- PN-AAQ-700

PROSPECTS FOR SMALL-SCALE IRRIGATION DEVELOPMENT IN THE SAHEL

THE SAHEL

USAID

WATER MANAGEMENT SYNTHESIS II PROJECT

WMS REPORT 26

936-4127

PROSPECTS FOR SMALL-SCALE IRRIGATION DEVELOPMENT IN THE SAHEL

This study is an output of
Water Management Synthesis Project
under support of
United States Agency for International Development
Contract AID/DAN-4127-C-00-2086-00

All reported opinions, conclusions or recommendations are the sole responsibility of the authors and do not represent the official or unofficial positions of any agency of the countries of the Sahel or the United States or of Utah State University and the Consortium for International Development.

Prepared by

Jon Moris
Derrick J. Thom
Utah State University

and

Ray Norman
Cornell University

Utah State University
Agricultural and Irrigation Engineering
Logan, Utah 84322

June 1984 WMS Report 26

PREFACE

This study was conducted as part of the Water Management Synthesis-II Project, a program funded and assisted by the United States Agency for International Development through the Consortium for International Development. Utah State University, Colorado State University and Cornell University serve as co-lead universities for the Project.

The key objective is to provide services in irrigated regions of the world for improving water management practices in the design and operation of existing and future irrigation projects and give guidance for USAID for selecting and implementing development options and investment strategies.

For more information about the Project and any of its services, contact the Water Management Synthesis-II Project.

Jack Keller, Project Co-Director
Agricultural and Irrig. Engr.
Utah State University
Logan, Utah 84322
(801) 750-2785

Wayne Clyma, Project Co-Director
University Services Center
Colorado State University
Fort Collins, Colorado 80523
(303) 491-6991

E. Walter Coward, Project Co-Director
Department of Rural Sociology
Warren Hall
Cornell University
Ithaca, New York 14850
(607) 256-5495

ACKNOWLEDGMENTS

A reconnaissance study like this one depends heavily upon many people. The invitation for a Water Management Synthesis Project Team (WMS-II) to visit the Sahel originated from the Sahel Development and Planning Team in Mali, where Theresa Ware and Emmy Simmons were especially helpful. Mary Tiffen of London's Overseas Development Institute oriented us to those involved with the Sahel in England and Rome, including Richard Carter and his colleagues at the U.K.'s National College of Agricultural Engineering, Silsoe; Professor A. T. Grove at Cambridge; Lyndon Vincent and her colleagues in the Overseas Development Group at the University of East Anglia; and P. J. Dieleman and H. Underhill in FAO at Rome.

After our arrival in the field the REDSO/West Africa engineers Glen Anders and Dan Jenkins went beyond the call of duty to see that we were fully briefed. Jani Elder of the Peace Corps, Mali, provided us with a welcome field base. USAID/Mali staff were generous in giving us interviews and documents, and we wish to recognize the extra help received from Susan Buchanan and Rebecca Niece, which made our Action Blé-Diré case study possible. In Niger we owe a particular debt to Maina Sanda and the other staff of ONAHA who saw that our time was productively used, to Jean-Claude Marcel, and to Wilbur Thomas and Dayton Maxwell of USAID. Others who assisted Ray Norman on his subsequent site visits include Steve Lellelid, Ken Byrd and M. S. Hamidou. The work of R. Royer on the Dallou system is also appreciated.

This report could not have been completed in its present form had it not been for the strong support of Dr. Jack Keller and Bryant Smith of the WMS-II Project, and the extraordinary patience and encouragement of Worth Fitzgerald and Doug Merrey of AID/Washington. We wish also to record our special thanks to Linda Fields and JoAnn Biery for their perseverance in bringing the text to its printed form. There are certain to be errors which have escaped our notice, which are our own responsibility. To the many others who also helped in making this project a reality, we record our gratitude.

ACRONYMS

ABD	- Action Blé-Diré, Mali; Action Wheat-Dire, Mali
AID	- Agency for International Development, Washington, D.C.
ARS	- Action Riz, Sorgho-Gao, Mali; - Action Rice, Soghum-Gao, Mali
AVV	- Autorité des Aménagement de Vallées des Volta; - Volta River Authority
CBLT	- Commission du Bassin du Lac Tchad; - Lake Chad Basin Commission
CFN	- Commission du Fleuve Niger; - Niger River Commission
CIEM	- Centre Inter-Africain d'Etudes Hydraulique; - Interafrican Center for Hydraulic Studies
CILLS	- Comité Inter-Etats de Lutte Contre la Sécherese du Sahel; - Interstate Committee for Struggle Against Sahelian Drought
CMDT	- Compagnie Malienne de Développement des Textiles; - Malian Company for Textile Development
CNRA	- Comité National de la Recherche Agronomique, Mali; - National Committee for Agronomic Research, Mali
CNRS	- Centre National de Recherche Scientifique, Paris, France; - National Center for Scientific Research, Paris, France
CWS	- Church World Service
FAC	- Fonds d'Aide et Coopération, Paris, France; - Fund for Aid and Cooperation, Paris, France
FED	- Fonds Européen de Devéloppement, Paris, France; - European Development Fund, Paris, France
GERDAT	- Groupement d'Etudes et de Recherches pour le Développment de l'Agronomie Tropicale, Paris, France; - Study and Research Group for the Development of Tropical Agronomy, Paris, France
IBRD	- International Bank for Reconstruction and Development
IER	- Institut d'Economie Rural, Mali; - Institute for Rural Economy, Mali

IFAN	- Institut Fondamental d'Afrique Noire, Senegal
IGN	- Institut Géographique National, France; - National Geographic Institute, France
IMF	- International Monetary Fund
INRAN	- Institut National de Recherche Agrnomique du Niger - National Agronomic Research Institute of Niger
LWR	- Lutheran World Relief
NBA	- Niger Basin Authority
NGO	- Non-Governmental Organization
OECD	- Organization for Economic Cooperation and Development
OMVG	- Opération pour la Mise en Valeur du Fleuve Gambie; - Operation for the Development of the Gambia River
OMVS	- Opération pour la Mise en Valeur du Fleuve Sénégal; - Operation for the Development of the Senegal River
ON	- Office du Niger, Mali
ONAHA	- Office National des Aménagements Hydro-Agricole, Niger; - National Office for Hydro-Agricultural Development, Niger
ORM	- Opération Riz-Mopti, Mali; - Operation Rice-Mopti, Mali
ORS	- Opération Riz-Ségou, Mali; - Operation Rice-Segou, Mali
ORSTOM	- Office de Recherche Scientifique et Technique d'outre Mer Paris, France; - Office of Overseas Scientific and Technical Research, Paris, France
OTER	- Office des Traveaux d'Equipment Rural, Mali; - Office for Rural Equipment Works, Mali
OVSTM	- Opération Vallée du Sénégal, la Térékolé et du Lac Maqui, Mali; - Operation of the Senegal Valley, Térékolé and Lake Maqui, Mali
OZL	- Opération Zone Lacustre, Mali - Operation Lacustrine Zone, Mali
PIRT	- Projet Inventaire des Ressources Terrestres, Mali - Land Resources Inventory Prject, Mali

PVO - Private Volunteer Organization

REDSO - Regional Economic Development and Services Office (AID), Abidjan, Ivory Coast

SAED - Société d'Aménagement et des Etudes de Développement; Company for Study and Execution of Development, France

SAED - Sociéte d'Aménagement et d'Exploitation des Terres du Delta;
- Delta Canal Development Corporation, Senegal

SEDES - Société d'Etudes pour le Développement Economique et Social, Paris, France;
- Company for the Study of Social and Economic Development, Paris, France

SDPT - Sahel Development Planning Team, Mali

SOGETHA - Sociéte Générale des Techniques Hydro-Agricoles, France
- General Company for Hydro-Agricultural Techniques, France

SONADER - Société Nationale pour le Développement Rurale, Mauritanie
- National Company for Rural Development, Mauritania

SONGREAH - Société Grenobloise d'Etudes et d'Application Hydrauliques, Grenoble, France
- Grenoble Company for the Study and Application of Hydrology, Grenoble, France

UNCC - Union Nationale de Crédit et de Coops, Niger
- National Union for Credit and Coops, Niger

UNDP - United Nations Development Program

UNEP - United Nations Environment Program

USAID/ - United States Agency for International Development (located in country [Mali, Niger, etc.]

WMS-II - Water Management Synthesis-II, an AID funded project through the Bureau of Science and Technology

EXECUTIVE SUMMARY

Introduction

Africa is the second driest continent and is generally characterized as having too much or too little rainfall, depending upon one's location. The variability of rainfall from year to year in many parts of Africa makes average rainfall statistics meaningless and rainfed cultivation a precarious endeavor. The problem of periodic drought is exacerbated by population growth where people are forced to cultivate more marginal land under rainfed conditions. These conditions are especially prevalent in the Sahel, located along the southern fringes of the Sahara where rainfall averages 100 mm to 600 mm per year.

Most of the Sahel is too dry for rainfed agriculture to ever become the basis for secure food supplies required by the zone as a whole. This fact has been recognized by USAID's Country Development Strategy Statement for the Sahel Development Program (FY 1984) which stresses the need for irrigation and water management as a long term solution to poor production. Within the Sahel zone there is considerable potential for irrigation -- FAO estimates 12 million acres. Yet with such potential it becomes too easy to confuse what is technologically feasible with what is economically desirable. The technological possibilities for irrigation are defined largely in physical terms; adequate water, suitable dam sites, etc., without consideration of costs, distances, alternatives and likely unit performances within the envisioned project.

Concern for increased food production in Africa and the failure of irrigation prompted AID's Science and Technology Bureau to request a field visit by WMS-II staff to the Sahel during July 1983. The goal was to investigate by rapid reconnaissance the prospects for small-scale irrigation within the Sahel generally; and in particular, whether in the field visits to Mali and Niger one might identify promising communally-managed irrigation systems for further study under the WMS-II research program. This report is the outcome of that visit.

Special Features of Irrigation in the Sahel

Water is the limiting constraint affecting all forms of land use in the Sahel. The utilization of the hydrological resources of the Senegal and Niger River basins extend agriculture into areas too dry for rainfed cultivation. Traditional small-scale irrigation has been practiced for centuries; however, large-scale irrigation schemes are relatively recent. With expansion of large-scale irrigation schemes health hazards -- schistosomiasis, onchocerciasis and malaria -- increase.

The major issues which emerge from an overview of irrigation in the Sahel include:

1. Populations continue to rise throughout the Sahel at a time when labor migration opportunities are being curtailed. A

primary motivation for irrigated production is the emerging food deficit, which under current trends can be expected to become steadily worse.

2. Major water control investments are being made on both the Senegal and Niger Rivers, which afford the technical prospects for increased large-scale irrigation. For these projects the question is basically who will operate the new systems, what crops can be grown profitably and how displaced local populations will participate, i.e., as laborers, tenants or farmers.

3. There are irrigation agencies already established in most Sahel nations. Some supra-community assistance for site preparation is often required, but the degree of bureaucratic intervention is variable and should be closely examined in project design. The Sahel nations could benefit greatly from more cost-effective operation of the many bureaucratic agencies which sponsor rural development activities.

4. Existing small-scale schemes, which are mainly clustered in the Senegal River Basin, appear to be more productive per unit of investment than are large-scale schemes. A key unresolved question is whether agencies like SAED (Société d'Aménagement et des Etudes de Développement, Senegal) and ONAHA (Office National des Aménagements Hydro-Agricole, Niger) can promote and assist small-scale schemes in a way which is cost-effective and does not alienate farmers.

5. There is substantial potential for further expansion of small-scale irrigation in Mali and Niger, especially Mali, but such investments will encounter great logistic, social, economic and technical problems.

Basic Concepts

In the Sahel situation how one defines "irrigation" has a large effect upon recommendations. Irrigation in the Sahel ranges from the small-scale, calabash hand irrigation to the large-scale total water control systems. Irrigation under multi-use situations is common throughout the Sahel, for farmers holding irrigation rights also attempt rainfed farming and may keep cattle and grow horticultural crops. There are also few, if any, community managed systems in the Sahel outside of Senegal. Most small-scale traditional systems are individually managed, whereas the large-scale, total water control systems that depend on modern technology have brought about government intervention and the creation of bureaucracies.

Traditional labor intensive irrigation systems currently found in the Sahel include calabash irrigation, shaduf irrigation and dallou

irrigation. Where flooding occurs, flood plain irrigation and depression irrigation (bas fonds) may develop. Recessional irrigation (culture de décrue) is a common practice where natural flooding occurs and crops such as sorghum are planted as the flood waters recede. Through the utilization of residual soil moisture the plant survives until the arrival of the rainy season. Controlled flood irrigation systems including traditional submersible dikes and the more sophisticated construction of dikes, canals and sluice gates to control the flow of water onto plots and perimeters are common along the Niger River. Modern total water control systems utilizing both gravity flow and pumping are found in the Sahel countries. One of the largest gravity flow systems is the Office du Niger in Mali, technically a well conceived scheme, but one which, because of management and social problems, has never fulfilled expectations.

Large-scale capital intensive and technologically advanced schemes in Africa are usually associated with bureaucratic control, whereas small-scale schemes have limited control over water and may employ traditional technology. While large-scale schemes in the Sahel have not been too successful, some of the Sahel's "small" schemes have been prohibitively expensive if one takes into account the few farmers actually assisted.

What is advocated in this report is the need for a greater interpenetration of desirable features between small-scale and large-scale types. There is no reason why "modern" technology must be large-scale and capital intensive. There are several attractive small-scale innovations in irrigation technology which Sahelian farmers might adopt. At the other extreme, large-scale schemes could greatly benefit from the devolution of functions to farmers and to their communities and from a more flexible approach to design.

Irrigation in Mali

The Government of Mali has made a commitment to the expansion of irrigation as a means of increasing food production. At present there exists an estimated 130,000 to 150,000 ha of total water control. Unquestionably, Mali has the greatest potential for irrigation among the Sahel countries with a conservative estimate of 1 million ha of potentially irrigable land. The potential for irrigation is concentrated in the Inland Delta of the Niger River and along the Niger River.

There is no single government institution that has sole responsibility for the development and organization of irrigation in Mali. Agricultural development under the aegis of the Ministry of Agriculture is delegated to various regional development organizations. The Office du Niger is a large-scale irrigation scheme which is responsible for the development of irrigation of the Inactive Delta of the Inland Delta. In other areas agricultural development is under the direction of various "Opérations" which usually have a division that

oversees irrigation development. Opération Riz-Ségou and Opération Riz-Mopti have been created for the sole purpose of increasing rice production through the development of irrigation. There are also smaller Actions such as Action Blé-Diré and Action Riz, Sorgho-Gao where development is at a smaller scale than the Opérations. All these institutions have their own administration, extension, study and programming services.

Irrigation has been practiced by many people and the prevalent systems in Mali include traditional hand watering, natural flood irrigation, recessional irrigation and total water control systems. Excluding the small-scale traditional systems, there presently exist 157,000 ha on 69 irrigation perimeters in Mali. This figure includes the 56,000 ha of the Office du Niger. The existing perimeters can be conveniently divided into those along the Senegal River in the Kayes Region and those in the Niger Basin which include Southern Mali, Upper Niger Valley, Ségou Region, Inactive Delta, Mopti Region, Lacustrine Zone and the Niger Bend.

Irrigation in Niger

Irrigation potential in Niger is estimated to be 220,000 ha. Most of this potential is located in the Niger River Valley and includes 140,000 ha of the projected Kandaji Dam Project. At present there is a total of 4855 ha of total water control schemes under the direction of ONAHA (National Office for Hydro-Agricultural Development). In addition to these rice growing schemes in the Niger Valley, ONAHA oversees 3880 ha of irrigated market gardens in the Maggia Valley and two small perimeters (137 ha) at Diffa and on the Komadougou Yobé. The official hectarage of irrigated land does not take into account the many small-scale traditional irrigated market-garden schemes in the region of the dallols, goulbis and Air Massif. This hectarage may be in excess of 5000 ha. A variety of irrigation types are observed in Niger and include the large-scale total water control systems along the Niger River, recessional irrigation, small pump systems, shaduf and dallou.

In 1978 ONAHA was created and charged with the responsibility for the development, maintenance, management and expansion of irrigation throughout Niger. With the cooperation of the Rural Engineers (Génie Rurale), irrigation perimeters are planned and constructed. The National Union for Coops and Credit (UNCC) is responsible for the extension component of training farmers and extension agents in the technologies of irrigation and the organization of farmers into cooperatives for marketing rice and vegetables.

The priority of the Government of Niger in the development of irrigation perimeters has been in the development of large-scale total water control systems. However, high development costs, difficulty in organizing farmers and heavy recurrent costs plus a desire to decentralize management has resulted in a new interest in small-scale

irrigation development. The approach at present appears to be a continued effort to expand the total water control systems, especially in the Niger Valley and also to provide support and assistance to small-scale development wherever feasible. Irrigation development is located in four regions of Niger: the Niger River Valley; the region of the Dallols and Goulbis; the Lake Chad-Komadougou Yobé Region; and the Air Region.

Case Studies of Small-Scale Irrigation

Brief discussions of several small-scale irrigation projects in Niger and Mali reinforces the notion that being small-scale does not guarantee success. The Tara Project in Niger is under the auspice of Africare and has been plagued with design, water distribution, maintenance problems and labor constraints. Success of ONAHA administered schemes in the Maggia Valley, Niger, is dependent upon the age and function of the cooperative, the size of the perimeter and the experience of the ONAHA perimeter director. Constant repair, rebuilding and abandonment of hand dug wells are identified as among the major concerns in the well gardening schemes of Niger. Investment of $580,000 by the Lutheran World Relief and USAID in lining 325 wells with concrete rings has provided 170 ha of small-scale irrigation for some 13,000 people and has been quite successful and cost-effective.

Action Blé-Diré in Mali provides a well documented, well conceived project that went awry despite the best intentions of USAID/Mali. Action Blé was funded by USAID to increase wheat production in the Lacustrine Zone around Diré. Through the provision of credit and 250 motor pumps from India, 1000 ha were to be irrigated. The failure of the project stemmed from financial problems and mismanagement caused by the "host country" contract; delays in starting up; the discontinuance of the production of the Indian Cooper pumps; the logistics of providing fuel and supplies to a remote area; and the lack of trained mechanics and spare parts. These and other problems resulted in the discontinuance of USAID support for Action Blé. It should be stressed that these problems are by no means unique to this project. It appears that the standard solutions which donors have access to -- equipment financing, farm credit, improved inputs, etc. -- are an insufficient basis for stimulating rural development in isolated settings where a commercial infrastructure does not exist. To the credit of Mali's USAID staff, these lessons have been learned and the Mission has become more cautious in choosing which interventions to sponsor. For Africa as a whole, however, the issue remains "How do governments start the process of rural development in places which, because of geography and markets, remain outside the mainstream of economic development as we know it?"

Social Aspects of Sahel Irrigation

The mixed ethnic situation that is often encountered in the Sahel has important implications for irrigation development.

1. Existing communities are often polarized along ethnic lines so that genuine participation may be actively denied to whichever groups are not dominant.

2. The degree of familiarity of different groups with particular cropping techniques can vary widely. This suggests a substantial amount of farmer training may be necessary when introducing irrigation technologies.

3. Any narrow focused mono-crop strategy directed toward the community as a whole is bound to conflict with the family's own economic survival.

4. The needs of seasonal residents should be allowed for in irrigation planning.

Sahelian farming is also characterized by various social restrictions on land and water rights.

1. Local members of a village enjoy prior claim to its land before outsiders.

2. Within a village the founding clans usually enjoy better land and greater control than do later arrivals.

3. Those who first clear land retain the right to its use and may pass on such claims to their children or heirs, provided their entry onto the land was permitted by the dominant compounds.

4. Male heads of household have prior claim over females who might acquire control because of continued use of a deceased husband's lands or by the clearing of their own lands.

5. Land is not supposed to be rented or sold, but in fact is increasingly being so treated.

In addition to the aforementioned, and closely associated with them, the following social factors need to be considered.

1. The impact of migration. What are the impacts of the absence of young males and household heads upon the farming system? What skills have they developed in their absence that can be put to use in small-scale development?

2. The impact of irrigation upon women. How does the introduction of irrigation impinge upon the traditional rights of women's access to land?

3. The labor constraints to irrigation development. Irrigation demands well-timed, disciplined, coordinated work, three

attributes which are seldom encountered from a peasant labor force in Africa. Very few, for example, will irrigate at night.

4. The role of cooperatives in irrigation development. An obvious way of bringing water user associations into the larger national system is to have them legally incorporated into cooperatives. Despite attempts to broaden participant decision-making in small-scale irrigation schemes, many participants are kept out, and the traditional leadership often has an overwhelming influence.

Implications

The general issues which affect irrigation in the Sahel include the following:

1. Economic Environment

   a. Sahelian producers operate in a marginal environment under conditions of high risk. Low prices, dictated by government pricing policies, discourage investment in irrigation.

   b. Isolated regions which suffer food deficits are also where unit costs and risks of production may be highest.

   c. Planning irrigation projects needs to be based upon actual costs derived from local research. The flow of traditional commodities is considerable, and any micro-analysis which ignores such transactions is bound to generate misleading conclusions.

2. Irrigation Stragegy

   a. Current implementation of irrigation development is usually capital intensive and foreign exchange intensive.

   b. Present commitment to river basin development, especially the Niger Basin, needs closer scrutiny because of negative impacts on existing small-scale irrigation and livestock grazing in the Inland Delta.

   c. There is a need for USAID missions to develop their own capacity to review irrigation sector decisions adequately.

3. Improving Large-Scale Irrigation

   a. Irrespective of cost-effectiveness, it is likely that

there will be further investments in large-scale irrigation schemes in the region.

b. Despite low cost-effectiveness there is an urgent need to increase productivity of "main system" management in existing schemes.

c. The nature of the problems with large-scale irrigation are both technical, reflecting poor design, and bureaucratic/ sociological.

d. Suggestions for improvement include:

(i) Work with local farmers as a subunit of the larger scheme;

(ii) Exchange experience between the Sahel and India; and

(iii) Undertake a WMS diagnostic analysis to identify empirically where productivity bottlenecks occur.

4. Irrigation Impacts

a. Consideration of potential impacts upon human and animal populations need to be carefully assessed.

b. Health hazards are an inevitable result of irrigation development in Africa and need to be more adequately addressed at the planning stage.

5. Maintenance Crisis

a. On-site visits in Mali and Niger indicate there is a maintenance crisis. Yet, while virtually all field engineers admit maintenance is a problem that reaches almost crisis proportions, nobody has studied schemes to demonstrate empirically why lack of maintenance occurs.

b. This problem needs to be studied collaboratively by main system engineers, farm economists, managerial analysts and sociologists.

There is considerable potential for the expansion of small-scale irrigation in the Sahel, and the main findings with regard to the small-scale subsector irrigation development include:

1. Communally-Managed Systems

a. Within Mali and Niger there were few existing examples of viable, communally-managed irrigation systems. However,

such systems do exist in Senegal and since Senegal was not visited, this report may underestimate the extent and significance of the communal element.

b. The opportunity for community-managed systems arises in connection with the new, smaller-scale irrigation perimeters presently being developed.

c. To activate communally-managed schemes two additional components are needed, one physical, the other organizational.

(i) An operational delivery system to transport water onto the farmers' field; and

(ii) An acceptable model which outlines for villagers how a water users' association can be formed and will function.

2. Small-Scale Technology Development

a. Field observations suggest there is a considerable gap to be bridged in improving small-scale technology.

b. There are scattered throughout Africa individuals, NGOs and PVOs, who have been working and improving small-scale irrigation. The collective experience of these individuals needs to be explored and disseminated.

3. Traditional Systems

a. There are traditional irrigation systems in operation in the Sahel that warrant further investigation. An often overlooked factor in the planning process is local expertise.

b. In-depth studies and analyses of the complex traditional irrigation systems of the Inland Delta need to be undertaken not only to tap local experience but also to understand the impact of proposed Niger River Basin Development proposals to stabilize the flow of the Niger River.

c. Small-scale oasis irrigation such as practiced in the Air Mountains and depressional (bas fonds) irrigation warrants more investigation to understand these systems.

4. On-Farm Water Management

a. Sites visited indicated that there were numerous on-farm water management problems. There were many examples of

leaking canals, unlined furrows in sandy soils, uneven fields and weed-choked canals, all creating water losses.

b. The situations observed indicated the need for on-farm interdisciplinary analysis of water management which WMS has provided for other countries.

5. Land and Water Relationships

a. While not directly related to irrigation, there is an urgent need to better understand the soil/water relationships in Africa's semi-arid and arid plateau lands.

b. Research is being undertaken but one leaves the Sahel with the impression that time is running out. Human and animal populations continue to rise, yet few of the many plans formulated after the 1968-73 drought have come to fruition and the opportunities for taking action are slipping away.

PROSPECTS FOR SMALL-SCALE IRRIGATION DEVELOPMENT
IN THE SAHEL

TABLE OF CONTENTS

Chapter		Page
	PREFACE	ii
	ACKNOWLEDGMENTS	iii
	ACRONYMS	iv
	EXECUTIVE SUMMARY	vii
I	INTRODUCTION	1
II	SPECIAL FEATURES OF IRRIGATION IN THE SAHEL	7
	The Sahel	7
	The Hydrological Resources	8
	Use of Water Resources	10
	Health Hazards	10
	Small-Scale Irrigation Systems	12
	Large-Scale Irrigation	15
	Emergent Issues	19
III	BASIC CONCEPTS	21
	Defining Irrigation	21
	The Small- to Micro-Scale Continuum	21
	Total versus Partial Water Control	21
	Irrigation Under Multiple-Use Situations	22
	Community versus Communally-Managed Systems	22
	Types of Farmer Participation	23
	Types of Traditional and Modern Irrigation	23
	Traditional Labor Intensive Systems	23
	Natural Flood Irrigation	25
	Recessional Irrigation (Culture de décrue)	25
	Controlled Flood Irrigation	26
	Total Water Control	26
	River Basin Development	26
	Bureaucratic versus Participative Systems	26

TABLE OF CONTENTS (Continued)

Chapter		Page
IV	Water Control Structures	65
	User Cooperatives	68
	Water Management	69
	Well Gardening, Niger	71
	Traditional Micro-Irrigation	71
	Action Blé-Diré	79
	Context	79
	Project Components	80
	Implementation under ABD	83
	Project Management	87
	Implementation under USAID	89
	Project Impact	92
	General Lessons	94
VII	SOCIAL ASPECTS OF SAHEL IRRIGATION	97
	Crops Associated with Irrigation	97
	Occupational Structure and Ethnicity	98
	Migration	99
	Land and Water Rights	100
	Impact of Irrigation Upon Women	102
	Labor Constraints	103
	Unanticipated Social Costs and Benefits	105
	Entrepreneurial Tradition	107
	Cooperatives	107
PHOTOGRAPHS		109
VIII	IMPLICATIONS	113
	Sahelian Irrigation in General	113
	The Economic Environment	113
	Irrigation Strategy	114
	Improving Large-Scale Irrigation	115
	Irrigation Impacts	116
	The Maintenance Crisis	117
	Small-Scale Irrigation	117
	Community-Managed Systems	118
	Small-Scale Technology Development	119

TABLE OF CONTENTS (Continued)

Chapter		Page
IV	IRRIGATION IN MALI	31
	The Physical Environment	31
	Climate	31
	Hydrology	31
	Irrigation Potential	33
	Institutional Structure	33
	Irrigation Perimeters	35
	The Kayes Region	35
	Southern Mali	39
	Upper Niger Valley	39
	Ségou Region	39
	Inactive Delta	40
	Mopti Region	42
	Lacustrine Zone	44
	The Niger Bend	47
V	IRRIGATION IN NIGER	49
	The Physical Environment	49
	Climate	49
	Hydrology	54
	Irrigation Potential	54
	Institutional Structure	54
	Irrigation Perimeters	57
	The Niger River Valley	57
	The Dallols and Goulbis	59
	Lake Chad and Komadougou Region	60
	Air Region	60
VI	CASE STUDIES OF SMALL-SCALE IRRIGATION	61
	Tara Project, Niger	61
	Project Background	61
	Water Management	63
	Maggia Valley, Niger	65

TABLE OF CONTENTS (Continued)

Chapter		Page
VIII	Traditional Systems	120
	On-Farm Water Management	120
	Land-and-Water Relationships	121

APPENDICES

A	WORKING BIBLIOGRAPHY	123
B	OPERATION RIZ-MOPTI (ORM)	147
C	THE DALLOU IRRIGATION SYSTEM by Ralph A. Royer	153

CHAPTER I

INTRODUCTION

Africa and South America differ sharply from Asia and North America in having only a small proportion of their land area under irrigation, the absolute figures (for 1976) being respectively 7.7 million ha and 6.7 million ha in contrast to 164.6 million ha for Asia and 23.2 for North and Central America (Berry et al., 1980). Yet much of Africa is drought-prone, with the unreliability of rainfall constituting the major constraint on existing agricultural production. As a consequence, the continent showed the highest percentage growth in irrigated land during the 1961-70 decade, 31 percent as contrasted with 25 percent for South America and 18 percent each for North/Central America and Asia (ibid.). With its small base of relatively recent irrigation schemes and with a large zone subject to unpredictable droughts, Africa would seem to have both an easier prospect and a strong incentive for achieving high initial returns from an improvement and expansion of its irrigation systems.

