Technology for Soil Moisture Management Project (TSMM)

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Foreword

Since 1983, a Participating Agency Service Agreement (PASA) has existed between the Agricultural Research Service (ARS) of the U.S. Department of Agriculture (USDA) and the Science and Technology Bureau of the U.S. Agency for International Development (USAID). The overall objective of the USDA/USAID PASA Project for Dryland Agriculture, also known as Technology for Soil Moisture Management (TSMM), is to provide technical assistance to USAID projects for improving soil and water management practices in dryland or rainfed agricultural systems in developing countries. TSMM's efforts are directed toward the extremely poor countries in three geographic regions where there is a critically urgent need to increase the productivity and stability of dryland farming systems, i.e., the Near East, sub-Saharan Africa, and South-Southeast Asia.

The major constraints to increased agricultural productivity and stability in these regions are coarse-textured, sandy soils that are inherently low in fertility, low in soil organic matter, low in water-holding capacity, and subject to severe wind and water erosion. Rainfall patterns are erratic and crops often suffer from moisture deficits and drought even during the normal rainfall periods. Such conditions are not unlike those in the drylands of the U.S. Great Plains and the Pacific Northwest where ARS has conducted extensive research for more than 50 years to develop efficient and effective conservation and production systems for dryland agriculture. ARS has probably the largest group of scientists and engineers in the world who are currently conducting research on soil, water, and crop management systems for dryland agriculture. This program has become even more important in the United States in recent years because of the increased economic costs and technological problems associated with irrigated agriculture.

The USDA/USAID PASA Project has been a mutually beneficial and productive effort for ARS. Our scientists and engineers who have served as consultants to this Project have returned from their assignments with increased knowledge and ideas for highly relevant research on aspects of conservation tillage, soil and water conservation, soil fertility management, integrated pest management, crop rotations and crop residue management. The Project has definitely fostered a two-way flow of technical information on dryland farming between the U.S. and developing countries. We look forward to the continuation of this excellent cooperative program with USAID and OICD in the years ahead.

Dr. E. B. Knipling
Associate Deputy Administrator
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Summary

Low rainfall areas constitute the major portion of the land area in many countries in the Near East, sub-Saharan Africa, and Southern Asia. These drylands traditionally produce most of the food grains and fibers consumed by their 700 million inhabitants. But in recent years, grain production per capita has declined. Currently the productivity in these areas is just a fraction of that obtained under comparable agroclimatic conditions in the U.S. Productivity of developing, low-rainfall areas can be increased by the improved management of soil and water resources.

Technology for Soil Moisture Management (TSMM) has been designed to provide technical assistance for the development of dryland and rainfed agriculture. The purpose of the program is to assist developing countries in the agronomic and economic assessment of their soil, water, and crop/livestock management systems under suboptimal conditions; and in the formulation of national strategies for increasing their agricultural productivity through research and technology transfer. TSMM helps these countries develop networks of research, extension, donor, and policy institutions for cooperative research and the exchange of information on agricultural systems management. It also provides for continual interchange between the U.S. scientific community and those of the participating countries in the international agricultural research community. The Participating Agency Service Agreement (PASA) between the Agricultural Research Service (ARS) and the Economic Research Service (ERS) of the USDA and the Science and Technology Bureau of USAID makes use of the skills of scientists and economists in ARS and ERS, respectively, and land-grant universities which have been studying problems specific to drylands and dryland agriculture in the U.S. Great Plains and the Pacific Northwest for more than 50 years.

In the past year, TSMM has helped scientists in Jordan develop a data base on soil, water, and crop management for rainfed agriculture; has helped sponsor a workshop in Niger; has provided assistance to four countries in the Near East for the development of a "Ribbon Project" on rainfed cereals and the relative value of crop residues for soil and water conservation versus feed for small ruminants; has cooperated with USAID/Mali to conduct a case study on the economics of improved soil and water management; and has provided technical assistance to several other countries including Niger, Senegal, Rwanda, Egypt, and India. TSMM is also a cosponsor and has been instrumental in the planning and organization of the "International Conference on Dryland Farming" to be held in Amarillo, Texas from August 15-19, 1988. Through its annual study tour of dryland/rainfed farming systems in the U.S. Great Plains, TSMM has helped make project managers and staff of international development agencies aware of U.S. expertise in dryland technologies. TSMM has increased communication among scientists who are working on soil and water management problems, both agronomic and economic. By integrating both agronomic and economic concerns, TSMM is unique.

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I. Background

A. Problem Definition

Arid and semiarid regions comprise 37 percent of the world's land area and accommodate 700 million inhabitants. Fifty-nine percent of these drylands are in developing countries. Low rainfall areas constitute from 75 to 100 percent of the land area in 21 countries in the Near East, Africa and Asia. These agroecological zones are characterized by such problems as erratic and limited rainfall; low water holding capacity of the soils; surface soil hardening; compaction; low infiltration rates and consequent excessive water runoff and soil erosion; wind erosion; shallow soils; stony soils; restricted soil drainage; salinization; and low fertility.

