Farming Systems Principles for Improved Food Production and the Control of Soil Degradation in the Arid, Semi-Arid, and Humid Tropics

United Nations
Environment Programme

International Crops Research Institute
for the Semi-Arid Tropics

The International Crops Research Institute for the Semi-Arid Tropics is a nonprofit scientific educational institute receiving support from donors through the Consultative Group on International Agricultural Research. Donors to ICRISAT include governments and agencies of Australia, Belgium, Canada, Federal Republic of Germany, Finland, France, India, Italy, Japan, Netherlands, Nigeria, Norway, People's Republic of China, Sweden, Switzerland, United Kingdom, United States of America, and of the following international and private organizations: Arab Bank for Economic Development in Africa, Asian Development Bank, International Development Research Centre, International Fertilizer Development Center, International Fund for Agricultural Development, The European Economic Community, The Ford Foundation, The Leverhulme Trust, The Opec Fund for International Development, The Population Council, The Rockfeller Foundation, The World Bank, and the United Nations Development Programme. Information and conclusions in this publication do not necessarily reflect the position of the above-mentioned governments, agencies, and international and private organizations.

The United Nations Environnment Programme (UNEP) was established in 1972. Its mandate is to keep the world environmental situation under review in order to ensure that emerging environmental problems of international significance receive appropriate consideration by governments, and to safeguard the environment for the benefit of present and future generations. It is the first global UN body with headquarters in a developing country (Kenya).

UNEP plays a catalytic and coordinating role with the organizations of the United Nations family and administers a fund, based on voluntary government contributions. The Fund of UNEP assists in promoting activities related to environmental assessment and management.

The ultimate aim of UNEP's activities is to promote development that is environmentally sound and sustainable.

Farming Systems Principles

for Improved Food Production and the Control of Soil Degradation in the Arid, Semi-Arid, and Humid Tropics

Summary Proceedings
of an Experts' Meeting sponsored by the
United Nations Environment Programme
20-30 June 1983,
ICRISAT Center, India

Published for the United Nations Environment Programme
by the International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1986

ISBN 92-9066-115-1

Correct citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) and UNEP (United Nations Environment Programme). 1986. Farming systems principles for improved food production and the control of soil degradation in the arid, semi-arid, and humid tropics. Summary proceedings of an experts' meeting sponsored by the United Nations Environment Programme, 20-23 June 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT; and Nairobi, P.O. Box 30552, Kenya: UNEP.

Contents

Guidelines and Research Priorities for Farming Systems to Prevent Soil Degradation

Summaries of Case Study Papers

Foreword

Each year, 6 million hectares of cultivated land are lost for agricultural production through soil degradation. With small populations, with prudent management, land can be farmed indefinitively. But the world's growing population demands the production of ever-increasing quantities of food, fiber, and fuel from the land. Consequently, more and more land is being farmed with increasing intensity. Since prime agricultural land is limited, marginal land is being brought into agricultural production. The soils of these areas are subject to degradation and cannot sustain higher levels of productivity for any appreciable length of time.

- This meeting reflects the concern of UNEP over the dangers of soil degradation resulting from inappropriate agricultural practices. They will lead to environmental degradation that trigger or exacerbate the neglect of land and of rural development. National development plans should emphasize the formulation and implementation of environmentally sound agricultural policies and practices. Priority should be given to soil conservation and the nonwasteful use of soil resources.
- It is intended to focus the attention of policymakers at all levels on the need to formulate appropriate soil policies, and to link programs of increased production with those of soil conservation. UNEP has been fortunate in having the collaboration of ICRISAT in organizing this meeting. We have tried to cover a wide spectrum of agricultural environments, ranging from deserts, through the semi-arid tropics, to the humid lowland tropics.
- A significant outcome of this meeting has been the drawing up of guidelines for farming systems to prevent soil degradation. These guidelines, supported by recommended research priorities, are intended for the use of policymakers and planners. The first part of these proceedings presents the guidelines and is followed by summaries of case study papers contributed by participants in the second part.

I hope that a beginning has been made in drawing the attention of policymakers, and of the institutions engaged in developing farming systems technology for different environments, to the need to ensure that higher crop productivity goes hand in hand with the prevention of soil degradation, both in the short and the long term.

I trust that these summary proceedings will serve as a useful background document in the formulation and development of national agricultural policies and practices.

Reuben Olembo
Director, Environmental Management Service
United Nations Environment Programme

Acronyms and SI Units Used in the Proceedings

Acronyms

ACSN	Asian Cropping Systems Network
AICRPDA	All India Coordinated Research Project for Dryland Agriculture (now CRIDA: Central Research Institute for Dryland Agriculture)
AUC	American University of Cairo
CSWCRTI	Central Soil and Water Conservation, Research, and Training Institute
CGIAR	Consultative Group on International Agricultural Research
DDDT	Desert Development, Demonstration, and Training
FAO	Food and Agriculture Organization of the United Nations
IARC	International Agricultural Research Center
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IFAD	International Fund For Agricultural Development
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Center for Africa
IBSRAM	International Board for Soils Research and Management
IRRI	International Rice Research Institute
NFT	Nutrient Film Technique
ORP	Operational Research Project
RIP	Rolling Injection Planter
SAT	Semi-Arid Tropics
UNEP	United Nations Environment Programme

SI Units

SI units have been used in this book, as follows:
t ha"' (for t/ha); t ha^{-1} a^{-1} (for t/ha/yr); Rs ha^{-1} (for Rs/ha).

Summary of the Meeting's Objectives

General Objectives

- To identify, and put into perspective, areas of farming systems research and development having potential to significantly increase food production and promote soil conservation for selected agroecological zones.
- To assist in actively pursuing the research needed to develop systems of farming that (a) combine adequate production with resource protection, and (b) are compatible with socioeconomic and cultural conditions.
- To formulate a plan of action to accelerate the implementation of improved farming systems evolved at research centers, by fostering cooperation among institutions and governments.

Specific Objective

To draft environmental guidelines for farming systems principles for food production gain, and the control of soil degradation in the arid, semi-arid, and humid tropics.

Welcome Address

L.D. Swindale

Director General, ICRISAT

I welcome you all to ICRISAT, and express our thanks to the United Nations Environment Programme for working to organize this workshop on an important subject. I am sure that, through our discussions, we will be able to make good progress in helping UNEP to prepare the guidelines that relate to the World Soils Charter and the World Soils Policy, thus helping FAO, UNEP, and ourselves at the same time. We, at ICRISAT, also work in a number of places outside India, such as Burkina Faso, Kenya, Mali, Malawi, Mexico, Niger, Sudan, and Syria. We expect to initiate ICRISAT programs in southern Africa in the near future.

I hope that you have got a copy of the illustrated booklet "Challenge and Response", describing the first 10 years of ICRISAT's work. In our next 10-year plan we have revised our objectives a little bit: To serve as a world center for the improvement of both yield and quality of our five mandate crops, sorghum, millet, chickpea, pigeonpea, and groundnut; to serve as a world repository for their genetic resources; and to develop improved farming systems that will help to increase and stabilize agricultural production through more effective use of natural and human resources in the semi-arid tropics. Dryland farming and upland crops have formed the mandate of ICRISAT from the very beginning.

We recognize that not all constraints to semi-arid agriculture are technological, and we must know enough about them in order to make technological solutions work and assist in the development and transfer of the technology. Our major effort, particularly in farming systems, is for the drier part of the world where there are less than 4.5 months of rainy season in a year. In this area our main target is the small farmer with limited means, low inputs, and a low resource base.

We concentrate particularly on our five mandate crops. We have made a lot of progress with our research on groundnut rust, a very serious disease, as we have with many others. We are pleased with the success that we seem to be having in dealing with Heliothis armigera, an extremely difficult pest with a wide range of host plants. We are obtaining encouraging results in finding resistance to Heliothis, both in pigeonpea and chickpea, and we are achieving some success in controlling other insects on our other crops. We also try to prepare for time-resistance against the parasitic weed Striga, which affects both sorghum and millet. We are also trying to attain stability in crop production by protecting it against physiological stresses, drought, and low fertility. Drought resistance is a difficult subject to deal with, but we are having encouraging success in this area, too.

We are also making good progress in our research into nitrogen fixation associated with coarse cereals. It is a very interesting area of work and, though the payoff may be a few years away, it is worth pursuing. Similarly, in the area of genetic engineering we are doing work in tissue culture, among other aspects. Here we are dealing with efforts to produce groundnut plants, and crosses between groundnut and wild species of Arachis, in order to create certain resistance characters in the crop.

In our training program we have already received several hundred trainees, coming particularly from African countries where the need for trained personnel is so great. We have scholars, research fellows, international interns, postgraduate fellows, and in-service fellows as well.

I do not want to go into the work of the Farming Systems Research Program to any great extent because you are going to discuss this during this meeting. Let me mention, however, that our major goals at ICRISAT are the following.

- To generate an economically viable labor-intensive technology for improving and utilizing, while at the same time conserving the productive potential of natural resources.

- To develop technology for improving land and water management systems.

- To contribute towards raising the economic status and the quality of life by developing farming systems in the semi-arid tropics.

Over the 11 years of ICRISATs existence the greatest progress has been made with the management of deep Vertisols. This will be the focus of ICRISATs presentation at this meeting. From an underutilized and degraded resource, we have been able to create a profitable, well conserved resource, without irrigation and without the use of large agricultural implements. This we have done particularly in a way that will benefit the Vertisols and related soils of India. We believe this technology has real promise and potential. We are just now starting to look at Sudan to see to what extent this technology is transferable, a long way away from ICRISAT Center.

