitize all the resource maps they produced - areal photo, topographic maps, etc. Recently EMA installed MAPINFO as GIS.

- National Meteorological Service Agency (NMSA) within the Ministry of Natural Resources.
  They are currently using ILWIS software for GIS and image processing.

4 Suggestions

Some duplications of work in the use of GIS are eminent among many institutions even within the same ministry. Indeed, some of the national land resources data digitized in GILES by Ex-LUPRED are not compatible with other systems and hence calls for the transfer of GILES data format into another standard data format so that the data can be used by other systems. However, this is not possible due to severe shortage of trained manpower in the field of GIS and other systems within the Land Use Study division.

To this end, the World Soils and Terrain Digital Database (SOTER) looks promising especially in relation to environmental assessment programmes. There is ample national and project-based land resources data within the Watershed Development and Land Use Planning Department. However, they are not yet digitized and analyzed since the bulk of these data are in report and paper map prints. SOTER may be one of the suitable programmes to store and analyze the stock of these data for the development of various national land resources management and policy issues. Possible and promising issues may include:

- Digitizing of the various national and project-based land use planning studies;
- Updating of the national sheet and rill erosion rate maps and the eventual development of erosion control policy and strategy issues through analysis and synthesis;
- Updating and digitizing of the national land use and natural vegetation data;
- Analysis for identification of potentially productive areas based upon available national land resources data;
- Analysis of the national soil management units map for evolvement of land classification which can be useful data input for natural resources management development at a national level.

A1.3 Lesotho

N. Mothokho

Status of soil survey

The most valuable resource of Lesotho, except for the people, is the land. Soil erosion has been a problem in Lesotho since the early 1900's. A lot of conservation work has been done in the past but there is still to much erosion and degradation. Drought, torrential rains, overgrazing and inadequate vegetative cover all contribute to the erosion problem.

Heavy demands are placed on the soil and water resources of Lesotho and the Conservation Division formulated a National Conservation Plan with recommended actions to improve and maintain these resources in the future. A National Resource Inventory was carried out in 1988. It dealt with land user, erosion and conservation.

No systematic national soil survey has been made. Ad-hoc survey cover selected areas in the lower western zones in the country where most of the agricultural activities are concentrated.

GIS facilities

The soil survey has a limited access to use GIS facilities of other departments. However, we have managed to access the LHDA project facilities if the operator is present. The LHDA is using PC Arc/Info software and is about to establish a Unix workstation within its premises.

We have managed to digitize the soil acidity map of Lesotho at scale 1:500,000 and the erosion hazard map. Digitizing of the Benchmark soil of Lesotho and the temperature and moisture zones will start soon.

The section has at present one computer with a printer. The following crop models are used: Ceres and Putu. Soil-pro for field data was obtained from RSA. Climwat and cropwat from FAO.

Other departments with GIS facilities are:
- Range Management Division
- Lands & Survey Department

The potential GIS users are in a process of registering the GIS society called LESGIS.

Problems

- Lack of trained manpower for GIS
- Difficult to obtain funds for software

A1.4 Madagascar

R. Rabeson

Natural resources inventories

The 'Projet Inventaire de Ressources Naturelles Terrestres' (Inventories Project on Terrestrial Natural Resources) of the 'Centre National de Recherches sur l'Environnement' (CNRE) had as objectives:

- the mapping and assessing of the natural resources for sustainable agriculture and environmental monitoring
- training of a national team consisting of a hydrologist, pedologist, hydrogeologist, geographer and cartographer.

The project lasted from 1985 to 1992 and was financed by the World Bank. The study area covered about 310,000 km^2. For the location see figure 3.

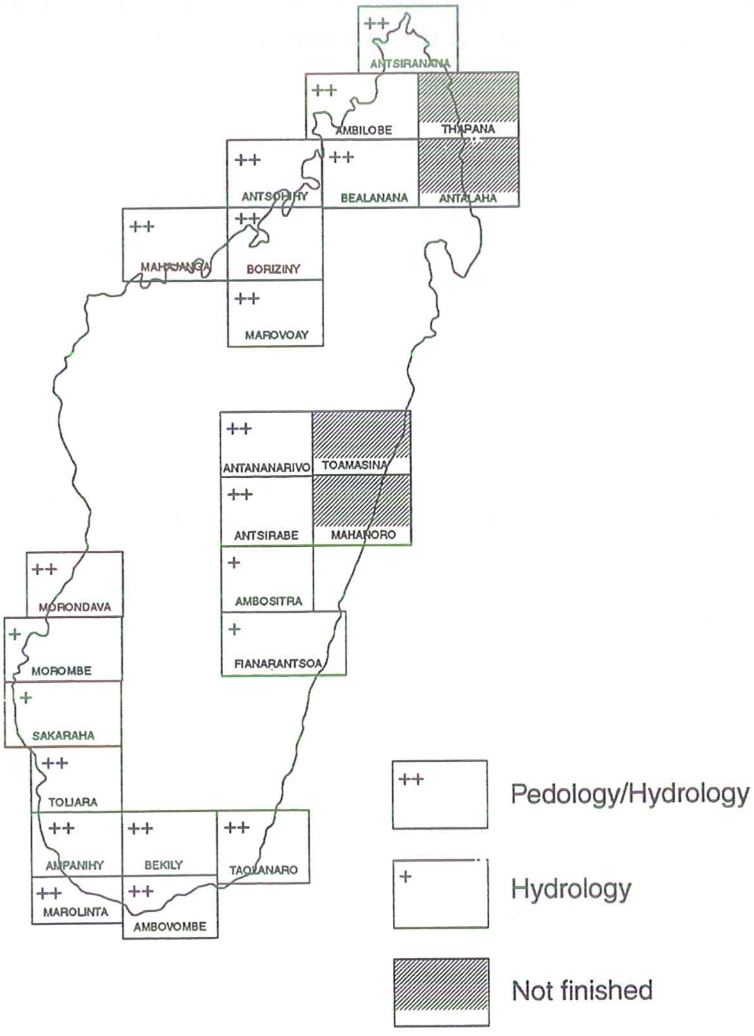

Figure 3 Localisation of mapping area.

The inventory started with a review of literature (map and data), embarked on a SPOT image interpretation by remote sensing techniques at scale 1:100,000 followed by field investigations. The model ('Maquette") of soil and hydrology resources was applied at the same scale. A total of 24 sheets of soil and hydrology resources at a scale of 1:200,000 was to be done.

In total 16 pedology maps and 20 hydrology maps at a scale of 1:200,000 were produced in cooperation with the Institut Géographique et Hydrographique National (IGHN/FTM).

Depending on financial support the project is to be continued to cover the whole of Madagascar.

GIS facilities

At the Centre National de Télédétection et Information Géographique/Institut Géographique et Hydrographique National the following GIS facilities are present:

Software:
- ARC/Info version 7.0 (3x)
- I^2S for image processing (2x)

Hardware:
- 2 SUN Spark 5 workstations
- 3 SUN Spark 20 workstations
- 2 A0 digitizers
- 1 A0 Inkjet printer
- 1 A0 Pen plotter

A1.5 Malawi

Patrick Banda and M.W. Lowole, Ph.D.

1 The Background of Soil Survey Work

In 1938, Hornby carried out a soil survey of part of Malawi and produced a soil map of Central Nyasaland (Malawi) which covers only a small part of Central Malawi, the larger part being covered is that of Southern Malawi.

Lockwood Survey Corporation Ltd. of Canada carried out a soil survey in the Lower Shire Valley In the Southern Region in 1970 at a scale of 1:50,000 with series as mapping units; the soils were classified according to the USDA 7th Approximation.

Young and Brown (1962), Brown and Young (1965), and Stobbs (1971) carried out an agro-ecological survey between 1959 and 1970 at a reconnaissance scale of 1:500,000. Taken together, they constitute the first natural resources survey to cover the whole country. In their approach, they integrated the factors of the physical environment, such as the soil, climate, vegetation, and landform. The soil was just one of these factors. As a result, the maps which were produced do not show soils but 'Natural Regions and Areas'. According to the authors, a 'Natural Region' is part of the earth's surface within which the characteristics of the physical environment were relatively uniform; the term 'Natural Area' is a subdivision of a 'Natural Region'. Soil series were identified in each 'Natural Area'.

The Surveys of Young and Brown (1962), Brown and Young (1965), and Stobbs (1971) were too general and therefore lack the detail required for agricultural purposes which were becoming increasingly intensive. In addition a soil report was not prepared by Stobbs for the Southern Part of Malawi. However, it should be noted that these studies have been used for purposes well beyond their intended level of utility because they were the only ones in a published form, and covering the whole country.

2 The Present Status of Soil Survey

In view of the reconnaissance nature of earlier surveys, a decision was taken to undertake more detailed surveys than previously. Hence the Soil Survey Section was formed in 1968 for this purpose.