In the past, priority has been assigned to the development of irrigated agriculture in low rainfall areas to increase productivity and provide a buffer against drought. The cost of irrigation projects has risen, the rate of expansion of irrigation projects has reached practical limits and yet the demand for foodstuffs has continued to increase. Drylands and traditional irrigation systems (wells, recessional and flood plains, permanent and seasonal swamps) continue to produce the major portion of total food grains. For example, 99 percent of all cultivation in the Sahel is dryland. But many of these countries have exhibited declines in grain production per capita in recent years. Consequently, the provision of technical input to the developing countries of these regions is critical if they are to improve the productivity of their dryland/rainfed farming systems.

A decrease in land degradation and an increase in the productivity of low-rainfall areas can be achieved by improved management of soil and water resources. In many locations, improvements can be achieved by more widespread application of known principles of soil and water management to crop and livestock production. Overall, the productivity in these areas is only one-fourth to one-half of that obtained under comparable agroclimatic conditions in the United States. In other situations, new concepts and methodologies appropriate to unique aspects of developing areas are required. Government policies, land tenure arrangements, and social, cultural, and economic factors also influence the way in which dryland resources are utilized. Achieving long-term sustained growth in the productive capacity of low rainfall areas will require sound decisions based on accurate assessments of resource problems and potentials and on careful analysis of alternative policies, programs, and projects.

B. Project Objectives

Technology of Soil Moisture Management (TSMM), also referred to as the USDA/USAID Dryland Agriculture Project, is a Participating Agency Service Agreement (PASA) between USAID and USDA. Under the contract, USDA/ARS provides technical expertise to USAID projects for improving agricultural management in dryland and rainfed systems. The overall objectives of TSMM are to maintain and improve the soil and water resource base for short- and long-term utilization and to improve output and income in crop and livestock production systems. To assist in this process, TSMM has the following objectives:

1. To develop soils information required for the development or transfer of optimal soil and water management practices;

2. To develop a base of agroclimatic information necessary for probabilistic analyses for soil, water, and crop management alternatives;

3. To develop erosion and runoff information required to evaluate the magnitude of the problem, develop predictive relationships for designing viable interventions, and improve the use of rainfall in productive output;

4. To develop economic information necessary to evaluate management practices at the farm, community, regional, and national level;

5. To develop and apply multidisciplinary approaches that integrate agroclimatic, soil, agronomic, and economic data for assessment and analysis of economically, technically, and environmentally viable agricultural systems and related policy and program planning options.

The major geographic regions of emphasis are the semiarid regions of the Near East, sub-Saharan Africa, and Southern Asia.

With this PASA, USAID has enlisted the best technical expertise in dryland agriculture developed over the last 50 years in the U.S. Great Plains and the Pacific Northwest. In the last 4 years, TSMM has helped scientists develop data bases on soil, water, and crop management for dryland/rainfed agriculture; sponsored workshops; assisted in the development of a "Ribbon Project"; provided technical assistance to several countries; and helped increase communication among researchers working on the agronomic and economic problems of soil and water management in dryland/rainfed systems.

II. Approach

Currently, TSMM is active in several countries in each region. Its approach involves three basic steps: 1) compiling an information base for improved decision-making, comprised of reported research relevant to dryland/rainfed agriculture, assessments/evaluations of the natural resource

base, and syntheses or analyses of the research information; 2) identifying research needs and priorities, fostering communication and research links among working scientists, and conducting national and regional workshops to assess the data base findings; and 3) providing assistance in the planning and implementing of regional research and economic studies on high priority problems in rainfed agriculture. Hopefully, this stepwise method of assessing knowledge, identifying problems, and mobilizing available resources for the development of solutions will serve as a model approach for other countries within each region.

TSMM also provides technical assistance to countries interested in improving dryland/rainfed production systems. Assistance includes providing scientific expertise to resolve problems of soil moisture management; participating in reviews of ongoing and proposed research projects; developing problem-solving strategies; facilitating information dissemination; and promoting regional collaboration through workshops, seminars, and training programs.

III. Accomplishments

A. Information Base

1. Research Data Base

A data base on soil, water, and crop management for rainfed agriculture in Jordan has been completed by Dr. A. A. Jaradat (Jordan University of Science and Technology). The data base report was edited by Drs. J. F. Parr and C. E. Whitman and returned in September 1987 for publication. The data base includes chapters on soil resources, agroclimate, traditional agronomic practices, government policy and the development of crop models, among other topics.

2. Agroclimate

Agroclimatic information helps to define agroecological zones and hence land use capability, in addition to providing the basis for models of rainfall probability and crop yield using early season meteorological indicators. Drs. E. T. Kanemasu and S. Van Donk (Kansas State University) are conducting an agroclimatic analysis focussing on cropping strategies in the Sahel. In Niamey, Niger they reviewed an agroclimatology-remote sensing project with AGRHYMET for potential collaboration; obtained feedback from AGRHYMET for modifying the project objectives; developed specific contacts for collaboration; and determined commonality among projects and ongoing or future USAID Mission projects. AGRHYMET has agreed to supply meteorological data from 1966 to 1978 for all Comite Permanent Inter-Etas de Lutte Contre La Secheresse dans le Sahel (CILSS) countries to be used in their analysis.