This meeting is important to us because it bears upon the role of the international agricultural research centers in farming systems research. This is a subject of great interest to our donors and to their Technical Advisory Committee and, of course, to us.

There are various definitions of farming systems research, and attempts to determine its structure. One view, important because it relates to my comments at the moment, divides the discipline into two major segments: upstream and downstream. Upstream means essentially research at research stations. Downstream means essentially research at the farm level. The latter implies a hefty and even a dominant contribution of economics. The farming systems research at ICRISAT both begins and ends on the farm. It combines both upstream and downstream elements. Our work recognizes four divisions in farming systems:

- baseline studies of farming systems;
- component research — mostly done on-station;
- on-station operational research; and,
- on-farm operational verification.

We work in all four divisions contemporaneously and interactively. I think ICRISATs Farming Systems Research Program is unique in its sophistication, but it is also expensive. The benefits must justify the costs. It must aim at replacing farming systems and not merely adjusting them, to use some terminology from a recent paper by Dillon and Virmani. In my view the benefits must also include more efficient use of soils and water. Benefits must accrue to society as a whole and not just to the farmer and his family.

Extolled virtues of downstream research, emanating mostly from developed-country economists, are influencing the expenditure on technical assistance towards only downstream work. It is a trend which must be of serious concern to participants in this meeting because farming systems research that works only at the farm level can only result in adjustments and changes at the margin. In my view, farming systems research should lead to farming systems development and should stress principles that will allow sufficient change to pay for the conservation measures that are necessary. That means significant change to increase productivity, profitability, employment, and the conservation of the resource, all at once.

I believe, Dr. Garbouchev, that you and your colleagues in UNEP share with us this great concern for ensuring that farming systems improvement does not lead to degradation of resources. I hope that you and Dr. Carpenter, from FAO, will stress in your future statements about world soil charters and world soil policies, that conservation without profits will have no more lasting benefits than profits without conservation. I think in our meeting we can stress the importance of both, and stress how farming systems principles can allow both to take place at the same time.

Thank you very much.

Purpose and Objectives of the Meeting

LP. Garbouchev
Senior Programme Officer (Soils), UNEP

Distinguished colleagues, gentlemen:

It is a privilege for me to extend to you the greetings and best wishes of the Executive Director of UNEP, Dr Mustafa Kamal Tolba, on the occasion of this expert group meeting. I was also asked by the Executive Director and Assistant Executive Director (Programme) Mr G.N. Golubev, to express special gratitude to ICRISAT, particularly to Dr Swindale and Dr Kanwar, who agreed to assist UNEP in organizing this meeting. I would also like to thank, on behalf of the Director of the Environmental Management Service of UNEP, Mr. R.J. Olembo.

Some of you are aware of the efforts to draw up UNEP's World Soils Policy by three expert group meetings in 1980 and 1981, which were convened in collaboration with FAO, UNESCO, and the International Soils Science Society. This Policy was, inter alia, endorsed by the 10th Governing Council of UNEP.

The World Soils Policy forms an integral part of the World Conservation Strategy. A number of priority issues identified in the World Conservation Strategy are directly concerned with maintaining soil productivity and soil degradation and stimulating soil reclamation. The World Soils Policy is addressed international and national bodies, as well as to individuals with interest in and responsibilities for safeguarding soil, water, and related resources.

Since the implementation of the World Soils Policy will necessarily be the responsibility of Governments, international action should be placed within that context and should be concerned primarily with what kind of advice can be given to States, particularly in the developing world, for improving the management of their land and soil resources.

The following objectives of the World Soils Policy are related to the subject of this meeting.

- To increase and apply scientific knowledge of world soils, with a view to increasing their potential for production and ensuring their sound management.
- To develop and promote agricultural production systems that assure the use of soil on a sustained basis.
- To share in promoting and supporting suggested international and regional activities.
- To intensify efforts for promoting optimum land use for sustained production on a worldwide basis, and international cooperation in the use and development of land and water resources.
- To actively pursue research needed to develop farming systems that combine adequate production with resource protection that are compatible with socioeconomic and cultural conditions.
- In developing the plan of action of national and international levels, we placed emphasis on the identification of vulnerable areas, and on action-oriented programs, to meet the needs of developing countries in particular, as well as on research, training, education and bilateral, national, regional, and international transfer of knowledge and experiences.

In 1982, the Executive Director of UNEP was requested by the 11 th Governing Council to submit a plan of action for the implementation of the World Soils Policy. In developing the plan of action at national and international levels, we placed emphasis on the identification of vulnerable areas, and on action-oriented programs to meet the needs of developing countries.

UNEP felt that the role of international bodies lies in particular in establishing broad priorities in achieving a transfer of resources, knowledge and experience, as well as supervision of internationally funded programs. We will give highest priority to assist individual governments in the initial stages to formulate their own national environmentally sound agricultural policies and practices. A number of elements are addressed, in our Plan of Action. Let me briefly outline some aspects of this comprehensive work.

We have to face the fact that we do not have methods that can reliably detect significant changes in those soil and land characteristics, which directly or indirectly affect the quantity and quality of the land.

It is widely recognized that many projects for land development have not only failed to yield the desired results but have often resulted in damage to the soil and land. As the pace of development of land management projects is increasing, lessons learned from past experiences should be applied to ensure that the causes of project success and failure are identified and modifications in procedures are suggested to ensure the success of future projects.

In this regard we should like to promote the approach of an integrated watershed management system. It is recognized that small watersheds are the best land units within which land use and management may be integrated to provide for optimum sustained use of each class of land in a manner that minimizes adverse impacts on other areas.

Taking the points mentioned into account, we in UNEP felt that governments and decision-makers should be advised on the establishment of environmentally-sound agricultural policies and their integration with other natural resources policies.

Our meeting here should aim to produce a set of guidelines for the use of decision-makers. This I conceive as an important priority for the implementation of UNEP's soil program.

Finally, I am glad that such initiatives as the World Soils Policy, the World Soils Charter, and documents such as those we are now addressing to governments, were created in order to tackle the problems of soil and water. I would like to thank everyone of you for participating, and would also like to express my confidence that we will accomplish our task.

Thank you very much.

Guidelines and Research Priorities for Farming Systems to Prevent Soil Degradation

Guidelines for Farming Systems to Prevent Soil Degradation

Introduction

Soil degradation is stated in the World Soils Policy to mean "The decline in soil quality caused through its use by humans. Soil degradation includes physical, biological, and chemical deterioration such as decline in soil fertility, decline in structural condition, erosion, adverse changes in salinity, acidity or alkalinity, and the effect of toxic chemicals, pollutants, or excessive inundation." It is also estimated that 5-7 million ha of cultivated lands are being completely lost for agricultural production every year through soil degradation.

Human populations in developing countries, where most of the soil loss is taking place, will double in the next 20-30 years. For most of this period, the needed increase in agricultural production will have to come from the existing cultivated land, large areas of which are already subject to degradation. We must therefore develop farming systems that permit greater food production and, at the same time, enhance the potential of the soil to produce more food, fodder, fuel, and fiber. Many such systems have been developed for the arid, semi-arid, and humid tropics by national and international agricultural research centers. This document recommends improvements in farming systems for different regions and describes areas in which further research is needed. It provides guidelines based on the improved technologies available — the essentials of which are described in the various presentations made at this meeting — to be observed when it is planned to improve farming systems on arable land in order to feed the growing world population.

Guidelines for Farming Systems for Arid (Desert) Lands

It is imperative to identify and adopt improved farming systems for the desert, to reclaim its sandy soils and improve agricultural productivity. In developing such systems, the following guidelines are recommended.

1. An integrated approach to desert development should be adopted. This should address (a) technological, (b) biological, and (c) socioeconomic aspects.
2. An appropriate blend and balance of traditional and improved technologies should be adopted. These will include the use of indigenous materials and techniques coupled with the use of solar, wind, and/or biogas energy sources.
3. Optimum use of land, water, nutrients, and energy are major goals. There is also the utmost need to establish appropriate crop rotations based on grasses and legumes. Improved horticulture and agroforestry should be included in the development of desert lands.
4. The fodder-animal-biogas system has good potential for increasing food and energy production, as well as improving desert soils.
5. The use of green manure, animal manure, no or minimum tillage and mulching techniques should be considered wherever appropriate.
6. In evaluating alternative approaches, considerations such as technical feasibility, financial and economic viability, suitability to desert environments, social acceptability, and replicability should be stressed.
7. The need for more applied research into alternative, integrated approaches should be recognized and supported.

Guidelines for Farming Systems for the Semi-Arid Tropics

1. It is essential to recognize catchments/watersheds as basic units for the development of land, water, and biological resources.
2. Land use planning must take land suitability into account. Areas unsuited to arable agriculture should be utilized for alternative land use systems.
3. Improved farming systems technologies should be related to prevailing socioeconomic conditions. For example, labor-intensive technologies are highly desirable for such countries as India that have a high density of rural population. In some African countries, labor-saving

technologies may be required when timeliness of farm operations is essential.

4. During the extended dry season, cultivated land should be left in a state such that it is resistant to wind erosion, but at the same time does not permit runoff if rains occur.

