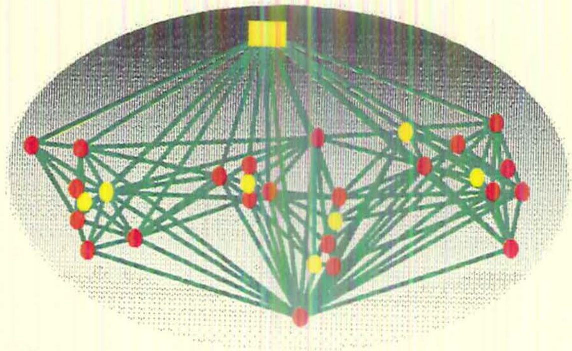

Workshop on

NATIONAL SOIL REFERENCE COLLECTIONS AND DATABASES (NASREC)

Wageningen, The Netherlands
November 6-17, 1995

Proceedings:
Volume 3 — Papers and Country Reports

Edited by
N.H. Batjes, J.H. Kauffman and O.C. Spaargaren

ISRIC

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

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Inquiries:
ISRIC
P.O. Box 353
6700 AJ Wageningen
The Netherlands
Tel.: +(31)-317-471711
Fax: +(31)-317-471700
E-mail: SOIL@ISRIC.NL

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FOREWORD

The workshop held at ISRIC from 6 to 17 November 1995 was a milestone in the National Soil Reference Collections and Database (NASREC) programme, which started on an ad-hoc basis in Colombia in 1980. The NASREC programme included a series of courses with participants from about 40 countries attending. During its first phase, training and major supporting activities took place in 3 countries, while 3 other countries were provided with minor support. In the second phase, from 1990 to 1994, the NASREC activities were expanded with the establishment of 11 soil reference collections in Africa, Asia and Latin America. NASREC activities were carried out in the framework of a technical assistance programme with major financial support from the Netherlands Directorate General for International Cooperation (DGIS) and complementary support from UNESCO, the European Community — Life Sciences and Technologies for Development Programme (STD2) and the Royal Dutch Academy of Sciences (KNAW).

The workshop is considered a milestone because it is the first occasion in which 36 soil scientists, from 30 countries, could share their experiences on soil reference collection projects completed in the last 15 years. It provided a unique opportunity to identify, discuss and propose follow-up actions at the national, regional and global level. The consensus of the workshop was that the scope of the NASREC programme should be broadened, in a possible third phase.

Firstly, it was recommended that a global communication network of national institutions should be established, aiming at an information and reference service facility on natural resources. Secondly, regional training facilities should be established at recognized national centres, aiming at an improved transfer of information about soil and terrain resources and on their sustainable use, to a wider range of users. Thirdly, it was recommended that the original scope of NASREC activities should be broadened to include geographic information systems for rural and environmental planning, soil laboratory information management systems, and library information services. We hope that, with the workshop, a sufficient basis has been created to implement these proposed activities.

Dr L.R. Oldeman
Director, ISRIC

J.H. Kauffman
NASREC Programme Coordinator

PREFACE

These proceedings are a compilation of extended abstracts and papers on special topics prepared for the international workshop on National Soil Reference Collections and Databases (NASREC), held at ISRIC, Wageningen (November 6-17, 1995). The main objective of the NASREC project is to strengthen the capability of national soil and land resources institutions to disseminate information about the major soils of their country, with special reference to their potentials and constraints for different types of land use, to a wide range of users. In order to achieve this objective four main categories of activities were implemented: basic training courses; building of soil monolith expositions with supporting documentation; development and handling of soil profile databases; and after-training support services. The current workshop is the result of a recommendation made by an international review panel at the end of the second phase of the NASREC programme.

The main objectives of the NASREC workshop were to bring together existing and potential NASREC collaborators and other resource persons to:

- review past achievements, discuss results, exchange information and share experiences,
- formulate a collaborative strategy and network structure,
- draft project proposals for NASREC, phase 3, and
- formulate workplans for collaborative activities.

The proceedings of the NASREC workshop consist of three volumes. The first volume comprises the recommendations and a summary of the workshop. The second volume, initially prepared as a background document to the NASREC workshop, contains papers on applications of soil databases developed at ISRIC (ISIS, WISE and SOTER). Papers in the current volume relate to oral presentations made by invited resource persons for which written contributions were received. It further contains written contributions on NASREC activities throughout the world, listed by country. The country papers relate to NASREC activities in different stages of implementation, ranging from the initial setting-up of a national soil reference collection to the later stages in which user-oriented database applications and publications are prepared. This aspect is reflected in the difference in level of detail of the various contributions. The proceedings also include a number of papers by representatives of organizations who were not part of the current NASREC network, yet implemented similar activities in their countries.

During the editorial process, changes have been made to most papers to conform with the editorial policy. This was done without interfering with the views of the authors or the professional aspects of the documents. In some cases, however, texts have been modified or condensed to enhance their legibility.

This volume has five parts, the first of which is a compilation of introductory addresses prepared by the resource persons. Part 2 includes papers in which user groups are highlighted. Part 3 is a compilation of papers focusing on assessment of physical land qualities while in part 4 the focus is on chemical land qualities. The final part is a compilation of extended abstracts which essentially review the status, achievements and future prospects of NASREC related activities in the various participating countries; most of these reports stress the need for better communication between users of soil and terrain data, and the professional soil scientists who collect and analyze the primary data. Country reports are presented in alphabetical order of the country of origin.

Sponsorship for the workshop by the Netherlands Directorate General for International Cooperation (DGIS), the International Service for National Agricultural Research (ISNAR), the Centre Technique de Coopération Agricole et Rurale (CTA), The European Community (EC), and the Food and Agriculture Organization of the United Nations (FAO) is gratefully acknowledged. We thank Hans Soekhram for the initial word-processing of documents not submitted on disk and all ISRIC personnel involved in the workshop for their contributions.

Information presented during the workshop, combined with great enthusiasm and friendship shown by the participants and invited resource persons, created an unique opportunity for discussion, exchange of information and future collaboration in the NASREC network. The current enthusiasm of the participants to increase awareness of the issues of user-need identification by soil survey institutes should now be translated into practical recommendations (see volume 1 of these proceedings).

It is hoped that the present volume will be of interest to extension workers, natural scientists, and policy makers who are concerned with the issues of collecting uniform environmental data for sustainable land use, technology transfer and a wide range of user groups.

N.H. Batjes, J.H. Kauffman and O.C. Spaargaren (Editors)
Wageningen, March 1996

PART I

INTRODUCTORY PAPERS

OPENING ADDRESS

L.R. Oldeman
International Soil Reference and Information Centre (ISRIC)
P.O. Box 353, 6700 AJ Wageningen, The Netherlands

Ladies and Gentlemen,

It is with great pleasure that I welcome you at the International Soil Reference and Information Centre (ISRIC) in Wageningen for the opening of the International Workshop on National Soil Reference Collections and Databases, the NASREC workshop for short. In particular I would like to welcome representatives of the Directorate General for International Cooperation (DGIS) of the Dutch Government, which has through many years supported the NASREC programme and stimulated ISRIC to organize this workshop. Although not all sponsors could participate in this opening session, I would also like to express our gratitude to the Centre for Technical Cooperation (CTA), to the Food and Agriculture Organisation of the United Nations (FAO), to the Science and Technology for Development Programme of the European Union, and to the International Services for National Agricultural Research (ISNAR). Notably for their generous support which made it possible for ISRIC to invite over 30 representatives from nations from the three continents Africa, Asia and Latin America to participate in this workshop.

ISRIC is a research-based service centre with as one of its major tasks the collection and dissemination of scientific knowledge of the soils of the world, in particular through the establishment of an international collection of soil monoliths, soil maps and reports and a soil database at its central location in Wageningen. It further provides support for the establishment of national and regional soil reference collections in developing countries.

Exactly 15 years ago Mr. Asiamah from Ghana and Dr Ikawa from Hawaii followed a course on soil monolith preparation at the then International Soil Museum. This course signalled the start of the NASREC programme. I am very pleased to welcome this so-called first generation of NASREC workshop participants, who attended these international training courses, held annually during the 1980s: A course in the establishment and use of national soil reference collections. Support for these training courses was provided by UNESCO.

It was soon realized that an international training course at ISRIC was not a sufficient guarantee that national soil reference collections would be established after participants returned to their home country. A follow-up activity was indeed needed to provide support to national soil resources institutions with materials, equipment and technical assistance to build their own basic collection of soil monoliths. In 1986, a three-year NASREC programme was formulated and financially supported by DGIS in the framework of UNEP's action plan for strengthening of National Soil Policies with the objective to 'strengthen ISRIC's capabilities to support countries initiating national soil reference collections'.

Mr. Guillermo del Posso from Ecuador who attended the 1986 training course in Wageningen is a representative of this so-called second generation of participants, whose institute received major support to set up a national NASREC. I am very pleased to welcome participants belonging to this second generation. During this three year programme major support was provided to Ecuador, Indonesia and Mali, while Ghana, Sri Lanka and Brazil received minor support.

During this 3 year period major developments took place at ISRIC in the field of information technology. ISRIC developed its own Soil Information System (ISIS), aimed at entering and handling all collected data on soils, terrain, climate, vegetation, land use in a computerized soil database.

ISIS, or its derived and somewhat more simplified SDB version prepared by FAO and ISRIC, is now operational in many developing countries. Simultaneously, activities took place at ISRIC at the initiative of the International Society of Soil Science (ISSS) for the development of a georeferenced soil and terrain database, the so-called SOTER programme, in which soil and terrain attributes are stored in a computerized database and linked to physiographic mapping units through a GIS.

During this same three year period ISRIC received numerous requests from countries in the three continents to provide assistance for development of NASRECs. We were very pleased that the Dutch government and UNEP decided to sponsor a second phase for an additional three years. The emphasis in this second phase (1989-1992) was more geared to interface with potential users of the NASRECs. So not only the establishment of a Reference Soil Monolith Collection, but also the development of a Soil Profile Database and application programmes for land evaluation. It was also realized that although provisional fact sheets on reference soils are of interest to professionals in soil science, they are not useful for potential clients who are not professional soil scientists. In this respect, I would like to quote some key sentences from an article by Neil McKenzie from Australia (see NASREC Newsletter No. 3).

'There is a staggering and wide-spread ignorance amongst professional groups such as bureaucrats, land use planners, agronomists, horticulturists, foresters on how soil and land information can be used to resolve our most pressing problems, e.g. low crop yields, land degradation, ...'

'Too often soil data are presented in a form that is incomprehensible even to other trained workers'.

'At each reference site a set of land qualities would need to be determined using detailed laboratory and field measurements. A possible minimum set of land qualities would include water availability, drainage aeration, nutrient quantities and intensities, toxicities, physical root limitations.'

This has prompted ISRIC to enlarge its NASREC programme and prepare so-called 'Soil Briefs', in close cooperation with participating countries. During the second phase, activities were initiated in Nigeria, Zimbabwe, Costa Rica, Nicaragua, Cuba, Peru, India, China. I am pleased to welcome this third generation of NASREC workshop participants.

When the second phase was nearing its conclusion, discussions were held with our major sponsor DGIS about results obtained so far and about the question: 'What next?' DGIS considered it appropriate at this time to take stock of the achievements through an external international evaluation panel and through intensive discussions with NASREC participants themselves.

The International Panel evaluation took place in September 1993. The panel concluded that the objectives of NASREC have been achieved to a great extent. Training courses were successfully held not only here at ISRIC, but also in the participating countries since 1990. Education and extension objectives have been achieved through the dissemination of the information to the users. The establishment of databases has gone beyond the terms of reference, in particular the development of user-friendly applications.

The panel also listed a number of recommendations for NASREC activities in a next phase. These recommendations will be discussed at great length during the workshop.

(1) The increased attention to information transfer and dialogue with different groups of users of soil information at the national level, such as the non-specialists professionals, farmers and the public-at-large. So far NASREC has mainly focused on the dissemination of information to the specialist professionals.

(2) Creation of regional training possibilities at a number of national collaborating institutes with comparative advantage in terms of organizational and technical strength and geographic placement. This will promote the so-called South-South relationships. The establishment of these so-called nodal institutions will strengthen regional training possibilities; creation of a critical mass of trained national scientists, and will enhance the spreading of knowledge and information to other interested countries.

(3) In line with Agenda 21 of UNCED, NASREC's focus should be on issues of environmental quality and sustainable use of the soil. We are all acutely aware about the deteriorating conditions of our soils due to increasingly intensive use of the soils, often mismanaged to obtain a short-term benefit. As soil scientists we realize that the soil is a fragile natural resource, non-renewable in the short term or very difficult to renew and expensive to reclaim or improve following erosion, physical degradation or chemical depletion. It is our duty to maintain the soil functions for the future, while obtaining the best benefit from its use today.

    Natural resources institutions should see it as their duty to provide well documented, easily accessible, standardized, and useful information about the land to a wide range of users and provide them options for sustainable land use. We do not only want to assess the present status of our soils, but also the future of our soils. During this workshop you will be exposed to several technologies developed at ISRIC, which might provide you with essential tools to achieve these goals. An integrated package of technology with elements of GLASOD, SOTER, SOILIMS could be considered in a NASREC follow-up programme.

(4) In a final recommendation the Panel advocated the organization of an international workshop bringing together existing and potential collaborators and other resource persons with the following objectives:

- To review past performance of NASREC;
- To map out a collaborative strategy and network structure;
- To develop elements for a project document for NASREC, phase 3.

To which ISRIC has added as a fourth objective:

- To familiarize participants with new information technologies in soil science and application programmes to enhance a better communication with users of natural resources information.

This then leads me finally to welcome the fourth generation of potential future NASREC collaborators.

As you will have seen from the programme of this two week workshop, we will focus on an intensive interactive approach. You will have little time to recuperate from your jetlag. You will be the main actors. We still hope that by the end of the workshop you may look back at an interesting experience, that you will have made new contacts or have renewed contacts with friends and fellow professionals from other countries, that you will have exchanged useful experience and were able to make useful contacts with resource persons that have shared their views with you and, last but not least, that new collaboration will be established with ISRIC.

During the last half year almost the entire ISRIC staff have in one way or another contributed to the preparation of this workshop under the enthusiastic leadership of Sjef Kauffman. During the workshop ISRIC will do its best to make your stay at ISRIC and in Wageningen as pleasant as possible. Please do not hesitate to call upon us if you need any assistance. I sincerely hope that you will be enriched with new ideas and experiences when you return home. Once again, welcome to all NASREC generations; all resource persons and all those that are here and care for our precious vulnerable soil. Thank you!

SOIL SURVEY: STATUS, CONSTRAINTS, NEEDS AND STRATEGIES

J.A. Zinck
International Institute for Aerospace Survey and Earth Sciences (ITC)
P.O. Box 6, 7500 AA Enschede, Enschede, The Netherlands

INTRODUCTION

In November 1992, an international workshop on 'Soil survey: perspectives and strategies for the 21st century' was held at ITC, Enschede, with the participation of 20 heads of national soil survey organizations. A valuable wish was emitted at that time, three years ago, to monitor changes taking place and progress achieved by applying some of the resolutions agreed upon in the workshop. Unfortunately, a follow-up meeting could not materialize so far. I am therefore very grateful to the organizers of the present event to provide the opportunity to bring the subject back into discussion.

It might be worthwhile to first look backwards and highlight some of the main features characterizing the soil survey status at the turn of the 1990s. From this situation, short- and medium-term perspectives can be identified in terms of a trend scenario, which considers constraints and needs. Finally, to correct some of the undesirable trends of the spontaneous evolution, realistic strategies shall be formulated, leading to a more optimistic scenario which allows to satisfy the needs by alleviating the constraints.

STATUS

Soil map coverage

An inventory conducted at the turn of the 1990s provides insight on the recent status of soil survey in several parts of the developing world (Zinck, 1995). Based on answers from 47 countries from Central and South America (12), Africa (20) and the Middle and Far East (15), the following general conclusions can be drawn as to the soil map coverage status (Table 1).

(1) Many countries have some kind of general map at very small scale, usually substantially smaller than 1:250,000. According to FAO statistics of 1991, only 32% of the countries were not yet provided, at that time, with a complete soil map coverage at 1:1 million scale or larger, but theses countries represent 69% of the world's surface area and 61% of the world's population (Table 2).

(2) Cartographic coverage for regional master planning at scales between 1:100,000 and 1:250,000 is largely incomplete, making it difficult to identify high-potential areas or, conversely, critical problem areas and their priority for more detailed inventories.

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(3) Soil maps appropriate for project planning at scales around 1:25,000 cover a very small percentage of the countries.
(4) Soil maps suitable for operational planning, usually at scales larger than 1:25,000, are seldom mentioned.

Table 1 Regional soil map coverage (% surface area) at different scales

Region	Small	Medium	Large
Middle and South America (12)†	50	20	18
Africa (20)	56	14	2
Asia (15)	34	34	12
Average (47)	47	23	11

† Number of countries included from ITC soil survey status questionnaire 1987 - 1990 is shown in brackets

Table 2. World soil map coverage (1:1 million scale or larger)

	Countries		Area		Population	
	Number	%	10^3xkm^2	%	10^9	%
Complete	109	68	42261	31	2.1	39
Not complete	49	32	94783	69	3.3	61
Total	158	100	137044	100	5.4	100

Source: FAO, 1991

This shortage results in a demand for medium- and large-scale maps virtually everywhere. These are precisely the scales at which the contribution of soil information to land use planning and problem solving is most directly effective.

Soil survey strength

The direct and personal opinions expressed by soil surveyors and survey managers indicate that soil survey may actually not be receding in developing countries.

(1) Fifty-four percent of the questionnaire respondents believe that national and regional budgets for soil surveys are increasing, 36 percent decreasing and 10 percent unchanged.
(2) There is active use of soil survey information by the official sector (93 percent) as well as by the private sector (74 percent).
(3) Soil survey activities and soil science teaching and research are expected to expand in the future (78 and 89 percent respectively).

Relative importance of soil survey fields

Expansion of soil survey operations leads to increasing needs for trained specialists. It requires also that soil survey education take into account priority fields as perceived by users from developing countries. Results from the questionnaire allow the following conclusions.

(1) There is a strong emphasis on multipurpose interpretation of soil survey information and its implementation in land degradation, conservation and management studies.

(2) There is a persistent importance for studying soil genesis and soil-geomorphic landscape relationships. It is felt that the understanding of soil formation is a condition for appropriate soil mapping and interpretation.

(3) Finally, technology-related fields, such as soil information and digital processing of satellite images, are not yet given high priority. Field surveyors, however, seem to be more sensitive than survey managers to the implementation of these new techniques, especially in relation to soil data handling and the establishment of soil databases.

CONSTRAINTS

Technical constraints

Requests for and dissemination of soil information are frequently hampered by a set of technical constraints, including insufficient visibility, inappropriate presentation and poor accuracy of soil information, together with high survey costs.

Insufficient visibility and inappropriate presentation of soil data

Soil information is often under-used or even neglected because maps, legends and reports are not presented in an accessible, purpose-oriented, user-friendly language and format. Maps, for example, are frequently difficult to use because of excessive cartographic detail that obscures the more general soil distribution patterns and potentials. The style of presentation and reproduction, as black-and-white copies, lacks appeal, leading the user to underestimate the quality of the contained information. Soil maps are also frequently misused for solving problems and making decisions lying outside the range of the project objectives. Legends and reports are difficult to read because a complex language is used to name soils. Non-soil-specialist users should be given only interpretive maps with uncomplicated legends for specific purposes.

Poor accuracy of soil information

Other objections refer to the precision of soil boundaries and homogeneity of map units. Boundaries of map-unit delineations as individual polygons are frequently not at the right place when compared with ground truth. This is actually an inherent difficulty of soil mapping caused by the general anisotropy of the soil cover and the occurrence of local, gradual changes affecting the soil continuum.

The soil map units are often not homogeneous enough for either general or specific purposes. The presence of large impurities or the inclusion of contrasting soils diminishes the quality of the predictions of soil potentials for practical uses. It may also occur that some soil properties needed for specific uses may be missing from the map legend or survey report because the inventory was designed and executed for general land use planning objectives, and not for narrow, local applications.

Hight survey costs

When questioning the justification for a soil survey, one of the main considerations taken into account is certainly its high production cost. Systematic soil survey is, in fact, a lengthy and costly operation. It involves university-educated specialists, field and laboratory equipment and determinations, several source documents such as remotely-sensed data, which altogether contribute to making soil information an expensive consumption product. Opportunity cost is frequently high because information is not provided at the right moment and decisions must be made without it. However, the added value of multipurpose soil interpretations from the same basic survey map has not yet been really evaluated. This added value approach would doubtless result in decreasing the cost per unit area.

Criticisms on the above constraints have been accepted as a basis for internal renovation of soil survey. An expanded body of quality control measures has been elaborated and is now generally applied during the survey operation and before the final product is delivered to the user.

New constraints on soil data

New constraints are showing up, resulting from the rapid development of information technology, such as GIS, and the increasing use of modelling procedures. Both need more and better soil data to be properly applied. The possibility and efficiency in inferring missing data through the use of pedotransfer functions can be enhanced only if an appropriate set of accurate primary data is available. The danger is that sophisticated techniques and technology will be used on poor datasets, which will diminish the quality of data interpretation and land use decision-making.

Regarding the so-called 'digital issue' of soil mapping, users in developing countries frequently resent that hardware and software developers are too commercially motivated. Equipment and programs become obsolete in a short time. Restricted budgets don't allow adjustment to the speed of technological innovation. Should there not be a sort of ethics allowing control of too insistent recommendations for too ambitious modernization of soil survey organizations?

Institutional and management constraints

The mission of a soil survey service, the modes of implementation of the soil information and the nature of the direct users depend very much on the organizational structure within which the service operates. When soil survey is embedded as a functional entity within a ministry, the scope is in general narrower than when it operates as an autonomous organization. Additionally, administrative and financial autonomy allow more flexibility for introducing innovative methods and technologies.

On the other hand, decentralization into regional offices may facilitate field operations and the transfer of information to users, but also creates problems for the application of survey standards, quality control and the introduction of computerized information systems. Obviously, methodological and technological innovations are not possible without staff development. And, of course, all these ideas are impossible without appropriate financial support.

Conjunctural constraints

Budget restrictions, as an effect of the ongoing economic recession, have led in many countries to a perceptible shrinking of natural resource inventories and related research activities, including soil survey projects. Soil survey, by national standards, is not considered as a directly productive activity. Derived benefits and cost-effectiveness are somewhat difficult to evaluate.

The expansion of free-market economics over the last decades tends to favour market control of soil occupation, to the detriment of governmental land use planning. As a consequence, less soil survey information is demanded or used.

In some western countries, systematic soil cartographic coverage at appropriate scales is completed or nearly done. Interests and funds are therefore shifting towards specific, project-oriented surveys and innovative applications.

NEEDS

Training needs

Compared with the 'laisser-faire' context prevailing at international level and also in some countries, the training needs as expressed by the heads of the national soil survey organizations are enormous (Zinck, 1995). A prioritized list of fields in which survey organizations need to achieve staff development is presented hereafter.

(1) Quantified land evaluation, including social and economic analyses, for land use planning and sustainable development.
(2) Use of remote sensing, including digital image processing together with the interpretation of conventional remote-sensing products, in soil survey, landscape analysis, land resource management, natural disaster mitigation and land use planning.
(3) Natural resource databases and GIS: database design, data processing, system management.
(4) Modern cartographic techniques for preparing soil maps.
(5) Application of geostatistics to soil survey and spatial variability analysis.
(6) Monitoring land degradation.

The research challenge

Similarly, hereafter is presented a prioritized list of fields in which survey organizations consider that research should be carried out to improve data collection and transformation, and provide information better adapted to the user needs.

(1) Soil inventory and classification
  - Application of remote sensing to soil survey and land use planning
  - Application of the FAO and USDA soil classification systems to different soils; modification of criteria for proposing new soil groups
(2) Monitoring soil changes
  - Influence of global climate change on soil organic matter content

  - Soil-plant nutrient cycling in the pedosphere
  - Environmental impact assessment of land use changes
(3) Land evaluation and farming system analysis
  - Field techniques for quantifying soil site attributes
  - Quantification of specific crop requirements
  - Study of the relationships between different farming systems and land degradation
(4) Sustainable land management
  - Indicators of sustainable land use systems
  - Calibration and validation of production models at the farm level
  - Application of GIS for sustainable land management at the farm level
(5) Land degradation
  - Establishing criteria for measuring and monitoring soil erosion
  - Indices for assessing land degradation
  - Development of land degradation models

STRATEGIES

Scientific and technical choices

If soil survey has reached a crossroads, it means that decisions have to be made to move in the correct direction. Future development of soil survey is not possible without changes concerning soil concepts, approaches to data capture and monitoring, and soil survey applications.

Diversification of soil concepts

A conceptual shift and diversification are necessary, from considering the soil as a natural body, to plant growth medium, to structural material, to water-transmitting mantle, to ecosystem component. In developing countries, this shift will be a long-term process, slowed by the lack of interaction with potential information users, quantitative and qualitative data deficiencies, and the scarcity of trained people.

Promotion of integrated approaches

More integration of soil survey with the inventory of other natural resources is desirable. This needs stronger linkages with other institutions, the recruitment of a larger variety of specialists, and the retraining of existing staff, resulting in an additional financial burden on the survey organizations. Integration may be made difficult by unexpected factors, such as mono-disciplinary promotion rules applied in some countries.

Creation of databases and validation of models

The need to organize soil data in databases and to use models at different levels and for various land uses is acknowledged. For many countries, however, the introduction of new techniques and technologies seems impossible in the short term. Pleas are also made for the conceptualization of simpler models, preferably rule-based, locally adapted and validated.

Reorientation of soil survey applications

Many developing countries suffer similar limitations in terms of staff training and project funding, but the specific problems faced may be different. Thus, soil survey should allow for more flexible and diverse applications. However, constraints imposed by factors such as short-term planning, exclusionary concepts of some professional groups, and the lack of integrated education will not be easily overcome.

Several application fields are recognized as having high priority:

- land evaluation for land use planning, with emphasis on prime agricultural land
- soil conservation
- sustainable land and environmental management
- soil quality monitoring

Monitoring soil properties and environmental features

Monitoring must be supported by problem-solving, applied research projects focusing on:

- systematic field data collection and mapping of stable properties to determine the reference date for assessing changes;
- periodic sampling of selected attributes that act as change indicators to evaluate the rate of change of dynamic properties (eg, organic carbon, calcium, phosphorous, bulk density, resistance to penetration, structure, thickness of A horizon, biologic activity, microclimate, etc.).

For that purpose, a network of base measuring sites is needed. Measurements obtained from field observations, as well as from remote sensing, should allow to determine threshold values of selected conditions relevant to sustainable land management. Features and processes that should be monitored include:

- conversion of prime agricultural land to other uses;
- land conversion to urban uses;
- deterioration of all types of prime land, including not only agricultural land, but also hydrologically (watersheds) and ecologically (biodiversity areas) important areas;
- watershed management;
- wildlife management;
- land subject to natural or human-induced hazards for disaster preparedness;
- risk management.

In an ideal situation, the above scientific and technical targets, leading to soil survey renovation and modernization, might be reached in a relatively short time by implementing a strict strategy of concrete actions, ie. a contrast scenario. What can actually be achieved with limited human and financial resources will vary in degree according to the severity of the limitations faced by each country. Gradual adjustments, locally adapted to real world conditions, may allow individual countries to bridge the gap at a slower pace by efficiently mobilizing scarce resources.

Limitations controlling the applicability of the proposed strategies are institutional, educational, technological and financial. The derived needs include:

- better data on soils and land resources to promote modelling and monitoring. The lack of data at large scales makes modelling less useful. In some developing countries, monitoring is considered impracticable for several years to come;
- guidance on methods of data capture and processing at different scales and for different purposes (eg, soil as a water-transmitting mantle, as an ecosystem component);
- guidelines on monitoring approaches and techniques concerning, in particular, soil and water quality, land use changes, social and economic changes, etc.;
- structural changes allowing improved interdisciplinary and inter-institutional coordination.

At short and medium terms, the following actions shall be envisaged:

- continuation of the current soil mapping programmes, with progressive adoption of modern techniques for data capture, storage, processing and display: 'first we have to know what we have before we start monitoring';
- updating of existing databases;
- inter-institutional cooperation to mobilize existing data and information;
- strengthening institutions through international cooperation, staff training and greater initiative in fund raising;
- efforts to bridge the gap between the current situation and an ideal future by fixing accessible targets and time horizons, and by monitoring the induced changes.

Institutional support

Proper positioning of national soil survey organizations

Because maps and reports do not meet users' needs or are untimely, soil survey services are frequently 'low profile' and have little persuasive power to raise funds and promote their activities. High-quality production raises the status of soil survey, increases its negotiating capability, and allows favourable positioning of the survey organizations with donors and users.

Reactivation of the World Soil Policy

The implementation of the World Soil Policy at country level is hampered by the gap between soil surveyors, administrators and policy makers, but also by the lack of funds, the weakness of the soil survey organizations, and their inefficiency in marketing soil survey products. Support is needed from an supranational body such as an international soil council.

Determination of priorities according to national needs

Soil survey priorities in terms of objectives, application fields and scales must be controlled by identified needs in each country. Locally, the global change issue might not be of high priority, but erosion problems will be.

Supply-demand promoting mechanisms

Direct demand is unusual. Strategies must be formulated and implemented to materialize (hidden) opportunities. For that purpose, the following actions are recommended via either status enhancement on the supply side or networking on the demand side.

Status enhancement on the supply side

- Free soil survey from its isolated and excessively self-serving position by means of cooperation with other soil sciences and related disciplines;
- Call public attention and create political awareness of the social and economic costs of soil degradation and losses through erosion, salinization, alkalinization, nutrient depletion and water logging resulting from inappropriate uses and management practices;
- Make the use and conservation of the soil resource part of the government's political agenda;
- Capitalize seed money through feasibility studies to attract attention to relevant issues such as, for example, sustainable agriculture;
- Train people not only in proposal writing but also in market survey and analysis to move from a re-active to a pro-active approach to fund raising;
- Emphasize the importance of the added value generated by multipurpose soil surveys.

Networking on the demand side

- Link up with international or regional agencies concerned with the proper use and conservation of the soil resource, through bilateral agreements and cooperation programmes (UNCED, FAO, UNESCO, World Bank, ISSS, ICSU, SADCC, etc.);
- Mobilize networks, especially through NGOs, having access to political and administrative entities;
- Adapt the soil survey supply to the agendas and priorities of donor agencies (eg, Agenda 21 of UNCED, small farmers programme of UNDP);
- Attract donors (not your international counterparts) into funding by submitting your own cooperative survey or research proposals;
- Stimulate partnerships by combining human, financial and material resources to sell soil survey expertise to other national services. Survey organizations must become more familiar with the rules and practices of submitting and marketing proposals.

CONCLUSIONS

Because global soil survey maps at scales of 1:1 million or larger cover scarcely one-third of the Earth's land surface, there is room for soil survey expansion, especially at large scales. For that purpose, less expensive methods for rapid appraisal should be implemented. Limitations are imposed by the acquisition and use of new technologies, too costly for developing countries.

The reliability of global soil maps depends on the accuracy and age of national soil maps used as input for their compilation. Interpretations derived from generalized soil maps may be unreliable if they exceed the scopes of these maps.

Presentation of soil survey reports and maps should be simplified, improved and oriented to the needs of users who are mostly non-soil scientists.

Regional soil database networks should be developed and provided with modern storage, processing and communication facilities.

The reluctance of world funding organizations to support soil inventories limits the contribution of soil information to tackling such crucial issues as environmental management and sustainability. The sustainability issue should be exploited to create greater awareness of the need for soil information.

Identified limitations to the development of soil inventories are mainly financial and institutional at local level, educational and institutional at national level, and financial at global level.

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KNOWLEDGE TRANSFER AND USER GROUPS

N. Röling
Department of Communication and Innovation Studies, Wageningen Agricultural University
P.O. Box 8130, 6700 EW Wageningen, The Netherlands

INTRODUCTION

As a social scientist in an agricultural university, I find that I have more in common with some natural science departments than with others. A typical case in point is the Irrigation Department. Its very field of study compels it to operate on the interface of natural and social sciences, paying attention to such issues as water distribution, catchment management, etc. The same goes for the Crop Protection Department. Especially when it comes to integrated pest management (IPM), crop protection must take into account farmers' practices and learning.

Soil science also fits this category. Soil science cannot be separated from human land use and the history of landscape development. In a country like The Netherlands, soil science is virtually impossible without an acute understanding of the history of land use and water management. Some Dutch soils scientists can read the landscape like a book, and know the meaning of obscure street and village names. Dr W.G. Sombroek who started the ISRIC is an avid member of the Wageningen Historical Society.

Let me start my presentation with some experiences with soil science applications from which I, as a student of extension, have gained a great deal.

CASE STUDIES

Making a micro-catchment map in Australia

The very rapid and large scale degradation of land in Australia has led the Landcare Movement, a virtually spontaneous effort by thousands of farmers, organised in Land Care Groups, to begin looking after natural resources in a sustainable manner. Taking care of the land requires scaling up from the farm level to the (micro-)catchment level. That is, farmers must come together and develop joint (micro-)catchment management. The case refers to the ways such groups efforts are facilitated. The focus is on resource mapping. The facilitation process requires a number of steps.

First, the group comes together and discusses the nature of the land resources. For example, they decide on the soil categories which characterise the area. They dig soil pits, examine typical soils, and agree on the categories they will use.

Second, they obtain an airphoto mosaic of their farm with an acetate on which to draw a resource map of their farm, marking soil types, vegetation belts, etc.

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Third, the farm maps are digitised and read into GIS software. This allows making a catchment soil map. Usually, the first time this map is somewhat of a mess, with soil types changing at farm boundaries.

Fourth, the result is discussed and adjusted until agreement is reached. There is now is an agreed-upon, shared map of the micro-catchment. In the process, the farmers who used to focus only on their individual properties have scaled up their perspective to a joint perspective on the micro-catchment.

Fifth, the farmers discuss the vulnerable areas in the micro-catchment. They develop a map with a catchment management plan, including vegetation belts, realignment of stock fences and farm roads, alignment of contour bunds, etc.

Acquaintance with this procedure taught me a few important lessons. First, it is important to work with people and use deliberate methods to construct a catchment map in a participatory manner. Doing this requires a deliberate facilitation procedure. Such a procedure is the product of very creative work.

Second, the effect was not achieved by transfer of technology from scientists to farmers, but by discovery learning.

Third, the facilitation procedure was based on sound scientific insight and created, in fact, by scientists. Yet, using the procedure caused a great deal of suspicion on the part of the soil scientists in the Department. They felt that the approach destroyed the 'integrity of science'.

Integrated arable farming in The Netherlands

The Netherlands has the highest use of nitrogen per ha in the world. Use of other minerals is also very high. There is a surplus of liquid manure of one tonne for every inhabitant. Minerals are washing into our subterranean water supplies, polluting out surface water, feeding acid rain, and causing automatic fertilisation through precipitation, also in areas where this is not desired. In other words, agriculture in the Netherlands is totally unsustainable from the point of mineral use.

One effort to clean up the mess is the introduction of integrated arable farming. My neighbour is one of 38 farmers who participated in a project to experimentally introduce integrated arable farming.

He used to be an excellent conventional farmer, following the normal practice of using very large quantities of inputs. His focus was on individual crops and on input/output relations, not on cycles.

Now he has changed. Instead of focusing on individual crops only, he takes into account the whole farm, in what can be called agro-system management. For example, instead of applying fertiliser to his potatoes for maximum production, he tries to manage nutrient flows across the entire crop rotation, and to fine tune his mineral applications so as to optimise production of the crops in the rotation while minimising emission of surplus minerals into the environment. He uses several techniques to do this. He spends much time on observing his crops and on taking soil measurements. He uses special techniques, such as potato leaf stem analysis to make visible the nutrient condition of the soil. He uses green manure crops during winter to keep nitrogen in the top levels of the soil and prevent them from leaching to deeper layers.

Acquiring such skills and trusting on one's own anticipation based on observation, as my neighbour now does, took a number of years to learn. It was not a question of adopting add-on innovations which had been transferred to him by extension workers. No, my neighbour underwent quite a transformation in his farm management as a result of an intense learning process, which took some years and which was facilitated by a highly trained extension worker who not only had a great deal of technical skill, but who could also help my neighbour and the small group of farmers who underwent the experiment to learn and discuss effectively.