The Soil Survey Section is responsible for characterising and identifying types of soils and their locations, estimating the area of land covered by each type of soil, and assessing the potential of each type of soil for agricultural and other uses. This is necessary for the rational transfer of technologies from research stations to areas where smallholder farmers engaged in agricultural production live, for selecting trial and research sites, and for rational land use planning.

Since it was formed, the Soil Survey Section has carried out soil surveys all along the lakeshore plain and the Shire Valley at scales ranging from 1:50,000 to 1:5,000. Some upland areas have been mapped at these scales. However, detailed soils information is still lacking for many areas. The work is hampered by inadequate funds, staff, vehicles, and equipment.

The absence of reliable detailed soils information at most of the Agricultural Research Stations, Sub-stations, and Experimental Sites in Malawi prompted the Soil Survey Section to embark on a soil survey and mapping programme of the existing research stations, substations, and experimental sites in 1976. Out of seven, only two of these have been covered so far; the work is continuing.

2.1 Soil, Classification and the Legend

The soil classification system currently used in carrying out soil surveys in Malawi is that formulated for the Agro-Ecological Surveys by Young and Brown (1962), Brown and Young (1965), and Stobbs (1971). The system is used in conjunction with the FAO Legend of the Soil Map of the World (1974; 1988), and the Soil Taxonomy (1975). The system is genetic at the higher levels, but morphological at the series level. The genetic part is based on the Inter-African Pedological Service Soil Classification System by d'Hoore (1964). Genetic Classification of soils is given in table 1.

Table 1. Genetic classification of soils

Drainage class	Group	Sub-group	Series
A. Free site drainage; leaching the dominant process; red, reddish brown, and yellowish red colours; latosols	1. Ferruginous soils		e.g. Ekwendi
	2. Ferrisols	(a) Ferrisols with some ferruginous features	Misuku
		(b) Ferrisols	Nchenachena
	3. Ferrallitic Soils	(a) Humic Ferrallitic Soils	Viphya
		(b) Weakly Ferrallitic Soils	Loudon
		(c) Sandy Ferrallitic Soils	Fort Hill
		(d) Sandy Ferrallitic Soils with laterite	Jalira
		(e) Ferrallitic soils developed from sandy parent materials	Kashata
		(f) Ferrallitic soils with impeded profile drainage	Bwabwa
B. Impeded site drainage; greyish brown, black, or mottled colours; calcimorphic soils	1. Lower members of latosol catenas		Kapemba
	2. Alluvial soils		Karonga
	3. Alkaline soils		Alkaline soils
C. Poor site drainage	Hydromorphic soils		Dambo clays
D.	Lithosols		Lithosols

Source: Young and Brown (1962)

2.2 Soil Resources of Malawi (1:1,000,000 Map)

Soils are the main source basis for agriculture in Malawi, on which much of the wealth of the country depends. Considering that the country is not very extensive, the variability of the soil is rather high. This is attributed to the high variability of the soil-forming factors. A soil map of the whole country has been compiled by Lowole (1983). The following are the soils mapped and their major features:

2.2.1 Upland (Residual) Soils

- The ferruginous soils are basically red, with sandy clay loam topsoil over a sandy clay or clay subsoil, weakly to moderately acid. They are most extensive In the central part of Malawi.

- The ferrallitic soils are mainly yellowish red to yellow or brown, sandy in texture, weakly to moderately acid. These occur in all parts of the country.

- The ferrallitic soils with laterite actually constitute a subgroup of the ferrallitic soils discussed above. They have a layer of massive laterite within 100 cm of the surface. They occur mainly in the central part of Malawi.

- Weakly ferrallitic soils have characteristics Intermediate between those of ferruginous and ferrallitic soils, but they tend towards the later. They mainly occur In the central part of Malawi.

- Humic ferrallitic soils are strongly leached, but have a higher organic matter content; they occur mostly above 1800 m above sea level. They occur mainly in the plateau areas of Vipha and Nyika, and on Mulanje and Zomba Mountains.

- Ferrisols are red, friable clayey soils, normally deep (> 2 m). They occur in high rainfall areas with a mean annual rainfall exceeding 1500 mm.

2.2.2 Upland Soil Associations

Ferruginous, ferrallitic soils with their intergrades occur in complex associations.

- Weakly ferrallitic and sandy ferrallitic soils contain weakly weathered and highly weathered soils with sandy loam or sandy clay loam textures. They mainly occur in the Northern part of Malawi.

- Ferruginous soils with Lithosols occur in all parts of the country.

- Ferrisols and Lithosols are mainly found in the Northern part of Malawi and are mainly used for crops such as tea and rubber.

- Humic ferrallitic soils with Lithosols occur at high altitudes and the soils are gravely: Ferrallitic soils and Lithosols are gravely and they mainly occur in the Northern part of the country.

2.2.3 Alluvial Soils and Soils Derived from Alluvium

- The alluvial soils are mainly characterised by stratification whereby layers of different textures and colours alternate with depth. In the old alluvial soils, stratification may be blurred by pedogenic processes so that textural variation with depth may not be clear.

- Vertisols are dark or black heavy cracking clays. They occur on basalt and basalt-derived colluvium in the Lower Shire Valley In the Southern part of the country. The soils are important for cotton growing in Malawi.

- Hydromorphic soils are dark - coloured or mottled soils that occur in valley floors (where they are locally known as dambo clays) and in marshes.

- Mopanosols is a name given to soils associated with the Mopano tree (*Colophospermum mopane*). These soils are compact, alkaline, dark grey sandy clays with free calcium carbonate. They mainly occur in the Southern part of the country.

- Regosols are very sandy soils derived from the former beach and dune sands. They are mainly used for cassava growing.

2.3 Land Resources Evaluation Project

From 1988 to 1992 a Food Agricultural Organisation (FAO) Land Resources Evaluation Project carried out a generalised land resources survey at a reconnaissance scale of 1:250,000 for the whole country. Some of the maps produced under this project are the Agro-Climatic Zones, Soils/Physiography, Vegetation and Land Use Maps and some Land Evaluation Maps. Since the survey was generalised, it lacks detail.

3 The Present Status of GIS facilities

According to Wellar (1993), a geographic information system (GIS) consists of computer software, hardware, and peripherals that transform geographically referenced spatial data Into information on the locations, spatial interactions, and geographic relationships of the fixed and dynamic entities that occupy space in the natural and built environments.

In Malawi GIS has only been used in special projects such as the one used at Chitedze Agricultural Research Station in the Maize Commodity Team. Usually, no use of GIS including the equipment and software is continued after the projects because of lack of trained Malawian personnel. A plan is being organised to introduce GIS in the country for national purposes, but funds are a major problem.

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A1.6 Mozambique

Moisés F. Vilanculos

Natural resources surveys

In Mozambique, agricultural research is mainly carried out and or coordinated by the National Agricultural Research Institute (INIA). This institute has responsibility to carry out research on the improvement of crop varieties, cultural practices, and on natural resources inventory and management. INIA has three research departments and two supporting divisions:

- Agricultural and Farming Systems (DASP) (comprises plant breading and production).

- Botany and Herbarium Department.

- Land and Water Department (DTA).

- Documentation Centre (CDA).

- Administration and Finance Department (DAF).

The research in natural resources inventory and management is executed by (DTA). The main activity of the department is to carry out research on management, use, conservation and evaluation of soil and water. DTA carries out soil survey and land evaluation studies for specific development projects (client oriented) and for natural resource and agro-ecological inventories (systematic surveys) at the provincial or regional levels. It is responsible for standardization and quality control of soil surveys and land evaluation executed by external consultants and various organization in the country. All soil survey information is stored in the soil database.

Current state of natural resources inventory at INIA

The DTA has published the national soil map at scale of 1: 1 million in February 1995. This map is the result of the compilation of the existing information covering a major part of the country at different levels of details. The use of satellite imageries, topographic and geological maps were the basic tools for soil unit delimitation, where there was no ground truth data available. All data related to this soil map have been stored into the database. The map is in hard copy and in digital formats and printed per province.

Soil Database

Presently the FAO/ISRIC Soil Database (SDB) is in use (Van Waveren, 1989), adapted to Mozambican conditions and translated into portuguese. About 2000 profiles have been entered so far. The profiles are identified by a profile code, which is sequence of two characters and four numbers (e.g. M00011).

Climate Data Base

Two databases are in use: The Meteo and SUIVI databases. The first one, which contains mean monthly average data and decade data was (and to same extent still is) mainly used for agroecological zoning studies.

The SUIVI climate database is used to store and analyze daily data. This data base will be used for land evaluation studies.