In Senegal, remote sensing is being used in the development of a ground-based crop yield model, two hydrologic development projects, land use evaluation, and the assessment of biomass on rangeland. In order to verify and standardize data collection methods and instrumentation, Drs. E. T. Kanemasu

and S. Van Donk conducted an agroclimatic assessment of Senegal's remote sensing projects for dryland agriculture. They found that many of the projects are without real time information and could benefit from automated data collection units and video remote sensing.

3. Runoff/Erosion

Problems common to drylands such as erratic rainfall, low water-holding capacity of the soils, low infiltration rates, compaction, and restricted soil drainage, contribute to excessive water runoff and soil erosion. Dr. C. A. Onstad (USDA/ARS) assessed runoff/erosion research needs in east Africa. The three main problems in Rwanda were streambank erosion, sheet and rill erosion, and mass movement. The Ruhengeri Resource Analysis and Management Project (RRAM) is addressing these problems and RRAM research sites are beginning to produce good data. It was recommended that the project be continued past its scheduled termination date.

Wind erosion frequently is coupled with water erosion in semiarid and arid regions. In northwest Egypt, Dr. D. W. Fryrear found opportunities to improve both moisture and soil conservation. In conjunction with conducting trials to evaluate the potential of various land forming and residue production/ management practices, it is necessary to collect weather data. This weather data can be used subsequently to validate the ARS Wind Erosion Model for universal application, a project beneficial to both the United States and Egypt.

4. Economics

Through the economic component (USDA/ERS) of TSMM, ERS established a new cooperative research agreement with Purdue University in FY-1987. This agreement will significantly strengthen USAID's knowledge base and its pool of talent for technical assistance activities. Purdue joins Washington State University in TSMM's program of research focussing on West African problems. Plans were made for Purdue to 1) contribute socioeconomic data from several years field studies in Niger and Burkina Faso to a TSMM Sahelian Data Base, 2) collaborate on crop growth modeling work with Dr. M. Sivakumar, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)/Sahelian Center, Niamey, and 3) prepare six research papers utilizing Nigerian data.

Dr. Day, USDA/ERS, initiated discussion with the Office of Arid Lands Studies (OALS), University of Arizona, regarding joint research and analysis work in Mauritania. OALS is in the second year of a 5-year farming systems research project in that country. Materials describing TSMM were forwarded to OALS. A topical outline of the TSMM research data base projects proposed for Mali and Niger was also forwarded to assist OALS in preparing the groundwork for such an activity. In addition, copies of the draft data base Memorandum of Understanding prepared for USAID/Mali were provided to OALS at their request.

B. Workshops

The proceedings of the workshop entitled "Soil, Water and Crop Management Systems for Rainfed Agriculture in Northeast Thailand" have been edited, artwork has been completed and the proceedings are currently in press through the USDA. Copies of the proceedings should be available in 1988. Recommendations from the workshop have been summarized and appear in Appendix A.

The workshop on "Soil, Water and Crop Management Systems for Rainfed Agriculture in the Sudano-Sahelian Zone" was cosponsored by the National Institute for Agricultural Research in Niger (INRAN), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), USAID and the Collaborative Research Support Program in Tropical Soils (TROPSOILS). It was held in the Palais des Congres, Niamey, Niger from January 11 to 17, 1987.

Forty technical papers in the following subject areas were presented: 1) rainfed agriculture; 2) soil/water management for conservation production systems in low rainfall areas; 3) crop/livestock relationships, residue management, and agroforestry; 4) cropping systems and cultural practices; and 5) systems modeling and economic considerations. Workshop sessions were held and recommendations given to alleviate or improve: 1) agroecological constraints and production systems; 2) soil and crop management for efficient use of water; 3) soil fertility management; 4) crop residue management in relation to livestock and soil and water conservation; and 5) the socioeconomic impact of improved technologies for farming systems. Participants came from Burkina Faso, Cameroon, Cape Verde, Chad, Cote D'Ivoire, Ethiopia, France [Tropical Agriculture Research Institute (IRAT-CIRAD); Office of Scientific Research and Technology for the Mediterranean Zone (ORSTOM)], Ghana, Great Britain, Italy, Mali, ICRISAT/Sahelian Center, ICRISAT/Hyderabad, Netherlands, Niger, Norway, Senegal, Sudan, United States, and Zaire. Workshop proceedings will be published early in 1988 by ICRISAT Information Services. A preliminary report was distributed in mid-1987. Recommendations from this report have been summarized and appear in Appendix B.