My neighbour's experience taught me a great deal. In the first place, there is a great difference between transfer of technology and facilitation of learning. In the second place, integrated, more ecological agriculture, requires a transformation of the farmer which goes much beyond the adoption of add-on innovations. In the third place, developing the 'curriculum' for learning integrated farming is a highly creative job which requires a great deal of scientific support, e.g., in understanding nutrient behaviour across a crop rotation. These lessons have since only been confirmed during visits to Indonesia's Integrated Pest Management Programme and other experiences.

DIFFERENT WAYS OF INTERACTING WITH CLIENTS

The general conclusion is that *there are many different ways in which soil science can be effective*. For example: Science can define problems and develop and transfer solutions, as in the case of fertiliser recommendations. But it can also performs complex services, such as analyzing soils on request. It can develop instruments for making things visible. It can develop methodologies and curricula for discovery learning, such as the facilitation methods for micro-catchment management used in Australia.

In all, my assignment is to speak of 'technology transfer' and user groups is not as easy as it sounds. In fact, one can distinguish three very different, internally consistent approaches to the way soil scientists interact with clients: (1)Transfer of Technology; (2) Consultancy; and, (3) Facilitation.

What I would like to do first in this paper is to describe and compare these three forms. Thereafter, I will draw the implications of each for the kind of products that a NASREC can develop. Finally, I will present some statements for discussion.

ASPECTS FOR DISTINGUISHING TYPES OF SCIENCE/CLIENT INTERACTIONS

The aspects form an integrated set of elements which are mutually coherent if an extension system is effective. There are five aspects;

- *practices* for dealing with the agro-ecosystem at the field, farm or higher system levels;
- ways of *learning* about dealing with the agro-ecosystem;
- ways of *promoting* such learning;
- a supportive *institutional* framework;
- a conducive *policy context.*

One could add one more element, we could call it the philosophy which underpins the different sets of coherent elements making up the different knowledge systems, which we shall discuss presently.

THE FRAMEWORK

Based on the above, let us now look at the framework for comparing the three different types science/client interactions:

	Transfer of technology	Consultancy	Facilitation
practices	-	-	-
learning	-	-	-
promotion	-	-	-
institutions	-	-	-
policies	-	-	-

Transfer of technology

We start off with illustrating the coherence of the five elements for the Transfer of Technology (TOT). It is the most prevalent, conventional type with which we are all familiar. It fits bureaucratic systems like a glove:

- practices: new technology packages to enhance the productivity of components of the agro-ecosystem. Usually these are uniform packages developed by science which are supposed to be effective across large recommendation domains.
- learning: adoption of add-on innovations by 'users' or 'receivers'.
- promotion: delivery of technology packages, transfer of science-based knowledge;
- institutions: sequence of interlocked institutions on a continuum from science to practice, i.e., Basic Research, Applied Research, Adaptive Research, SMSs, FLEWs, Contact Farmers, Follower Farmers. But input companies, seed multiplication companies, etc. should not be forgotten.
- policies: subsidies on inputs, public funding of agricultural research and technology transfer, coincidence of national interests and progressive farmer interests through technology-propelled productivity gains, the benefits of which are eventually passed on to the consumer (voter).

For the case of TOT, the five elements are clearly coherent and consistent. One cannot look at each in isolation. They form an integrated whole.

The philosophy which informs the linear knowledge system is realism/positivism, i.e., reality is considered to exist independently of the human observer and to be objectively knowable if 'discovered' by science.

Consultancy

We do not need to go too deeply into consultancy. We present it to show that there are alternatives to TOT. An example is the type of extension used in the Kenya Dairy Development Programme. It does not work with barely trained generalists, but with highly mobile subject matter specialists who cover large areas and focus on developing the small scale dairy industry through zero grazing, proper calf rearing, introducing quality cattle, etc. These specialists are able to deal with any aspect of dairy production and have a large repertoire of expertise which they can draw upon according to the intake with the farmer in question.

- practices: farm plans, strategies, technologies, and skills for developing a specific enterprise, e.g., cut flowers, pigs, dairying, tea;
- learning: capital and knowledge-intensive commercial enterprise management training and business learning;
- promotion: training and advisory work in all aspects, including credit, marketing, etc.
- institutions: network of highly mobile advisors with backstopping through in-service training and electronic or print support. Processing companies, marketing structures, animal health services, etc.
- policies: incentives for quality, investment in infra-structure development, tax incentives, export promotion. Often works with brand names and niche markets.

Facilitation

Facilitation is emerging in many countries as a distinct set of highly cohesive elements. Its focus is necessarily on farmers as experts in managing complex, diverse and variable agro-ecosystems and businesses. Unlike the other two types, the facilitating allows addressing such policy goals as equity and sustainability in addition to productivity and competitiveness.

Its demonstrated achievement is that it can change farmers from passive receivers of packages and routine appliers of chemicals into active and creative movers, and stagnant farmer groups into vibrant hubs of self-help, learning and innovation. The five elements of facilitation are:

- practices: based on system approach to field, farm, or catchment. Use of natural processes and controls. Low external input management of local resources. Building on diversity. Active resource development. Locality-specific application of general principles.
- learning: farmer takes expert decisions based on observation and agro-ecosystem analysis, using indicators and equipment that make things visible. Anticipation based on observation and understanding. Emphasis on discovery learning and collective local learning. This type of learning is very different from adopting add-on innovations and requires more time.
- promotion: creating conditions for discovery and experiential learning. Training in observation, experimentation and collective decision making. Facilitation of learning rather than transfer of existing solutions for preset problems. Participatory methodologies (use PRA, PTD and tools for discovery learning).
- institutions: decentralised local learning networks of farmers and facilitators. Local farmer organisations 'in charge' of process. Linkage to existing body of scientific knowledge, but not necessarily through research.

- policies: financial support for labour intensive facilitation and for local networking (e.g., meetings and transport). Regulation of use of harmful chemicals. Market development for ecological products. Support of 'alternative actor networks'. Acceptance of multiple policy goals and trade-offs among them.

Facilitation also forms a coherent whole. It is totally different from the TOT. It has been shown in different countries, for example, that it is impossible to promote ecological practices, such as IPM, through TOT-type extension systems.

THE MANAGEMENT OF CHANGE ACROSS THE THREE TYPES

The types are coherent wholes. Once on thinks along the lines of one type, it is not easy to move to another type. This is also caused because of the strong integration of the five elements of each type, including the supportive institutions and the conducive policy contexts.

For example, the T&V system which has been introduced in many of your countries focuses on transferring bits of science-based information from research to farmers in a topical transfer of technology approach. The institutional framework is developed around the continuum from science to practice. A total different approach is advisory work of specialist advisors who help, say, cut flower growers in their knowledge and capital intensive businesses. Instead of TOT, these advisers are engaging in consultancy: they can respond to problems that farmers bring forward and have a wide repertoire of possible answers and solutions to problems. Moving from TOT to consultancy is not easy and requires careful management of change.

The same goes in case of changing from TOT to facilitation. This has become necessary because in many high potential areas the Green Revolution has petered out. That is, miracle seeds and uniform technology packages which blanket large recommendation domains cannot be expected to advance production much further. What is necessary is an approach which facilitates farmer learning so that they become experts at optimising locality specific and diverse opportunities. In low potential areas, the Green Revolution has never taken hold. In these areas, which are usually rainfall dependent, highly diverse, drought prone and rapidly degrading, only facilitation approaches seem able to create the kinds of collective resource management which we already encountered in the Land Care example. This requires careful management of change to move the extension services, the institutional framework, and the policy makers to the new approach.

IMPLICATIONS FOR NASRECS

The importance of the distinction between TOT, Consultancy and Facilitation is that each type of interaction with clients leads to different kinds of roles and institutional niches for NASRECs.

Transfer of Technology is the normal manner in which NASRECs interact with clients. The focus is on expertise-based information and the delivery of knowledge products. One must recognise that this type of interaction with clients remains important. Scientists have developed much useful knowledge which is laid down in maps, soil classifications, land suitability data and so forth. People want this information. It is sometimes very frustrating that those people do not seem to recognise all the wonderful information which scientists have developed. The skill NASRECs need here is to make people realise the usefulness of the information available.

The typical institutional niche that NASRECs occupy in the TOT mode is as an intermediary between science and practice. The NASREC is a store of scientific knowledge which can be 'delivered' to 'users'. In this mode, it is very important that NASRECs have adequate linkages with scientific research one the one hand, and with extension services, farmers and others on the other.

In the case of **Consultancy** the focus is on services which clients need. The analysis of demand for such services is very important. One cannot do everything for everybody. Therefore it is important to carry out 'market research' to identify likely markets and segment them into useful client categories for which one can develop appropriate services and products. Typical examples are soil analyses on demand, carrying out diagnoses when problems occur, helping farmers make farm plans, etc. Typical areas include soil fertility, water retention, soil-borne diseases, soil structure, erosion and erodibility.

The skills NASRECs need is to carry out market analyses to identify clients and their needs, and to develop appropriate products.

In case of consultancy, the institutional niche of the NASREC is a totally different one. It now is one of the service institutions in the networks serving certain categories of clients, say the building industry or the horticulture industry. Such industries need services such as bookkeeping, input delivery, quantum surveyors, and also soil services.

Facilitation is the hardest one. The focus is on helping in creating learning experiences. The cases of Landcare and integrated arable farming which I presented in the beginning have provided some examples. The NASREC product could be a curriculum for discovery learning by farmers, much as was developed for micro-catchment groups in Landcare. Or it could be instruments which farmers can use to make visible the situation of their soil. Typical examples are do-it-yourself soil kits, soil drills, soil corers, or indicators for different types of soils. Another typical example is a 'rainfall simulator' used in Australia which allowed farmers (who usually sit inside their houses when it rains) to see what happens to their fields in a big rain storm when they leave them unprotected. Such a learning experience is capable of generating a tremendous amount of energy and enthusiasm for better soil management. One can also think of schools. It is one thing to let a bus full of school children look at all the wonderful monoliths on the wall. Quite another to teach how to make their own monolith and draw conclusions from comparing the monoliths they have made at different places in their own environment. That is exactly the difference between TOT and facilitation.

The institutional framework in the case of facilitation is different again. One would need to maintain close linkages of collaboration with teachers or farmer facilitators and clients themselves to help develop adequate learning experiences. Participatory product development would be the essential skill which NASREC workers would need to develop to play a role in facilitation.

CONCLUDING STATEMENTS

- NASRECs should develop a different set of offerings (products, skills, services) for each type of interaction with clients.
- NASRECs should develop a different institutional niche (linkages, networks) for each type of interaction with clients.
- The future for NASRECs is likely to move increasingly in the direction of consultancy and facilitation.

DATA NEEDS FOR SUSTAINABLE AGRICULTURE

P.R. Goldsworthy and S.W. Duiker
International Service for National Agricultural Research (ISNAR)
P.O. Box 93375, 2509 AJ The Hague, The Netherlands

ABSTRACT

The paper describes briefly some of the implications, particularly for developing countries, of the changing context of agricultural research, from one in which production alone was the primary emphasis, to one in which environmental concerns and the sustainable use of natural resourcc havc become additional and equally important objectives in the research agenda. It discusses how these changes have contributed to a progression in the evolution of research approaches, employing systems methods to deal more effectively with the spatial and temporal integration that is needed to understand and predict the probable consequences of different agricultural technologies, and the trade-offs between production and environmental objectives. The discussion focuses particularly on the collection and management of the biological, physical, and social data required to adequately characterise agricultural environments, data on which these new approaches depend. The paper is a contribution to a dialogue with scientists from national research systems about how the institutions which collect the data can address some of the institutional and management constraints that make their task more difficult, and how they can participate in and benefit from the activities of the international scientific community.

INTRODUCTION

Many developing countries will have to double their food production within the next 25-30 years if they are to meet the food requirements of their rapidly growing populations. But there is now wider recognition that as agricultural production expands, so does its effect on the natural resource base, and on other users of the resources. It is no longer sufficient to consider production goals alone. There is a realisation that a longer view and more spatial integration are required in research to assess the sustainability of agricultural practice and the consequences of introducing new technologies. Making agriculture more efficient in the use of natural resources while conserving resources for future productivity and well being requires informed policies, new technologies, and better information on the state of natural resources. Governments will need the means to anticipate what the consequences of the growing demands on the natural resources are likely to be. They will need information on the probable consequences of different options for the use of land and water resources that take into account environmental, economic,

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social, demographic, cultural and political factors. There are usually many competing inter-sector interests for the use of land and water resources. Cross-sector planning will be a key to integrating environmental and development goals, and information will be a key requirement for the planning process.

Whereas in the past the main output of research has been improved technologies, and the sole clients have been farmers, information to guide development decisions will become relatively much more important, and policy makers will become principal clients for research. Already in many developing countries policy makers are asking their agricultural research services to supply information, in an accessible form, showing the technical options available for meeting both environmental and developmental goals. In other countries the first task of the research community may be to convince those responsible for policy of the value of agro-ecological research and of the contribution it has made to agricultural development in the past, so that characterisation of agricultural environments is better supported in the future. They then need to ensure that research continues to produce results that are valuable for development, and that the resources available for research are used to best advantage, by clearly defining research policy and research priorities. Their third task is of course, to communicate and use the results of research.

TRADITIONAL AGRICULTURAL RESEARCH

Agricultural scientists have always needed to interpret the results of research work in relation to environments which vary in terms of rainfall, soils and temperature from place to place, but also from year to year at any one location. They have had to decide how to extrapolate experimental results from one or a few experiment sites to other sites, seasons, and management situations. The more variable the region (e.g., in terms of the amounts and distribution of rainfall) the more difficult this task becomes. The ultimate target of their research is the individual farmer, but each farmer and field is unique, and that remains the central problem.

Until now agricultural research strategy has been predominantly production oriented and based on transfer-of-technology by analogy. The well established programmes of international nurseries and yield trials are an example of this approach, which has been widely employed in the past. They have served to evaluate performance of improved varieties of food crops in widely separated locations. Experimental results have been statistically analyzed, perhaps clustering or ranking sites. But, this approach is costly and time consuming, and its value has been confined mainly to crop breeding programmes. Now it is being questioned whether such networks of sites are necessary. In many cases no environmental or geographic information was recorded to characterise either the experiment sites or the locations they were intended to serve. The approach does not therefore reflect the diversity of agricultural environments within a region which individual farmers have to contend with. It has therefore been evident for a long time that alternative approaches are required.

NEW APPROACHES TO RESEARCH

The shift in the focus of research from commodities to a land-use systems perspective, and the integration of natural resource management (NRM) concerns into agricultural research implies a much broader research agenda for national and international agricultural research (Crosson and Anderson, 1993), but also a change in the character of the research problems. Research will no longer be seen solely as a generator of new technology, but also as a source of information for the formulation of development policy and planning (Janssen, 1994).

This change in emphasis is contributing to an evolution in the research methods used. The evolution has progressed in the past from simple trial and error, transfer by analogy, statistical correlation methods, various forms of analysis of variance, and more recently to systems analysis and simulation methods. The different approaches are not mutually exclusive and can be used in combination.

The growing use of systems methods for dealing with the problem of spatial and temporal integration offers a means of coupling environmental data more closely with the experimental observations. It enables the results from one environment (or agro-ecological zone) to be used to predict the probable results in another which is similar, or which differs from it in known, but important respects. The ability to do this can greatly diminish the amount of field work that has to be repeated in the new environment, and hence the cost and time required to transfer results.

In this context, the concept of agro-ecological zones as comparatively homogeneous units of land bounded by fixed lines on a map may imply a degree of rigidity of classification which is not appropriate. Instead, it is often more useful to think in terms of an agro-ecological characterisation of environments, which can then be classified as required for particular purposes. If viewed in this way, mapping is a useful but not essential part of the process, as the boundaries illustrated are rarely fixed but may be modified as information is improved or boundary conditions change. Maps are useful for illustration, but they are transitory and they represent no more than best estimates at a particular point in time.

INFORMATION DATA BASES

One of the first need when applying systems approaches is to identify the primary data elements required, and ways to measure or estimate them. Second, data must be given accurate geographical reference, a task that can now be done with relatively inexpensive portable satellite positioning equipment (GPS).

The aim is to assemble geographically referenced inventories of natural resources which include biophysical and socio-economic data from which to assess land capability and patterns of land and water use. These inventories are crucial for development planning and for the integration of NRM into agricultural research. Geographic information systems (GIS) provide a structured framework for the management of these inventories. They facilitate the acquisition, storage, retrieval, analysis, and display of the data.

Coupled with appropriate models of the production systems being studied, the inventories can be used to provide not only a descriptive information, but also predictions of the probable outcome of different land-use options. An agricultural strategy based on systems methods and simulation must balance these two components, i.e., the model component (symbolic representations of reality); and the required input data for the models to operate effectively. It is the model which determines the minimum data set required.

Information-based technologies such as crop and land use modelling, geographic information systems (GIS), and the use of remote sensing are among the tools that NARS will be expected to use as part of their NRM research. It is a public sector responsibility to ensure that an inventory of this kind is maintained. Collecting information on the NR base and about the impact of agricultural activities on it and on the environment will present a considerable challenge to NARS. Such characterisation of a country's natural resources will depend on access to information management systems that so far only a few NARS have developed.

Standardisation of data: International and regional organisations, and their partners in both developing and developed countries, share a common need to describe the environments of particular localities, regions, and sites. They all require information on terrain (topography), soils, rainfall and temperature, and their variations in space and time. For many purposes derived or complex functions of primary data may be required (e.g., the seasonal course of the water balance), but they all depend on similar primary data which can be used in different ways and with different models. Since much of the essential information that all users need is the same, even though their purposes may have different, there is a need for common standards, and for assembling data sets in similar or compatible ways into databases that can be used and shared.

Clearly, there are benefits if all use the same internationally accepted units and conventions in assembling and managing data. An example of the kind of standardisation needed is illustrated by the manual of codes which WMO has provided a for national meteorological services, and the CLICOM, (Climate Computing) project which offers a PC-based package designed by WMO.

The common data sets should contain the minimum necessary to meet the most demanding of the foreseen needs, and they should be designed and managed in a manner that permits them to be expanded to meet other needs when required. Apart from the passport elements needed to describe each data set (e.g., location, longitude and latitude, elevation, date and methods of observation) the common data sets should include information on the main environmental elements, which are listed below.

Climatic data: is needed to define the agro-climate of an area or location. It may be used for example, to estimate the variability in the amount and distribution of rainfall within and between seasons. These kinds of estimates require detailed, daily data from a sufficient number of sites to permit variability to be described adequately and climatic risk to be estimated.

Soils data: the importance of the physical and chemical characteristics of soils in influencing the productivity of agricultural systems will be adequately covered elsewhere in this workshop. A database for soils has to contain detailed data as well as more general information. There is a need to clarify which variables it is essential to store, so co-operation between users on the development of common data bases and standards offers clear advantages.

Vegetation data: can serve to indicate production potential of land, but relations between vegetation type and environment tend to be qualitative rather than quantitative. Vegetation data is nevertheless useful where other information is lacking. Vegetation cannot indicate much about what kinds of management might be productive when the vegetation is removed, but the amount and composition of natural vegetation can indicate changes in the environment, including those which result from human activities. Changes in vegetation cover and indications of erosion are dynamic features of a landscape which can be important as indicators of sustainability.

Production data: Qualitative and quantitative information on the distribution of crops and livestock production are essential for understanding farming systems and their productivity, and for understanding what determines the distribution and range of adaptation of crops and other components of the systems. Crop distribution data from surveys or censuses is scarce. Remote sensing data may be an alternative source of information about where crops are being grown. FAO has perhaps the largest collection of data on the distribution and yield of crops and has to do a great deal of work to remove inconsistencies which arise from different ways of collecting the data.

Hydrological data: The depth and duration of flooding, and its variability are particularly important factors in rice producing areas. Similar information may also be required for the development of swamp areas. In more marginal environments in which agricultural activity depends mainly on rainfall, interest may focus on the development of supplementary irrigation. Data on surface and underground water resources then becomes important. Data on water quality, and changes in quality with time are sometimes required as indicators of sustainability.

Elevation data: Digital information for analyzing and mapping terrain elevation can be stored either as contour strings or as randomly chosen elevation points. The method can be used to generate maps of elevation, slope and aspect of a site, which are required for example, for development of erosion control or for characterising sites in mountainous terrain.

Socio-economic data: should be considered in any classification of agricultural environments, but the kinds of data in this category which are relevant varies from one locality or situation to another. It is also subject to influences other than the physical characteristics of the environment so far described, and it changes over time. Socio-economic data may be require to describe farming systems and to diagnose problems, and as a means to determine priorities for research. A second use is in testing possible solutions in association with producers. There is little or no agreement on what constitutes a minimum or standard set of this category of information. Some forms such as demographic data are quantifiable, but at the other extreme are behaviourial attributes (opinions and beliefs) which are much more difficult to represent. For example, data on household expenditure and farmer's decisions are not unrelated, but they are not the same. A minimum data set implies something that is constant across crops and system, but minimum socio-economic data for a tropical perennial tree crop and for temperate cereals would clearly be different. Thus we are unlikely to find one standard set for all needs.

THE NATIONAL INSTITUTIONS AND INTERNATIONAL ORGANISATIONS

Much of the information on agricultural environments has been organised, and collected by international and regional research agencies. UNDP, UNEP, UNESCO, CGIAR agricultural research centres, other international scientific institutes such as ORSTOM, NRI, KIT based in developed countries are all major sources of global information on agricultural environments. Efforts are being made by many of these agencies to improve the consistency, compatibility and use of these data sets on agricultural environments for research and development purposes.

We will be hearing later in this workshop about one databases which UNEP has set up: the Global Resources Information Database (GRID, Geneva and Arendal), and perhaps also of another, the Global Environmental Monitoring System (GEMS, Nairobi). They are intended to provide distributed nation-based networks of geographic information systems, rather than global databases, but they depend on co-operative efforts to determine what data should be incorporated.

Integrating natural resources and environmental concerns into the research agenda will greatly add to the responsibilities of already overburdened NARS at a time when for most of them, budgets are declining. Guidelines on the future information requirements of developing countries, including procedures for data collection related to the sustainable use of natural resources, need to be developed. The knowledge base necessary to support informed agricultural and environmental policy requires integration of expertise from different disciplines during data collection, to ensure that physical and economic data are compatible and that scientific research and policy analysis can be linked

NARS will need to acquire the skills to assemble, maintain and manage environmental databases. Two sets of skills may be needed. One is to build and maintain local databases on research and the state of natural resources. The other is to use and apply where possible the information available in global databases. New collaborative mechanisms will be required to facilitate access to sources of information held by others, and for a NARS to make its database available for use by others. GRID is an example of an international initiative to develop an environmental database that is compatible with the needs of both international agricultural research centres (IARCs) and NARS.

In this context, it is important for the international research community to recognise that apart from being users of environmental information the national institutions are also the source of much of the data. The nations collect and store data for their own purposes and bear the cost of doing so. All primary data (other than that collected by remote sensing) are inevitably collected within countries. In some cases national meteorological services (which report to the international meteorological network) are not the sole agents that collect climate and weather data. Similarly, the national research agency may not be the sole agency for soils. In some countries both of these data are collected by the military, and part of it may be classified. This all adds to the difficulty of assembling comprehensive databases on environmental and natural resources

CONCLUSION

The CGIAR centres need to harmonise their collection efforts with those of the national institutions, who increasingly will have to become partners in this work as the emphasis on ecoregional activities increases. National services are looking to the international and other organisations for help with methods of data collection, storage and management. The purpose of the one-day discussions as part of this workshop will be to identify some of the technical and institutional constraints that they face, the kinds of action they themselves need to take, and the support that others can give to help them to overcome these constraints.

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A PROVISIONAL WORLD CLIMATIC RESOURCE INVENTORY BASED ON THE LENGTH-OF-GROWING-PERIOD CONCEPT

E. de Pauw[1], F.O. Nachtergaele[2] and J. Antoine[3] [1]

1 *Land Resources Consultants*

2 *Land and Water Development Division, FAO, Rome*

3 *Land and Environment Information Systems, FAO, Rome*

INTRODUCTION

The length-of-growing-period (LGP) has been defined as the period of the year in which agricultural production is possible from the viewpoint of moisture availability and absence of temperature limitations. This concept has been applied in many continental, regional and country-level studies as the basis for climatic inventories, which were used, in combination with soils, terrain and crop information, to assess agricultural potentialities and constraints (e.g. FAO, 1978-81; Kassam *et al.*, 1981-82; de Pauw, 1989; Higgins *et al.*, 1983; Nachtergaele and Bruggeman, 1986). Most of these studies were situated in tropical and subtropical areas where temperature constraints were in general of less importance than moisture availability in the position and properties of agricultural seasons.

Several attempts have been made to extend its application to the assessment of production potentials of temperate and cold areas (e.g. Stewart, 1983; Van Velthuizen and Kassam, 1983; Verheye *et al.*, 1987). The approaches followed diverged in accordance with the specific nature, extent and intensity of the climatic limitations and resources. Obviously in temperate and cold areas temperature becomes a more critical factor in determining the growing season than in tropical and subtropical areas. In addition, variations of day length, negligible at lower latitudes, becomes sufficiently important at higher latitudes to influence the agricultural productivity of particular seasons. At the same time moisture constraints remain important determinants. Under such conditions the possibility of interactions increases which may lead to complex growing seasons patterns that can not be adequately modelled through the original LGP-concept, which, as indicated earlier, has been designed mainly to detect moisture constraints.

For this reason a need has been increasingly felt to develop a consolidated LGP- approach that would give better recognition to the relevant climatic constraints in any major region of the world. This paper outlines a methodology for a global climatic inventory that is based on the traditional LGP-concept but includes extensions and modifications that give more justice to temperature and day length variations, where they are relevant, and therefore make the

[1] Based on preliminary work at IIASA by G. Fischer and H.T. Van Velthuizen

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assessment more globally applicable. This new approach, while still under development, has been tested out using a gridded global climate database and is discussed in the next sections.

THE ORIGINAL LGP-APPROACH

In the original length-of-growing-period approach the operational definition of growing period is *'the period (in days) during the year when precipitation (P) exceeds half the potential evapotranspiration (PET) plus a period required to evapotranspire up to 100 mm of water from excess precipitation assumed stored in the soil profile'* (FAO, 1978). The rationale for these operational limits can be found in the source publication, but basically they represent empirically validated thresholds for the reliable start and end of the agronomically relevant growing period, which take due account of respectively early, unreliable rains, and stored soil moisture. To assess the quality of a growing period various types of growing periods were distinguished (Figure 1):

(a) A *normal growing period* contains a subperiod in which rainfall exceeds potential evapotranspiration (the *'humid period'*). Presence of a humid period within the growing period indicates that (a) the full evapotranspiration demands of rainfed upland crops at maximum canopy cover can be met and (b) the moisture deficit of the soil is replenished.

(b) An *intermediate growing period* is defined as a growing period that does not contain a humid subperiod. Within the intermediate growing period monthly rainfall is always below the full but above half the monthly potential evapotranspiration. Under those conditions water availability does not meet the full water requirements of major food crops at maximum canopy cover.

(c) An *all-year-round humid growing period* is a growing period in which the average monthly rainfall exceeds for every month of the year the average potential evapotranspiration.

(d) An *all-year-round dry period* is characterized by an average monthly rainfall that does not exceed half the potential evapotranspiration for any month of the year.

It is clear that these definitions and types are all based on the moisture characteristics of growing periods. The temperature adequacy of a growing period is implied from the condition that no month can be part of a growing period unless its average mean temperature exceeds 5°C. The thermal regime of an area was further established through a broad climatic subdivision mainly based on temperature conditions throughout the year as outlined in Table 1.

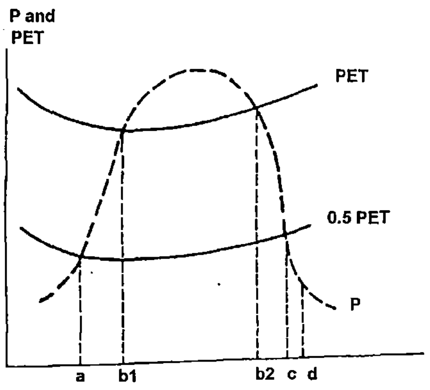

Fig. 1a Normal growing period

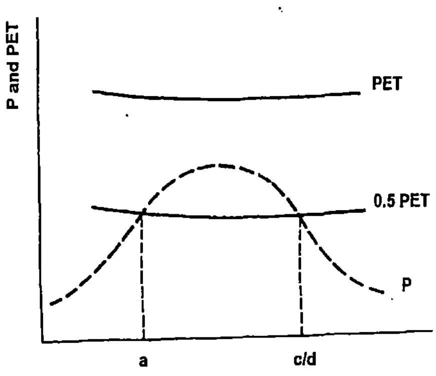

Fig. 1b Intermediate growing period

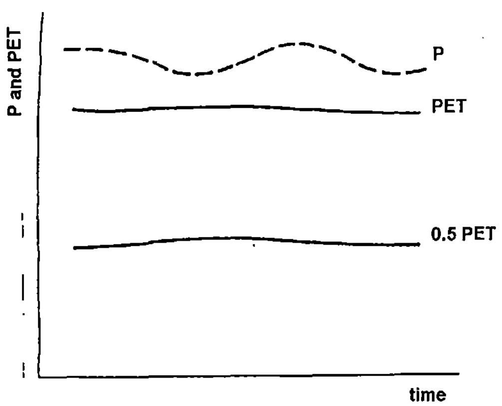

Fig. 1c Year-round humid growing period

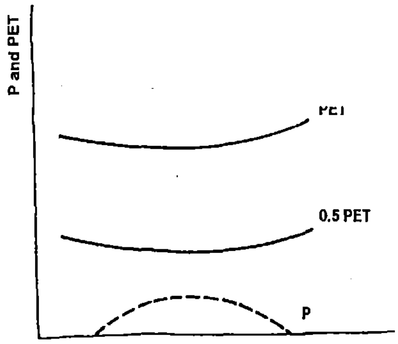

Fig. 1d All-year-round dry period

Fig.1 Examples of four types of growing period

(Legend: a is beginning of rains and growing period; b1, b2 are start and end of humid period, respectively; c is end of rains and rainy season; d is end of growing period; P is precipitation; PET is potential evapotranspiration)

Table 1 Major climatic divisions (from FAO, 1978-1981)[2]

Climate	Climatic subdivisions	Characteristics
Tropics (All months with monthly mean temperatures, corrected to sea-level, above 18°C)	Warm Tropics	Mean daily temp. during growing period >20°C
	Moderately cool Tropics	Mean daily temp. during growing period 15-20°C
	Cool Tropics	Mean daily temp. during growing period 5-15°C
	Cold Tropics	Mean daily temp. during growing period <5°C
Sub-tropics (One or more months with monthly mean temperatures, corrected to sea level, below 18°C but above 5°C)	Warm sub-tropics	Mean daily temp. during growing period >20°C
	Warm, moderately cool Sub-tropics, summer rainfall	Mean daily temp. during growing period >15°C
	Warm, moderately cool Sub-tropics, summer rainfall	Mean daily temp. during growing period >15°C
	Moderately cool sub-tropics, summer rainfall	Mean daily temp. during growing period 15-20°C
	Cool Sub-tropics, summer rainfall	Mean daily temp. during growing period 5-15°C
	Cold Sub-tropics, summer rainfall	Mean daily temp. during growing period <5°C
	Cool Sub-tropics, winter rainfall	Mean daily temp. during growing period 5-15°C
	Cold Sub-tropics, winter rainfall	Mean daily temp. during growing period <5°C
Temperate (One or more months with monthly mean temperatures, corrected to sea level, below 5°C)	Cool temperate	Mean daily temp. during growing period 5-20°C
	Cold temperate	Mean daily temp. during growing period <5°C

[2] Since cooler climates than the reference may occur at any latitude, depending on the elevation above sea level, the major climatic subdivisions were separated on the basis of temperature conditions reduced to sea level, in order to obtain unfragmented geographical areas. In the climatic subdivisions actual temperatures were used.

AN APPROACH FOR A GLOBAL CLIMATIC RESOURCE INVENTORY

The original LGP-approach was primarily designed to detect moisture-related constraints, taking account of both rainfall and soil moisture storage. In this approach temperature is not really seen as a constraint to agricultural productivity but as a general qualifier determining the type of crops that can be grown (see Table 1).

In this paper we propose an approach to LGP-modelling that will better integrate temperature- and moisture-related constraints and make the concept more suitable for a global climatic resources inventory.

Temperature and moisture thresholds

Thresholds used in the literature to define growing periods from a thermal point of view differ according to the particular characteristics of the local climate. For instance, Stewart (1983) defines for Canadian conditions, characterized by large temperature variations between winter and summer, the growing period as the 'frost-free period', which is delimited by the period during the year when the mean minimum air temperature is greater then or equal to 5°C. Verheye *et al.* (1987), on the other hand, use a mean monthly temperature of 6.5°C as threshold for the less continental conditions of Europe. In the current approach the temperature threshold for a growing period remains, as in the standard LGP-approach, a mean temperature of 5°C.

The temperature and moisture-delimited growing period is defined through both waterbalance and temperature thresholds. The *start of the temperature- and moisture-delimited growing period* is the moment when either the mean temperature rises above 5°C or rainfall exceeds half the potential evapotranspiration, whichever comes last. The *end of the growing period* occurs when either (i) 100 mm of soil moisture has been evapotranspired after rainfall has dropped below half the potential evapotranspiration or (ii) at the onset of a premature temperature drop, whichever comes first. A *premature temperature drop* occurs when mean air temperature falls below 5°C before the end of soil moisture depletion and does not rise again.

A *cold break* is the termination of the growing period as a result of a temperature drop below a kill threshold that is function of the snow cover. If a cold break occurs, it is assumed that crops will not be able to restart biological activity within the current growing period and any favourable temperature and moisture conditions that may occur later during the year are inventoried as part of a second growing period.