SDB and METEO databases have been linked to the ALES (Automated Land Evaluation System, which has been developed at the Cornell University, Ma.), (Rossiter, 1988), by an interface which allows land evaluation applying the criteria developed by Sys (1985).

Presently an interface connects SDB with ALES expert system is being developed and tested. This interface allows the land evaluator to select any set of land qualities/characteristics and to enter selected profile data into ALES database for further modelling. The land evaluator can develop models and apply unique sets of decision trees, which greatly improve the flexibility.

The results of an evaluation are generally exported to ILWIS, a GIS system, in which the results can be combined with other information (overlays).

The final maps are presently being printed in the ILWIS environment, but later this year Adobe software and appropriate hardware will be purchased for enhanced map production capability.

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A1.7 South Africa

D.P. Turner

Introduction

The aim of this paper is to present an overview of the natural resource maps and inventories of South Africa, and to report on their incorporation in computerized databases. The paper provides information on the systems of Soil Classification currently used for the assessment of soil resources in South Africa. In keeping the theme of this workshop which focuses on a "Global Soil Resource Inventory" at a continental scale, natural resource surveys with country wide coverage receives prominence in the paper.

In South Africa the Land Type Survey with its main elements the demarcation of land with homogenous climate, terrain form and soil has assessed much of these natural resources.

This survey has a publishing scale of 1:250,000. It also has similarities with approach outlined in the "Global and National Soils and Terrain Digital Databases - SOTER" manual (UNEP-ISSS-ISRIC-FAO, 1993).

Details of the nature of Land Type Survey information and progress with its incorporation into GIS databases are reported. Finally two examples of the interpretation of natural resource information for agricultural development are reported.

Soil Classification

Soil Classification as a means of mapping and naming soils in a consistent way is essential to the understanding of the spacial distribution and properties of the soil. Soil classification strives to groups like soil individuals, and distinguish them from soils with differing properties. A natural system of soil classification is applied for soil survey in South Africa. The system is documented in two published editions namely:

1. "Soil Classification: A Binomial System for South Africa" (MacVicar, De Villiers, Loxton, Verster, Lambrechts, Merryweather, Le Roux, Van Rooyen and Harmse, 1977), and

2. "Soil Classification: A Taxonomic System for South Africa" (Soil Classification Working Group, 1991).

The Binomial System is a two category system which permits the easy identification of soils from largely field identification. The upper more general category contains soil forms, while the lower more specific category contains soil series. Soil forms are defined by a vertical sequence of diagnostic horizons. Five topsoil horizons and 15 subsoil horizons have been defined which give rise in combination to 41 soil forms. The definitions used to define diagnostic soil horizons follows the pattern adopted by the FAO Soil Map of the World: Revised Legend (FAO-Unesco-ISRIC, 1990), that of Soil Taxonomy (Soil Survey Staff, 1975) and World Reference Base for Soil Resources (ISSS-ISRIC-FAO, 1994). There exists much similarity between two editions of the South African Soil Classification System on the one hand and these systems referenced above on the other. Thus the definitions for melanic A horizon (South African System) and the mollic horizon (World Reference

Base) set out to identify dark, well structured, base rich soil materials. A correlation between the Binomial System and other systems used in Southern Africa has been prepared (SARCCUS:Standing Committee for Soil Science, 1984).

In practice soil profiles are classified by identifying the diagnostic horizons, being first allocated to a soil form (via a key) and then to a series on the basis of the relevant soil properties which define classes. Communication is accomplished by means of form and series names, with both classes being given place names in accordance with convention. Since the number of series names is fairly large, communication is made easier using the form and series name abbreviations.

The Binomial System of Soil Classification has been applied with widespread acceptance in South Africa since 1969. It remains the basis for the Land Type Survey. The system underwent revision resulting in the publication in 1991 of "Soil Classification: A Taxonomic System for South Africa" (Soil Classification Working Group, 1991). Whilst the basic approach remains unaltered a number of changes were introduced. Definitions for certain horizons were adapted in keeping with present knowledge and definitions for additional subsoil horizons were incorporated. The number of soil forms identified from field survey increased to 73. The soil series defined in the Binomial System on the basis of texture often split natural soil bodies in an artificial manner. The Taxonomic System does not formally define the soil series category making the way clear for research towards the recognition of naturally occurring soil bodies at the lowest level of soil classification. Consequently the soil family, a higher category than the soil series, is the lowest category in Taxonomic System. Each form and family is named and has a abbreviation code. This is complemented with a topsoil textural class.

For example the Hutton form, family 1100, medium sandy loam topsoil texture has the code Hu1100meSaLm. This code accommodates all freely drained red (Hutton, Hu) dystrophic soils (1) with a marked increase in clay (class 1200) from the A to B horizons. Soil names used in the Binomial System retain their significance in the Taxonomic System.

The South African soil classification system has the ability to describe and easily recognise real soil differences is widely accepted and used by specialists and non-specialists alike.

Soil and Terrain Mapping

An assessment of the natural agricultural resources of South Africa commenced in 1972 with the Land Type Survey. The survey has as its main objectives:

(i) the delineation of areas, known as land types, at 1:250,000 scale such that each land type displays a marked degree of uniformity with regard to terrain form, soil pattern and climate,
(ii) an inventory of each land type in terms of terrain, soil and climate parameters, and
(iii) an in-depth analysis of a number of soil profiles, termed modal profiles, selected to represent the range of soils encountered during the survey.

With this information it would be possible to define and, with reasonable accuracy, estimate the areas of the main climate - soil - slope classes that occur in each demarcated area. Yield potential and production technique data could be coupled to these classes in information storage-retrieval systems.

Until 1991 land type maps were published as overprints to 1:250,000 scale topo-cadastral maps. Land type and modal soil profile data, and a description of the methods used, are contained in memoirs of the Land Type Survey (Land Type Survey Staff, 1984). Each memoir deals with one or more land type maps.

The survey of each 1:250,000 map was carried out by the systematic survey on each of its component 1:50,000 quarter degree sheets. First, existing information and maps, since 1979 also satellite imagery, relevant to the terrain, soils and climate of the area were collected and studied. After an orientation excursion, areas called terrain types, each displaying a marked uniformity of terrain form, were delineated. Then the soils in each terrain type were identified and areas known as pedosystems, each with uniform terrain and soil pattern, were delineated. Representative or modal profiles were described and sampled for in-depth laboratory investigation. A separate map showing the distribution of climate zones was then drawn. This was superimposed upon the pedosystem map to arrive at a map of land types, each displaying marked uniformity of terrain, soil pattern and climate. On completion of these steps the land type boundaries were transferred from the 1:50,000 to the 1:250,000 maps. Finally, an inventory of each land type was compiled in terms of terrain, soil and climate parameters.

Terrain Types

A terrain unit is any part of the land surface with homogeneous form and slope. Terrain can be thought of as being made up of all or some of the following kinds of terrain units: crest, scarp, midslope, footslope and valley bottom or flood plain. A terrain type in this context denotes an area of land over which there is a marked uniformity of surface form and which, at the same time, can be shown easily on a map at a scale of 1:250,000. Land shown on a map as belonging in a terrain type may cover only a single terrain unit (e.g. a flood plain), it may cover a single crest-valley bottom sequence (e.g. an escarpment) or it may cover a large number of crest to valley bottom sequences that repeat themselves three dimensionally (e.g. a large area of rolling hills).

Pedosystems

A pedosystem denotes land over which terrain form and soil pattern each displays a marked degree of uniformity. Soils do not occur randomly in a landscape, but follow a pattern determined by factors such as geology and topographic position, many of which in turn have either played a part in shaping the landscape or are inherent features of the landscape (e.g. a valley bottom).

The soil composition of a terrain type was described by detailing which soil series of the Binomial System (MacVicar et al., 1977) occur on each terrain unit (e.g. the midslope) and by giving an estimate of the area of each series on a given terrain unit.

At this stage modal profile sites were identified, pits dug and the profiles described and sampled. Analytical facilities required that these profiles, chosen to represent the range of soils encountered during the survey, be limited in number.

Climate Zones

The climate map required was one which would show the distribution of climate zones within each of which all agriculturally important climate parameters would display either a narrow range of variation or a marked regularity in pattern of variation. Since meteorological stations were often too widely scattered or recorded too few climate parameters, the use of meteorological parameters alone proved to be inadequate. Therefore greater reliance was placed on natural vegetation, soils, crop performance, altitude and topography as indicators of climate boundaries.

Some climate zones cover no more than a terrain unit (e.g. a plateau, a flood plain), some a single crest-valley bottom sequence, while many cover a large number of crest to valley bottom sequences that repeat themselves three-dimensionally (e.g. a large undulating plain).