C. Research Needs and Priorities

The Indian Council of Agricultural Research invited the Far Eastern Regional Research Office (FERRO) of the Office of International Cooperation and Development (OICD), USDA, to select a team of U.S. scientists to evaluate problems and research projects in India's drylands. The U.S. Dryland Farming Team, led by Dr. J. F. Parr, TSMM coordinator, was in-country from March 28 to April 18. The team visited Indian scientists in agricultural research institutes and universities, reviewed research proposals, and suggested additional studies which would eventually lead to increased water use efficiency in dryland cropping systems. A "Combined Report" by the U.S. Dryland Farming Team and the U.S. Economics Team was published in December and has been distributed under the auspices of the Indo-U.S. Subcommission on Agriculture. Included are proposals submitted by scientists of the Indian Council of Agricultural Research and primarily from the Central Research Institute for Dryland Agriculture at Hyderabad and the Central Arid Zone

Research Institute at Jodhpur. These were reviewed by the U.S. Dryland Team with particular emphasis on research which would be of benefit to both India and the United States. Recommendations from the report have been summarized and appear in Appendix C.

Dr. Parr has been appointed to the Research and Education Committee of the Indo-U.S. Subcommission on Agriculture and will continue his advisory activities at future meetings of the Committee.

D. Communication and Research Links

1. Sabbatical

As part of the goal of fostering scientist linkages, Dr. A. S. R. Juo is on sabbatical leave at Beltsville Agricultural Research Center, USDA/ARS, and the Division of Renewable Natural Resources, USAID/S&T/AGR. Dr. Juo, a senior scientist with the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria, has conducted extensive research on nutrient cycling and crop management systems in sub-Saharan Africa. At Beltsville, Dr. Juo is working with scientists at the Data Base Coordination Laboratory on the analysis of data from long-term soil management experiments and modeling light interception in alley cropping. In addition, he is preparing manuscripts on mixed root crop ecosystems in sub-Saharan Africa and new farming system development in the humid tropics. His activities in association with S&T/AGR include reviewing USAID and the Consultative Group for International Agricultural Research (CGIAR) achievements and developing proposals for improving linkages between S&T/AGR projects and CGIAR centers. Activities in natural resource management and farming system research emphasize developing sustainable soil and water management technologies for sub-Saharan Africa.

2. Study Tour

TSMM is in the process of organizing a study tour of dryland/rainfed farming systems in the U.S. Great Plains to be conducted July 10 to 16, 1988. The World Bank has requested that the tour emphasize low input, sustainable agriculture techniques and systems with potential for adaptation to developing countries. Conservation tillage methods such as minimum tillage or no-till, stubble mulching, cover crops, legume-based crop rotations and application of composts, animal manures, and green manures, can increase soil water retention and fertility, improve soil tilth, and reduce soil erosion by wind and water. When these practices are used individually and in combination with one another the need for high cost inputs (mineral fertilizers, pesticides, herbicides, etc.) can be reduced while maintaining or increasing productivity. In developing countries where external inputs are generally unavailable to farmers due to inadequate supplies and high costs, conservation technologies are attractive alternatives.

An itinerary including visits to commercial farms, agricultural experiment stations and major land grant universities in Iowa, Kansas, and Nebraska has been developed. Participants, including scientists, economists, project

managers, and top administrators from USDA/ARS, USDA/ERS, USDA/SCS, USAID, and the World Bank, will observe low input and sustainable agriculture practices and meet with scientists and farmers to discuss underlying economics.

3. International Conference on Dryland Farming

TSMM has been instrumental in planning and organizing the "International Conference on Dryland Farming" to be held in Amarillo/Bushland, Texas from August 15-19, 1988. The conference will feature keynote addresses, papers, and posters on such topics as soil conservation, agroclimatology, water conservation, soil fertility, residue management, socioeconomic concerns, cropping systems, environmental concerns, integrated crop/livestock systems, and pest management. Participants from around the world will help evaluate past research and identify problems that need to be addressed for the future. The proceedings of the conference will be published by Texas A&M University. Optional pre- and post-conference tours of farmers' fields and experiment stations in the U.S. Great Plains will be offered.

The Conference is truly a cooperative international effort. To date, 319 papers have been accepted for the Program. Of these, approximately 250 papers are volunteered. Forty-four countries are represented, with 100 papers submitted from developing countries (excluding papers submitted by researchers at the International Agricultural Research Centers). In addition to USAID and USDA/ARS, other agencies helping to sponsor the Conference are: the Texas Agricultural Experiment Station, USDA/CSRS, the Food and Agriculture Organization of the United Nations (FAO), the World Bank, the Rockefeller Foundation, USDA/SCS, and USDA/OICD.

E. Regional Research

The Jordan Highlands Agricultural Development Project (JHADP), a USAID-funded bilateral project with Washington State University as the lead U.S. university, has implemented a comprehensive effort to improve crop production and resource conservation in the dryland/rainfed areas of Jordan. The host-country agency involved in this cooperative project is the National Center for Agricultural Research and Technology Transfer (NCARTT). At the request of JHADP and with strong concurrence by NCARTT, TSMM is providing technical expertise for developing a "Ribbon Project" for Jordan.

The proposed research is the result of recommendations of working groups at the January 1986 workshop entitled "Soil, Water and Crop/Livestock Management Systems for Rainfed Agriculture in the Near East Region" held in Amman, Jordan. A summary of these recommendations appears in Appendix D. A chief consensus of this regional workshop was that a major problem throughout most of the drylands is lack of application of effective soil and water conservation practices. The participants strongly recommended that a regional research project be initiated to determine the relative value of crop residues for soil and water conservation, maintenance of soil fertility and productivity, and feed for small ruminant animals. Since the use of residues for water conservation and erosion control would be in direct competition for

use as animal feed it is necessary to know what compromises and trade-offs are possible for the benefit of both.