Within the growing period so-called *'dormancy periods'* may occur, when temperatures are too low to support biological activity but not low enough to kill adapted crops. Dormancy periods are defined by the period within the growing period that the mean monthly temperature is in the interval [-8°C, 5°C]. If dormancy periods do occur, the length of the temperature-delimited growing period is reduced by the number of days of the dormancy periods. The *length of the growing period* (LGP_{tm}) will thus vary in accordance with the presence of dormancy periods or premature drops of temperature as per following decision rules:

(a) if no dormancy periods or premature drops of temperature occur, LGP_{tm} is the time interval between the start and the end of the growing period;

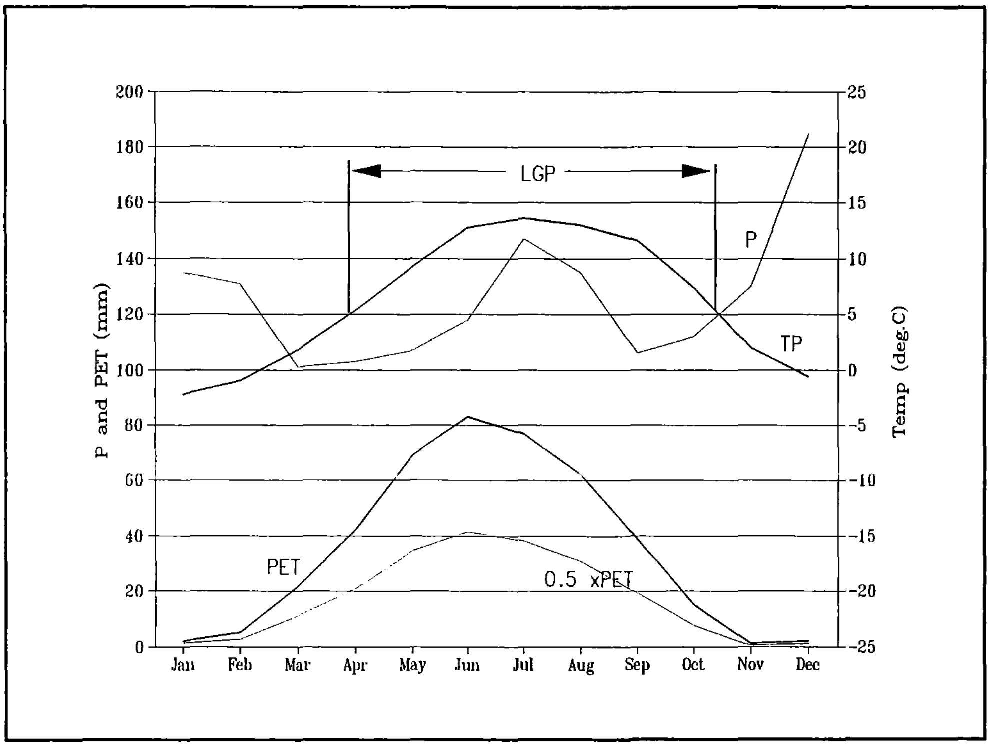

Fig. 2a Climate diagram: Botrange, Belgium

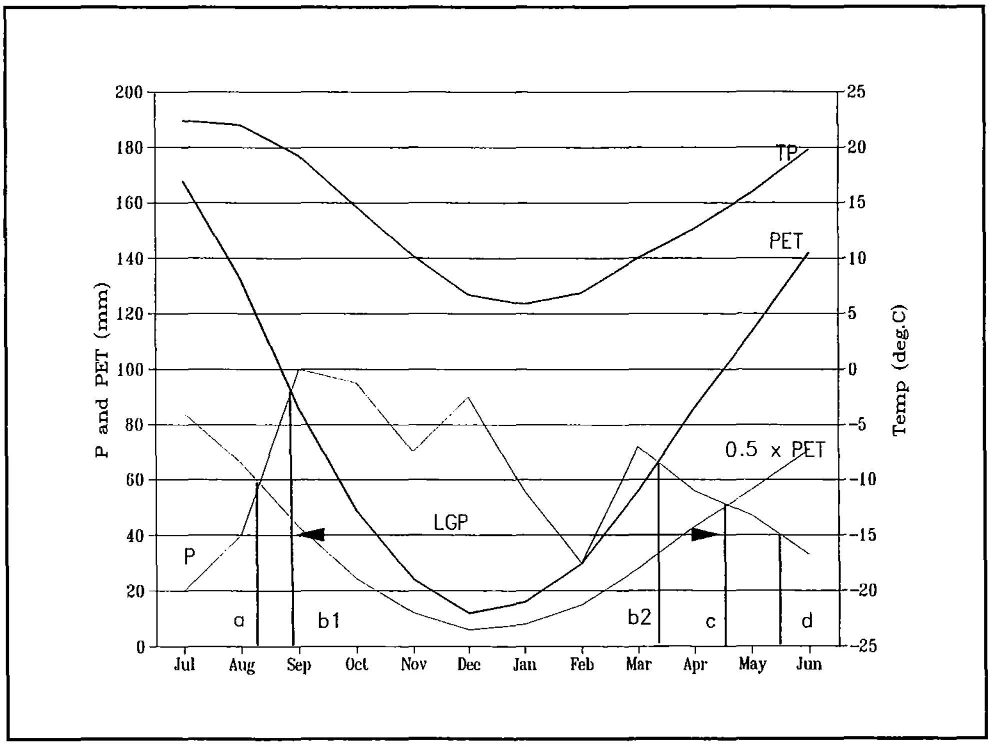

Fig. 2b Climate diagram: Montpellier, France

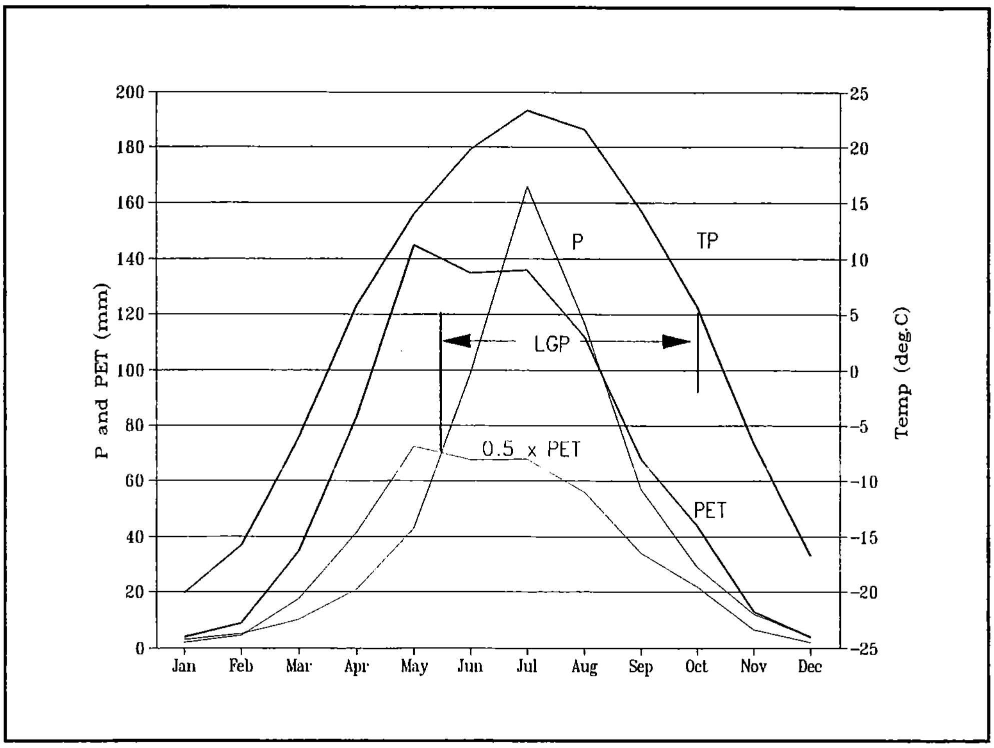

Fig. 2c Climate diagram: Harbin, China

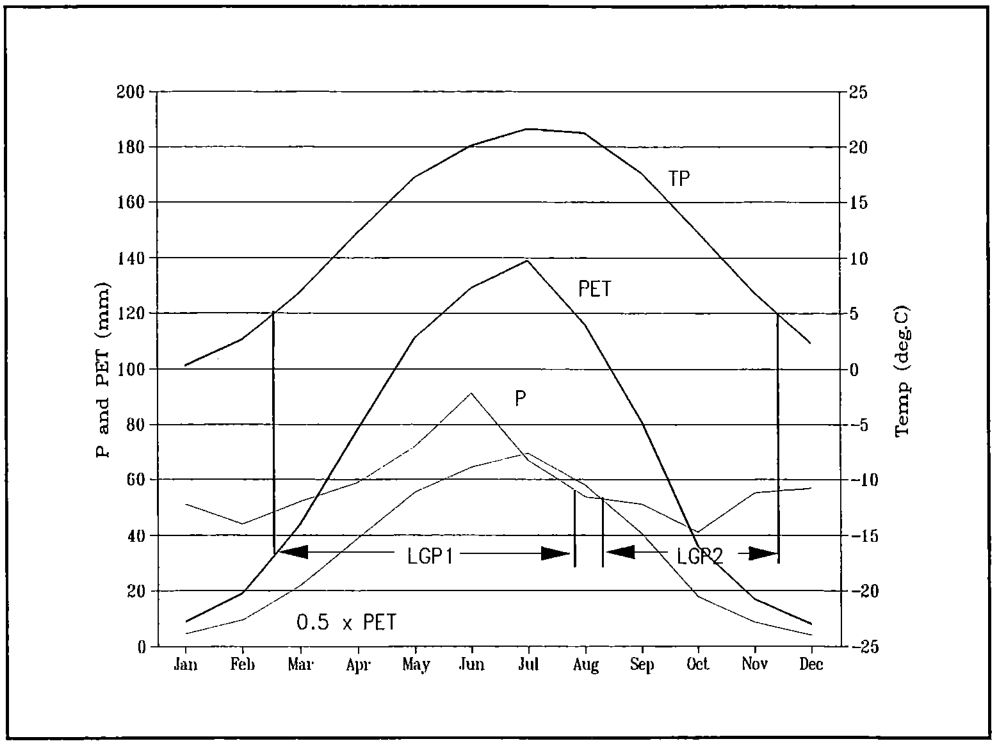

Fig. 2d Climate diagram: Beograd, Serbia

(b) if one or more dormancy periods occur within the start and end date of the temperature- and moisture-delimited growing period, LGP_{tm} is reduced by the total length of the dormancy period(s);
(c) if a premature temperature drop occurs, the end of the growing period is the onset date of this drop.
(d) if a cold break occurs, the end of the growing period is the onset date of the cold break.

Examples of climatic conditions where either temperature or moisture conditions or both determine growing period onset, end and duration are given in Figure 2 (data from FAOCLIM CD-ROM (FAO, 1985)). Figure 2a illustrates a station (Botrange, Belgium) where moisture is non-limiting and where the growing period is delimited by temperature. In Montpellier (Fig. 2b), on the other hand, the growing period is purely delimited by moisture availability, as in the classical LGP-concept (see also Fig. 1a). In Harbin, China (Fig. 2c) the start of the growing period is determined by moisture availability, the end by low temperatures. In Beograd, Serbia (Fig. 2d) temperature and moisture conditions are both limiting, resulting into two growing periods, each one delimited by either low moisture or low temperature.

Waterbalance

In the original LGP-model the waterbalance adopts a simple bookkeeping procedure that assumes all stored soil moisture can be consumed in any one period to meet the evapotranspiration demand. It is felt that this approach tends to overestimate actual moisture availability and that a better approximation of reality is achieved by considering different moisture depletion rates as a function of moisture availability. In the current methodological revision this requirement is approximated by assuming that a certain fraction of the soil moisture is easily available, i.e. can be completely exhausted during one time interval. When the soil moisture content drops below this easily depleted fraction, water use is restricted and proportional to its current availability.

A second modification of the waterbalance concerns the fact that in temperate and cold areas rainfall can be in the form of snow. In the case of snow a significant above-ground water reserve can build up outside the growing period that can supplement rainfall in determining the start and duration of the next growing season. In the case of snowfall a different waterbalance is run of which the specifications are outlined in Table 2.

A snow cover also protects crops and vegetation from killing air temperatures. This effect is simulated by taking -22°C as the killing temperature in the presence of a snow cover of 65 cm or more (based on data from Russia by V. Stolbovoy, IIASA, *pers. comm.*) and an interpolated value between -8 and -22°C for snow covers between 0 and 65 cm.

A final modification of the waterbalance refers to dormancy periods with temperatures above 0°C but below 5°C. In the absence of biological activity only bare soil evaporation can occur which is simulated by a reduced potential evapotranspiration rate (0.5 PET).

Qualifiers of the rainfall/water demand relationships during the growing period (growing period types, see Fig. 1) are retained in this approach.

Table 2 Specifications for defining the temperature and moisture-delimited growing period

Start	R > 0.5 PET or T_{MEAN} >5°C, whichever comes last
End	date when 100 mm soil moisture has been depleted after R/PET =0.5 or after T_{MEAN} <5°C, whichever comes first
Dormancy period	-8°C < T_{MEAN} < 5°C. Maximum length: 200 days
Killing temperature	T_{MEAN} = -8°C - .22°C/cm snow depth
Length	end-start -[duration dormancy period(s)]+1
Waterbalance	
1. Soil moisture depletion	- easily available fraction p of soil moisture varies in accordance with PET (Doorenbos and Kassam, 1979); - slow release fraction 1-p is depleted in proportion to its relative availability (SM/S_{max})
2. Snow waterbalance	*Snow* Is inferred when T_{MEAN} <-1°C *Stock size* snow treated as an above-ground stock that eventually is transferred to the soil as a function of S_{max} *Variations of the snow stock in winter* - continue waterbalance calculations for each month and diminish the stock with the bare soil evaporation, if any; - the full snow stock is the net accumulated stock at the end of winter; - the snow stock has no size limit as in the case of soil storage. *Stock depletion in spring* - the moisture stock from snowfall is added to the soil moisture reserve up to S_{max}. - afterwards the standard waterbalance treatment.is continued; - depletion rate of the snow stock: C x(T_{MEAN}-T_{melt}) with T_{melt}: -1°C; C: melting rate constant (5.5 mm/day/°C) (Yates, 1994)
3. Waterbalance in dormancy period	water demand = k x PET with k=0 if T_{MEAN}<0°C; k=0.5 in interval [0°C < T_{mean} <5°C]

Notes: R is rainfall; PET is potential evapotranspiration; SM is current soil moisture; S_{max} is soil moisture storage capacity.

DATABASE AND DATA PROCESSING

The revised model outlined above was run on a 30' grid database of climatic data developed by Leemans and Cramer (1991) and updated and expanded by Cramer (Cramer, 1995, *pers. comm.*). The database used contains gridded interpolated monthly values of T_{mean}, rainfall and sunshine, derived from respectively about 11,600, 18,000 and 6,000 stations. In addition, an overlay with PET calculated according to the method of Priestly and Taylor (1972) was available. The basic climatological averages used in the grid database apply to the reference period 1931-1960 and are a compilation of existing climatological databases, amongst others Müller (1982), Walter and Lieth (1960-67), UK Meteorological Office (1966-83).

To simplify programming all datasets (temperature, rainfall and potential evapotranspiration) and calculations were standardized to a daily time step through the application of quadratic spline functions. The output of the calculations is obtained by processing these daily values. It needs to be kept in mind, however, that the latter do not present physical realities since they are all based on monthly data.

PROVISIONAL RESULTS

A number of thematic maps were generated from the LGP-analysis [see Volume 2 of these proceedings]. In the following text these thematic maps are discussed in some more detail.

Thermal climate classification

The thermal climate classification map is based on the older AEZ climate classification (see Table 1) but differs by (i) the addition of *boreal* and *polar/arctic* thermal climates, and (ii) the distinction between a *continental* and an *oceanic* variant in the temperate zones. The oceanic variant is characterized by less variation between warmer and colder months than the oceanic variant. The classification units are given in Table 3. For reasons of clarity of presentation at a very small scale, the current classification is less elaborate for tropical and subtropical areas than the one followed in the previous continental assessment (Table 1), but obviously there are no objections in principle to use the same subdivisions for large map representations.

Thermal growing period zones

The map for thermal growing period zones displays, in 30-day intervals, the length of the period when mean temperatures are above 5 °C. Legend unit '365' represents a temperature-unlimited growing period throughout the year. Owing to the permissiveness of the temperature condition, some important tropical highland areas with cooler conditions (e.g. the East-African Highlands) and temperature constraints in some parts of the year are included in the latter group. To some extent this is also due to the coarse grid of the database.

Table 3 Thermal climate classification units

Division	Subdivision	Characteristics
Tropics		monthly T_{mean} > 18°C
Subtropics	- Summer rainfall	monthly T_{mean} > 5°C and at least one month T_{mean} <18°C rainfall mainly in summer
	- Winter rainfall	As above, but rainfall mainly in winter
Temperate	- Oceanic	4 or more months T_{mean} > 10°C and at least one month T_{mean} < 5°C Difference in T_{mean} between warmest and coldest month ≤ 20°C
	- Continental	As above, but difference in T_{mean} between warmest and coldest month >20°C
Boreal	- Oceanic	Less than 4 months with T_{mean} > 10°C and at least one month T_{mean} < 5°C Difference in T_{mean} between warmest and coldest month ≤ 20°C
	-Continental	As above, but difference in T_{mean} between warmest and coldest month >20°C
Polar/Arctic		Monthly T_{mean} < 10°C

Frost-free period zones

Frost-free conditions have been inferred from the average data when T_{mean} >10°C. The same remark can be made as in the section on 'thermal growing periods' for some tropical highland areas, which are included in the year-round frost-free zone as a result of data aggregation and the limited resolution of the database.

Annual precipitation

This map has been derived directly from the Cramer-Leemans database and is self-explanatory.

Annual potential evapotranspiration

Annual PET has been computed in the Cramer-Leemans database from the datasets on mean temperature and cloudiness and used without modification in the current LGP-analysis. The information contained in the corresponding suggests that the PET values computed by the Priestly-Taylor method (1972) are significantly lower than Penman-Monteith PET.

Growing period characteristics

This map displays the number and types of growing period (year-round humid, year-round dry, normal, intermediate as well as those characterized by a dormancy period). The relevance of the 'dormancy' concept is evidenced by the large areas in Europe, central and western Asia, China and north America where growing seasons have a dormancy subperiod.

The limited occurrence of the legend unit '*two or more growing periods*' to only East Africa and parts of China and Alaska has as yet not been fully analyzed. To some extent this can be explained by the inclusion of soil moisture storage in the definition of growing period and the use of strongly aggregated data. If variability of rainfall were incorporated using year-by-year data, a bimodal pattern would probably become apparent in more areas. We also suspect that the low Priestly-Taylor estimates of PET are involved.

Temperature- and moisture-delimited growing periods

The *Length of growing period zones* map displays in 30-day intervals the zones of temperature- and moisture-delimited growing period, calculated according to the model specifications outlined earlier.

Legend unit '365', which refers to a year-round growing period, has the following subunits:

- '*-365*': some days of the growing period the full evapotranspiration requirement can not be met from rainfall + soil moisture storage
- '*365*': rainfall and soil moisture storage combined are adequate throughout the year to support the full evapotranspiration demand
- '*+365*': rainfall exceeds PET throughout the year (all days humid)

In this map both temperature and moisture constraints are taken into account, but the specific nature of the limitations can at this stage only be derived by comparison with the map of thermal (temperature-delimited) growing periods. The map confirms that in the tropical and subtropical areas growing periods are restricted by moisture, whereas at higher latitudes more complex growing period patterns emerge due to the interactions between moisture and temperature constraints.

Reference permafrost zones

This map displays the reference permafrost zones, which refer to climatic conditions assumed to be conducive to the formation and maintenance of permafrost.

FUTURE DEVELOPMENTS

The present inventory is provisional. It is based on a relatively coarse gridded database (30' resolution) and on extensions to an existing methodology that require more extensive verification work.

In terms of database development, it is planned to upgrade in the short term, with the assistance of the Potsdam Institute for Climate Impact Studies (PIK), the current 30' grid climatic database by inclusion of new datasets on maximum mean temperature, minimum mean temperature, wind run and relative humidity. This will enable calculation of potential evapotranspiration according to the generally recommended Penman-Monteith method (Smith, 1992) and hopefully eliminate certain anomalies seen in some maps.

In the longer term it is planned to develop, in association with PIK and FAO's Agrometeorology Group, a 5' grid database that will include all parameters required to estimate PET according to the Penman-Monteith method. The rainfall data will also be adapted by including averages for the reference period 1961-90 and historical rainfall and number of raindays on a monthly basis. An improved climate database on a finer grid can be integrated with the FAO Soil Map of the World, which is already available on a 5' grid, and will allow to modulate growing periods in response to actual moisture storage capacities, which can make a considerable difference in growing period length (de Pauw, 1989).

In terms of methodology development there is a need to attach to the growing period quality indicators. A length-of-growing-period concept inherently assumes the equivalence of time. However, owing to considerable variations in day length and radiation regime, it is clear that a day does not have the same quality in terms of biomass productivity in every part of the globe and any time of the year. Particularly in temperate and cold regions seasonal differences in quality need to be incorporated in the LGP-modelling. Suitable quality indicators are thermal units (e.g. growing degree days above an agreed base temperature), day length itself and biomass productivity during the growing period. These parameters can all be calculated from the database.

It is also becoming clear that in the future we will no longer be able to visualize LGP as a single attribute that can be displayed in a single map and can be interpreted on its own without reference to quality and soil conditions. For global climate resource assessment LGP-analysis will continue to be a powerful instrument. The complexity of the interactions between temperature, waterbalance, soil conditions and quality of the growing period for biomass production can be modelled at a generalized level and result into a range of derived attributes (e.g. various climate classifications, LGP onsets, ends, durations, LGP modifiers, dormancy period, number and types of growing periods, quality indicators etc.). To get the maximum interpretation content out of the information generated by LGP-analysis, the various attributes can be combined and manipulated through database management systems and processed into derived thematic maps of practical significance for a large user community. This group intends to continue efforts in that direction.

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USE OF GEOGRAPHIC INFORMATION SYSTEMS IN AGRICULTURAL RESEARCH MANAGEMENT

C. Heberlein
UNEP-GRID, Arendal, Longum Park Technology Centre,
P.O. Box 1602, N-4801 Arendal, Norway

INTRODUCTION

With the increasing concern about environmental changes the role of GIS in agricultural research becomes more important. Geographic analysis can provide a considerable input to research where the spatial dimension is relevant. Applications range from service functions such as collecting and providing geo-referenced data to modelling of crop yields, identification of key areas of population pressure, biodiversity conservation and complicated impact assessment analyses.

With the UNEP/CGIAR joint project an attempt is made to concert common efforts, to share knowledge and information in order to make optimal use of existing capacities and building up new ones.

The main objective of the UNEP/CGIAR project for the 'Use of Geographic Information Systems in Agricultural Research Management' is to establish long-term cooperative links between UNEP and the CGIAR system to effectively integrate natural resource and socio-economic information into agricultural research activities. The following 3 areas are covered by the project activities:

(1) Networking
- Establish and maintain links to cooperating institutions, international organizations and donors.
- Coordinate and monitor the capacity and production activities.
- Hold project initialization and follow-up workshops to discuss the activities with representatives from CGIAR and UNEP.

(2) Institutional Development
- Define requirements and mechanisms for the transfer of data and information from UNEP to IARCs and between IARCs; set up mechanisms to serve these needs, building on existing UNEP and CGIAR facilities.
- Ensure that formal and informal training efforts are in place for IARC management and staff in GIS technology and its application to sustainable agricultural development.

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- Develop methodologies and implement pilot projects to demonstrate the utility of the use of the data sets, in conjunction with the use of GIS technology for research and planning purposes in the CG centres.
- Facilitate and encourage technology transfer among Centres and the UNEP network, GIS vendors and external institutions with suitable expertise through formal and informal secondments, meetings, and workshops, and undertaking cooperative projects.

(3) Production

- Implementation project plans for compilation, review and distribution of priority data sets, such as basic topographical data, climate, population soils and others. The data sets are compiled by the institutions best suitable for the tasks under supervision of the project management under subcontract agreements.

UNEP/CGIAR PROJECT OUTPUTS

Project products include the following:

- High quality natural resource and socio-economic data sets at global, regional, national and project levels taylor-made for IARC's available on a public-domain basis.
- An effective functional information network and distribution mechanism for data and information to the various user groups (governmental organizations, research institutions, the general public, decision-makers).
- Documented methods and technologies for the production and quality assurance of such data sets.
- Staff in IARCs trained and experienced in the effective utilisation of GIS technology for sustainable agriculture.
- Dissemination of advances in GIS utilisation for agricultural research in published journals and reports.
- Use of integrated data sets for planing and execution of research for sustainable agricultural development.

PROJECT ACTIVITIES AND OUTPUTS FOR 1995

The set of activities presented here are based on the steering committee meeting following-up Arendal II workshop (Martin, 1995):

(1) Management and Networking

The following tools are envisaged to enable networking between CG, UNEP and the outside world:

- Electronic Newsletter (monthly): A newsletter on the current developments of the project as well as on the activities in the centres will be distributed to the GRID and CG centres on a monthly basis. This news bulletin will be edited by the project secretariat at GRID-Arendal.
- Published Newsletter (biannual): A more comprehensive newsletter, informing on subject matters relevant to the project (spatial analysis, information for decision-making, networking, etc.) will be issued twice a year. Audience of this newsletter will go beyond

the core CG and UNEP groups. GRID-Arendal will be responsible for this newsletter requiring close cooperation and participation from the centres.

- Executive Brochure: A brochure giving an easily understandable overview of the project will also be prepared. The Steering committee will provide inputs on the broader issues relevant to the project.

(2) Institutional Development

There is a clear need for institutional development related to GIS in the CG system. There are however some sensitivities around a systematic and centralized approach in assessing the CG centres capacities and needs related to spatial data and information management. GRID-Arendal will design and initiate requirement studies as a tool to find out the needs of the individual centres.

- ToR requirement studies: GRID-Arendal will develop standard Terms of References for requirement studies. These studies will then be conducted by persons at the centres in close cooperation with the project secretariat (if possible on visits to the centres).
- Visit of priority centres: In conjunction with the requirement studies and also database activities, priority centres will be visited by project staff. Priority can be seen both in terms of strategic importance (CIAT, ICARDA, IFPRI, IRRI, ISNAR) and on the basis of high-level request from the centre.
- Priority proposals: A direct outcome of the requirement studies and the centre's visit will be concrete project proposals for institutional development to be presented to donors.

(3) Data set production

This element of the project will focus on three items:

- Metadatabase: Design and implement CG-wide Metadatabase (MDB catalogue) listing existing spatial data sets. The MDB will be populated both by the centres and by the project (in conjunction with centres visits).
- Make available existing data sets: Depending on the needs, existing data sets will be collected and made available to the centres. This activity requires closer cooperation with data centres of excellence (GRID nodes, USDA, DMA, WCMC, etc.). If there is a demand these existing data sets could also be published on CD-ROM.
- Value-add and make available priority data: As an outcome of the workshop, data set production proposals will be handed to GRID-Arendal. A mechanism will be implemented to appraise these proposals, emphasis has to be put on relevance to the CG system's application needs. Production will be subcontracted. A proposal on continental population data has already been submitted.

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PART II

REACHING USER GROUPS

ETHNOPEDOLOGICAL STUDIES IN MEXICO

C.A. Ortiz-Solorio
Programa de Edafologia, Instituto de Recursos Naturales, Colegio de Postgraduados, Carr. Mexico-Texcoco, km 35.5, 56230 Montecillo, Mexico.

Research on ethno-edaphology started 15 years ago in Mexico. The main aim was to understand the perceptions, concepts and theories of soil of farmers. Early work involved a historical approach and study of soil folk-taxonomy structures. Subsequently, it was assessed how the knowledge of farmers could be used for soil mapping and land suitability assessments.

In ancient Mexico, the main facts of science and life were recorded in pictorial manuscripts with glyphic writing. Nowadays, it is still possible to find documentary evidence of land survey maps made by the Aztecs in the 16th century. The traditional soil (land) nomenclature has been preserved by the rural people. Several ethnical groups have conserved the original soil names while other groups have translated the original names into Spanish.

Manuscripts from the Aztecs, Mayas and Otomies suggest that folk soil perceptions are taxonomically structured, with three hierarchical levels. Many soil types are labelled by what appear to be descriptive phrases denoting an unitary attribute such as ' black' or 'sand', but they are multidimensional, generic level taxa.

The process of generating knowledge of land conditions by farmers, is actually based on their observations and comparison of different land classes over time, that is through monitoring. This is probably the most important difference with our current, technical knowledge.

The rural land (soil) classification has a practical use in that land classes are related with: (1) adapted crops; (2) land management; (3) weeds; (4) land reclamation; and, (5) non-rural land uses. Another aspect in this research has been the possibility of making maps of land classes that take into account the local knowledge of the rural people.

Early maps of land classes were made to 'ejido' level (small areas, less than 1,000 ha), showing great detail (scale between 1:5,000 and 1:10,000). Subsequent work involved the production of maps at the regional level (more than 5,000 ha), using aerial photography.

Recently, attention has been focused on (1) use of modern techniques (databases, automatic cartography and GIS) for land classification, and (2) the application of agricultural knowledge of good farmers into an interpretative land classification scheme, using multivariate methods such as discriminant analysis.

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The current research has shown that it is possible to combine knowledge of rural people with modern scientific techniques in order to develop a new methodology for appraising soil and land suitability. Such an approach can be useful in identifying and solving agricultural problems in developing countries.

SPECIFIC USER GROUPS OF NASREC PROJECT AND THEIR ROLE IN SUSTAINABLE AGRICULTURE IN INDIA

T. Varghese[1], S. Natarajan[2], M.S. Badrinath[3] and M.S. Iyer[1]

University Soil Reference Collections and Database Project (USREC), INDIA

1 Kerala Agricultural University (KAU), Vellayani

2 Tamil Nadu Agricultural University (TNAU), Coimbatore

3 University of Agricultural Sciences (UAS), Bangalore

INTRODUCTION

Soil resources of the planet Earth are finite and the number of people the earth has to support continues to grow rapidly. Agricultural development is thus confronted with a problem that will soon become critical, unless population growth is curbed. Efforts of the agricultural sector to respond to this challenge have been ongoing during the past 6-7 decades in many developed countries by mounting massive research involving huge funds. However, in many developing countries such programmes, launched recently, could not yield fruitful results.

With the introduction of high yielding varieties, the productivity of food crops in many states of India increased significantly during the late 1970s and early 1980s. Now, however, declining yields are reported for many parts of India. With respect to perennials and tree crops, the trend is most alarming. The greater stress on genocentric measures and lack of stress on pedocentric programmes may be cited as a major reason for this phenomenon. This state of affairs shows the need for identifying soil-related constraints of production and the necessity of addressing them in a rational and scientific manner. A major lacuna is the lack of reliable and comprehensive information about the soils with respect to their potential and limitations for primary users.

The National Soil Reference Collections and Database (NASREC) project, in the form of the University Soil Reference Collections (USREC) launched in India during November 1992, is an effective programme for soil based agro-technology transfer to achieve sustainable agricultural development.

RESULTS AND ACHIEVEMENTS

The USREC programme is progressing in three State Agricultural Universities (SAU), viz. Kerala Agricultural University (KAU), Tamil Nadu Agricultural University (TNAU) and the University of Agricultural Sciences at Bangalore (UASB). The results and achievements of the USREC project in India are summarized in Table 1.

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The user groups, identified in India, are as follows: (a) scientists, for training, reference and correlation purposes; (b) students of Soil Science and Agronomy departments; (c) extension workers of the Krishi Vigyan Kendras and other development departments; (d) scientific staff of the R&D institutes of the State Committee on Science, Technology and Environment; (e) students of Geology, Geography Biology and Environment disciplines of traditional Universities; (f) staff of State Department of Engineering, Irrigation and Forestry; (g) workers of People's Science Movements like Sastra Sahitya Parishad and Environmental Movements like Nature Clubs and World Wide Fund for Nature; (h) students of nearby Vocational Higher Secondary schools in the three States.

Table 1 Overview of results and achievements of the USREC project, India

Item of work	KAU	TNAU	UASB
Ecological zones monolith collection†	5 (16)	7 (15)	10 (15)
Soil exposition	Jan. 1996	Oct. 1995	Apr. 1995
Soil Briefs:			
English	5	5	6
Local language	5	7	10
Country Report of India	<-------------	in progress	------------>

† Figure in the parenthesis indicates the number of soil monoliths.

The main user groups expected to visit the Soil Exposition in a year are shown in Table 2. Agricultural scientists, extension service personnel and planners are the main users of the exposition. They get acquainted with the potential and limitations of the major soils of their state. Since the ultimate target group with respect to agriculture is the farmers, it is imperative that this information reaches the farmers in their own language. In order to reach this objective, a concerted effort is needed in which results of research are integrated with extension activities for soil based agro-technology transfer.

Table 2 Main user groups of soil exposition

	Farmers	Planners	Students	Others
KAU, Vellayani	3000	25	2000	250
TNAU, Coimbatore	3000	30	1000	150
UAS, Bangalore	2000	20	500	100

CONCLUSIONS

Soil information is of value not only to soil scientists but also to other users who do not understand the specific, technical language. Hence user specific information has to be generated in a common language, using a popular terminology. The USREC project has to take into account this aspect when making proposals for sustainable agricultural development. The results of the NASREC project are vital to the country's planning process with respect to land and soils.

The USREC project is now active in three SAU's and there is a need for making available its expertise to other SAU scientists in India. A regional centre in India may become a nodal point to cater for the needs of future USREC activities.

ESTABLISHMENT AND ACTIVITIES OF THE AMCEN'S SOILS AND FERTILIZERS NETWORK

R.D. Asiamah
Soil Research Institute, Private Post Bag, Academy Post Office, Kwadaso - Kumasi, Ghana

INTRODUCTION

The Soils and Fertilizers Network (SOFERNET) of the African Ministerial Conference on the Environment (AMCEN) was established in December, 1985 to bring together African Soil Scientists to solve the problems of environmental degradation, biodiversity and food security of the continent through technical cooperation among the Scientists and Institutions.

The African Ministerial Conference on the Environment (AMCEN) organised by the United Nations Environment Programme (UNEP) in cooperation with the United Nations Economic Commission for Africa (ECA) and the Organisation of African Unit (OAU) met in Cairo, Egypt for the first time from 16 to 18 December, 1985. A total of 147 delegates from 41 African States attended the Conference.

Observers from 15 Non-African States including the U.K., USA, Germany and Japan also attended the Conference. Twelve United Nations bodies and specialised agencies including FAO, UNDP, ECA, UNESCO, WHO and World Bank also sent observers.

The Resolution adopted by the Conference under the Cairo Programme for African Cooperation included the establishment of 8 Regional Technical Cooperation Networks on environment and eco-development.

The Conference in resolving to establish the Technical Cooperation networks decided:

(1) That co-operation between the technical and research institutions of African States should be strengthened and developed through the exchange of information and the conduct of the basic studies and scientific research necessary for the environmentally sound utilization of African resources;

(2) To strengthen and develop technical co-operation among African countries through the development of horizontal scientific and technical links between national departments in specific areas;

(3) Further decided for that purpose to establish or strengthen eight specialized regional networks, in the fields of environmental monitoring, climatology, soils and fertilizers, water resources, energy, genetic resources, science and technology and education and training;

(4) Also decided that the networks should concentrate their efforts in the first place on:
   - The adoption of comprehensive soil and water development and conservation measures in irrigated and rain-fed agricultural areas in Africa;

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- The improvement and protection of rangelands and the introduction of better rangeland, livestock and wildlife management in Africa;
- Protection of the existing vegetation and replanting of denuded areas in Africa;
- Reafforestation and the use of alternative energy sources means of combating desertification.

TERMS OF REFERENCE FOR THE REGIONAL NETWORKS

The following factors were taken into account in the establishment of the eight regional networks:

(a) Availability of infrastructural facilities such as existing institutions, e.g. sub-regional environment groups, economic communities development organizations, etc.;
(b) Geographical distribution of the co-ordination units of the networks;
(c) Encourage the application of scientific information in the conservation of soils and in reducing the loss of productive agricultural and forest land to other purposes;
(d) Monitor changes in soil quality and in land use;
(e) Asses local fertilizer resources and advise on their appropriate use;
(f) Seek solution at national, sub-regional and regional levels to the problems of large-scale production of cheap local fertilizers in Africa.

Criteria for selection of national institute membership are:

(a) A government soil survey department (Ministry of Agriculture/Natural Resources);
(b) A government soil conservation department;
(c) A soil research institute or research unit within an agricultural research institution;
(d) An unit for fertilizer studies in an industrial research/development institution;
(e) A land-use planning unit within the national planning authority;
(f) A department of soil sciences in an university school or agriculture.

Criteria for the location of the regional network co-ordination unit are:

(a) The unit should be located within a recognized centre or institution dealing with soil conservation/management in Africa, preferably in a country affected by acute soil erosion problems;
(b) In addition to meeting the requirements for membership in the network, the location of the unit should have access to institutions/departments dealing with fertilizer application.

LOCATION OF THE SOFERNET

At the first meeting of the Conference Bureau in Nairobi in October 1986, decisions were taken on the location of the Network. Out of the 33 institutions from 22 African Countries that applied to host the SOFERNET, the Conference Bureau selected the Soil Research Institute of Ghana at Kwadaso-Kumasi as its Regional Coordinating Unit (Host Institute).

The Soil Research Institute was established in 1945. Until Ghana's independence in 1957, the Institute was the centre of soil research activities for the British Colonies. The Institute is presently one of the 18 research institutes, centres and units of the Council for Scientific and Industrial Research of Ghana. The Institute has five main Research Divisions of: (a) Soil

Genesis, Survey and Classification; (b) Soil Chemistry and Mineralogy; (c) Soil Fertility; (d) Soil and Water Management; and (e) Soil Microbiology. It has a Research Centre in Accra that caters for research and laboratory analyses in Southern parts of Ghana and for laboratory and map drawing activities from outside Ghana. Research stations of the Institute are located in all the agro-ecological zones of the Country. The Soil Research Institute of Ghana has a staff strength of 441 out of which 35 are of research grades.

MANAGEMENT OF SOFERNET

The Network is managed externally by the Management and Planning Group (MPG). The Group consists of eminent soil scientists selected mostly by their governments to be member of the Group. Presently, the following countries representatives serve on the (MPG): Egypt (Dr. M.A. El-Nahal); Nigeria (Prof. A.A. Agboola); Senegal (Mmc. R.D. Fall); Sudan (Dr. Mohammed G. Yunis); Ghana (E.A. Dennis); Burundi (-); Zambia (Dr. V.R.N. Chinene); and the Director of SOFERNET. The alternate members are: Algeria; Cape Verde; Ethiopia; Mozambique; Sierra Leone; and Zaire.

Internally, SOFERNET, is managed by the Management Board of the Regional Coordinating Unit (Soil Research Institute). This Board is made up of eminent Soil Scientists, Government representatives, farmers industrialists and other user agencies.

SOFERNET has been run on funds from UNEP and Ghana Government. Salaries and allowances of staff of SOFERNET Secretariat are provided by the Government of Ghana. The Network also uses facilities and staff of the Soil Research Institute for any of its works. UNEP has been providing funds for the projects as well as meetings of the MPG.