Land Type Map

A land type denotes an area that can be shown at 1:250,000 scale and that displays a marked degree of uniformity with respect to terrain form, soil pattern and climate. One land type differs from another in terms of one or more of terrain form, soil pattern and climate. Different occurrences of the same land type may be separated from one another by other land types. The land type map was compiled by superimposing the climate map on the pedosystem map. The land type inventory was then compiled using data collected during the terrain, soil and climate survey phases.

On each map a list is given of the modal profiles that are located on it; the positions of these profiles are also shown. The co-ordinates, description and analytical data for each profile are contained in the memoir that deals with the land type inventories for the particular 1:250,000 map. On each map is a list of the numbers of the land types that occur on the map. In addition, the area (ha) of each separate occurrence of every land type is given.

The legend of each land-type map comprises a possible 28 "Broad Soil Patterns" including: red and yellow freely drained soils, plinthic catena, duplex soils, vertisols, lithosols and others. Land types are identified by the symbols of the Broad Soil Pattern and a sequential number.

The land type survey now nearing completion has defined some 6,000 land types and 2 300 climate zones. Some 2,000 modal profiles have been described and analyzed.

The land type inventory

A terrain and soil inventory, and a climate inventory is prepared for each land type and indexed against the land type number. The inventory contains map location information, the total area of the land type the profile numbers of any modal profiles. A brief description is given of the geological formations present.

Estimate of the proportions of a possible 5 terrain units namely: crest, scarp, midslope, footslope and valley bottom, together with their area, slope range, slope length range, slope shape and mechanical restrictions are prepared (Land Type Survey Staff, 1984). A terrain type class with 8% slope as a threshold value provides a useful overview of the terrain features of the land type.

The soils series (MacVicar et al, 1977) encountered during field survey are listed giving their depth range, mechanical restriction class, clay percentage range of the A, E and upper B horizons, texture class range and depth limiting materials. The proportion of each soil series occurring on each terrain unit is evaluated.

The climate inventory provides on a monthly basis, and subject to availability of data: 6 rainfall parameters, class A-pan evaporation, thirteen temperature parameters and 7 frost parameters.

Modal Profiles

Modal profile sites chosen to represent the dominant soils were described and sampled. The profile description method is based on that in the Soil Survey Manual (Soil Survey Staff, 1951). Adaptions to the field description method (Dohse, Idema and Van der Walt 1985; Pedology Staff, 1992) and the development of the SOILPRO profile database have facilitated the capture of soil profiles in a computerized system.

The physical, chemical, micronutrient and mineralogical analyses were performed on these samples using standard recognised methods (Land Type Survey Staff, 1984). These analyses include particle size distribution, air water permeability ratio, water retentivity, Atterberg limits, cation exchange properties, acidity, soluble salts, organic carbon, CBD extractable Fe, Al and Mn, micronutrients (Zn, Mn, Cu, B, Co), P-status and P-sorption: Mineralogical analyses is by X-Ray diffraction with the relative intensities of the diffraction peaks being used as estimates of the minerals present.

Geographic Information Systems linked to soil and terrain natural resources

An overview of some databases which has bearing on the SOTER methodology is presented in table 1. Information captured in the terrain, soil and climate is discussed briefly below. In the land type database digitizing of the spacial data has taken place directly from the original field sheets. Extensive soil and terrain inventory information has been captured, while capture of the monthly climate inventory data is ongoing. Similarly, capture of soil analytical data into the SOILPRO database is ongoing with regular use of these databases.

Databases unless otherwise indicated are maintained at the Institute for Soil, Climate and Water.

(1) Original information maintained elsewhere.
(2) Institute for Veld and Forage Utilization, Agricultural Research Council.
(3) Geological Survey.
(4) Institute for Soil, Climate and Water, ARC & Forestek, CSIR.

Interpretations derived from natural resource information

A range of interpretations using manual means and GIS technology could be considered. Two examples are quoted below. An algorithm to determine agricultural potential index for rainfed crops was prepared. The index was assigned to polygons of the land type database giving a continuous map. The index was calculated by assigning weighted means to elements of the terrain, soil and climate inventories. Similarly, a land use potential index and map was prepared by assigning land type polygons to adapted land capability classes similar to those proposed by Klingebiel and Montgomery (1961). This algorithm was tested in the Gauteng Province.

Table 1. An outline of the spacial and non-spacial components of databases linked to the natural resources terrain and soil. The databases focus on national coverage.

Database	Spacial	Non-spacial
Land types Inventory	1:250,000 maps digitized from original 1:50,000 field sheets	Soil inventory Terrain inventory
Land type Climate zones	As above	Climate tables (monthly)
Soil profile SOILPRO	Soil profile positions	Soil analytical data
Agrometeorology	Weather station locations	1. Daily data of up to 7 weather elements e.g. rainfall 2. Long term summaries
Detailed soil maps	Soil polygons Limited coverage	Soil map legend
Topographical (1)	Point elevations	50, 200 and 400 m grid positions
Cadastral (1)	District, farm boundaries	Limited information
Vegetation (2)	Maps/data at various intensities and methodology. Working towards national coverage	Construction of new classifications in progress
Geology (3)	1:1 million and various 1:250,000 and 1:50,000 maps	Referencing to geophysical, engineering geology, geochemical, palaeontology information. Literature
Land cover (4) (under construction)	Map	Land cover classes
Drought monitoring	NOAA/NOVI 1:1 km resolution	Vegetation condition index only

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A1.8 Sudan

Osman Abdelrahman M. El Tom

1 Introduction

The Sudan, a the largest country of Africa covering 2.5 million km^2, is a country where agriculture plays a vital role in its economy. It accounts for about 35% of GDP and reaches 95% of export earnings (JICA, 1990). About 75% of the population are involved in agricultural activities (table 1).

Irrigated agriculture covers about 1.89 million hectares while rainfed and traditional agriculture cover about 7.77 to 8.4 and 2.94 million hectares respectively. Thus soils are considered one of the major components of its natural resources together with the Nile River which almost bisects the country from south to north through a variety of climatological zones. Generally these zones start from desert, semi-desert, monsoon and highlands proceeding from north (latitude 22°) to south (latitude 4°).

The Soil Survey Administration (SSA) of the Sudan Ministry of Agriculture, Natural Resources and Animal Wealth executed soil surveys of more than 8 million hectares at detailed, semi-detailed and reconnaissance levels in addition to most of the regions in the centre and northern parts of the country at exploratory levels. Foreign companies executed soil surveys of considerable areas particularly before the establishment and strengthening of the Sudan Soil Survey Administration.

Table 1. Some agricultural information about Sudan

Item	Description
1. Location	North East Africa, lat. 4-22°N, long 22-38°E
2. Extent	2.5 million km^2
3. Climate	Desert, Arid, Semi arid, Monsoon and Highlands
4. Agricultural	35% of GDP, 95% of export earnings
4.1 Irrigated	1.89 million hectares
4.2 Rainfed	7.77 to 8.4 million hectares
4.3 Traditional	2.94 million hectares
4.4 Animal wealth	60 million of cattle, sheep, camels and goats
4.5 Forestry	75-80% of energy needs of the country
4.6 Fishery	30,000 tons per annum

2 The Sudan Soil Survey Administration Activities

When the Soil Survey was a small unit within the Agricultural Research Corporation, soil scientists used to evaluate the soils by what is known as the Na-value which is (Anonymous, 1957):

$$Na\text{-}value = \frac{m.e.Na/100g soil x 100}{CxD}$$

where C = clay content in %
D = oven dry weight of 100 g of air dry soil.

In the early sixties the small Soil Survey Unit was developed into a division outside the Agricultural Research Corporation when FAO phase I started to strengthen it. Again FAO in the seventies started Phase II where more technical know-how in soil survey and soil science was emphasised. During these two phases much of the soil survey activities in the Sudan were executed using the American Soil Taxonomy (1975 and 1992) for soil classification and an American modified system of land capability (Tahir and Robinson, 1965) which has been replaced by an FAO modified system of land evaluation (Van der Kevie and El Tom, 1987). These soil survey activities are briefly described below.

2.1 Irrigated agriculture

Due to the high capital invested in irrigated agriculture the soil survey for such a land use alternative was carried out at either detailed or semi-detailed levels. These activities covered about 4.5 million hectares mainly along the Nile in the northern regions.

The Soil Survey Administration has been involved since 1987 in very detailed soil survey of the Gezira Scheme, one of the largest irrigation schemes in the world as it covers an area of more than 840,000 irrigated hectares under one management. Soil samples at an intensity of one observation per 75 hectares have been and are being are collected, analyzed and interpreted for agricultural purposes. Till now the are covered is 336,000 hectares out of 1,260,000 hectares.

2.2 Rainfed agriculture

Extensive areas were mapped at reconnaissance levels for rainfed agriculture particularly in what is known as the Central Clay Plain of the Sudan which is a vast cracking clay plain that is classified as Vertisols. Rainfall ranges from almost zero in the extreme northern part of the country increasing southwards to 1400 mm per annum.