Instead, the African continent is littered with derelict irrigation schemes. Even some of the few earlier successes like Gezira in the Sudan or the Kilombero in Tanzania are now candidates for rehabilitation. In the whole continent, the literature suggests that only the Gezira and Mwea in Kenya are modest successes. From Montgomery's 20 system comparison, Mwea is the single African scheme given a productivity rating above the "poor" level (Montgomery, 1983). For the larger part, the longitudinal record of African irrigation systems has been dismal (here see the three cases in Heyer et al., 1981, and De Wilde's depiction of the Office du Niger, 1967). Nevertheless, it is the African continent where population growth is most rapidly outstripping the food supply and where foreign donors like U.S. Agency for International Development (USAID) will of necessity be exploring the underutilized potential of irrigation technologies during the next two decades (Eicher, 1982).

Nowhere is the divergence between potential, need and likely response wider than it is in regard to the prospects for irrigation in the Sahel zone of West Africa. In USAID's Country Development Strategy Statement (CDSS) for the Sahel Development Program in FY 1984 (1982) it is recognized that:

> . . . increased irrigation is a <u>sine qua non</u> for attaining the region's agricultural production goals and food security by the year 2000 and beyond . . . There is substantial opportunity to improve the traditional systems technically, to develop additional areas and to rehabilitate certain run-down perimeters; indeed these activities will require years of collective effort throughout the region.

USAID's open-ended commitment to irrigation development as the long-term answer for the Sahel's food needs arises from the region's unique

situation in regard to its land and water resources -- aspects which are outlined in the following chapter, "Special Features of Irrigation in the Sahel." It does not grow out of satisfaction with the present performance of irrigated agriculture in the Sahel, which indeed is stagnant or even declining, e.g., the Office du Niger.

Put most crudely, the basic argument is that most of the Sahel is too dry for rainfed agriculture to ever become the basis for secure food supplies required by the zone as a whole. At the same time, through accidents of geography, the Sahel is crossed by a number of large rivers, principally the Niger and Senegal, and also by subsurface aquifers which in some places coincide with alluvial soils that are highly suitable for irrigation. The Sahel nations have several times experienced devastating drought, most recently in the 1968-73 crisis which brought their plight to international attention. As poor nations unable to import food, if these countries desire stability and food security over the longer run, then irrigated farming remains the one underexploited technological possibility still available.

In the world as a whole, most development projects have probably arisen out of locally perceived technological opportunities. For the Sahel, the temptation to put heavy investment into irrigation becomes almost irresistible. As Eicher and Baker (1982) point out:

> The FAO has estimated that the Sahelian region . . . has about 12 million acres of land which is potentially available for irrigation . . . The Club du Sahel, however, estimated that only 80,000 hectares was under irrigation in the mid-1970s (1977). The gap between 80,000 hectares and 12,000,000 acres is staggering . . . In summary, even though estimates of the potential land for irrigation are some of the weakest data for any sub-sector, the technical potential for irrigation is large and estimates likely will be increased as more information becomes available. . . .

It is this dramatic technological potential which appears to have motivated the many large-scale projects either planned or under construction for improved water management through the Sahel.[1]

In such situations, it becomes all too easy to confuse what is technologically possible with what is economically desirable. The technological possibilities for irrigation are defined largely in physical terms -- adequate water, suitable dam-sites, etc. -- without consideration of costs, distances, alternatives and likely unit performance within the envisioned projects. USAID's Sahel CDSS statement is well aware of this fact, and cites the improvement of rainfed agriculture as being a more cost-effective strategy for Sahelian

---

[1]Waldstein (1980) points out that there are over 230 large-scale development projects in Africa, with 31 of them located in the Sahel.

development in the short-run. But this is an unsatisfactory answer, given that the same report also supports irrigation development for longer term investment. The USAID country missions are left to answer for themselves the key questions concerning the form, timing and location of irrigation projects which they may choose to support.

Within the WMS-II team, which is currently trying to synthesize the worldwide "lessons of experience" from irrigation investment, we have found it useful to view irrigation options within a larger, strategic framework. A country cannot get very far in the planning of specific interventions if it has never asked the more basic questions which ought to establish the criteria for particular choices. In hierarchical form, these are:

A. Food Policy

- Produce at home or buy from abroad?
- What staples? What urban/rural subsidies? Pricing policy?
- What degree of fluctuations can be tolerated?

B. Balance between Irrigated versus Rainfed Farming

- Comparative costs of production.
- What technical opportunities for each?
- Balance of effort between each?

C. What Kinds of Irrigation

- Full versus partial, total versus supplement.
- Large-scale versus small-scale.
- Authority managed versus locally managed.

D. What Crops

- Present yields, irrigation versus non-irrigation.
- Available packages and input implications.
- Foreign exchange component.
- Existing returns and experience.

E. Where, When and with Whom

- Phases in development.
- Location of projects.
- Sources of farmers, staff and expertise.

Depending upon the answers to these questions, we find that even where irrigation is desirable, it may take various forms. Some are more effective than others; and some much more expensive than others. The technology for delivering water onto crops has been enormously refined and diversified over the past five decades. Today there will be a few situations where there is only one feasible form of irrigation

development. The options often differ in regard to investment cost, associated health risks, foreign exchange requirements and necessary operator's skills, all key considerations in a poor African country. And yet we still find that field projects are often saddled with bad technical solutions which are inappropriate to their immediate context.

It is clear from the Comité Inter-états de Lutte Contre la Secheresse du Sahel (CILSS) studies that the present extent of irrigation (see Table 1) could be dramatically expanded. However, the usual tactic at the country level of establishing subsidized parastatal agencies responsible for expanding flood rice cultivation has not been very effective. There is growing willingness to consider alternative ways of implementing irrigation, such as through small-scale or village-managed schemes (Miller, 1984; Vink, 1983; Diallo, 1980; Stryker, 1978; Lowdermilk, 1978; Zondervan-Droz, 1978; Adams, 1977; and Langley, 1977). Alternatively, the overcentralized large schemes might be reorganized to permit greater farmer involvement and thereby raise productivity. And there is the as yet unresolved question concerning what form future irrigation investments should take within the large river basin management schemes which are already on the drawing board. Finally, USAID's own policy now stresses the involvement of the private sector and non-governmental organizations in African development: two groups conspicuously lacking in earlier plans for Sahelian irrigation.

These concerns appear to have been responsible for a request from AID's Science and Technology Bureau for a field visit by WMS-II staff to the Sahel during July of 1983. Our goal was to investigate by rapid reconnaissance the prospects for future small-scale irrigation development within the Sahel generally and, in particular, whether in field visits to Mali and Niger we might identify promising communally-managed irrigation systems for further study under the WMS-II research program. This report is the outcome of that visit.

TABLE 1

AREA IRRIGATED
1978
(in 000's ha)

COUNTRY	WATER CONTROL*		TOTAL
	Total	Partial	
Cape Verde	1.9	--	1.9
Chad	0.5	4.0	4.5
Gambia	2.2	--	2.2
Mali	42.0	69.0	111.0
Mauritania	1.9	--	1.9
Niger	4.8	1.0	5.8
Senegal	14.0	77.0	91.0
Upper Volta	5.8	3.2	9.0

Source: Club du Sahel -- CILSS, "The Development of Irrigated Agriculture in the Sahel -- Review and Perspectives," Mimeo, April 1980, p. 6.

*These figures should be regarded as estimates for the unreliability of statistical results in figures varying from study to study.

CHAPTER II

SPECIAL FEATURES OF IRRIGATION IN THE SAHEL

The Sahel is a distinctive region within the larger community of West African nations. Since some users of this report will lack firsthand familiarity with this area, we thought it best to begin with an overview to explain why the choice of irrigation strategy is such a key issue within the Sahel region. At present, irrigation plays only a minor role in the agriculture of the Sahel countries (affecting perhaps 500,000 ha out of some 13 million ha), but this modest total, for reasons we shall discuss, is not a useful measure of the potential contribution of irrigation to the welfare of the Sahel.[1]

The Sahel

Strictly applied, the term "Sahel" refers to a climatic zone encompassing the lands immediately south of the Sahara which receive between 100 to 200 and 500 to 600 mm of rainfall per year (authors differ in their specification of the zonal limits). Along the southern border of the Sahel there is the Sudanic zone, where rainfall is generally sufficient to permit rainfed agriculture. In the Sahel zone, however, the risk of inadequate rainfall is so great that unless farmers have access to at least supplemental irrigation they will experience frequent crop failures. Along the southern margins of the Sahel zone farmers and pastoralists are intermixed; but as one moves northwards into the dry lands pastoralism predominates except where water availability makes full irrigation possible.

For the outside world, the "Sahel problem" arises in those years when rainfall fails all along the 2,600 mile Sahel/Sudanic zone boundary (as it did in a series of bad seasons from 1968-73). Then even the farmers in the more densely settled Sudanic zone are put at risk, and unless outside assistance is received hundreds of thousands of people and animals may die.

Politically, the Sahel region consists of a chain of former French African nations stretching in a band across the southern margins of the Sahara from Senegal to the Sudan. In sequence from west to east there is Cape Verde (islands offshore Senegal to the west), Senegal, The Gambia, Mauritania, Mali, Upper Volta, Niger, the northern portion of Nigeria, Chad, and even part of the Sudan. Except for Cape Verde, The Gambia, Nigeria and Sudan, they are all French-speaking nations who received their independence more than two decades ago (in 1960) and who now f and

---

[1] The figure of 500,000 ha includes traditional irrigation; as already noted, the area under "total water control" within officially recognized perimeters is much smaller.

Previous Page Blank

themselves as primary producers in a dry environment among the poorest nations in the world. From Mali eastward (with Nigeria again the main exception) they are also landlocked states forced to pay high transport costs for goods moved inland from the distant coast. Excluding Sudan and Nigeria, the total population for the zone is not high -- World Bank figures for 1979 (Table 2) suggest 30 million people in all, spread over a vast area of over 5 million square kilometers -- but these figures are misleading in two respects. Of the four larger states, most of their northern lands lie in the Sahara desert so that their actual populations are strongly clustered along the Sahel/Sudanic zone margins in the South. Furthermore, for the reasons already stated, the whole population of the Sahel becomes vulnerable in times of drought (which have been a recurrent phenomenon).

The Hydrological Resources

The Sahel situation would offer little prospect for anything but mineral and livestock development if it were not for accidents of geomorphology. As it happens, the heavy rainfall received in the highlands of Guinea and Ivory Coast drains north towards the Sahara rather than south towards the ocean. Thus, the Niger and Senegal Rivers resemble the Colorado in the American West, in that they traverse hundreds of miles of semiarid land carrying water derived from far-distant highland sources.[2] Furthermore, in Pleistocene and earlier times the flow of the Niger northeastwards across a very flat gradient on the margins of the Sahara led to the deposition of a vast inland delta, and eventually to a large inland lake whose lacustrine sediments are cross-cut by the modern river channels. When we remember that the Niger is Africa's third largest river, we can see that its complex route from Guinea through Mali, Niger and Nigeria offers many opportunities for development despite the low rainfall along its central arc into the Sahara borderlands.

Less dramatic but also significant from the standpoint of small-scale irrigation are the fossil and subsurface drainages (dallols and goulbis). It is known that during earlier geologic periods the Sahara extended far south of its present margins, while at other times it enjoyed a wetter climatic regime. The fossil drainages are the remnants of the wetter period. While no longer carrying surface flow, these drainages may yet contain substantial subsurface storage suitable for tubewell extraction. On an even smaller scale, individual sand dunes may become water collecting surfaces, creating and then destroying oases as they move. The development and stabilization of water supplies in such environments may require complex hydrological information even though the techniques for extraction are quite simple.

---

[2]For longitudinal representations of the Nile, Niger and Congo and a schematic diagram of the Niger's discharge, see Grove (1970).

TABLE 2

BASIC INDICATORS FOR THE SAHEL

Country	Population mid-1979 (millions)	Total Area (000 sq kms)	GNP per capita (dollars 1979)
Chad	4.4	1,284	110
Gambia	0.6	11	250
Mali	6.8	1,240	140
Mauritania	1.6	1,031	320
Niger	5.2	1,267	270
Senegal	5.5	197	430
Upper Volta	5.6	274	180

Source: The World Bank, Accelerated Development in Sub-Saharan Africa. Washington, D.C., 1981, p. 143.

Use of Water Resources

At both extremes of scale, entire river systems or individual wells, the economist's concept of externality helps pinpoint the dangers inherent in unplanned exploitation of water resources in the Sahel. First, water is the limiting constraint affecting all forms of land use within the zone. In such a situation, when water is available it is used for many purposes: for human consumption, for harvesting fish, for transport, for livestock and for farming. Since irrigation is a net consumer of water, any allocation to this purpose must be weighed against alternative uses. Second, the major river systems cross several national boundaries. When Nigeria installs dams and irrigation systems along the upstream reaches of the Komadougou River and its tributaries which feed into Lake Chad, this has direct consequences for the parts of the Chad basin lying in Niger and Chad.[3] Similarly, the planned developments on the Niger and Senegal Rivers within Mali will have direct downstream repercussions in the countries of Niger and Senegal. The same topography which feeds water into the drier Sahel lands thus makes its exploitation a joint concern between many of the nations in the region. In response, the Sahel nations have agreed to the formation of a series of multinational river basin authorities (Table 3). Of these, the Opération Mise en Valeur du fleuve Sénégal (OMVS) involving the Senegal River is the farthest along, but all are potentially significant within their respective zones.

Health Hazards

Another externality which is not so tidily dealt with is the high incidence of debilitating diseases which seems to accompany irrigation in most of Africa, but which assumes peculiar virulence in the Sahel ecology. Several of Africa's most debilitating, endemic diseases are associated with water: schistosomiasis (or bilharzia), which is spread by small snails living in irrigation channels; malaria, encephalitis and yellow fever, all spread by mosquitoes which breed in standing water; and onchocerciasis, or river blindness, carried by flies that breed in fast flowing water. There are also numerous other tropical diseases such as cholera which can contaminate water supplies and thereby spread within the whole human population. The linkage to irrigation development occurs because structures for surface irrigation often make ideal breeding grounds for disease vectors, because irrigation extends favorable moisture conditions over a longer part of the year, and because field workers typically lack adequate sanitation or other safeguards. Those coming from lands with cold winters and adequate sanitation have difficulty appreciating just how severe the disease problem can become in African environments. Whole sections of the Sudanic zone in West Africa

---

[3]Following the 1968-73 drought, Lake Chad never recovered its former extent and we were told the shoreline has in recent years receded beyond Niger's borders.

TABLE 3
WATER DEVELOPMENT AGENCIES

A. River Basin Commissions

AVV	Autorité des Aménagement de Vallées des Volta; Volta River Authority
CBLT	Commission du Bassin du Lac Tchad; Chad Basin Commission
CFN	Commission du Fleuve Niger; Niger River Commission
OMVG	Opération pour la Mise en Valeur du Fleuve Gambie; Operation for the Development of the Gambia River
OMVS	Opération pour la Mise en Valeur du Fleuve Sénégal; Operation for the Development of the Senegal River

B. Agencies with an Irrigation Component

ABD	Action Blé-Diré, Mali
ARS	Action Riz, Sorgho-Gao, Mali; Action Rice, Soghum-Gao, Mali
ON	Office du Niger, Mali
ONAHA	Office National des Aménagements Hydro-Agricole, Niger; National Office for Hydro-Agricultural Development, Niger
ORM	Opération Riz-Mopti, Mali; Operation Rice-Mopti, Mali
ORS	Opération Riz-Ségou, Mali; Operation Rice-Segou, Mali
OVSTM	Opération Vallée du Sénégal, la Térékolé et du Lac Maqui, Mali; Operation of the Senegal Valley, Térékolé and Lake Maqui, Mali
OZL	Opération Zone Lacustre, Mali; Operation Lacustrine Zone, Mali
SAED	Sociéte d'Aménagement et d'Exploitation des Terres du Delta, Senegal; Delta Canal Development Corporation, Senegal
SONADER	Société Nationale pour le Développement Rurale, Mauritanie; National Company for Rural Development, Mauritania

have been abandoned because of the threat of river blindness. On the positive side we should note that some of the newer irrigation technologies such as overhead sprinkler systems do not pose the same level of health costs upon farmers.[4]

Small-Scale Irrigation Systems

Sahel farmers have traditionally practiced several types of irrigation of their own devising, which have come to be known today under their French or Arabic designations -- e.g., décrue, bas-fond, dallou, shaduf, etc. Much of Chapter III is devoted to a description of these types, which are of particular interest here because they are all small scale and locally managed even if they may be quite widespread in extent.

Over much of the zone the key bottleneck we observed was the farmers' inability to deliver available water onto their crops in an energy-efficient manner. The Dogon hand-carried "calabash" system which we observed in Mali shows the extremes to which some Sahel farmers are willing to go, a commitment of 6 to 8 hours of watering per day in order to keep plants alive. In such circumstances even the marginal improvement of a portable hand pump constitutes significant assistance to the farmer. While many farmers have alternative power sources at hand, bicycles, mobylettes and oxen, the bottleneck remains because water delivery technologies at the small-scale end focus upon household supplies and do not maximize yield per unit of energy input. An obvious way to begin assisting small-scale irrigation would be to start developing technologies to meet this need.

Where seasonal flooding of major rivers solves the farmers' water delivery problem, cultivators have adopted types of floating rice which require minimum labor input once established (since no weeding is necessary). While in Vietnam the development of conventional flood-basin rice destroyed the downstream "floating rice" regime, so far this has not yet happened in the Sahel. Donors have to the contrary capitalized upon the situation by improving the dikes which hold water over the fields and permit a regularization of the rivers' recessional phase (see Operation Riz-Mopti, Appendix B).

Indeed, farmers traditionally used the gradual lowering of the river levels to extend the zone of arable crop production on the river terraces and along the margins of the seasonal swamps. It is very important to

---

[4]While there is a large literature on the health impacts of irrigation schemes, relatively few workers have concentrated on design changes within the spectrum of available technologies which might minimize health costs. Sources include Ackerman et al., 1973; Family Health Care, 1979; Feachem et al., 1977; Hughes and Hunter, 1970; Joseph and Scheyer, 1977; McJunkin, 1970 and 1975; Rajogopalan and Shiffman, 1974; Stanley and Alper, 1975; Tillman, 1981; and White, 1978.

note that the stabilization of river flows so desired by engineers in regard to power production and river transport may nevertheless narrow significantly the band of soil which farmers utilize over the season. Within the traditional system, particularly in the middle valley of the Senegal River and in the Niger's Inland Delta, farmers have learned how to turn fluctuating river levels to their advantage. Since this area is currently supporting a relatively dense human and animal population, we should be wary of assuming that regularized flows constitute a benefit to farmers. The same argument applies with even greater force to pastoralists, who can easily harvest forage from the expanding riverside pastures as the water recedes.

Where river banks may be steeper outside the Inland Delta, farmers do face a formidable obstacle if they wish to pump water several meters vertically onto the river terraces. River terrace situations occur for hundreds of miles throughout the Sahel along the larger rivers. The more promising sites have often been incorporated into national plans for expanding flood rice irrigation. Here medium-sized pumping stations (usually based on diesel engines) will be installed, and are typically managed by whatever agency is in charge of irrigation development, e.g., Office National des Aménagements Hydro-Agricoles (ONAHA) in Niger. However, there are many similar sections along the existing rivers which would not merit the heavy capital investment required to create permanent site works of the kind favored by civil engineers. These sites constitute one of the main opportunities for small-scale irrigation development in the Sahel. A single farmer or a small group should be able with some assistance to purchase a small pump and flexible hoses adequate for market garden crops needing less water than rice. The chief technical difficulty to overcome remains the necessity of moving the pump outwards as the river level drops, and the high consequent lift of water to the terrace levels. Further experimentation to solve these problems would be essential before embarking upon a large-scale program, as Mali's troubles with its USAID-assisted Action Blé-Diré attest. Nevertheless, the financing of individual pumpsets to local entrepreneurs should not necessitate the heavy expenses associated with the usual "irrigation agency" approach.

The isolation of many sites suitable for either small-scale or large-scale irrigation development needs to be recognized. Some technically attractive sites lie where any grain crop would be subject to prohibitive transport costs, and maybe even where people will be unwilling to live. The delivery of diesel supplies or spare parts for several hundred kilometers upriver is not something to be undertaken lightly. Many of the early projects undertaken in response to the 1968-73 drought floundered for economic and logistic support reasons which ought to have been anticipated by the planners. In the short run these factors will probably determine where irrigation development takes lasting root.

Even when most irrigators are clustered within reach of markets, a logistic/support breakdown can occur. One danger is that a donor will

bring in "orphaned" types of equipment which cannot be locally serviced. Another is that because of foreign exchange shortages, fuel deliveries are curtailed. The aggregate modeling of pump supply networks is not something water engineers are accustomed to doing, but it might well merit their further attention given what we know about the difficulties which other African countries are experiencing these days. Such analysis would also have direct applicability within the pastoral sector, which depends upon diesel pumps. On the plus side, most Sahel countries share relatively easy access to European equipment suppliers, an argument for leaving the choice of brands to local market forces.

The 1968-73 drought brought a large number of external voluntary agencies into action within the Sahel. Many for obvious reasons concentrated upon small-scale water development. There have been hundreds of wells dug, dams built and other "intermediate technology" interventions tried. With the benefit of hindsight, we should realize that even at a small scale there have been difficult technical problems to overcome -- ones which have defeated many well-intended non-governmental organization (NGO) projects. This valuable experience needs to be tapped, since the constraints affecting small NGOs are simlar to those which individual entrepreneurs and small firms face.

The drought also motivated increased attention from the larger donors. When funding eventually became available, it seems that the individual donors sometimes had difficulty deciding which strategy to follow. For whatever reasons, a substantial proportion of Sahel aid seems to have gone into the several thousand technical studies, making the Sahel one of the better studied parts of the modern world (see Appendix A). Unfortunately, much of this work (by academic researchers and consultants alike) was confined to the customary disciplinary frameworks. Our understanding of the individual parts to the problem today greatly exceeds our ability to see how these components interact within the larger regional system. A major benefit of an on-farm orientation to water management is its synthesizing, integrative concern with overall farm welfare rather than with increased water deliveries per se. This multidisciplinary, integrative perspective is greatly needed in the Sahel, where up to the present farming systems projects are being approved which exclude irrigation, while river basin management studies ignore the needs of pastoralists and livestock studies fail to consider social forestry. A drought makes obvious the interconnected nature of life in a semiarid environment, and sometimes the proximate causes of the disaster are not the longer run reasons for the ecological collapse (the main point of Franke and Chasin's excellent introductory treatment, Seeds of Famine, 1980).

To the lasting credit of the Sahel nations, their own response in 1973-74 was to create a planning organization called the Permanent Interstate Committee for Drought Control in the Sahel (or CILSS). This organization was charged with the task of seeing to it that long-run solutions to the poverty and vulnerability of the Sahel might be found. The Sahel governments also agreed to plan for their external needs in

liaison with the Club du Sahel, the donors' counterpart to CILSS. The actions taken by CILSS and the Club du Sahel merit book-length treatment (see Lateef's Crisis in the Sahel, pp. 68-69). A basic feature of the CILSS approach has been to plan separately for irrigation and rainfed agricultural development, and to divide measure between short, medium and long-term initiatives. This emminently reasonable procedure has generated a continuing series of technical monographs on the agricultural situation in each of the Sahel countries. For our topic, the key starting work is therefore the Club/CILSS review of irrigated agriculture in the relevant country, e.g., Development of Irrigated Agriculture in Niger (Sahel D[79]46) or Development of Irrigated Agriculture in Mali (Sahel D[79]42).

Large-Scale Irrigation

In addition to background research, donors accepted the Club du Sahel's view that the region's difficulties stemmed in large part from lack of infrastructure. In the irrigation sub-sector, this has been translated into an open-ended commitment to support the multi-state, river basin management authorities which came into vogue in the early 1970s within the Sahel. Today these exist for most of the major rivers (Senegal, Gambia and Niger) as well as for the Chad Basin (see Table 3). While the Senegal system, the Opération Mise en Valeur du Fleuve Sénégal (OMVS), is the farthest advanced, the Niger River system exceeds it substantially in regard to the size of the impact zone.

There are several disturbing features about the productivity of investment in river basin authorities of this type. These include:

- River basin management assumes accompanying land-use management. In fact, land use is largely uncontrolled throughout much of the Sahel, with consequences which may negate significant features of the water management strategies.

- A key presumption of engineering interventions to increase river management is that regularized flow increases benefits to the population. For many Sahel farmers, this is not necessarily true.

- Interstate parastatal organizations have a notorious record in Africa, and tend to become emasculated by internal tensions mirroring members' rival interests. All the major river basin agencies are multinational in character, and will be forced to implement their plans on top of those of existing national agencies.

- Large bureaucratic organizations in the region such as the Office du Niger suggest that these agencies will also suffer from pronounced managerial bottlenecks.

- The production estimates which have been used in preliminary planning are often wildly optimistic, being derived in the

irrigation sector from crude estimates of irrigable soils multiplied by assumed per ha yields. Actual schemes already on the ground in the same areas are not being expanded according to target and are not -- with the possible exception of some of the Office National des Aménagements Hydro-Agricoles (ONAHA's) perimeters -- realizing planned yields.

- Most importantly, the larger projects are being developed in ignorance of the full range of impacts upon downstream users. For the Niger's Inland Delta, upstream "development" could spell disaster.

These general observations about the likelihood of negative impacts from the river basin investments can be supported from the micro-studies which have been done to date, though the officials involved prefer to speak "off the record." Let us take as our example the Senegal River system, which is by far the best studied. The supposed navigational benefits neglect the fact that the Kayes area of Mali, which is to receive year-round navigabiilty, is already served by underutilized rail connections and that the downstream section of the river which is the most navigable currently carries the least amount of river traffic, while existing boat capacity upstream "far exceeds the amount of material actually transported" (Miller, 1984). Then there is the matter of the Diama Dam, which has been constructed on the delta as a barrier against salt-water incursion up the river during times of low flow. If, to the contrary, the salinity in the Senegal delta originates from the subsurface water table kept partially in abeyance by existing freshwater flow, then the Diama Dam may actually increase surface salinity by raising the water table and altering freshwater flow (Miller, 1984). Another neglected cost is the loss of fishing in the delta, which has been a substantial source of income to local households in the past. As for the upstream dam at Manantali (on the Bafing tributary in Mali), the plan calls for a transition away from flood-recession farming to controlled irrigation of 47,000 ha made possible by the dam. Given the slow rates of expansion in irrigated agriculture which the OMVS states have been able to achieve to date, the low productivity of Mali's other bureaucratically-sponsored schemes, and the likelihood that peasants will resist relocation and the transition to double cropping, we are justified in questioning whether the anticipated production increases will occur.

If the actual productivity increases promised by these large schemes do not materialize, this will have serious consequences at the local and the national levels. Locally, we can predict that water users -- farmers, fishermen, river transporters, etc. -- will be quite adverse to paying user fees of any kind. In turn, the lack of immediate economic benefits will reduce the incentive for member states to pay their allocated portions of operational costs necessitated by the new dams and other water control structures. The railway system will become even less profitable than it is now.

At the national level it should be anticipated that project returns will be low and many projects will be unable to cover the recurrent costs

required for continued support and maintenance. This is, in fact, what has already been occurring throughout the Sahel zone (Gray and Martens, 1982; CILSS, 1982). Gray and Martens point out that the Sahelian countries already employ a full arsenal of tax measures, that governments are pre-empting available credit to support their inefficient state enterprises, and that foreign reserves are being drawn down. In such circumstances massive new capital development schemes may well presage economic disaster, as they have in Ghana and Tanzania. The low productivity of irrigation investments may be only the extreme case within a larger spectrum on non-viable rural development projects, few of which can support themselves from the increased revenues they were supposed to have generated.

Why then are such projects likely to persist? For national governments the most important reasons are the prospects for hydroelectric power generation and mineral exploitation. If we return to the Senegal River example, damsites have been identified capable of producing 4,733 megawatts, of which 3,384 would come from Mali's First Region. In the same region are found two billion tons of iron ore (500,000 easily exploitable) and more than 800 millions tons of high alumina content bauxite ore. If we add in 600 million tons of iron ore from Senegal's Falémé Region, it is clear why the two states have been willing to cooperate within OMVS.[5] All the Sahelian nations have witnessed the prosperity which Niger reaped in the 1970s from its uranium mining (now in marked decline because of low prices). For poor landlocked states with little to sell internationally, the prospect of cheap power development coupled to mineral exploitation and potential industrialization is almost irresistable, no matter how dubious such hopes might appear from a world market perspective.

For the donor nations the river basin authority concept was welcome for several reasons. It seemed to offer a mechanism for combining expensive technical inputs (hydrological surveys, traffic projections, etc.) under a single program serving several countries. The authorities being created were autonomous organizations, which greatly simplified donor negotiations and contractual matters. The procedures for multi-use water resource planning were already developed and in use elsewhere. There were precedents to show how two states could share the allocation of water rights, e.g., the Columbia River. And the organizational model had a respectable pedigree, going back to the Tennessee Valley Authority in the U.S.A. and a direct copy, India's Damodar Valley Authority.