A workshop was organized by JHADP, NCARTT, and USDA/USAID and held in Amman, Jordan on 31 January-2 February, 1988 to plan research on crop residue management to enhance soil and water conservation and the production efficiency of crop/livestock systems in the Jordan drylands. The specific objectives were to develop: 1) research criteria, experimental plans, and methodology that will provide a set of common results from different participating locations for evaluating how crop residues are best managed in crop/livestock systems to optimize economic return and resource utilization and protection, and 2) a plan of action for implementing, coordinating, and reporting the interdisciplinary, multilocation research, and for maintaining a high level of cooperation among the working scientists and ensuring high quality scientific results.

The proposed research was designed to be a part of a much broader USAID "Ribbon Project" on soil and water management which is to be extended to other countries of the Near East region. Agencies involved in addition to USAID/TSMM are: the Soils and Water Research Institute, Ministry of Agriculture, Agriculture Research Center, Giza, Egypt (Drs. Y. A. Hamdi and A. T. Moustafa); Jordan University of Science and Technology, Irbid, Jordan (Dr. A. A. Jaradat); International Center for Agricultural Research in the Dryland Areas (ICARDA), Aleppo, Syria (Drs. H. C. Harris and E. R. Perrier); Central Anatolian Regional Agricultural Research Institute, Ankara, Turkey (Dr. N. Durutan); Cukurova University, Adana, Turkey (Dr. M. S. Yesilsoy); Washington State University, Pullman, Washington, United States (Drs. W. R. Butcher, R. Cook, and K. E. Saxton). The underlying goal of the soil and water "Ribbon Project" is to: 1) provide economically feasible technology that can increase the amount of water available for production of crops and animals, and at the same time conserve soil resources of dryland areas; and 2) develop an information and scientific contact network, linking scientists conducting dryland soil and water research in developing countries within a region and the United States.

A report has now been compiled by Drs. R. I. Papendick and J. F. Parr (USDA/ARS) which presents guidelines for planning research and designing experiments that can serve as a multilocation, interdisciplinary research project to study residue management for profitable crop and livestock production and efficient use of soil and water resources. As a result of this effort, we expect that some version of the "Ribbon Project" will be implemented at two and possibly three locations in Jordan by NCARTT, and one location by ICARDA.

The "Ribbon Project" has taken a considerable amount of time and effort to plan and implement. Whenever more than a few agencies and countries are participating in a project, more time will be needed to get that project started. TSMM has observed, however, that by working with in-country agencies, the project will have a more lasting impact.

Dr. K. E. Saxton, Agricultural Engineer, USDA/ARS, Pullman, Washington, was requested by JHADP to assist them in the design and development of an experimental no-till drill for use in collaborative cereal research with NCARTT

in the dryland regions of Jordan. Travel and per diem costs for Dr. Saxton's involvement with JHADP/NCARTT are provided by the USDA/USAID PASA Project on Dryland Agriculture (TSMM).

Much of Dr. Saxton's current research is directed toward the development of more energy-conserving, reduced-tillage drills for conservation tillage systems. He and his co-workers at Pullman have been collaborating with Dr. John Baker, Agricultural Engineer, Massey Agricultural University in Palmerston North, New Zealand. Together they have designed a new and innovative opener which is currently referred to as the inverted-tee or cross-slot concept. This design required considerably less energy than the earlier double-disc openers that are used on heavier no-till drills. Also, the opener causes much less disturbance of soil surface conditions and practically eliminates the problem of "tucking" of surface residue into the seed slot.

Dr. Saxton and his co-workers have constructed several experimental cross-slot drills that appear to be very promising in overcoming the inherent problems in no-till systems. Because of its simple design, this new drill offers considerable potential for improving productivity in dryland regions of developing countries.

F. Economic Case Studies

Dr. J. C. Day (USDA/ERS) continued his efforts to develop cooperative research activities with the USAID Mission in Bamako, Mali. In January he and Dr. Meyer (S&T/AGR) met with Mission staff and personnel of the South-East Consortium for International Development (SECID) Farming System Research and Extension Project (FSR/E) to clarify TSMM goals and objectives and to define specific areas of collaboration. TSMM projects focus on soil and water problems that are consistent with the USAID country development strategy, yet collaborative work is on hold until the redesigned FSR/E Project is in place.

Acting on the advice of Mission Director Chiavaroli, Dr. Day prepared a draft AID/GRM Memorandum of Understanding pertaining to a proposed data base development activity. This activity is seen as an important step in pulling together existing agroeconomic research information in Mali. This activity is also on hold pending resolution of the status of the FSR/E Project.

In addition to the above efforts, TSMM/Economics staff continue to utilize secondary data from Mali in case study analyses of soil, water, and crop management practices. Five papers have been completed. Three have been accepted for publication in 1988 and two are in the review process. A sixth manuscript is in process and should be published in FY-1988 as well. Papers drawing on Mali data are underway on the following topics: farm models, risk, optimal control analysis of soil and water management (Washington State University), and soil-water balance modeling (ERS).