Areas soil surveyed by SSA for rainfed agriculture are about 3.6 million hectares. Cutting trees for energy and developing such vast areas under monocropping and applying inappropriate agricultural practices are reasons for desertification and retreat of the rainfall isohyets southwards.

2.3 Regional Soil Surveys

Using satellite images, the Soil Survey Administration, covered most of the potential agricultural regions in the country at exploratory levels. Purnell and Venema (1976) reported areas of agricultural potential in the Sudan. North of isohyet 400 mm they reported about 142,500 km^2 of agricultural potential land and about 614,500 km^2 south of isohyet 400 mm. Table 1 gives information of those areas.

3 Activities of Foreign Companies and Consultants

Foreign companies executed soil surveys at exploratory levels for considerable areas prior to the establishment of the Government Soil Survey Organism. Hunting Technical Services in fact did more than 90% of the soil survey areas executed by foreign organisms. The total area covered by these foreign companies is about 4,537,000 hectares mostly at exploratory levels indicating areas of agricultural potential which were further studied at more detailed levels by the Sudan Soil Survey Organisation. Table 2 shows the hectares covered by Soil Surveys in Sudan at different levels.

Table 2. Soil survey coverage in Sudan.

Name of Organ and Land-use Alternative	Level of Survey	Area in Million Hectares
1. Sudan Soil Survey Administration: 1.1 Irrigated Agriculture 1.2 Rainfed Agriculture 1.3 Regional surveys	 Detailed and semi-detailed Reconnaissance Exploratory	 4.5 3.6 14,250,000
2. Foreign Organisations: 2.1 Regional	 Reconnaissance and exploratory	 4,537,000

4 The need for a Geographic Information System (GIS)

The use of a Geographic Information System (GIS) in the Soil Survey Administration (SSA) of the Sudan is a necessity, in land resource assessment. The voluminous data obtained by SSA through more than thirty years of its activities in different parts of the Sudan need a GIS that allows different datasets to be input, stored, analyzed, updated, edited and output at different scales. This system will enable SSA to carry out soil and land use mapping, analysis, monitory and management to occur simultaneously. Thus the establishment of a full database/GIS capability to link remotely sensed data, cartographic data as well as conventional tabular data is necessary.

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A1.9 Swaziland

B. Masuku

Introduction

Swaziland is a land-locked country, 17,370 km² in area, located in Southern Africa, and surrounded by South Africa and Mozambique. Though small in size, it is a country with wide ranges in physiography, climate and soils. The altitudes range from less than 400 to more than 1400 m above sea level. Moisture regimes have been described as ranging from humid to dry semi arid.

Soil survey status

Soil survey in Swaziland started in the 1950's as part of a joint effort with other African states to get a unified to get a unified soil classification system for the entire continent. The result was the evolution and definition of broad soil mapping units at exploratory level (1:1 M) which provided a framework for refinement, modification and adaptation for local conditions and requirements.

In 1963, the nation witnessed the inception of a national soil reconnaissance programme which was spearheaded by G. Murdoch. The completion of the work in 1968 was signalled by the publication of a book entitled "Soil and land capability in Swaziland" which was accompanied by a reconnaissance soil map and a land capability map of the whole country at 1:125,000 scale.

The mapping described in the reconnaissance documents comprises sets and series. The former is a straightforward assemblage in mapping form of soil series that are alike in their morphology and in the practical use that can be made of them. Soil sets can also be regarded as geomorphologically associated soils.

Land systems mapping

After the publication of the results of the reconnaissance survey, a physiographic approach of grouping the soils into larger units was carried out. This system provides a rational subdivision of the country, both as a suggested framework for the systematic collection and widening of information on the natural resources of the country and as a supplementary guide to regional planning.

The basic unit of land classification employed, the land facet is a recognizable piece of the landscape, usually with simple form and with a particular rock, soil and water regime that is either uniform over the whole facet, or if not, varies in a simple and predictable way.

Each land facet is sufficiently homogeneous over its extent to be managed uniformly for all but the most intensive forms of land use. Land facets are of such a size that they can be mapped at scales from 1:10,000 to 1:50,000 and they are recognizable on aerial photographs at scales in this range.

Recurrent patterns of land facets constitute a land system. They are convenient groupings of land facets for mapping at scales from 1:250,000 to 1:1 M. They have been mapped at 1:5 M for the whole country. The land systems are the legend to the map. Each land system is described stating its geology, relief, altitude, geomorphology, hydrology and dominant vegetation and soils. Its component land facets are then described individually as fully as available information allows.

Detailed and semi-detailed mapping

After the publication of the reconnaissance soil map, the Ministry of Agriculture embarked on a programme of improving the reliability and usability of its soil survey data through detailed and semi detailed soil surveys for specific projects. As of today the soil survey statistics stand as follows:

level of survey	% of total area of Swaziland
reconnaissance	100
land systems map	100
semi detailed	32
detailed	25

Other related natural resources information

Other departments were also engaged in natural resources surveys under their mandates and the following products have been made available:

- geological map of Swaziland 1:250,000
- Geological map of Swaziland 1:50,000
- Vegetation cover 1:250,000
- Hydro-geological map 1:100,000

Soil database and GIS

In 1992 the Ministry of Agriculture and Co-operatives initiated an exercise through a FAO supported project to establish a computerized soil database. The FAO-ISRIC soil database was used as the base for development by adjusting the FAO (1990) Guidelines for soil description coding system to suit local conditions. About 500 soil profiles were described and are stored in the database.

The soil database is linked to a GIS (IDRISI). For land evaluation, the Automated Land Evaluation System (ALES) is used.

The project has generated the following products:

- physiographic map
- climate characterization
- actual erosion map
- agro-ecological zones map
- land tenure map
- land use map
- land suitability map for several crops

A1.10 Tanzania

Samweli Mugogo

1 Introduction

Tanzania extends between approximately latitudes 1°-12° S and longitudes 29°-41° E. It has an areal extent of 883,000 km^2 with a population of about 26 million. Tanzania's economy is predominantly agricultural. More than 90% of the population is directly dependent on agriculture, while 80% of total export earnings are derived from agricultural sector. Agriculture plays ail important role in ensuring both domestic food supplies and earning much needed foreign currency for imports.

Diverse agro-climates permit the production of a wide range of food and cash crops and potential for further diversification. Topography, soil types, a permanent water supply, the presence or absence of the tsetse fly and climatic condition all influence regional concentration of agricultural activities. The main land use systems range from a nomadic type of pastoralism in the semi-arid, mid-altitude areas in the central parts of the country to high-intensity mixed agriculture in the humid high altitude areas of the northern and southern highlands.

Planning research and advising on land use in Tanzania requires a broad knowledge of natural resources especially land, soils characteristics, climatic conditions and agricultural potential. This calls for proper identification, characterization and inventorying of the land resources along with identification of factors limiting production.

Soil and land resources surveys and mapping have been carried out in the country for more than 50 years. Surveys and mapping have been carried out at a wide range of scales and with different objectives. Soil maps have been made for land use planning at country, regional and district levels, for establishment of refugee settlements, for the planning of the country's new capital and for the estate and irrigation management.

This paper will present soil and land resources studies already done in the country, responsibility, scales, purpose, coverage and the state of GIS facilities in the country.

2 History of natural resources inventories

Geoffrey Milne is the founder of natural resources inventory studies in Tanzania. He prepared the first Provisional Soil Map of East Africa (Milne 1936) and later an exploratory soil survey of parts of the then Tanganyika Territory (Milne 1947). He used soil categories such as "plateau soil", "plain soils" and "red earths" (laterised and non laterised). Outstanding, however, is the introduction of the concept of the soil catena as a mapping unit. He defined the catena as "a regular repetition of a certain sequence of soil profiles in association with a certain topography".

After Milne subsequent workers include Calton (1954), Scott (1963), D'Hoore (1964), Anderson (1 967), Baker (1970), Hathout (1972a, b & c), Samki (1977 & 1982) and De Pauw (1983 & 1984). These authors used different approaches in their studies. Maps were produced on the basis soil morphological mixed with landscape, topography, genetic, soil textures and drainage, soil colours, parent materials, stoniness and drainage.

Besides land resources inventory, land evaluation studies were also carried out mainly by, Hathout in 1972, when he compiled some land qualities including water availability, water holding capacity and natural soil fertility in map form. He also compiled agricultural soil capability maps. Other maps and studies include a map showing land use in Tanzania (Berry & Berry 1969), a map depicting agro-economic zones (Conyers 1973) and an estimate of irrigation potential (Kates, et al., 1969).