However, while the river basin authority has been a useful vehicle for funding research and planning activities, where the implementation of irrigation is concerned countries have been unwilling to yield operational control to the multinational organization. Instead, the usual pattern has been to form separate implementation agencies within

---

[5]Figures drawn from an OMVS publicity document, River Senegal: Mali-Mauritania-Senegal, 1979.

each country (see Table 3). These are in turn divided along sectoral lines, and sometimes are also confined to particular regions of the country. Of necessity, therefore, the overall authorities like OMVS and OMVG become high cost organizations superimposed on top of executive agencies at the national level which partially overlap their functions.

While the Sahel's irrigation agencies are broadly similar in structure and purpose, they differ greatly in terms of their relative size and respective resource endowments. Mali's OVSTM (active in its First Region) has a staff of only about 50, whereas by way of contrast SONADAR in Mauritania has roughly 325 and SAED across the border in Senegal has about 1,200 (down from nearly 2,000 in 1980).[6] An irrigation bureaucracy of some type is probably inevitable when large areas must be dealt with centrally, e.g., the 53,000 ha in the Office du Niger or even the 7,400 ha which constitute Senegal's privately owned Richard-Toll sugar plantation. Such schemes still constitute the larger part of "official" irrigation within the Sahel. In Senegal's portion of the Senegal River Basin, for example, out of 23,000 ha developed for irrigation about 21,000 ha occur within eleven large (500 ha or above) schemes found in the delta. However, over 90 percent of Senegal's total number of schemes are small, less than 500 ha each, though they cover only 16 percent of the total irrigated area. According to figures cited by Miller (1984) the estimated construction costs per hectare for small-scale schemes are less than $5,000 in contrast to costs of as high as $10,000 to $15,000 per hectare for large-scale projects. Yet on the whole, the per hectare productivity has been higher in small-scale than in large-scale schemes.

To explain the weak performance of some of the Sahel's existing irrigation agencies, one is inevitably drawn into an analyis of bureaucratic functioning. Any organization which employs hundreds of water guards, survey assistants, field supervisors, etc., is bound to become a special interest group resistant to external accountability. The record of parastatal operations in the Sahel is not, on the whole, encouraging. Yet none of the major reports on irrigation in the Sahel deals convincingly with the organizational issues associated with African field bureaucracies. Compared to the Sahel's marketing boards, the irrigation authorities are not especially large. Nevertheless, to try to support hundreds of minor officials from overhead charges levied against smallholders represents an enormous financial burden for the rural sector to bear. It is said that SAED in Senegal had an operating deficit of over 800 million CFA francs in 1978 (Miller, 1984). In place of large, hierarchical organizations of this kind we envision a need for a relatively small, professionalized cadre which is mainly concerned with assisting farmers at the start-up phase of scheme development.

---

[6]Figures in this paragraph are derived from a useful overview of irrigation development in the Senegal Basin, Chapter 2 in Miller (1984).

Emergent Issues

We can summarize the issues which emerge from our overview of irrigation in the Sahel as follows:

- Populations continue to rise throughout the Sahel at a time when labor migration opportunities are being curtailed. A primary motivation for irrigated production is the emerging food deficit, which under current trends can be expected to become steadily worse.

- Major water control investments are being made on both the Senegal and Niger Rivers, which afford the technical prospects for increased large-scale irrigation. For these projects, the question is basically who will operate the new systems, what crops can be grown profitably and how displaced local populations will participate -- i.e., as laborers, tenants or farmers.

- There are irrigation agencies already established within most Sahel nations. Some supra-community assistance in site preparation is often required, but the degree of bureaucratic intervention is variable and should be closely examined in project design. The Sahel nations could benefit greatly from more cost-effective operation of the many bureaucratic agencies which sponsor rural development activities.

- Existing small-scale schemes, which are mainly clustered in the Senegal River Basin, appear to be more productive per unit of investment than are large-scale schemes. A key unresolved question is whether bureaucratic agencies like SAED (in Senegal) or ONAHA (in Niger) can promote and assist small-scale schemes in a way which is cost-effective and yet does not alienate farmers.

- There is substantial potential for further expansion of small-scale irrigation in Mali and Niger -- more in Mali than in Niger -- but such investments will encounter great logistic, social, economic and technical problems. This report is a preliminary attempt to identify the likely points of stress which better organization of water users might be able to alleviate.

CHAPTER III

BASIC CONCEPTS

Defining Irrigation

In the Sahel situation, how one defines "irrigation" has a large effect upon recommendations. Differences stemming from definitional confusion explain in part the vastly divergent estimates of "irrigable" land in the zone. Let us briefly note five areas where conceptual confusions have hampered the adoption of sensible and necessary water development strategies suited to the Sahel's particular needs:

The Small- to Micro-Scale Continuum

Improved water delivery to plants in the Sahel occurs along a spectrum ranging from conventional flood-basin irrigation schemes of thousands of ha down to the microscopic instances of calabash delivered water onto plots of 1 m x 1 m (the Dogon hand-watering system). At the small end of the scale there is no clear cutoff between technological alternatives. We saw a diversity of opportunities for very small improvements, such as would follow from the installation of a single pump. Many of these lie well below the threshold which a field irrigation engineer is used to dealing with. Such systems are more nearly horticultural in nature, even though the plants may be a grain crop like wheat or sorghum. Reports written by civil engineers on prospects for irrigation in the Sahel tend to overlook the small-scale end of the spectrum, where we believe much potential for improvement can be found.

Total versus Partial Water Control

Again, some of the engineering reports apply the textbook definition of "irrigation" as total water control within a given farming system. The ideal of "total water control" is rarely achieved for long for several reasons:

- Even within large systems theoretically designed to achieve "total" water control there are typically so many situational constraints -- seepage losses, clogged drains, pumps not working, etc. -- that in few areas can it be claimed that water delivery is under a high degree of control.

- As a general rule land use in the Sahel is not under planned control so that systems are rapidly affected by incursion, siltation, sheet erosion and other environmental changes.

- On the larger perimeters we often find that while one cropping

Previous Page Blank

cycle is grown entirely under irrigation, the other is not (because it overlaps the rainy season).

- The sandy soil/market gardening situation served by small pumps (a major niche for potential development) is typically characterized by supplemental irrigation, high water losses and the sharing of water between multiple uses.

- On the whole the combination of high fuel and transport costs, unreliable servicing, equipment breakdowns and poor field leveling makes partial water control the best that can be expected under average field conditions. The main implication of this observation is, of course, when it comes to estimating the yield improvements which are supposed to result from given irrigation investments.

Irrigation Under Multiple Use Situations

There is a tendency within the existing reports on the Sahel to distinguish sharply between irrigation and rainfed farming, implying that the needs of each can be planned for separately. In the same way, both research and project assistance have treated crops, livestock and social forestry as distinct subsectors. A main benefit to be derived from the on-farm water management perspective is the realization that in semiarid environments water becomes the limiting factor affecting all living systems: crops, trees, goats, camels, cattle, fish and the farm family alike. In actual fact, within the zone where irrigation is most attractive along the Niger and Senegal Rivers there is a complex interweaving of occupations and land use. Many farmers who hold irrigation rights also attempt rainfed farming, keep cattle and may grow horticultural crops (spice, onions) for commercial sale. Irrigation perimeters usually house large herds of cattle at certain seasons and sometimes also contain fishing villages. All along the rivers one sees people occupied in trade, transport and other non-agricultural occupations (e.g., basket weaving). During the dry season "irrigation water" must be shared between plants, cattle and people. Fisherfolk rely on the riverine system for their livelihood, though some species of fish constitute a major pest in the flood rice systems (e.g., Opération Riz-Mopti). While on the larger perimeters irrigated crop production may be the dominant use of water being provided, it is never the sole use. This fact needs greater recognition in the design of future irrigation projects within the Sahel.

Community- versus Communally-Managed Systems

It became apparent in field interviews that the term "community-managed systems" is subject to some misunderstanding. From an engineering viewpoint, any irrigation system (or sub-component thereof) which is small enough so it does not require the continuing presence of

outside technological assistance (usually in the form of some sort of irrigation agency) can be termed a community-managed system. In WMS-II we have further agreed that if there are those who can manage to irrigate on their own, this is a welcome development since it lessens the tension put on the government's own scarce expertise. From a social science viewpoint, on the other hand, there is a tendency to equate community-managed systems with communally-managed irrigation. The latter would be defined as a situation where irrigation resources are jointly developed by farmers and are managed on behalf of and for the benefit of the whole community. This second situation is quite rare in Africa, if we exclude for the moment the large "official" schemes. While there are many instances of self-reliant irrigators -- i.e., "community-managed" systems by our first definition -- these are usually not jointly operated. If more than one farmer is involved the others are likely to be clansmen or the better-off members of the community participating as individuals in a commercial venture. Tubewell pumping could easily lead to this type of "community-managed" system, but would not necessarily bring about the sharing of water and of control over the system. In our visits we stressed that our goal was to explore the potential for community-managed systems in general, whether or not these happen to have a substantial communal element in regard to how they were developed and are managed at the local level.

Types of Farmer Participation

Following Uphoff, Cohen and Goldsmith (1979), many authors recognize four types of participation involving four kinds of participants. The types of participation include: (a) decision-making; (b) implementation; (c) benefits; and (d) evaluation. The participants may be: (a) local residents; (b) local leaders; (c) government personnel; and (d) foreign personnel. In applying this categorization to the Sahel we found that there are significant additional distinctions necessary when one is analyzing irrigation farming. The fact is that farmers can potentially participate in many aspects of scheme planning, construction, operation and maintenance (see Table 4). We feel the literature fails to stress the potential for farmers to be involved in field layout and channel location, just as it took a field visit to ONAHA in Niger to make us aware of the many benefits which can result if farmers themselves are hired to do large-scale construction in their area.

Types of Traditional and Modern Irrigation

Traditional Labor Intensive Systems

Three important traditional systems that are found in the Sahel are Calabash irrigation, Shaduf irrigation and Dallou irrigation.

Calabash Irrigation. While the irrigation engineer may not consider hand delivery of water onto a field as irrigation, it is a labor

TABLE 4

TYPES OF FARMER PARTICIPATION

Within irrigation development, there is a range of possibilities for farmers' involvement. These include:

1) problem diagnosis
2) project location
3) field and channel layout
4) land ownership
5) financing of capital works
6) construction of capital works
7) ownership of roads and access rights
8) selection of service agencies
9) selection of enterprises
10) decisions on enterprise scale
11) deciding on water rules
12) water delivery schedules
13) resolution of disputes
14) sharing of operating expenses
15) sharing of input orders
16) access to agency employment
17) policing of members' obligations
18) sharing of field equipment/operations
19) shared storage/transport
20) shared system maintenance
21) access to profits
22) sharing of liabilities
23) sharing of environmental impacts
24) degree of control over houseplot
25) right to determine inheritance

intensive system that offsets the vagaries of rainfall and provides a reasonably reliable crop. Calabash irrigation is thus a system of hand watering from streams or wells and is found in scattered isolated areas throughout the Sahel with usually vegetables being the dominant crop grown.

Shaduf Irrigation. The shaduf is a traditional water lifting device that has probably diffused into the area from the Nile Valley. The shaduf comprises a long-suspended rod with a bucket at one end and a weight at the other allowing water to be lifted and swung around for depositing into irrigation channels. This method is found especially in Southern Niger along the Komadougou River.

Dallou Irrigation. This is not a widely practiced system but is important in the foothill areas of the mountain oases of Niger. Water is lifted by oxen from wells that are 4 to 5 meters deep. Through gravity flow water is distributed throughout the plot by channels. The garden plots are usually about 1 ha in size with a variety of crops among which wheat, maize, millet, potatoes, tomatoes and onions are the most important.

Natural Flood Irrigation

Two types of natural flood irrigation occur in the Sahel.

Flood Plain Irrigation. In flood plain areas of rivers and streams where annual flooding occurs rice is quite often planted. Rice is usually sown at the beginning of the rainy season and allowed to germinate before the arrival of the floodwaters. This system is risky and the rate of success is not high. Problems arise with respect to the arrival of the flood waters which may bring excessively early or late submersion. Water may rise too rapidly; more than 5 cm per day for floating rice will drown the plant. Because of the high risk involved rice in many areas is a secondary crop with primary emphasis given to rainfed subsistence crops such as millet and sorghum cultivated above the flood plain level.

Depressional Irrigation (Bas-fonds). Another type of natural flood irrigation is often carried out in depressions (bas-fonds) where the water table rises during the rainy season to inundate the depression. Rice is the most common crop grown in these bas-fonds.

Recessional Irrigation (Culture de décrue)

In areas of natural flooding a common practice is to plant crops such as sorghum as the flood waters recede. Through the utilization of residual soil moisture the plant survives until the arrival of the rainy season. The plant matures with the onset of the rainy season and is harvested before the rising waters inundate the fields. This "culture de

décrue" is practiced extensively in the middle valley of the Senegal River, in the Lacustrine Zone of the Inland Delta of Mali and along the Niger Valley from Tombouctou into Niger. This system is usually individually managed.

Controlled Flood Irrigation

This type of irrigation permits the regulation of the rise of flood waters to 5 cm per day for floating rice and 3 cm per day for paddy rice. In some areas small submersible dikes are built around plots to inhibit the rapid rise of flood waters. These traditional systems of diking are still found in the Inland Delta of Mali and along the bend of the Niger River. With the application of more modern technology, dikes, canals and sluice gates have been constructed to control and drain the water from perimeters and protect the crop from rice eating fish. Such a system provides a greater reliability to the farmer for a successful crop and is usually a government-managed system.

Total Water Control

The introduction of full water control systems through the construction of dams, dikes, canals, drains and sluice gates provides a dependable supply of water and allows drainage of leveled plots. Both gravity flow systems and pump systems are found in the Sahel countries. One of the largest gravity flow systems is the Office du Niger in Mali, technically a fairly well-conceived scheme but because of management and social problems has never fulfilled expectations.

River Basin Development

Currently there is the development of interstate river basin authorities on the Senegal, Gambia and Niger Rivers. The Senegal River basin planning is well under way through OMVS, whereas the Gambia Basin planning is just getting under way with the Gambia River Basin Development Project (OMVG). The Niger Basin Authority has been created, but there has been very little accomplished and very little coordination between the Niger Basin States in terms of irrigation. A problem that may develop with the growth of the river basin authorities is the emphasis upon transportation and power generation to the detriment of irrigation.

Bureaucratic versus Participative Schemes

The above listing of irrigation types conveys the superficial impression that there is an array of technologies with different schemes coming at various points along a broad continuum. While a dispersal of types with varying characteristics is theoretically possible, in practice

irrigation is usually done under one of three organizational settings (Table 5). In this typology, which is derived from Miller's work in Senegal (1984), it can be seen that large-scale schemes in Africa are usually associated with bureaucratic control over most of the aspects we have already identified in Table 5. Such schemes, listed here as "Type I," are typically large-scale, capital-intensive and technologically advanced. Types II and III are, to the contrary, small-scale, have limited control over water and may employ traditional technology, e.g., the shaduf for water lifting. In Senegal Miller found a sharp break between the Type I and Types II/III. Most schemes were either quite large (500 ha or more) or very small (under 20 ha). We have expanded his listing of attributes in Table 5 to make clear the different preferences which these institutional models incorporate.

An examination of the diagnostic traits identified in Table 4 suggests that the root difference between "bureaucratic" versus "participative" managerial approaches is whether farmers' satisfaction or total scheme efficiency is being maximized. Or, in other words, the difference is a function of whose interests take precedence: the engineer's or the farmer's? The "rational" decisions a civil engineer might recommend to get maximum physical output from a given siteworks investment may, nevertheless, externalize other unexamined costs onto farmers. (On our visit to FAO in Rome we were told of an example from Egypt where engineers chose to do scheme repairs at just the time when farmers' needs for water were most critical.) From the farmer's perspective it is "rational" to prefer to irrigate during the day and not at night, to live in sight of the fields (for security reasons) and to control access onto the land. Engineering designs which assume 24 hour irrigation and which place farmers' residences far away entail other, continuing costs which farmers must pay.

From an African farmer's viewpoint of changing prices, unreliable water delivery, shortages of labor, multiple enterprises and varying access to credit and inputs, the "efficient" large-scale scheme may nevertheless represent a quite unfavorable production situation. The concept of "efficiency" is therefore inappropriate as a design criterion unless attention is paid to all costs of operation, the scheme's, the community's, the family's and the individual's, and not simply those associated with the siteworks investment.

Where organizatioal types are as contrasting as they are in this instance there is a tendency for proponents of either type to insist theirs is the intrinsically superior approach. In the Sahel one does not hear too much about the superiority of large-scale schemes; the Office du Niger's record is too widely known. Nevertheless, there are powerful pressures towards capital-intensive engineering devices and even greater degrees of standardization. At the other extreme some social scientists have been quick to claim that participative, small-scale schemes are inherently low-cost and high yielding, which of course they are not. Indeed, some of the Sahel's "small" schemes have been prohibitively expensive if one takes into account the few farmers actually assisted.

TABLE 5

TYPES OF IRRIGATION CONTROL

Tasks	Scheme Type		
	I Large-scale	II Small-scale	III Small-Private
Initiative	B	B	C,F,I
Construction	B	C	C
Training	B	B	C
Provision of inputs	B	B,C	C
Production decisions	B	C	C
Maintenance decision-making	B	C	C
Maintenance tasks	C	C	C
Water allocation	B,C	C	C
Conflict resolution	B	C,B	C

KEY: Those Responsible:

B = Bureaucracy (extra-local)
C = Community
F = Family
I = Individual

Source: Miller (1984, p. 86)

TABLE 6

TYPES OF IRRIGATION MANAGEMENT

Aspects	Type I	Type II
Scale	Large-scale	Small-scale
Cost allocation	Engineering costs minimized	Farm costs minimized
Major channels	Dictated by terrain	At boundaries
Field layout	Uniform grid	Conforms to land rights
Field operations	Standardized timing at agency's convenience	Variable timing at farmers' convenience
Land rights	Held by agency	Held by farmer
Enterprise mix	Single cropping at agency's discretion	Multi-cropping at farmers' discretion
Livestock access	Excluded	Included
Fuel supplied	Excluded	Included
Domestic water use	Excluded	Included
Field bunds	Minimal construction requiring protection	Used for transport and access
Residences	Excluded	Interspersed within field units
Water scheduling	On rotation or at off-peak periods	On demand/or at peak and critical periods
Managerial structure	Bureaucratic	Participative
Optimization	Scheme efficiency	Farmers' satisfaction

What this report advocates is the need for greater interpenetration of desirable features between small- and large-scale types. For example, there is no necessary reason why "modern" technology must be large-scale and capital-intensive. In the field several engineers pointed out to us attractive small-scale innovations in irrigation technology which Sahelian farmers might adopt. Here the French irrigation engineers have a good record, having experimented with movable platforms for riverside pumpsets. But there is much more that can be done. At the other extreme, the large-scale schemes could greatly benefit from a devolution of functions to farmers and to their communities and from a more flexible approach to design matters (physical and organizational). One must anticipate that over time operators will emerge who can manage intermediate-scale schemes, larger than 20 ha but not requiring the expensive infrastructure of the typical 1000 ha irrigation perimeter.

CHAPTER IV

IRRIGATION IN MALI

The Republic of Mali, frequently listed among the ten poorest countries of the world, is a country of limited resources whose poverty is compounded by its landlocked position and lack of adequate transporation. Located between 11° - 24° north latitude, Mali penetrates deep into the Sahara Desert. The majority of the 7 million population are subsistence farmers and pastoralists who survive in an environment where rainfall is highly variable from year to year and the spectre of failure of rainfed cultivation is a constant threat.

The Physical Environment

Climate

Much of the present-day poverty of Mali can be attributed to its environmental position astride three ecozones. Southern Mali lies within the Sudanic Zone where rainfall is sufficient for rainfed cultivation (1500 mm to 700 mm). In this zone the rainy season begins in April and lasts 4 to 7 months (Figure 1). North of the Sudanic zone rainfall decreases (700 mm to 200 mm) and the dry season in this Sahel zone lasts 7 to 9 months. Rainfed cultivation is precarious yet the vagaries of rainfall are offset by traditional irrigation in the vast Inland Delta and the Niger Bend which support relatively dense populations. North of the 200 mm isohyet true desert conditions prevail, an area that covers 60 percent of Mali's surface area. Except for a few scattered oases and mountainous areas that provide a reliable source of water, this zone is virtually devoid of population.

Southern Mali thus lies within the Sudanic zone with sufficient moisture for rainfed cultivation. Northern Mali lies within the Sahara where desert conditions prevail and nomadic pastoralism is a dominant way of life. Between these two extremes is the Sahel, a transition zone of marginal lands where there is an interdigitation of agriculturalists and pastoralists.

Hydrology

Mali is dominated by two major river systems, the Senegal and Niger Rivers, with their respective tributaries. Both rivers rise in the Fouta Djalon mountains of neighboring Guinea. The Senegal River flows from the southeast for approximately 100 km across western Mali before entering Senegal. Irrigation potential on the Senegal River of Mali is generally limited because of the rugged terrain through which it flows.

The Niger River flows for 1700 km in a broad loop from the southwest cutting through each of the ecozones to Tombouctou before flowing

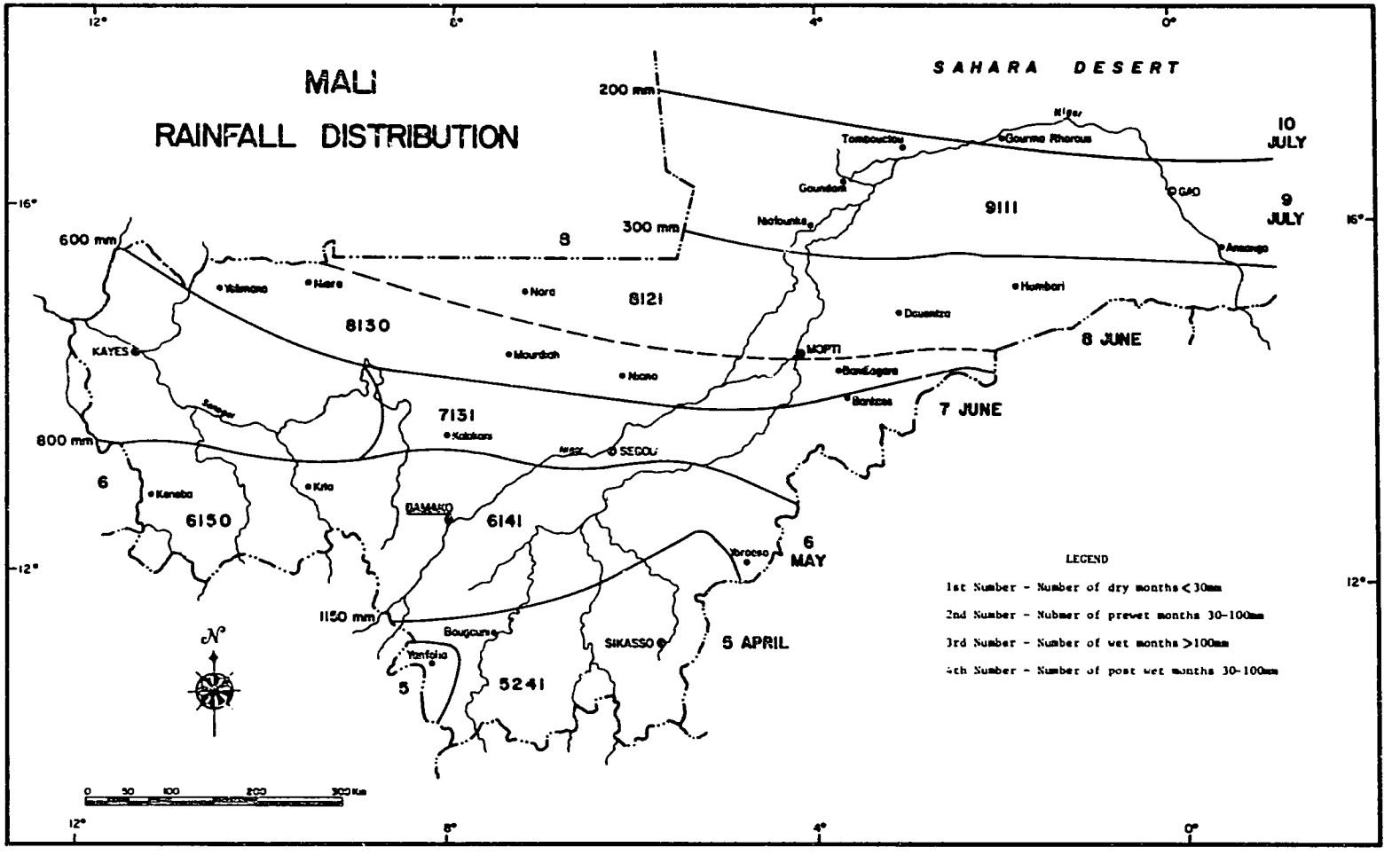


Figure 1. Mali Rainfall Distribution.

southeast into the Niger Republic. In many respects the Niger River and its tributaries are the lifeline of Mali with population concentrated along the river valleys and Inland Delta. The Inland Delta is an area of 20,000 sq km that floods annually and has become a focal point for the concentration of agriculturalists, pastoralists and fisherfolk who have adapted to the annual ebb and flow of the floodwaters. A diversity of crops are grown in this area by means of small-scale irrigation.

Irrigation Potential

The Government of Mali has made a commitment to the expansion of irrigation as a means of increasing food production and combating food deficits. At present there exists an estimated 130-150,000 ha of natural flood irrigation, 100,000 ha of controlled flood irrigation and 50,000 ha of full water control. Unquestionably, Mali has the greatest potential for irrigation among the Sahel countries of West Africa with a conservative estimate of over 1 million ha of potentially irrigable land. The potential for irrigation is not evenly distributed throughout the country but is concentrated in the Inland Delta and along the Niger River. In many respects this area has the potential to become the breadbasket of West Africa.

Irrigation has been practiced by many people and the systems prevalent in Mali today include traditional hand watering, natural flood irrigation, controlled flood irrigation, recessional irrigation and total water control systems.

Institutional Structure

There is no single government institution that has sole responsibility for the development and organization of irrigation. Agricultural development, under the aegis of the Ministry of Agriculture, is delegated to various regional development organizations. The Office du Niger is a large-scale irrigation scheme which is responsible for the development of irrigation in the Inactive Delta. It is an institution with financial and administrative autonomy.

In other areas of the country agricultural development is the responsibility of the Opérations such as the Compagnie Malienne de Développement des Textiles (CMDT) in southern Mali or Opération Vallée du Sénégal, la Térékolé et du Lac Magui (OVSTM) in the Kayes Region (Figure 2). Usually these Operations will have a division that oversees irrigation development. Other Opérations such as Opération Riz-Ségou and Opération Riz-Mopti have been created for the sole purpose of increasing rice production through the development of irrigation. There are also the smaller Actions such as Action Blé-Diré and Action Riz, Sorgho-Gao, where development is at a smaller scale than the Opérations. All these development institutions have their own extension services, administration, study services and programming departments.

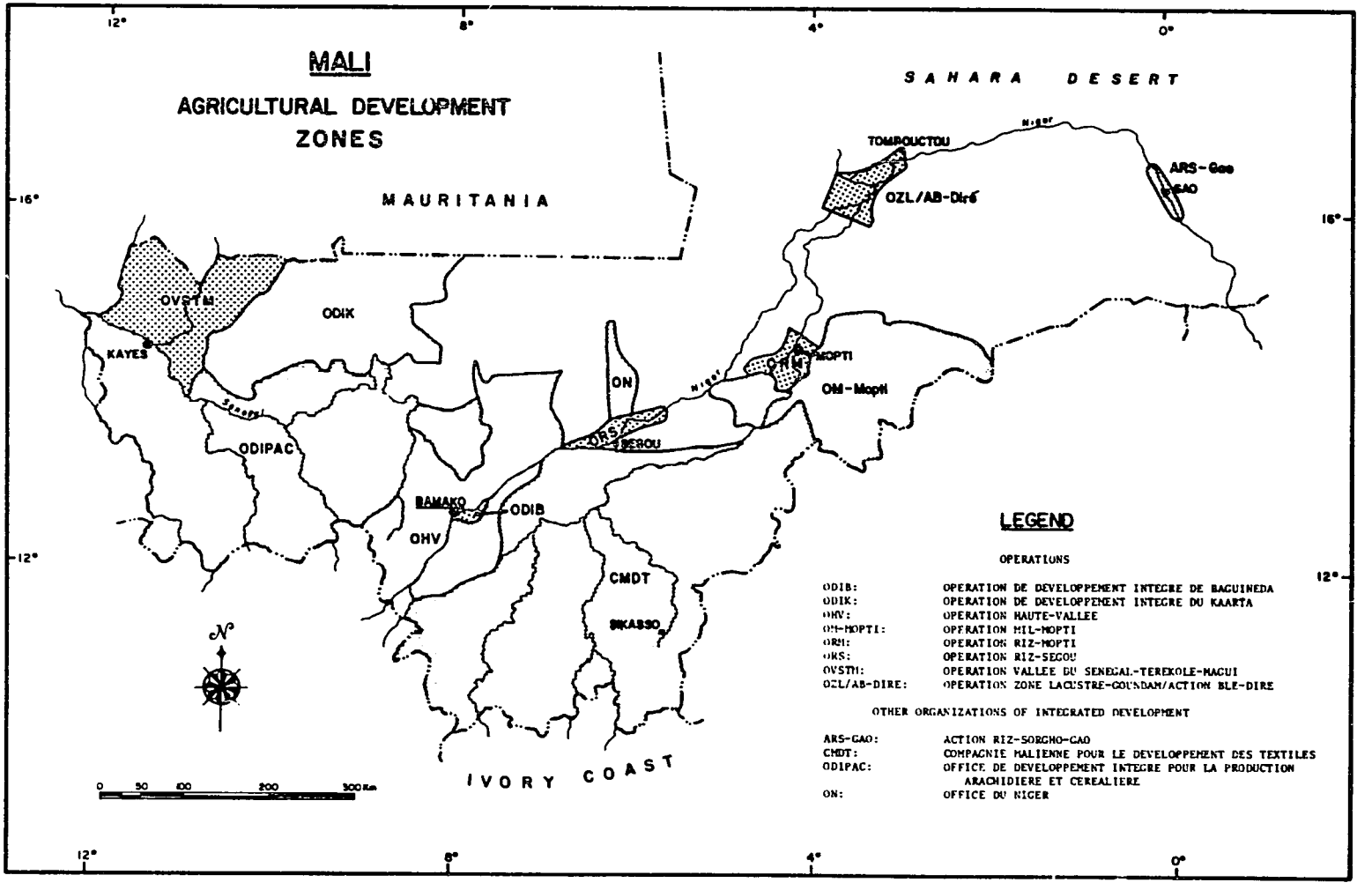


Figure 2. Agricultural Development Zones -- Mali.