ACTIVITIES OF SOFERNET

Activities of the SOFERNET include:

(1) Secretariat:

The Secretariat of SOFERNET has been set up in the building of the Soil Research Institute. It is presently adequately staffed and equipped to enable it carry out its duties effectively. The permanent Office Complex is under construction and will be completed in 1996.

(2) Seminars, Workshops and Meetings:

A number of these have been organised or attended by the Network towards achieving its aims, among which are:

- Seminar on Soil Conservation strategy for Africa in Accra - August 1989.
- Training Seminar of the FAO - UNESCO Soil Legend of the Soil Map of the World in Kumasi - December 1990.
- Training workshop on Soil and Water Management at Jenoi, Gambia - April 1991.
- Workshops on sources, usage and policy of fertilizers in Africa, Dakar - December 1993.
- International Workshop on Degradation Process and Land-use problems in Tropical Regions, Nairobi - 1991.
- MPG Meetings - Accra, Kampala, Nairobi and Dakar.

(3) Publications/reports by network:

- Directory of expert and Institutions on Soil and fertilizers in Africa.
- Report on workshop on Soil and Water Management.
- Report on Workshop on the Sources Usage and policy on Fertilizers in Africa.
- Report on Seminar on Soil Conservation Strategy for Africa.
- Report on Workshop on the FAO-UNESCO Legend of the Soil Map of the World.
- Soil Degradation and Conservation in West Africa.
- SOFERNET Annual Reports.
- SOFERNET Newsletter.

(4) On-going project

A project started on preparing a Manual on Soil Conservation started two years ago. The main chapters have been written. The MPG meeting in Dakar decided that contributions must come from the various agro-ecological zones in Africa. Copies were sent to MPG members and some experts for their contributions to complete the project. The project is to be completed by the end of the year.

CONSTRAINTS

The main constraints facing the running of the Network are funding and lack of Communication between the Secretariat and experts and institutions.

SOIL INFORMATION SHARING IN THE PHILIPPINES

R.N. Concepcion
Bureau of Soils and Water Management, Soils Research and Development Center
Elliptical Road, Quezon City, Philippines.

INTRODUCTION

The Bureau of Soils and Water Management (BSWM) during the last 20 years has generated soil and land use information for use in the development of a land use information system and to promote a better understanding of the uses of soil information and soil technology in the improvement of soil and land productivity in the Philippines. In 1990, the BSWM, through the JICA Grant and Technology Cooperation Project, acquired a complete set of laboratory and computer facilities including video facilities. Under this cooperation, the soil and land use surveys were accelerated and a study for the entire country was completed. Important soil and land use information is now on display at the Centre's Soil Museum.

RESULTS AND ACHIEVEMENTS

Soils sampled and described

Soil samples were collected from two major ecological domains, as follows:

- Lowland Ecological Domain (6 soil profiles): Typic Ustipsamment (1); Aquic Eutropept (2); Typic Eutropept (1); Typic Haplustalf (1); and Udorthentic Pellusterts (1).
- Hilly-land Domain (5 soil profiles): Oxic Dystropept (1); Typic Eutropept (1); Typic Haplustalf (2); Ultic Haplustalf (1).

Additional monoliths and soil samples are being collected for display at the Center's Soil Museum.

Exposition status

The exposition was designed to meet the interest and discussion focus of various groups of visitors and trainees. Together with the soil profile exhibition, samples of soils, land use publications and thematic maps are on display. The thematic maps on display in the Soil Museum include: (a) Lahar flows and eruption-affected areas near Mount Pinatubo; (b) Soil conservation guided farming; and (c) Small Water Impounding Projects.

Currently, the soil museum contains various banner programs of the Department of Agriculture. Highlighted are graphics and posters that depict the Medium Term Agricultural Development Plans as well as maps of Key Production Areas that advocate planting of right the crop(s) in the right location.

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Main users

The Bureau of Soil of the Soil Research and Development Center is a member of the Science Community in Quezon City. This community encourages regular visits by grade schools in the city and nearby cities. The anticipated users of the exposition are students, farmers, politicians, planners, teachers of environmental sciences, agriculturists and primary schools.

METHODOLOGIES, DATABASE AND APPLICATION PROGRAMS

The BSWM has developed a National Land Evaluation System which is based on soil-landscape classification and information. The soil units are classified according to the USDA Soil Taxonomy.

The Center has a pool of computer programmers who work with soil scientists in the development of the Philippine Soil Information System (PHIILSIS). A soil taxonomic map was produced at the scale of 1:500,000 using ARC/INFO. PHIILSIS is now being linked to the Fertility Classification (FCC) using SRDC-BSWM's computer system. The present IBM mainframe is being used to develop a Soil Productivity Capability Classification (SPCC) and Geostatistics. The Center has likewise developed the computerized Land Resource Information System (LARIS) which is now being used by land use planners in the Province. The soil database now forms an important component in land use planning, soil erosion studies, soil research designs and formulation, and fertilizer distribution and use programs.

Soil information collected for all provinces and islands in the country was published in the form of reports and maps. A standard national legend for soil resources has been completed and there are efforts to digitize soil and land use maps for the Centre's GIS database.

The BSWM-Soil Research and Development Center has been conducting research on various aspects of soil productivity improvement and soil use planning. Recently concluded research activities include an assessment of the 'inherent fertility of soils' and of the 'status of human-induced soil degradation' in the Philippines.

CONCLUSIONS

The Center was able to develop an integrated database of soil and soilscapes providing the primary building blocks for land use interpretations. Soil-landscape units called Land Management Units (LMU), were considered in the Physical Planning Document for the Philippines. The database is now accepted as the primary source of information for environmental and land use planning in the country. The Center's database is now used in the formulation of important legislation (e.g. Network of Protected Areas in Agriculture).

Priorities for future work include: (a) Digitization of all provincial soil maps in the country; (b) Development and utilization of the soil productivity capability classification; and, (c) Nation wide production of maps and digital data.

PART III

PHYSICAL LAND QUALITIES

SUMMARY OF SOIL CONSERVATION RESEARCH ACTIVITIES IN ETHIOPIA

S. Sertsu

National Soil Service Project, Department of Watershed Development and Landuse

P.O.Box 147, Addis Abeba, Ethiopia

Ethiopia, with a land area of about 1.1 million km^2 and a population of 53 million, is an old agrarian country. The diverse physiographic and climatic conditions have endowed the nation with the potential for growing many types of agricultural crops. The highlands, which occur above 1500 m.a.s.l., cover about 43% of the total land area (Hurni, 1988). They receive sufficient rainfall and support more than 85% of the population and 60% of the livestock. The northern and central highlands, which are predominantly mountainous with rugged topography, have been exposed to serious water erosion, mainly due to poor farming practices which date back from several centuries. The remnants of the natural vegetation show that the majority of these highlands was once covered with dense forest. They were gradually deforested as agriculture extended southwards as the population grew. At present, almost no natural forest remains and most of the mountains and hills are extremely degraded.

Due to excessive runoff, mainly on sloping land and terrain, and as a result of insufficient traditional soil conservation practices more than 50 % of all cropped land in Ethiopia is seriously eroded. This degradation seems to continue at an alarming rate. As a case in point, soil losses of 33 t ha^{-1} yr^{-1} have been reported in Tigrai region while in the central highlands soil loss was estimated to be 17 million tons or the equivalent of 12 ha of one meter, deep fertile land in 1975 (TRDS, 1975). Consequently, very low and declining crop yields and expanding desertification are causing recurrent famine. In order to counteract soil loss through runoff, extensive physical conservation practices (mainly stone bund terrace techniques) were launched by the government some 30 years ago through food for work programmes. Although an extensive area has been covered through this programme, the outcome was not satisfactory because of reluctance of farmers in accepting the technologies and their lack of interest in maintaining the conservation structures.

The severe soil degradation (erosion) problem required immediate intervention in terms of conservation measures and rehabilitation activities. Realizing the importance of research in generating data that are critical to the development of effective conservation measures, a Soil Conservation Research Project (SCRP) was established in 1981 by the Institute of Geography of the University of Berne and the Government of Ethiopia. The SCRP has established a number

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of research stations and has been engaged in the compilation of soil conservation related data during the past 14 years (NSSP, 1993; SCRP, 1994).

The SCRP was established with a broad objective of supporting through research, experimentation and training the national soil conservation efforts of the country. During the last four phases of three years each, the immediate objectives of the project were:

(a) monitoring of soil erosion damage, soil loss, runoff and landuse and production;
(b) development of viable models of soil loss, measure and productivity;
(c) development of acceptable conservation measures and approaches;
(d) training of research and technical personnel.

To test the effectiveness of physical soil conservation measures, experiments were conducted at seven research sites on farmers fields in regions representing the major agro-ecological zones of the country. The treatments were: level contour bunds; graded contour bunds; level fanya-juu; graded fanya-juu; grass strips; and a control plot without treatment. The effectiveness of the various soil conservation treatments in reducing soil erosion was assessed in comparison with the control treatment, the soil loss of which was set at 100%. The average soil loss reduction at the seven experimental sites for each treatment which was calculated in comparison with the control plot. The figures as reported by Grunder (1988) are shown in Table 1 which shows that soil conservation practices, if properly implemented, can be very effective in counteracting soil erosion. Also by reducing the loss of nutrients, present in the soil or applied with chemical fertilizers, soil productivity can be increased.

Table 1 Soil conservation effects of various treatment measures on soil loss

Treatment	soil-loss reduction (%)
control	0
graded bunds	32
graded fanya-juu	54
grass strips	66
level bunds	80
level fanya-juu	89

Although the soil and water conservation efforts undertaken in Ethiopia can be considered tremendous in view of the financial, material and personnel inputs made, they still do not suffice to combat land degradation effectively. In order to improve the sustainable management of soil and water resources, a considerable input through farmers participatory and adaptive research is intended to be implemented in the future. This is done to support institutions, organizations and individual farmers in their efforts to increase the productivity of land. Future plans include strengthening of orientation towards integrated technologies, which include production aspects and institutional and economic support from out-side the farming communities, as well as broadening of research objectives to allow such multi-level intervention approaches (SCRP, 1993).

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CATEGORIZATION OF DEGRADED LANDS USING SATELLITE DATA - A CASE STUDY FOR INDIA

S. Natarajan, C. Palaniswami, R. Krishan and Rani Perumal
Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore 641 003, India.

INTRODUCTION

Land degradation occurs due to continuous removal of soil by erosion, salinity and alkalinity, mining and deforestation activities. Most of these degraded lands are distributed in Tamil Nadu, Andhra Pradesh, Karnataka, Maharastra and Madhya Pradesh States in India (Gawande, 1990). The present study was conducted in Dharmapuri district of Tamil Nadu which has a total geographical area of 961,589 hectares. Space borne multi-spectral data by virtue of synoptic repetitive coverage in narrow and discrete bands of electromagnetic spectrum holds very good promise for mapping and categorising the degraded lands in a time and cost effective manner with reasonably accepted accuracy. Hence, multidate satellite imageries of Indian Remote Sensing Satellite (False Colour Composite) with 1:250,000 scale were used in the present study.

MAPPING APPROACH

The study area was differentiated into different mapping units based on land form (terrain) and terrain components, similar to the SOTER mapping approach (Van Engelen and Pulles, 1991). The differentiation of mapping units was done by visual interpretation of satellite imageries of 1:250,000 scale using the image interpretation keys such as tone, texture, structure, shape, pattern, association and also by referring Survey of India toposheets of 1:250,000 scale. Sample strips were chosen covering most of the mapping units and field investigation was conducted to find out the soil and land use composition, status and extent of land degradation and the causative factors for land degradation. After the completion of field work, the final map of the study area was prepared with the legend showing the terrain component, soil and land use composition and kind and status of land degradation. From this map, the degraded land map was abstracted and the extent of area under different categories of degraded lands was arrived.

RESULTS

The categorization of degraded lands was done following the procedure adopted by Oldeman *et al.* (1991). The soil degradation types include loss of topsoil by water erosion, loss of nutrients/organic matter, salinization by chemical deterioration, and waterlogging by physical

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deterioration. Four degree classes (light, moderate, strong and extreme) and five extent classes (infrequent, common, frequent and dominant) of degradation types were identified (Table 2). The causative factors for land degradation and their extent are given in Table 1.

Table 1 Causative factors of land degradation and extent

Causative factors	Area (ha)
Deforestation	17,594
Agricultural mismanagement	527,840
Over-exploitation for domestic use	237,528

Table 2 Land degradation for Dharmapuri district (ha)

Type	Light	Moderate	Strong	Extreme	Total
Loss of top soil by erosion	133,786	301,019	267,572	66,893	769,270
Loss of nutrients/org. matter	-	-	128,211	256,423	384,635
Salination -	4,077	6,615	-	10,692	
Waterlogging -	3,000	-	-	3,000	

CONCLUSION

Satellite imageries on 1:250,000 scale are useful for preparing small scale maps showing the kind, extent and causative factors of land degradation. Such maps are useful for regional level planning and development. However for operational level planning, large scale satellite data or aerial photographs need to be employed.

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SUMMARY OF SOIL EROSION RESEARCH IN LESOTHO

M. Williams
Ministry of Natural Resources, Department of Science and Technology
Private Bag A23, Maseru 100, Lesotho

INTRODUCTION

'Reports show that 0.5% of the total area of Lesotho has been irreparably damaged by erosion and that six per cent of its soils are highly vulnerable to water erosion. Of this six percent, 20% are soils in the lowlands' (Schmitz and Rooyani, 1987).

In Lesotho, about 400,000 ha of land are suitable for cultivation and all of it is used for that purpose. One quarter of that area is so badly eroded that it should not be cultivated (Schmitz and Rooyani, 1987). Extensive soil loss is seen on the lowlands and evidence of water erosion is widespread in Lesotho in the form of rain splash, sheet erosion and by mass movement which is quite common in the mountains, while gully erosion is high in the lowlands.

RESEARCH ACTIVITIES

To address the erosion problem researches have been done on magnitude and causes of soil and nutrient losses from different land uses in Lesotho. The following are among the topics researched on:

(1) Gully Erosion in Lesotho Lowland — a geomorphological study of interactions between extrinsic and intrinsic variables (Nordström, 1988). The aims of this study were to:
  - determine the present state of gully erosion in eight selected catchments and identify the ones that are severely eroded;
  - determine the effects of different variables on gully erosion, for example climate, soils, vegetation and human activities;
  - analyze and explain the differences in gully erosion and development between the selected areas.

(2) Soil Erosion and Reservoir Sedimentation in Lesotho (Chakela, 1981). The purpose of the study was to document the types, rates and extent of soil erosion and sedimentation within three chosen catchments in Lesotho.

(3) Monitoring Soil Loss at Different Observation Levels — Case studies of Soil Erosion in the Lesotho Lowlands (Strömquist, 1990). The report is a summary of results of previous joint Swedish-Lesotho research on soil erosion carried out in collaboration with the Department of Geography, the National University of Lesotho. The research included

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studies of sediment source areas, sediment routing as well as studies of the spatial distribution of different erosion types and their rates of operation.

(4) An Evaluation of the SPOT Imagery Potential for Land Resources Inventories and Planning Lesotho — A Lesotho case study (Strömquist *et al.*, 1988). The aim of the study was to assess the extent to which relevant information concerning basic planning components such as geology, soils, hydrography, current land-use, roads can be derived from the analysis of satellite imagery by visual interpretation. The studies included land evaluation, soil mapping and soil erosion mapping.

(5) Sediment Sources, Sediment Transfer in a small Lesotho Catchment — A pilot study of the spatial distribution of erosion features and their variation with time and climate (Strömquist *et al.*, 1985). The study focused on the erosion and sediment transport processes and their evidence in landforms and sediments in a small drainage basin in southern Lesotho.

(6) Soil Erosion and Nutrient Loss Studies in the southern Lesotho Lowlands (Rydgren, 1993). The study was part of an inter-disciplinary effort comprising soil loss, rainfall, economic and financial aspects, nutrient loss and soil fertility loss, and social aspects. The results reported in this research dealt primarily with the physical aspects of the research.

(7) A Multi-level Approach to Soil Erosion Surveys — Examples from Lesotho lowlands (Strömquist, 1993; Chakele and Stocking, 1988; Stocking *et al.*, 1988). This study was a study on soil erosion and sediment dynamics. The major aim was to increase knowledge of how to identify the most important sediment sources, sediment transport routes and temporary sediment storage areas in relation to landforms because geomorphological units are easily identified. The purpose was to find ways of making future conservation works more cost-efficient by concentrating the initial work on the most sensitive land units. The multi-level surveys were categorized into three levels:
   - Regional observation level: These included erosion and erosion hazard mapping at national scale based on the studies of satellite imagery, air photo interpretation and compilation of existing data on topography, rainfall, land use and soil erodibility.
   - Local observation level: Surveys of erosion and sedimentation at catchment level based on air photo interpretation and field measurements of sediment source areas, erosion processes, land use and conservation practices.
   - Field observation level: Observation of sediment routing in mini-catchments or at plot-size in order to analyze the importance of micro-relief, vegetation cover and land use.

(8) Environmental Impacts of Soil Erosion and Soil Conservation — A Lesotho case study (Rydgren, 1993). In this study, the magnitude of and causes of soil and nutrient losses from different land uses in southern Lesotho Lowlands were investigated.

SUMMARY OF RESEARCH RESULTS

The results show that the factors contributing to erosion in Lesotho are complex, both extrinsic and intrinsic. The findings indicate that rates of reservoir sedimentation vary from 0.0-25 cm m^{-2} yr^{-1} with suspended sediment yields of 0.0-1800 ton km^{-2} yr^{-1} (Chakela, 1981).

Although erosion processes vary in intensity from one landform to another, there is a predominance of surface wash (sheet erosion) on uncultivated mountain slopes, while on cultivated mountain slopes, foothills and dissected plains in the lowlands formation of rills and gullies are the major forms or erosion. Mass movements, gully erosion, wind erosion, sheet and splash erosion occur on escarpments and overgrazed areas. Gully, piping and channel erosion are more predominant along the major streams and rivers and the valley-side slopes nearest the main streams.

The sediment deposition occurs at the following locations:

(1) Foot of scree slopes where infertile sediments often flood the bottom land.

(2) On gently sloping sections of the main stream channels and major gullies.

(3) Where gully-side slopes have fallen into gullies or streams.

Table 1 Erosion studies at different levels in Lesotho

Conservation level	Year	Study objective
Regional level:		
Strömquist *et al.*	1986	Satellite mapping of regional soil erosion intensity (Landsat-based) in the Lesotho lowlands.
Strömquist *et al.*	1988	Satellite mapping of regional soil erosion intensity (Spot-based) in the Maseru area.
Chakela and Stocking	1988	Erosion hazard mapping of Lesotho.
Local level:		
Chakela	1974	Studies of sediment transport and reservoir
	1981	Sedimentation in selected catchment areas in the Lesotho lowlands.
Strömquist *et al.*	1985	Spatial and temporal variation in sheet and
Lunden *et al.*	1986	gully erosion.
Nordstrom	1986, 1988	Spatial and temporal variation in gully development
Schmitz	1980, 1984,1987	Land systems and correlation of landforms, geology and active processes.
Gerding	1984	Practical application of Schmitz's studies for land-use planning.
Field level:		
Rydgren	1985, 1986,1989	Catchment and plot studies of soil loss in a soil conservation area.
Kulander	1986	Wash erosion studies in relation to vegetation type and cover by wash trap.
Kulander	1986	Studies of sediment sources, routing and storage on fields in mini-catchment areas.

Results from the gully erosion studies show that cycles of gully erosion in the lowlands of Lesotho are highly local; 'areas within the same region may show entirely different erosion rates and gully extent' (Nordstrom, 1988). The intrinsic and extrinsic variables of gully erosion were analyzed, and it was concluded that it is the overall effect of several stress factors that cause the threshold of intense gully erosion to be transgressed. These are factors like climate i.e. potential erosion proportional to rainfall, soil type where duplex soils are very susceptible to piping and gully erosion, and extrinsic variables like inappropriate land-use. The study further revealed that slope did not have direct impact no gully erosion since gullies may occur even on flat areas and where depth of erodible material to the bedrock is limited (shallow soils) (Nordstrom, 1988).

In soil erosion and nutrient loss studies, the results show that rainfall is very unpredictable within a short period of the research, hence the soil loss results very much from the average but, nevertheless, there is significant indication of soil loss and loss of soil nutrients. The cost of replacement of the lost nutrients were calculated based on the figures of the lost nutrients (Burnt, 1993).

A summary of erosion surveys done in Lesotho lowlands has also been made by Strömquist (1993). This summary shows the significance of multi-level study approach because it provides the inside into the relations between geology, geomorphology, land use, and land degradation through use of several observation levels linked by common field control areas and reference data (Table 1). The approach also provides a full understanding of the landscape, its conservation potential and sensitivity to recent environmental change. The results the studies at regional level show that the national erosion pattern is more related to history of land-use and land-use factors rather than to the physical parameters.

The catchment or local level surveys reveal the effects of the physical factors (geology, topography and soils) on erosion processes and sediment transport, and the relation between human impact (land use) and natural process.

Studies at the field scale provide quantitative data on impacts of conservation efforts, land use and vegetation cover which can be used to identify the land units which are important indicators of the processes.

The combination of the three observation levels provides an enhanced understanding of the human influence and natural processes, compared to single level approach (Strömquist 1993).

CONCLUSION

The general conclusion is that past research has concentrated on the physical factors of soil erosion in Lesotho. Little research has been done on the socio-economic factors whose impact is clearly indicated from the results above. There is a need for land users to understand better the dynamics of their environment.

The dissemination of all research results and recommendations to the land users is lacking, i.e. the research findings are not available to the community of land users. Therefore, there is the need to correct by interventions from the decision-makers and planners. This is proved by the continued severe soil erosion in Lesotho regardless of the heavy investment in past conservation measures efforts.

As pointed out by Douglas (1993), although is recognized that soil and water conservation practices can substantially contribute to reversing land degradation, the implementation of successful soil conservation programmes is dependent on identifying the differences in perspectives of farmers and land user and development planner as regards the severity and nature of the problems, and appropriate ways to overcoming them. In order to reach common understanding the planners should reconcile their differences with farmers and redefine the problem (Douglas 1993).

Taking into consideration the human needs in the conservation of natural resources, a programme called 'Production Through Conservation', was initiated in Lesotho. It was formulated in the context of production-oriented methods. The key elements being the following:

- Production through conservation: Support land users to increase production by integrating it with conservation of the natural environment upon which production depends.
- Client demand: Land-users have primary responsibility for production and conservation. The role of the Ministry of Agriculture is to participate supportively in land users production and conservation tasks, responding to their expressed needs with strategic guidance and technical advice.
- Unified extension approach: In order to obtain a sustainable production together with good land husbandry there should be a centrally unified extension strategy.

The Production Through Conservation Programme is an approach that the Government of Lesotho has chosen to pursue in the implementation of these policies in the Southern districts of the country. This type of approach needs time and thorough research to evaluate its effectiveness.

Regardless the good efforts mentioned above, a lot still remains to be done. In order to implement an interdisciplinary (holistic) approach to the problem it is essential to introduce research that is geared to the needs of small scale farmers and land users in general. Above all it is necessary to pass on the results of research to the communities and land users in a readily understood language, while maintaining the quality of research.

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A RESEARCH ON WATER EROSION ASSESSMENT WITH WIDELY AVAILABLE DATA

B.G.J.S. Sonneveld
Centre for World Food Studies of the Free University (SOW)
De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

INTRODUCTION

Before the NASREC workshop a questionnaire on water erosion assessment was distributed in the framework of a joint research activity of ISRIC and the Centre for World Food Studies (SOW). The research objective is to develop a model which assesses the severity of water erosion based on widely available data. The questionnaire compiles (field) information on erosion assessments for sites where characteristics are well described. This allows to relate the field erosion assessment, as the dependent variable, to the location specific information (ISIS database) serving as the independent variable, using regression techniques.

This contribution begins with a discussion of the latest developments in water erosion assessment. Thereafter it is argued that the research on sophisticated erosion assessments should be complemented with less sophisticated models which use readily available data. Next the methodology that will be used to assess the model is presented. Finally, the procedure to develop the model by comparing the 'goodness-of-fit' between observed and predicted values is discussed.

WATER EROSION ASSESSMENT METHODS

Soil erosion by water (water erosion) has a negative impact on agricultural productivity and infrastructural works (i.e. sedimentation of artificial lakes and road damage). Water erosion occurs when the natural resources are used beyond their capacity. The technique of water erosion assessment aims at an evaluation of the suitability of the natural resources for a diversity of land uses. The evaluation identifies vulnerable areas for soil erosion and gives information on soil conservation measures, necessary to start the cultivation or development of the land. An analysis of the socio-economic conditions will show whether development of the area is beneficial.

The latest research in erosion assessment is directed towards the development of conceptual models which are based on physical laws (e.g. EUROSLEM, Morgan *et al.*, 1985; ANSWERS, De Roo, 1993). These models require a considerable data input, given their empirical character, and elaborate validation. This is somewhat in contrast to the rapid expansion of soil erosion and the availability (and accuracy) of data in areas where the problem is most prominent. The time and efforts that are involved in collecting the data and implementation of these advanced models

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will not be able to keep up with the rate of advance of the world wide problem of soil erosion. Of course, these sophisticated models have their merits but a less sophisticated approach should complement the research for erosion assessment in cases their application is constrained by time and resources.

In fact less sophisticated methods are already in use. There exists a widespread agreement among field experts on universally applicable rules for erosion hazard assessment based on first-hand experience of an observational and qualitative nature. This is also confirmed by the first results of the questionnaire; four out of the five respondents indicated that they used either a qualitative model or a quantitative model which was not calibrated. The results of these models are widely used and applied in both developing and developed countries (e.g. Jefferey *et al.*, 1989; Eweg, 1995; Mellerowicz *et al.*, 1994). Results are mostly represented in a discrete classification like: no erosion, moderate erosion and severe erosion. Often these evaluations were done with the limited data that were available, yielding the best result that can be produced under these conditions. These 'rules' and their results, however, have not been documented in a scientific way allowing criticism and improvement. Therefore it remains difficult to transmit this knowledge to others as long as these erosion assessment procedures are not formalized.

The current research aims at a systematic documentation and validation of this 'expert knowledge'. In the next section the elaboration of the information from the questionnaire is discussed. The model and the special regression techniques that will be used due to the discrete classification of the dependent variables are introduced. In the last section, the model is tested for its consistency in the erosion hazard assessment.

METHODOLOGY

Compilation of information

In the first reply form participants were asked to give an erosion assessment, according to their personal observations, for the ISIS profile for different land uses. The selected types of land use are: (a) the actual land use and original vegetation as annotated in the ISIS database; (b) a bare soil; and, (c) four broad categories of land use, *viz.* annual crops, perennial crops, rangeland and forest. The state of erosion was rated into five classes: 1= no erosion, 2= slight, 3= moderate, 4= severe, 5= extreme.

Qualitative response models

Usually, a logical step would be to use the standard regression techniques to relate field observations with a set of explanatory variables and estimate their parameters. In this case, however, the classical Ordinary Least Square regression technique cannot be used since the dependent variables are presented in discrete numbers and not as a continuous dependent variable. A regression with OLS assessments in the case of discrete dependent variables leads to many undesirable properties of the estimator (Greene, 1990).

In the case of dichotomous (yes/no) or polytomous (light, moderate, severe) dependent variables it is preferred to use qualitative response or discrete choice models (Cramer, 1990). These models indicate the probability of occurrences of a discrete class as a function of the independent variables. Their parameters are assessed by the technique of maximum-likelihood estimates (Greene, 1990).

The probability model is formalized by transforming the explanatory variables in a function that has a sigmoid curve which stays within 0 and 1 and flattens out on both ends so, as to respect the limits of these bounds. The general form of the bivariate probability model is:

$$Pr(Y=1) = F(Xb) \quad (1)$$

$$Pr(Y=0) = 1 - F(Xb) \quad (2)$$

where:

Pr(Y=1) is the probability that Y= 1, etc.
F is a function that meet the above specified requirements
b is a vector of parameters
X is a vector of dependent variables.

There are several functional relationships which comply with the prerequisites of a sigmoid curve which stays within the 0 to 1 bounds. However, LOGIT and PROBIT are the forms most frequently used programs nowadays. The PROBIT model refers to the transformation of the explanatory variables into a cumulative normal distribution function. In the case of the LOGIT model the dependant variable is transformed in a logistic function:

$$Pr(Y=1) = exp(Xb)/(1+exp(Xb)) \quad (3)$$

Figure 1 shows the sigmoid shape of the curve of the logistic function. The X-axis shows the Xb values and the Y-axis shows the probabilities of occurrence of the Xb values. In practice there are some differences in the results whether the PROBIT or the LOGIT model is being applied, however, they are not substantial.

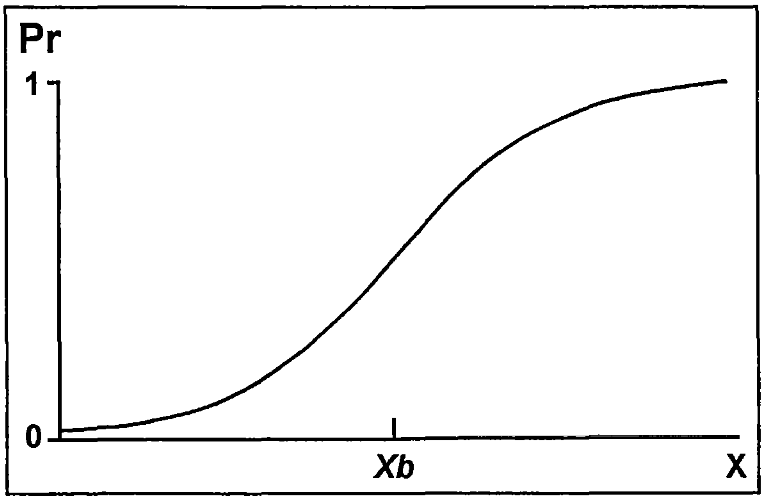

Fig. 1 The logistic curve

In the present case there is a ranked polytomous dependent variable (1 to 5; where 5 > 4 > 3 > 2 > 1) to model these ordinally classified variables. The bivariate model has to be extended to an ordered multinomial PROBIT or LOGIT model (Zaivona and McKelvey, 1975). Analogue to the dichotomous models the multinominal models predict the probability of occurrence for the ranked ordinal classes.

Model evaluation

Upon compilation of a sufficiently large data set, the observed and predicted grouped observations will be compared and tested for their goodness-of-fit by, for example, using a Chi-square test.

EXPECTED RESULTS

The research is expected to generate a model which evaluates the suitability of the natural resources regarding their vulnerability for the erosion process with widely available data.

In a first step the complete data set, of all the countries, can be used to evaluate the different combinations of explanatory variables by a stepwise regression. For every evaluation a variable in the model is included and the explanatory power of the model is compared to previous and new combinations of the variables. Further, it can be investigated whether the modifications of the variables (for example with the USLE equations) might lead to a better result, though, it will also require additional information. The model that is derived from this exercise can be applied per country to test the consistency of the erosion assessments for the given set of explanatory variables.

If the results of this universal model are not satisfying the model can be developed and tested for its consistency at more desegregated levels like country level or agroecological zones.

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PART IV

CHEMICAL LAND QUALITIES

SOIL ACIDITY AND ITS AMELIORATION

H.G. dos Santos and D.V. Pérez
CNPS/EMBRAPA, Rua Jardim Botânico, 1024, 22460-000, Rio de Janeiro, Brazil

INTRODUCTION

Most soils in Brazil are Oxisols (Ferralsols-FAO) and Ultisols (Acrisols-FAO), which cover approximately 70% of the national territory (EMBRAPA, 1981). These soils usually have low base saturation, low cation retention capacity, high exchangeable aluminum content and a mineralogical composition predominated by kaolinitic or oxidic materials. Under natural conditions, pH values are smaller than 5.5 associated with high levels of exchangeable aluminum. Exceptions within the Oxisol order are found in the greatgroups of 'Eutrustox' and 'Eutorthox', corresponding with the 'eutric' terminology of the Soil Taxonomy (Soil Survey Staff, 1975) and FAO-UNESCO system (1989).

Ferralsols are usually deep, porous, well aggregated and highly permeable soils of the tropics. They have low base saturation and pH values ranging from 4.0 to 5.5. Frequently, the pH measured in KCl is higher than the pH measured in water. This is characteristic for the presence of clay minerals with a pH-dependent charge, which usually occur in the deeper horizons of Acrustoxs and Acrorthoxs (Soil Survey Staff, 1975). Ferralsols occur on old geomorphic surfaces and were developed through processes of intensive weathering under predominant climatic conditions of high temperature and rainfall.

The acid Acrisols are moderately deep to deep with an argillic B horizon, low base saturation and low cation retention capacity. They usually have a textural gradient between the A and B horizon with a pronounced accumulation of clay in the B horizon. As a result, Acrisols are less permeable and more susceptible to water erosion, especially where slopes are steep. Like most Ferralsols, Acrisols are developed from base-depleted parent materials which results in acid soils of relatively low natural fertility. Nonetheless, the permanent cation exchange capacity of Acrisols is usually higher that of Ferralsols (Pratt and Alvahido, 1966).

Other acid soils are found in the tropics on large areas of sandy materials derived from acidic sandstone. These are mostly Ferralic, Albic, and Haplic Arenosols (Red and Yellow Quartz Sands). The Quartz Sands normally have less than 15% clay, a very low water and cation exchange capacity, low organic matter content and very low natural fertility. There are also significant areas of Histosols and Podzols that are generally acid under natural conditions.

Soil minerals, mainly those in the clay fraction, affect cation retention in different ways. Minerals in the sand fraction may be considered to be inactive due to their low specific surface

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charge. However, they may become important sources of plant nutrients upon weathering (Resende *et al.*, 1988).

The 'dystric', 'acric' and 'allic' designations used in Soil Taxonomy (Soil Survey Staff, 1975) and the FAO Classification System (FAO-UNESCO, 1989) are helpful in identifying areas of acid soils around the world using available soil maps.

ORIGIN AND NATURE OF SOIL ACIDITY

Causes for soil acidity may be related to pedogenesis, soil parent materials originally poor in bases, and extreme weathering processes leading to a low cation exchange capacity. Other causes for soil acidification are the addition of anions to the soil solution and, most relevant, the use of acidifying fertilizers, resulting in base lixiviation (Raij, 1981).

Raij (1981) described two ways in which anions can be added to the soil solution without the original, corresponding cations. Firstly, the natural dissociation of carbon dioxide which produces hydrogen and bicarbonate ions. The hydrogen ion is immediately transferred to the mineral surface, liberating an exchangeable cation that may be removed by lixiviation with a bicarbonate ion. Secondly, through the use of acidifying fertilizers such as ammonium sulphate. The ammonium (NH^{4+}) added to the soil is transformed in nitrate (NO^{3-}), causing the transfer of basic cations to the soil solution and their lixiviation through the profile. The same process of acidification occurs when the ammonium originates from the mineralization of organic matter.

Soil acidity and exchangeable aluminum concentrations are correlated. According to Sanchez (1976) aluminum is precipitated above a pH of 5.5. These pH values correspond with medium to high base saturation levels.

The determination of soil acidity is of permanent concern in soil fertility management. Soil chemists are constantly trying out methods that take into account the effective exchange capacity of the soil, the organic matter content, the texture, and the pH-dependent charge of various clays minerals.

ACIDITY PROBLEMS, SOIL MANAGEMENT AND EFFECTS ON CROP PRODUCTION

Sanchez (1976) observed that acid soils in the tropics are mostly characterized by aluminum toxicity, calcium or magnesium deficiency and manganese toxicity which affect root development and cation uptake by plants.

Unless tolerant varieties are selected, soil acidity is likely to affect the production of sensitive crops. Research with acid soils in savannah areas has shown that proper soil and water management can improve food production (Cornell University Annual Report, 1973). Deep incorporation of lime increased the depth of rooting as a result of which crops can make better use of soil moisture reserve during a dry period.

Although liming of acid soils increases crop production, over-liming may have disastrous results (Kamprath, 1971). Over-liming decreases the availability of phosphorous, boron, zinc and manganese for plants (Quaggio, 1985) and it induces soil structural deterioration (Sanchez, 1976). It may also induce a decrease in the rate of nitrogen microbial fixation in leguminous species, due to the reduced availability of zinc, molybdenum, manganese, and also affect soil microbial activity.