The earliest national wide exercise of application of aerial photography techniques to soil mapping was done during a soil survey of the whole country, split into four regions, in 1967-68 by the American Peace Corps (Johnson & Tiarks 1969; Sheely & Green 1969; Wegel et al., 1969 and Stuartz & Duckworth 1969). These studies were not published but were later compiled into soil maps at scales between 1:2,000,000 and 1:250,000,000.

Between independence in 1961 and 1972 natural resources inventory activities were carried out by different institutions both local and international and by different ministries. In 1972 a soil and fertilizer use research programme was founded with a responsibility of undertaking and coordinating soil research activities in the country. However, due to a shortage of funds and a lack of its own programmes and clarity in its mandate, the programme is unable to undertake and coordinate land resources inventory in the country.

3 Present status of natural resource inventory

3.1 Organization and responsibilities

Soil and land resources surveys are carried out mainly by the National Soil Service (Soil and Fertilizer Use Research Programme) based at Agricultural Research Institute Mlingano. It has three sections - a Soil and Land Resources Survey section, a Soil Fertility section and a Soil, Plant and Water analysis section. The National Soil Service is within the Ministry of Agriculture, division of Research and Training, under the National Soil Research Coordinator. The National Soil Service is responsible for carrying out soil and land resources inventories, correlation, coordination of all soil research activities and set up of guidelines and standards for soil surveys, land evaluation and other soil research disciplines including soil analysis, soil fertility, fertilizer use and management. Other institutions within the Ministry of Agriculture which undertake soil surveys studies include Uyole Agricultural Centre in the Southern Highland regions and Agricultural Institute Seliani in Arusha for wheat growing areas. Virtually all soil surveys work is client oriented. There is no government-funded progressive inventorying of the country's land resources.

The Institute of Resource Assessment (IRA) is part of the University of Dar es Salaam. Its domain includes basic and applied research in five main areas: natural resources and environment, agricultural systems, water resources, population and human settlements, and remote sensing.

The Meteorological department under the Ministry of Communication and Works is responsible for all climatic and weather recording stations, weather forecasting and data compilation.

Besides these local organizations, there are many international organizations which have carried out natural resources inventories either for the Government or for Donor-aided projects.

3.2 Objectives, methods of soil and land resource surveys in Tanzania

The main objectives of the soil and land resources surveys in Tanzania are:

- identification, characterization and mapping of the country's land resources at a scale usable for land use at National level;

- provision of soil survey and land evaluation services to farms, districts and regional land use planning bodies;

- development of methods and procedures for soil mapping and the assessment of the suitability of land for relevant production systems.

The primary purpose of the national programme of soil survey and land evaluation in Tanzania was and is to provide adequately the information required about soil and land resources of the whole country by carrying out a systematic national inventory of land resources . This has not been achieved due to budgetary, and manpower constraints. This has led to compilation of a national land resources map and data base not being progressive and continuous. As a result almost all of the soil survey work is client-oriented and all costs of the studies are met by the clients. Clients are varied and include government agencies and parastatal organisations, donor-funded development programmes and private farmers.

The approach to soil survey approximates to the USDA Soil Survey Manual (31) and land evaluation is based on the methodologies developed by FAO. Soils are described according to the FAO (9) guidelines for soil profile description. The official soil classification system adopted is the FAO-Unesco legend of the World (5;11) although it is commonly correlated to the USDA Soil Taxonomy (32).

Land evaluation follows the FAO (10) framework and the later, more detailed guidelines on land evaluation for rainfed and irrigated agriculture (12; 13).

The legend construction is physiographic whereby mapping units generally are natural bodies of soils separated by natural identifiable boundaries. The main and first entry in the legend is physiography (landform), at exploratory and reconnaissance level. The second entry is the parent material (geology) from which the soil has been formed and at the third level the soils are being separated. For more detailed surveys slightly different approaches may be followed, depending on the survey areas and purposes of the surveys.

Every soil map has a legend printed on the map. The map legend consists of two parts: the descriptive and the identification parts. The descriptive legend provides the information on each mapping unit and explains the most important characteristics and limiting factors to agriculture of the soils including their classification and the relation of each soil units to their positions in the landscape. The identification part provides a link between the descriptive legend and the map and consists of codes constructed as a fraction with the numerator consisting of a symbol for the landform and another for the parent materials while the denominator representing the soil type e.g.:

$\frac{AB}{c}$ where A = landform
B = parent material
C = soil type

Particular features which are affecting land suitability may be indicated with patterns, screens or special marks on the map units e.g. escarpments.

Table 1 summaries the characteristics of the various soil surveys undertaken in Tanzania. The table shows the type of surveys, the purposes for which those surveys are carried out, the established mapping scales and the general methods.

4 Soil and land resources surveys

4.1 Current state

Identification, characterisation and mapping of the soils of Tanzania at national level has been done by various authors at different scales. The most recent are those of Samki (29) and De Pause (6) at 1:2 million scale. Together with these soil maps are agro-ecological zones maps produced by the same authors at the same scale. These reports and maps were compiled from existing information at larger scale. From these documents fertilizer recommendations have been improved from the blanket type to broad AEZ-specific. For proper and adequate agricultural land use planning at a national level

Table 1. Characteristics of soil surveys in Tanzania

Type of survey	Purpose	Map scale	Kinds of mapping units	General methods
Exploratory (national soil resources Inventory)	Establishing major soil regions for agricultural planning and research at national level, international soil correlation and data exchange	1:2,000,000 1:1,000,000	Physiographic units enclosing) associations	Deductions from natural resources maps, specifically geologic maps; (re-) interpretation of existing soil maps and field data; study of satellite imagery using small-scale topographic maps as auxiliary information (1:2,000,000): Study of satellite imagery, aerial photo interpretation, soil observations at selected sites throughout the country and laboratory analysis of soil profiles (1:1,000,000)
Reconnaissance (land resources inventory of regions and districts)	Systematic inventory of land resources with multi-purpose land evaluation for regional planning and project location (pre-feasibility)	1:250,000 1:100,000 (Some surveys have been done at 1:500,000)	Associations and complexes consociation	Aerial photo interpretation and study of satellite imagery; extensive field observations; laboratory analysis of selected profiles; development of land evaluation keys for land suitability assessment
Semi-detailed	General purpose (e.g. high potential areas) and special purpose (e.g. project feasibility studies, development of a particular land use)	1:50,000 1:20,000	Consociation and associations, some complexes	Aerial photo interpretation; intensive field observations; limited field testing (irrigation surveys); laboratory analysis of selected profiles and composite samples; development of land evaluation keys for land suitability assessment
Detailed	Special purpose (e.g. farm, estate and project development and planning, characterization of trial sites, irrigation lay-out and planning)	1:1,000 1:5,000	Consociation and some complexes	Very intensive field observations; relatively little emphasis on aerial photo interpretation; field testing (irrigation surveys); laboratory analysis of soil profiles and composite samples; development of land evaluation keys for land suitability assessment
Site evaluation	Special purpose (e.g. soil fertility appraisal, salinity assessment, project identification)	Variable	Physiographic units enclosing major soils or soil associations	Aerial photo interpretation; extensive field observations (rapid soil inventory); rapid laboratory testing; rapid reporting

a soil map at a scale of 1:1 million is desired. This map should be compiled from existing maps covering various parts of the country at different scales supplemented by additional mapping where gaps exist.

Soil and land resources surveys for several regions and districts have been done at scales between 1: 100,000 and 1:500,000. Almost half of the country has been covered in this way (Figure 4). To date the following areas have been covered:

Region	Coverage
Arusha	Mbulu district and parts of Hanang district (wheat growing areas)
Coast	Rufiji basin
Dar es Salaam	None
Mwanza	Geita and Sengerema districts
Kagera	None
Ruvuma	None
Mbeya	Whole region
Iringa	Whole region
Rukwa	Whole region
Singida	None
Tabora	Whole region
Dodoma	Whole region (including Capital City District)
Mtwara	Whole region
Lindi	Whole region
Tanga	Whole region
Kilimanjaro	Whole region
Kigoma	None
Morogoro	Morogoro district (in progress) and Rufiji basin
Mara	None
Shinyanga	Maswa district

Most of this work was done as part of the Regional Integrated Development Programme (RIDEPs) for the different regions in the country and by different organizations both local (including the National Soil Service) and international.

A number of detailed and semi-detailed soil surveys have been undertaken. They include farms, estates, irrigation schemes and villages scattered throughout the country and their total extent is estimated at 10,000 km^2. Although their coverage is minimal compared to the size of the country, their impact however, is big because they are used either directly for solving production constraints or for project design and implementation.

4.2 Other activities

Agriculture in Tanzania is largely rainfed. Due to erratic nature of rainfall in most parts of the country moisture availability during the growing season is a big bottleneck. A method of growing season analysis based on the FAO (11) methodology for agro-ecological zones has been developed and tried in reconnaissance surveys of Geita and Sengerema districts (5) and Dodoma Capital City District (7).