5. The farming system used should permit the early development of maximal crop cover in the wet season. Such cover can be achieved through the practice of dry-seeding, the use of cultivars with early seedling vigor, and the use of fertilizers.

6. The land management techniques used should include elements of soil and water conservation, i.e., the aim should be to permit high infiltration rates and adequate drainage, particularly in soils with a high clay content.

7. Experience shows that the application of minimum cultivation techniques lead to improvements in soil structure. The introduction of traction zones, and crop-growing zones, through the use of broad beds and furrows could help achieve this objective.

8. The growing of intercrops that have different growing periods helps to stabilize crop production and optimize resources.

Guidelines for Farming Systems for the Humid Tropics

A. For uplands

1. The land management system should be such that a layer of vegetation or mulch covers the soil surface throughout the year, including the dry seasons. At the same time it should minimize cultivation of the land where possible, by using reduced tillage.

2. Traffic on the land should be minimized, and preference should be given to equipment with low pressures on the soil. When compaction occurs, appropriate measures should be taken to loosen the soil and restore the structure.

3. When ridging, bedding, or mounding is necessary it should be done with measures that preserve a mulch on the soil. Long and steep slopes must be avoided for this type of land preparation.

4. Where possible, multiple cropping should be practiced. Sequential cropping should include crops known to produce good stubble mulches and/or weed-suppressing shade crops. Intercropping should include mixtures of shallow and deep-rooted species. Care must be taken to return all organic residues to the soil. Judicious and timely application of the proper nutrients (N, P, K, Ca, Mg, S, Zn, and others) in adequate and balanced quantities, and also lime for maximum biomass production, is necessary.

5. In most areas, soil-building rotations with planted fallows will have to be included in the farming systems, in order to maintain satisfactory levels of productivity. Alley cropping can achieve this without diminishing the production of essential food crops. Some intercropping or multistorey cropping can be economically attractive, where market conditions are favorable.

B. For lowlands

1. The first requirement for sustained high levels of rice production is a high standard of water control. Canals and drainage ditches should be kept clean so that the soil can be kept flooded to a depth of 5-10 cm from seedling stage to maturity, and so that the soil may be drained just before harvest time.

2. The next most important requirement is to maintain an optimum level of availability of those nutrients needed by the rice crop. Attention must be given to maintaining a proper balance of the nutrients required. These should be soil-applied to minimize volatilization of nitrogen or undesired eutrophication.

3. In areas where a dryland crop is grown before or after rice, it is desirable to use tillage methods and organic manures that sustain economically optimal soil conditions for both the rice crop and the upland crops grown in sequence.

4. Chemicals for disease, insect, and weed control should be used whenever advantageous, but only to supplement cultural practices developed to ensure minimum pest incidence. Steps must be taken to ensure that the pesticide degrades readily, and does not contaminate soil, water, or vegetation.

Research Priorities

A. For the Semi-Arid Tropics (SAT)

1. Characterization of resources and identification of benchmark sites

Compilation of information on the agroclimatic and soil resources of the SAT should receive high priority. These should be used for developing and evaluating new technologies for a wide range of environments in the SAT.

2. Improved technology of Vertisols and associated soils

On-farm verification studies over a wide range of soils and agroclimates are required to test the applicability of the technology. On the shallower black clay (Vertic) soils, further research is needed to refine the systems before on-farm verification begins.

3. Development of improved land and water management techniques for Luvisols and Acrisols

A substantial research effort should be made to develop land-and-water management systems for the light-textured Luvisols and Acrisols, both in India and West Africa.

4. Cropping for diverse environments

Research on various options should emphasize the development of systems that make more efficient use of limited resources, especially moisture and nutrients. This should involve multidisciplinary studies followed by operational research.

5. Development of machinery and tools

Emphasis should be on the selection and development of simple and reliable agricultural machinery appropriate to the conditions experienced by, and resources of, the farmers.

6. Management of nutrients

Special attention should be given to improving the efficiency of utilization of nutrients in the various SAT cropping systems. Priorities need to be placed on improving the use efficiency of fertilizer nitrogen under a range of soil and moisture conditions. Long-term studies of residue management, biological nitrogen fixation, and green manuring should also be conducted. Phosphorus, zinc, sulfur, and potassium also require additional research.

7. Management of weeds, pests, and diseases

New and improved cropping systems frequently generate unforeseen weed, pest, and disease problems that will inevitably require a research response.

B. For the Upland Humid Tropics

The need to achieve substantial and immediate increases in food production in many developing countries warrants the development of more productive, efficient, and environmentally stable land and soil management methods. To better attain this goal in the upland humid tropics, more research is required in the following areas.

1. Environmentally sound land-clearing and post-clearing management techniques for the major soils should be developed.
2. There should be extensive agronomic and socioeconomic validation of currently recommended agricultural production techniques. Such research should be conducted through a network of trials on selected benchmark sites, with on-farm testing at many locations.
3. The potential for using herbaceous, shrub, and tree legumes in sustaining continuous agricultural production and supplying local consumers' needs of food, fuel, and fiber should be explored.
4. Methods for the restoration of degraded soils should be developed.

C. For the Lowland Humid Tropics

1. There is a need to study the effects of tillage practices on the physical and mechanical prop-

erties of wetland soils, with reference to soil-water relations, pan formation, and the suitability of these soils as a rooting medium.

2. The effects of long periods of rice cultivation with and without fertilizer should be studied in a range of environments, including sites where upland crops are grown before and after rice.

3. More information is needed regarding salinization and desalinization of paddy soils and the effects of prolonged use of poor-quality irrigation water.

4. Studies are needed on management methods that will permit acid sulphate soils, tropical peats, and Piano sols to be successfully used for rice production without causing soil degradation.

Summaries of Case Study Papers

Desert Development, Demonstration, and Training Program in Egypt

Adley Bishay
Director, Desert Development, Demonstration, and Training Center, Egypt

The Concept

Deserts account for roughly 96% of Egypt's land surface, and the available arable land is inadequate to support the rapidly growing population, which is currently about 44 million. Accordingly, in Egypt and other parts of the Middle East, the need to increase the productivity of arid lands is a national priority. The Agricultural University in Cairo's (AUC) Desert Development, Demonstration, and Training Program (DDDT), initiated in 1979, undertakes applied research into alternative, economically viable, integrated approaches to arid land, agricultural, and community development. The ultimate goal is to demonstrate alternative patterns that can be replicated for the establishment of viable desert communities for Egypt. Such communities should offer a quality of life attractive enough to encourage the migration of families from the overcrowded cities and villages to desert areas.

The following are the goals of the DDDT.

1. The program's emphasis is on arid-land agriculture, where water supply and energy costs are the primary constraints. Optimum land and water resource management is a major goal.
2. Applied research and demonstrations in the utilization of solar, wind, and biomass energy in rural communities; studies of energy-efficient low-cost housing.
3. A training program for both the private and public sectors.
4. The identification and demonstration of technologies appropriate to the resources and environment of Egypt, and other countries with similar environments.
5. An interdisciplinary approach in every part of the program.
6. Demonstrations of small-scale agriculturally based industries.
7. The assessment of the suitability of indigenous materials for construction and other development activities.
8. Applied research, and identification and demonstration strategies, for the development of desert communities, within the framework of local resources and social norms, and without detriment to established standards in the preservation of health and environment.

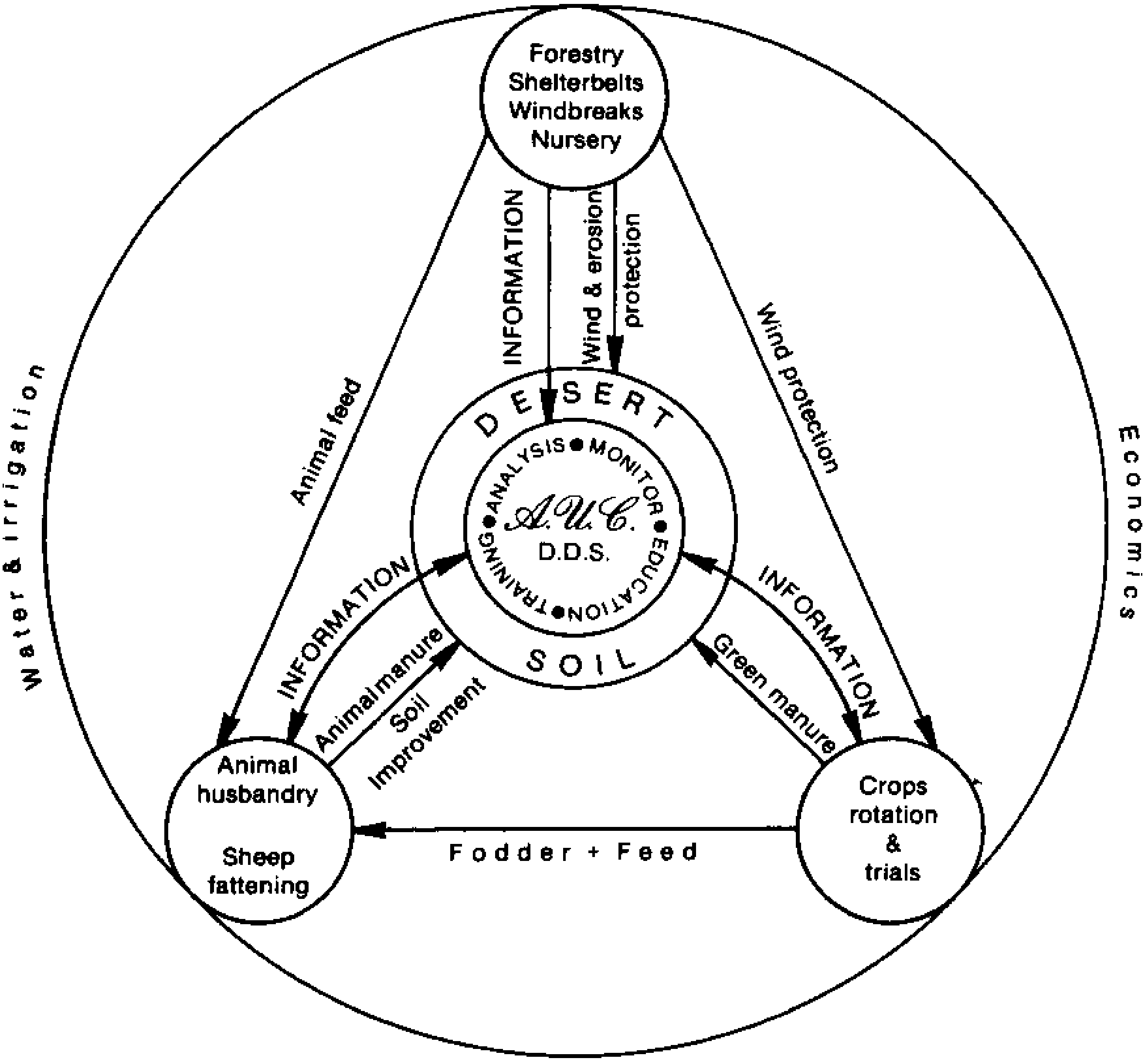
All results of the DDDT activities are to be made publicly available for application in agricultural, economic, or development work by others. The University has established cooperative relationships with experts and several research institutions for assistance in applied research, training, and demonstration activities.