The general recommendation is that highly weathered, acid soils of the tropics should be limed to a pH between 5.5 and 6.5, depending on the crop variety. Management practices for acid soils should have, as the main objective, the identification of the best economic amount of lime needed, the selection of aluminum tolerant species, and the incorporation of lime. The latter in order to stimulate vertical root development whereby soil moisture reserves in the underlying horizons can be accessed (Sanchez,1976).

MODIFICATION OF SOIL ACIDITY

Liming

There are several methods to determine lime requirements. Kamprath (1970) recommended that liming must be based on the amount of aluminum in the topsoil multiplied by 1.5 to find the millimoles of calcium needed. In soils with high organic matter content this factor must be higher (between 2 and 3) to balance for the presence of hydrogen ions (Sanchez, 1976).

Three methods are well accepted in Brazil to determine the lime requirement: (a) increasing the base saturation; (b) use of SMP-buffer solution (Shoemaker *et al.*); and (c) the neutralization of aluminum and raising of the concentration of calcium and magnesium (Raij, 1981). The first method (a) is based on the estimation of the amount of lime needed to reach a certain pH value according to the equation: pH = 4.5 + 0.025xBS%. In the SMP-buffer solution method, a small amount of soil is mixed and stirred with a certain volume of the buffer solution. The pH of the suspension is then determined (pH SMP) and then compared with values of lime needed to reach a pH of 5.5, 6.0 and 6.5. The third method (c), in which exchangeable aluminium is neutralized and the concentration of calcium and magnesium in the soil is increased, is dependent on several equations which vary with crop variety and soil type.

In 1985, only 5.6% of Brazilian farmers limed their soils. In the State of Sao Paulo, the largest consumer of lime, 21.4% of the farmers use lime to remedy soil acidity. Other statistical data for Brazil show that about 20% of the applied fertilizer is lost in acid soils. One of the reasons for this loss of fertilizer is the low fertilizer/lime ratio (Table 1).

Table 1 Changes in lime consumption, fertilizer consumption and the fertilizer/lime ratio (x10^3 ton)

Year	Fertilizer (A)	Lime (B)	Ratio (A:B)
1988	10,085	15,152	1:1.5
1989	9,019	14,446	1:1.6
1990	8,325	9,493	1:1.1
1991	8,600	9,000	1:1.0
Ideal			1:4.0

Source: Ferreira and Santos (1992)

The consumption of lime has decreased in Brazil since 1984 (Table 2), mainly due to inadequate agricultural policies, the high cost of transportation, and insufficient extension service.

Table 2. Yearly consumption of lime in Brazil (x10^6 ton)

Year	Consumption
1984-87	13
1989	15
1990	9

Note: consumption needs are 53x10^6 ton of lime. Source: Rocha (1985)

Gypsum

Application of gypsum is effective in lowering the concentration of exchangeable aluminum in acid tropical soils (Seminário ..., 1992). In Brazil, gypsum is a byproduct of the treatment of phosphate rock with sulphuric acid in the industrial production of phosphorous. For each ton of P_2O_5 produced there are about 4 to 5 tons of gypsum. In 1991, the phosphorous fertilizer industry had accumulated 31x10^6 ton of gypsum. This amount is estimated to increase at an annual rate of 3.4x10^6 ton. Gypsum needs are estimated as a function of concentration of calcium and aluminum in the soil. Gypsum needs are confirmed when Ca^{2+} is less than 3.0 $mmol_c$ dm^{-3} and/or Al^{3+} is higher than 5.0 $mmol_c$ dm^{-3}. The amount of gypsum to be incorporated depends on soil texture.

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FERTILITY OF SELECTED SOILS OF NIGER REPUBLIC

Salou Moussa
Ministry of Agriculture and Livestock, National Institute of Agronomic Research of Niger (INRAN/DRE)
B.P. 429, Niamey, Niger.

INTRODUCTION

The economy of Niger is based on agriculture and livestock. Yet the conditions of the soil are not well known. The territory covers 1,267,000 km^2 of which one third is used for crop production. A land locked country, Niger has a semi-arid and arid climate. Rainfall decreases sharply from south to north and evapotranspiration is high. Except for Gaya region (July and August), evapotranspiration exceeds rainfall throughout the year in the Niger. Over 75% of the country lies above the 300-350 mm isohyet where rainfed agriculture is untenable. The northern part of the country is desert.

This communication will focus on the soils of the agricultural area of Niger. It will not describe all the soils in detail because a study of that importance has not been initiated yet. Case studies will be presented for four distinct landscapes: (a) the Dallols; (b) the lake Chad basin; (c) Dunal soils; and (d) the river Niger basin.

THE DALLOLS

The Dallols are a wide sand-plugged fossil valley in which surface flow is obtained intermittently during the rainy season. The main geomorphic feature of the Dallol system is a series of dunes of micro relief and prominent depressions which are vestiges of ancient channels (Sogetha, 1963b). Soils in the Dallol show only weak pedogenic development in terms of horizonation and organic matter accumulation. The A horizon (<15 cm) has a low content of organic matter. The soils are structureless to weak subangular blocky, which is characteristic for a low clay content and high percentage of water dispersible clay (Bui, 1986).

Two different types of soils were identified in the channel (geomorphic position) both of which exhibit characteristics of an aquic moisture regime and a well developed structure. In the first type, dark organic rich A and B horizons occur at a relatively shallow depth. The second type is characterized by horizons with distinct mottles in a grey matrix. The underlying grey sandy layer occurs at greater depths (Table 1).

Soils developed on the dunal geomorphic unit are generally sandy (> 85 % of fine earth). Clay distribution does not follow a consistent pattern with depth (Table 2) which is an indication of their alluvial origin.

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Table 1 Selected morphological, physical and chemical of selected channel soils

Horizon	Depth (cm)	Colour	pH_2O (1:2.5)	Clay (%)	F.Sand (%)	C.Sand (%)	CEC	BSAT (%)	OM (%)
			KALA Pate (Dallol Bosso)						
A	0-13	10YR5/4	6.8	5.3	14.4	75.6	2.6	98	0.15
Bw1	13-30	10YR3/1	8.8	11.1	10.6	69.7	7.3	101	0.16
Bw2	30-48	10YR4/4	9.0	17.1	8.0	64.3	13.0	99	0.21
Bw3	48-76	10YR/3/3	9.2	20.2	6.8	64.8	16.3	99	0.24
Bw4	76-102	5Y3/1	9.3	38.1	6.6	46.1	27.6	100	0.28
BCg1	102-117	2.5Y4/0	8.8	24.0	13.7	55.2	21.1	98	0.16
BCg2	117-126	MOTTLED	9.1	16.1	9.6	69.0	15.9	100	0.10
			Kwara N'debe (Dallol Foga)						
Ap	0-10	2.5YR2/0	6.0	17.6	30.2	10.0	40.3	34	3.94
Bw1	10-19	5Y2.5/1	5.8	21.3	29.7	4.2	38.3	35	4.23
Bw2	19-33	2.5YR2/0	7.0	34.3	22.8	2.2	36.4	35	3.55
Bw3	33-54	5Y2.5/1	8.2	31.6	24.9	0.5	22.2	43	1.09
Cg	54-68	2.5Y6/2	8.2	2.3	89.9	0	3.0	20	0.07

CEC is expressed in $cmol_c\ kg^{-1}$; BSAT is Base Saturation; OM is Organic Matter.

Table 2 Selected morphological, physical and chemical of selected dunal soils

Horizon	Depth (cm)	Colour	pH_2O (1:2.5)	Clay (%)	F.Sand (%)	C.Sand (%)	CEC	BSAT (%)	OM (%)
			KALA Pate (Dallol Bosso)						
Ap	0-13	10YR4/6	5.6	4.0	24.7	71.0	1.3	52	0.13
A2	13-38	7.5YR4/4	5.2	3.4	27.1	66.5	1.5	9	0.09
B	38-57	7.5YR4/4	5.0	3.9	28.6	67.1	1.3	10	0.18
Bc	57-89	7.5YR6/8	4.6	2.8	28.1	67.7	1.1	9	0.04
C1	89-120	7.5YR8/8	5.1	1.8	23.8	72.9	1.0	24	0.02
C2	120-153	10YR8/8	5.1	1.7	46.6	33.3	1.1	29	0.03
			Kwara N'debe (Dallol Foga)						
Ap	0-15	10YR4/4	5.8	4.6	77.7	8.8	5.1	24	0.20
Bt	15-36	10YR3/4	5.5	8.3	72.7	7.8	5.9	24	0.19
Bc1	36-55	10YR4/4	5.2	6.1	75.8	7.7	5.3	22	0.15
Bc2	55-78	7.5YR4/6	5.8	4.0	75.5	8.4	4.1	21	0.08
2Bt1	78-89	7.5YR4/6	5.8	5.3	76.9	8.2	4.3	35	0.06
2Bt2	89-122	5YR5/8	5.1	8.9	74.7	8.3	5.1	25	0.06

CEC is expressed in $cmol_c\ kg^{-1}$; BSAT is Base Saturation; OM is Organic Matter.

The moisture retention capacity is low. Soils that occur in the channel are fine textured. Dunal soils are acid. The pH decreases to a minimum between 50 and 70 cm and then increases slightly with depth. Soils in channels are neutral to alkaline and there is a general increase in pH with depth (Table 1). Cation exchange capacity of dunal soils ranges from 1.0 to 5.9 $cmol_c\ kg^{-1}$. Soils in the channel geomorphic position have a high cation exchange capacity. Base saturation of the dunal soils is relatively low as compared to the heavier textured soils in the channels.

Soils in the channels have high contents of Na and Ca salts which accumulate at the surface during the dry season.

THE LAKE BASIN

The organic matter content and C:N ratio is low for soils well provided with water all the year long; 0.35% to 17% on average. The most homogeneous texture is observed for soils with salt efflorescences and in natron soils formed by a sandy cover and showing some times clayey horizon in depth (8 to 10% of clay towards 50 - 100 cm against 1% to 5% at the surface). The texture is coarse at the surface and fine below. The granular or polyhedric subangular structure is generally well developed. Moisture retention capacity ranges from good to very good. Saltiness is more or less marked throughout the landscape. The organic matter content is somewhat higher than that of the other soils. The soils are very poor in nitrogen, rich in available phosphorus and very rich in potash because of their sandy nature. Soil reaction is from neutral to alkaline or strongly alkaline (Table 3 and 4).

DUNAL SOILS

Dunal soils are the most extensive and used for millet, sorghum, peanut, corn, bean, cassava, cowpea, etc. They are coarse texture with the sand content ranging from 71 % to 99% in the surface horizon (0 - 20 cm). The water retention capacity is very low as a result. The dunal soils have a very high hydraulic conductivity (150 to 200 cm d^{-1}) and the internal drainage is very rapid. Although exchangeable potassium is low in most soils a response to potassium application is rarely observed. Dunal soils are brittle because of the low clay content and organic matter content. A large part of the effective cation exchange capacity of these soils is associated with the organic matter. Available and total phosphorus are present in small quantities (Table 5). Although phosphorus fixation is low, phosphorus deficiency constitutes the most serious constraint for agricultural production. Investigations have shown that P problems can be solved by application of phosphate rock. The response to nitrogen fertilizer application depends on the total rainfall but there is a great loss of it because of the sandy nature of these soils.

Table 3 Analytical results of a selected profile from Lake Basin, Niger

Depth	Particle size distribution %					pH		Elec. cond.	Organic matter			
		sand		silt	clay							
cm		coar.	fine			H2O	KCl	dS m^{-1}	C %	N %	C/N	OM %
0-8	LS	41.5	13.1	28.8	16.6	102	9.4	1.35	1.38	0.075	18.4	2.38
8-37	A	14.7	9.1	33.9	42.3	9.8	8.9	1.58	1.57	0.085	18.5	2.71
37-62	A	3.4	3.2	37.8	55.7	9.1	8.5	1.45	1.34	0.060	22.3	2.31
62-107	A	0.6	0.7	33.4	65.4	9.1	8.5	1.36	0.88	0.025	35.2	1.52
107-147	AL	1.0	1.1	41.1	56.9	9.2	8.4	1.24	1.08	0.046	23.5	1.86

Depth cm	Exchangeable bases Ca	Mg	Na	K	Total bases	CEC	Base satu. %	Phosphorus ppm tot	avail. Bray P1	Iron % tot	Free	CaCO %
	<---------	-meq/1	00g---	-----	------>							
0-8	12.5	1.2	21.75	24.55	60.0	60.40	99.33	-	3.9	-	-	-
8-37	13.9	1.9	20.61	10.27	46.68	46.92	99.48	-	60.2	-	-	-
37-62	17.9	5.8	15.26	0.76	39.72	40.29	98.58	-	65.8	-	-	-
62-107	17.8	6.0	10.95	2.02	36.77	37.13	99.03	-	65.8	-	-	-
107-147	18.3	6.6	10.73	2.01	37.64	37.98	99.10	-	3.9	-	-	-

Table 4 Analytical results of selected profile from Lake Basin, Niger

Depth cm	Particle size distribution %	sand coar.	fine	silt	clay	pH H2O	KCl	Elec. cond. dS m^{-1}	Organic matter C %	N %	C/N	OM %
0-6	-	46.2	11.5	26.6	15.7	7.5	6.8	0.16	1.17	0.055	21.3	2.02
6-16	-	20.8	8.7	38.5	32.0	7.5	7.3	0.45	1.92	0.136	14.1	3.31
16-35	-	6.3	14.1	43.8	35.7	7.0	6.9	1.33	1.40	0.200	7.0	2.41
35-58	-	0.8	3.4	34.9	60.9	6.3	5.9	0.57	1.04	0.140	7.4	1.79
58-99	-	2.1	8.9	32.9	56.1	6.6	6.3	0.62	0.58	0.094	6.2	1.00
99-142	-	1.1	3.8	30.9	64.2	5.6	4.8	0.58	0.58	0.053	10.9	1.00

Depth cm	Exchangeable cations Ca	Mg	Na	K	Total bases	CEC	Base sat. %	Phosphorus ppm tot	avail. Bray P1	Iron % tot	free	CaCO %
	<---------	-meq/1	00g---	-----	------>							
0-6	36.0	7.2	0.50	3.03	46.73	47.13	99.15	-	63.0	-	-	-
6-16	37.6	7.2	1.18	2.54	48.52	48.89	99.24	-	77.0	-	-	-
16-35	28.8	4.0	1.81	1.52	36.13	36.40	99.25	-	98.7	-	-	-
35-58	22.4	7.6	1.63	2.06	33.69	33.85	99.52	-	70.7	-	-	-
58-99	18.4	9.6	1.60	1.45	31.05	31.26	99.32	-	41.7	-	-	-
99-142	23.2	8.0	1.77	1.43	34.40	34.54	99.59	-	52.5	-	-	-

SOILS OF RIVER NIGER BASIN

The river Niger flows through the western part of the country on about 500 km. More than 7,500 ha were managed as modern irrigation schemes on both banks for rice production. Soils generally have an aquic moisture regime, are very fine or fine textured with 36 % or more of clay content in the upper horizon. The structure is generally polyhedric. Drainage varies from rapid to slow. The ground water occurs within 150 cm depth and is salty, with high contents of sodium and calcium carbonate. Soil pH ranges from 5 to 8. The content of organic matter is very variable, ranging from 0.5 to 1.5 % between 0-20 cm after which it decreases with depth.

The cation exchange capacity ranges from 8.3 to 25 $cmol_c$ kg^{-1}. The base saturation is variable, i.e. low for clayey soils and high for other soils. Nitrogen and total phosphorus contents are respectively 0.3 and 0.15‰.

Table 5 Range, mean and standard deviation of physical and chemical properties of selected dunal soils of western Niger

Parameters	Range	Mean	Std
pH-H2O	4.0-7.6	6.17	0.66
pH-KCl	3.4-7.0	5.05	0.77
Clay (%)	0.70-13	3.90	2.67
Sand (%)	71-99	88.00	8.00
Organic matter (%)	0.14-5.07	1.40	1.09
Total nitrogen (mg kg^{-1})	31-226	46.00	455.00
Exchangeable bases ($cmol_c$ kg^{-1})			
Ca	0.15-16.45	2.16	3.01
Mg	0.02-2.16	0.59	0.55
K	0.03-1.13	0.20	0.22
Na	0.01-0.09	0.04	0.01
Exch. acidity ($cmol_c$ kg^{-1})	0.02-5.6	0.24	0.80
ECEC ($cmol_c$ kg^{-1})	0.54-19.20	3.43	3.80
Base saturation (%)	36-99	88.00	17.00
Aluminum saturation (%)	0-46	3.00	8.00
Total phosphorus (mg P kg^{-1})	25-941	136.00	151.00
Av. P (Bray P1)(mg P kg^{-1})	1-83	8.00	14.00

Note: Std= standard deviation; Exch. acidity= exchangeable acidity; ECEC= effective cation exchange capacity; Av. P= available phosphorus.

CONCLUSIONS

Most soils in Niger are sandy and acid. They have low contents of organic matter and are poor in nutrients. Farmers cannot utilise fertilizers in view of their low purchasing power. In addition to this they practise monoculture which enhances soil fertility decline. Due to repeated droughts large areas of Niger are desertified. Large areas of land are affected by wind and water erosion.

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NUTRIENT DEPLETION AND SOIL MINING IN SUB-SAHARAN AFRICA AGRICULTURE

R.D. Asiamah
Soil Research Institute, Private Post Bag, Academy Post Office
Kwadaso - Kumasi, Ghana

INTRODUCTION

Agriculture and agro-based industries have long been the backbone of African countries. The Production of food, shelter, clothing and energy has gone on throughout man's existence. This practice has gone on without much regard to replenishing the soil nutrients taken up by the crops. A serious limiting factor to the enhancement of agriculture productivity is the steady decline of soil fertility or loss of soil nutrient throughout Sub-Saharan Africa. The region's soils are fragile and deficient in nutrients and organic matter and in the absence of conservation measures, they become susceptible to degradation and loss of nutrients over time from intensive use or misuse. It is known that about 320 million hectares of vegetated lands have been degraded over the past decades in sub-Saharan Africa.

DISCUSSION

Nutrient mining is significant in the sub-region especially in arable lands that undergo continuous intensive cropping for extended periods without replenishment of essential nutrients which are removed by growing plants (Table 1 to 3). Estimates indicate a net loss of about 700 kg of N, 100 kg of P, and 450 kg of K per hectare in about 100 million hectares of cultivated land over the last 30 years. By contrast, during the same period commercial farms in North America and Europe built nutrient capital by about 2000 kg of N, 700 kg of P, and 1000 kg of K per hectare.

The major impact of nutrient mining is on crop yield and total food supply. Agricultural production in the sub-region increased by only 1.6% between 1965 and 1980, and about 1.3% per annum during the 1980's. The current yields of cereals in sub-saharan Africa now average 1 metric ton per hectare.

In the past, without direct fertilization by peasant farmers who form the bulk of the agricultural producers, the only means of restoring soil fertility after the land is cropped for sometime was by shifting cultivation or land rotation. This practice which allowed a piece of previously cropped land to rest for some years and naturally restore its fertility, is no more practicable. This is because of the need for more lands for agriculture to produce more for the ever increasing population and more lands for other non-agricultural uses.

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The answer to this problem is to keep the land in permanent production with effective restoration of its fertility at all times. This can be achieved through the application of fertilizers, both organic and inorganic.

In view of the fragile nature of our tropical soils, their continuous cultivation and harsh environmental conditions, special measures are required to stabilize soil fertility. There is clearly a need for rapidly changing farming practices involving much greater fertilizer use in combination with high levels of organic residues.

The problems associated with the use of fertilizers are many and are usually beyond the solution of peasant farmers. The policies of fertilizer use in most of our countries do not encourage the peasant farmers to adopt fertilization resulting in soil mining.

Low fertilizer usage has been due to a number of constraints such as:

- Fertilizer availability and price affordability
- Correct methods of application - rates and time of application
- Genuineness of imported fertilizers
- Storage problems
- Distribution systems
- Credit and subsidy policies
- Ineffective extension services

Even though fertilizers are the major inputs in food production accounting for over 50% of crop yield increases in Africa, the level of fertilizer input in sub-saharan Africa is very low, being less than 10 kg ha^{-1}, compared to 70 kg ha^{-1} in India and 260 kg ha^{-1} in China (Sobulo, 1993). Meller *et al.* (1987) gave fertilizer the first functional priority in accelerating food production in the sub-saharan Africa and suggested that even under existing technology, it should be possible to achieve a 15% rate of growth in fertilizer consumption leading to a very significant impact on food production.

FAO (1981) has indicated that 55% of the increase in crop yield in developing countries during 1956-76 came from fertilizer application and that there is a clear relationship between higher fertilizer application and above average agricultural production. The FAO estimates that for all developing African Countries, fertilizer consumption needs to increase to between 4.1 and 6.7 million tonnes by the year 2000.

Even though the general fertilizer use is low in sub-saharan Africa, consumption is increasing steadily. With a total consumption 146,000 tonnes in 1974 there has been a steady growth to 269,00 tonnes in 1977, 389,000 tonnes in 1981 and 491,000 tonnes in 1985.

The modest growth in rates of fertilizer consumption differ in various countries in the sub-region for a range of technical and sociological reasons. Fertilizer consumption in the sub-region is dominated by Nigeria, Senegal, Côte d'Ivoire, Cameroon and Ghana.

In 1989, the average fertilizer use per hectare increased from 1 to 6 kg ha^{-1}, 1 to 8 kg ha^{-1} and 2 to 12 kg ha^{-1} in Burkina Faso, Togo and Nigeria, respectively. In Côte d'Ivoire, Ghana and Senegal, there were sharp variations in the levels of fertilizer use over time from 3 to 24 kg ha^{-1}. During the same period average fertilizer use for Zimbabwe varied between 51 and 68 kg ha^{-1};

21 to 68 kg ha^{-1} in India; 28 to 78 kg ha^{-1} for all developing countries and 102 to 124 kg ha^{-1} for all developed countries (Safo, 1993).

One major factor underlying the low use of fertilizers in sub-saharan Africa is the small local production base. The bulk of the fertilizer production in the sub-region is undertaken mainly by Côte d'Ivoire, Nigeria and Senegal; the remaining countries rely exclusively on fertilizer imports. Other practices that cause reduction in soil fertility include:

- Removal of vegetative covers
- Charcoal production
- Annual bushfires
- Organic materials for other uses
- Soil erosion
- Land tenure

Practices that remove the vegetative covers prevent addition of organic matter into the soil. Organic matter is the main source of fertilization in peasant farms in absence of commercial fertilizers. Organic matter not only supplies plant nutrients, but it has also a major role in the maintenance of physical, chemical and biological properties of the soil.

In tropical soils organic matter supplies most of the soil Nitrogen, Phosphorus and Sulphur. Typically, 95% of the total N and S and 55% to 80% P are in the organic form. There is positive correlation between soil organic matter and soil CEC, micro and macronutrients, biological activities and soil physical characteristics (Agboola, 1993).

The main sources of domestic fuel are charcoal and fuelwoods, in the sub-region charcoal production results in deforestation of the environment and burning of the soils and its organic matter content depriving crops of nutrients. Living organisms are also destroyed. Carbonation of the wood for charcoal occurs on sites for 10 to 14 days causing continuous burning on the site to great depth, and caking the subsoils (Asiamah, 1989). Shifting of the practices from site to site results in a total sum of large area of the landscape burnt and devoid of plant nutrients. Charcoal production occurs extensively in our rural areas supplying the urban dwellers large quantities of charcoal. It is reported that in the city of Accra and its environ, 79% of the households use only charcoal for their energy (Nketia *et al.*, 1988).

Bush fires are common in the sub-region not only in the savanna regions but even in the high rainforest zones. The annual burning of the vegetation deprive the soil of plant nutrients.

Most of the organic materials that can be used in place of unavailable commercial fertilizer are in most cases used for non-agricultural purposes especially in our savanna regions, where woody plants are scarce.

Left-overs after harvest are collected and used for a number of works in the home. Building of living rooms, fencing and rood thatch and cooking are the main practices to which the woody fractions of agricultural left-overs are put. The leafy materials are also collected off the farm for domestic uses. These practices deprive the farms of organic matter.

Table 1 Total arable land and land under permanent crops, total fertilizer use and average fertilizer rate per hectare

Country	1975	1980	1985	1987	1989
Burkina Faso (274,200 km^2)					
Crop area (1000 ha)	2,536	2,785	3,035	3,140	3,568
Total fertilizer Use (1000 MT)	1	4	12	18	21
Average fertilizer Rate (kg N + P_2O_5 + K_2O ha^{-1})	1	1	4	6	6
Côte d'Ivoire (322,463 km^2)					
Crop area (1000 ha^{-1})	2,915	3,095	3,580	3,640	3,660
Total fertilizer use (1000 MT)	38	53	42	33	41
Average fertilizer Rate (kg N + P_2O_5 + K_2O ha^{-1})	13	17	12	9	11
Gambia (11,295 km^2)					
Crop area (1000 ha^{-1})	152	156	165	170	178
Total fertilizer use (1000 MT)	1	2	4	3	2
Average fertilizer Rate (kg N + P_2O_5 + K_2O ha^{-1})	7	13	24	18	11
Ghana (238,537 km^2)					
Crop area (1000 ha^{-1})	2,700	2,760	2,820	2,870	2,720
Total fertilizer use (1000 MT)	25	12	13	11	8
Average fertilizer Rate (kg N + P_2O_5 + K_2O ha^{-1})	9	4	5	4	3
Nigeria(923,768 km^2)					
Crop area (1000 ha^{-1})	30,000	30,385	31,085	31,335	31,335
Total fertilizer use (1000 MT)	54	174	316	310	378
Average fertilizer Rate (kg N + P_2O_5 + K_2O ha^{-1})	2	6	10	10	12
Senegal (196,192 km^2)					
Crop area (1000 ha^{-1})	5,000	5,225	2,225	5,225	5,225
Total fertilizer use (1000 MT)	47	19	21	21	29
Average fertilizer Rate (kg N + P_2O_5 + K_2O ha^{-1})	9	4	4	4	6
Togo (56,000 km^2)					
Crop area (100 ha^{-1})	1,415	1,420	1,427	1,431	1,444
Total fertilizer use (1000 MT)	2	3	10	11	12
Average fertilizer Rate (kg N + P_2O_5 + K_2O ha^{-1})	1	2	7	8	8

Source: FAO Agricultural Statistics (1990); Crop area represents Total Arable and Land under Permanent Crops.

Table 2 Fertilizer production in West Africa: N, P_2O_5 and total NP (metric tonnes)

Country	1984/85	1985/86	1986/87	1987/88	1988/89	1089/90
Nitrogen						
Côte d'Ivoire	1,000	2,600	1,000	1,600	-	-
Nigeria	-	-	-	73,000	243,400	272,400
Senegal	10,000	12,000	5,600	16,000	12,000	17,000
Total	11,000	14,600	6,600	90,600	225,400	289,400
Phosphate (P_2O_5)						
Côte d'Ivoire	3,100	2,600	2,700	900	1,500	2,500
Nigeria	5,000	5,000	5,000	5,000	27,400	44,100
Senegal	30,000	37,500	30,000	35,000	35,000	42,000
Total	38,100	45,100	37,700	40,900	63,900	88,600
N + P_2O_5 Total						
Côte d'Ivoire	4,100	5,200	3,700	2,500	1,500	2,500
Nigeria	5,000	5,000	5.000	78,000	270,800	316,500
Senegal	40,000	49,000	35,000	51,000	47,000	59,000
Total	49,100	59,700	43,700	131,500	319,300	378,000

Source: FAO Fertilizer Yearbook, 1990.

Accelerated soil erosion causes loss of soil fertility in the sub-region through loss of the relatively humus-rich and fertile top soils. It is a threat to continued and sustained agricultural production. The erodibility of the soils is high. Soil loss through both wind and water erosion is common in our forest and savanna areas. Several thousands hectares of once biologically fertile lands have become improductive as a result of erosion.

Studies have reveal alarming rates of erosion loss in the sub-region. In the Interior Savannah Region of Ghana, Adu (1972) reported a loss of 90 cm of soil by sheet and rill erosion. Some severely eroded savannah land has also lost all of its 120 cm thick solum above the unweathered parent rock. Run off plot studies in various ecological zones in Ghana show soil loss to range from 187 ton ha^{-1} yr^{-1} in the semi-deciduous forest zone to 0.56 ton ha^{-1} yr^{-1} in the Coastal Savannah Zone (Bonsu, 1979).

In Ghana, results of Soil Research Institute investigations revealed that, 29.5% of the country is liable to slight to moderate sheet erosion, 43.3% to severe sheet and gully erosion and 23% to very severe sheet and gully erosion (Asiamah, 1987). This trend is common to sub-saharan African countries. The inappropriate land-use, poor management coupled with deforestation of arable lands have caused the prevailing decline in productivity and increasing land degradation (Sant'Anna, 1989).

Land tenure varies from country to country and tribe to tribe. There are quite a number of land tenure and most of them do not encourage the tenant farmers to improve productivity of the land. In situations where farmers have no permanent title to a piece of land, there is reluctance to adopt conversation and fertility improvement measures. The less secure the land, the greater the tendency to exploit it.

In most parts of Africa, the land is held in trust by the chiefs and family heads or tindanis, and is leased to tenants under special conditions. In Ghana, all lands of the Ashanti tribe, belong to the Golden Stool and are held in trust by the paramount chiefs. No land can be bought. Tenant farmers agree either to pay some fixed amount per period or share the crop yields. In some cases, the land may be taken away from the tenant at close notice when he defaults, or when a 'better tenant' is found. In such situations tenants are not eager to invest to improve the productivity of land but continue to mine the soil.

Table 3 Average fertilizer use in 1989

Country	Ferilizer use (kg ha^{-1})
Burkina Faso	1 - 6
Togo	1 - 8
Nigeria	2 - 12
Zimbabwe	51 - 68
India	21 - 68
Developing countries	28 - 78
Developed countries	105 - 124

Source: Safo 1993

CONCLUSIONS

In most parts of Africa, the problem of food security as a result of poor agricultural yield is becoming more grave annually. This is not due to land availability but principally due to the decline of the productive power of the soils. The condition is due to the absence of culture maintaining soil fertility at the acceptable levels at all times.

There is an urgent need to adopt policies that will enhance the usage of soil amendments to enrich the soils in Africa. This can be achieved through the strengthening of extension services, making the essential fertilizers available to the farmers at affordable prices and at the correct time of need.

Total solution of the problems mitigating the high and constant yields of our agricultural efforts will definitely help Africa out of its crisis. Experts put it that African countries need an agricultural growth rate of at least 4% annually to solve its food problems. The present trend in food production, without effective fertilization and soil conservation, must change rapidly to reduce poverty and increase household income. Without restoration of soil fertility, Africa will continue to face the prospects of serious food imbalances and widespread malnutrition and eventual famine. A framework for the restoration of soil fertility should be established in Africa. Opportunities abound in African countries to revitalize agriculture and become self-sufficient in food production.

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SALINITY PREVENTION AND RECLAMATION IN PAKISTAN

M.A. Tahir
Soil Survey of Pakistan, Ministry of Food, Agriculture and Investment
Multan Road, Lahore - 54750, Pakistan

Pakistan is located in a subtropical zone in which the climate is predominantly arid and semiarid. The temperature may climb to 50 °C during the day and the average precipitation is around 100 mm per year in the middle part of the country. Evaporation may exceed precipitation by a factor of 20. Pakistan possesses the biggest single gravity flow irrigation network in the world capable of handling over 12.3 MHM of water to irrigate about 14.0 million ha of alluvial soils deposited by the five main rivers of the Indus system. The country has two large storage reservoirs, 17 barrages, 8 link canals and an extensive conveyance network consisting of main canals, branches, distributaries and minors measuring nearly 640,000 km and 90,000 farm outlets. The accumulated conveyance losses at various segments have been estimated to be at least 50%. Over 250,000 tube-wells in the private sector and about 14,000 tube-wells in the public sector are pumping more than 4.4 MHM of various qualities irrigation water at farmgate. Salinity is an essential component both under depositional pattern as well as in man-induced irrigation system.

Soil surveys revealed that about 23% of the canal commanded area of Pakistan is saline. The salinity encountered was categorized into five classes namely: (1) dense saline-sodic soils; (2) porous saline-sodic soils; (3) strongly saline soils containing gypsum; (4) porous moderately saline soils with saline-sodic surface; (5) normal soils with saline-sodic surface resulting from the use of low quality ground water.

These categories point towards the economic reclaimability and hence help in fixing priorities for the reclamation of various salt affected soils. Province wise extent of various types of salt affected soils is presented in Table 1. In view of the alarming extent of salt-affected soils and ever increasing danger of secondary salinization given rising water tables from perpetual seepage from canals, water courses and irrigated fields the issue of salinization got national importance.

The problem of salinization had caught the sight of planners even before the independence of Pakistan in 1947, as a Drainage Board was established in 1917. Installation of vertical drains along canals was initiated in 1944 and a Directorate of Land Reclamation was setup in 1945. After independence the work on reclamation of salt affected soils was intensified and in 1949 FAO was approached to help Pakistan solve this problem. Surveys and investigations were recommended and thus an organisation named Water And Soil Investigation Division (WASID) was created within Water And Power Development Authority (WAPDA). WAPDA initiated programme of Salinity Control And Reclamation Projects (SCARPs) to provide lasting solution to the problem. A ten year

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waterlogging and salinity control programme was formulated in 1961 envisaging boring of 31,500 tube-wells, 12,000 km of major drains and 40,000 km of supplementary drains. This programme was revised by Dr Revelle, and his team from the U.S.A. in 1961, who proposed that the groundwater be pumped extensively not only to capture the whole of recharge but also to mine the aquifer so as to lower the watertable by 30 meters in 30 years in the non-saline areas and by 17 meters in the saline area.

Master and Regional Plans for waterlogging and salinity control were then formulated by WAPDA in 1963. These plans apart from suggesting measures for the control of waterlogging and salinity dealt with optimum development of fresh ground water resources for enhancing and sustaining irrigated agriculture.

Table 1 Soils affected by various types of salinity and sodicity (x 1000 ha^{-1})

Type of Soil	Province				Pakistan
	Punjab	Sind	NWFP/FATA	Baluchistan	
Surface/patchy salinity and sodicity:					
Irrigated	472.4	118.1	5.2	3.0	598.7
Un-irrigated	-	-	-	-	-
Gypsiferous saline/saline sodic:					
Irrigated*	152.1	743.4	-	76.6	972.1
Un-irrigated	124.5	428.8	-	160.1	713.4
Porous saline sodic:					
Irrigated†	790.8	257.0	25.7	29.4	1102.9
Un-Irrigated	501.0	150.1	7.8	73.5	732.4
Dense saline sodic:					
Irrigated	96.7	32.5	0.9	-	130.1
Un-irrigated	530.0	379.7	8.9	159.5	1078.1
Total	2,667.5	2,109.6	48.5	502.1	5,327.1

† Some of this land is not yet irrigated but as it is located within the canal commands, it is likely to be irrigated in the near future.

An action programme for irrigation and drainage was then prepared, in 1967, based on Lieftinck's plan. An accelerated programme on waterlogging and salinity was prepared in 1973 for 1974-75 to 1984-85 period under which Federal Government would assist the Provincial Governments in providing drainage facilities to an area of 5.7 Mha. This programme would include construction of fresh groundwater tube-wells.

A Revised Action plan was then prepared in 1974 by WAPDA for the development of the irrigated agriculture up to 1990 and there after a perspective plan up to the year 2000. The strategies relating the waterlogging and salinity were:

- All future developments of usable groundwater should be entrusted to the private sector, but with the assistance of the public sector in the form of supervised credit, technology supply and information.
- Present SCARP tubewells in usable groundwater areas should be gradually phased out and replaced by private tubewells.

After this plan a usable ground water strategy was developed and still another one namely Disastrous Area Strategy was chalked out for the recovery of 2 Mha. Then SCARP Transition strategy was evolved under which private sector participation was to be encouraged to participate in the drainage and reclamation of the affected lands having fresh groundwater.

The Seventh Five Year Plan Strategy (1988-93) came into being with an envisaged program of protecting 1.4 Mha, installing 2,771 tubewells, transference of 180 tubewells to the farmers, excavating 3640 km of open drains, remodelling 309 km of surface drains and laying 119,750 ha of tile drains. A comprehensive drainage plan of Pakistan (1988-1998) was then developed. Under this programme only those areas would be covered where the water table is within 2 m of the surface. The rice growing area will be excluded from this program. All completed and on-going SCARP programmes will not be considered under this plan. All fresh ground water area will not be taken up.