Planning and design of dams and irrigation networks is the responsibility of the division of Génie Rurale (Rural Engineer) of the Ministry of Agriculture. The actual construction of dams and irrigation networks is the responsibility of the Office des Travaux d'Equipment Rurale (OTER -- Office for Works of Rural Equipment). Agricultural experimentation, socio-economic surveys and monitoring is the responsibility of the Institut d'Economie Rurale (IER -- Institute for Rural Economy).

There are few, if any, communally managed irrigation systems in Mali. Most small-scale, traditional systems are individually managed. By contrast, the large-scale, controlled flood irrigation and total water control systems that depend upon modern technology have brought about government intervention and the creation of bureaucracies. Inevitably this has led to a top-down approach and has generated difficulties in the smooth functioning of the irrigation perimeters. The Office du Niger is a classic example of management problems and animosity developing between government and individual farmers. Similar problems have been observed in the small-scale Actions.

Irrigation Perimeters

There presently exist 157,000 ha on 69 irrigation perimeters in Mali (Table 7). This figure includes the 56,000 ha of the Office du Niger. The existing perimeters can be conveniently divided into those developed along the Senegal River in the Kayes Region and those in the Niger Basin which include perimeters developed in Southern Mali, Upper Niger Valley, Segou Region, Inactive Delta, Mopti Region, Lacustrine Zone and the Niger Bend (Figure 3, Table 8).

The Kayes Region

The Kayes Region falls within the Operation Mise en valeur du fleuve Sénégal (OMVS) and is marked for future investment from USAID. The Integrated Development Project will be funded by USAID and will include an irrigation component. There is, however, only minimal potential for irrigation in the Kayes Region. At present there are only about 13 small-scale projects covering about 220 ha (Table 7). Future potential is estimated to be only about 1000 ha. Development of the area is under the jurisdiction of Operation Vallée du Sénégal-Térékole-Magui (OVSTM) which is responsible for extension, inputs, marketing and group management. Because of limited funding and staff, extension and management have been minimal. There has, however, been cosiderable local initiative through the Périmètre Irrigué Villageois (PIV) that have requested the development of irrigation and have even organized themselves for clearing and constructing canals.

Irrigation development in the Kayes Region faces many problems, among which are the environmental constraints, the high cost of pumping

TABLE 7
EXISTING IRRIGATED PERIMETERS

Name	Area ha	Name	Area ha
NIGER RIVER BASIN			
Southern Mali		Upper Niger Valley	
Gouéné	65	Nanguna	
Kado	200	Bankoumana	650
Korgouan	160	Krina	200
Loulouni	300	Samanko	500
Doumanaba	1,200	Baguineda	3,000
Kléla	100	Ségou	
Touroumadie	200	Tamani	8,900
Banbadougou	150	Farako	4,000
Langourala	280	Dioro	15,200
Samorossoni	140	Sosse-Sibila	3,450
Niéna	100	Ké-Macina	2,250
Farako	760	San Ouest	1,000
Sinkolo	70	Pénenesso	2,500
Dalabani	650	Kouniana	750
Faboula	60	Sourbasso	600
Inactive Delta		Zangasso	
Office du Niger	56,000	Lacustrine Zone	
Mopti		Kassoum-Soumpi	600
Saron-Tohbo	4,000	Koboro	2,500
Sofara	700	Zangaaso	
Torokoro	510	Dangha	2,500
Saré-Mala	3,120	Lac Oro	10,000
Soufouroulaya	4,500	Gara	1,200
Mopti-Sud	3,900	Dire	120
Mopti-Nord	5,800	Koryoumé	600
Ibétémi	300	Bourem Inaly	200
Karbaye	500	Bourem Sidi Awar	
Tiroguel	1,050	Niger Bend	
Ouro-Néma	4,130	Tacharan	2,000
Dramba-Kourou	400	Gargouna	600
Dia-Tenenkou	6,500		
SENEGAL RIVER BASIN			
Upstream from Kayes		Downstream from Kayes	
Sapou Kakoulou	15	Sobokou	40
Fanguéné	15	Moussala	25
Maloum	20	Gakoura	25
Dioumekon	12	Sebetokoura	7
Moussaguya	8	Kamankolé	10
		Danfagabougan	10
		Diala	12
		Samankidi	20

Source: Projet Inventaire des Ressources Terrestres, Mali. Bamako: USAID/TAMS, 1983.

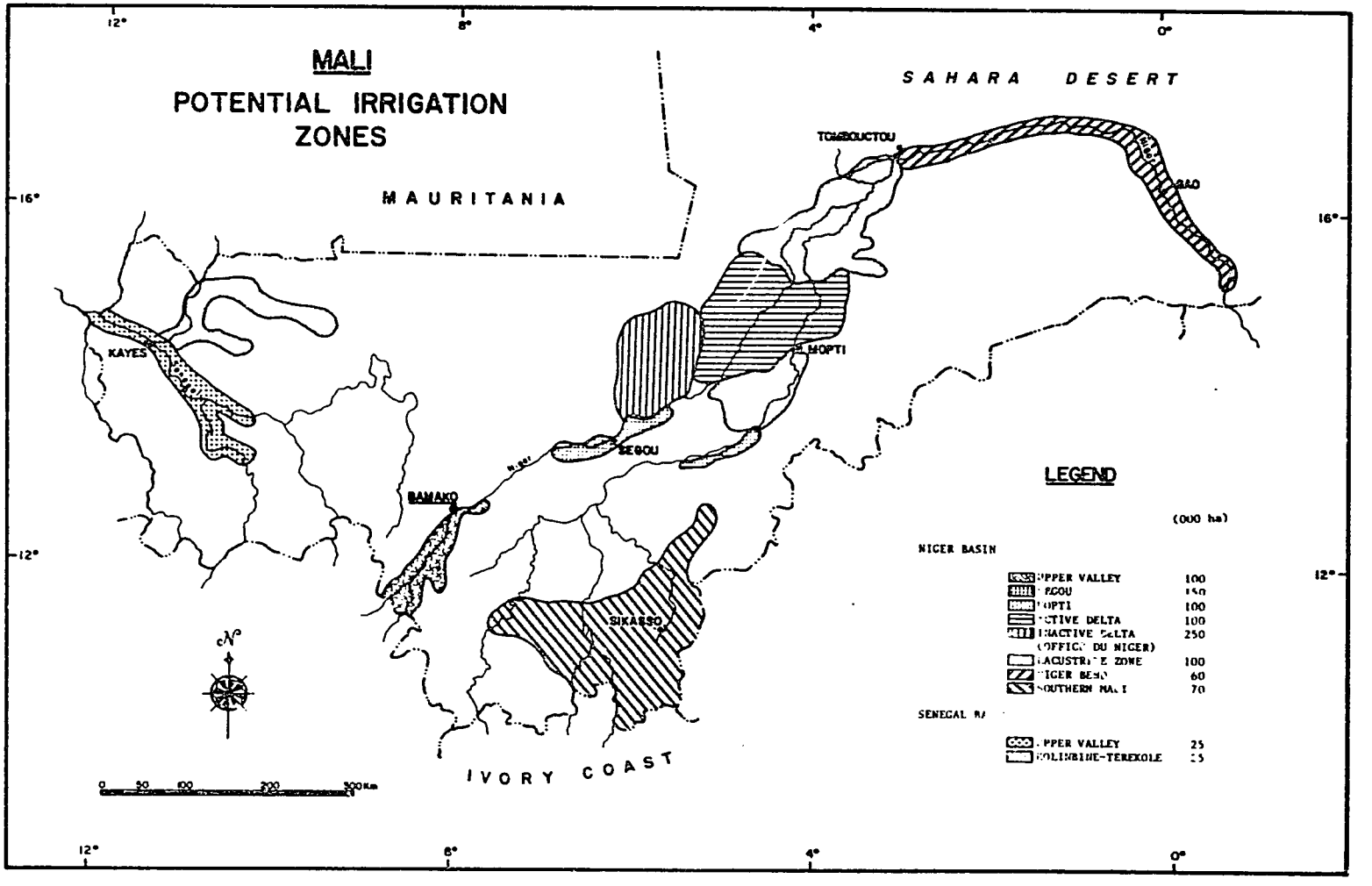


Figure 3. Potential Irrigation Zones -- Mali.

TABLE 8

IRRIGATION IN MALI 1982

IRRIGATED PERIMETERS

	Total Control		Controlled Flooding Recessional	
	1982 (000 ha)	2000 (000 ha)	1982 (000 ha)	2000 (000 ha)
Niger Basin				
Upper Valley	3.5	5.8	1.0	5.2
Segou	--	--	39.0	79.0
Office du Niger	53.0	93.0	3.0	--
Mopti	--	--	35.0	59.0
Lacustrine	0.4	5.0	18.0	38.0
Niger Bend	--	0.1	2.6	5.0
Southern Mali	--	--	4.7	5.5
Senegal Basin				
Upper Valley	.2	2.8	--	3.0

Source: Projet Inventaires de Ressources Terrestres, Mali. Bamako: USAID/TAMS. 1983.

and the relative isolation. The focus on market gardening whereby each farmer is provided with a 25 square meter plot for vegetables and a 50 square meter plot for other crops has raised a problem of uncertain markets for the crops being produced. Isolation, limited access and limited markets bring into question the viability of the expansion of irrigation in the Kayes Region.

Southern Mali

Southern Mali lies primarily within the development region of the "Compagnie Malienne pour le développement des Textiles" (CMDT) where cotton has been an important focus as a cash crop. Since 1977 Fonds Européen de Devéloppement (FED) financing has supported Opération Riz-Sikasso for the expansion and improvement of bas-fonds rice cultivation through CMDT. Insofar as rainfed cultivation is more reliable in this zone, there has been little incentive to expand irrigation. Rice production remains of secondary importance and is primarily the responsibility of women, with the result that most time and effort is expended in producing the traditional subsistence crop of sorghum, with cotton as a cash crop. Within Southern Mali there is an estimated 4,700 ha of irrigated land and an estimated potential of about 70,000 ha.

Upper Niger Valley

In the area along the Niger River from Bamako to the Guinea border there is an estimated potential for irrigation of 100,000 ha. While this figure may be overly optimistic, there is nevertheless considerably more potential than the 3500 ha presently being cultivated. Most of the irrigated land in the Upper Niger Valley is in the vicinity of Bamako where private gardens produce a variety of vegetables and fruits for the Bamako market. Many of the plots are owned by businessmen and civil servants who provide financing for a pump or perhaps canal construction. Irrigation is usually by pumping from the Niger River or shallow wells or by manual lifting. Considerable hand watering of vegetable plots is carried on within Bamako on vacant lots.

The recently constructed Selingué Dam on the Sankarani River provides Bamako with a more reliable source of hydroelectric power. Plans are underway for the construction of an 1100 ha perimeter that will permit through gravity flow a double cropping of rice. Several other rice perimeters exist along the Niger River and include Bankoumana, Samanko and Baguineda where both rice and vegetables are cultivated. The controlling of the flow of water by the Selingué Dam will increase the low water flow in the Niger and will probably enhance the operation of the Office du Niger.

Ségou Region

The Ségou Region extends from Ké Macina to the east of Ségou along the Niger River to Farako to the west of Ségou. It also includes the

rice perimeters around Kirina and San on the Bani River. This region falls under the development jurisdiction of Opération Riz-Ségou (ORS). There are approximately 39,000 ha of controlled irrigation in the area with an estimated potential of 200,000 ha irrigable land. ORS has elaborate plans to expand irrigation and work out some of the problems encountered in the exisitng perimeters. Some of the problems encountered include maintenance, leveling and management.

Inactive Delta

The Inland Delta of Mali is divided into three physiographic regions: the Active Delta (Delta Vif), an area that is flooded annually; the Lacustrine Zone (Zone Lacustre), an area of lakes and dunes; and the Inactive Delta (Delta Mort), an area that previously had been inundated in the recent geologic past (Figure 4). The Inactive Delta is the site of the Office du Niger (ON), a large-scale irrigation scheme that began in 1932. The ON has never measured up to expectations and has been beset with management, economic, maintenance and social problems since its inception.

The Office du Niger is a total water control system that utilizes water from the Niger River. The construction of the Markala Dam resulted in raising the Niger River, and through gravity flow, water is distributed via the Canal du Sahel (25 km) north to Niono and Sokolo and via the Canal de Macina (14 km) east to Kolongolomo. The Office du Niger was originally designed to irrigate 150,000 ha; however, only about 56,000 ha have been developed. There are approximately 40,000 ha in the Sahel sector, most for rice cultivation, although there are 3,000 ha of sugar produced on two perimeters at Siribala and Douabougou. There are approximately 14,500 ha of irrigated rice cultivation in the Macina Sector.

The Office du Niger supports approximately 51,000 people cultivating 39,000 ha of rice. Almost 90,000 tons of rice are produced annually with 65,000 tons marketed officially. Despite being the major rice producing region of Mali, the Office du Niger is fraught with problems and as a consequence has never measured up to its potential. The lack of upkeep and maintenance of the infrastructure has resulted in the abandonment of 14,000 ha. Settlers have been abandoning the project because of the artificially low official price of rice combined with the costs of participating in the project, resulting in meager benefits. Furthermore, the high-handed manner of administration of the central bureaucracy has created a lack of confidence on the part of many of the settlers. Thus, both economic and social pressures have resulted in a trend of settler abandonment over the past few years. In an attempt to resolve some of the management and social problems, Dutch aid is presently managing about 600 ha and appears to be having some success.

The Office du Niger has been well studied and provides excellent examples of lessons learned, but not too much on how to resolve the

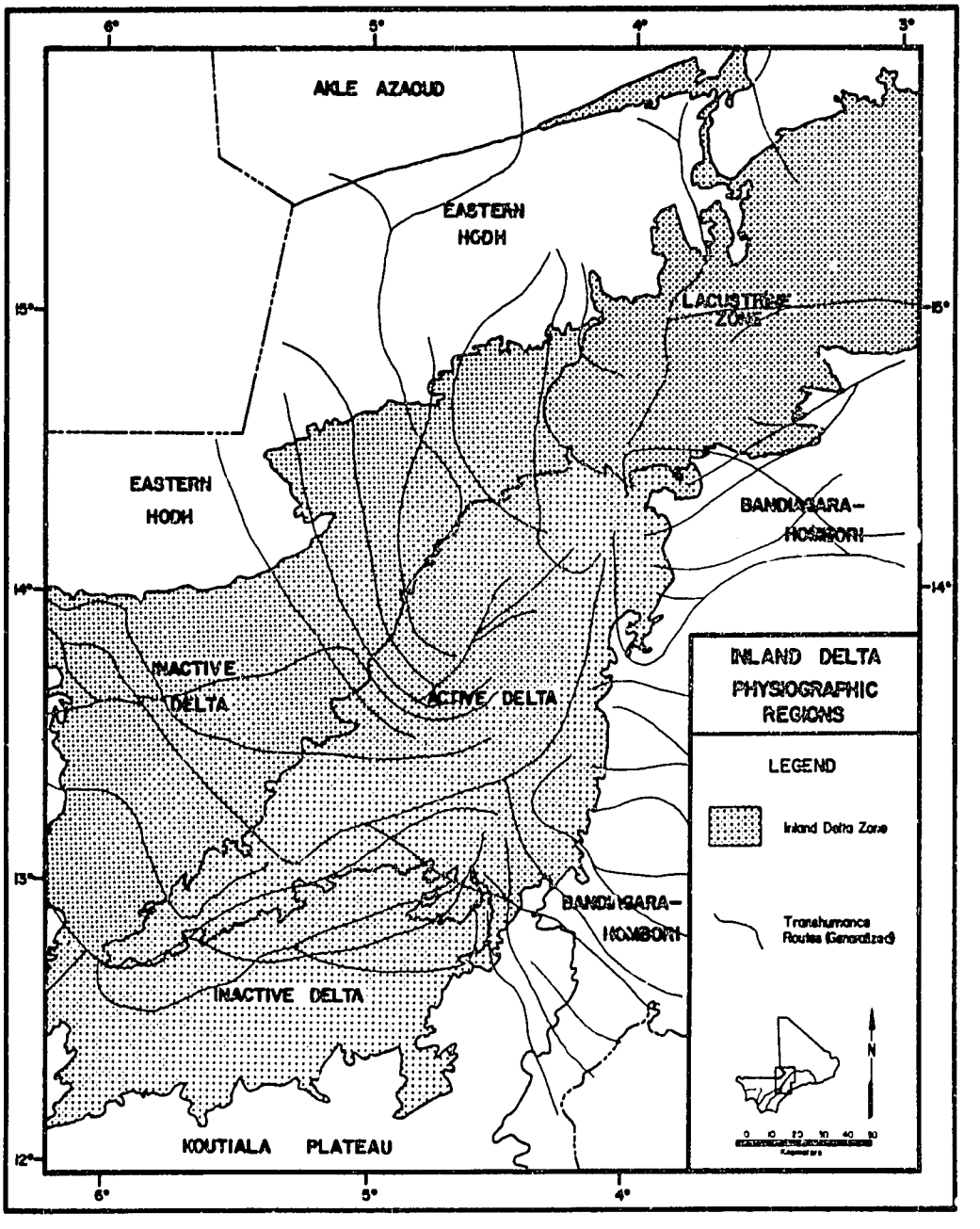


Figure 4. Inland Delta Psysiographic Regions.

problems. French assistance and support for the Office du Niger continues to be strong although the Chinese have provided assistance for the sugar cane perimeters. Future expansion includes the construction of the Costes Canal whereby it is hoped that by 1990 an additional 40,000 ha will be added to the Office du Niger. It is estimated that within the Inactive Delta there are 250,000 ha of potentially irrigable land.

Mopti Region

The Mopti Region encompasses two very different physiographic regions. Mopti is situated at the confluence of the Niger and Bani Rivers, and is thus located on the periphery of the Active Delta. East of Mopti is the Bandiagara Plateau that provides a very different set of circumstances for small-scale irrigation (Figure 5).

Active Delta. There is considerable potential for controlled flood irrigation around the periphery of the Active Delta. In 1972 Opération Riz-Mopti (ORM) was created to control the natural flooding of the Niger and Bani Rivers in the region of Mopti. Through funding from Fonds d'Aide et de la Coopération (FAC) and the World Bank, approximately 38,000 ha of controlled flood irrigation have been developed for rice cultivation through the construction of dikes and flood gates. At present only 29,000 ha are being cultivated in six "casiers" (see Appendix B).

Operation Riz-Mopti is a top-down approach whereby the government provides a range of services for the cultivation of a 3 to 4 ha plot. Farmer participation and selection is based upon four established criteria:

1. The principal occupation of the participant. Preference is given to those who are exclusively farmers.

2. The size of the family and the number of active workers.

3. The equipment owned by the farmers with preference being given to those with draft animals and a plow.

4. The distance of the farmer's village to the perimeter with preference given to those located closely.

Extension assistance is provided through the subdivision of ORM into zones, casiers, sub-casiers and cells. The administrative structure is a classic example of a top-down approach with very little input from the individual farmer.

Through the construction of dikes and floodgates, the control and management of the natural floodwaters has resulted in a greater reliability for a successful harvest. There is, however, still an element of unreliability in that planting takes place with the onset of

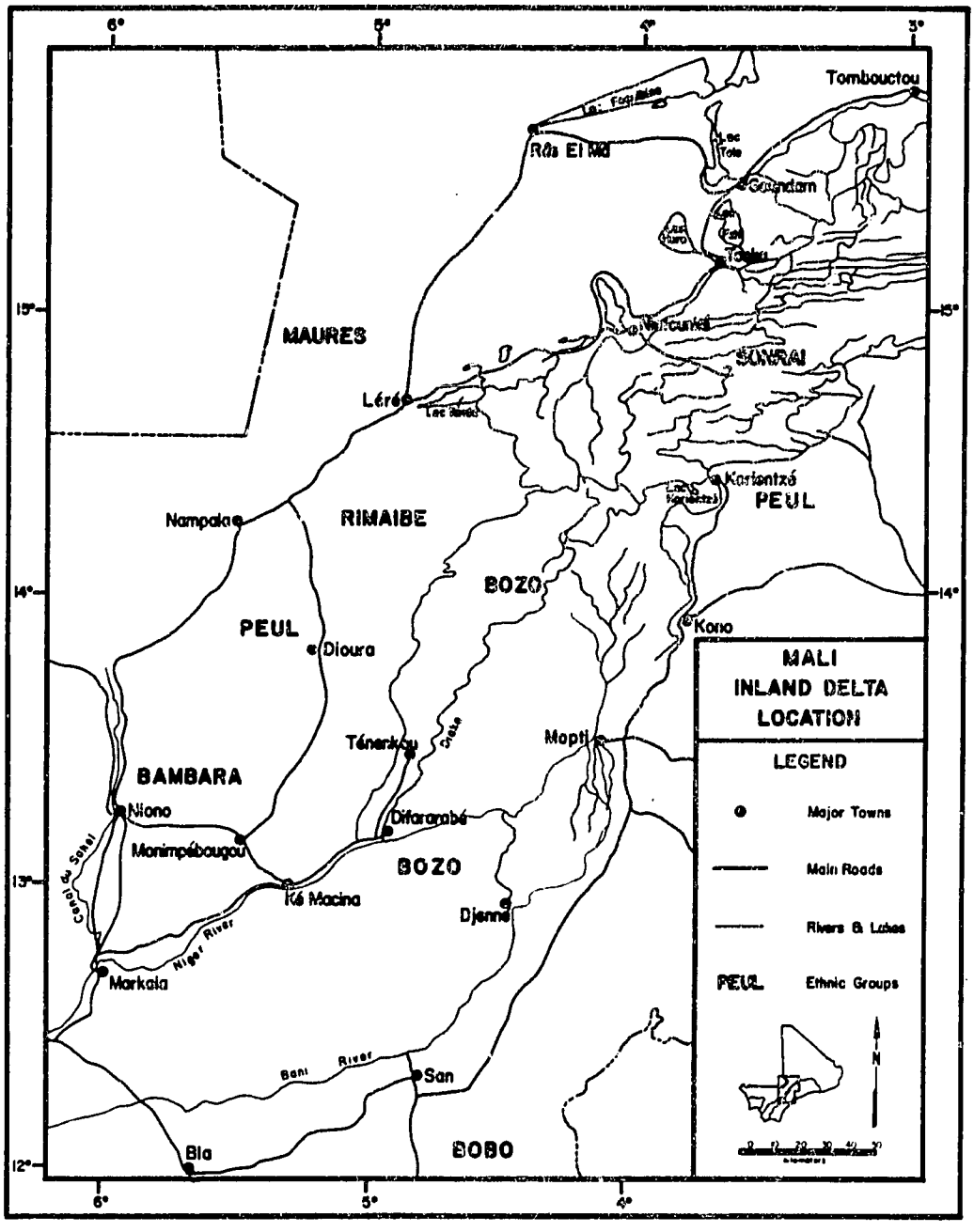


Figure 5. Mali Inland Delta Location.

the first rains and the early plant growth is dependent for the first month to month-and-one-half on rainfed conditions until the arrival of the floodwater. Insofar as the perimeters have utilized the natural lay of the flood plain there has been very little leveling undertaken and this has caused some problems. Usually in the deeper areas floating rice is the dominant crop, whereas paddy rice is grown primarily on the outer perimeters.

Present funding of ORM is aimed at consolidating the present gains and resolving management problems. However, there are future ambitious plans which include the construction of the Djenné Dam, 12 km upstream from Djenné, and the Talo Dam about 42 km upstream from San. These dams, both on the Bani River, will permit the creation of six new perimeters, adding an additional 30,000 ha of irrigated land. Similarly, there are future plans to expand and create new perimeters north and west of Tenenkou. The potentially irrigated land in the Active Delta is estimated to be 100,000 ha.

Another significant land use in the Active Delta is livestock raising. During the dry season the recessional forage that grows following the annual recession of the floodwater becomes a focal point for pastoralists. It is estimated that one-fourth of the national livestock herd (1 million cattle) is concentrated in the Active Delta during the dry season. With the return of the rainy season and the advance of the flood waters, the pastoralists migrate to surrounding rainy season pastures.

Bandiagara Plateau. The Bandiagara Plateau is inhabited by the Dogon, who are noted for their labor-intensive agricultural systems. Located on a rocky plateau, the Dogon utilize virtually every patch of available soil. Through labor-intensive "calabash irrigation," the Dogon produce high value vegetable crops such as onions. Occasionally soil will be transported to create plots for cultivation on flat, rocky surfaces adjacent to an available water supply. It has been estimated that eight hours of labor per day are devoted to irrigating the small plots by calabash, a figure that could be reduced to two hours with the introduction of hand pumps.

There are several small dams that have been built on the plateau through Génie Rural, German aid and USAID. Potential for irrigation is limited and there is some question on the economic viability of dam construction. For example, German aid has constructed three barrages at Daga, Anahada and Sibi-Sibi and provided lined canals for irrigating 40 ha. On-site visits illustrated a major problem with leveling of plots.

Lacustrine Zone

The Lacustrine Zone of the Inland Delta is one of the more productive regions of Mali, providing a diversity of crops and supporting a relatively dense population (Figure 6). The productiveness of the

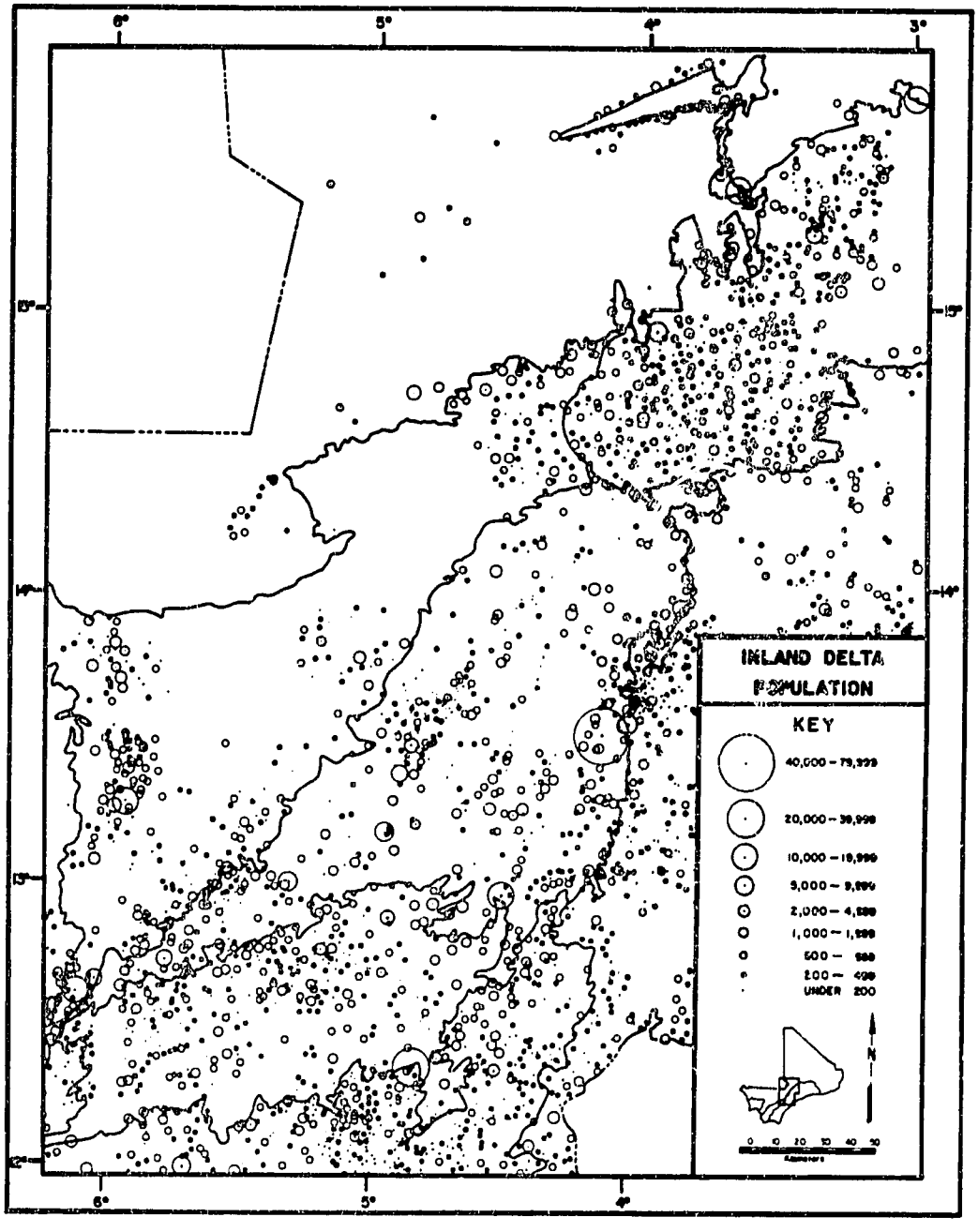


Figure 6. Inland Delta Population.

region is made possible through a combination of natural flood irrigation, controlled flood irrigation, recessional irrigation, calabash irrigation and pump irrigation. The Lacustrine Zone extends from Lake Korientzé north to Lake Faguibine and Tombouctou. The floodwaters of the Niger River flow from the Active Delta into the Lacustrine Zone channeled between dunes, gradually filling depressions, ponds and lakes. Because of the time lag of flooding from south to north, farm calendars are tied to the annual ebb and flow of the flooding. Generally, rainfed millet is grown on the higher ground. Dry season terrace cultivation of wheat is possible through calabash or motor pump irrigation. Vegetables are also grown in this manner. As the floodwaters recede, sorghum, millet or maize will be planted from March to May, utilizing residual soil moisture until the arrival of the rains. Harvesting occurs from May to October depending upon the crop and the arrival of the floodwaters. Rice cultivation is carried out in the flooded areas either through natural flood irrigation or controlled flood irrigation. Lake Horo is a good example where the flow of water into the lake is controlled by dikes and floodgates filling the lake to a determined level for rice cultivation and producing sorghum through recessional irrigation. The interior of the lake becomes a focal point for livestock that graze the recessional forage (bourgou) during the dry season.