The Program

The DDDT has identified a number of areas for conducting applied research, leading to the demonstration of arid-land improvement oriented towards small-farmer development, or to the setting up of models for agroindustrial activities that could eventually become alternatives in solving Egypt's food and population problems.

As a first phase for studying alternative desert fanning systems, a project supported by IDRC on "Integrated Approaches for Improving Productivity of Sandy Soils" has been undertaken. The following are some of the areas of applied research that are currently being conducted, or are planned for initiation as soon as funds are available (see Fig. 1).

Project sponsored by
The International Development Research Centre (IDRC)
Phase One (3 years)



The American University In Cairo (A.U.C)
Desert Development Systems (D.D.S.)

Figure 1. Integrated fanning system for improving the productivity of sandy soils.

Research in Soil and Water Conservation

Technological practices

Soil survey and soil management. The soil of the South Tahrir site is mainly of the coarse sandy type; the level of nutrients is very low. Several field experiments were conducted to determine the most balanced NPK fertilizer for the different crops. Soil survey and management studies are also undertaken at the Sadat City site.

Irrigation systems and water management. Accurate and statistically analyzed hydrological and meteorological data, water requirements of desert crops, effective methods of irrigation and drainage, techniques for increasing soil moisture retention and decreasing water losses, are all included in the development of optimum water management, and associated designs and practices. Meteorological data are currently collected and analyzed at the Sadat City site. The South Tahrir site depends on Nile water delivered through a small canal connected to the NASR Canal. Systems of drip and biwall irrigation, and four side-roll sprinkler systems are in use. The Sadat City site depends on underground water for irrigation; this is pumped from a well by two solar pumps. Systems such as sprinkler, drip, or biwall irrigation are water-efficient, but their energy consumption is high. A system using thin-walled, corrugated plastic pipes of sufficient diameter to permit low head operation is currently used for watering the casuarina trees planted as wind breaks around the site.

Controlled-environment agriculture. A proposal for conducting cooperative work has been submitted by the AUC for the Sadat City site. Associated use of the nutrient film technique (NFT) is currently being discussed.

Renewable energy sources. On the application of renewable energy technologies for desert development, a number of projects have been or are currently being implemented.

Desert materials and architecture. To be appropriate for the project, associated construction work must maximize the use of locally available materials. Major activities consist of a survey of raw materials in the area and the production of suitable bricks.

Biological practices

Desert crops and crop rotation. Agricultural crops are chosen with the goal of maximizing their potential economic productivity under prevailing environmental conditions. In addition to useful indigenous plants, the exotic plants currently being tested are: jojoba (Simmondsia chinensis), guayule (Parthenium argentatum), euphorbia, and buffalo gourd (Cucurbita foetidissima). A number of cereals, legumes, fruit, vegetable, and oil crops are also being tested.

Afforestation and desertification control. In addition to windbreaks, the afforestation program includes adaptive research for the identification of tree species for the production of wood-based material (pulp or fuel), animal fodder, and human food or annual cash crops. The use of some tree species, e.g., leucaena, for soil rehabilitation is also under study. Desertification control studies and activities aim at controlling sand movement and salinization, and serve as demonstrations for application in other similar, or more extreme, conditions. Zero or minimum tillage has been considered to be of potential value as a way of minimizing wind erosion.

Livestock development. In the livestock development program, cattle and sheep are to be experimented with for improved meat, milk, and cheese products. On-site management and training of personnel will be a primary activity. At this stage, sheep fattening is practiced as a part of the integrated project for improving desert soil productivity. Another project under consideration is based on an integrated system of fodder, cattle, and biogas, including applied research and demonstrations of small-farm units and/or pilot agroindustries (meat, milk, etc.).

Biosaline research. Cooperative work in this field has been initiated under the project on "Applications of Renewable Energy Technologies for Desert Development" in Sadat City. Some salt-tolerant species (Distichlis spicata, Sporobolus virginicus, A triplex triangularis) are now being tested.

Community planning

It will be important to consider what types of individuals will work on the land, perform other functions, and on what terms. This will involve experimenting with school and university graduates in agriculture (middle class people and landless peasants), and setting up criteria for selections from both groups. There should be incentives designed to attract professionals to live and work in the desert. The University's Social Research Center has a wealth of data based on settlement problems in Egypt, from which future guidelines can be developed.

Improved Farming Systems for Vertisols in the Semi-Arid Tropics

J.R. Burford and S.M. Virmani
Principal Soil Chemist, and Program Leader, Farming Systems Research Program, ICRISAT

Introduction

The semi-arid tropics (SAT) extend over 2.1 billion ha, and support a large population — 750 million in 1980. Ninety percent of this area and 99% of this population are located in developing countries. Currently crop yields are low throughout most of the nonirrigated SAT. Substantial increases in productivity of all crops will be needed in the future to sustain population increases. India contains about 56% of the SAT population on about 10% of the SAT area. Improved productivity in this area is now urgently needed. Of the major soils of India, the Vertisols possess the best potential for increasing crop yields severalfold. This paper discusses the traditional and improved systems for the Vertisols in the Indian SAT. Aspects needing consideration for transfer to other SAT environments have been illustrated. Because maintenance of long-term productivity is a cause for serious concern, the discussion includes the implications for reducing the current degradation of the soil.

Vertisols and their Environment

Physical resources

Soils. Vertisols and associated soils occur extensively in India (72 million ha), but true Vertisols probably extend over 27 million ha (Murthy et al. 1982). The characteristic of Vertisols that gives these soils such a high potential for increases in crop yields in the drought-prone SAT environment is their high water-holding capacity. This results from their clay content of 35-65% and the normal dominance of montmorillonite in the clay fraction.

Agroclimate. Based on probabilities of weekly rainfall, the Vertisol area in India has been divided into the area in which rainfall during the rainy season is sufficiently assured for reasonably-reliable cropping, and that in which it is not assured (Fig. 1). Analyses such as these are used for planning systems that provide high productivity as well as stability, keeping in view the risk associated with a particular environment.

Socioeconomic constraints. The SAT is one of the poorest economic regions in the world. Within India, average incomes are lower in the SAT than in the remainder of the country. In India, as there is very little cultivable land not already in use, all future population increases must be fed from increased production per unit area. This will place increasing pressure on the land, with the risk of increasing soil degradation under existing agricultural practices.

Soil degradation. In India, Vertisols are particularly subject to the high risk of substantial soil loss by water erosion under the prevailing traditional systems of bare-fallowing during the rainy season. Erosion losses are also promoted by the very low infiltration rates of Vertisols once the soil becomes saturated. Prediction of such erosion is currently being attempted at ICRISAT. The consequences of soil loss under the traditional monsoon fallow system are frightening. Measurements at Sholapur, on land with a slope of only 1-2%, indicate that 50 cm of soil has been lost by erosion over the past 100 years (ACRIPDA, Hyderabad, personal communication). Diminution of the depth of the soil profile will reduce water-storage capacity and thus the long-term productive capacity of the soil. Further, little attention has so far been given to the degradation of the nutrient status of the soil by either traditional or improved farming systems.