The result of all the above mentioned hectic and budget consuming efforts came out to be as follows:

- About 3.8 Mha of affected land has been covered through 36 SCRAPS schemes constructed so far.
- Only 1.5 Mha of irrigated area remains seriously waterlogged.
- The extent of Soil salinity has gone down from 40% to 28%.

Simultaneously an agronomic approach has been developed by Soil Survey of Pakistan which has the following priorities:

(1) Improvement of standard of farming, corrective measures to off-set and prevent soil deterioration resulting from the use of low quality tubewell water; and reclamation of salinity occurring in patches within the cultivated fields.
(2) Increase in water supply to achieve a cropping intensity of at least 150% of already cultivated, good agricultural land.
(3) Wherever water is available in excess of the need of better land e.g. the fresh ground water region and in Indus delta extension of cultivation to class III land comprising porous saline-sodic soils containing gypsum.
(4) Reclamation of class IV land comprising dense saline-sodic soils should have a very low priority and may be deferred for the time being.

This whole approach is concentrated on the use of gypsum as a soil amendment, availability of water after satisfying the need of good agricultural lands and fixing of priorities according to the reclaimability of soils. Government has launched a scheme to provide 50% subsidy to the farmers who would use gypsum for the reclamation of their soils. A comprehensive program of lining water courses and distributaries is underway to check the seepage losses. This program is being carried out with the collaboration of farmers.

MANAGE-N: THE USER FRIENDLY PACKAGE FOR NITROGEN MANAGEMENT IN RICE

J.J.M. Riethoven[1], H.F.M. ten Berge[1] and H. Drenth[1,2]

1 *DLO Research Institute for Agrobiology and Soil Fertility (AB-DLO)*
P.O. Box 14, 6700 AA Wageningen, The Netherlands

2 *Department of Theoretical Production Ecology, Wageningen Agricultural University*
P.O. Box 430, 6700 AK Wageningen, The Netherlands.

MANAGE-N is an advisory tool for rice researchers and extension workers. The overall purpose of MANAGE-N is to provide a sound agronomic basis for designing optimum nitrogen (N) fertiliser management strategies for specific combinations of cultivar, site, season and soil type. When supplied with the proper parameter values, MANAGE-N can generate information on:

- the highest attainable yield (versus fertiliser N-level),
- the highest attainable income from applied N fertiliser (versus fertiliser N-level),
- the optimal time path for N application at each input level of N,
- the yield response to specific split N application schemes,
- a site-and-cultivar specific calibration factor (FS) expressing productivity of light and nitrogen, and
- patterns of N uptake, biomass accumulation and other intermediary variables.

The MANAGE-N model requires crop and soil characteristics (parameters) and weather data (daily radiation) as inputs. The core of the package is the dynamic simulation model ORYZA_0 (Ten Berge *et al.*, 1994). The model describes those aspects of rice physiology that have a direct relevance to fertiliser management: N uptake, N partitioning, and N utilisation by the crop. ORYZA_O is an exploratory (process-based) model which uses plant and soil characteristics that can be measured at most experimental stations.

The ORYZA_0 model is completely embedded in MANAGE-N which is custom-made to provide easy communication with the model. The procedure for selecting input files, editing input data files, and viewing output (tabular and graphics) is fully supported by MANAGE-N in a user-friendly manner.

Numerical organisation of nitrogen application patterns that result in maximum grain yield is fully automated: several user-defined N input levels can be optimised in on go. Based on the outcome of these optimisations, MANAGE-N calculates grain yield response to N input level, displays the optimum timing of fertiliser N application, and determines economic optimum based

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on additional income of the individual farmer. Another module permits to assess effects of discrete split schemes of crop performance. These discrete splits can be derived from (in the user's mind) optimised continuous N applications.

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PART V

COUNTRY REPORTS

NASREC PROJECT AND ITS APPLICATION IN CHINA

Luo Guobao and Gong Zitong
Institute of Soil Science, Academica Sinica
P.O. Box 821, Nanjing, People's Republic of China.

INTRODUCTION

For an embryonic form of a soil collection and exhibition in China one should go back 600 year, to the Ming Dynasty. In order to express the people's gratitude to the land god and food god, a sacrificial altar was built in the eastern part of Tiananmen Square, nowadays located inside of the Zhongshan Park, which uses the colour of five soils widely distributed in the country. The true NASREC project, however, was conducted during the years 1985-1994. This was an important period for the social and economic development in China. The project is playing a vital role in raising awareness of our government and people about the importance of soils — which support our lives — when they devote themselves to economic development.

The NASREC project is closely related with a project on Chinese Soil Taxonomic Classification, which is funded by the National Natural Science Foundation of China and by the Academia Sinica. The results of the NASREC project have been applied in soil research work, agricultural production, education, environmental protection and international exchanges. Furthermore, the basic data of the NASREC project are becoming useful for an increasingly large number of people, including non-soil specialists.

RESULTS

There are many types of soil in China, due to the varied topography, climate and long cultivation history. Some of these soils are unique in the world. During the NASREC project, a total of 55 reference soil profiles have been collected according to major ecological regions. These profiles are representative for the main soil types of the country, and include soils from: (sub)tropical China with its typical monsoon climate and long cultivation history; northwest China with its hyper-arid climate (mean rainfall of only several mm yr^{-1}); northeast China with a cryic soil temperate regime and flat topography; the Loess Plateau and the Purplish Basin of Central China; the alpine region of Tibet, with an elevation of about 5,000 m. The relevant monoliths are displayed according to degree of soil development going from Anthrosols, Andisols, Spodisols, Vertisols, Aridisols, Aquisols, Isohumisols Ferrallisols, Fersiallisols, Siallisols through to Primarosols, of which Paddy soils (Anthrosols), Alpine meadow soils, Aridisols, Black soils (Isohumisols), Red soils and Latosols.

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Since the beginning of the exposition at ISSAS, there have been more than 1,000 visitors each year. These include students and teachers from schools and universities in Nanjing, Beijing, Shanghai, Shandong, Guangdong, Henan, etc.; government officials, workers, farmers from all over the country, who came primarily to increase their knowledge of national soil conditions; scientists and planners. Recently some agricultural universities have requested our monoliths for teaching purposes, because their present budget is too limited to allow students to gain practical experience in the field. The Exhibition Room, with its soil monoliths, will become a fixed-item on scientific tours to Nanjing. This is important to increase awareness about the importance of soils as an non-renewable natural resource.

In addition to the above activities, we are completing information on the soil monolith collection, including climate data and soil data which are stored in the user-friendly dBASE IV format. The computerized data are useful for different applications. Firstly, in establishing the GIS system they can be used as a control points. Secondly, they supply a framework on how to classify soils according to the Chinese Soil Taxonomic Classification system and they permit also correlation with other diagnostic soil classification systems. Thirdly, the profiles are useful in research on soil degradation, since they can be compared with data obtained about 30-50 years ago. Thereby, they can be used to study changes in soil conditions over time following environmental change. Finally, the profiles are useful for quantitative land evaluation and land use planning. For example, we have carried out a study to identify land suitable for growing potato in China. With the establishment of the information 'high-way', it is anticipated that the digital profile data will have many more applications.

To date, the main users of NASREC data, applications and publications are pedologists, GIS scientists, environmental scientists, agronomists, university teachers, staff of the extension service, and planners.

CONCLUSIONS

Since its inauguration in China almost 10 year ago, the NASREC project has collected and exhibited 55 soil monoliths. These are representative for the main soil types of China, covering major physiographic and climatic zones. The assembled data, available both as hard and soft copy, is presented in the international standard format of the Chinese soil database. Thereby it can be used for different applications, including research and extension. The soil monoliths have been useful to correlate soils according to the Chinese Soil Taxonomic Classification system, a key project in China.

The main problems encountered are: (a) 55 soil profiles are still insufficient to reflect the range in soil conditions in China. More soil profiles should be collected according to the uniform NASREC guidelines; (b) The basic data and publications are in English, which limits their widespread usage in China and it is anticipated that a Chinese version will be prepared soon; and (c) it is still not fully understood how to best use the available information in the context of environmental studies.

In order to fully use the data for agricultural and environmental applications, it is suggested to write a monograph on the soils, agriculture and environment of China based on the NASREC results. In order for the NASREC information to become widely accessible and used, it would be useful to make it accessible in electronic form.

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COLOMBIA SOIL MUSEUM: STATUS AND ACTIVITIES

A. Correa Salazar
Instituto Geografico 'Agustin Codazzi', Carrera 30 No. 48 - 51, Santafé de Bogotá, Colombia

INTRODUCTION

The soil museum of Colombia was started by the Instituto Geográfico 'Agustín Codazzi'. It originated as a result of the interest to publish on soil classification and soil properties in relation to position in the landscape, using the 50 year experience of the Colombian soil survey programme.

The philosophy of the museum is to increase awareness of soil and its importance as a land resource, to generate investigations in soil science, and to create general conscientiousness about the need to conserve the soil. It is believed that it is necessary to familiarize people with the properties and suitability of the different soils of Colombia. The slogan of our institute is: 'To produce while protecting.'

RESULTS

The soil collection was initiated in 1973 and underwent a strong stimulation in 1981 through the ISRIC-IGAC cooperation programme. Within this programme eighteen soils were sampled, preserved, and prepared as monoliths ready for display. Duplicates of these eighteen profiles are included in ISRIC's World Soil Reference Collection in the Netherlands.

During 1984 the museum was opened with a display of 41 monoliths characterized and classified according to the USDA Soil Taxonomy, the French and the FAO classification systems. Presently, there are 64 monoliths in the collection comprising the 11 orders of USDA Soil Taxonomy. The collection is considered representative of the main soils of Colombia.

In the early stage, the main activity of the museum consisted in collecting monoliths but now it is to increase the distribution of the existing information. In the near future we expect to facilitate user-access to information on physical, chemical and mineralogical soil characteristics, landscape position and soil geographic distribution through computer systems.

The display room has two units. In the first, a didactic room, general soil characteristics, physical, chemical and micro-morphological properties, soil forming factors and processes are taught. Examples of diagnostic horizons necessary for soil classification and single elemental information about soil cartography are shown also. Soil monoliths representing the seven physiographic regions of Colombia are displayed in the second unit. Biophysical characteristics of the environment of these regions are illustrated through radar and satellite images, aerial photographs as well as diagrams of climate, evolutive pedogenetic soils models, and land use.

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Each monolith is displayed by USDA Soil Taxonomy and FAO classification. Magnified micro-morphological photographs of the A and B horizons are presented also, together with a data chart describing the soil profile morphology, position in the landscape, and physical, chemical and mineralogical data. The monoliths have been selected to represent a particular cartographic unit in a specific area within the soil survey (e.g. country, state, town). This information is to be included in the database of the 'Subdireccion de Agrología' that can be accessed from a terminal in the museum room.

Main visitors of the museum include; pupils (elementary-grade and pre-scholar), university student, scientists, planners and tourists. There are about 4000 guests each year.

CONCLUSIONS

The most important achievement of the Soil Museum has been to increase the interest of teachers and students in different aspects of the soil, and that of scientists who can now increase their knowledge of the soils on display without having to go to the field.

The Museum has organized about 10 expositions outside the display centre at IGAC in the framework of soil science and environment meetings.

Two audiovisuals have been produced: 'Taking and preparing soil monoliths' and 'The geography of Colombian soils'. Three brochures have been issued as well, two of these dealing with the monoliths on display and the third with the use of Colombian soils.

CASREC ACTIVITIES IN CENTRAL AMERICA — ORGANIC MATTER MANAGEMENT AND AGROFORESTRY

D.L. Kass[1], M. Jimenez H.[1] and W.A. Campos A.[2]

[1] *Centro Agronomico Tropical de Investigación y Enseñanza (CATIE)*
App. Postal 187, 7170 Turrialba, Costa Rica

2 *M.S. Pindeco, Buenos Aires, Costa Rica*

INTRODUCTION

Mostly due to limitations of funds, CASREC activities in Central America concentrated in Nicaragua and Costa Rica. As in all Central America, due to a great variability of soil formation processes (vulcanism, recent uplifts, and climatic variability), soils are extremely diverse. Because it coordinates a large number of regional projects in Central America, CATIE was chosen as the lead institution for this activity. Work in Nicaragua was carried out in association with the Universidad Nacional Agraria.

RESULTS/ACHIEVEMENTS

The CASREC collection contains a total of twenty monoliths, representing seven different soil orders (Alfisols, Entisols, Vertisols, Andisols, Inceptisols, Mollisols, and Oxisols) although Ultisols, Spodosols, and Histosols also occur in the region. Although only seven of the soils were classified as Andisols, all of the soils in Costa Rica and four of the nine soils in Nicaragua were formed from volcanic materials.

Collection activities to some degree reflected research activities in the region concentrating in the Atlantic zone of Costa Rica, the Turrialba region, the Guanacaste conservation district, the Chacosente nature reserve in Nicaragua, and the Managua region. Soils are grouped in the collection by country and by ecological zone within each country. The collection has mostly been used to assist teaching and research activities at CATIE. Drafts of Country Reports for both Nicaragua and Costa Rica have been prepared as well as five Soil Briefs.

SPECIAL TOPIC

CATIE has the longest tradition of agroforestry research of any institution in the world. Three of the soils in the collection represent sites where agroforestry research has been carried out since 1982. Largely because of their volcanic origin and perhaps to a lesser degree due to higher elevations and the presence of a long dry season along the Pacific Coast, soils in Central America generally have higher organic matter levels than is commonly associated with soils of

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the tropics. Traditional soil management methods may also have contributed since much of the area has been farmed continuously for over three thousand years, when population levels were probably as high as they were at the beginning of this century, if not at present. Organic matter management has therefore been a major focus of CATIE's research activities both within and outside the agroforestry area. Recent interest in carbon sequestering in and emission of greenhouse gases from tropical ecosystems has strengthened this focus.

At the CR001 site, an agroforestry experiment was set up in 1984 and maintained for eight years. Soil carbon and nitrogen levels were measured every six months (Table 1). The soil at the experimental site had much higher organic carbon levels than in the profile sampled because it was in forest when the experiment was begun while the profile was taken in an area which had been cropped for several years and base levels in the Bw1 horizon were higher than in the Ap.

Table 1 Effect of eight years (16 crops) of maize grown in alley farming with *Erythrina poeppigiana* on soil properties and incomes

Tree Spacing	Maize yield (kg $ha^{-1}yr^{-1}$)	Loss of C from soil (kg $ha^{-1}yr^{-1}$)	Loss of N from soil (kg $ha^{-1}yr^{-1}$)	Gain (+) or Loss (-) of K (kg $ha^{-1}yr^{-1}$)	Net in-come (\$ $ha^{-1}yr^{-1}$)
6m x 1m	3600	1879	375	+17	-124
6m x 2m	4000	1835	250	+ 5	- 6
6m x 3m	4040	2803	250	+ 8	+ 30
6m x 4m	4400	2991	375	+20	+ 92
Fertilized - no trees	5000	3468	525	-15	+ 80
Unfertilized - no trees	2800	4378	575	-22	-166

Source: J.C. Dominique, M.S. Thesis, CATIE, 1994.

Fertilizer applied kg $ha^{-1}yr^{-1}$

E lement	Without trees - fertilized	with trees	Without trees - fertilized
N	0	0	58
P	0	15	22
K	0	0	-

At the site of monolith CR002, a long term agroforestry experiment has been carried out since 1982 and has been the subject of several publications (Haggar *et al.*, 1991, 1993; Soto Pinto *et* al., 1993; Paniagua *et al.*, 1995). High organic matter levels seem to have affected the rates of nutrient release from various organic amendments and alley farming treatments. Little nitrogen was recovered from tree prunings in crops associated with trees in the year in which prunings were applied (Haggar *et al.*, 1993) while soil organic P pools were more depleted when organic amendments were the only source of P to crops. At this site, which had been cropped for several years prior to the installation of the experiment, alley farming resulted in significant increases in soil carbon levels (Paniagua *et al.*, 1995). Both maize and beans responded positively to various organic amendments (prunings of *Erythrina poeppigiana* (Walp.) O.F. Cook, *Gliricidia sepium* (Jacq.) Walp., and *Gmelina arborea*, as well as dairy manure. Sustained yield of beans required organic amendments while maize yields were adversely affected by alley farming (Soto Pinto *et al.*, 1993).

The soil at the CR004 site had considerably different physical and chemical properties than the CR001 and CR002 sites, both of which were classified as Eutric Dystropepts, loamy, halloysitic, isohyperthermic. Although less than five km from the other two sites, the CR004 site was located on the slope of the Turrialba volcano and was classified as an Acrudoxic Melanudand, clayey, mixed, isohyperthermic. Low base status, lower pH values in H_2O than KCl, and accumulation of nitrates all indicated that horizons below 75 cm had net positive charge. An agroforestry experiment was set up at this site with standard runoff plots. Data were taken over three years. Poor performance of the alley farming treatments was possibly due to poor tree growth as soil Mg levels remained low even after liming and Mg application (Table 2) (Kass *et* al., 1995) Soil losses were low on this soil with very good physical properties although they were further reduced by alley farming (Lebeuf, 1993).

Table 2 Yield of crops and net nutrient balances for five different cropping systems on an Acrudoxic Melanudand (CR004) (kg $ha^{-1}yr^{-1}$)

Treatment	Maize yield	Bean yield	N	P	K	Ca	Mg
Control	1824	1243	-45	- 2	-12	+135	-12
E.fusca -6m rows	1249	996	+59	+ 3	+42	+220	+ 3
E.fusca -4m rows	1345	1082	+83	+ 6	+60	+232	- 1
Inga edulis mulch	2764	1962	+193	+10	+75	+242	+ 8
E. fusca mulch	2315	2006	+274	+18	+133	+298	+ 2

Source: Kass *et al.* (1995)

CONCLUSIONS

The monolith collection at CATIE contains some key soils of the Central American region. Lack of funds and personnel assigned permanently to this activity limited the size of the collection. Some research projects located at the sites sampled have been discontinued. In those sites where research activities have continued, the collection has been of great value in interpreting research results since they are clearly related to the characteristics of the soils where they were carried out. High organic matter contents, andic properties, low base status, the presence of variable charge clays, good physical properties, low bulk densities, and high P retention, all revealed by the CASREC characterizations, explain to a great degree the results obtained in agroforestry studies on the CATIE sites.

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CUBA NASREC PROJECT: ESTABLISHMENT AND RESULTS

R. Villegas[1], J.H. Kauffman[2], Regla Chang[1], M.E. Sanchez[3], R. Marin[1], E-C. Balmaseda[1], E. Pineda[3], I. Fernandez[3], J. Arcia[1], D. Ponce de Leon[1], L. Benitez[1], R. Más[3] and I. Machado[1].

[1] *National Sugarcane Research Institute of Cuba (INICA). Ave Van Troi # 17203, CP 19210, Boyeros, C. Habana, Cuba*

[2] *International Soil Reference and Information Centre (ISRIC) P.O. Box 353, 6700 AJ Wageningen, The Netherlands*

[3] *Provincial Sugarcane Research Station of Villa Clara (EPICA VILLA CLARA). Autopista Nacional, km 246, Ranchuelo, Villa Clara, Cuba*

INTRODUCTION

Cuba is an agricultural developing country, situated in the Latin-American and the Caribbean region, formed by an archipelago of 110,000 km^2 with about 10 million inhabitants. Havana, the capital, has a population of about two million. The climate is warm and sunny and the mean air temperature is 26-30 °C. The most important economic activities are growing of sugarcane, tobacco, coffee and citrus. Sugarcane forms the backbone of the cuban economy.

Of particular importance at present are the development of: (a) new techniques for soil management according to the different edapho-climatic conditions, automated systems applied to scientific data management; (b) technology transfer on a scientific base; (c) evaluation of main culture-limiting factors in all agricultural zones in the country; and (d) development of technologies for reclaiming salinized and eroded soils, and for rational land use with a view to improving agricultural productivity and to increasing fertilizer-efficiency.

To carry out all these activities, an easily accessible scientific base is needed which relates soil characteristics with environmental conditions (climate and land management) in all agricultural zones of the country. The establishment of a National Soil Reference Collection provides this scientific base, with comprehensive field and analytical data for a number of reference soils representative for the major soil types of the country. This information is stored in the ISIS data handling system.

Plans for establishing a national soil collection already existed for a long time in Cuba. They could be realized as a joint cooperation project of the National Sugarcane Research Institute of Cuba (INICA) and the International Soil Reference and Information Centre (ISRIC), in the period 1990 to 1994. The collection was inaugurated with 22 soil reference profiles presented at the occasion of technical-tours during the XVth World Congress of Soil Science. The joint project was carried out in the framework of ISRIC's National Soil Reference Collection (NASREC) programme.

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The monolith exposition is housed in the Provincial Sugarcane Research Station of Villa Clara province, in the centre of the country, belonging to the INICA network. Duplicates of these soils were collected for the World Soil Collection of ISRIC.

The short term objectives of the exposition are:

- To provide scientific knowledge on sugarcane growing soils in order to establish optimum fertilizer application rates, management practices, and yield potentials under different environmental conditions.
- To expand the collection with soils under different crops throughout the country.

The long term objectives are:

- To establish a Regional Soil Reference and Information Centre on sugarcane growing soils for technology transfer and a variety of exchange programmes for Latin American and Caribbean Countries.
- To establish a broad Soil Reference Database. The aim is to use the collection as a Training and Documentation Centre for students and researchers, as a link between the research centres and the extension services, and as a Natural History Museum.

RESULTS

A large team from INICA collected 23 reference profiles from all over the island, with technical assistance of and support from ISRIC. Soils were described according to the Guidelines for Soil Profile Description (FAO, 1990) and analyzed by INICA and ISRIC laboratories according to uniform procedures (Van Reeuwijk, 1987). Soils were classified according to the FAO system (1988), Soil Taxonomy (Soil Survey Staff, 1992) and the national classification system (Anon., 1975).

The first level grouping of the exposition is according to the national soil classification system and takes into account the type of soil (distinguishable from colour and main soil forming process) and its extent in each province of Cuba. The second level grouping is according to other soil-forming processes and special features observed in the profile.

At present the collection comprises 23 reference profiles, with accompanying documentation on soil classification, soil characterization, evaluation of soil/land qualities, photos of land use, landscape and special features observed in the profile. The data are stored in ISIS, version 4, and documented in eight Soil Briefs and one Country Report. The criteria for grouping reference soils in the Soil Briefs are also used for the exposition.

Main users of the exposition are students and professors from universities, agricultural schools, researchers from National Agricultural Research Institutes, and staff of the extension service from Sugar and Agricultural Ministries.

At present the database is being explained to all Provincial Sugarcane Research Stations of INICA. It is INICA's intention to apply the database fundamentally in studies related to soil fertility and land evaluation, and also to link it to data processing programmes and dynamic simulation models. Potential users of the database and publications, include staff of agricultural universities, soil and plant nutrition scientists, professors and students from agricultural universities and extension service personnel of the Sugarcane Ministry.

CONCLUSIONS

The collection is important for soil studies, both in Cuba and in similar agro-ecological regions of the world. Since its inauguration, the exhibition has been visited by about of 500 persons. The main visitors come from universities, agricultural schools and research institutes near to Villa Clara province. Other visitors are from the extension service of the Sugar Ministry and include soil scientists.

The most important achievements have been the organization of a soil course, using the exposition. This course, entitled 'Soil Collection of Cuba', takes place twice a year (April and September). The course programme takes into account the major wishes of the users. So far these have been: familiarization with the FAO-UNESCO legend and Soil Taxonomy classification system; soil description and characterization according to ISRIC's methodologies; evaluation of soil/land qualities; usc of thc cxposition for establishing a better management practices; and familiarization with the ISIS programme.

The first course took place in April 1994 with 20 students from Central University of Villa Clara province and from the National Tropical Vegetables Research Institute and soil laboratory staff of the Ministry of Agriculture. The next course is scheduled for October with the participation of 20 extension service personnel of the Sugar Ministry and researchers from INICA's Provincial Experiment Stations. Other achievements have been the compilation of all soil information in a series of Soil Briefs and a Country Report, for which there is a great demand.

Problems encountered include: lack of sufficient national and international documentation/ publications; limited capability for communication, both inside and outside the country; lack of lacquer and dermoplast for expanding the reference collection; unavailability of a Spanish version of the Guidelines for Description and Coding of Soil Data.

Priorities for future work are to: (a) finalize the publications (Spanish version); (b) edit and distribute a brochure on CUBA-NASREC; (c) continue giving the 'Soil Collection of CUBA' course; (d) expand the collection and database with new reference soils (under different crops) throughout the country; (e) link the ISIS programme with other data processing facilities and dynamic models; and (f) to publish a Spanish version of the Guidelines for Description and Coding of Soil Data in order to facilitate the widespread use of ISIS.

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ASSESSMENT AND EVALUATION OF LAND RESOURCES IN SINAI

S.I. Abdel Rahman
Soils and Water Use Department, National Research Centre
El-Tahrir Steet, Dokki, Giza, Egypt

INTRODUCTION

A major research project has been conducted in the National Authority for Remote Sensing and Space Sciences (NARSS) to map the natural resources of Sinai Peninsula (1992-1994). Landform, hydrology, geology and soil maps have been produced based upon LANDSAT Thematic Mapper (TM) data. The mapped land units were evaluated using a parametric land capability model. The results of the land evaluation were displayed on land capability maps at scale 1:100,000 (36 sheets). The aim of the study was to demonstrate the capability of remote sensing data, land information systems, and geographic information system for land use planning in El Hasana region in Central Sinai as a pilot area.

RESULTS

El Hasana region covers about 3,500 km^2 and is located in Central Sinai Peninsula between latitude 30°00' N 30°30' N and longitude 33°35' and 34°05' E. This area was selected to examine the capability of Landsat TM data for soil mapping in an erosional-depositional landform in a very aridic environment. The interpretation of satellite imagery, combined with field investigations, was found to be very useful for producing a soil consociation map at scale (1:100,000). The map units were defined mostly based on their soil characteristics, geomorphology, land cover and land use. The main geomorphic units in the study area were: wadis, sloping lands, pediplains, hills and domes. The physiographic map units were subjected to evaluation using a parametric land capability model. The high potential lands and the availability of water resources were the main aspects for locating areas for agricultural extension projects. Wadi Al-Arish has moderately severe soil, climate and erosion limitations. The calculated capability indices were ranging between 0.5 and 0.7. Therefore, Wadi Al Arish and its tributaries classified as capability class II or III. The main water resources in Wadi Al Arish are rainfall (50-75 mm yr^{-1}), huge amounts of runoff water, and ground water of low quality.

Digital image processing, which included principal component analysis (PCA) and unsupervised classification techniques, was performed for two sites in Wadi Al Arish. Site selection was carried out based on the availability of soil data and the potential for agricultural land use. Five soil types could be distinguished in the first based on their spectral reflectance. These classes were: Wadi terrace, gravely plain, flood plain, Wadi bottom(bed), and playa. The

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reflectance characteristics and the total area for each class were calculated. However, in the second site, which is located a few kilometres to the south of the first site, only four soil classes were identified. The soil characteristics of each classified unit were determined and the effect of vegetation cover, land use and soil erosion on spectral characteristics were discussed.

The classified soil units were subjected to evaluation using a computerized land suitability model to determine their suitability for wheat, watermelon and olive. The study reveals that the suitability indices for the tested three crops are similar for each soil unit. Only the flood plain was found to be suitable for cultivation of the tested crops with suitability indices ranging between 0.6 and 0.7. About 4,800 acres can be cultivated with winter wheat,watermelon and olives. The results were displayed on maps using GIS facilities.

THE NATIONAL SOIL REFERENCE COLLECTION OF ECUADOR

G. del Posso and Luis Aldaz
Agriculture and Livestock Ministry (MAG), PRONAREG and Ecuadorian Museum of Natural Sciences, Av. Nacionales Unideas C.C.N.U. Torre B, 7°#703, Quito, Ecuador

INTRODUCTION

Like in some other developing countries knowledge of the importance of soil resources for many practical purposes, particularly for agriculture, remains limited in Ecuador. In order to increase agricultural production and to prevent soil degradation, comprehensive and accessible data on the soil and other environmental factors are needed. In this context, 'the soil reference collection' is recognized as one of the best instruments for the national development of soil science and its practical applications.

In January 1984 contacts have been established between MAG/PRONAREG, Ecuador, and ISRIC, The Netherlands, about the establishment of a National Soil Reference Collection (NASREC). At the beginning of 1986, Ecuador was chosen as one of the major support countries for the establishment of a NASREC Project. The long-term objective is to establish a National Soil Reference Collection for Ecuador, with a view to maximizing the use and management of different types of soil for the benefit of the people and to prevent land and soils from being degraded. The short-term objective is the establishment of a core collection of about 12 to 14 soil monoliths representative for the various agro-ecological regions of the country.

The Ecuadorian NASREC currently contains 20 monoliths, representative for the 4 major regions of the country. There are plans to gradually increase the soil collection. In conjunction with the NASREC activities, research on regionally relevant topics is made. In this context, 'indurated volcanic' (cangahua) soils are an important topic of investigation.

RESULTS AND ACHIEVEMENTS

According to the objectives of the Ecuadorian NASREC, the soil collection consists of twenty monoliths (The initial plan only aimed at 12 to 14 profiles) representative for the four natural geographical or ecological regions of the country. These are: Amazon, Inter-Andean Valley, Coastal and Galapagos Islands.

The NASREC collection is organized according to major soils, using the following criteria:
- Agro-ecological region;
- Suitability for important crops, including banana, cotton, coffee and rice;
- Geographical distribution (e.g. location, classification, landscape, climate, actual land use, evaluation of land suitability, micromorphology, ISRIC codes and remarks).

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- Ecological risk, such as erosion in the Inter-Andean Valley, and destruction of primary vegetation in the Amazon region and the Galapagos Islands.

An overview of the twenty soil monoliths, which includes the ISRIC code, location, classification and remarks, is given in Table 1.

Table 1 Key information on soils of the Ecuadorian NASREC

ISRIC code	Location	Classification	Remarks (FAO)
EC 1	Cayambe	Eutric Cambisol	Canghua (duripan)
EC 2	St. Catalina	Humic Andisol	INIAP Exp. station
EC 3	El Corazon	Humic Andosol	4000 m altitude
EC 4	Galapagos	Humic Acrisol	500 m altitude
EC 5	Galapagos	Vertic Luvisol	Lowland
EC 6	El Coca	Dystric Nitosol	Amazon Region
EC 7	San Carlos	Ferric Acrisol	Amazon Reg.INIAP st.
EC 8	Tandapi	Humic Andosol	1500 m altitude
EC 9	St. Domingo	Ochric Andosol	Oil palm INIAP st.
EC 10	Buena Fe	Luvic Kastanozem	Cocoa Coastal Reg.
EC 11	El Elpalme	Luvic Chernozem	Soybeens maize C. Reg.
EC 12	Conocoto	Ochric Andosol	Cangahua (duripan)
EC 13	Calderon	Vitric Andosol	Interandean Valley
EC 14	Portoviejo	Chromic Vertisol	Cotton Coastal Reg.
EC 15	Jipijapa	Calcic Cambisol	Coffee Coastal Reg.
EC 16	Machala	Calcaric Fluvisol	Banana Coastal Reg.
EC 17	Boliche	Calcaric Gleysol	Rice INIAP st.
EC 18	Machachi	Mollic Andosol	Interandean Valley
EC 19	Palmira	Ochric Andosol	Interandean Valley
EC 20	Aloag	Vitric Andosol	Interandean Valley

In summary 9 monoliths are from the Interandean Region, 7 are from the Coastal Region, 2 profiles are from the Amazon Region, and 2 monoliths are from the Galapagos Region. During the field work an additional 20 soil profiles were sampled (40 in total) for the World Soil Collection and sent to ISRIC.

The NASREC collection is housed officially in the exhibition hall of the Ecuadorian Museum of Natural Sciences in Quito.

Technical assistance and advise is given by the National Coordinator of NASREC. Also a person is in charge of the collection during the opening hours, and this 5 days per week.

The main users of the soil collection are students from universities, particularly the faculties of Agronomy, Geology, Ecology, Forest, Biology, Geography, Natural Sciences and Zootechnics. The collection thus has an important educative function. The collection also provides information about soil sequences in the landscape and the effect of different soil management practices on soil conditions. Soil degradation problems and their ecological impacts are also addressed.

An other important group of users of the collection are students from secondary and primary schools, principally from Quito. These students are mostly interested in learning about the soil as a natural resource that needs to be protected. Other visitors include students of universities and schools outside the capital as well as scientists, agronomists, planners, farmers and the general public. Occasionally, there are visitors from other countries, especially the United States and Europe. These are particularly interested in the monoliths that originate from the Galapagos and Amazon region.

A computerized database with data on the soil monoliths and their environment is operational. The principal applications of this database are the evaluation of the suitability of the land for specified uses, according to the FAO Framework. Other applications are in the field of soil fertility assessment and soil conservation. The main users of the applications and of the basic information of the soil collection are pedologists, agricultural engineers, planners, and university professors interested in research and some students for their graduate thesis.

The study of indurated volcanic soils, called 'cangahua', is important in order to enable their reclamation and management whereby these eroded lands may be included in the agricultural production of the Interandean Valley.

CONCLUSIONS

During tenure of the Ecuadorian NASREC twenty soil monoliths, representative of the four major ecological regions of the country, have been described and sampled. A permanent exposition of these monoliths was inaugurated during a seminar aimed at increasing the number of users interested in the collection and at producing general publications.

The main problems encountered are the limited physical space and the financial state of the Ecuadorian NASREC. As a result it has not been possible to increase the collection according to our plans, and finding ways to achieve these goals are our priority for the future.

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ESTABLISHMENT OF THE NATIONAL SOIL REFERENCE CENTRE, ETHIOPIA

S. Sertsu
National Soil Service Project, Department of Watershed Development and Landuse, P.O.Box 147, Addis Abeba, Ethiopia.

INTRODUCTION

Due to the varied physiographic and climatic situations the soils of Ethiopia are diverse and their productivity varies greatly. Although a well developed soil reference centre is essential for research, teaching and development purposes, no attempt was made in the past to establish such a centre at the national level. Since the major objective of the National Soil Service Project (NSSP) is to play a leading role in the advancement of soil services at national level, it was thought timely and appropriate to establish a National Soil Reference Centre during the project phase. With this intention, the NSSP of the Ministry of Natural Resources Development and Environmental Protection, supported by the development aid fund obtained from the FAO/UNDP, initiated the collection and assembly of a soil reference unit towards the end of 1993. Guidelines for the collection and preparation of soil monoliths were obtained from ISRIC.

RESULTS

From the establishment of the National Soil Reference Centre a total of 27 soil profiles were opened in a six month period. Monoliths were collected for these soils which occur in different parts of the country and represent the 18 major soil associations (grouping based on the FAO-UNESCO Soil Map of the World). The soils were described and classified according to the FAO (1988) legend and USDA Soil Taxonomy (1992) system. The monoliths were mounted on wooden-board, according to ISRIC's standard procedures, and displayed in an exposition room with accompanying pictures and description leaflets. In addition to field descriptions, except for micro-morphological and mineralogical parameters, most of the physical and chemical analyses were conducted on sub-samples. All environmental information was recorded. During the project period it has not yet been possible to collect soil monoliths for all representative soil types in the country and the collection has been limited to the soil unit (soil order) level. In the future, when time and resources permit, the collection may be extended to the series level.

Main users of the exposition are research and development scientists, university students, development agents, visiting scientists, planners, high-school students and laboratory specialists for data interpretation purposes.

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The exposition room is open during working hours and all interested groups and individuals are allowed to visit it with the assistance of the responsible expert. The database in the soil reference room is used for soil fertility and land evaluation purposes, and by graduate students working on soil related problems. With further strengthening of the Reference Centre, the scope of usage and users is expected to expand.

CONCLUSIONS

The establishment of the National Soil Reference Centre, which is the first of its kind in Ethiopia, is considered a major achievement. Several major soil types still need to be sampled and described. The local unavailability of adhesive lacquer and shortage of funds form major constraints for expanding the monolith collection of the Reference Centre. If funds can be identified through external assistance or collaborative programmes, it is envisaged to expand the collection of soil monoliths to the series level in order to arrive at a complete representation of the soils of Ethiopia.

NATIONAL SOIL REFERENCE COLLECTION AND EXPOSITION, GHANA

R.D. Asiamah and O. Dwomo
Soil Research Institute, Academy Post Office, Kwadaso-Kumasi, Ghana

INTRODUCTION

The collection and exposition of soil monoliths in Ghana started in 1980, when the first trainee of the Soil Monolith Collection course at ISRIC returned home to start the project. The initial aim of the training was to set up an African Soil Museum in Ghana. The Organisation of the African Unity Scientific and Technical Committee proposed to set up this museum in Accra. Though the project could not take-off, the Soil Research Institute sought moderate funds from the Government and started the project on a national level. The project is linked with the soil survey programmes of the institute as well as research and development work of other research institutes and universities.