Attempts to increase wheat production at Diré has been supported by USAID through Action Blé-Diré. Through the provision of motor pumps and credit to farmers, 250 pumps are irrigating an estimated 500 ha. The creation of a management "Opération" representing a government top-down approach has proven to be unsatisfactory. The final report of the project site analyst suggested that if AID were to continue funding they should consider abolishing the Operation and turning it over to a Private Volunteer Organization which "seems to work better with individual farmers."

Economic analyses have also suggested that the project is not economically viable because of the high cost of fuel, maintenance of the pumps and the distance to markets. Despite a demand for wheat at Bamako, the distance and condition of the transportation network makes it a costly proposition. Furthermore, the use of motor pumps and the inability to provide adequate maintenance, spare parts and fuel suggests that an inappropriate technology was adopted. The development of hand pumping techniques, while not as efficient, may have been more appropriate and would certainly have been less costly. Action Blé-Diré provides examples of lessons learned with severe problems developing as a result of financial mismanagement, logistics, maintenance, transportation and dissatisfaction with government intervention (see Chapter VI).

There is an estimated 100,000 ha of irrigable land in the Lacustrine Zone. At present about 18,000 ha of perimeter construction have been developed, although there is considerable traditional flood and recessional irrigation being carried out on the area. Future development plans propose improving the Kessou-Killy perimeter (10,000 ha), and the development of controlled rice irrigation at Daye (1000 ha) and El Ouladji (1500 ha).

The Niger Bend

Along the Niger River from Tombouctou to Ansongo natural flood irrigation, controlled flood irrigation and recessional irrigation provide a subsistence livelihood based upon rice, sorghum and vegetable gardening. Systems of irrigation vary from small dike systems delaying the entry of water after sowing to the development of low-lying areas with a protection dike and control of the filling and draining by canals. Many small projects of the farmer exist; those of the latter type include Tacharane and Garouna.

Tacharane and Garouna have received funding from USAID through Action Riz-Sorghum to construct dikes, floodgates, fish screens and drainage channels. Almost 150 motor pumps have been installed and 60 submersible dikes have been constructed. Tacharane encompasses approximately 2000 ha with 1200 ha devoted to rice, and Garouna has 600 ha with 250 ha devoted to rice. USAID funding for Action Riz-Sorghum will be terminated because of organizational, management and social problems. The distance and communication problems between Bamako and Gao were also cited as factors for discontinuing funding after December 1983.

There is an estimated 60,000 ha of irrigable land along the Niger Bend; approximately 2600 ha have been developed. Future plans for the Gao Region include the development of perimeters at Forgo (200 ha), Bara (160 ha) and Ansongo (2000 ha). These projects will be similar in design to Tacharane and Garouna.

CHAPTER V

IRRIGATION IN NIGER

The Republic of Niger, located to the east of Mali and north of Nigeria, extends from 11°37' N to 23°33' north latitude. This latitudinal extent in the interior of West Africa results in much of the country penetrating deep into the Sahara Desert where lack of moisture inhibits the development of rainfed cultivation. The majority of Niger's 6 million population is concentrated along the Niger River in the west and the southern borderlands adjacent to Nigeria (Figure 7). Despite revenue derived from uranium exploitation over the past ten years, Niger remains one of the poorest countries in the world with more than 90 percent of its population dependent upon the agricultural sector for its livelihood. Rainfall variability, periodic drought and a landlocked position have all exacerbated Niger's poverty. Furthermore, declining demand for uranium has resulted in the government cutting back on many of its development projects, although irrigation development remains an important priority.

The Physical Environment

Climate

Niger extends through three broadly defined ecoclimatic zones, the Sudan, the Sahel and the Sahara. The Sudanic Zone is located in the extreme southwest between Gaya and Say on the Niger River (Figure 8). Annual rainfall in this zone ranges from 550 mm to 900 mm with a six month dry season and a four- to six-month rainy season beginning in May-June. This zone is dominated by rainfed agriculture.

North of the Sudanic Zone is the Sahel which is divided into the Southern Sahel (350 mm to 550 mm) and the Northern Sahel (250 mm to 350 mm) (Figure 9). The Southern Sahel is characterized by an eight-month dry season and a three-month wet season which begins in June. Agropastoral activities with agriculture dominant prevails in this zone. The Northern Sahel is extremely marginal for agriculture; consequently, the dominant landing is agropastoralism, with pastoralism dominant (Figure 10). The Northern Sahel has a nine-month dry season with a one or two-month rainy season which begins in July. Only 70 rainy days per year can be expected; consequently, agricultural activities are usually limited to areas where supplemental water is available either in river valleys (goulbis) or fossil river valleys (dallols).

The Sahara dominates north of the 250 mm isohyet and encompasses the northern two-thirds of Niger. Nomadic pastoralism is the dominant economic activity, although mining and agriculture do occur in isolated areas. Agriculture is practiced in isolated enclaves where local conditions permit the development of traditional irrigation.

Previous Page Blank

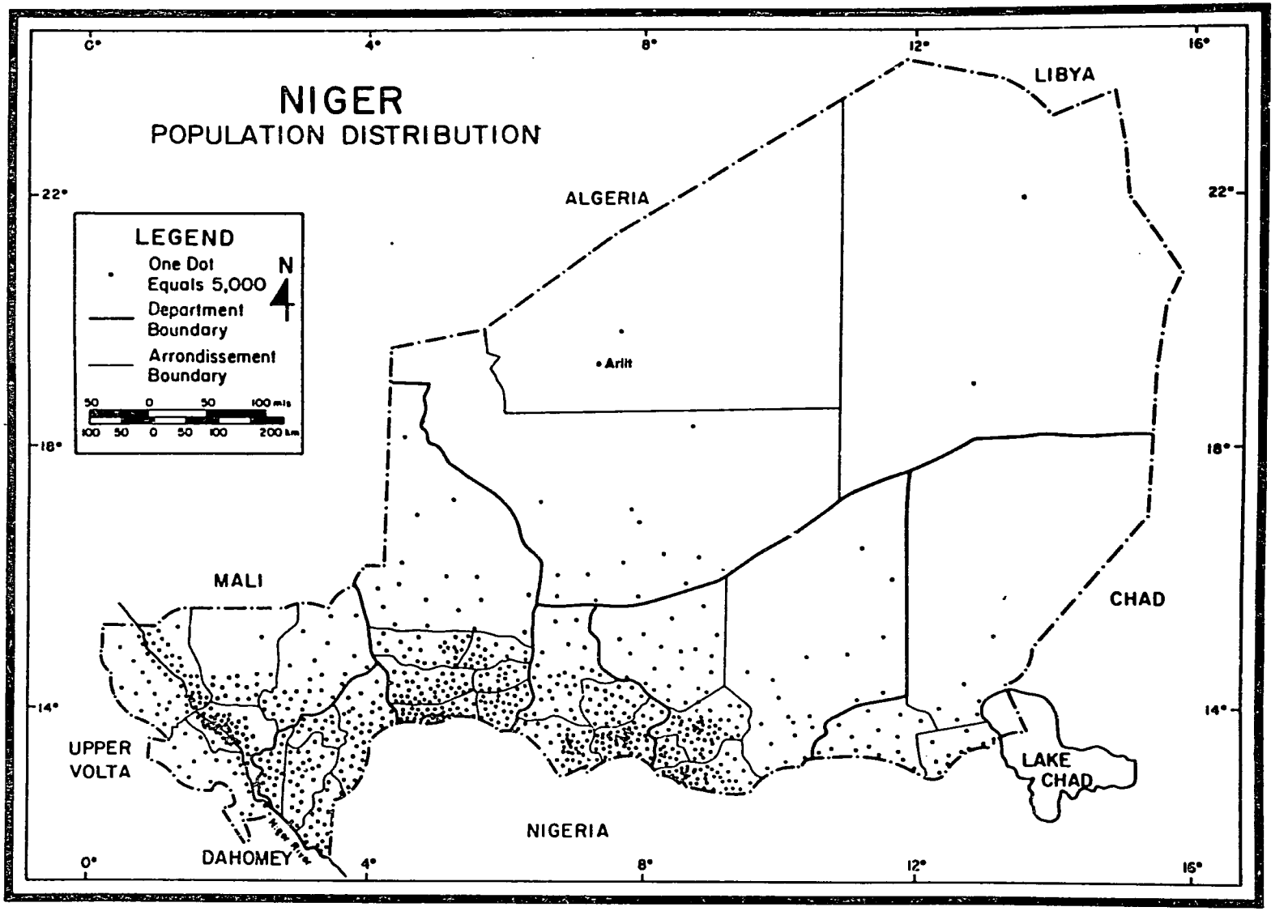


Figure 7. Niger Population Distribution.

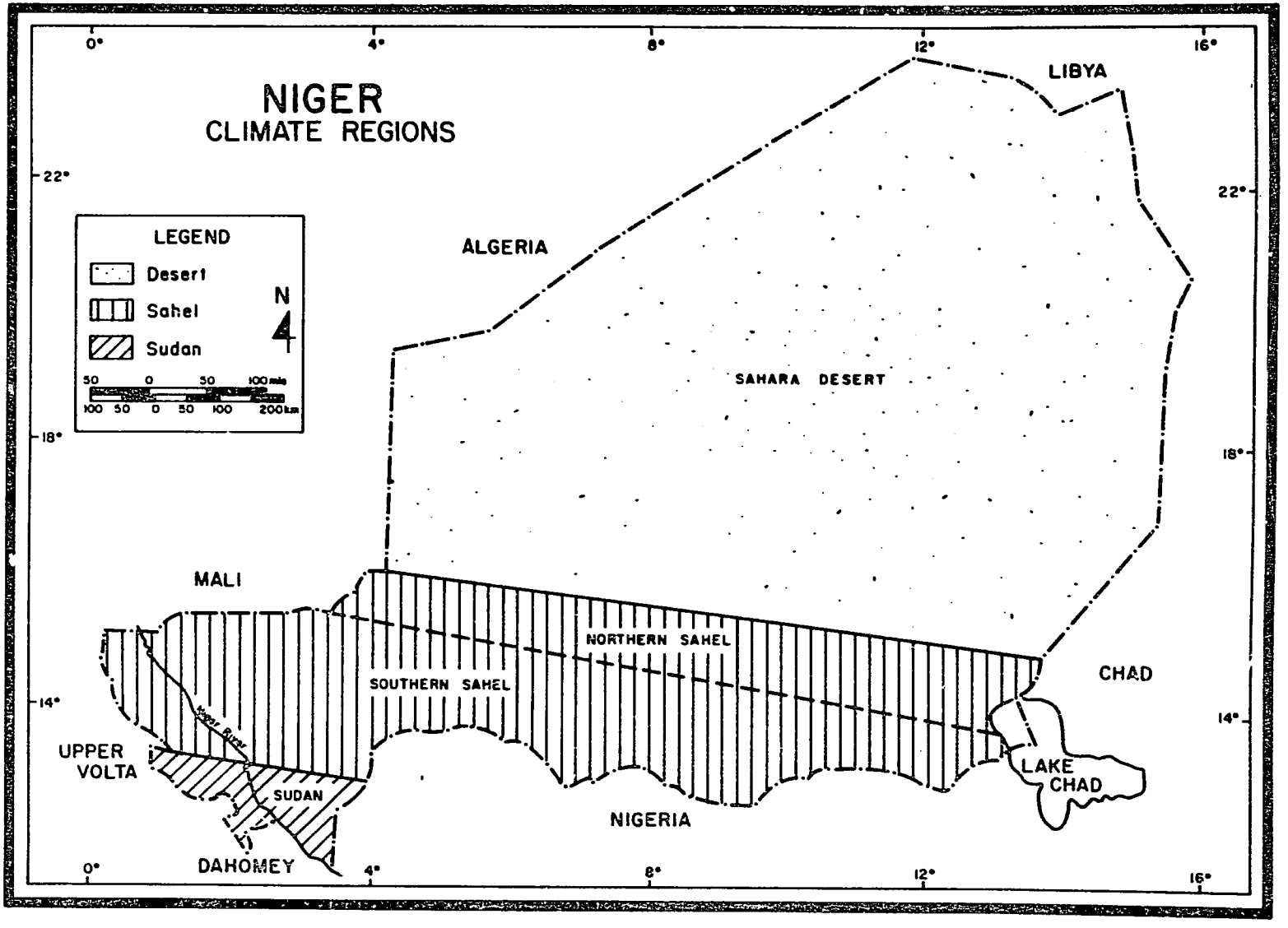


Figure 8. Niger Climatic Regions.

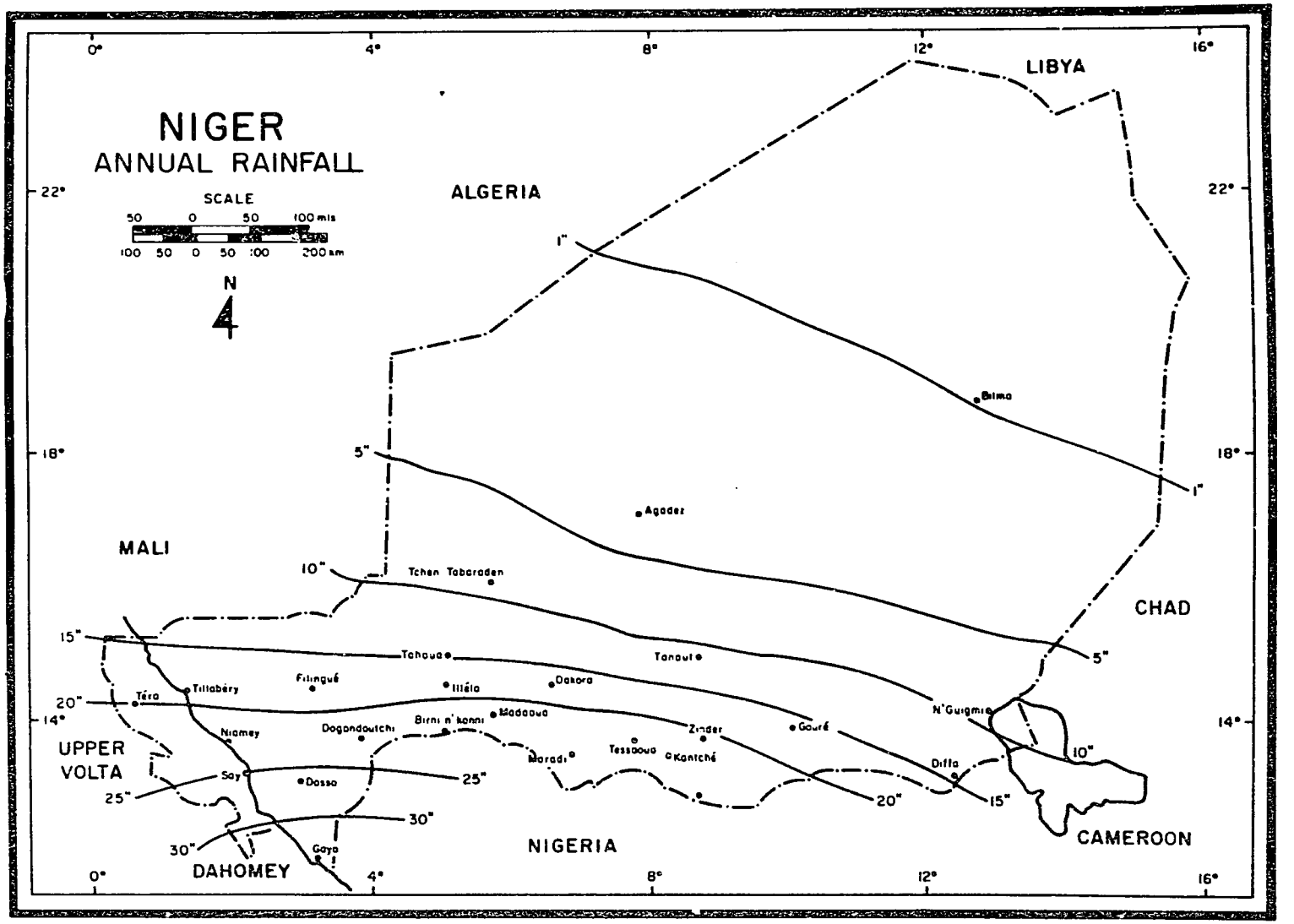


Figure 9. Niger Annual Rainfall.

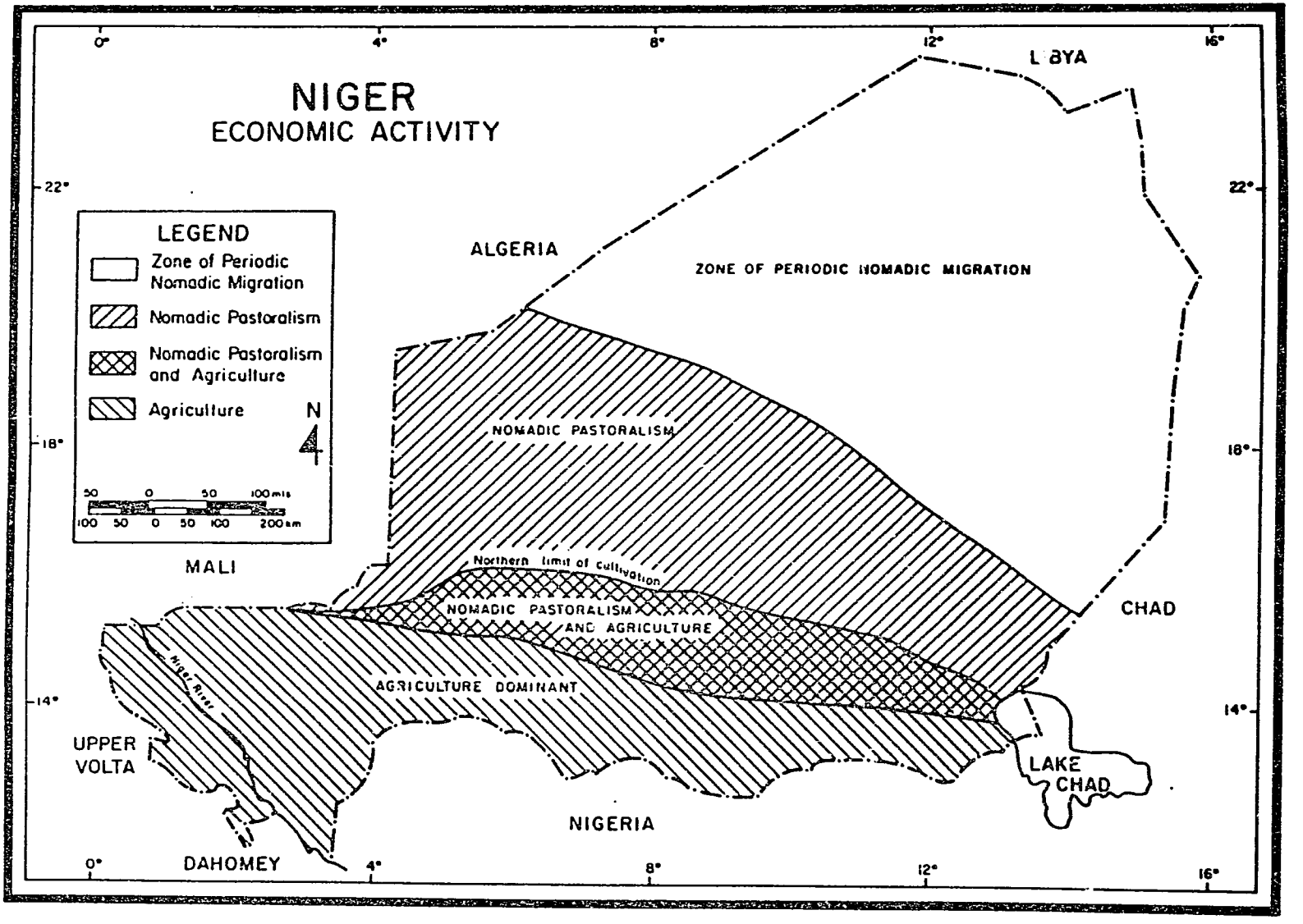


Figure 10. Niger Economic Activity.

Hydrology

Two basins extend into Niger, the Niger River Basin in the west and the Lake Chad Basin in the east. The Niger River flows for 550 km across the southwest corner of Niger, whereas approximately 3000 square kilometers of Lake Chad is located in the southeast corner.

The flow of the Niger River peaks in January and February during the dry season at approximately 1800 m^3/sec, dropping to below 150 m /sec in June-July at the beginning of the rainy season. Population is concentrated along the Niger River and the intermittent streams (goulbis) that form its tributaries. Villages have also been established along the fossil valleys, remnants of tributaries that once flowed into the Niger River during more humid prehistoric times. These fossil valleys (dallols) are characterized by a high water table and occasionally may have a flow of water during an exceptionally rainy season. With water close to the surface traditional irrigation techniques have been applied to cultivate these relatively fertile alluvial valleys.

Lake Chad, divided between Nigeria, Chad and Niger, is shallow, one to four meters, and has diminished significantly in recent years. The Komadougou Yobé is one of four tributaries of Lake Chad and forms a portion of Niger's southern boundary with Niger. Irrigation is carried on along the Komadougou and around Lake Chad where it is feasible.

Irrigation Potential

Irrigation potential in Niger is limited with an estimated 220,000 ha. Most of this potential is located in the Niger River Valley and includes 140,000 ha of the projected Kandaji Dam Project. At present there is a total of 4855 ha of modern total water control systems under the direction of the National Office of Irrigation Development (Office National des Amenagements Hydro-Agricole -- ONAHA) (Table 9). In addition to the predominantly rice-growing schemes listed in Table 9, ONAHA also oversees 3880 ha devoted to market gardening in the Maggia Valley (Table 10), plus two small perimeters (137 ha) at Diffa on the Komadougou Yobé. The official hectarage of irrigated land does not take into account the many small-scale individual traditional irrigated market-garden schemes in the region of the dallols, goulbis and Air Massif. This hectarage may be in excess of 5000 ha. A variety of irrigation types are observed in Niger and include the large-scale total water control systems along the Niger River, recessional irrigation, small pump systems, shaduf and dallou.

Institutional Structure

Prior to 1978 irrigation development in Niger was primarily under the auspices of the National Union for Coops and Credit (UNCC -- Union Nationale de Crédit et des Coops) of the Ministry of Rural Development.

TABLE 9

NIGER RIVER VALLEY
EXISTING IRRIGATED PERIMETERS

Site	Year	Total Area ha	Area Cultivated ha	Number of Farmers	Funding
Tillakeina	1967	76	43	78	F.E.D.
Sakoira	1966	42	42	72	F.A.C. - F.N.I.
Toula	1975	250	244	528	F.E.D.
Kokomani	1975	45	38	110	F.A.C.
Lossa	1975	190	180	288	F.A.C.
Sona	1975	167	152	360	F.A.C.
Koutoukale	1966	410	220	424	F.E.D.
Karma	1972	150	144	426	F.E.D.
Karaigourou	1970	145	146	560	F. Cheysson
Kourtere	1970	10	9	32	Ex dignitaire
Saadia	1973	115	105	396	Lybie - F.N.I.
Kirkissoye	1965	100	94	334	F.A.C. - F.N.I.
Saga	1969	385	380	1,010	Chine Formose
Libore	1977	250	250	730	Chine Nat.
N'Dounga 1	1977	280	280	802	Chine Nat.
N'Dounga 2	1978	280	280	750	Chine Nat.
Seiberi	1980	430	385		Chine Nat.
Namarigoungou	1981	1,500			B. Mondiale
Say	1981				R. de Belgique.
Tara	1978	130		480	Africare.
TOTAL		4,855	2,992	6,996	

Source: Republique du Niger, ONAHA, Fiches Signaletiques Niamey, 1981, p. 3.

TABLE 10

MAGGIA VALLEY

IRRIGATION PERIMETERS

Site	Hectares
Koni I & II	2600
Guidan - Magagi	128
Ibohamane (Keita)	750
Moullele	64
Kawane	52
Tounfaffi	24
Galmi	262
TOTAL	3,880

UNCC planned, organized and promoted the development of irrigation through its technical, extension and marketing services. In 1978 the National Office for Hydro-Agricultural Development (ONAHA -- Office National des Amenagements Hydro-Agricoles) was created and the irrigation operations of UNCC were transferred to ONAHA. This institution has the responsibility for the development, maintenance, management and expansion of irrigation throughout Niger. With the cooperation of Rural Engineer (Génie Rurale) irrigation perimeters are planned and constructed. UNCC has retained the extension component of training farmers and extension agents in the techniques of irrigation and the organization of farmers into cooperatives for marketing rice and vegetables.

The main office of ONAHA is located at Niamey with regional offices at Tillaberry and Tahoua. In addition to UNCC and ONAHA, the National Agricultural Research Institute of Niger (INRAN - Institut National de Recherches Agronomiques du Niger) undertakes research in irrigation crops through its Hydro-Agricultural divisions at Maradi, Kolo and Tillaberry. Irrigation perimeters for research in rice cultivation are located at Libore, Saadia, Seberi, Mali and Tara.

In addition to the governmental institutions that are responsible for various facets of irrigation, there are a number of private volunteer organizations that have been active in promoting small-scale irrigation in different parts of the country. These include Africare, Church World Service, Lutheran World Relief, French Volunteers for Progress and Dutch volunteers. The projects of the various volunteer groups include digging and lining shallow wells, improving traditional irrigation systems, constructing small reservoirs and introducing motor pumps for irrigation.

Irrigation Perimeters

The priority of the Government of Niger in the development of irrigation perimeters has been in the development of large-scale total water control systems. However, the high development costs, difficulty in organizing the farmers and heavy recurrent costs plus a desire to decentralize management has resulted in a renewed interest in small-scale irrigation development. The approach at present appears to be a continued effort to expand the total water control systems, especially in the Niger Valley, but also to provide support and assistance to small-scale development wherever feasible. Irrigation development is located in four regions of Niger: the Niger River Valley; the region of the dallols and goulbis; the Lake Chad -- Komadougou Yobe Region; and the Air Region (Figure 11).