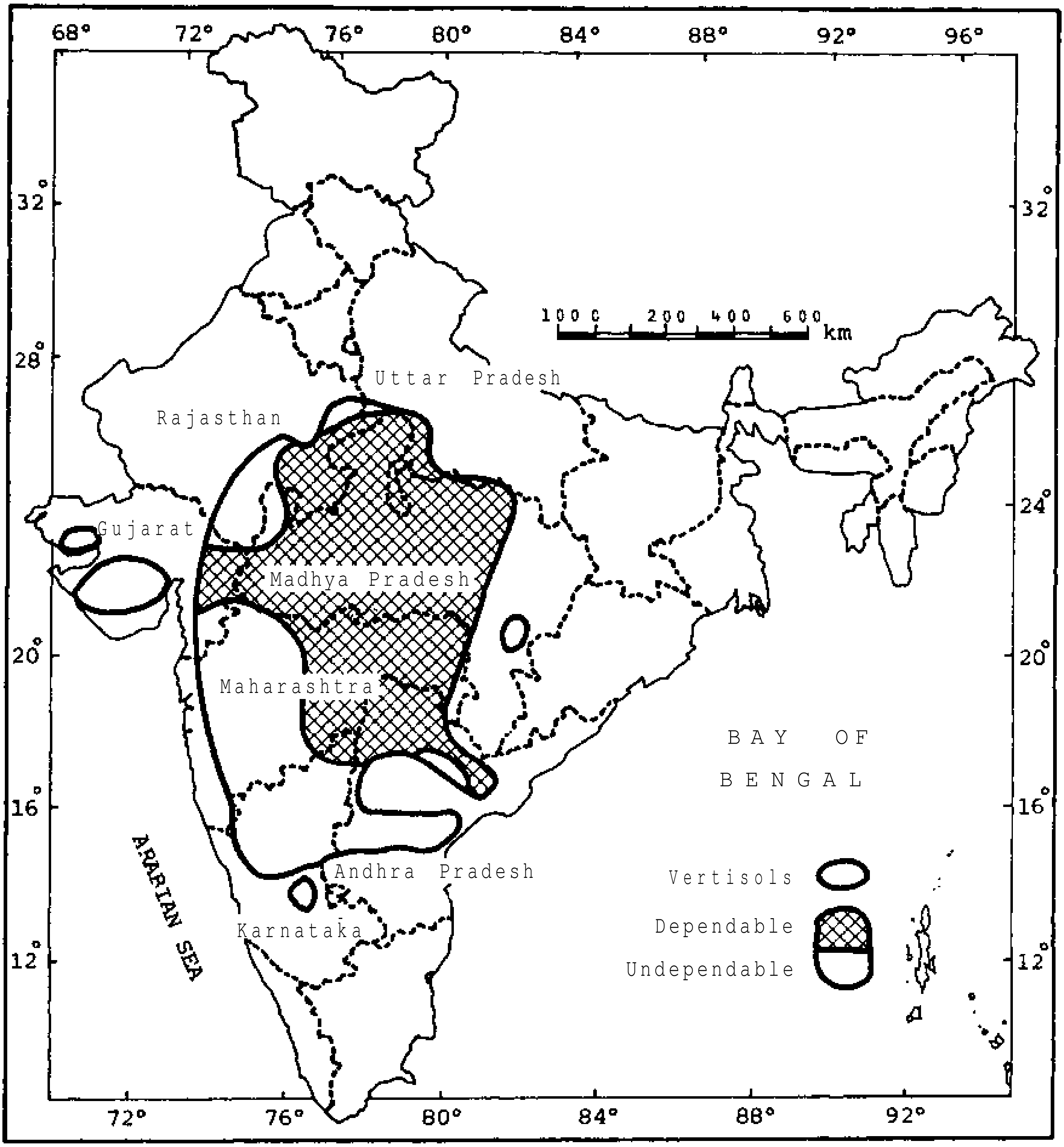


Figure 1. The Vertisol areas of India where rainfall is dependable (low risk) and independable (high risk). Source: Virmani et al. 1981.

Farming Systems

Traditional systems

Prevailing land use patterns. In the Indian SAT, on the shallower (Vertic) soils, cropping is confined to the rainy season. Of the deep Vertisols (1.0-1.5 m), a few are cropped during the rainy season, but perhaps 50% or more are left fallow during the rainy season, and cropped once only, during the postrainy season. On rainy-season fallow areas the commonly grown crops in the postrainy season are sorghum, wheat, or chickpea, and intercrops (sorghum/oilseed), or a 2-year rotation of wheat-chickpea or wheat-linseed. Full use of the land — by two crops spanning both seasons — extends over less than 10% of the area (Krantz et al. 1974). Crop productivity is low but reasonably stable, because inputs are low and risks of loss are low. This low-risk system was satisfactory while population pressures were relatively low. Increasing populations now require increasing crop-productivity per unit area.

Prevailing production constraints. Indian farmers' traditional systems have several major problems and limitations. The poor internal drainage of the heavy soils can severely restrict operations during the rainy season, the cultivation equipment lacks versatility, the crop cultivars have low yield potential, and the farmers' crop options are often limited.

Soil degradation hazards. The most serious deficiency in the rainy-season fallow system is that it promotes a diminution of the resource base because of erosion. This is many times greater on uncropped land than where the surface is protected by the growing crop.

Improved farming systems for Vertisols

Innovation and components. ICRISAT has developed an improved farming system for Vertisols. The key elements of this system are the following.

a. A double-cropping system in which each of the two crops is more productive than the farmers' single crop.
b. Use of improved cropping systems, which include sole crops, intercrops, and sequential crops as options.
c. Use of fertilizers, usually N and P carriers and, less commonly Zn.
d. Introduction of improved land and water management techniques.

The basic elements of the improved management techniques are these.

a. Shaping of the land to promote disposal of excess water, by the introduction of broadbeds and furrows, grassed waterways, etc.
b. Commencement of land preparation immediately after the previous crop is harvested.
c. Completion of seedbed preparation after the first premonsoon rain.
d. Placement of seed and fertilizer.

While the productivity gains are greatest when all options are introduced, the improved system contains a number of options for the farmer.

Productivity gains. On operational research areas at ICRISAT Center, the improved double-cropping system consistently gives grain yields of 3 t ha^{-1} cereal (maize or sorghum) and 1 t ha^{1} intercropped legume (pigeonpea), as compared with 0.5-0.8 t ha^{-1} a^{-1} of grain under traditional systems. The latter is commonly priced at 3 times the value of sorghum so that the eventual yield is equivalent to about 6 t ha^{-1} cereal grain. An increase in net profits of 500-600%, and a return of 250% on the additional funds invested has been obtained.

Transfer of the Improved Systems

India

On-farm verification. After several years of testing of these improved systems at ICRISAT Center, evaluations commenced on other Vertisol sites in 1981, where all operations were conducted by the farmers. Preliminary results were encouraging (Ryan et al. 1982). The data in Table 1 gave a 244% rate of return on expenditure in the improved system. This compared well with the return of 250% obtained previously in operational research at ICRISAT Center.

Adoption, adaptation, and constraints. A number of issues have been identified even at this early stage in the verification process (Ryan et al. 1982). These are: the need for improved availability of credit; timely supply of fertilizers in villages; and improved capacity for manufacture of the wheeled tool carrier. On technical aspects there is need for further research on cropping systems options, use of small

Table 1. Economics of improved watershed-based technology options on deep black soils in Tadanpally village, Andhra Pradesh, India 1981-82.[1]

Cropping systems	Proportions grown	Gross returns	Operational costs	Gross profits	Yields: Cereals Grain	Yields: Cereals Fodder	Yields: Pulses/oil seeds/vegs Grain	Yields: Pulses/oil seeds/vegs Stalks
Improved watershed[2]	%	...(Rs ha^{-1})[3].			........(100 kg ha^{-1})			
Sorghum/ pigeonpea intercrop	50	4930	1092	3838	19.5	72	4.6	19
Maize/pigeonpea intercrop	6	4304	1395	2909	16.4	34	6.0	22
Maize-safflower sequence	6	2301	1190	1111	16.2	35	0.5	-
Maize-chickpea sequence	5	5097	1831	3266	22.9	50	4.6	-
Mung bean-sorghum sequence	17	3352	1261	2091	5.9	17	4.7	-
Mung bean-safflower sequence	3	3715	1321	2394	-	-	5.2 (mung bean)	
							7.3 (safflower)	—
Mung bean-(sorghum/chickpea)	4	4073	1495	2578	0.8	2	4.8 (mung bean)	-
sequence							5.2 (chickpea)	-
Mung bean-chilli sequence	2	4625	1450	3175	-	-	5.2 (mung bean)	
							5.0 (chilli)	—
Fallow chilli	7	2551	734	1817			4.1	-
	100							
Weighted averages		4242	1183	3059	-	-	-	-
Traditional farmer's fields								
Fallow sorghum	90	2194	536	1658	6.7	18	-	-
Fallow chilli	4	3208	2036	1172	-	-	7.2	-
Mung bean-sorghum sequence	1	3964	1526	2438	9.7	24	3.1	-
Sorghum/ pigeonpea intercrop	5	1544	310	1234	5.5	25	1.2	16
	100							
Weighted averages		2220	595	1625	-	-	-	-

1. Prices used were based on actual realized or market prices just after harvest. They were as follows:

Grain	Rs/100kg	Grain	Rs/100 kg	Fodder	Rs/100 kg
Hybrid sorghum	100	Pigeonpea	298	Hybrid sorghum	20.0
Postrainy-season sorghum	220	Safflower	300	Postrainy-season sorghum	37.5
Maize	112	Chickpea (sold as seed)	450	Maize	10.0
Mung bean	300	Chilli	618	Pigeonpea stalks	10.0

2. Data refer to 14.48 ha of the 15.42 ha watershed. In three plots data were not available.
3. Rs 12.5 = 1 US$.

farm ponds to ensure success of the postrainy season crop, better prediction of optimum sowing dates, and better methods of weed control.