G. Report to FAO on "Improving and Sustaining Productivity of Dryland Areas"

TSMM participated in drafting a report on drylands to the Committee on Agriculture, FAO. The paper, entitled "Improving and Sustaining Productivity of Dryland Areas" was used for the Ninth Session of the FAO Committee on Agriculture (FAO, 1987, COAG/87/7).

IV. Conclusions and Recommendations

The constraints to agricultural productivity in arid and semiarid regions are common among the countries in the Near East, Africa, and Asia. They are: erratic rainfall, large water losses, erosion, and poor soil tilth and fertility. The principal problem is insufficient water.

Currently available technology can be used to alleviate these constraints. In some dryland/rainfed systems existing technology may need to be modified or new technologies developed. The following general recommendations have emerged:

1. More uniform and comprehensive classification of soils and agroclimate is needed, combined with land use mapping, in order to develop crop recommendations for various agroclimatic zones.

2. Application of soil and water-conserving practices such as soil amendments (crop residues, manure, etc.), tillage, water harvesting, and weed control, is necessary to improve water infiltration and soil fertility, reduce water loss, and control erosion.

3. In order to increase crop yields but reduce the cost of fertilizer N to the farmer, more use of on-farm organic materials should be made. Times, rates, methods, and frequencies of application must be optimized with respect to cost, crop yield, and water and N use efficiency for combined N sources, i.e., mineral and organic N.

4. Farmers are reticent about new technologies for reasons related to financial risk, technical know-how, shortage of cash and other socioeconomic considerations. Efforts should be increased to conduct adaptable on-farm trials and demonstrations of promising technologies.

TSMM has stimulated communication and cooperation among scientists who are working on soil and water management issues and has enhanced the awareness of U.S. expertise in dryland technologies among developing country scientists and among project managers and staff of such international development agencies as the World Bank, FAO, Winrock International, IDRC, and the IARCs. Further cooperation and collaboration should contribute to more effective dryland development.

V. Publications, Reports, and Papers

Butcher, W. R. and J. C. Day. 1987. Economic analysis of soil and moisture management on marginal croplands. IAEE/CAAE/CAASS Symposium, Beijing, China. 25-29 October.

Day, J. C. 1987. Soil moisture management in Mali: A case study analysis for West Africa. In Proc. Workshop on Soil, Water and Crop/Livestock Management Systems for Rainfed Agriculture in the Sudano-Sahelian Zone, Niamey, Niger. 11-16 January.

Day, J. C. 1987. Soil-water balance relationships and economic analysis of dryland technologies. Seminar, Department of Agricultural Economics, Purdue University, West Lafayette, Indiana. 22 June.

Day, J. C. Water conservation in arid and semiarid agriculture. In Proc. VIth International Congress on Water Resources, Ottawa, Canada. 29 May-4 June. 1988.

Day, J. C. Soil, water and crop management options in dryland agriculture: Economic perspectives from West Africa. (In preparation for R. P. Singh and J. F. Parr (eds.), Dryland Technologies.)

Day, J. C. and M. P. Aillery. 1987. Economic impacts of soil and water management technologies: Preliminary results from a case study analysis in Mali. In Proc. Workshop on Soil, Water and Crop/Livestock Management Systems for Rainfed Agriculture in the Sudano-Sahelian Zone, Niamey, Niger. 11-16 January.

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Glossary

ARS	Agricultural Research Service, U.S. Department of Agriculture
CGIAR	Consultative Group for International Agricultural Research
CILSS	Comite Permanent Inter-Etas de Lutte Contre La Secheresse dans le Sahel
CRSP	Collaborative Research Support Program
ERS	Economic Research Service, U.S. Department of Agriculture
FAO	Food and Agriculture Organization, United Nations
FSR/E	Farming Systems Research and Extension Project, Mali
IARC	International Agricultural Research Center of the CGIAR system
IBSRAM	International Board for Soils Research and Management
ICARDA	International Center for Agricultural Research in the Dryland Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Center, Canada
IITA	International Institute for Tropical Agriculture
INRAN	National Institute for Agriculture in Niger
IRAT	Tropical Agriculture Research Institute in France
JDHAP	Jordan Highlands Agricultural Development Project
JUST	Jordan University of Science and Technology
NCARTT	National Center for Agricultural Research and Technology Transfer, Jordan
OALS	Office of Arid Lands Studies, University of Arizona
OICD	Office of International Cooperation and Development, U.S. Department of Agriculture

ORSTOM	Office of Scientific Research and Technology for Mediterranean Zone, France
PASA	Participating Agency Service Agreement
RRAM	Ruhengeri Resource Analysis and Management Project, Rwanda
S&T	Science and Technology Bureau, U.S. Agency for International Development
SCS	Soil Conservation Service, U.S. Department of Agriculture
SECID	South-East Consortium for International Development
TROPSOILS	A Collaborative Research Support Program (CRSP) in Tropical Soils
TSMM	Technology for Soil Moisture Management
USAID	U. S. Agency for International Development
USDA	U. S. Department of Agriculture
World Bank	International Bank for Reconstruction and Development

Appendix A
Thailand--General Recommendations

Agriculture in Northeast Thailand is limited by erratic rainfall, large water losses, poor soil tilth, and fertility. Collaborative efforts by various departments within the Ministry of Agriculture and universities are necessary to alleviate constraints and increase the productivity of cropping systems in the northeast region. The creation of networks among scientists within Thailand and throughout Southeast Asia would facilitate technological progress in soil, water, and crop management systems.