The Niger River Valley

The Niger River Valley is the region of greatest potential and most developed with total water control systems. Traditionally flood irrigation and recessional irrigation (culture de décrue) were practiced

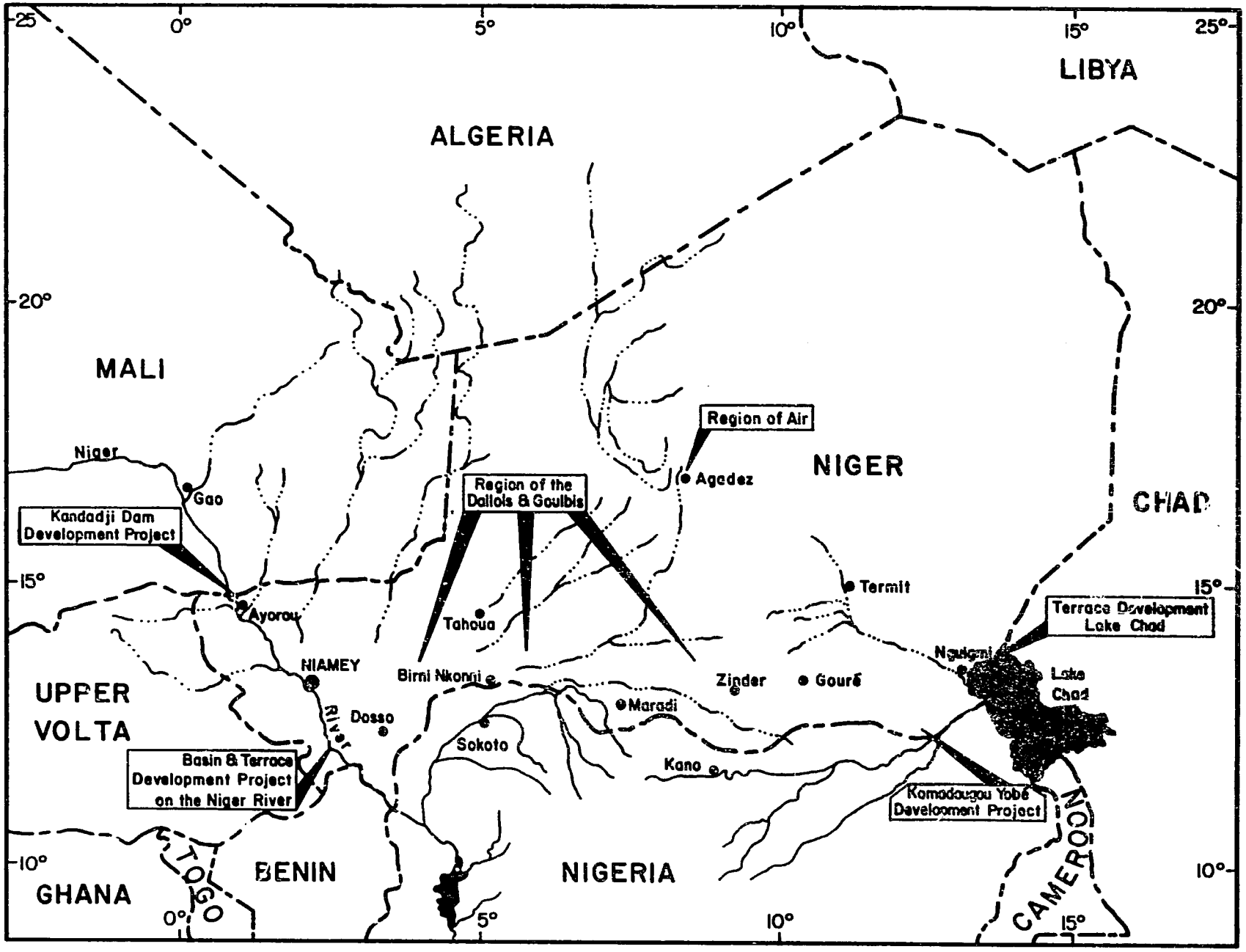


Figure 11. Niger Irrigation Development.

along the flood plain of the river. The development of total water control with modern delivery systems has expanded agriculture onto adjacent terraces through the use of diesel pumps to lift the water. In 1981 a total of 4855 ha had been developed along the Niger River Valley. The World Bank Project at Namarigougou, 1500 ha, is the largest but was not operational in 1981. In 1981 93 percent of the irrigated land was cultivated (2992 ha out of 3225 ha) by 6516 farmers. The average size holding was slightly less than 0.5 ha. Most of the irrigation perimeters along the Niger River Valley were planned for two rice crops per year, but most are producing a single crop. A common practice on some perimeters is for women to grow garden vegetables on plots on the outlying margins of the perimeters.

Maintenance of the irrigation canals appears to be a serious problem in most of the Niger River perimeters. The presence of weeds and even bushes in the canals seriously reduces the efficiency of water delivery and has resulted in the abandonment of outlying plots. The destruction of dikes caused by the trampling of herds of cattle is another serious problem. Labor priorities also cause problems at the beginning of the rainy season when the rice harvesting begins. Farmers are more concerned with preparing and planting subsistence plots of rainfed sorghum and millet on their land outside the perimeter.

Future plans for expansion of irrigation include the construction of the Kandadaji Dam. It is estimated that north of Say irrigation would not exceed 12,000 ha in double cropping under present conditions of low water levels in June. The construction of the Kandadji Dam at Ayorou would regulate the flow of water and provide additional electricity for development along the Niger River.

The Dallols and Goulbis

Extending from the Niger River to Zinder is a region characterized by ancient dry stream channels (dallols), intermittent streams (goulbis) and hill catchment areas that provide water for irrigation. The potential for irrigation in this region is estimated to be 40,000 to 60,000 ha.

One of the most developed areas of this region is the Maggia Valley with eight perimeters comprising 3880 ha. The Maggia Valley is a large, wide alluvial valley surrounded by low-lying hills. Through the construction of eight earthen dams at the base of the hills water is stored and provides water for irrigation. Distribution canals have been constructed by various donors (French and Dutch). During the rainy season irrigation is supplemental for the growing of sorghum and cotton. With reduced storage of water in the dry season the total cultivated area is reduced with the dominant crops being onions, wheat, tomatoes, maize and niébé (cow peas). The diversity of crops produced depends upon the quantity of water available.

In addition to the developments in the Maggia Valley, there are the vegetable gardens located in the dallols and goulbis where there is a high water table. Through the construction of shallow wells, water is extracted either through manual power, animal power or shaduf to irrigate small plots. Distribution of water is either through crude earthen canals or by hand watering. The main crops grown include sorghum, maize, fruit trees, onions, tomatoes and niébé. The small-scale individual traditional schemes have been the focus of private volunteer organizations such as the Lutheran World Relief (LWR), an organization that has provided assistance in the construction and lining of wells. Over 1500 wells have been constructed with another 1800 planned. These lined wells are more efficient than the traditionally constructed wells which are prone to collapse.

Lake Chad and Komadougou Region

It is estimated that there are 15,000 to 25,000 ha of irrigable land adjacent to Lake Chad and an additional 5000 ha in the Komadougou Valley. Traditional flood control and shaduf systems are present in the area. More recently small gasoline pumps have been introduced and enterprising farmers who have the capital to purchase a pump, irrigate neighboring farmers' fields at a variable cost. The irrigation of garden crops, especially tomatoes, are of prime importance and generate a source of cash income.

ONAHA maintains two projects on the Komadougou River at Diffa. One perimeter is 120 ha and the other is 17 ha. Rice, sorghum and wheat are produced during the rainy season under natural flood irrigation using supplemental water through pumping when needed. Rice is grown during the dry season using pump and gravity flow in calans.

Air Region

The Air Region, focusing upon the town of Agadez, is located in an area of true desert where annual rainfall is less than 125 mm (5 inches) per year. Survival is dependent upon a short rainy season and runoff derived from the Air Massif. Small-scale irrigation is carried out through the Dallou system. Small shallow wells and catchment basins built through the construction of small dams at the base of the Air Massif provide water for the irrigation system. The traditional dallou system produces a variety of crops including wheat, maize, millet, potatoes, tomatoes, onions, garlic, pumpkins and a variety of other crops (see Appendix C). The total area under dallou irrigation is unknown, although it is estimated that there may be as many as 2000 to 5000 systems, each averaging about 1 ha of irrigated land. The potential for expansion is limited but there is room for improvement in the system and the development of potatoes for marketing in the urban centers of Niger and Northern Nigeria if transportation facilities were improved (see case studies in Chapter VI).

CHAPTER VI

CASE STUDIES OF SMALL-SCALE IRRIGATION

This chapter presents a selection of case studies in Niger and Mali which illustrate the actual problems future schemes within the Sahel are likely to encounter. In presenting these cases we are aware that many interesting examples could also have been found in Senegal. Definitely, Senegal's Bakel and Matam projects merit further study, although some of them are described in detail by Miller (1984), Patterson (1984), Keller et al. (1983), Fresson (1978) and Adams (1981). When it is considered that the great majority of the Sahel's organized, small-scale systems are located along the Senegal River -- Diemer and van der Laan give a total of 250 in Senegal, 150 in Mauretania and 17 in Mali -- our inability to visit the Senegal Basin was unfortunate.

However, we did visit or obtain information on several less well known small-scale schemes in Niger and Mali, which provide the basis for this chapter. The cases presented here are all recent examples, either still under implementation or just concluded. They have been selected to illuminate the issues which arise when matching types of technology to particular environments. They also describe the learning process which outside agencies, USAID, the national irrigation bureaucracies and NGOs, must go through when sponsoring interventions within small-scale systems. Agencies of all three types have made similar mistakes, but the encouraging aspect of these cases is the degree of organizational learning which has occurred.

The first half of the chapter is drawn from Ray Norman's continuing research in Niger. The cases contrast riverside perimeter irrigation at Tara, under PVO management, with ONAHA's successful attempt to irrigate from small dams in the Maggia Valley. Information is also given on the use of individual wells for intensive market gardening. The second half of the chapter turns from the hydrologic aspects to look at small-scale project management in isolated environments, a situation typical of much of Africa and illustrated by USAID's Action Blé-Diré Project in Mali. We will document how over a period of five years the Mali USAID Mission has learned many of the key lessons required for working on a small-scale in remote locations.

Tara Project, Niger

Project Background[1]

The village of Tara is located in the southern part of Dosso

[1] This case is based on a site visit by Ray Norman, an interview with Ken Byrd, the Africare Project Manager, and a project submission document, Revised Tara Hydro-Agricultural Project, Tara, Niger, Africare, October 1982.

Department on the banks of the Niger River about 16 km from Gaya, the local administrative headquarters. It has 500 families, just over half of them involved in the rice irrigation component, with about 2,000 people living in the community and another 1,600 involved through linked activities spread over the larger area (fishing, etc.). In this part of southern Niger the annual rainfall is about 40 inches, sufficient for growing a range of crops: millet, sorghum, peanuts, rice and garden vegetables. The Project has four cooperatives: one for irrigated rice farming, another for poultry farmers, a third for 20 fisherman from the town, and a fourth for carpenters and blacksmiths. However, this description will focus only on the Project's irrigation and water management activities.

As it happens, the idea for irrigation at Tara originated with a Rhodesian farmer who came through during the great drought and decided to stay. He built the first dike at the river's edge and began growing peanuts. Subsequently his farm came under the control of the national peanut parastatal (SONARA) and then in July 1975 the Niger Government decided to turn the land back to the local people for small-scale farming. Africare was contacted and became the Project's executive agency responsible for implememting a $3.5 million investment program (drawing upon approximately $1 million USAID assistance.)[2] From its inception the Project embodied the "new directions" approach which USAID and other donors were promoting in the mid-1970s, including:

- Execution by Nigeriens and their local institutions, with donor assistance only in areas needed to reinforce local capability;

- Inclusion of all the necessary components, applied research, transport and health and education facilities, making this an "integrated rural development" project; and

- Villagers' participation not only in food production but also in the organization and mangement of the Project.

Phase I of the Project had no less than 12 subcomponents: the construction of dikes and an irrigation system, rice production and research, cooperatives, credit, fisheries development, adult literacy, poultry production, appropriate technology, community development, construction of a farm-to-market road, primary health care training and agricultural extension. Recently the Project has also begun working with women's vegetable gardens away from the irrigation perimeter, assisting well diggers to undertake cement lining of shallow wells.

Despite its multiple components, the primary justification for the

---

[2]Africare is a private, non-profit organization established in 1971 when West Africa was experiencing one of the worst droughts in its history. Africare undertakes both short- and long-term projects and has work under way elsewhere in the Sahel.

Tara Project was the need to teach farmers how to irrigate rice under a regularized water control regime. The irrigated area consists of a long sliver of flat land on the bank of the Niger River that was formerly under traditional recessional irrigation. It appears the original dike was built with the intention of obtaining gravity flow irrigation. Under a Génie Rurale design, a new dike of 4 kms length was added in 1977 with pump intakes at the upstream end leading into a distributory canal system to the rice paddies. The primaries are cement lined, but the secondaries are unlined. Six Lister pumps with a theoretic output of 420 m^3hr were installed. The first design anticipated an irrigated area of 200 ha, later reduced to 140 ha because of high spots within the perimeter. As of the 1983 rainy season farmers had 73 ha under irrigation, with plot sizes ranging from .25 to .50 ha.

The rice cooperative has 256 members and supplies them with credit for seed, implements, animal traction if needed, and some training. Seasonal debts are recovered from the harvest, with a high level (85 percent or above) of repayment in the first three seasons but a marked drop to 57 percent in the fourth. Credit is advanced to the cooperative from the usual Nigerien Government institutions, the CNCA (La Caisse Nationale de Crédit Agricole) or the UNCC. The Project also advanced additional funds for various special purchases, such as a rice dehuller or animal traction equipment. The irrigators' cooperative is in turn linked to others from the eight communities participating in Tara under a general assembly, which elects a five member administrative committee (president, secretary, treasurer and two bookkeepers) responsible for overall coordination and supervision.

Water Management

The primary problems in the Tara Project arise from serious design mistakes made in the early stages of the Project. It was originally conceived that the Project would provide water for both a rainy and dry season rice crop; however, the expectations of the latter have never fully materialized. The pump intake at the head of the system was set at a level which was based on a nearby bridge. There was no consultation on behalf of the designers with the local residents or farmers who no doubt had spent most of their lives along the banks of the river. As a result, the pump intake level has been above the dry season flows for most of the years since. Several attempts have been made during the dry season to move one or two of the four Lister pumps out on the dry riverbed and place them in series with portable pipe in order to reach the receded water level. The difficulty encountered here was in getting a flow rate high enough for water to reach the tail end of the system. Seepage through the cracks in the concrete canals compounded this problem (i.e., in pumping to the tail end of the sysem the cumulative seepage rate was higher than the output rate of the pumps in series). Attempts have also been made to dig out a channel to the receded water level from the pump intake, but this has met with little permanent success since high flows fill the dug channel with sediment. Farmers then tried to link up

plastic pipes in series to the pump intakes, but the pipes soon split. Thus, at Tara the simple neglect of "ground truthing" by the perimeter's designers resulted in a continuing water supply problem which has been difficult to resolve.

Other problems can also be traced to faults in the design stage. Before implementation of the Project began no soil survey of the area had been made nor was it called for in any of the Project papers. This resulted in the dike being partially built over an old sandbar as well as several areas within the perimeter being uncultivable due to large pockets of sand. Several areas in the lower half of the perimeter do not receive water through the canal network due to channels being lower than the fields. However, since most of these plots are in the sandier areas, during the rainy season when the river rises sufficient water percolates under the dike up through the sandier soils for rice cultivation. Initially a pumping station was constructed and outfitted with several pumps at the tail end of the system for the purpose of drainage. This station has been neither used nor needed since most of the paddy water drains out under the dike as the river level recedes toward the end of the rainy season, and water delivery via canals to the end of the system is a problem, anyway. The reason that farmers have been successful in cultivating these marginal areas probably lies in their knowledge of traditional recessional rice cultivation. Many farmers maintain traditionally irrigated rice paddies in the rainy season outside of the irrigation perimeter. These farmers are opportunists and do admirably well with what they have; such is exhibited by the deepwater rice planted in most of the drainage canals between fields. Finally, poor design resulted in one of the two primary canals being built at the immediate base of the dike. Subsequent erosion of the dike by rainfall and livestock traffic has caused portions of the canal to be completely filled with sediment.

Africare's oversight and administration of the Tara Project, particularly with respect to the cooperative, is considerably more flexible than a typical ONAHA system. The resultant more "independent" system has both positive and negative consequences.

Maintenance, as with many of the projects visited along the Niger River, is a key problem. At the time of the site visit, labor competition with dryland cropping was the primary reason cited for poor canal maintenance. This competition was also causing serious water distribution difficulties. The cooperative president was trying to get the farmers to plant in the perimeter at roughly the same time, so that some type of orderly water distribution could be made. Many farmers were, however, still in their upland fields trying to get their millet harvested. The delay in planting rice not only complicates water delivery timing, it may also mean that those who plant late will have trouble getting their rice harvested before an onset of the seasonal bird problem. When asked about the weeds in the canals, the local perimeter director said the cooperative had previously scheduled that very day for cleanup, but it had been postponed to the following day so that the

farmers could spend time killing birds which had become a more serious and immediate problem in their millet fields. This suggests that organizational problems within the users' cooperatives are not the sole reason for maintenance difficulties.

Other maintenance problems were noted in connection with the dike itself. It is regularly used as a pathway for livestock, which results in erosion. Larger weeds and shrubs were being allowed to grow along the slopes and in places these were planted to millet or maize -- both of which could easily result in root cavitation. This seemed to be merely an information problem. A more serious problem was the many animal burrows which could be seen along the sides of the dike.

Tara Project was visited by IBRD engineers, who recommendd a whole gamut of further surveys to identify soils types precisely and assist in releveling of the fields. We consider the main problem to be the question of the intake design and levels; otherwise, farmers have developed their own solutions to what might appear as technical difficulties (e.g., planting floating rice in the partially flooded area between the two dikes). Perhaps it would be more realistic to acknowledge that in a 40" rainfall area there will always be a competition between rainfed farming and the second cycle of irrigated rice production.

Maggia Valley, Niger[3]

The Maggia Valley is a large, wide alluvial valley which generally follows a north-south course. It has a comparatively higher water table than the surrounding area, and is encircled by low-lying hills. It is intensively cultivated during the rainy season. Over the years a number of reservoirs and canal distribution systems have been developed by European donors. The eight systems presently in existence in the valley are administered by ONAHA. Most of the schemes have been in operation for several years, some for more than 15 years. The six smaller schemes, with perhaps the exception of Konni I and II (see Chapter V) are similar to the "tank" systems of southern India and Sri Lanka.

Water Control Structures

The water storage of these systems consists of reservoirs with earth and stone embankments usually situated in a contributary watershed adjacent to the wide alluvial valley. The embankments/dams consist usually of a central clay core (as a moisture barrier), overlaid with soil and capped entirely with stone. Thus, essentially all materials

---

[3]This case is based on information supplied by M. Hamidou, one of ONAHA's perimeter directors in the Maggia Valley, supplemented by site visits undertaken by Ray Norman.

used are local. These appear to be well constructed; no apparent seepage was noted at the base of the two visited, and their coverage with large stones (well fit together) inhibits any excessive vegetative growth. The only noticeable damage seen was at the base of the Moullele Dam where livestock traffic had caused some erosion. It was said that this area along the embankment had to be repaired periodically. Due to the reservoirs' proximity to the scarcely vegetated, rocky hills which lie around the perimeter of the main valley, much of the runoff comes from this terrain. Thus, sedimentation (siltation) buildup has been a serious problem. For example, Ibohamane, one of the older schemes, is said to have lost half of its storage capacity due to sediment buildup in the reservoir. The recent droughts in the area have amplified the problem somewhat since the resultant loss of vegetation has increased the sediment loads of runoff in the catchment areas. The topography of the region varies from flat to rolling so that the reservoirs are typically wide and of minimal depths. Thus, evaporation losses are expectedly high.

Generally, there is one main point of discharge from the reservoir located at the center of the dam and consisting of an internal drainage pipe which discharges at the dam base into the head of the primary canal. The command area, which usually lies immediately below the catchment area, is fed through a rather simple network of canals and a minimum of control gates. The canals of the older schemes are made of flat local stone held together with concrete mortar. Over the years this type of construction has resulted in some cracking between the rocks. Often this is due to the eroding away of the soil support underneath and behind the canal sidewalls. This in turn is due to farmers cultivating too close to the canals. Farmers are asked not to cultivate within a number of meters near the canals, but due to the scarcity and value of land in the perimeter this request is sometimes ignored. The newer canals of the larger systems more often are constructed only of concrete.

There usually exists one main large gate at the head of the main canal which allows the total water flow to be both measured and controlled. In the smaller systems permanent canals usually exist only down to the secondary level, occasionally to the tertiary level.

In most of these systems the turnouts to the fields are not in the form of a common small gate, but rather consist of permanent pipe fixtures running from the floor of the canal through the canal embankment (Figure 12). These turnouts were designed by the French specifically for the Maggia Valley schemes and have become known for their suitability and effectiveness. They are commonly known as the "type Maggia" turnouts. The positive reputation is due to their simplicity and their aid in water management. The rate of flow outward is dependent on the head (water level in the canal) only. Thus, a farmer can easily reduce his "designated" amount of flow (by simply blocking the outlet), but has no easy way of increasing that flow (as in opening a gate wider). This also negates the need for locked turnouts. The only way the flow can be increased is by placing rocks in the canal immediately downstream of the

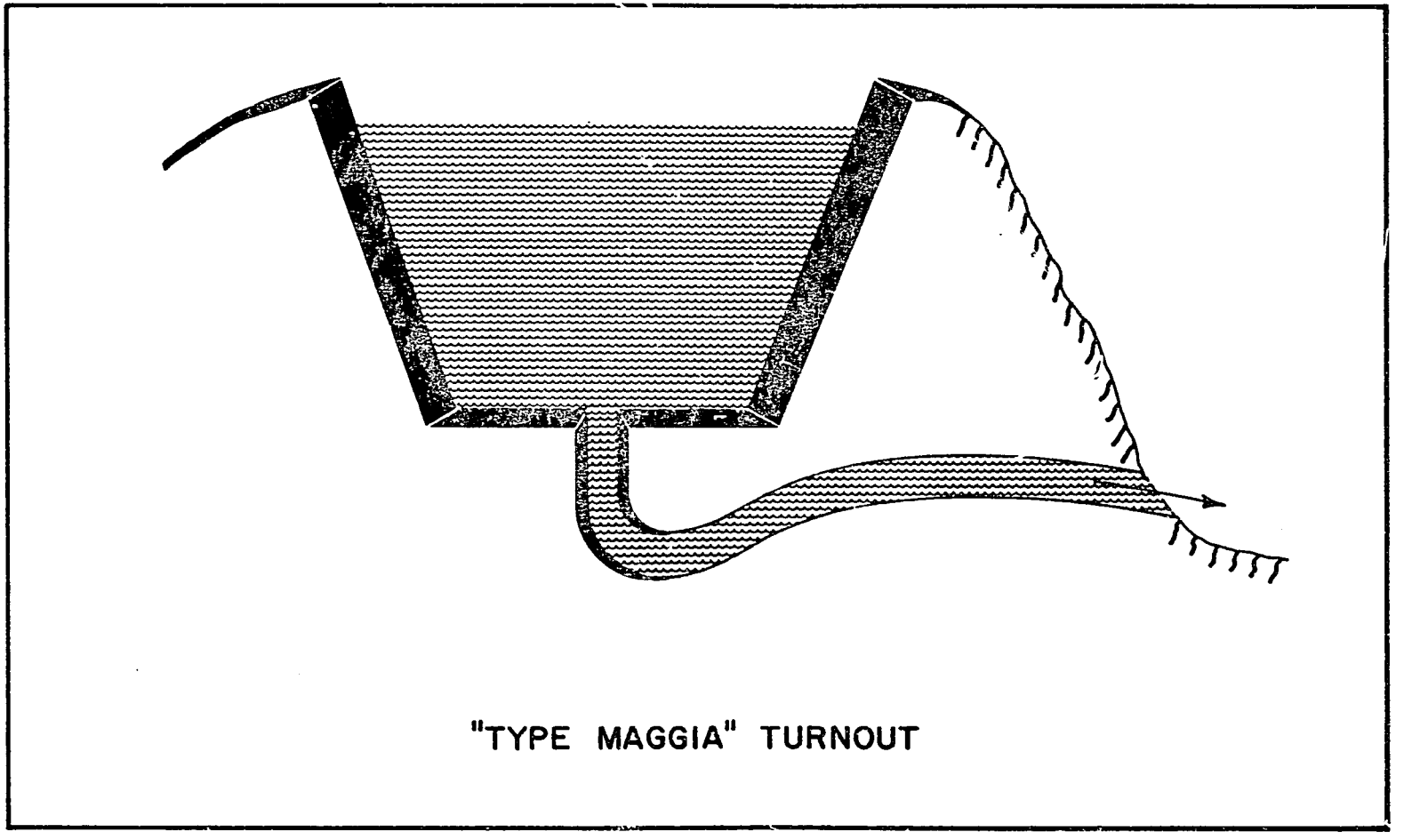


Figure 12.

orifice to increase the head. Although this is done occasionally, it is a conspicuous exercise and of marginal benefit and thus is not practiced widely. If a farmer does not wish to receive water when the canal is flowing he simply blocks the entrance to the pipe with a few rocks and/or sticks and straw. After the water passes through the turnout into the farmer's plot it usually flows through a series of small temporary earthen canals which the farmer constructs to the various plots in need of water.

Perhaps the most striking aspect of the Maggia Valley schemes was the appearance of a well maintained infrastructure. The canals in particular were well maintained and cleaned, even in the older schemes. At Moullele a portion of the canal system had obviously just been weeded and cleaned out within the past two or three days. The sections which were not covered in the recent cleaning effort, however, were not overgrown (as was typical of the larger Niger River schemes) and had obviously been cleaned previously at periodic intervals. No excessive overgrowth in canals was noted in any of the systems visited. The coop's maintenance committee organizes cleanup crews and oversees maintenance as the needs arise. To help support the maintenance and repair needs, in some of which ONAHA is involved (particularly the major repairs), each farmer at harvest gives approximtely 8000 CFA/ha/growing season to the coop. This is utilized by the coop and/or ONAHA in upkeep of the system. ONAHA also makes financial allotments to each scheme for upkeep, on a per hectare basis as well.

User Cooperatives

When asked about land allocation, distribution and particularly redistribution under the hands of the coop administration, Mr. Hamidou said that the coop is usually able to handle such transactions effectively, especially in maintaining equitable land holdings and allotments. From what we were able to gather, upward flow of information from the farmers to the coop, coop leaders and the perimeter director is quite effective. Problems do and have arisen with illegal and/or inequitable land holdings and land control. A classic example occurred at one scheme where the traditional village chief managed to get a number of his "slaves" (servants) to get new parcel allotments within the scheme. By doing so the chief, in addition to his own parcel, actually had control over a much larger amount of irrigated land. The farmers/coop soon identified the situation and the man's parcel was taken from him.

When such an action is taken, usually an administrative person such as the local sous-préfet will be present. This type of problem has occurred before in these schemes but in general is not a major problem. Such problems are easily identifiable (and thus dealt with by the coop), since a list of coop members and their parcels within the perimeter is written down for all members to see and examine at any time they wish.

The occcasional problem of "pirates" also arises within the schemes. This usually is done simply by driving a pipe through the canal bank and/or creek in the canal if it is concrete or stone. However, such problems are usually quickly identified by neighboring farmers or the perimeter director and the fellow is thus reprimanded and/or disciplined by the coop. Repeated violations of this sort can result in the loss of one's parcel.

One of the main hinderances in the coop development within these schemes has been the low education level, particularly in literacy. It is felt that some degree of literacy must be achieved within each coop before full self-sufficiency can be obtained. The need for this is primarily for efficient and effective record and bookkeeping. ONAHA officials feel there is a need for a functional literacy campaign in these coops. Some minimal attempts have been made at literacy training but the expense of such have been prohibitive. The Ibohamane coop president is literate and this is cited as being one of the main reasons that the coop is one of the more successful in the Maggia Valley. On the whole, compared to many situations throughout the Sahel, these cooperative systems appeared to be working remarkably well. Much of this is probably due not only to the farmers' interest and cooperativeness, but to the capable ONAHA personnel working in the region as well. According to Mr. Hamidou, however, the coops are not yet a "complete" success, as there are none yet that can function independently. The main continuing assistance is in the financial area (accounting, etc.).

Water Management

In the rainy season irrigation is supplemental as necessary. During this season sorghum and cotton are the principal crops grown within the perimeters (approximately 50 percent of the hectarage in each crop). Water is usually released for irrigation no longer than 20 days after the last rainfall. After inquiry was made as to how the 10-day period related to their crop water requirements it was found that it was based on another constraint entirely. Apparently in most of these schemes the soils tend to crack after drying out. (One ONAHA official called them "vertisols" . . . whether or not they actually are is still in quesion; yet it can be assumed that the characteristics are somewhat similar.) Thus, 10 days was the last limit set, beyond which it was felt that serious damage to crop roots would result, and irrigation water loss through/beyond the root zone would be too great.

In the dry season reduced storage volumes result in a reduction of cultivated/irrigated area. As an example, generally the minimum hectarage irrigated in the dry season for Konni I and II, Guidan-Maggia and Galmi were 1000 ha, 50 ha and 100 ha, respectively. Of the total area of the Maggia schemes the figure given was 1600 ha. At Moullele, one of the sites visited, only 10 ha (out of 64 ha) were cultivated last dry season (all in onions). Primary dry season crops were reported to be

onions, wheat, tomatoes, corn and niébé (cow peas). The diversity naturally depends on the quantity of available water at the onset of the dry season. When it is significantly limited, it seems that onions are the preferred crop (generally used as a cash crop), as exemplified in the Moullele case. We were told that a farmer received 30 CFA/kilo for his onions at the end of March and 100 CFA/kilo in August. When purchased from the "middleman" along the road they sell for about 120 CFA/kilo in August and up to 200 CFA/kilo along the coast (after being transported). It was mentioned that post-harvest storage was also a problem; tomatoes are plentiful in the projects and are usually dried before marketing.

As far as overall water management/systems performance issues go in these schemes, it appears that water quantity (as opposed to, say, land availability) is the primary limiting factor. Essentially, water availability determines how and what is irrigated. In the rainy season the amount of rainfall largely determines how much water is used. What remains in storage thus determines how much land can be irrigated in the oncoming dry season. The dry season, therefore, is the period when the critical water management/distribution issues arise. Aside from the constraint of water storage, other relative issues affecting overall system performance which seemed to be notable are:

- Soil cracking, soil type;
- Weeding (considerable labor time is spent on this, and significant transpiration losses are likely; this appeared to be a widespread problem);
- Seepage, cracks in canals, related water losses, etc.; and
- Occasionally, "pirates."