Other countries

With the transfer of technology exercise well under way in India, it is appropriate to consider other geographic areas that would benefit from the new system. Sudan is a logical choice for extension of the present verification studies. The area of Vertisols in that country is particularly large (63 million ha), out of which about 42 million ha of Vertisols may have a growing season in excess of 2 months. More detailed studies of soil characteristics, reliability of rainfall, and socioeconomic aspects will now be needed.

Institutional Frameworks

The management of land and water in the dryland areas needs the individual farmer's, or a group of farmers', cooperation, to put together a watershed and lay out the drainage channels. For improving drylands, there are a number of components that need to be adopted as a basic unit by the farmers. System transfers, as opposed to a single-component transfer, are difficult and have a longer gestation period. It is a considerable task — in training and creation of awareness — that the institutions involved will have to undertake, if the technologies generated by them are to be adopted on a large scale. There are other institutional and financial issues related to the farmer's capacity to use the facilities, services, and inputs available. All these issues must be addressed so that the promise offered by the new technology can be translated into a real potential.

References

Krantz, B.A., and associates. 1974. Cropping patterns for increasing and stabilizing agricultural production in the semi-arid tropics. Pages 217-248 in International Workshop on Farming Systems, Hyderabad, India, 18-21 Nov 1974. Patancheru, A. P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Murthy, R.S., Battacharjee, J.C., Landey, R.J., and Pofali, R.M. 1982. Distribution, characteristics, and classification of Vertisols. Pages 3-22 in Symposium Papers 3. Transactions of the 12th International Congress of Soil Science, 8-16 Feb 1982, New Delhi, India. New Delhi 110 012, India: Indian Agricultural Research Institute.

Ryan, J.G., Virmani, S.M., and Swindale, L.D. 1982. Potential technologies for deep black soil in relatively dependable rainfall regions of India. Pages 41-46 in Proceedings of the Indian Bank Seminar on Innovative Technologies for Integrated Rural Development, 15-17 Apr 1982, New Delhi, India. New Delhi, India: Indian Bank.

Virmani, S.M., Willey, R.W., and Reddy, M.S. 1981. Problems, prospects, and technology for increasing cereal and pulse production from deep Vertisols. Pages 21-36 in Improving the management of India's deep black soils. Patancheru, A.P. 502324, India: International Crops Research Institute for the Semi-Arid Tropics.

Soil and Water Conservation Research in India

V.V. Dhruva Narayana
Director, Central Soil and Water Conservation Research and Training Institute (CSWCRTI), India

Introduction

In India, where population pressures on the land are high, rational utilization of soil resources assumes great importance for optimum and sustained food production. This involves proper land utilization, protecting the land from deterioration, building and maintaining soil fertility, conserving water for farm use, provision of proper drainage, flood protection, and erosion control. Out of the 328 million ha of India's land area, nearly 175 million ha (where 140 million ha are under cultivation) are subject to soil erosion, out of which nearly 70 million ha suffer from serious hazards, such as sheet, gully, and hill-side erosion. From 1981, the Indian government has organized large-scale soil and water conservation programs. Beginning with contour-bunding programs in the early phases, the concepts of integrated land-use planning on a watershed basis were introduced through a chain of Soil Conservation Research Demonstration and Training Centres. Staff of these Centres, during the last 25 years, have identified the soil and water conservation problems of the country and produced some viable technologies for field application.

Research Programs

Agricultural land

Soil and water conservation practices include: contour farming, mulching, intercropping, bunding, graded bunding and bench terracing on steep slopes, and the harvesting, storage, and recycling of runoff water.

Contour farming. Soil loss from areas having slopes as high as 25% was reduced, for example, from 39 to 15 t ha^{-1} when potato farming was done on contours (Table 1). Some cultural practices that reduced soil loss were closer plant spacings, intercropping, and mulching.

Mechanical measures. These include contour and graded bunding, contour ditching, and bench terracing (on relatively steep slopes). On deep lateritic soils in high rainfall areas with average slopes of 25%, bench terraces with lengths of 100 m, longitudinal grades of 0.2 to 0.8%, and inward grades of 1%, conserved the soil and moisture relatively more efficiently and also produced higher yields of potato.

Harvesting, storing, and recycling runoff. Harvesting of runoff is necessary and possible for the better utilization of rainfall, control of erosion, and the provision of life-saving irrigation during droughts and for growing a second crop. The development of seepage control techniques (especially important in alluvial soils) for farm ponds is still in the experimental stage. But the cost of lining small farm ponds with bricks and cement mortar, and cement concrete, appears to be justified, particularly in areas where there is no other source of irrigation water.

Nonagricultural land

Establishment of vegetative cover is one of the effective ways of conserving soil and water. Growing trees helps in the interception of 14-26% of the precipitation, and reduces its impact on the soil surface.

Fuel-fodder plantation. Fuel-fodder requirements are progressively increasing in India. Experiments conducted at several locations with fuel-fodder plantations have been successful.

Special problem areas. Ravine areas, which occupy nearly 4 million ha, require special soil con-

Table 1. Effect of soil conservation measures on sloping lateritic soil (25% slope) on various losses.

Treatment	Runoff (mm)	Runoff as % of rainfall	Soil loss (t ha^{-1} a^{-1})	Nutrient loss (t ha^{-1} a^{-1})	Potato yield (t ha^{-1})
Up and down cultivation	52	4.0	39	333	12.6
Simple contour cultivation	29	2.3	15	130	13.4
Bench terracing	15	1.1	1	10	17.0

Source: B. Raghunath et al. Sixth Annual Convention of the Indian Society of Agricultural Engineers, Bangallore.

servation measures. Techniques have been developed for use in areas having gullies of varying depths. By closing the ravine lands to grazing and other biotic interferences, it was observed that poor and inconsequential annual plant species were replaced by more useful species. These ecological changes have also resulted in a natural reduction in runoff and soil loss from the area, along with improvement in the quantity and quality of grass yields.

Technology Transfer

The transfer of technology, based on the concept of watershed management, is important in soil conservation work. The CSWCRTI has adopted the concept of Operational Research Projects (ORPs) for finding out by actual experience what gains accrue from the transfer of technology, and what constraints and difficulties are involved. These ORPs are located in watersheds of 300 to 400 ha. The success achieved in these programs has prompted the Indian Council of Agricultural Research and the Indian government to intensify the activities involved by establishing 46 model operational research watersheds all over the country.

Soil and water conservation practices are expected to generate three benefits in a watershed: (1) increased production of food, fodder, fuel, timber, etc.; (2) sedimentation control; and (3) a favorable water regime. An economic analysis of each of the soil and water conservation measures in agricultural land, as well as their combined effect in ORPs, have shown that the benefit: cost (B:C) ratios range from 1.8 to 3.6 (Table 2). The highest B:C ratios are obtained for water storage and recycling in rainfed lands, thus emphasizing that adoption of soil and water conservation measures will not only protect a development area but increase its productivity.

Conclusion

Watershed management enhances the acceptability of soil and water conservation measures among the people involved. Naturally, management practices in the upper catchment of a river basin directly affect the management of arable land in the lower areas of the same basin. The solution lies in the development of methods of land use that are both profitable to the local community and also give a better control of the flow-regime in the watershed, and to get these methods adopted by the local community.

Table 2. Economic evaluation of different soil and water conservation measures in agricultural lands, India.

Project	B:C ratio	Remarks
Economics of unlined farm pond for supplemental irrigation at Dehra Dun	1.8:1	Irrigation at presowing stage of wheat with 50 kg ha"' N
Economics of supplemental irrigation to sorghum, Bellary	3.4:1	5 cm irrigation at critical stage
Economic evaluation of soil conservation measures, ORP, Fakot	3.6:1 2.9:1	Rainfed agriculture Orchard plantation

Cropping Systems Research Program of IRRI

J.W. Pendleton and D.J. Greenland
**Head, Multiple Cropping Department,
and Deputy Director General, IRRI**

Introduction

The aim of cropping systems research at IRRI, which began in 1965, is to identify productive rice-based rainfed cropping systems acceptable to small farmers in specific regions. Early research demonstrated that rice farmers in the tropics were not using available soil and climate resources to capacity and that crop intensification should receive more attention. Current research is farm-based, with farmers as active participants in the design, testing, and evaluation of new cropping systems. We seek the technology that will increase production both by improving crop yields per hectare and by growing an extra crop. This paper presents the evolution, development, present research areas and achievements, and future challenges in cropping systems research by IRRI.

Formation of the Asian Cropping Systems Network

The Asian Cropping Systems Network (ACSN) was formed in 1975. The member countries of the network are: Bangladesh, Burma, China, India, Indonesia, Nepal, Malaysia, Philippines, South Korea, Sri Lanka, Thailand, and Vietnam.

The Asian Cropping Systems Working Group, which brings together scientists from national research institutions, has met periodically under the auspices of IRRI to formulate a framework for cropping systems research, develop research methods, and design collaborative research. Study tours and a 5-month training program held at IRRI are two other major areas of support for national programs. The International Fund for Agricultural Development (IFAD) supports the core program, and the International Development Research Centre (IDRC) supports the Network. The number of on-farm cropping systems research sites is 106 in 11 countries.