At present, 29 reference soils have been collected, prepared and exhibited. Six others have just been collected and will be prepared shortly. Twelve monoliths are exhibited at our Soil Research Centre in Accra, 11 at our exhibition hall in Kwadaso-Kumasi, 4 at the Savanna Agricultural Research Institute in Tamale and 2 at the Oil Palm Research Institute at Kusi-Kade.

It is planned that the project will be extended to cover the whole country under the National Soil Survey, Land Evaluation and Soil Reference Study programme. Expositions are to be established in the Universities and Colleges for teaching purposes and in the National Museum.

RESULTS

Since the programme started in 1980, 35 soil monoliths have been collected. These soils are representative for the major ecological zones of Ghana. Twenty-seven of these soils have been prepared and are displayed permanently in the Institute's exhibition hall. Monoliths have also been shown at three international exhibitions in Accra in 1986 and 1991. They have also been on display at international and national Soil Science and Science Conferences, and at workshops.

Six technicians of the Institute were trained locally. Both authors received their training at ISRIC, in 1980 and 1987 respectively.

So far over 1,200 persons visit the exhibitions annually. They include groups of students of agricultural institutions and universities, members of Ghana's army, agricultural scientists, extension officers and farmers. Students from neighbouring Togo and Burkina Faso also pay normal visits.

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CONCLUSIONS

The results of the Institute's soil collection activities are not computerised yet. The information is published and disseminated in bulletins, annual reports, soil survey reports and so on. Information on soil description and classification, soil suitability, soil fertility status, soil degradation, general land use is available also as well as soil maps and soil suitability maps of the regions of Ghana at scales of between 1:250,000 and 1:1,500,000.

The achievements of this project are enormous, giving the necessary information on the country's soil resources to various users. Training of the Institute's technical staff and students from the colleges and Universities benefits from the monolith collection, and soil correlation exercises are made easier.

The major problem facing the project is inadequate funding, making the collection of monoliths a slow exercise. As a result, only a few monoliths are collected each year. A convenient vehicle to transport the monoliths is not available.

There is a plan to speed-up the collection and to have samples of all the major soils of Ghana for our exhibition halls in Accra and Kumasi and for the colleges and Universities and the national museum.

USE OF SOIL RESOURCES OF KARNATAKA FOR SUSTAINABLE AGRICULTURE

M.S. Badrinath
Department of Soil Science and Agricultural Chemistry, College of Agriculture,
University of Agricultural Sciences, GKVK, Bangalore - 560 065, India

INTRODUCTION

Concern for environmental matters shows the importance of soil and environment-oriented projects, such as NASREC. In India the first NASREC training course was held at Kerala Agriculture College in 1992. The USREC project became very popular following visits by several soil scientists of the neighbouring state's Agriculture Universities to the soil exposition which is housed at the Department of Soil Science and Agricultural Chemistry.

USREC, through NASREC, aims at the establishment of a national soil reference collection which includes a soil exposition, soil database and related publications, issued in the local languages. The collected data on agro-climatology, soils and pedogenesis help to bridge the communication gap between the soil science community and target-groups such as students, farmers and land use planners.

The NASREC project in India was scheduled to terminate in March 1994, but it was extended up to June 1995 without any further financial commitment from ISRIC.

RESULTS

The exposition at Bangalore is a selection of soil profiles from ten agro-climatic zones of Karnataka (Table 1a, b). These soil types are of particular interest for agricultural and environmental studies, and are presented by major agro-climatic region. Zone 1 and 10 form the extremes in terms of annual precipitation, which is clearly reflected in their pedogenesis.

The opening ceremony of the soil exposition took place on 24 April 1995. From that day, the exposition has been visited on a regular basis by all visitors to the University of Agricultural Sciences (UAS) at Bangalore. These include students from other universities, farmers from Karnataka and other states, planners of the Government of India, and scientists of ICAR and other State Agricultural Universities (SAU). One of the former vice-chancellors of UAS-Bangalore has expressed the need for such a comprehensive soil exposition in every State Agricultural University. Staff of the extension service have indicated that the Soil Briefs should be issued in the local languages in order to be widely accessible.

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Table 1a Pedogenic particulars of soils of Karnataka

Code No.	Name of the Agro-climatic zone	No. of zone	Pedon location	Latitude (N)	Longitude (E)
IND 67	North-Eastern Transition zone	1	ARS Bidar	17°45′-18°50′	76°42′-75°30′
IND 64	North-Eastern Dry zone	2	ARS Bhimarayangudi	15°45′-17°30′	76°30′-77°10′
IND 61	Northern Dry zone	3	RRS Bijapur	14°30′-17°25′	74°30′-77°10′
IND 63	Northern Dry zone	3	ARS Gangavathi	14°30′-17°25′	74°30′-77°10′
IND 62	Northern Dry zone	3	ARS Siruguppa	14°30′-17°25′	74°30′-77°10′
IND 55	Central Dry zone	4	ARS Arsikere	12°50′-14°55′	75°30′-77°20′
IND 56	Central Dry zone	4	ARS Hiriyur	12°50′-14°55′	75°30′-77°20′
IND 57	Eastern Dry zone	5	GKVK Bangalore	12°10′-14°00′	76°35′-78°45′
IND 54	Southern Dry zone	6	RRS Mandya	11°30′-13°05′	76°05′-77°45′
IND 65	Southern Transition zone	8	RRS Dharwar	14°30′-16°30′	74°10′-75°40′
IND 53	Hilly zone	9	IIHR Chethalli	12°00′-15°40′	74°10′-76°15′
IND 58	Hilly zone	9	ICRI Sakaleshpur	12°00′-15°40′	74°10′-76°15′
IND 66	Hilly zone	9	RRS Mudigere	12°00′-15°40′	74°10′-76°15′
IND 59	Coastal zone	10	RRS Brahmavara	12°30′-15°00′	74°05′-76°00′

Table 1b Pedogenic particulars of soils of Karnataka

Code No.	Precip. (mm yr^{-1})	Mean Max. Temp. (°C)	Geology	USDA Soil Taxonomy	FAO Classification
IND 67	765	32.9	Laterite	Rhodic Paleustalfs	Chromic Luvisols
IND 64	767	33.4	Deccan Trap	Typic Haplusterts	Chromic Vertisols
IND 61	585	32.4	Deccan Trap	Typic Haplusterts	Chromic Vertisols
IND 63	767	33.4	Archean	Vertic Ustropepts	Vertic Cambisols
IND 62	767	33.4	Archean	Typic Haplusterts	Pellic Vertisols
IND 55	794	30.2	Archean	Rhodic Paleustalfs	Eutric Nitisols
IND 56	611	30.8	Dharwars	Chromic Haplusterts	Chromic Vertisols
IND 57	776	29.2	Archean	Kandic Paleustalfs	Dystric Nitisols
IND 54	734	29.1	Archean	Tyoic Rhodustalfs	Chromic Luvisols
IND 65	869	30.6	Archean	Ultic Haplustalfs	Orthic Luvisols
IND 60	780	30.1	Dharwars	Typic Haplusterts	Chromic Vertisols
IND 53	2726	24.1	Archean	Ustic Palehumults	Humic Acrisols
IND 58	1041	28.5	Archean	Ultic Paleustalfs	Dystric Nitisols
IND 66	2209	25.2	Archean	Paleustalfs	Ferric Acrisols
IND 59	3893	30.7	Archean	Typic Kandiustults	Orthic Acrisols

CONCLUSIONS

A main achievement of the NASREC activity at UAS-Bangalore has been the establishment of the soil exposition. Nonetheless, progress has been hampered by a number of constraints, including the flow of funds under the USREC project at SAU level. Although this might be due to procedural delays, it is a point for immediate attention.

Soils of the different regions of Karnataka state show different constraints, including soil acidity and soil salinity (saline-alkali soils), in combination with an ustic soil moisture regime in the major part of the state. This points at the need for future research on irrigation needs in ustic zones in order to permit growing of 2 crops per year, which is crucial for increasing agricultural productivity in the region.

Priorities for future work under the USREC project include the establishment of an adequate training programme on database handling. USREC is in a sound position to realize co-operative activities with apex soil institutes. The soil exposition at UAS-Bangalore is the first of its kind in the history of SAU's in India and evinced interest from the target groups. In order to reach the long-term goals, i.e. reinforcement of the extension and research capacity, a longer project period is required.

ISRIC has supported SAU's through the USREC project. The experience gained, shows the need for continuation of ISRIC's advisory role along with material support. This is essential because the scientists from neighbouring SAU's need to be trained in order for them to establish soil reference centres at their own universities. Fellowships to attend these training courses are direly needed. The establishment of an ISRIC regional centre at the UAS-Bangalore could serve as a future nodal point for extending the objectives of ISRIC to the unserved countries in Southeast Asia and other State Agricultural Universities in India.

RESULTS OF USREC PROJECT IN TAMIL NADU STATE, INDIA

S. Natarajan and R. Perumal
Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University
Coimbatore - 641 003, India.

INTRODUCTION

Tamil Nadu, the southmost state in India, is located between 76°14′ and 80°21′ E longitude and 8°14′ and 13°54′ N latitude. It has a total area of 13 million ha and is divided into seven agroclimatic zones on the basis of rainfall pattern, altitude and irrigation sources. A soil resource inventory has been completed by the Soil Survey Organization of the Department of Agriculture. Soil maps on 1:50,000 scale have been prepared which depict the distribution and occurrence of soil series. The soils belong to major orders viz., Entisols, Inceptisols, Alfisols, Ultisols, Vertisols and Mollisols of USDA Soil Taxonomy.

Voluminous data have been generated on the soil properties, soil fertility, cropping systems and land use by State Soil Survey Organisation, National Bureau of Soil Survey and Land Use Planning, the all India Soil and Land Use Survey and Tamil Nadu Agricultural University. However work on the soil data collection and specimen collection and exposition did not make any head way. At this juncture in 1993 the International Soil Reference and Information Centre (ISRIC) contacted the three State Agricultural Universities in Southern India viz., Tamil Nadu Agricultural University (TNAU), Kerala Agricultural University (KAU) and the University of Agricultural Sciences (UAS) at Bangalore, and provided technical and financial assistance for the project on the 'Establishment of University Soil Reference collections'. The project was implemented in TNAU from November, 1993.

The objectives of the project include identification and collection of reference soils, preparation and exposition of soil monoliths, establishment of soil database and preparation of Soil Briefs and brochures for the users.

RESULTS AND ACHIEVEMENTS

Fifteen reference soils were selected based on the agro-ecological zone at the first level, major land use at the second level, and the benchmark soil of major land use at the third level. The list of reference soils is presented in Table 1.

The exposition of the soil monoliths is according to the agro-climatic zone, followed by local soil name, soils series name and taxonomical classification (USDA, 1994). The exposition hall is expected to be kept open for visitors from October, 1995.

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Table 1 Reference soils in Tamil Nadu

Agro-ecological zone	Local soil name	Soil classification	Major land use
1. North-eastern	Low level laterite (Vallam series)	Typic Haplustalfs	Oil seed crops
2. North-western	Red loam (Vannapati series)	Typic Ustropepts	Millets
3. Western	Red loam (Irugur series)	Typic Ustropepts	Groundnut, millets
	Brown calcareous (Palladam series)	Typic Ustropepts	Pasture, minor millets
	Mixed black (Periyanaickan-palayam series)	Vertic Ustropepts	Cereals
4. Hilly	High level laterite (Ooty series)	Typic Dystropepts	Tea
5. Cauvery delta	River alluvium (Padugai series)	Typic Ustifluvents	Paddy
	Coastal alluvium (Kohur series)	Vertic Ustropepts	Paddy
6. Southern	Laterite alluvium (Madukkur series)	Typic Haplustalfs	Paddy
	Black cotton soil (Pilamedu series)	Typic Haplusterts	Cotton
	Deep red loam (Palaviduthi series)	Typic Haplustalfs	Horticulture crops
	Low land laterite (Vayalogam series)	Typic Rhodustalfs	Pulses
	Theri soils (Udangudi series)	Typic Haplargids	Banana, coconut
	Deep red loam (Thenkasi series)	Typic Ustropepts	Horticulture crops
7. High rainfall	Low land laterite (Pechiparai series)	Typic Happludults	Rubber, coconut

The main users of the exposition include school and university students, farmers, scientists and planners. It is expected that 3,000 to 4,000 visitors shall visit the exposition hall annually.

The soil data collected for the fifteen reference soils will be used for studies related to land evaluation, soil fertility, cropping pattern and soil erosion.

Soil Briefs and brochures are the two kinds of publication on the reference soils. Five Soil Briefs and fifteen brochures will be prepared. The Soil Briefs (SB) will be prepared in English for reference soils of the following agro-climatic zones: SB1: Northeastern and Northwestern zone; SB2: Western zone; SB3: Cauvery delta zone; SB4: Reference soils of Southern zone; and SB5: High rainfall and Hilly zones. The main users of Soil Briefs are soil scientists. The brochures will be published in Tamil, the local language, for the use of farmers and in English for the use by non-soil scientists, extension workers and planners.

CONCLUSIONS

The USREC project has made possible the collection and exposition of the major soils of the main agro-climatic zones in Tamil Nadu; it is the first of its kind in the state. Much of the research information already generated on the reference soils can be integrated for studies related to land evaluation, soil fertility, cropping pattern, etc. as most of the sites for soil monoliths were chosen in Regional Research Stations or State Seed Farms or established private farms. There is scope for collection and exposition of nine more reference soils in addition to the presently collected fifteen soils. The database could be linked to crop yield modelling and land evaluation programmes.

ESTABLISHMENT OF A KENYAN NATIONAL SOIL REFERENCE COLLECTION AND PEDON DATABASE (KENASREC)

B.K. Waruru and H.N. Onyono
Kenya Soil Survey, National Agricultural Research Laboratories,
P.O. Box 14733, Nairobi, Kenya

INTRODUCTION

The history of the Soil Reference Collection in Kenya dates back to the early seventies during the formative years of the Kenya Soil Survey (KSS) and especially during the pioneering work on the Exploratory Soil Map of Kenya (Sombroek *et al.*, 1980). To complement the FAO/UNESCO Soil Map of the World (1971-1981), the International Soil Reference and Information Centre (ISRIC) had the task of collecting representative profiles of the major soils of the World.

Due to the diversity in landform, geology, relief, climate, altitude and therefore soils, the major soil groupings in Kenya were found to be representative of the cross-section of the soils of the African continent. Much of the present KSS's collection are duplicates of the profiles sampled for ISRIC's World Soils Collection.

Initially, the purpose and functions of the collection were vague. With no proper and systematic records of accompanying soil, site and land use data, some of the profiles were hang for display along KSS corridors where they gathered dust, got damaged and in time lost meaning.

The formal establishment of a Kenyan National Soil Reference Collection and Database (KENASREC) at KSS was noted in 1985 when one of the technical staff was formally trained in soil reference collection and use at ISRIC. The KENASREC project document is now approved (3rd quarter of 1995) and the project will be realised during an 18 months period with the co-operation of and collaboration with ISRIC.

Since its inception in 1972, KSS has been charged with the responsibility of mapping soils and other related land resources for accelerated development. Over 250 publications and reports on soil surveys have been prepared for different parts of the country using different mapping scales. Some of these are stored at KSS. Copies of the soil reports are distributed to the organizations (including individual farmers) requesting such surveys, various educational institutions and Regional Research Centres. A growing concern is that the reports are not fully utilized by the target user-group. The reports and soil maps are too technical to non-soil

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The present challenge of KSS is to make the distribution of soil information as effective and efficient as possible. This is in terms of timeliness, appropriateness and usefulness. To address this situation, KSS has embarked on deliberate and innovative methods of soil survey, soil and land information dissemination. These include surveys by districts as opposed to surveys by Map Sheets, the establishment of the Geographical Information System (G.I.S.), the Soils and Terrain Digital Database (SOTER) programme for Kenya, and the holding of GIS district workshops. A National Soil Reference Centre (NASREC) at KSS is another endeavour to increase and improve the efficiency and effectiveness of soil and land information documentation and dissemination.

KENASREC at KSS will complement Soil Surveys and help to publicize their value. By strengthening and widening the state of knowledge on the country's soil resources, the centre will improve communication between the soil surveyors, other soil scientists and the other clientele of soil information. The NASREC (and particularly the exposition) will provide the tool to bridge the gap between the abstract soil maps, soil survey reports and the actual soils in the field. The collection elaborates visually, clearly and simply soil characteristics and the various ways soils information can be used. This will provide KSS a Public Relation (PR) facility educating the general public, including farmers, to be more 'soil conscious'.

REFERENCE COLLECTION AND DATABASE STATUS

Reference collection

ISRIC has collected 71 profiles from various parts of Kenya.The site, profile descriptions and analytical data will be availed to KSS from ISRIC for the publication of the Country Report 'Soil Reference Profiles of Kenya'. Prior to 1989, KSS collected a total of 64 profiles. In 1989, 13 profiles were issued on permanent loan to the Soil Science Department of the University of Nairobi at Kabete Campus. Presently, KSS has 51 profiles of which 18 are on display in the exposition hall, 33 are in the monolith store and 5 are pending preparation.

Although there is no particular grouping criteria, profiles on display in the exposition hall represent major (coverage) soil groupings, the major Agro-Ecological Zones (AEZ), high potential and problem soils. In store are duplicate and damaged profiles. A selection of 3 - 5 profiles (from both those on display and those in store) is used as a mobile collection for display and demonstration at shows of the National and Regional Agricultural Society of Kenya. The selection of the profiles for the mobile collection depends on show theme, the geographic (or AEZ) region and the soil(s) associated with the major land use.

There has hitherto existed no proper handling of these soil materials or documentation of associated land and site data. The present exposition hall for example doubles as the KSS (and even Kenya Agricultural Research Institute's) meeting room.

During and after the exploratory inventory of the country's soils, the build up of the country's reference collection (though by default) was most timely. It has occasioned the assembly under one roof of most of the major soil groups in the main agro-ecological zones.

The profiles at the KSS Exposition hall already aroused much interest to the host of visitors to KARI headquarters, National Agricultural Research Laboratories and KSS. No matter their specific interest, an orientation at the exposition is always courtesy.

Ad hoc visitors of the exposition have included KSS Soil Surveyors, other KARI researchers, students from agricultural Institutions and Secondary Schools. Newly recruited NARL and particularly KSS Soil Scientists have always had their first touch on soils from an orientation at the exposition hall.

Database

KENASREC will comprise of an exposition of the reference profiles and an associated database of the soil and site information. Although KSS has presently an assembly of representative samples of a cross-section of the country's major soil groupings, most of the soil's site and profile description data has hitherto been difficult to access both for perusal, update and for electronic storage. With the completion of analysis of the duplicate samples from ISRIC this information will be available in the proposed computerized database at KSS (the ISRIC's Soil Information System-ISIS).

Besides the improved accessibility of data, the data sets of the well-studied reference profiles will be amenable for use in crop production simulation models (e.g., the World Food Studies model, WOFOST), in the assessment of land related constraints (e.g. STRESS using the Automated Land Evaluation System, ALES); the SOTER Water Erosion Assessment Programme ,SWEAP, which is based on two erosion models: (a) Universal Soil Loss Equation, USLE, and (b) the Soil Loss Estimation Model of South Africa, SLEMSA); the semi-automated Soil Classification System - DIAGNISIS and applications in GIS.

A generic soil classification system is always dynamic. With new advances in soil science, new concepts and taxa-defining criteria evolve. A well managed soil reference database will be necessary to incorporate all new concepts and update classification.

Towards the establishment of a computerized pedon database, a Personal Computer (PC) has already been procured for KENASREC. Installation, procurement of the necessary software and training on the operation and data management will be realized during the project period.

CONCLUSIONS

KENASREC will be realized within 18 months duration starting from the 4th quarter of 1995. The specific goals of the project will be threefold:

- to update, upgrade and present in a display the already existing soil collection;
- to upgrade the exposition hall and computer room and instal the computerized database;
- to publish the Country Report on Kenya's Reference Profiles and a series of Soil Briefs;

Follow-up KENASREC Activities are:

- phase out (in a systematic replacement) the old and damaged profiles (monoliths and/or lacquer peels) with fresh profiles with comprehensive and updated information.

- establish regional NASREC's at tertiary institutions, district museums, district information documentation centres, National/Regional Research Centres (NRC's/RRC's), International Institutions (e.g. ICRAF and ICIPE). This will involve collaboration with these institutions.
- establish a mobile profile collection for displaying and demonstration during International or Regional trade fairs/exhibitions (e.g. at ASK shows and open/field days of NRC/RRC's).

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Appendix 1 Profiles in the Kenya monolith store

No.	MAP SHEET CODE	CLASSIFICATION FAO (1974)	LOCATION	AEZ
1	148/4-1	Nitisol	Nairobi (NARL)	III-4
2	121/2-2	Dystric Cambisol	Mt. Kenya	I-3, I-4
3	122/3-45	Humic dystric Cambisol	? Embu	II-3
4	190/4-204	Chromic Luvisol	Tsavo East	IV-1
5	122/3-49	Chromic Acrisol	Chuka	II-3
6	122/4-33	Chromic Acrisol	Ishiara	IV-1
7	161/3-83	Vertiluvic Phaeozem	Kajiado	V-4
8	133/2-?	Dystric Andosol (Vitric)	Suswa	V-5
9	122/3-2	Humic Nitisol	Chuka	III-2, III-3
10	180/3-4	Rhodic Ferralsol	Tsavo East	?
11	54-?	Cambic Arenosol	HEDAD	VII-1
12	54-7	Luvic Xerosol	HEDAD	VII-1
13	122/3-51	Gleysol Cambic	Chuka	II-3
14	161/4-86	Pellic Vertisol	Kajiado	V-4
15	122/4-39	Calcic Luvisol	Ishiara-Embu	IV-1
16	190/3-4	Rhodic Ferralsol	Tsavo East	VIa
17	190/4-41	Orthic Solonetz	Tsavo East	VIb
18	126/-30	Eutric Fluvisol	Garissa	VII-1
19	163/3-17	Plinthic Acrisol	Makueni	?
20	190/3-13	Ferric Luvisol	Tsavo East	IV-1
21	200/1-1048	Acrisol	Vigurungani- Kwale	V
22	190/1-103	Ferralic Cambisol	Tsavo East	VI-1
23	122/2-M	Chromic Luvisol	Mitunguu-Meru	IV-1
24	137/2-191	Rhodic Ferralsol	Ngomeni	V-1
25	138/-2	Chromic Acrisol	Sosoma	VII-1
26	43/-5	Takyric Solonchak	Chalbi Desert	VII-1
27	161/4-51	Planosol	Kajiado	V-4?
28	126/-32	Rhodic Ferralsol	Garissa	VII-1
29	200/2-380	Arenosol	Kwale	V?
30	190/4-92	Rhodic Ferralsol	Tsavo East	VIb
31	136/3-16?	Vertisol	Mwea	IV

Appendix 2 Profiles in the Kenyan exposition hall

No.	MAP SHEET CODE	CLASSIFICATION	LOCATION	AEZ
1	161/4-82	Eutric Planosol	Kajiado	V-5
2	137/4-189	Chromic Vertisol	Nguni (Ukase)	V-1
3	122/3-26	Ferraro-Chromic Acrisol	Chuka	III-2, IV-2
4	122/2-54	Plinthic Acrisol	Mitunguu-Embu	III-2
5	Ex6	Humic Acrisol	Thika	?
6	122/3-44	Orthic Acrisol	Chuka	III-2, III-3
7	161/4-84	Orthic Rendzina	Kajiado	V-4
8	200/1-1048	Orthic Luvisol	Vigurungani-Kwale	V
9	108/3-332	Plinthic Gleysol	Meru (Kianjai)	?
10	202/1-205	FLuvisol	Vanga-Lunga Lunga	III
11	161/4-85	Chromic (Plinthic)	Kajiado	V-4
12	?	Humic Nitisol	Muguga-Kiambu	II-5
13	136/1-4	Ferralsol	Siakago-Embu	III-3
14	134/2-21	Humic Andosol	Gituamba-Murang'a	I-5
15	190/2-212	Calcic Cambisol	Tsavo East	VIb
16	200/4-167	Arenosol	Njele-Kwale	III
17	134/1-?	Dystric Planosol	Kinangop	III-7, II-7
18	126/-31	Orthic Solonetz	Garissa	VII-1

ESTABLISHING OF NASREC IN LESOTHO

M. Williams
Ministry of Natural Resources, Department of Science and Technology, Private Bag A23, Maseru 100, Lesotho

INTRODUCTION

With a land area of 30,000 square kilometre and population of 1.6 million (in 1986), Lesotho is one of the countries where population pressure on land resource is high and coupled with limited availability of good agricultural land. Only about 13% of the country is suitable and over 70% of all the Basotho Nation is involved in agriculture, the largest contributor to the Gross Domestic Product. Therefore, rational utilization of soil resources assumes a great importance for optimum and sustained food production.

The effective increase and sustainable production can be attained through sound land use planning and management which is based on clear understanding of the natural resources and the environment. This cannot be achieved without the active support and involvement of the land users.

Through many years, Lesotho Soil Survey Office has acquired extensive data on soils and land use of the country. This information is in the form of reports and maps. The information is under-utilized by the community outside Soil Science. The effective use of the data depends upon the existence of efficient systems that can store and transform them into a usable form for a particular set of purposes.

NASREC in Lesotho with its short and long term objectives will therefore provide compiled information which will include soil exposition, database and publications with the aim of removing part of the constraints to the development of Soil Science and its practical applications.

ACHIEVEMENTS

The achievements include development of a soil database, database application and publications, maps, and training.

- Soil database: SoilPro was linked to GIS.
- Database applications: (a) PARCH, CMKEN and PUTU crop simulation models; (b) SCS hydrology and runoff simulation model; and, (c) CROPWAT irrigation simulation model.
- Publications: (a) Benchmark Soil of Lesotho. Their classification, Interpretation, Use and Management by P.M. Cauley (1986); (b) Soils of Lesotho 'A system of classification for interpreting Soil Surveys Conservation in Lesotho' by the office of Soil Survey, Conservation

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Division (June 1979); and, (c) Soils, Geology and Geomorphology of Lesotho, by F. Rooyani (1987).

- Maps: (a) Reports on former Soil Conservation Projects which entail detailed Soil Maps (1:20,000 scale) used as base maps for land use planning and project implementation; (b) Topographic Map (1979) (1:250,000); (c) Reconnaissance Soil Map (1:250,000); (d) Lesotho Land Use System Map (1:250,000); (e) Topographic Map (1:250,000) scale; (f) Agricultural Potential Map (1:250.00); (g) Land Satellite Map (1:250,000) scale; (h) Digitized Soil Acidity Map (1:500,000); (i) Erosion Hazard Map (1:500,000); (j) Lesotho Temperature Zones Map (1:500,000)
- Training: Lesotho being represented by Mr. N. Mothoko attended an international workshop held in Kenya, Nairobi (March 1994) on KENSOTER applications and results.

The above mentioned information can be made available and be fully utilized (through NASREC) by the following: (a) soil scientists; (b) agronomists, ecologists and engineers (e.g., the proposed project/study to be done collaboratively between British Biological Survey, the National University of Lesotho and the University of Natal, on 'The genesis properties and classification of dispersive soils for engineering purposes'); (c) Universities (Agricultural Faculty; Geography Faculty); (d) Technical, Polytechnical and vocations Institutions; (e) Ministry of Agriculture (Agronomy Department, Agric. College and Agric Research); (f) Education; (g) Natural Resources (Mines and Geology Department; Science and Technology; Water Affairs; Energy Department); and, (g) the Community.

CONCLUSIONS

The data on soil of Lesotho exist in different forms but cannot be fully utilized adequately by the current and potential users. NASREC with its soil exposition database and accompanying publications can, to a greater extent, remove part of the constraints to soil science development and its practical applications. Lack of facilities and trained manpower are some of the drawbacks in meeting the requirements of NASREC establishment.

ACKNOWLEDGEMENTS

Gratitude is expressed to ISRIC, the Netherlands Government and other International Organizations for their efforts, support and guidance towards accomplishment of the above mentioned Mission.

THE NATIONAL SOIL REFERENCE COLLECTION OF MALI

O. Doumbia
Laboratoire Sol-Eau-Plante, Boite Postale 438, Sotuba, Mali

INTRODUCTION

The project NASREC/MALI has begun by the contact laid in 1983 between the Director of the Project of Inventory of Earth Resources (PIRT) and the Director of ISRIC, Wageningen. The PIRT Director expressed his wish to extend the results of his project to as many people as possible. At the time ISRIC could not support such a project financially. PIRT and ISRIC therefore developed a project proposal for submission to the UN Environment Program (UNEP), Nairobi, Kenya. The Dutch Ministry of International Cooperation helped to get a positive response from UNEP. Thereby the activities of NASREC could start in October 1986; the program of activities of phase I of the project were put under the joint responsibility of Mr. Sjef Kauffman of ISRIC and Mr. Oumar Doumbia of Mali. During the first phase Mr. Kauffman carried out a mission in Mali (16 October to 30 November 1986) during which eight monoliths were sampled. Information was collected also concerning the soil profiles and their environment. PIRT sent a duplicate set of monoliths to ISRIC for inclusion in its reference collection. The second phase of the project (17 November to 13 December 1988) dealt with the preparation of monoliths for inclusion in a database, the installation of an exposition hall and the organisation of a inauguration of the exhibition of the NASREC collection. The fusion of the Desertification Laboratory, which replaced PIRT, and the Soil Laboratory, which created within the new Soil-Water-Plant Laboratory a unit which is dealing with the soil data base and the GIS. This offered a real prospect of development of the NASREC/MALI project. Before reviewing the results of the NASREC/MALI project the ultimate goal of this project must be mentioned. This goal is to arrive at a better allocation of the natural resources as mentioned in the National Program against desertification (PNLCD). The specific objectives of the project were: extension of the PIRT results; increase awareness of decision makers and utilisers of resources information; and creation of a network of exchange between soil scientists.

RESULTS

Soils of the collection

The soils of the national collection partially show the soil types prospected during the cartographic studies realised by PIRT, from 1980 to 1983, financed by USAID, FAC and the government of Mali with its goal to collect and to analyze the information about the natural

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resources of Mali. The PIRT has benefitted from the technical supervision of the american company TIMS.

The soil survey was carried out at 1:200,000 scale and the final map was published at the scale of 1:500,000. The analysis of soil samples was done by the Lincoln Laboratory, Nebraska, USA and by the Soils Laboratory, Sotuba, Mali. The soils were classified according to USDA Soil Taxonomy and correlated with the French classification system (CPCS) and the FAO-UNESCO legend of the Soil Map of the World.

Results of the PIRT project were published in a document, entitled 'Les resources terrestres au Mali' in 1983. In three volumes this document provides information on the soil, vegetation, water, people and actual utilisation of the land in the southern half of the Mali. This area covers about 582,000 km^2.

The legend of the soil/vegetation map defined 10 groups of soils on the basis of geomorphology: stable dunes (D), eroded dunes (DA), plains of clayey material (PA), plains of loamy material (PS), plains of silty clay material (PL), lands underlain by laterite (TC), rocky lands (TR), hydromorphic non-flooded lands (TH), flooded land (TI) and special land types (X) for instance lacustrine sediments with diatoms, eolian deflation surfaces, permanent water, active dunes). The soil groups were subdivided into 69 taxonomic units each corresponding to a soil type with its own vegetation subgroup. At the group level of the Soil Taxonomy 39 types of soils have been recognized in seven soil orders. The extent of the soil groups and the dominant soil orders in Mali is shown in Table 2 and 3, respectively. The most widespread soil groups are D and DA, TC and PL. Spatially, Alfisols, Entisols, Aridisols and Ultisols are the most important orders.

Table 2 Surface of soil groups in Mali

Group	Surface (km^2)	% of study zone
D	100,378	17.2
DA	58,089	10.0
PA	12,656	2.2
PL	92,140	15.8
PS	21,410	3.7
TC	123,854	21.3
TH	19,657	3.4
TI	26,203	4.5
TR	43,912	7.5
X	34,259	5.9
Inclusions	50,220	8.6
Total	582,778	100.0

Table 3 Surface of soil orders in Mali

Order	Surface (km^2)	% of study zone
Alfisols	184,909	31.7
Aridisols	94,423	16.2
Entisols	124,902	21.4
Inceptisols	27,432	4.7
Mollisols	2,374	0.4
Ultisols	61,211	10.5
Vertisols	761	0.1
Inclusions	50,220	8.6
Others	36,546	6.3
Total	582,778	100.0

The centre of the NASREC-MALI project consists of seven monoliths representing the taxonomic units as shown in Table 4. The units were chosen from south to north in function of the following criteria:

(a) Soils which are representative of the most important soil types of the country according to the PIRT study,
(b) Soils of the Soudan and Sahelian regions, which are most used for the main crops, like cotton, groundnut, millet, sorghum, maize, rice and grazing,
(c) Soils of the central Delta.

Status of the exhibition

The actual exhibition is located at Sotuba in the conference hall of the ex-PIRT; the building is now used by the Forestry Research Department. The monoliths are supported by wooden panels and consist of nine panels of which eight are for the monoliths with supporting information and one panel serves to extent of desertification in Mali. The panels are organized by climatic zone from the Soudan (South and North) to the Sahel (South and North). The exhibition shows also examples of catenas. The exhibition includes photographs of the landscape and actual land use, data on soil classification (FAO/UNESCO, USDA and CPCS), the location of the profiles, climatic data (evaporation curve; insolation; relative humidity; temperature) from a representative station, and a list with the evaluation and the suitability of the soil. Copies of soil morphological descriptions and the analytical results are available to the visitors. Other photos show examples of degradation caused by actual land use practices (e.g. areas affected by salinization and drought). Technical facilities for the exposition hall are good.

Table 4 Classification of soils types in the NASREC collection for Mali

Code ISRIC	Code PIRT	Classification	Surface	% zone PIRT
MLI 01	PL 11	Oxic Haplustult Ferric Acrisol Sol ferrugineux lessivé	22,889	3.9
MLI 02	TI 5	Entic Pellustert Chromic Vertisol Vertisol	761	0.1
MLI 03	DA 4	Ustalfic Haplargid Luvic Xerosol Sol brun rouge sub-aride	10,771	1.8
MLI 04	TH 4	Typic Haplaquept Haplic Xerosol Sol sodique	1,763	0.3
MLI 05	X 1	Typic Torriorthent Eutric Regosol Sediment diatomitique	527	0.1
MLI 06	D 1	Typic Torripsamment Ferralic Arenosol Sol mineral brut	37,795	6.5
MLI 07	TC 6	Typic Cuirorthent Plinthic Acrisol Sol peu évolué	27,793	4.8
MLI 08	TC 7	Petroferric Haplustult Petroferric Acrisol Sol ferrugineux lessivé	8,958	1.5

Users of the exhibition

Until recently the main users of the National Soil Reference Collection of Mali were agronomy students of the Rural Polytechnic Institute (IPR), students of the History and Geography section of the Scientific College (ENSUP) in their final study year. The students use the data to write their theses. Other users include researchers and consultants, both expatriate and nationals, who use the database of PIRT for various applications.

Since 1994 the direction of the agricultural station of Sotuba and that of LaboSEP have carried out an important program of extension using private and public means, such as open days. Groups of farmers visit the exhibition as well as parliament members and certain diplomats, agents of multi- and bilateral organizations (USAID, GTZ, Mission Française de Cooperation, etc.); these people are getting increasingly interested in soil management. The visits are often conducted in the national language, Bambara.

Applications and main users of the database

In a general sense, awareness of the NASREC exhibition completes a series of actions undertaken to disseminate results of the soil survey. The exhibition has helped much to implement the field improvement scheme at national and local scale. Also several local development committees (CLD) composed of representatives of technical services and administration at district level are taking into account the soil, vegetation and water resources data in the evaluation of the production potential of their district.

The Management of Natural Resources Project, working on village improvement plans for the agroecological zone of Haut-Bani-Niger, based derived its methodology from the NASREC project.

Several research programs at the national and west African scale, such as the toposequence project, the project concerning a network of long term observation ROSELT, the project concerning the re-enforcement of scientific capacity in the Sahel RCS-Mali and various projects on erosion control measures in the south Mali region and in the Niger valley have been formulated from PIRT data.