At the beginning of each dry season, the perimeter director assesses the quantity of water in storage (he does this both from experience and from the use of a water level-storage volume graph specific to the particular reservoir's design) and then makes a recommendation to the coop on how much land should be prepared for irrigation that season, and on the percentage of various crops that should be grown. When this plan is presented to the coop it is discussed and adjusted and/or revised (or sometimes accepted as it is) by the coop. A "master plan" for the season is then agreed upon between the coop and perimeter director. M. Hamidou and one of the perimeter directors commented that the farmers are very good at "eye-balling" the reservoir and making accurate estimations of how much water is available for irrigation use. Thus, the perimeter director's annual estimation and recommendation is carefully, and rather accurately, checked by the farmers themselves at the onset of each dry season.

The water director also commented on the farmers' ability to maintain a mental reckoning of the water balance/crop water requirement budget for their fields by simple memory of rainfall amounts (which in this area are sparse and unpredictably spaced). In the Maggia Valley farmers are able to make quite accurate assessments for how much and when their crops are in need of water. The perimeter director largely relies

on these judgments, which are generally community decisions, for water allocation. It seems plausible that farmers in the semi-arid zones seem generally to possess a more accurate understanding of hydrologic and crop water processes than do farmers farther to the south where water is much more plentiful.

There appears to be a correlation between maintenance, water distribution and perimeter size. Generally the smaller the perimeter, the smaller the coop, the easier it is to organize. The smallest perimeter, Tounfaffi (24 ha) is more efficient and better maintained than most of the larger perimeters. However, the functioning, administration and experience of the coop personnel is an important facet in system maintenance. The 128 ha Guidan-Maggia scheme is reputed to be the most well maintained, and this is attributed to the efficiency of the coop and its personnel. A similar situation occurs at Ibohamane. On the other hand, where the coop is not functioning smoothly at Konni I and II, many problems are encountered.

From information given by M. Hamidou and visits to two sites, it seems that overall system performance depends largely on three main criteria:

1. Age of the coop/coop function;
2. Size of perimeter; and
3. ONANA perimeter director (personal capabilities and experience).

Well Gardening, Niger

Traditional Micro-Irrigation

In numerous areas throughout Sahelian West Africa there exist large quantities of subsurface water found at relatively shallow depths. The WMS-II team was told that many such areas exist within Niger. Traditional well gardening has been practiced in Niger for centuries, but reliance on wells has significantly increased since the drought of the early 1970s -- particularly for dry season cropping.

Most well gardening occurs in the southern third of the country, in low depressional areas and wide valleys throughout the Southern Region. In addition to these are found the animal powered dallou systems in the Air Mountains of the north. Still another type is the shaduf system in the Komadougou Valley bordering Lake Chad. Let us review these three types of traditional irrigation before turning to a case study of the Lutheran World Relief (LWR) Well Program.

Madaoua-Galmi Onion Production. An extensive area of onion production using traditional well irrigation exists in the Madaoua-Galmi region. The onions, which are known as the "Galmi Red," are produced as a cash crop and exported by truck to Nigeria, Togo, Benin and Ivory

Coast. They are grown in two cropping seasons each year (rainy and dry) and marketed to middlemen who transport them by animal or small vehicle to the nearest good road where they are in turn resold to truckers. The truckers transport them to the South and usually return with grain from the coastal regions. Niamey itself gets most of its onions from this region.

Farmers using traditional technology are usually able to produce between 25 to 40 tons/ha (25,000 to 40,000 kg/ha). (The figure for maximum outpout of 40 tons/ha was verified by Steve Lellelid of LWR in a survey of 20 to 30 farmers in early 1983). Although gardens vary greatly in size -- depending on factors such as cropping season, family size, recharge rate, depth of the water table and amount of land in dryland crops -- most plots are small, less than 1/10 to 1/3 ha, with a minimum of one well for every 1,500 to 2,500 square meters.

In the main harvest period of each season, the middleman or the farmer selling directly at the road can get 2,500 to 3,000 francs CFA per bag. (These bags are sold on a volume basis and typically weigh about 100 to 120 kg). If they wait two months after the main harvest, they can get up to 8,000 francs CFA on the road, and upwards of 20,000 CFA even later. The primary problem is storage. The onions are not dried; thus, the longer one waits to sell the more he loses of his original harvest. Lellelid reported a 20 percent loss in the village of Shindigi over a four-month storage period. Discussions at the national level are examining the possibility of constructing an onion drying plant in Galmi or Madaoua.

The large scale of onion production and marketing in the area is of recent origin. One elder farmer said that onion production here is less than a generation old. The last few years have seen the most marked increase. As one drives through the region one can see it is a thriving business. Farmers said that 7 to 10 years ago one bag sold for only 1,000 francs CFA or less. Even today the cost of onions in Niamey is two to three times higher than what one would pay directly to the farmers, indicating that the middleman and transporters are also doing quite well.

The wells are traditionally hand dug. They usually require rebuilding or rehabilitation once a year and must be abandoned every few years because in the sandy soil wells are prone to collapse entirely. The depth of the water table can range from about 2.5 m up to 20 m. The sites visited had depths of around 3 m. Below 2 m the subsoil was essentially pure sand, which appears to be the general case in the area. The farmer must pack small logs, sticks and straw along the walls of the lower reaches of the well to retard caving in of the walls. These must be frequently repacked. The mouth of the well is also stabilized with a few logs so the farmer can stand at the edge to draw water. Most hand dug wells have only from 10 cm of water storage depth to perhaps 30 cm in a "good" year. The wells are usually about 1 m in diameter. Too much excavation below the water table will cause excessive cave-in of the wall. This constraint is a serious problem for the farmer, since the

rates of recharge are not nearly enough to keep up with his pumping. To remedy this difficulty he usually has a second well 30 to 40 m distance from which the farmer will draw while the first well is refilling. The farmer works between the two until the irrigation is completed. Obviously, well spacing is a concern, but the farmers seem to have a fairly good understanding of the distance wells should be spaced.

The garden visited was about 20 by 30 meters with a well situated on each of the shorter sides. (Often the wells are not centrally located.) Water is drawn by a rope with a "puisette," a half gourd or shallow container made from inner tubes, attached to the end. The water is poured into a small dirt canal which feeds it to distributory canals. The first meter or two of the main canal is lined with reeds to prevent destruction of the canal by the poured water. The water is eventually channeled into small individual beds of aproximately 1 x 2 m or less. Rechanneling the water from one bed to another or from one distributary canal to another is simply done by placing a few handfuls of soil to divert the flow. The canals are about 30 to 40 cms wide and 10 to 15 cms deep.

Most farmers work on their plots from 7 a.m. to 6 p.m. Actual time spent drawing water ranges from about two to six hours per day depending upon many factors (area of plot, recharge rate and volume of the well, depth of the well and infiltration rate of the soil). Farmers claimed that the depth of the water table does not vary as much between seasons as does the recharge rate. During the dry season, which is the primary onion growing period, farmers often spend twice as much time irrigating not only because of higher evapotranspiration rates but also because of greatly reduced groundwater recharge rates. The physical limit here is that the hand dug well cannot be deepened below the water table or widened to increase storage without bringing about a collapse of the well. Tremendous seepage losses in the small canals are also encountered, although farmers still find using their channels less time consuming than hand delivery to the beds. Farther to the north around Tahoua (outside the "onion" region) where the water table is considerably lower, garden farmers cannot draw water fast enough to keep it flowing and thus must deliver it all by hand. One obvious area for experimentation would be to look for better conveyance devices which would avoid the high infiltration losses without sacrificing portability. It also seems that the limited recharge rate makes motorized pumping less attractive than it would be otherwise.

Dallou Systems of the Air Mountains.[4] A somewhat similar adaptation is found in the valleys of the Air Mountains north of Agadez, a region within the Sahara so dry that 75 to 150 mm of rain annually constitutes a "good" year. Despite the very low precipitation, the high infiltration

---

[4] Assistance was obtained for this description from Ralph Royer of the Church World Service, whose account of the Dallou system is given in Appendix C.

rates of the sandy soils in the enclosed, rocky valleys allows much of the runoff to be captured in the underground natural reservoirs formed by the valley itself. People who have worked in the area say the resilience of groundwater recharge has been good, even after droughts. The "dallou systems," as they are called, constitute about 1 ha of irrigated land each. Widely fluctuating estimates are given as to their total number, ranging from 2,000 up to 5,000.

As Royer's report indicates (see Appendix C), these systems rely on local materials and knowledge only. As with the Madaoua-Galmi wells, these usually collapse after a few years' use and leave a depression which cannot be cultivated. With arable land being so scarce, the collapse of a well uses up precious gardening space. Farmers are frequently rebuilding wells and relocating their gardens from spot to spot within their valleys. It is said that over time farmers develop a keen appreciation of the subsurface characteristics of their likely water supply. With a knowledge of the amount of recent rains and of the level of the water in their wells, farmers usually know at the beginning of the cropping season, primarily for the dry season crop, how much water they will have for irrigation over the next few months, and thus how large they should make their gardens that season. For this reason, when the Church World Service was installing stabilzed wells in the Air region, it generally placed them at points specified by the local farmers.

The infrastructure of these systems indicates an impressive effort. The gardens are constructed in flat-lying areas. Most of the delivery canals must be built up to an elevated level in order to deliver water to the farthest reaches of the garden. Many of these have been built to a height of 1 meter at the well and slope downwards gradually over distances up to 50 meters, with secondary delivery channels going off at various points. These are all earthen canals made from existing soils at the site. Diversions from one canal to another or to different beds are simply done by hand, using soil. The leveling and sloping of these small and often intricate canals and the relative efficiency with which water delivery takes place indicates a significant knowledge of the traditional resource base.

The whole structure of the lifting device is also made from local materials, using the doum palm on the main parts and for lining of the wells as a stabilization measure (see Appendix C for details). The leaves are twisted into rope for drawing water and for tying the structure together. A local acacia variety is also used because it furnishes a very hard, long-wearing wood vital for certain structural components. Wood and trees are scarce in the region and there is competition for their use. The acacia trees provide forage for livestock, and the soil underneath the tree canopy is prized as a form of natural fertilizer which is mixed with the garden soil. Explanations why it should be effective include that fallen leaves contribute organic matter, that livestock gather to browse branches or take advantage of the shape and deposit excreta or that because the trees serve as rookeries for the birds in the area, the soil also accumulates excreta. For

whatever reason, the value of such soil is recognized and farmers periodically remove it for use in the garden beds.

The fundamental constraint limiting development in this region is the difficulty of access from the outside and the lack of local infrastructure. Existing roads are very poor and often only seasonal in character. It would not make sense to introduce gasoline or diesel powered pumps, since parts and fuel supply would be a certain problem. Several individuals familiar with the area supported the idea that potatoes could be grown more widely, since apparently the Air Region is known for good quality potatoes which are already produced in small amounts. Whether the problems of transport could be solved is not clear, but at least the question of what should be grown in the Dallou systems deserves further review from the perspective of the area's longer run development.

Komadougou Valley.[5] The region of the wide alluvial Komadougou River Valley, a tributary to Lake Chad, receives minimal amounts of rain, approximately 300 mm annually, and the river often ceases its surface flow in the dry season. Traditionally farmers have irrigated garden crops, again, primarily in the dry season, along the river using the shaduf system for lifting water from the river or deepened depressions dug along its banks. Water is then conveyed and distributed through an intricate system of small earthen canals, similar to those of the Hausa onion gardens or the Dallou systems. Gardens are usually no farther than 500 m from the river. A principal cash crop is tomatoes, which are dried, sold and then shipped out by road. Recent droughts have caused the water table to drop as low as 3 m below the ground surface in the dry season, thus posing serious problems for the shaduf irrigators.

Since a farmer's livelihood depends heavily upon tomato production, an irrigation perimeter was constructed with the intention of augmenting dry season irrigation. After construction it was found that the riverbed could not sustain the necessary flows, rendering the irrigation perimeter useless during most dry seasons. As with the Tara Project, one wonders why local farmers were not consulted about the likely low water levels which the project could expect to encounter.

There are some enterprising individuals in the area who have been purchasing small gasoline pumps capable of lifting up to 6 to 7 m and irrigating 5 to 7 other farmers' fields, at a variable cost of up to about one-third of their produce. Before other farmers increase their cultivated area it will be necessary to provide pump use on a more stabilized cost basis to prevent a few farmers from exploiting their monopoly position. There is also tremendous potential for further pump development away from the river within the wide alluvial valley and around Lake Chad, provided the reported groundwater resources are confirmed by field surveys.

---

[5]Based on information supplied by M. Mayna Sanda of ONAHA; the WMS-II team was unable to visit the Komadougou area.

Lutheran World Relief Well Program, Niger.[6] Another of the PVOs which has been active in Niger is the Lutheran World Relief (LWR), which began with a well digging program in 1975. Financing has been principally through the LWR's head office in New York, supplemented by a small amount of USAID assistance in Niger. An external evaluation team in 1982 pointed out that the $580,000 spent in the previous three years had resulted in 325 wells, 170 ha of irrigated, small-scale gardening and other improvements affecting approximately 13,000 people (Hoskins and Weber, 1982), making this a highly cost-effective program.

The program's central technological innovation consists of concrete rings 1.4 m in diameter and 1 m in length which are inserted into a well while it is being dug. As digging proceeds, additional rings are placed on top, the whole set of rings gradually moving downwards under compression. The finished wells are typically from 4 to 10 meters in depth, with a few being even deeper. Usually they are a meter or more deeper than the traditional hand dug wells in the vicinity.

The advantages of these wells are twofold. First, they provide a stable, more or less permanent well not susceptible to caveins. Second, by insuring sidewall stability below the water table, more storage volume is acquired. With a typical depth of 8 meters (or 8 rings), each well costs about $100 per meter. While relatively cheap for what it produces, it is nevertheless an expensive investment for a farmer, family or local community.

Since 1975 the LWR construction teams have installed over 1,500 shallow wells of this type in Niger. Two sites were visited, one near Madaoua and the other near Tahoua. At the Madaoua site the well visited was 4 m deep with about .5 m of water in it. As early rains had been sufficient, no irrigation from the well was taking place. There were six other shallow hand dug wells in the rather large garden plot surrounding the LWR well. The nearest traditional well to the LWR well was about 18.5 m away. Even though the newer well has signficantly greater storage capacity, the labor required to carry water manually or the losses from seepage from channels over a certain distance from the well are apparently greater than the labor needed to dig and maintain other wells. A second and perhaps more important reason is that in the dry season the recharge rates are so slow that these other wells are needed in addition to the improved one so that time is not wasted in waiting for a depleted well to refill. Further improvements are needed in regard to lifting methods, expanded storage capacity (which would permit higher flow rates in the canals) and improved conveyance methods.

The second LWR site was in the Tahoua Valley. As already mentioned, in this area farmers do not generaly use canals to distribute well

---

[6] Based on site visits by Ray Norman, an interview with Steve Lellelid of LWR and a program evaluation report by Marilyn Hoskins and Fred Weber, "Evaluation of Lutheran World Relief Projects, Niger," February 1982.

water; instead they distribute it by hand. As water is drawn from the well it is poured into a basin adjacent to the well. It is then delivered in a bucket or gourd from the basin to the garden beds or even to individual plants (e.g., sorghum, maize, fruit trees, etc.). In recent years 55 gallon metal drums have been used as basins. The LWR team found that farmers often asked for an additional cement ring to be left beside the well; when put on a concrete base this became an excellent storage basin. As with most well gardens in Niger, standard practice is to encircle the garden with a thicket fence to keep roaming animals out and to protect plants from wind erosion. Because of the lower water table, it takes much more effort to dig traditional wells in this area.

The 1982 Evaluation Report provides a wider view of the LWR program and also contains additional descriptions of selected local sites which convey a more complete impression of what is being achieved. First, because the technology is both extremely simple and generally effective, it has been rapidly taken up elsewhere in Niger. Other donors have begun using the same basic technology and have sent construction teams to be trained by the Nigerien LWR well construction personnel. Second, the LWR program depends heavily on existing irrigation skills as a determinant of the gardening component's success. Third, by standardizing ring size to conform with the Niger Government's own cement culverts, the problem of obtaining additional rings was diminished, while a door was opened for national distribution. Alternatively, the cost of each well is within reach of what private contractors could supply if the present demand continues. Fourth, a follow-up effort to add a cement apron and assist the farmer with water storage and hedge maintenance is necessary. And, fifth, the presence of LWR as a donor sponsoring vegetable gardening has in many areas given legitimacy to claims which local families had already been attempting to assert over land use immediately adjacent to traditional wells. The "losers" in such instances would be pastoralists who sometimes rely upon the same water sources during certain months. This competition explains why the hedging component in the LWR program was not totally successful, and why as a rule it is often desirable to improve two wells at each site, one for gardening and one for animal use.

The evaluators stressed the positive effect of the well gardens on family stability (Hoskins and Weber, 1982):

> We were constantly told how these gardening efforts were helping to prevent an exodus of local people who would otherwise have been forced to go great distances to look for additional employment.

Comments in the same vein were also made to survey staff in Mali's Action Blé program reviewed later in this chapter.

Without denigrating the overall quality of effort evidencd in LWR's well program, we should note that even at this very small scale of operation negative impacts can and do occur. By no means all of LWR's

projects have been successful. Cases reported by the evaluators from on-site visits indicate some of the problems to expect.

For example, in the Damana area where LWR installed 120 wells in three villages, the Nigerien agricultural service was unable to supply seeds in time for planting, while the manioc cuttings it introduced were infected and should not have been used as planting stock (Hoskins and Weber, 1982). To create the nursery at Borgo land was taken away from existing farmers, while at Kobi Village the women who had been gardening were displaced when Project inputs became available primarily to male household heads. In the third village the more influential families received wells they do not fully use for gardening, while excluding the poorer farmers. Instead of voluntary work by beneficiaries, the projects were being built by paid labor engaged by the local agricultural agents. Nevertheless, "the total appearance shows poor management and supervision."

A representative of one of the other PVOs summed up the Damana Projects problems as (Hoskins and Weber, 1982):

> . . . goals were too ambitious, site and participant selection was bad, there was "enforced" participation, some of the more important villagers got wells first and then did not use them intensively, some families fear that if they participate they will "lose land" or will be forced to grow certain new crops . ., over-reliance on ineffectively constructed wire fencing, rural outmigration draining available labor during gardening season, sons often refuse to work in their father's garden and older people abandon plots when they become ill. Gardeners who receive imported metal fencing materials "for a start" do not perceive the need to develop live fencing or other local protection schemes.

Without going into detail, evidence was given that similar problems occurred elsewhere. Sometimes villagers cut off traditional cattle tracks by the placement of their gardens. Sometimes structures were built but the laborers not paid, and new agricultural staff had no knowledge of a project's previous commitments. Often fences were left unrepaired. Record keeping was lax. The wells built without aprons became health hazards. There was conflict with the Forest Department over the cutting of branches to make fences. When projects were successful, market saturation sometimes occurred.

Such difficulties are common to the whole of Africa and do not outweigh the significant positive impacts which the LWR's well improvement program is making. What they do suggest, however, is that we should not assume automatically that small-scale projects will be immediately popular, or can circumvent weaknesses in the local supply system. Using water for gardening means obtaining land in settings where land within reach of a well may be highly prized. Villagers under inegalitarian control are likely to see existing imbalances perpetuated

within the well improvement program unless direct steps are taken during implementation to see that this does not happen. Farmers will need seeds, transport and markets. Where the agricultural service is already ineffectual it will continue to be so after implementation of the project. We suggest that field planners for small-scale projects need a simple checklist to help evaluate invididual sites being reviewed for assistance of this nature. More generally, there is a strong case for exchanges of expertise betweeen the various PVOs working in the Sahel so that lessons learned in one area can be extended to others.

Action Blé-Diré

Action Blé-Diré (or ABD) is in Mali's Sixth Region in the Lacustrine Zone bordering the Sahara north of Mopti towards Tombouctou. It is an exceptionally interesting project from the standpoint of anyone considering small-scale pump irrigation in remote areas of Africa. Since ABD was not included in our itinerary, we cannot speak from firsthand observation (though one of us has been in the Sixth Region on earlier assignments). However, several of those who have worked in ABD were interviewed, and we were furnished an excellent set of field reports from which this case is drawn.[7]

Context

Action Blé-Diré is located on the northern margins of the Inland Delta almost 1000 km from Bamako and 311 km from Mopti, without a reliable road connection (it is about 100 km to Tombouctou, also without a reliable road). The area has long been subject to trans-Saharan influences, with its leading nobles being the mixed descendants of Sonrai landholding families and Moroccan troops who invaded in 1591 seeking salt mines. Thus, Sonrai families have been growing wheat and making bread from before the time of the American Revolution. Today the area is strongly Islamized. Koranic customs are followed and women play a relatively minor role in agriculture, in contrast to African societies farther south. The central "arrondisement" of Diré had in 1975 a population of 21,360 (excluding the town of Diré itself), of which almost 80 percent were Sonrai (the dominant ethnic group), and the rest being mostly Peuls (Fulani), with a sprinkling of Bellah (Crystal, 1981). The

---

[7]Besides the Action Blé Project Paper (1978), the USAID/Bamako Office has also the following unpublished draft reports: C. Crystal, "An Analysis of the Socio-Economic Factors Which Distinguish Innovators from Traditional Farmers in the Action Blé-Diré Project," 1981; D. Mattern, "Final Report, Action Blé-Diré," 1981; W. De Rafols, "Economic Analysis Update," 1982; Susan Buchanan, trip reports, 1983; L. Smith, "Survey of Sixth Region Pump Farmers -- 1982-83 Wheat Campaign," 1983; and E. Olsen, "On-Farm Water Management of Small Irrigated Perimeters, USAID/Mali," 1983.

larger area served by ABD under USAID assistance, including Bourem, Diré and Dangha, has a population of 77,265 (Rafols, 1982).

The comparatively dense population in the Diré area, despite its low rainfall (a 20 to 40 day growing season under arid conditions), is explained by the presence of alluvial soils and the annual Niger flood. The brief "rainy" season occurs in July-August, tapering off in September, and is throughout exceeded by potential evapotranspiration (Olsen, 1983). Rice and sorghum are cultivated on riverfront lands during the brief wet season, the rice then becoming established in time to utilize the river's flood from October onwards. Wheat is planted in October-November and harvested in March-April. There are also important secondary crops planted during the winter, vegetables (okra, onions, tomatoes, cabbage), tobacco and spices, which are hand watered by calabash. It has been estimated that wheat requires 8,000 m^3/ha of water over its growing sason of 110 to 120 days, or from 12 to 14 irrigations per season, whereas for sorghum about 4,200m^3/ha is needed (Rafols, 1982). Rice would require a greater amount if it were not supplied from the river's flooding.[8] Existing wheat farming employs "calabash" irrigation wherein two men stand in the channel and lift water by hand to flow into short, unlined canals which distribute it into small 2m x 2 m hand-dug basins. Evaporation salts tend to accumulate on the ridges, while the clay in each basin holds the water for a day or two, allowing gradual infiltration. Olsen (1983) suggests the traditional basins ("cuvettes") are a good techical solution, but perhaps 30 percent of the water is being lost in the unlined distribution system. Under this sytem as it was before the introduction of pumps, the most wheat a family could manage to cultivate was about .4 ha (roughly 1 acre). Pump delivery could result in a maximum of 4 to 5 ha per unit, a tenfold increase.

Project Components

USAID's involvement with Diré followed the Malian Government's own efforts under Action Blé-Diré, assisted by FAC. ABD's actual activities were to set up its office and a medium-sized irrigation perimeter at Diré. Farmers rented land in this perimeter, but rice yields were low (600 to 700 kg/ha). As at Bakel, a large French solar installation was supposed to provide water, but instead farmers have had to rely on several large diesel pumps. As an experiment in 1977, ten French Bernard pumps were supplied on credit to village notables in the surrounding area (utilizing the same system of float-mounted pumps which had been

---

[8] Olsen's calculations of actual crop water needs suggests that the ABD approach requires overwatering because of its rigid timetable. Plant water needs change over the growing cycle, and at Diré farmers have tended to wait until plants begin to wilt before irrigating. If more attention were paid to soil moisture, the wheat might be irrigated more frequently at the time of its peak needs, but the total water pumped would be less.

pioneered in Senegal). ABD wanted another donor to expand its provision of pumpsets and USAID/Mali complied under a "host country" implementation arrangement. A project Paper (No. 688-0213) was finalized in early 1978 for a four million dollar project. It anticipated immediate implementation since ABD was already active in the Sixth Region.

It was recognized by USAID that assisting ABD would be difficult. The project area was very remote, even by Mali's standards. Farmers were almost entirely traditional, there being only one plough in the whole area, aside from an unused one in the ABD offices. On the positive side, however, was the fact that farmers already knew how to grow wheat and were irrigating, albeit by hand. It seemed likely that better wheat varieties could be introduced, subject to local adaptive trials at the ABD research station. Farmers would have a strong incentive to adopt them, since wheat is their staple food and the area is cut off from external markets. The area seemed free of wheat diseases. A visit by CIMMYT technicians confirmed that even under calabash irrigation some farmers were achieving yields equivalent to 5 tons/ha, better than elsewhere in Mali. In years when there was a surplus it was planned that the excess could be milled into flour for sale elsewhere in Mali; USAID entered into negotiations to insure that a flour milling capacity was established. The pump technology was already in operation within remote areas of Senegal and under proper use could permit 4 ha of wheat to be produced from each pump. With Mali Government support it should be possible to import fuel and parts by river transport during the highwater wheat growing period and to export wheat by truck during the dry season following harvest. What was missing was the finance for purchase of pumpsets, seasonal inputs, credit for participating farmers and a system of logistics and servicing to keep the pumps operating.

The USAID Project Paper envisioned several components to circumvent the obvious technical and organizational problems which ABD was bound to encounter when introducing more pumpsets into the isolated Sixth Region. It should be noted that the design was relatively complete: had each of the components worked as planned, the project would have been a success. And, of course, it had the attraction of avoiding entirely the kind of expensive siteworks which have been necessary on most other irrigation projects.

First, USAID/Mali wanted to avoid the problems associated with having a large pump mounted on a floating platform in the river (the Senegalese pattern). Instead it proposed to finance small, skid-mounted diesel pumps which two men could lift. USAID staff also decided to make their ABD project a test case for Washington's new policy of encouraging Third World suppliers. Aproximately 250 diesel, five horsepower pumps were ordered from India, with enough spare parts to last the life of each pump. While of a Lister design, the Indian pump is said to have cost about a quarter of what a similar pump from Europe would have cost.

Second, it was planned that four farmers would become the associated owners of each pump since one pump could handle up to 4.5 ha of wheat and

one farmer on his own would have enough labor for only about one hectare (Rafols, 1982). This aspect was soon dropped under opposition from the farmers, leaving a single owner responsible for each pump. A village commission was also to be formed composed of pump owners and elders to scrutinize applicants for pump loans. Each loan would be amortized over a 4-year period, requiring payment of 175,000 MF in annual installments. It would be cosigned by two other farmers who must promise to act as security for the loan. The village commissions were supposed to represent farmers in any disputes which might arise with ABD.[9]

Third, the project design called for ABD to set up a special revolving account from which farmers' short term crop financing would be provided, at 8 percent interest and based on nonsubsidized, commercial prices. An interesting innovation provided that these seasonal input loans,for fuel, seed and any other charges, would not be issued without the signing of a contract obligating the farmer to repay credit promptly within 30 days of harvest but also obligating ABD to supply fuel, oil, fertilizer, spare parts and mechanics' services. A levy of 10 MF/kg was initially foreseen to cover project operating costs.

Fourth, there were to be eight contract mechanics to insure maintenance and repairs during three years while local village youths would be under training to replace them. Six months in advance of the beginning of pump installation a repair shop would be constructed and a spare parts system established. Farmers would pay for spare parts as required, but ABD would pay the mechanics' salaries during the initial period.

Fifth, ABD would upgrade its extension service in the project areas. It would also, as seen by the project paper's authors, engage in an ambitious program of action research. Investigations would be launched covering a broad range of topics: socio-economic factors, appropriate technology for pumps, reforestation and even the undertaking of a functional literacy program. ABD would run agronomic trials to test fertilizer applications and to identify promising wheat varieties. Its experimental farm would include demonstrations on water control, wing beans, pigeon peas, sunflowers, etc.

All of this was to be organized under the standard USAID "host country" contractual arrangements whereby the ABD Director would be in charge of the project assisted by a USAID-supplied Project Analyst. While the Project Analyst was given numerous responsibilities within the scope of work as defined in the Project Paper, the position carried no authority within the ABD or, for that matter, the Malian administrative system generally. The ABD Director was responsible for maintaining

---

[9]This and the following section on implementation difficulties are based on David Mattern's final report, October 1979-April 1981. Additional information is derived from interviews with the former ABD Project Manager and USAID/Mali's engineering staff.

documentation on the expenditure of USAID supplied funds, in accordance with standard AID regulations.