A soil information system (SISTAN) has been set up with facilities for rapid data base query and information output (23). The system is also used to generate parts of soil survey reports. The system

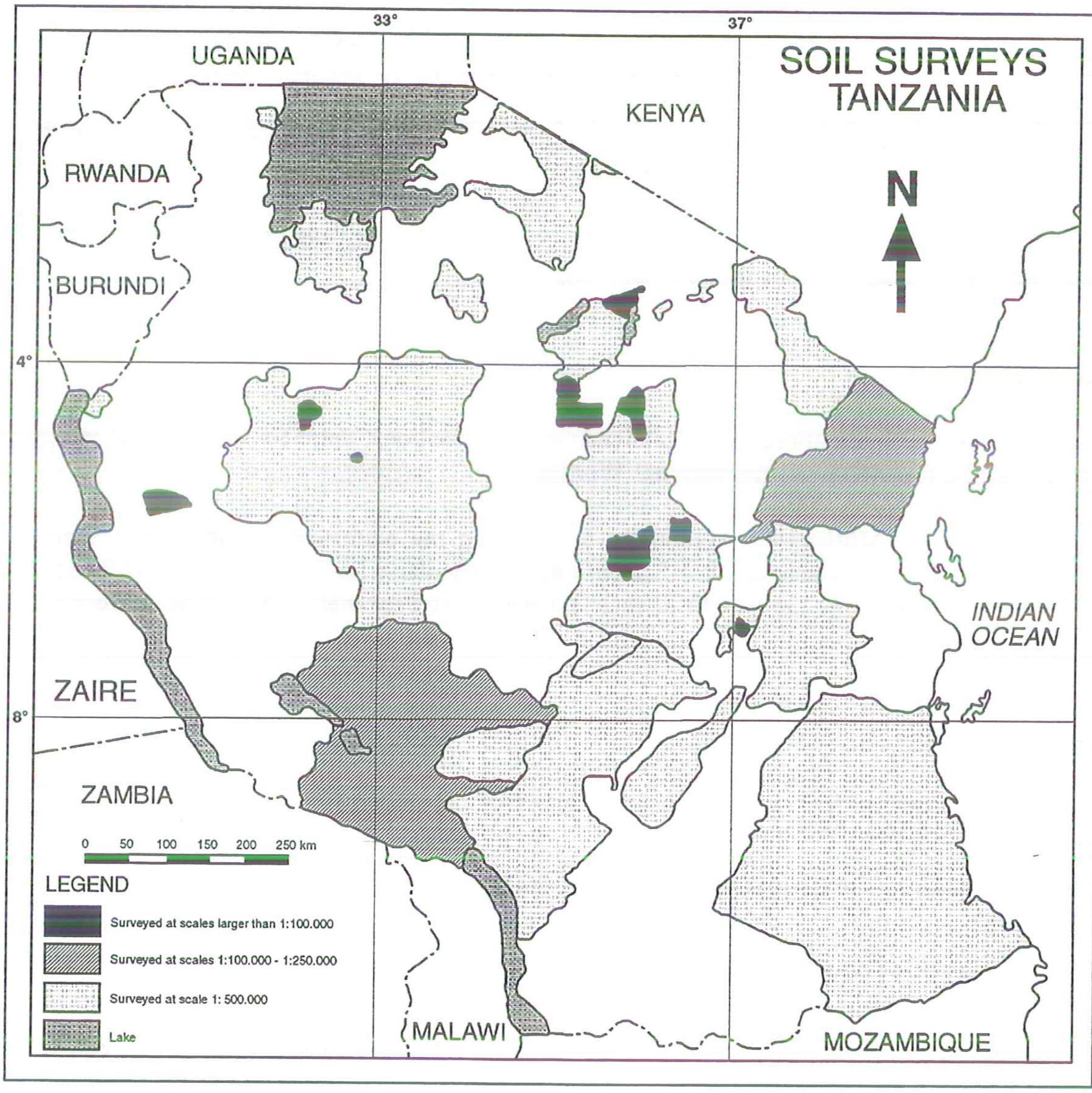

Figure 4 Areas covered by soil surveys in Tanzania.

now holds soil pedon data and analytical data for all soil profiles described in district and regional soil surveys. The georeferencing system has been changed from the local grid system to GPS based degree coordinate system.

A start has been made in computerization and automation of land evaluation. The ALES package (28) has been used in the land evaluation of sample areas in Kilosa district (17; 18). The ALES package has also been used extensively in the land evaluation assessment of Mbulu district (24) during which interface models for transfer of ALES output into reporting format were written.

A soil laboratory manual for Tanzania has been prepared while writing drafts of soil survey guidelines and priority areas for soil surveys in Tanzania have been completed. Work in compilation of soil fertility and land evaluation guidelines is in progress.

There are two organization in Tanzania which make use of GIS. They are the National Environment Management Council (NEMC) and the Institute of Resource Assessment (IRA). GIS is used for inventory of coastal forests, environment regional profiling, mapping, of vegetation types, monitoring of bushfires, analysis and trends and changes in land use types in selected areas in Tanzania. Software used include IDRISI, CHIPS and ARC/Info.

Many organizations in Tanzania, including the National Soil Service, would like to set up GIS. They are constrained by lack of funds and trained manpower.

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A1.11 Zambia

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Introduction

The Soil Survey Unit (SSU) of the Research Branch, Department of Agriculture, is responsible for providing an inventory and assessment of soil resources. The data and information is primarily intended for use in agricultural planning, management and research.

Soil survey activities in Zambia started in the early 1950's with the main aim of providing soil information to European settlers. The SSU in its present form was established during the early 1980's with the support of the Norwegian Agency for International Development (NORAD). During NORAD's support, significant capacity building, in terms of infrastructure and human resources was achieved. A number of systematic and ad-hoc soil surveys were undertaken during the period of NORAD support which ended in 1991.

Past achievements

Soil survey
- All 9 provinces have been mapped at scale 1:1 M and 6 of the provincial maps and reports have been published.
- The national soil map at scale 1:1 M has been compiled and is being printed in Norway.
- 6 out of 52 districts have been mapped at scale 1:250,000.
- A total of 290 ad-hoc soil surveys at detailed, semi detailed and reconnaissance scales have been carried out.

Soil correlation
- The first, second and third edition of the soil series classification system have been published. The latest in 1987.
- A technical guide to stages in soil correlation and establishment of soil series was published in 1973.
- The geomorphic legend of Zambia was published in 1985. It accompanies a map at scale 1:8 M.
- The methods of soil analysis were published in 1985.
- 25 benchmark site have been established.
- A profile description manual was published.

Land evaluation
- National suitability maps for maize, cotton and soybean at scale 1:4 M.
- An agro-ecological zones map at scale 1:2.5 M has been published.
- A reconnaissance and semi-detailed semi-quantified land evaluation system for rainfed agriculture has been published.

Soil Information System and Geographic Information System (GIS)

- A soil database system called ZAMSIS was established but is not working at the moment due to bugs in the programme.

- Two computer versions of the land evaluation system were established but neither is operational because of bugs or incomplete programming of some sub-modules.
- GIS was established.

Computer/GIS facilities
- 486 (25 MHz, 8 MB RAM, 200 MB HD)
- 386 (33 MHz, 4 MB RAM, 200 MB HD)
- 386SX (16 MHz, 4 MB RAM, 60 MB HD)
- 286 (10 MHz, 4 MB RAM, 70 MB HD)
- 4 UPSs
- Calcomp Artisan A0 pen plotter
- Brother HL 8D laser printer
- Calcomp A3 plotter
- 2 dot matrix printers
- Legal copies of:
  - PC ARC/Info v. 3.4D (2 hardware keys)
  - Wordperfect v. 5.1
  - dBase IV v. 1.1
  - Harvard Graphics v. 2.3
  - Quarter Professional v. 2.0
  - Turbo C^{++}
  - SPSS/PC^{++}
  - Norton utilities

Current bottlenecks
- Lack of an A0 digitizer
- Lack of maintenance of computer hardware
- Lack of computer consumables
- Lack of programming expertise to revive the soil database and land evaluation systems.

A1.12 Zimbabwe

M. Wuta

1 Introduction

Zimbabwe covers an area of 390,000 km^2 and has a soil map at 1:1,000,000 on the basis of information gathered at reconnaissance level. The classification system used was evolved by Thomson in the early 1960's and is largely based on principles of the Inter-Africa Pedological Services used in the Soil Map of Africa. The classification is based on soil properties that reflect the degree of weathering and leaching that soils derived from different parent materials have undergone. Geology and rainfall are therefore given prominence and their consideration has enabled classification of Zimbabwean soils into four taxonomic levels namely order, group, family and series.