More and more the LaboSEP plays a role in the characterisation of plots and fields and the use of soils data in the management of their farm.

CONCLUSIONS

The NASREC-Mali project has contributed enormously to informing planners, rural development organisations and other users about the necessity for better management of the soil resources. It has made soil scientific data available to a wider audience. More and more actions are being undertaken to improve soil management at the community and individual level. An important constraint remains that the Sotuba site is inaccessible for large audiences. Also the number of trained technicians is insufficient. Future priorities of the project are the development of the new Databank/GIS unit of LaboSEP. In that perspective it is envisaged to acquire better office facilities to create satellites at the station level. In doing so, the Sotuba centre may receive monoliths from other parts of Mali for inclusion in the National Collection, while preserving the regional collections.

SOIL COLLECTION COURSE IN MEXICO

C.A. Ortiz-Solorio
Programa de Edafologia, Instituto de Recursos Naturales, Colegio de Postgraduados
Carr. Mexico-Texcoco, km 35.5, 5620 Montecillo, Mexico

INTRODUCTION

The Mexican participation in the NASREC project has only been in the field of personnel training. In 1982, the author attended the international course on the Establishment and Use of Soil Reference Collections, which was given by staff of the International Soil Museum (now ISRIC). With the acquired knowledge, it was proposed to organize a formal course on Soil Collections at the Colegio de Postgraduados (Mexico). This course, 'EDA-623 Colecciones de Suelos', was officially registered in 1983. Since then it has been held 12 times, during the summer period, with an average attendance of five students.

RESULTS

The main achievement of the Soil Collection Course has been the training of postgraduate students. On some occasions, the course has been useful in helping national and international soil meetings, for example, on 'Clay Soils' and 'Volcanic Soils with Indurated Layers'.

During the Summer Period, students are trained in making a soil collection. This includes: field work; preparation of soil monoliths with lacquer impregnation; laboratory analysis; soil classification, recently using the FAO-UNESCO legend and USDA Soil Taxonomy (1994); and, making of a soil exhibition. The preparation of soil thin-sections is generally omitted from this short course (6-8 weeks), although some samples are collected for micromorphological research. The course discusses the major climatic zones of Mexico (arid, temperate and tropical zones) and their main soils. Soil units that have been sampled include Vertisols, Regosols, Fluvisols, Phaeozems, Cambisols, Solonchaks, Andosols, Lithosols, Rendzinas, Luvisols, Xerosols, Kastanozems and Gleysols.

After completion of each course, a small Soil Collection of about ten soil monoliths is prepared. This collection, which is displayed during one year, is mainly visited by students and scientists. There is no formal place where the exhibition can be displayed on a permanent basis. Therefore, it has been necessary to donate most soil monoliths to Government Institutions, Universities, Technical Schools and Farmer Organizations.

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CONCLUSIONS

There are two major problems related to soil collections in Mexico:

- The limited detail of soil maps produced by government agencies, which reduces their suitability for selecting representative sites. Our experience has shown that this problem can be solved by using the local soil knowledge of the farmers (see Ortiz-Solorio, this volume);
- Soil science in Mexico during the last 50 years has been dominated by scientists who are mainly interested in crop production. It is crucial to increase awareness about the importance of soils.

Based on our experience in teaching a Soil Collection course for more than 10 years, it can be observed that Mexico is now well versed with the relevant procedures. Many people have been trained so that it should be relatively simple to obtain our National Soil Reference Collection within a few years.

ESTABLISHING NASREC IN AN UNSTABLE POLITICAL ECONOMY — NIGERIA'S EXPERIENCE

A. Gbadegesin
Department of Geography, University of Ibadan, Ibadan, Nigeria

INTRODUCTION

Prior to the establishment of NASREC in Nigeria, the soil scientists of the University of Ibadan have been proposing to establish a soil museum similar to the ISRIC collection in Wageningen. However, they have been handicapped by lack of appropriate technology and funds. Such a museum is expected to display the wide range of soil types and research information which would benefit agricultural and environmental students and scientists alike as well as other users of soil data in Nigeria. In addition, the museum is expected to bridge the gap between soil scientists and end-users of soil data and on the long-run be beneficial for the Nigerian agricultural production while at the same time contributing to the sound ecological use of the nation's soil resources.

The participation of the author in ISRIC's Soil Reference Collections and Database Course in Wageningen, in 1989, facilitated the establishment of a cooperative project between ISRIC and the University of Ibadan in 1990. The project, Nigeria-NASREC benefitted from the financial and technical support of the Government of the Netherlands (DGIS) and the University of Ibadan, Nigeria, between 1990 and 1992.

The main objective of establishing a NASREC in Nigeria is to reinforce the education, extension and research in soil science at the University of Ibadan through the exposition of a 'core' collection of representative soil types of the forest and savanna soils of Southern Nigeria. The establishment of a computerized database related to the soil collection, has helped to meet the requests for information of the different user groups.

RESULTS AND ACHIEVEMENTS

Despite the unstable political economy of the country, Nigeria has successfully completed the NASREC II project under the technical assistance programme of the DGIS for the period 1990-1992. Although Nigeria's NASREC activities were finalized in 1993, the inauguration of the exposition is yet to be realised.

Among the notable achievements of Nigeria-NASREC are:

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(a) Within the NASREC II period, 15 soils of the forest and savanna ecological belts were studied and sampled. Duplicates of all profiles were sent to ISRIC. In addition, the 15 soil profiles were prepared for display in the Department of Agronomy, University of Ibadan.
(b) A total of 124 soil samples were analyzed at ISRIC and at the laboratory of the Department of Agronomy, University of Ibadan.
(c) An exposition hall with 15 soil monoliths is already in use. The current users of the exposition are mainly students of the Faculty of Agriculture and Geography Department as well as soil scientists from neighbouring institutions. Information on the exposition, such as comprehensive data sheets, brochures, exposition posters and Soil Briefs, is in the final stage of preparation.
(d) Eight Soil Briefs of 15 locations in Southern Nigeria (NG1 to NG8) have been prepared, sent to ISRIC for assessment and are in the final stage of publication. The Soil Briefs describe the soils of the tropical rainforest and the savanna ecological belts, focusing on the interfluve-valley soil series sequences.
(e) The desktop computer provided through the NASREC II programme was installed by the University in an adequate air-conditioned office in 1991. The University of Ibadan Soil Information System (UISIS) database is currently in use and diskettes with data have been sent to ISRIC. In addition, the first version of Soil Data Graph was received and installed. It remains of limited use because of the unavailability of the required data.

CONCLUSIONS

The adoption of the Structural Adjustment Programme in Nigeria in the late 1980s and the fluctuating rate of Naira have affected the prices of the budgeted materials and equipments for the Nigeria-NASREC programme and consequently our achievements. In addition, the unstable nature of the political environment of the country has lead to the postponement of the inauguration of the exposition (three times). The exposition was first planned to begin in November 1992, but until today this has not been realized.

Fieldwork in Nigeria and the Mambilla Plateau, planned for 1993, has not been accomplished partly because of the dwindling financial resources of the Nigeria-NASREC and partly because of the unstable political climate in the country. Nevertheless, it is hoped that when the political-economy of the country is stabilized, the above aims will be achieved. In addition, it is hoped that given the notable achievements of the Nigeria-NASREC, the outcome of this workshop will lead to the establishment of an African Regional Centre for soil reference collections in Nigeria. We believe it is the only way to decentralize ISRIC's activities and to ensure interactions among NASRECs in Africa.

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NASRIC STATUS IN PAKISTAN

M. A. Tahir
Soil Survey of Pakistan, Ministry of Food, Agriculture and Investment, Multan Road, Lahore - 54750, Pakistan

INTRODUCTION

Since its inception in 1962 the Soil Survey of Pakistan (SSP) has been trying to collect samples of the various soils in the country (e.g. mini-monoliths, correlation boxes and as bulk samples) for classification purposes. This phase ended with the author's participation in the third International Course on the Establishment and Use of Soil Reference Collections at the then International Soil Museum (ISM, now ISRIC) in May 1983. In 1986, six soil profiles were sent in duplicate to the ISM with a hope of getting back six well prepared macromonoliths but their fate is not known till today. Then SSP started looking for funds to create NASRIC. This effort seemed to be bearing fruit when Mr. J.H. Kauffman happened to visit Lahore in November, 1990, with a proposal of initiating the NASRIC programme. Both parties strived to make this programme a reality but could not sail it out. During this period SSP could prepare eight macromonoliths of soils extensive in Pakistan.

A three year project, Strengthening of Soil Survey in Pakistan is to take a start from September 1995 with, of course, Dutch Aid in which NASRIC is one component. This component comprises, construction of a display hall, recruitment of three staff members and preparation of 60 macromonoliths. Initially the reference material will be used for correlation and guidance of soil scientists, researchers and university students.

RESULTS

Eight soil profiles have been sampled and preserved for display. The soils were formed on river and piedmont alluvium, aeolian sand and residual parent materials. One of the soils is highly saline and another is saline-sodic. The soils occur in arid to humid subtropical continental climates, as summarized in Table 1 (see overleaf) .

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Table 1 Summary data of NASRIC profiles, Pakistan

Soil Series	Classification		Main Characteristics	Land use/Vegetation
	USDA	FAO		
Shahdra	Coarse-silty, mixed, hyper-thermic Typic Torrifluvent	Calcaric Fluvisols	Ochric epi-pedon, stratified profile, river alluvium	Flood moisture seasonal cropping of wheat, oilseed and gram. Where irrigated; vegetables, fodder and wheat are sown
Rasulpur	Coarse-loamy, mixed, hyper-thermic Ustr-ochreptic Camborthid	Calcaric Cambisol	Ochric epipedon, cambic horizon, low water and nutrient holding capacity, low in organic matter, moisture stress a common constraint, river alluvium	Irrigated wheat, peas, gram, water melon, millets and sorghum
Hafizabad	Coarse-loamy, mixed, hyper-thermic Ustic Haplargid	Haplic Luvisol	Ochric epipedon, argillic horizon, river alluvium	Irrigated wheat, maize, clover, orchards and sugarcane
Kotli	Fine, mixed, hyperthermic Typic Chrom-ustert	Eutric Vertisol	Ochric epipedon, cambic horizon, gilgai relief, intersecting slickensides, cracks 1 cm up to 50 cm, wedge shaped structure, very hard dry, very sticky wet, difficult land pre paration	Irrigated rice, fodder, sunflower and oats
Pitafi	Fine, mixed, hyperthermic Typic Salorthid	Haplic Solonchak	Ochric epipedon, salic and cambic horizons	Irrigated jantar and wheat
Eminabad	Coarse-loamy, mixed, hyper-thermic Typic Natrustalf	Haplic Solonetz	Ochric epipedon, natric horizon	Barren, *Eragrostis cynosuroides*, Australian grass
Thal	Mixed, hyper-thermic Typic Torripsamment	Calcaric Arenosol	Aeolian sands, part of longitudinal ridge system	Natural vegetation of *Calligonum poligonoides, Pennisetum dichotimum, Eleusine compressa, Laptedenia spp., Aerua javanica* and *Salvadora oleoides*
Murree	Fine-silty,mixed, mesic Typic Hapludoll	Haplic Phaeozems	Mollic epipedon, cambic horizon, paralithic contact at 115 cm, high organic matter, colluvial and residual material from shales and sandstones at 50% mountain slope, altitude 2000 m	Fir and blue pine forrest with fair undergrowth of shrubs and grasses

SOIL MONOLITH PREPARATION, EXPOSITION OF BENCHMARK SERIES AND SOIL DATABASE APPLICATIONS IN TAIWAN

Zueng-Sang Chen
Soil Survey and Classification Laboratory, Department of Agricultural Chemistry, National Taiwan University Taipei, TAIWAN 106, Republic of China

INTRODUCTION

Detailed soil surveys were conducted by the National Chung Hsiung University (NTCU) and Taiwan Agriculture Research Institute (TARI) from 1962 to 1974 in Taiwan. Maps were published on a scale of 1:25,000 for 178 field sheets. Detailed soil surveys of hill-lands were conducted by the Bureau of Soil and Water Conservation of Taiwan Province from 1980 to 1986 on a scale of 1:25,000 (215 field sheets). The total area of cultivated soils in Taiwan is about 880,000 ha. There are 680 series of 'rural' soils and 380 soil series for the hill-lands. The 1949 USDA-soil classification system was used in survey reports published before 1985. After 1985, the Soil Taxonomy system was introduced and tested in the island. County and 70 benchmark soil series were selected for experiments and extension work (Chen, 1993; Hseu *et al.*, 1994). About 15 representative soil monoliths were prepared and exhibited in the soil laboratory of National Taiwan University. From 1992, a soil resources and survey project (similar to the NASREC project) was conducted and about extra 50 soil monoliths were prepared for public display in December, 1994. Soil databases have been established at the Taiwan Agriculture Research Institute (TARI), the National Chung Hsing University (NCHU) and the National Taiwan University (NTU). The databases are used mainly for land use planning, improvement of problem soils, preparation of crop productivity maps, and formulation of soil management recommendations.

RESULTS AND ACHIEVEMENTS

Classification of 'rural' soils is based on USDA Soil Taxonomy (Soil Survey Staff, 1994). The distribution of 'urban' soils in Taiwan is as follows: Entisols (5%), Inceptisols (30%), Alfisols (25%), Ultisols (5%), Mollisols (<1%) and Vertisols (<1%) (Chen, 1992). Haplaquents, Fluvaquents, Udifluvents and Udipsamments occur on alluvial fans near the seashore in western and eastern Taiwan. Haplaquepts, Dystrochrepts, Eutrochrepts, Haplumbrepts, Ochraqualfs, Hapludalfs and Haplustalfs, the main greatgroups formed on alluvium, are most important for crop production. Hapludults, Paleudults and Hapludoxs are common in upland soils on terraces. There are also some Mollisols and Vertisols in eastern Taiwan.

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Criteria for the selection of representative soil monoliths (for benchmark soil series) are: (1) the agricultural importance of the soil series and (2) the extent and representativeness of the series in Taiwan. In addition to this, special soils are also considered including Andisols, Mollisols, Vertisols and Histosols.

There are five district agricultural experimental stations in Taiwan. Ten benchmark soil series were selected for each experimental station. Seventy benchmark soil series were selected out of the ≈ 1000 soil series occurring in Taiwan (Chen, 1993, Hseu *et al.*, 1994). About 50 soil monoliths have been sampled, prepared and grouped in an exposition. These reference soils belong to ten different 10 orders (Soil Survey Staff, 1994), except Aridisols.

The Department of Agricultural Chemistry of National Taiwan University and Taiwan Agriculture Research Institute have expositions with more than 50 soil monoliths. Smaller expositions, with less than 10 soil monoliths each, are held in the district of six agricultural experimental stations. Undergraduate students of soil science courses (university), teachers of primary and secondary schools, and soil scientists are welcome to visit the exposition and to discuss the collection. One exposition was attended by more than 200 agricultural scientists in December 1994.

A computer system has been configured for the purpose of integrating and analyzing the information on agricultural land resources (Lin and Lin, 1991). It comprises three levels. The first level, the hardware, includes workstations and personal computers as the basis for a network, which will be linked to computers from Taiwan Agricultural Research Institute. The second level is the geographic information system. The third level, or knowledge-base, is composed of several computer models and expert systems. Important applications of this system and database include: land use planning; identification of problem soils; pollution surveys; and, preparation of crop productivity maps (Lin and Lin, 1991; Lin and Chai, 1994).

Soil databases of 'rural soils' are established in ARC/INFO, FOXPRO and EXCEL software at the Taiwan Agriculture Research Institute. Maps of soil properties can be plotted for the assessment of crop production and management of soil fertility (Guo, 1990, 1993). The database includes data on soil morphological, physical and chemical properties. The soil maps are published on a scale of 1:25,000.

Software has been developed to handle the soil morphological, physical and chemical data for Taiwan. A system was developed to display 3D figures of morphological characteristics and the distribution of clay, free iron, organic carbon, CEC and soil pH with depth (Chen and Shy, 1990). Maps of soil temperature and soil moisture regimes were plotted using long-term (> 30 yr) precipitation and air temperature data collected at 94 stations islandwide. Soil temperature, at 10, 20, 50 and 100 cm depth, was measured at 20 sites from 1987 to 1991 (Chen, 1994; Chen *et al.*, 1995).

Special studies carried out in recent years in Taiwan include: (1) soil erosion tolerance maps for sloping lands (NCHU); (2) improvement of soil fertility of rural soils (TARI; Guo, 1994); and (3) the testing and evaluation of remediation techniques for cadmium and lead polluted soils (Chen and Lee, 1995).

CONCLUSIONS

(1) About 50 monoliths of 70 benchmark soils were prepared and exhibited at TARI and NTU. These soils belong to 10 soil orders, except Aridisols (Soil Survey Staff, 1994).

(2) Soil databases of 'rural soils' were established at Taiwan Agriculture Research Institute, National Chung Hsing University, and National Taiwan University. The databases are mainly used for land use planning, improvement of problem soils, preparation of crop productivity maps, and soil management recommendations.

(3) Maps of soil temperature and soil moisture regime were plotted for the island.

(4) Additional monoliths, for Podzols and related soils, will be prepared in the next four years.

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SOIL REFERENCE AND INFORMATION CENTRE OF THE MARACAIBO LAKE BASIN STATE OF ZULIA, VENEZUELA

N. Noguera P., W. Peters, L. Jiménez and J. Moreno
Departamento de Edafologia, Facultad de Agronomia, Universidad del Zulia, Apartado 526, 4001-A Maracaibo, Venezuela

INTRODUCTION

The main reason for starting a NASREC Project at regional level within the Maracaibo Lake Basin in the State of Zulia, Venezuela, was to create a combination of reference soils of the area and a computerized information system to be used first at University level during lecturing at pre- and post-graduate level, research and extension.

The Maracaibo Lake Basin was chosen for the following reasons: the area represents a natural unit with a unique combination of very particular characteristics; it represents the main area of direct influence of the Zulia State University; and, at national level, the Basin represents one of the most important areas of agricultural production. The main objectives of the Soil Reference and Information Centre of the Maracaibo Lake Basin are:

(1) To support teaching activities at different levels (university and high school).
(2) To support research in defining priorities of interpretations and correlation for instance.
(3) To support planning at regional level indicating potentialities and limitations of the land.

The project started 4 years ago and its first phase has been concluded (regional level). Follow up activities include the creation of a limited soil collection (up to 20 monoliths with its information) at national level to be carried out during the next 3 to 4 years.

RESULTS

Fourteen soils have been collected, sampled, described and analyzed. The main criteria for grouping soils in the exposition room have been the ecological subregions of the Maracaibo Lake Basin — defined according to climate, soils and terrain, natural vegetation and land use — and their extent.

At this moment the exposition room, located in the Department of Edaphology of the School of Agronomy of Zulia State University, is open to the public. The main users of the exposition are university and high school teachers and students, university researchers, regional planners of governmental organizations and extension workers. The accompanying database has been used mainly for taxonomic classification exercises by students, land evaluation for fertility purposes and land capability classification according to USDA and COPLANARH (a national approach in Venezuela). This specific aspect of the Reference and Information Centre is in its initial

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phase. The main users group once again are students teachers and researchers at university level including the personnel of the extension service of the School of Agronomy.

CONCLUSIONS

The creation of a soil reference and information collection of the Maracaibo Lake Basin has proven to be useful for teaching natural sciences in high schools, and natural resources at university level, mainly in the School of Agronomy.

The database part of the reference and information centre encountered some problems at the beginning of the project because of lack of funds to carry out special analyses (mineralogical and micromorphological).

The priority for future activities is to look for a larger exposition room in order to accommodate a soil reference collection at the national level and to guarantee sufficient resources for collecting, sampling, transporting and analyzing some 20 soils of the whole country.

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ESTABLISHMENT OF A NATIONAL SOIL REFERENCE COLLECTION IN VIETNAM

Thai Phien
National Institute for Soil and Fertilizer, Chem, Tu Liem, Hanoi, Vietnam

INTRODUCTION

The usefulness of a soil collection (modelled along the lines of the collection at ISRIC) for training, research and extension purposes has been recognized by an increasing number of countries. Over the last decade, this recognition has been expressed by a large number of requests to ISRIC to support the establishment of national or regional soil collections in combination with a data bank. In this regard, Vietnam is not an exception. Because of limited manpower, technology and funds in Vietnam for realizing this project, the Netherlands/ISRIC have been requested to assist in the establishment of this project.

In Vietnam, the National Institute for Soils and Fertilizers (NISF) is responsible for soil and fertilizer research and extension. Since 1982 contacts have been established for the implementation of a soil reference collection in Vietnam. Two staff members of NISF attended international training courses at ISRIC, in 1983 and 1989.

At the beginning of 1995, NISF has received support from the government to establish a National Soil Reference Collection in Vietnam.

ACHIEVEMENTS

Up to now 15 soil monoliths have been collected of which 10 are ready for display. The latter include an alluvial soil, a degraded soil, an acid sulphate soil, a saline soil, a latosol on schist, a latosol on basaltic rock, an acrisol on granite and an acrisol on gneiss. Soil samples were analyzed at the laboratory of NISF. All soil physical, chemical and micromorphological data are used to set up a soil database.

PRIORITIES FOR FUTURE WORK

Three steps are foreseen:

(1) Field work and data collection:
- User group identification; staff members of related institutions, students of National Universities and other staff of soil-related branches have to be trained.

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- Collection of soil profiles, soil samples, description of soil and environmental data.

(2) Preparation of monoliths and data processing:

- Execution of soil analyses: Soil and environmental data for each soil monolith should be entered in the database at NISF. NISF is responsible for preparing standardized national guidelines for soil characterization, classification and evaluation.
- Processing of all data in the form of text, tables and diagrams including photographs of landscape and land use for the exposition.
- Preparation and conservation of soil monoliths for the exposition, using nitro-cellulose lacquers.
- Organization of the exposition facilities.
- Establishment of a digital soil database.

(3) Installation and use:

- Installation of the soil exposition and of all accompanying materials.
- Finalization of publications of the displayed soils
- Inauguration of exposition and organization of a seminar for user groups to increase public awareness.

AGRO-ECOLOGICAL ZONING OF ZAMBIA

R. Msoni
Soil Survey Unit, Mt. Makulu Research Station, P.B. 7, Chilanga, Zambia

INTRODUCTION

The ability of the land to produce is limited, and the limits are set by climate, soil and landform conditions, and the use and management applied to the land (FAO, 1993). Agro-ecological zones once defined and delineated represent areas that are homogeneous in terms of climate, soils and landform conditions at the given scale. Consequently, the bio-physical potential for production within a given agro-ecological zone is similar. As a result agro-ecological zones provide a means for planning optimal land use, and subsequent agricultural and economic development that is sustainable in the long term. Veldkamp *et al.* (1984) defined and delineated the agro-ecological zones of Zambia.

The main purpose of deriving the agro-ecological zones of Zambia was to facilitate the preparation of small scale crop suitability maps. In this paper the methodology used by Veldkamp *et al.* (1984) to produce the agro-ecological zones of Zambia and the results obtained thereof are presented.

METHODOLOGY

The agro-ecological zones map of Zambia was produced by combining climatic (agro-climatic map) and soil (soil map) parameters. Long term climatic data from 29 stations across the country were used. In total five parameters were included in the preparation of the agro-climatic map, *viz.*:

- Length of growing season (70% probability).
- Occurrence of drought in rainy season (70% probability).
- Mean monthly temperature (minimum, night and maximum) in the period December to February.
- Amount the sunshine in the rainy season.
- Occurrence of frost in the dry season (usually June-August).

The growing season was indicated by its beginning and final decade (10-day period) which usually fall in November - December and February - May, respectively. The beginning and last decades are those periods in which rainfall within the decade exceeds half the potential evapotranspiration.

Instead of average values the 70% probability values for decades were used. In this way the length of the growing season is a fairly reliable value and can be expected in 7 out of 10 years.

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As the rainfall during the beginning and the end of the growing season is often erratic, an additional half decade was added in some cases, where it was thought that this would actually represent a real part of the growing season.

The soil moisture storage capacity was included in the determination of the length of the growing season. Fifty per cent of the estimated available water holding capacity of the soil up to 1.0 m depth was divided by the PET (70% probability) to estimate the extension of the growing season resulting from soil moisture storage. This resulted in an estimation of the extension of the growing season by 1 - 2 decades.

Occurrence of drought in the rainy season was estimated by counting those decades in which rainfall was less than 30 mm. A dry decade at the beginning or end of the rainy season was however, not counted given the often erratic rainfall in such periods. However, when both start and end decades showed serious drought occurrence, they were counted as half dry decades.

Mean monthly minimum and night temperatures during December to February were used to indicate areas with relatively cool rainy seasons. Areas with high mean monthly temperatures during the same period were indicated as well.

The amount of sunshine has a significant effect on the yield potential of crops. Especially in the northern high rainfall zone of Zambia more overcast weather reduces this potential. Data were obtained from Hutchinson, 1975.

Ground frost occurs especially in the south-western part of the country. Elsewhere it is only of some importance in the topographically lowest places (valleys, dambos). Data were obtained from the frost map of the ministry of Lands, Natural Resources and Tourism, 1974.

In general the agro-climatic map was compiled as follows:

(1) Occurrence of drought was classified into five classes and the areas within each class were kept separate.

(2) Occurrence of frost was added to the class of occurrence of drought.

(3) The length of the growing season was superimposed. For length less than 130 days (70% probability) separation into 10-day intervals was made. Areas with a longer growing season were only separated on basis of differences in occurrence of drought and amount of sunshine or occurrence of frost.

(4) The temperature data for each zone were not used for subdivision of zones, but to characterise areas with relatively cool or hot growing seasons.

In order to identify agro-ecological zones, the agro-climatic map was overlaid on the Soil Map. By relating the boundaries between the agro-climatic zones to soil boundaries, a better indication of the actual zones was probably obtained. It was assumed that important soil boundaries e.g. between swamps and often waterlogged areas compared to well drained soils, could be used to draw the most probable location of boundaries between agro-ecological zones. For further details the reader is referred to the report of Veldkamp *et al.* (1984), which also includes copies of the agro-ecological zones map of Zambia.

RESULTS

A total of 36 agro-climatic zones were delineated on a map. The zones are characterised by the length of growing season, occurrence of drought and frost, amount of sunshine during the rainy season, and mean temperatures during December to February. The soil type according to FAO-UNESCO classification is also given.

The zones are numbered from 1 to 36, following a general south-north direction across the country. In general zones in the south of the country have short growing seasons whilst those in the north have long growing seasons. The growing season ranges from 80 to 100 days (70% probability) in zone 1 in the south of the country and 160 to 200 days in zone 36, in the north of the country. In the middle of the country, the growing season ranges from 120 to 150 days. Occurrence of drought reduces from the southern zones to the northern zones. This means that rain is more reliable in the north than south of the country. As many as 3 to > 5 drought-decades may occur within the growing season in the southern agro-ecological zones.

Ground frost occurrence is largely restricted to zones in the south-west of the country. Zones experiencing frost are generally associated with Arenosols or Gleysols. Sunshine during the rainy season is restricted or low in zones numbered 25 to 36 except for zones 30 and 32. All the zones in which sunshine is restricted or low are in the north of the country. Mean monthly temperatures are lowest in zones 27, 28 and 33 (14 to 15°C mean minimum, 17 to 18°C mean night and < 30°C mean maximum) and highest in zones 1 and 2 (20 to 21°C mean minimum, 23 to 24°C mean night and > 30°C mean maximum). The lowest and highest mean monthly temperatures are associated with high plateaus and river valleys respectively.

The agro-ecological zones are further characterised by soil type. In some agro-ecological zones this leads to further subdivisions. This is especially so in the central and eastern parts of the country where the soil distribution is rather varied and includes Acrisols, Gleysols, Cambisols, Luvisols/Phaeozems, Vertisols and Lithosols. In the north and west of the country the soils are rather uniform and are dominantly Ferralsols and Arenosols, respectively. Consequently in the north and west of the country one soil type can occur in more than one agro-ecological zone.

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AN OVERVIEW OF SOIL CLASSIFICATION, SOIL MAPS, INVENTORIES AND SOIL DATABASES IN SOUTH AFRICA

D.P. Turner and M.E. Rust
Institute for Soil, Climate and Water (ISCW), Agricultural Research Council (ARC), Private Bag X79, Pretoria 0001, South Africa.

INTRODUCTION

To date South Africa's participation in programs of the International Soil Reference and Information Centre (ISRIC) and development of the National Soil Reference Collections and accompanying databases (NASREC) has been limited. However, much work has been done in gathering, collecting and disseminating soil information within South Africa that could be parallel to broad objectives of NASREC.

The aim of this paper is to present an overview of the available soil information at ISCW in South Africa and to report on the incorporation of this information in computerized databases and Geographic Information Systems (GIS). The paper provides also information on the systems of Soil Classification currently used for the assessment of soil resources in South Africa.

In South Africa the Land Type Survey, with as its main elements the demarcation of land with homogenous climate, terrain form and soil, has assessed much of the natural resources. This survey has a publishing scale of 1:250,000. It also has similarities with approach outlined in the 'Global and National Soil 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, some examples on the interpretation of natural resource information for agricultural development are reported on. During the workshop it is the sincere wish of the South African representatives to establish a formal agreement on the collaboration of ISCW in the NASREC programme.

SOIL CLASSIFICATION

Soil classification as a means of mapping and naming soils in a consistent way is essential to the understanding of the spatial distribution and properties of the soil. Soil classification strives to group similar soil individuals and to distinguish between soils with differing properties. A natural system of soil classification is applied for soil survey in South Africa. The system is documented in two publications:

(1) 'Soil Classification: A Binomial System for South Africa' (MacVicar *et al.*, 1977), and
(2) 'Soil Classification: A Taxonomic System for South Africa' (Soil Classification Working Group, 1991).

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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 follow 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 of the World Reference Base for Soil Resources (ISSS-ISRIC-FAO, 1994). There exists much similarity between two editions of the South African Soil Classification Systems on the one hand and the 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 a convention. Since the number of series names is fairly large, communication is made easier using the form and series name abbreviation codes.

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 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 the Taxonomic System. Each form and family is named and has an 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 Hu1100 meSaLm. This code accommodates all freely drained red (Hutton, Hu), dystrophic soils (1) with an increase in clay (class 1200) from the A to B horizons and a medium sandy loam topsoil texture. 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. It is widely accepted and used by specialists and non-specialists alike.

THE NATIONAL LAND TYPE SURVEY

General

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:

(1) 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,

(2) an inventory of each land type in terms of terrain, soil and climate parameters, and

(3) 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. GIS technology has been used since 1992 to produce the outstanding 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 images, 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. A number of the above concepts are described in greater detail in the following sections.

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.

Estimates of the proportions are prepared 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 (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, subject to availability of data, six rainfall parameters, class A-pan evaporation, thirteen temperature parameters and seven frost parameters.

Modal Profiles

Modal profile sites chosen to represent 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 *et al.*, 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 analysis is by X-Ray diffraction with relative intensities of the diffraction peaks used as estimates of the minerals present.

GEOGRAPHIC INFORMATION SYSTEMS FOR SOIL, CLIMATE AND TERRAIN INTERACTIONS

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 databases is discussed briefly below. In the land type database digitizing of the spatial data has taken place directly from the original 1:50,000 field sheets. Extensive soil and terrain inventory information has been captured, while capture of the monthly climate inventory is ongoing. Similarly, capture of soil analytical data into the SOILPRO database is ongoing.

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

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

Database	Spatial	Non-spatial
Land types - Inventory	1:250,000 maps digitized form 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 and descriptive data
Agrometeorology	Weather station locations	(1) Daily data 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 as available
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, literature
Landcover (4) (under construction)	Map	land cover classes
Drought monitoring	NOAA/NDVI; 1:1 km resolution	Vegetation condition index only

[a] Databases unless otherwise indicated are maintained at the Institute for Soil, Climate and Water, Pretoria.
(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 and Forestek, CSIR.

terrain, soil and climate inventories. Similarly a land use potential index and map was prepared to assign land type polygons to adapted land capability classes as proposed by Klingebiel and Montgomery (1961).

Recently much research was done to establish soil, climate and terrain suitability for different crops. This research is ongoing.

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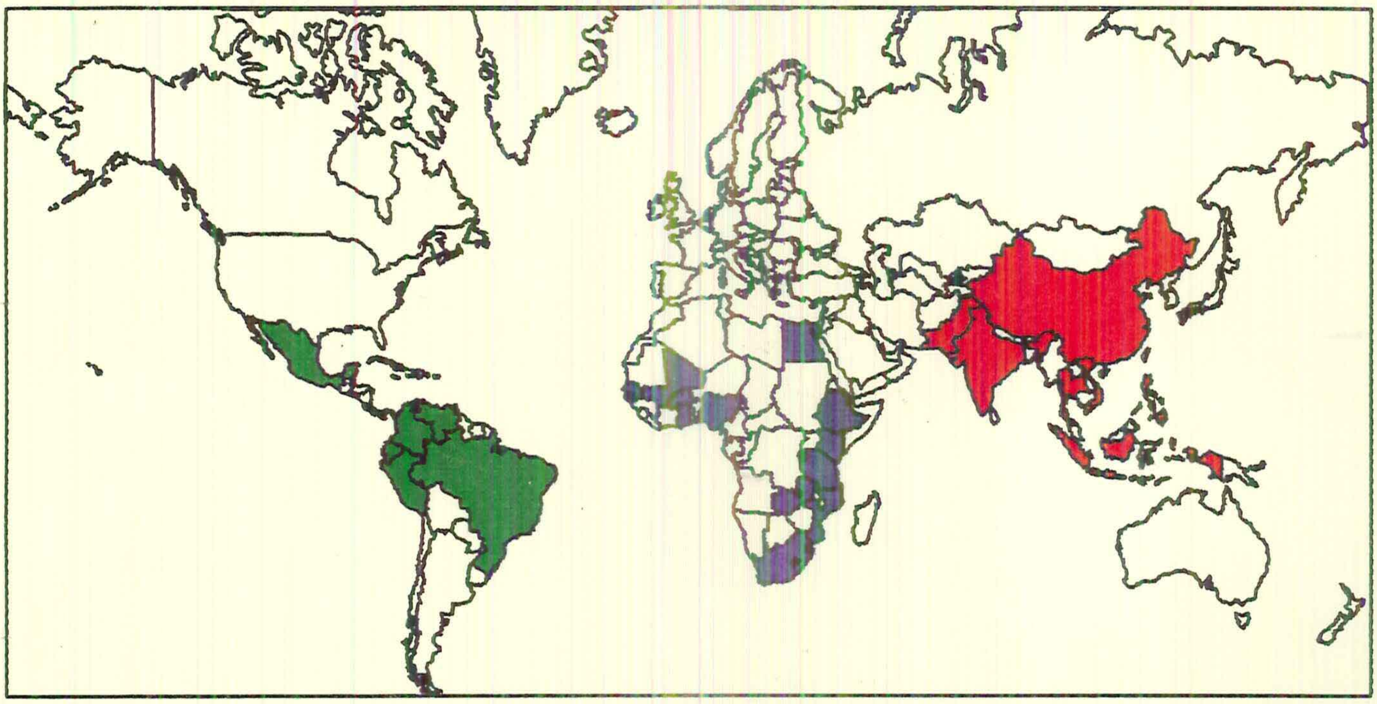
Appendix - Broad soil patterns

Red-yellow apedal, freely drained soils	(map units Aa - Ai)
Plinthic catena: upland duplex and margalitic soils rare	(map units Ba - Bd)
Plinthic catena: upland duplex and/or margalitic soils common	(map unit Ca)
Prismacutanic and/or pedocutanic diagnostic horizons dominant	(map units Da - Dc)
One or more of: vertic, melanic, red structured diagnostic horizons	(map unit Ea)
Glenrosa and/or Mispah forms (other soils may occur)	(map units Fa - Fc)
Soils with a diagnostic ferrihumic horizon	(map units Ga, Gb)
Grey regic sands	(map units Ha, Hb)
Miscellaneous land classes	(map units Ia - Ic)

A WORLD WIDE PLEDGE

We undertake to listen to the users demands for soil information and to develop user friendly products to satisfy their needs:



Brasil

Colombia

Costa Rica

Cuba

Ecuador

Mexico

Peru (1)

Peru (2)

Venezuela

Burkina Faso

Egypt

Ethiopia

Ghana

Kenya

Lesotho

Mali

Mocambique

Nigeria

Senegal

South Africa (1)

South Africa (2)

Tanzania

Zambia

China

Indonesia

Pakistan

Philippines

Taiwan

Vietnam

India (1)

India (2)

India (3)

Thailand