1. Agroecology

In some locations in Northeast Thailand, farming practices have evolved which alleviate climatic and soil constraints to productivity. These practices should be studied along with rainfall and soil characteristics, particularly soil hydraulic properties in the laboratory and in the field under different management regimes. Agroecological zones present in the region should be identified, and agroclimatic and crop models should be developed and validated on-farm to define crop-soil-water relationships and aid in the development of crop management systems for more efficient water use.

2. Soil and Water Conservation

Rice is the traditional crop grown in the lowland areas and on as much of the middle and upper terraces as water availability permits. In order to increase water infiltration, retention, and storage, the methods, amounts and timing of tillage, surface mulches, composts, crop residues, and animal manures should be evaluated. The establishment of water balances for major soils and crops should assist in the development of improved crop calendars and crop sequences for greater crop productivity.

3. Soil Fertility

The inherent tilth, fertility, and productivity of northeastern soils are low. The use of soil amendments by farmers could substantially improve soil quality. Research should be conducted on the effects of crop residues, organic wastes (composts), green manures, and legumes on soil tilth, salinity, and nutrient status alone or in combination with chemical fertilizers. Crop requirements/response curves for N, P, K, and micronutrients should be determined in order to improve nutrient management practices.

4. Socioeconomic Aspects

Research and extension programs that facilitate the technology transfer and dissemination process must be developed. Toward this end, adaptable on-farm trials and demonstrations of promising technologies should be implemented.

Appendix B
Niger--General Recommendations

There is an urgent need for 1) research and training at all levels; 2) dissemination of research data to the farmers through extension services; 3) improving distribution circuits for agricultural inputs and products (marketing, infrastructure, etc.); and 4) providing incentives for production through appropriate pricing policies, subsidies for inputs, and farm credit facilities for both farmers and suppliers. Toward these ends, national and international institutions should strengthen their cooperation through broader dissemination of the results of research, joint programs that avoid duplication, and closer contacts.

1. Agroecology

Technical information on climate, soils, and production systems should be inventoried, placed in a data base, and made accessible to researchers. Systematic collection of minimum data sets for agroclimate and soils, including information on soil fertility and toxicity, is needed to prepare maps at the field, national, and regional levels for land use evaluation/classification. The data sets can also be used for risk analysis/management, crop model development/validation, and the development of crop recommendations.

2. Soil and Water Conservation

Farmers interested in short-term gain often adopt management strategies that neglect long-term conservation activities. Priority should be given to studies of soil amendments, tillage, improving infiltration, water harvesting, weed control, and management systems, including crop associations and upgrading fallow. Specifically, research should detail soil and climatic conditions which are suitable for tied ridges or furrow dikes; the effects and interactions of plant density, spacing, and intercropping on crop biomass, yield, and water use; the effects of chemical weed control for certain crops and soils on water use and soil properties vs. mechanical weed control and the long-term effects of tillage on soil properties. In order to improve integrated crop/livestock/pasture management systems, the quantities, frequencies, and modes of application of crop residue or manure necessary to maintain optional soil fertility, control erosion, and improve soil/water conservation, must be determined.

3. Soil Fertility

The main causes of low soil fertility in the Sudano-Sahelian zone are: uncertain climate, wind and water erosion, leaching, decreasing fallows, and insufficient know-how at the farm level. Organic and mineral fertilizers

should be used in intercropping, mixed farming, mulching, and in correcting the pH of the soil with due respect to the quantities, types, forms, application dates, and methods. These practices must be related to agronomic conditions such as water availability, drainage, land preparation, and soil quality. The economic benefits of using local resources such as natural phosphate, gypsum, and dolomite to reduce spending incurred in foreign currency must be investigated. The contributions of biological nitrogen fixation, mycorrhizae to plant phosphorus uptake, and special stress tolerant varieties to on-farm cost efficiency should be evaluated.

4. Socioeconomic Aspects

To date, farmers have been reticent about new technologies for reasons related to financial risk, technical know-how, shortage of cash, and other socioeconomic contingencies. Efforts should be increased to conduct field surveys and on-farm demonstrations during the development and dissemination of new technologies. A variety of technologies may be necessary to provide alternative solutions and varying levels of inputs to accommodate special problems.

Appendix C
India--General Recommendations

Primary factors reducing water use efficiency of crop production in semiarid India are: erratic and limited rainfall; low infiltration rates; excessive runoff; soil erosion; low water holding capacity; high evaporation rates from soils and water storage ponds; and poor fertility. Factors which reduce crop water use efficiency in arid regions are: limited erratic rainfall; sandy soils with low water holding capacity; water loss through deep percolation, evaporation, and salinization of water that is pumped or transported; and destruction of vegetation by uncontrolled grazing.