Development of Methodology

On-farm cropping systems research (CSR) must satisfy the following requirements (Zandstra et al. 1981).

- The research has to be related to a specific production environment.
- Farmers must participate in the design and testing of the new technologies.
- The research has to cover several commodities and be multidisciplinary.
- The tasks and the responsibilities of the team members must be identified.
- The research must emphasize cropping patterns that increase cropping intensity, are economically advantageous, and acceptable to the farmers.

The six essential components of this methodology are site selection, site description, design of improved cropping systems, site testing, preproduction testing, and the production program. The last one, that is the production program, is the ultimate objective — to provide government decisionmakers with sufficient information that they may make firm decisions about supporting improved cropping systems programs and technology that will lead to greater food production and better family welfare for small Asian rice farmers. The CSR team helps prepare the recommendations for production programs with extension staff or government policymakers.

Program Accomplishments

- The development of a methodology for designing, testing, and transferring improved technology for increasing food production.
- The formation of the Asian Cropping Systems Network and its continued growth and development.
- Specialized training at IRRI in cropping systems to trainees from many countries who return to be program leaders.

Environmental Factors and Management

IRRI scientists have spent considerable effort in characterizing the physical environment. The compilation of a rainfall map of Southeast Asia was sponsored by the ACSN (IRRI 1974). Rainfall probabilities are used to schedule planting dates for crops in two or three annual sequences. This seems to offer a promising approach in rainfed areas. A combined classification based on the determinant rainfall pattern, slope, soil texture, and soil order has been provided.

Crop modeling has been used as a tool to predict rice yield performance. A soil-water balance model aided evaluation of alternative cropping patterns selected at one site for extrapolation to other sites.

IRRI has shown that the growing of mung bean, soybean, cowpea, groundnut, maize, sorghum, and wheat offers an opportunity for additional production in rice areas. Techniques have been developed to quantify yield losses caused by insects at each crop growth stage. The rolling injection planter (RIP), originally designed at IITA, has been successfully used to plant mung bean, maize, soybean, sorghum, and wheat. It has potential as an injector of granular fertilizer beside the seed.

Future Challenges and Trends

Future challenges exist primarily in the following areas.

Variety improvement. Varieties that are tough enough to withstand stresses of too much water or too little water, that is the ability to produce relatively stable yields, are needed. Improvement of dryland crop varieties for rice-based cropping systems has been identified as the long-term objective. It is agreed that both the empirical and the physiological approaches should be utilized. Cultivars with low sensitivity to both temperature and photoperiod are needed.

Management and tillage. For most soils, the conversion from puddled to well aggregated, well aerated soil conditions is expensive, time-consuming, and wasteful in terms of residual soil moisture. The transition period of as much as 1-2 months can be avoided by seeding the following crop in the uncultivated drained paddy field. Recent trials show promising results from this technique.

Fertilizers. Maintenance of soil fertility and efficient fertilizer use in intensive cropping systems is beginning to receive attention. The ACSN members collaborate in long-term fertility trials and studies on controlled-release nitrogen carriers, to generate more information about tailoring fertilizer practices to fit rice-based cropping systems. We are also conducting research on systems where organic and inorganic fertilizers are used in a complementary manner. Symbiotic nitrogen fixation must continue to receive attention for all legume types. Our trials have shown that a green manure crop before rice can contribute the equivalent of 30 kg ha^{-1} of fertilizer N.

Environment. Agrometeorological and land capability studies will receive more attention as a means of identifying areas where present cropping systems might be intensified. Basic rice growth modeling for rainfed rice will continue. Better information on the physical environment should assist us in understanding and controlling pest outbreaks. Closer identification of critical soil moisture levels for component crops is needed.

The cropping systems research handbook (Zandstra et al. 1981) provides the basis for developing more productive cropping systems for many environments. Socioeconomic variables are much harder to measure than physical parameters and simpler, faster methods are needed.

One of the future challenges for IRRI is how best to serve the increasing demands of national programs that have recently evolved from cropping systems programs dealing with only the cropping component of farming systems programs. It remains necessary to integrate livestock, agroforestry, aquaculture, and other components of farmers' production into the system. This will receive increasing collaborative attention.

References

IRRI (International Rice Research Institue). 1974. An agroclimatic classification for evaluating cropping systems potentials in Southeast Asian Cropping Systems test sites. Los Banos, Philippines: IRRI.

Zandstra, H.G., Price, E.C., Litsinger, J.A., and Morris, R.A. 1981. A methodology for on-farm cropping systems research. Los Banos, Philippines: International Rice Research Institute.

Farming Systems Approach to Controlling Soil Degradation in Thailand

Chirtchart Smitobol
Chief, Soil and Water Management Research Branch, Farming Systems Research Institute, Thailand

Introduction

Soil degradation in Thailand occurs at a considerable rate. Better soil management is an integral part of farming systems research. Related work is now the task of the Farming Systems Research Institute, established in April 1982.

The land area of the Kingdom of Thailand is approximately 514000 km^2, one-third of which is cropped. Annual rainfall ranges from 800 mm, or even less in rain-shadow areas, to over 4000 mm in the eastern and southwest coasts of the peninsula. There are 13 agroecological zones, based on rainfall and soil characters. The Farming Systems Research Institute has proposed five production stability zones for annual crops based on the following factors (in order of importance): rainfall variability; soil texture and water table; and organic matter in the topsoil.

The stability of crop production is affected mostly by the low water-holding capacity of soils. Due to high soil temperatures, organic matter accumulates slowly. There is therefore a low infiltration rate in heavy soils, and a low water-holding capacity in light soils. These are recognized as the major causes of loss in production.

Socioeconomic Setting and Production Constraints

More than 75% of the population is engaged in agriculture. Out of a total cropped area of 16.8 million ha, 82.7% is rainfed. This includes 80% of the rice paddy areas and all of the land used for growing rubber, coconut, and field crops. The most remunerative crops are: cassava, sugarcane, and coconut. Nonfarm activities are also an important source of income for the farmers. At one project site (Bangplama District, Suphanburi Province), in 60 farming families 80% of the farm attendants were school-age children, women, and farmers of retirement age. In the northeast region, where such a situation is prevalent, per capita income is about US$ 100 per year. In the central plains, on the other hand, more land is irrigated and cropping is more intensive. There, farming incomes are about $ 200 per year.

Soil Degradation

Two significant ways in which soil productivity is lost are soil/water erosion and the depletion of nutrient elements due to plant removal. An estimate of soil erosion loss conducted by the Land Development Department indicates that the country was subjected to very severe soil loss on over 12% of total area (Table 1). Likewise, after investigating plant nutrient removal under cassava it was found that yield on a sandy loam soil in Mahasarakam Province, without fertilizer, decreased from 23 t ha^{-1} in 1977 to 15 t ha^{-1} in 1980.

Farming Systems Research

The primary concerns of farming systems research in Thailand are cropping intensity and appropriate technology. Various cropping patterns have been tested in each agroecological zone.

Recommendations

Recommendations that can be made at the present

Table 1. Estimated annual soil loss in Thailand.

Degree of soil loss	Soil loss ($t\ ha^{-1}\ a^{-1}$)	Area (million ha)	Area (%)
Very slight	0.06 - 6.25	19.0	37.0
Slight	6.31 - 31.00	14.4	28.0
Medium	31.25- 125.00	4.2	8.2
Severe	125.06 - 625.00	6.8	13.6
Very severe	625.00- 6041.56	6.3	11.9
Other		0.7	1.4
Total		51.4	100.1

time are the following.

1. In the north and northeast, cultivation at a slight grade, across the steepest slope of the land to arrest excessive runoff and soil loss, should be popularized.

2. Two crops instead of one late-planted crop should be grown. In most areas this can be done by (a) plowing the field immediately after harvest to incorporate crop residues; (b) tilling the soil again in the dry season to control weeds and facilitate greater infiltration of the early monsoon showers; and (c) early planting.

3. In the northeast, where farmers generally grow only one crop during the year on the upper terraces, field crops can be successfully grown. On the middle terraces, short-duration legumes can be grown. On the lower terraces, short-duration legumes can be grown on beds ahead of rice by draining excess water to the lower levels. If large amounts of rain are received and farmers wish to transplant rice immediately, they can do so by plowing in the legume and blocking the openings in the bunds.

4. Rice fields should be properly levelled before transplanting, to permit better water management and weed control.

Technology Transfer and Government Policies

In Thailand an institutional approach seems to provide a good level of efficiency in technology transfer. Individual approaches — widely practiced in the country — are not so effective because of the lack of qualified extension personnel. Currently, one extension worker is responsible for more than 1000 farm families.

The delegates at the Soil and Water Conservation Symposium in Chonburi Province in 1982 proposed to the Royal Thai Government the formulation of the National Soil and Water Conservation Policy through:

- education, research, and training;
- soil and water conservation laws;
- soil and water conservation implementation, and improvement of responsible agencies;
- supporting activities to campaign for soil and water conservation and the observance of a National Soil and Water Conservation Day.