Only few discrete parts of the country have been mapped at family and series level. Due to political conditions that prevailed prior to 1980, soil research and soil surveys were concentrated in commercial areas and correlations with other soil classification systems such as the FAO and the USDA systems were virtually non-existent. The soil survey section of the Chemistry and Soil Research Institute besides carrying out surveys, is charged to amend these inadequacies.

2 The present status of soil survey

2.1 Pedology and Soil Survey Section

2.1.1 Organisation and Responsibilities

The Pedology and Soil Survey section is one of the four sections within the Chemistry and Soil Research Institute of The Department of Research and Specialist Services. The section has four subsections.

There are:

- Pedology - This subsection is responsible for carrying out field work to map soils of the country.

- Soil Chemistry - This subsection is responsible for the chemical and physical analysis of the soil samples brought in by pedologists as well as other institutions interested in soil resources.

- Soil Physics - This subsection provides information on soil physical properties such as available water capacity and bulk density.

- Soil mineralogy - This is a subsection that provides a backup service in clay mineralogy information essential for soil classification.

The following are the kinds of surveys carried out by the pedology and soil survey section

2.1.2 Land use surveys

These soil surveys are carried out for specific objectives such as assessment of soils suitability for irrigation. Ad hoc surveys are carried out at detailed to semi-detailed scales of between 1:5,000 to 1: 50,000. At the beginning of each field season (April to October-November), a soil survey liaison meeting is convened. It is at such meetings that government departments, parastatal and private organisations submit survey requests to the section. Surveys have been carried out to assess the irrigation suitability of soils commanded by dams already in existence. More recently the trend has been to assess the irrigation potential of soils prior to dam construction. The section has also been involved in soil surveys for general purposes such as better agricultural practices. Soil surveys done by the section for the Department of National Parks and Wildlife Management for purposes of determining soil vegetation relationships have been a major input to ecological land use studies.

2.1.3 Systematic Surveys

Because of the small scale of the soil map of Zimbabwe, a decision was made in 1976 to start a programme of systematic regional mapping of the country. This was designed to cover the country with soil maps at scales of between 1:50,000 to 1:250,000 which will be of more use to various users. Little progress has been made in this area because of commitments from ad hoc surveys listed above. However, work to meet similar objectives has been complemented by the World Bank Communal Areas natural resources appraisal that commenced in 1985.

2.1.4 Physical Resources Inventory of communal lands of Zimbabwe

With the advent of independence, there has been a rapid expansion of agricultural development particularly in the communal lands. More than 75% of the population of the country live in these areas where soils are derived from granite. They are sandy, vulnerable to erosion and generally not as fertile as soils derived from rocks rich in mafic minerals. The need to resettle some of the inhabitants to ease population pressure has created a demand of soil survey in many parts of the country.

The Communal Lands Physical Resource Inventories initiated as a component of the International Bank for Reconstruction and Development (IBRD)/International Fund for Agricultural Development (IFAD) funded National Agricultural Extension and Research Project were carried out during the period 1985 - 1991. They were intended to provide basic land resource data at a mapping scale of 1:250,000, to support farming systems research, resettlement and land use planning in the 42% of Zimbabwe which is under communal land tenure.

The various surveys were under taken by the Pedology and Soil Survey Section and the Ecology Unit, National Herbarium and Botanic Gardens, both under the Department of Research and Specialist Services and staff from the British Overseas Development Administrations' Natural Resources Institute. The Ecology Unit has undertaken a complementary survey of natural vegetation in Communal Lands.

2.2 Private sector

The private sector has played an important role in natural resources inventories in Zimbabwe especially after independence. The surveys mainly carried out by private companies and the University of Zimbabwe's Department of Soil Science and Agricultural Engineering staff are land use surveys especially for irrigation assessment and natural resource inventories of large areas for land use planning.

3 Present coverage

Soil surveys have been carried out in Zimbabwe since the 1940's but the total area surveyed so far is small. Less than 15% of the land area has been covered excluding the area covered by the communal resource inventory. This is due to the following reasons:

- Most of the early work has been advisory in nature.

- Much of the later work consisted of high intensity surveys done in response to land suitability assessment.

The need to meet immediate demands has resulted in lack of a coherent and systematic national soil mapping programme. Table 1 shows surveys carried out over the past fifteen years. It is clear that most of the surveys were for irrigation. Variability of the total area covered per season is due to scale requirements as well as constraints of manpower and equipment. The 1:1,000,000 soil map is essentially a stepping stone to which surveys of larger scales are to evolve. The communal land survey mentioned earlier is an example. It is envisaged that systematic surveys will be stepped up and the entire country will be ultimately mapped at 1:50,000.

Table 1. Progress of Soil Survey in Zimbabwe

Year	Total Area (Ha)	Purpose
1980	5 300	Irrigation
1981	67 970	Irrigation
1982	109 000	Irrigation and Ecological Studies
1983	184 040	Irrigation and Systematic Surveys
1984	142 603	Irrigation and Systematic Surveys
1985	6 000	Irrigation
1986	6 000	Irrigation
1987	18 000	Irrigation and Forestry Research
1988	19 074	Irrigation
1989	24 484	Irrigation and Identification of Research Plots
1990	5 990	Irrigation and Advisory Work
1991	17 460	Irrigation and Forestry Research
1992	207 350	Ecological studies and Irrigation
1993	7 100	Ecological Studies and Irrigation
1994	102 104	Ecological Studies and Irrigation

Total for 15 years = 922 475 ha.

4 Present state of GIS facilities

4.1 National Remote Sensing Facility (NRSF)

The National Remote Sensing Facility (NRSF) which is based in Harare was established jointly by the Federal Republic of Germany through the GTZ and the Zimbabwe Governments. The NRSF operated under the aegis of the Department of Geological Survey in the Ministry of Mines until it was transferred to the parastatal, Scientific, Industrial, Research and Development Centre (SIRDC) in 1992.

Mandate of NRSF

To offer technical services to users of remotely sensed data; this includes:
- the acquisition, distribution and storage of data as per user requirements.
- provision of a comprehensive library of imagery covering the whole country. The Archive is updated periodically.
- analyzing and recommending suitable equipment (hardware and software) to help users accomplish their projects.
- to execute projects jointly with the users and train users in Remote Sensing/GIS.

5 Conclusion

A lot of soils data has been collected since the early 1940s. Most of this data which is kept in the Pedology and Soil Survey Section in the form of reports and maps is difficult to access. A system like the SOTER programme which can store detailed information on natural resources in such a way that these data can be readily accessed, combined and analyzed from the point of view of potential use, in relation to food requirements, environmental impact and conservation would be the best solution to this problem.

The NRSF will definitely be an asset in the establishment of a SOTER programme at the Chemistry and Soil Research Institute or the University of Zimbabwe's Department of Soil Science & Agricultural Engineering because of the expertise which exists at these institutions.

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APPENDIX 2. PROGRAMME

Tuesday 14 March

9:00-10:30 Welcome by the Director NARL
Speech by the Director KARI
Speech by the representative of UNEP
Speech by the Director ISRIC
Opening speech by the Director of Research of the Ministry of Research, Technical Training and Technology

10:30-11:00 Coffee/tea

11:00-12:30 SOTER methodology - an overview (van Engelen)
KENSOTER activities (Gicheru)
Demonstration of KENSOTER results (Maingi)

12:30-14:00 Lunch

14:00-15:30 Demonstration of KENSOTER results (Maingi)

15:30-16:00 Coffee/tea

16:00-17:00 Country reports
(Current state of natural resources inventories in each country, status of GIS facilities)
- Botswana
- Ethiopia

Wednesday 15 March

9:00-10:30 Country reports (continued)
- Lesotho
- Madagascar
- Malawi

10:30-11:00 Coffee/tea

11:00-12:30 Country reports (continued)
- Mozambique
- South Africa
- Sudan

12:30-14:00 Lunch

14:00-15:30 Case studies Kenya
- Automated Land Evaluation

15:30-16:00 Coffee/tea

16:00-17:00 Case studies Kenya (continued)
- SOTER water erosion assessment

Thursday 16 March

9:00-10:30 Country reports (continued)
- Swaziland
- Tanzania
- Zambia
- Zimbabwe

10:30-11:00 Coffee/tea

11:00-12:30 Possibilities for SOTER activities in participating countries

12:30-14:00 Lunch

14:00-15:30 Possibilities for SOTER activities in participating countries (continued)

15:30-16:00 Coffee/tea

16:00-17:00 Project formulation and potential funding

Friday 17 March

9:00-10:30 Drafting of Workshop Recommendations

10:30-11:00 Coffee/tea

11:00-12:30 Final discussions

12:30-14:00 Lunch

14:00-17:00 Demonstrations (optional)

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