1. Agroecology

Agroclimatic parameters have been well-characterized in India but their use in modeling crop growth and yield is limited by a lack of information on critical crop developmental stages and the effect on yield of varying levels of water stress at those times. In contrast, there is a great need for improved characterization of India's dryland soils, including identification of soil texture-depth profile relationships, plant available water capacities and hydraulic conductivities, water infiltration and retention, and plant-water use patterns. Soil water balances quantified in conjunction with crop yields would allow for the development and validation of models of crop water use.

2. Soil and Water Conservation

The presence of model watersheds at Bijapur, Solapur, and Bangalore provide systems within which the effects of individual and combined soil conservation technologies on water balance, erosion, and crop yields can be quantified. Data collected on afforestation, bund strengthening, contour or cross-slope bunding, contour bunding with intercropping, contour bunding with grass/legume combinations planted on bunds, and contour bunding with sole cropping, can be incorporated into crop yield and water management models to increase understanding of soil-crop water processes.

In addition to the more traditional studies of soil and water, there is a need for identification and evaluation of herb and woody species suitable for use in soil and water erosion control and the revegetation/rehabilitation of problem sites. Genotypes of major crops should also be screened for increased water use efficiency and tolerance to drought at critical development stages.

3. Soil Fertility

To increase crop yields but reduce the cost of fertilizer N to the farmer, more on-farm organic materials such as crop residues, animal manures, and green

manures should be made. Times, rates, methods, and frequencies of application must be optimized with respect to cost, crop yield, and water and N use efficiency for combined N sources, i.e., mineral and organic N.

4. Socioeconomic Aspects

New and improved technologies that are developed through these efforts must be made available to farmers. Approaches that enhance the adoption of improved technologies must be identified, along with the socioeconomic impacts of their adoption at the farm/village level.

Appendix D
Jordan--General Recommendations

1. Agroecology

The cultivation of a minimum of traditional crops, perceived profits, and a lack of adequate categorization of soil/land for best use have resulted in suboptimal use of lands. More uniform and comprehensive classification of soil and agroclimate is needed, combined with land use evaluation and mapping capability, in order to develop crop recommendations for various agroclimatic zones.

2. Soil and Water Conservation

There is a lack of application of soil- and water-conserving practices on much of the land, such as proper tillage, contouring, terracing, weed control, cover and green manure crops, and fertilizer and organic matter management methods to increase the fertility and organic matter contents of the soils. Some general recommended courses of action include research on methods to maximize infiltration and retention of water; economic benefits of crop residues for water conservation and erosion control vs. benefits for livestock production; alternatives to chemical weed control; soil mulching methods; and organic matter management. There is also support for demonstration projects on contouring and planting of shrubs and trees for wind erosion control.

The water available for agriculture can be better used through the identification and introduction of grains such as barley with higher water use efficiency than wheat, other drought resistant or tolerant cultivars, and legumes adapted to winter temperature and moisture conditions. Research on methods of increasing available water, such as small scale capture and storage of surface water and waste water for supplemental irrigation, and on cultural practices resulting in increased available soil moisture, such as minimum tillage and weed control, is needed.

3. Soil Fertility

Very little information is available in Jordan on the soil fertility and the fertilizer requirements to maximize nutritional benefits and crop yields for different crops and for major soil types. Fertilizer and fertilizer x soil moisture trials are needed for the various soil types and major crops, in addition to soil fertility testing, in order to develop efficient fertilizer and crop recommendations for farmers. Research on the use of crop residues, composts, green manures, and the use of nitrogen-fixing crops and crop rotations to augment/replace chemical fertilizers, is needed.

4. Effects of Livestock and Crop Residue Practices on Soil-Water Conservation

The historic practice of grazing livestock on crop residues and weeds growing in fallow areas greatly reduces soil water storage and soil organic matter and increases soil compaction and erosion. Research is needed to determine optimal crop residue/moisture balance, and the degree of grazing pressure that can be tolerated before acceptable levels of runoff and erosion are exceeded. Likewise, there is a need to develop alternative livestock feeds, such as rangeland forage crops and hay, and the technologies necessary for their adoption. On-farm demonstrations of the benefits of using crop residues for water conservation and erosion control vs. benefits for livestock production should be conducted.

5. Socioeconomic Aspects

The major constraints to the adoption of sound soil/water management practices, as well as other available technologies, are socioeconomic. In order to improve cropping and livestock systems and farmer practices, agricultural research extension programs need to be developed to introduce new technologies for improving farming systems; conduct on-farm demonstrations of the costs/benefits of new methods and technologies; and provide crop management techniques specifically for small farming systems and women in agriculture. The government should adopt policies and programs that assist farmers, such as provide incentives to farmers to increase farm inputs; maintain and develop local markets for agricultural products, in addition to developing export markets; allow free market factors to deal with the problem of overproduction; and encourage soil and water conservation and other policies which protect agricultural lands.

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