Farming Systems to Prevent Soil Degradation in the Humid and Subhumid Tropics

C.H.H. Ter Kuile and B.T. Kang
Program Leader, and Soil Scientist,
Farming Systems Program, IITA

Introduction

Greater awareness and concern for the dangers of soil degradation have focused attention on the need for a better assessment of the processes involved, and for improved preventive measures and soil reclamation methods (FAO/UNEP 1974; UNEP 1982a; ISSS 1978). One limitation in discussing the problems of land and soil degradation is the lack of a generally accepted definition. UNEP (1982b) defined soil degradation as the decline in soil quality caused by its use by humans. Considering the many factors involved and the consequences of soil degradation, a more encompassing definition appears to be necessary.

Degradability of Soils in the Humid Tropics

Most systems of farming leave the soil surface bare and exposed to the weather until the crop is well established, in contrast to the soil cover provided by natural vegetation. Tropical soils are very susceptible to erosion and degradation whenever adequate protective plant covers are absent. In order to quantify the hazards of degradation in different soils listed in Table 1, a set of generalized ratings of physical and chemical degradability have been prepared, as follows.

Easily degradable soils. These include Alfisols and Ultisols in humid and subhumid regions of West Africa. These soils also are subject to rapid chemical degradation. Under intensive cropping without chemical or organic additives, the fertility of these soils declines rapidly and becomes a major limitation for farming.

Moderately degradable soils. Examples are the Oxisols, Alfisols, and Ultisols, other moderately weathered soils, and Inceptisols from volcanic ash. Decreases in soil fertility and crop yields are slower in these soils. Additives and fertilizers can make

Table 1. Approximate distribution of soils in rainy tropical climates, by percentages.

Soil grouping	Rainy (9.5 12.0 humid months)	Seasonal (4.5 9.5 humid months)	Total tropical rainy area
1. Highly weathered soils dominated by low-activity clays (mainly Oxisols, Ultisols, Alfisols)	77	67	71
2. Very sandy and shallow soils (Psamments, lithic soils)	7	11	10
3. Moderately weathered soils, moderate to high base status (Alfisols, Inceptisols, Vertisols, Mollisols)	4	13	9
4. Hydromorphic (alluvial) soils (Aquic suborders of various orders)	12	9	10
Total	100	100	100

continuous farming possible.

Rarely degradable soils. Physical and chemical degradations are rare under normal management practices in hydromorphic and alluvial soils within the acquic suborders. These soils are generally quite productive.

Traditional Farming Systems

Two of the commonest systems throughout the humid tropics are the bush fallow and shifting cultivation systems. Both are inherently limited in their productivity and their ability to respond to increased demand for food staples within national, regional, or even local economies.

In addition, various agroforestry systems and compound farming methods are practiced in the humid and subhumid tropics. Compound farms occur in all the humid tropics, and are completely subsistence in nature, producing a variety of foods and fruits for daily farm use. All four systems have a common characteristic in that they are nondestructive in relation to the ecosystem, especially the soil.

Alternative Techniques to Prevent Soil Degradation

The following are some of the better options currently available.

Improved land clearing and development techniques. In general, techniques that create the least soil disturbance during clearing, and minimize compaction by heavy machinery have proved superior.

Minimum tillage methods. The merits of minimum and no-tillage farming have been demonstrated, and their success depends on subsequent agronomic management.

Mulches and cover crops. Closely associated with no-tillage practices is the use of mulches and cover crops. It is economical and effective to grow selected annual cover crops that leave the soil surface covered with thick organic mulches after the cropping season. Studies are also under way to develop live-mulching methods. A live mulch of Psophocarpus palustris, at the IITA Center, also provided an appreciable amount of nitrogen for the growing maize crop (Akobundu 1980). Considerably more research is needed in this area.

Fertilizers and soil additives. Clearly some of the chemical changes leading to soil degradation can be delayed or modified by the use of fertilizers and other chemical additives, such as lime. There is a place for these materials in all farming systems in the humid tropics, but such chemicals have to be used with care.

Alley cropping. In an effort to improve the bush fallow system and make it more productive, IITA has investigated the effectiveness of alley cropping. The system has the advantage of combining the cropping and fallow phases. It also controls erosion, reduces weed infestation, and optimizes land use.

Improved fallows and multistorey cropping. Paramount in this research has been the idea that total abandonment of fallow land fails to produce any benefits for the farmer. Planting fast-growing leguminous trees has shown promise in some regions. Research is also under way by the International Livestock Centre for Africa (ILCA) and IITA on an adaptation of the alley cropping method for the production of pastures and browse for small ruminants.

Farming Systems Guidelines to Prevent Soil Degradation

Based on experience and observations at IITA and elsewhere in the humid tropics, an attempt is being made at IITA to produce some principal farming systems guidelines to prevent soil degradation.

1. The land management should be such that a vegetative or organic matter layer covers the soil surface during the whole year. It should involve reduced tillage systems. The residues should be retained on the land.
2. Traffic on the land should be minimized. When compaction occurs, appropriate measures should be taken to loosen the soil.
3. Proven conservation measures should be used when ridging, bedding, or hilling. Long and steep slopes must be avoided. Mulch cover must be preserved.

4. Continuous production of the same crop should be avoided and, where possible, multiple cropping and intercropping should be practiced, preferably with mixtures of shallow- and deep-rooting species. All organic residues should be returned to the surface.

5. The prevention of soil degradation will generally require judicious and timely applications of fertilizers and soil amendments, such as lime, to maintain a satisfactory nutrient balance for maximum biomass production.

6. As an alternative to bush fallow, alley cropping can help maintain satisfactory levels of productivity without losing production of essential food crops. Depending on economics and markets, some intercropping or multistorey cropping with perennial cash crops can make an effective system.

References

Akobundu, I.O. 1980. Live mulch: a new approach to weed control and crop protection in the tropics. Pages 377-382 in Proceedings of the British Crop Production Conference on Weeds.

FAO/UNEP. 1974. A world assessment of soil degradation. Report and recommendations of the expert consultation. Rome: Food and Agriculture Organization.

ISSS (International Society of Soil Science). 1978. Soil deterioration and reclamation through man's activity. Pages 214-260 in Symposia Papers 3. Proceedings of the 11th International Congress of Soil Science, Edmonton, Canada.

Moormann, F.R., and van Wambeke, A. 1978. The soils of the lowland rainy tropical climates: their inherent limitations for food production and related climatic restraints. Pages 271-291 in Symposia Papers 2. Proceedings of the 11th International Congress of Soil Science, Edmonton, Candada.

UNEP (United Nations Environment Programme). 1982a. Guidelines for the formation of national soil policies. Nairobi, Kenya: UNEP.

UNEP (United Nations Environment Programme). 1982b. World soils policy. Nairobi, Kenya: UNEP.

Participants

Dr. Adley Bishay
Director
Desert Development, Demonstration
and Training Center
American University in Cairo
Cairo
EGYPT

Dr. J.R. Burford
Principal Soil Chemist
International Crops Research Institute
for the Semi-Arid Tropics (ICRISAT)
Patancheru
Andhra Pradesh 502 324
INDIA

Dr. N.R. Carpenter
Chief, Farm Management Unit, AGS
FAO
Via delle Terme di Caracalla
00100 Rome
ITALY

Dr. LP. Garbouchev
Senior Programme Officer (Soils)
United Nations Environment Programme
P.O. Box 30552
Nairobi
KENYA

Dr. D.J. Greenland
Deputy Director General
International Rice Research Institute (IRRI)
P.O. Box 933
Manila
THE PHILIPPINES

Dr. C.R. Jackson
Director for International Cooperation
International Crops Research Institute
for the Semi-Arid Tropics (ICRISAT)
Patancheru
Andhra Pradesh 502 324
INDIA

Dr. B.M.T. Kang
Soil Scientist
International Institute of
Tropical Agriculture (IITA)
PMB 5320
Ibadan
NIGERIA

Dr. J.S. Kanwar
Director of Research
International Crops Research Institute
for the Semi-Arid Tropics (ICRISAT)
Patancheru
Andhra Pradesh 502 324
INDIA

Dr. S.A. Krastanov
Project Director
Institut po Pochvoznanie Programirane
na Dobivite Pushkarov
Shose Bankya 3
Sofia
BULGARIA

Dr. V.V. Dhruva Narayana
Director
Central Soil and Water Conservation
Research and Training Institute
218 Kanlagarh Road
Dehra Dun 248 195
INDIA

Dr. Ahmed Osman
Director, Soil Science Division
Arab Center for Studies of Arid Zones and Drylands
P.O. Box 2440
Damascus
SYRIA

Dr. Chirtchart Smitobol
Chief
Soil and Water Management Research Branch
Farming Systems Research Institute
Department of Agriculture
Bangkhen
Bangkok
THAILAND

Dr. R.P. Singh
Assistant Director General-cum-Project Director
All India Coordinated Research Project
for Dryland Agriculture (AICRPDA)
Saidabad P.O.
Hyderabad 500 659
INDIA

Dr. L.D. Swindale
Director General
International Crops Research Institute
for the Semi-Arid Tropics (ICRISAT)
Patancheru
Andhra Pradesh 502 324
INDIA

Mr. H.L. Thompson
Head
Information Services
International Crops Research Institute
for the Semi-Arid Tropics (ICRISAT)
Patancheru
Andhra Pradesh 502 324
INDIA

Dr. S.M. Virmani
Program Leader
Farming Systems Research Program
International Crops Research Institute
for the Semi-Arid Tropics (ICRISAT)
Patancheru
Andhra Pradesh 502 324
INDIA

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

ISBN 92-9066-115-1 Printed at ICRISAT Center ICR 86-0006