Implementation under ABD

When approved in 1978 the Project Paper envisioned rapid establishment of a logistic base in time for the initial delivery of pumps before the start of the wheat growing season in October 1979. As often happens in USAID projects, there were delays caused by USAID's insistence that the Mali Government meet certain "conditions precedent" before any release of funds could occur. For example, USAID insisted upon and eventually received the Mali Government's compliance with the continuance of a "free Market" for cereals in the project area. As a consequence, the project's funds were not finally released until August 1979. This one year delay in financing meant that pumps would be supplied for the 1979-80 season without farmers' receiving advance training in their maintenance, without the hastily recruited mechanics having tools and without the construction of the field workshop. In an heroic effort to avoid losing a year in the project's implementation plan USAID/Mali decided to have the pumps it was ordering airlifted into the country. The enormous expense this entailed in turn made it mandatory that the project proceed with what was on hand for the 1979-80 season. When ABD submitted its budget in October 1979 it proved unacceptable to USAID, but to avoid further delay the project manager obligated one-tenth of the total and proceeded to make an advance of funds for operating expenses. Even so, the project was able to install only 34 pumps in its first season, and participating farmers were forced to plant late.

The project's initial effort was concentrated in the Bourem sector, about 12 km from Diré. Later its activities were spread into villages in the Diré and Dangha sectors. At its maximum the project was working with about 50 villages and 250 pumps. Since the average family size for pump owners was 11, there were approximately 2,500 direct beneficiaries. However, Action Blé-Diré's involvement as the project's executive agency became so problematic that in January 1981 USAID froze further disbursement of funds. The project did not resume field operations until September 1982 when a second phase of "emergency" phaseout activities were launched by USAID (in an attempt to get the project working so that it could be officially handed over). Before we examine the second phase activities, which were especially directed at the problems of pump maintenance and support, let us first review the first phase. There has been a tendency among some advisors in Mali to put most of the blame for the first phase on the ABD. One can also make a plausible case, however, that the decisions made by October 1979 had already set the stage for many problems which surfaced in 1980.

From USAID's standpoint the most objectionable feature in the first phase was the ABD's nearly complete absence of acceptable accountancy procedures (as judged from U.S. agency practice). The final report by the Project Analyst goes into this aspect in some detail, since it led to

the subsequent freezing of project funds by USAID. Mattern (1981) points out that the Malians had almost no understanding of American concepts of financial management. The ABD's head accountant worked "under the direct and constant scrutiny of the director," who kept the books himself. There were no separate sections for budgeting, accounting, cash flow or even salary payment. While the ABD's proposed budget for 1979-80 was not approved, as already noted, the Director did receive some funds to begin field operations. He continued to use the submitted budget for making purchases up to April 1980:

> Items that were nowhere found in the PP (project paper) budget were purchased . . . such as furniture for Division Chiefs, a car cassette player, a football, and pre-project training programs were approved for reimbursement, along with valid items. It is understandable that AID did everything possible to get the project moving but in these oversights and AID's constant admonition to the Director of ABD to "move" the project money as quickly as possible were the beginnings of mismanagement and project failure.

Meanwhile, there was no operating fund; consequently, when the Director was absent all disbursements ceased. This had an extremely adverse impact on the field staff:

> The lack of cash reserves in Diré meant that contractors ("encadreurs," survey takers, mechanics, drivers, etc.) often went months between pay periods with a corresponding lack of enthusiasm for work . . . . It should be emphasized that in an AID financed project, contractors for ABD have not been paid for six months. In effect, they have worked an entire wheat season without pay.

One reason for this severe and continuing cash flow problem was that ABD was trying to make its key equipment purchases -- boats, generators, tools, etc. -- direct from its in-country operating expenses. Such items should have been passed through the USAID Management Office but the Malians were uncertain about the necessary procedures, and probably feared further delays. When major commitments were being undertaken there was no sysem for mutual notification between ABD and USAID:

> The first indication USAID received of the transport of 425 pumps and accessories from Bamako to Diré was a RAC message demanding payment of 44 million francs to the transporter.

ABD blamed USAID's reimbursement policies for delays in making payments, a complaint one hears across Africa. Under these circumstances it was not surprising that when farmers did begin to repay their loans at the end of the first wheat season ABD used the funds to pay its operating expenses rather than placing them in a special blocked fund as the grant agreement had stipulated (Mattern, 1981).

A second area of immediate conflict arose in regard to the mechanical services which ABD was supposed to supply to pump owners. A French head mechanic was engaged to set up the parts diagnosis and supply system and to control the vehicle park. Since vehicle use is often a sore point in African projects a system was discussed whereby the Division Heads submitted their travel plans a week in advance. The system worked well until the Director needed a vehicle in disregard of the schedule; "soon vehicle use again became confused and unorganized" (Mattern, 1981). After three months the head mechanic left and never returned to Diré. The routines he had started quickly fell into disuse, partly because only a few of the mechanics could read or write. Spare parts were never inventoried nor stocked in warehouse. Lack of a repair shop meant "that pumps stored in Bourem for major repairs were exposed to dust, sand, rain and wind for long periods and tools were often misplaced or lost" (Mattern, 1981). On top of all these site difficulties, USAID officials in Bamako learned to their dismay that the Indian pump manufacturer had diversified and was therefore discontinuing the project's model of Cooper pumps.

Of the initial field mechanics hired, all were from the south of Mali and therefore did not speak Sonrai; half were neither good mechanics nor serious about their work (Mattern, 1981). For the first half of the initial season they lived at Diré, more than 12 km from the main project site. Although they all were given mobylettes, there were frequent periods or when fuel was not available or there was no money to purchase it. Of necessity they went into debt with farmers and storekeepers at "outrageous interest rates" (Mattern, 1981). There were never enough tool sets, leading to borrowing, confusion, missed assignments, poor work and loss of tools. By the time extra sets arrived the season was finished; in April of 1980 eight sets were on hand for 16 mechanics. The mechanics were said to have been:

> . . . impolite and contemptuous of farmers for their lack of techical knowledge. Farmers in their turn were impolite by the standards of the South. A mechanic traveling 10 kilometers to fix a pump, after work and at meal time, often was not offered anything to eat or drink (Mattern, 1981).

The third and perhaps most crucial failure from the farmers' viewpoint was ABD's inability to provide the inputs farmers had been promised. In a survey of the project's socio-economic impacts Crystal notes (1981):

> For the pump owners cultivating this year, the incompetence of the Action Blé staff constituted by far their most serious constraint on production. The failure to provide promised seed, lateness in obtaining cutting permits, insufficient quantities of motor oil and diesel fuel delivered at planting time reduced hectarage planted by an estimated 30 percent and delayed planting by as much as two months in some villages. Further, a diesel fuel shortage at the critical moment of wheat

> maturity (the milky stage) threatened the fecundity and nutritional quality of the developing seed . . .

In fact, in each of the first three cropping seasons ABD was unable to prevent a break in fuel supply during the crop's critical period. By the 1980-81 season most pump owners had found ways to obtain small quantities of fuel from merchants in Tombouctou or elsewhere, but often receiving dirty or watered-down fuel purchased on credit at inflated interest rates and "exhorbitant prices" (Mattern, 1981).

Seed supplies proved equally problematic. All farmers were trying to save some of their own seed but few managed to last out the year without eating it. According to a subsequent Project Administrator's observations (Smith, 1983):

> Those who do go to great lengths -- sending it off to relatives in the South and even poisoning it -- to guarantee it won't be eaten. They prefer to buy seed on the market as ABD apparently mixes the varieties, which results in crop loss as maturation periods are not the same. The farmers are very variety conscious . . .

While in 1979-80 over 600 wheat varieties (many of them obtained through USAID intervention from CIMMYT) were planted, seeding was done late on exhausted soils and the trials were unsuccessful. In May 1980 the ABD set aside a 5 ha field to become the project's research plot but the field was never cleared. Fertilizer trials could not be started because of a delay in receiving the fertilizer. Yet, in the Project Analyst's judgment:

> The research division was the most organized of all the divisions set up to manage the project. Detailed programs of agronomic and socio-economic research were worked out cooperatively, budgets and implementation plans were elaborated . . . . The problem, however, was that neither of these programs was given funds according to a budget, but only small sums to alleviate pressing needs (Mattern, 1981).

Indeed, the whole ABD extension effort must be judged a failure. In her subsequent 1983 production survey Smith found that only the very first of the pump owners had received any advance training from ABD; the second received none. While contact staff (or "encadreurs") usually possessed nine years of general education, their technical training had been of a highly theoretical nature far above their actual comprehension. Most had atended classes in agronomy and plant pathology but did not know how to perform simple field measurements. A majority of the supervisors (or "moniteurs") were from the south and few could communicate with the local Sonrai farmers. Extension themes for each cropping season were based on the agricultural operations elsewhere in Mali, not on local farmers' needs. The real issues such as pump maintenance or seeding dates were ignored. Agents lacked measuring

tapes, string, fungicides and transport. Most frustrating of all, however, was the matter of the non-payment of salaries and allowances:

> At this moment (May 1981), all contractors have been waiting since 1 November 1980 for their salaries. Agents are deeply in debt to farmers in their villages who rightly consider them parasites. No work gets done because no one has been paid (Mattern, 1981).

And yet ABD continued to employ additional staff, agents, mechanics, survey takers, piroguiers and gardiens in the secteurs, until there were 94 employees for 158 farmers, not including government employees in Diré. As of early 1981 ABD was paying 36,434,280 MF in salaries and allowances yearly at a total levy of 5,688,000 MF and an estimated total production value of 161,600,000 MF (Mattern, 1981).

Farmers' reactions to these circumstances were conditioned by their understanding of the contractual relationship between themselves and the ABD. (It seems the idea of having loans issued against a mutual contract was USAID's.) In the 1979-80 season ABD found farmers refused to pay the 10 F/kg levy because ABD's late installation of pumps and insufficient supplies of diesel fuel resulted in late seeding and poor harvests. Those who repaid any of their credit insisted it be applied only toward the purchase of the pump, not toward fuel costs or the levy. There was the further problem of the 10 Bernard pumps sold to the local elite in 1977. By 1979 many were not working and spare parts were unavailable. When ABD could not provide spares, the village leaders owning the pumps refused to repay their loans, and other, less well-to-do farmers were likewise disinclined. Ultimately it was decided loans should be recovered in either cash or kind. About 15 tons of wheat were received from the 44 participants in the 1979-80 season but this required a heavy administrative input in making visits to farmers and in transporting the wheat back to ABD. Farmers had assumed the grain they paid ABD would be retained by the organization and reissued to them as seed grain. Instead, in 1980-81 when there was a shortfall of 30 tons of seed ABD supplied seed only to those who had not already participated and then only enough for 1 ha each. As of May 1981, when further USAID financing had already been frozen, the unpaid loans outstanding to ABD were about 56 million MF (Mattern, 1981).

Project Management

In small-scale pump irrigation the technical aspects of water management are sometimes less important than the overriding issue of supporting services and fuel availability. We should recognize that parts to pumps can be conceptualized in almost the same way as the supply of subsurface water from a limited recharge acquifer. The relative efficiencies of individual pump models become less significant than the relative capacities of the supply and support systems. When we consider

the situation at Diré, without reliable road access or fuel storage capacity and at the end of a 300 km track from Mopti, it becomes clear that to stay in operation the project required unusually efficient and flexible administration. Insofar as one can deduce from the reports, neither attribute was much in evidence.

A basic managerial flaw was the widespread African custom that the unit's director must control all matters of consequence personally. The USAID Project Analyst describes the ABD's managerial structure as follows:

> ABD personnel from the Division Chiefs down to the "encadreurs" had no incentive to perform their duties. They were given responsibilities only on paper; never the means to carry them out. When the Director was called away, there was never any money left in Diré as an operating fund . . .
>
> The centralized control of every aspect of ABD functioning by the Director constituted the critical weakness of the Action. He hired contractors and paid them personally, purchased commodities, kept the books, wrote and negotiated contracts, and made all the decisions. When he was absent from Diré, which was frequent, he left such a vacuum of leadership that all activity was suspended (Mattern, 1981).

Early on in the life of the project communication between USAID/Mali and ABD broke down. USAID officials felt the Director rarely kept his USAID appointments. ABD's planning procedures were not formalized. Key decisions such as expansion of work into the Dangha sector were reached without consideration of managerial capacity or likely costs. USAID's procedural requirements were not understood by the Malians. In place of written instructions "these procedures were communicated from the Project Manager to the Project Analyst verbally, then in meetings to the Director in an ad hoc manner" (Mattern, 1981). However, the Project Analyst's lack of official status in the highly centralized Malian system meant that his role "quickly deteriorated into that of an observer."

> Frozen out of all decision-making at ABD he reported current developments to AID in Bamako and took the blame for AID's lack of response to the myriad problems besetting the Action (Mattern, 1981).

It is easy to blame ABD's difficulties on its lack of managerial skills. One can argue to the contrary that the style of management ABD evidenced is widespread in Africa, where it represents a functional adaptation to extreme circumstances outside the usual range of American experience. For example, USAID's complaints over the Director's monopoly of cash payments became muted when it was realized that there was no place in the project where money could be securely kept. When, after great effort, a safe was finally brought to the site, the instructions had been lost and nobody could discover how to lock it! (It was to serve

for a year in Bourem as a filing cabinet.) The new generator being transported to Diré so that the project workshop could have electricity was smashed to pieces in transit between Mopti and Diré, but then the workshop wasn't even started because of still other delays. The project's social scientist spent weeks developing 11 types of survey questionnaires to measure project impact, only to discover that interviewers were not paid for months on end and project funds were cut off just before computer analysis was to have begun. As so often happens in Africa, the eventual socio-economic report was based on hand tabulation of those questionnaires which a judgmental review suggested wwew at least plausible, if not authentic. Such examples indicate that managerial procedures are themselves a form of social technology and, as such, must be adapted to suit particular local conditions. The combination of shared management, decentralized control, line item rigidity, scrupulous accounting, multiple objectives, advance planning and data intensive monitoring which was built into the project design far exceeded what the Malian system could supply. Yet this was a "host country contract," supposedly being implemented by the ABD as the primary executive agency.

Implementation under USAID

In the second phase of implementation from September 1982 onwards USAID/Mali attempted to provide the project's support by working directly with village leaders and the political party, i.e., what was termed "activités paysannes." This strategy obviated the need to rely on ABD. It also meant, however, that USAID itself had to organize the project's supply and managerial functions. This was accomplished by personal services contracts with individuals already in-country,[10] and by obtaining Peace Corps volunteers to act as temporary field mechanics.

The multiple outputs specified in the initial Project Paper were now jettisoned for the overriding goal of getting as many pumpsets as possible back into operation so that the project could be officially handed over. While assisting farmers during the 1982-83 season, it was hoped the new project team could get the long anticipated workshop built, recruit and train more mechanics and reestablish a fu .ioning spare parts system. The location of the engine manufacturer in India and the phasing out of the project's model of pump tremendously complicated the whole process. We were told that at one point USAID/Mali was even trying to secure assistance from the U.S. Embassy in Delhi to expedite arrangements. At times nearly the whole of the USAID/Mali Mission was engaged in trying to resolve the project's "nightmarish" logistics problems.

USAID's new field team soon discovered the same constraints which had afflicted ABD's field support efforts. There was insufficient

---

[10] One unexpected obstacle turned out to be the difficulty of getting such individuals bonded, an AID legal requirement.

repayment from the existing pump owners to cover fuel orders for the new season which was already beginning. Low rainfall in 1982 meant that farmers without pumps lost their sorghum crop. The 1982-83 wheat season was again characterized by a low water year on the river and the consequent drying up of the side ponds ("mares") normally used by farmers to extend irrigation. Thus, pumps were pressed into double duty, supplying water from the river into the "mares" and then again from the "mares" to the fields (Smith, 1983). The first delivery of fuel for the wheat season did not occur until December 21. This late start meant that crop maturation was delayed into the season of high temperatures and (in early 1983) unusually high winds, requiring still more pumping. It then turned out that the commercial supplier had provided the wrong weight of engine oil. Farmers objected to the change but in the absence of an alternative, some used it only to find that under extended operation in hot conditions the pump crankshafts began to seize, one of the two most common reasons for total breakdown. When the river levels dropped unexpectedly early, the project's final shipment of fuel became stranded on barges somewhere upstream in the Inland Delta.

The various trip reports and field memos submitted in connection with the campaign to resurrect farmers' pumps provide an insider's view of the real-world problems which such programs can be expected to encounter in remote African environments.[11] First, the manufacturer's list of needed parts had been based on Indian experience and did not coincide with ABD'S actual needs. One obvious possibility was that farmers were very inexperienced and simply did not know how to maintain their pumps. A second problem was that some parts appeared to have been supplied in the wrong sizes or else disappeared in transit to Diré. A third was that in mounting pump engines on sleds, unless the pump assembly was very firmly built, there was vibration in the flywheel and an eventual seizure of the crankshaft. The more often a pump was moved the more likely such problems occurred. Alternatively, placing the motor on a slant at installation also caused uneven wear, with the same ultimate consequences. A fourth common cause of breakdown was because of watered fuel, causing the injectors to run hot and necessitating frequent replacements. A fifth problem was the operation of the pumps without frequent enough oil changes or with dirty oil. A sixth problem occurred when the flywheel was insufficiently tightened, usually because mechanics lacked proper tools. Similarly, breakage of gears was common and could have been caused by insufficient tightening, poor manufacturing or total lack of lubrication (improper quality and quantity of oil). By early January 1983 the USAID engineer assisting the project found that within less than a month's operation already three kinds of key parts were totally out of stock. At the observed rate, before the season's end

---

[11] See especially memos by Susan Buchanan, GDO/ENG, for dates January 11 and 18, 1983, and for February 11, 1983, respectively. The trip report for the period 19 November to 17 January is particularly illuminating and underlies this account.

there would be at least 31 pumps out of operation, whose owners would lose their entire crop.

The emergency campaign approach to pump fixing, while necessary to revitalize the program in late 1982, did little to improve the long-run prospects for pump support. There were two distinct groups of mechanics: the Malian former employees of ABD and ten Peace Corps volunteers. The two groups tended to work separately, going out in "sorties" village by village to identify and fix broken pumps. This concentration on the inoperative pumps was deliberate. It had been found that when mechanics tried to make minor repairs on a working pump it would end up in worse shape that it had been before. Of course many of the running pumps already had serious problems which if left uncorrected would cause an eventual breakdown after the mechanics had left. It was also apparent that without training farmers to do the necessary maintenance at the time when repairs were made, the problem would soon reappear. As the USAID/Engineer observed

> Maintenance, the unique responsibility of the pump owner, and the single most important factor to minimize the number of breakdowns, was ironically the most neglected input. Approximately 90 percent of the pumps which our team repaired had broken down or were running poorly due to the owner's negligence in performing even the most basic maintenance . . . (Buchanan memo, February 11, 1983).

It was obvious that improved performance depended upon a cluster of interconnected factors: availability of fuel and oil, sufficient spare parts of the right kinds, a mechanic availabe to install the part and farmers who understood enough to perform their own routine pump maintenance. This meant providing mechanics with tools, training mechanics and farmers alike and verifying the state of all pumps to identify which parts were the most needed and which problems were still occurring.

The search for Cooper parts proved an exercise in frustration. The Peace Corps mechanics who were now leaving had resorted to "cannibalizing" new engines for parts, a practice which for obvious reasons could not be continued. While lists were being forwarded to India for order, a new difficulty emerged, how to open a letter of credit with a third country now that the project was divorced from ABD. The USAID engineer, the contractor and the remaining ABD mechanics struggled to get the existing jumble of parts and half-complete engines into an orderly system. This task had already been attempted twice before, by the original ABD staff and then by two Peace Corps volunteers, without lasting success, in large part because of the chaotic circumstances engendered by the emergency repair campaigns. Parts had gone on sale again in December to farmers without there being a master list or even sometimes agreed price estimates. There were English, French, Indian and Malian French names for the parts to reconcile. A military workshop was located which could machine some of the missing parts, but quality

control was so weak that each part had to be checked against specifications; later a second machine shop evidenced the same problems at higher prices. Difficulties arose concerning what could be substituted for special alloys found in some of the bearings. Even the "simple" task of designing the new workshop was complicated by Diré's remoteness, by uncertainty concerning its functions and by the fact that the project had less than a year's funding left. The USAID staff found themselves traveling back and forth between Diré, Markala and Bamako to relieve the pressure on the project's one vehicle.

While becoming responsible for pump support, USAID staff began to discover why the ABD mechanics had been operating as they did during the earlier seasons. For example, when leaving by boat for a remote village the mechanics were severely limited in regard to what parts they could carry with them. Inevitably there were unanticipated needs and if an item was not available the field team would be forced to take a "better" part off someone else's broken pump to fix another pump which could be repaired, the very practice for which the ABD mechanics had been criticized. The question of whether to continue working with the ex-ABD mechanics was commented on at some length by the USAID engineer:[12]

> The mechanics situated in the field were of varying degrees of competence . . . and their fees were generally too high for most farmers, who were used to receiving these services for free from the times of Action Blé. There were many reasons why these fees were too high, and it most often depended upon the personal relationship between the mechanic and the farmer. Frequently, when farmers couldn't or wouldn't pay, the mechanic counted on the few occasions that a farmer could, and made up for his losses with high fees. Efforts to group farmers to contract with a mechanic for services during an entire season had been attempted, but often failed when a member of one of the parties didn't come through. In some cases, when a repair was completed and if the farmer didn't pay the fee agreed upon, the mechanic would remove the part repaired, thus spreading their reputation for "sabotage." It was evident that a unique history existed between each mechanic and farmer, whether good -- family or friends, good hospitality, or a helping hand offered; or bad -- a meal or bed not given, tools stolen, bad work performed, or arrogance between different ethnic groups . . . I was not convinced that training a whole new breed of village mechanics was either feasible or desirable.

Project Impact

The Project Paper specified that ABD should be assisted by the services of an on-site social scientist, whose report in 1981 gives at

---

[12]Buchanan, trip report for 19 November to 17 January; memo of 11 February, 1983.

least a preliminary picture of pump owners.[13] Of those receiving pumps 21 percent had non-farm occupations, either as religious leaders ("marabouts") or as school teachers. There were some traders but these were already farming. The pump owners controlled more than twice as much land as non-pump owners: an average of 7.0 ha versus 2.8 ha; of this, wheat accounted for 2.6 ha versus .5 ha for non-pump owners. It seemed likely that pump owners were generally the descendents of village founders. Most wheat (75 percent) was planted in fields by the main channel of the Niger, with a further 22 percent in locations served by flood recession ponds ("mares"). In the 1980/81 season the area planted to wheat was increased about 19 percent over 1979-80, chiefly it seems by an ABD initiative which gained permission for farmers to clear areas along the river otherwise protected as forest reserves. Pump owners in general had greater wealth than non-pump owners, but it was difficult to get reliable answers on grain yields, since this information could be used to increase farmers' ABD assessment and general tax liabilities. Farmers were also afraid that they might be beseiged by neighbors asking for handouts, and sometimes even a man's wives did not know for certain how much grain he had locked in his store. In the anthropologist's view, reported figures were below actual yields by up to about 30 percent. A "reasonable estimate" of yields being achieved on average was 1,500 kg/ha (Crystal, 1981).

Perhaps the most dramatic effect of the project was in reducing the work time required for growing wheat. While a pump owner would put in 157.5 person days/ha, a calabash irrigator would need three times as much effort -- 483.6 person days/ha. A significant difference is that the non-pump operators who must manually lift water usually dug longer and deeper canals, "frequently as deep as two meters by a meter wide and as long as 300 to 500 meters" -- a task which sometimes took up a month's effort (Crystal, 1981). For calabash farmers who did not gain access to pumps the project had serious negative impacts: seed availability declined, labor costs more than tripled between 1978 and 1981 and various traditional forms of work and commodity exchange between households declined. Those "calabasiers" who tried to circumvent these consequences by association with pump owners earned little more than those who did not (Crystal, 1981). It was clear that whereas farmers used to rely upon unpriced reciprocal exchange to meet many household needs, they now had to learn how to calculate production costs in monetary terms. There were no significant differences between pump owners and non-pump operators in the kinds of tasks performed by women, e.g., seeding, threshing and winnnowing. Of "natural" problems, water shortages and birds were the two major difficulties. Women and children were reported to have spent from two weeks to a month guarding the fields before harvest, though only 3.7 percent of the male farmers interviewed thought it necessary to mention this as a woman's activity! The most serious overall problem in

---

[13] C. Crystal, "An Analysis of the Socio-Economic Factors which Distinguish Innovators from Traditional Farmers in the Action Blé-Diré Project," USAID/Bamako, 1981.

the 1980-81 season was listed as "the incompetence of the Action Blé staff" (Crystal, 1981).

The question of how much pump owners were actually benefitting surfaced as a priority issue when an economic analysis update in early 1982 concluded that the project was not economically viable since at an average of 1.5 tons/ha, wheat farmers would be making a loss of -98,313 MF per ha. Unless farmers could achieve more than 2.5 tons/ha or receive much higher wheat prices, their operation would still give negative returns (de Rafols, 1982). Why then were farmers at Diré and Bourem still eager to participate? A follow-up survey in the 1983 season found that earlier estimates missed two key facts: (1) in the poor rainfall years, such as both 1981 and 1982, farmers without access to pumps did not cultivate at all or else lost their crops; and (2) 86 percent of the pump owners were cultivating secondary crops such as onions, spices or tobacco. While the areas planted to these other crops were low, about 63 ha in project total versus 454 ha for wheat, the prices were very high. At Niamey a kilo of spice was worth approximately 4,000 MF (versus 212 MF/kg for wheat at Diré). The investigator concluded:

> To summarize, the pump is not only less fatiguing than the calabash, it is the <u>only</u> means of cultivating enough land to feed the area's people. It is said here that the pump is responsible for repopulating the area (Smith, 1983).

General Lessons

Let us step back from the details of Action Blé-Diré to review the general lessons which the USAID staff in Mali feel they have learned.

First, the project's financial woes stemmed in large part from adoption of a "host country contract" by USAID for the project's implementation. USAID officials in Mali stressed the need for planners to recognize that such arrangements are extremely problematic in Africa since they presuppose tight financial control in the recipient agency. Where this element is lacking access to donor financing becomes an almost irresistable temptation for unauthorized expenditures or even the outright diversion of funds by participants. The plain truth is that host country contracts should be avoided in countries where administrative accountability is weak. To USAID officials such contracts may seem to offer a handy device for circumventing weak implementation capacity at the Mission level. In actual fact, they increase the demands put on a Mission's supervisory capacity.

Second, the control devices to which USAID officials have access can easily contribute to a project's failure, as they did in this instance. The bargaining at the start of the project because of USAID's "conditions precedent" delayed implementation in a setting where achieving timely action was already difficult. This in turn triggered ill-advised steps which were both enormously expensive and ultimately ineffective. Again,

the freezing of USAID funds was probably necessary (given what the WMS-II team was told about ABD's financial irregularities), but the loss of a full year at mid-point in the project's life had strongly adverse impacts on its ultimate institutionalization. Perhaps there is no easy answer. Nevertheless, we cannot help wondering whether there aren't other, less legalistic approaches to project control which might avoid the negative consequences for project implementation.

Third, many of this project's difficulties stemmed directly from well intended actions taken in the initial year to make up for "lost time." Again and again in Africa we see that projects take longer to establish on the ground than planners have initially allowed. The pressures arise when USAID mission staff fear either that they will lose a year's obligated funding or that perhaps the project life will not be extended. Project extensions pose delicate issues fraught with various legal and operational considerations. In the USAID system Mission directors may be reluctant to commit themselves on an extension of the project period because this can open the door to the contractor's asking for additional funding. AID/Washington may feel it is a matter to be left for the mid-term evaluation. In either event, field staff become trapped into taking steps which undermine project effectiveness from the very start. The "shortcuts" which typically occur are in essence a tradeoff to allow completion of physical targets at the cost of diminished institutional capacity. This tradeoff is very widespread within AID's African projects, not only because they are slow to begin but also because the implementation schedules are often overly optimistic. What we can say with some certainty, and a point illustrated from this case, is that under African conditions there is no possibility that staff can "buy time" by greater expenditure of resources. Such actions simply diminish further the likelihood that a project will be effectively institutionalized.

Fourth, the decision to import Cooper pumps from India when there was no in-country parts supplier had disastrous consequences. The French Bernard pumps may not have been technically optimal, but at least their requirements are well known in Mali and resupply of critical parts to Bamako from Paris can be arranged within a matter of days, if not overnight. Around Africa USAID Missions have a reputation for bringing into country tecnological "orphans." Such equipment, whether Indian or American, makes recipients totally dependent upon USAID staff, a dependency which AID's procurement restrictions encourage, but in turn becomes a major and continuing drain on their time. If a project already suffers from logistic difficulties (as this one did), the imposition of an unsupportable technology all but guarantees failure.

Fifth, this case shows clearly the many time-consuming tasks which contractors will encounter when they try to extend the umbrella of modern commercial services by bureaucratic means beyond their present extent. To involve subsistence farmers in commercialized agricultural production means creating for them access to reliable input delivery systems, mechanics, spare parts suppliers, localized banking and transport and

adequate fuel supplies, all of which were lacking in Diré. Existing planning guides do not prepare design teams to anticipate the complex requirements which must be met in moving a subsistence system into a fully commercial one in a single step. For example, it should have been obvious that effective pump support in the project area could not occur until a major diesel storage capacity had been constructed. Again, without a place for keeping large amounts of cash it was almost certain funds would begin disappearing during the course of each field campaign.

Sixth, this case makes apparent the extent to which the advancement of seasonal farm loans must be preceded by effective producer services. It was shown that in virtually every single season the project was late in getting fuel and seeds to farmers, thereby guaranteeing diminished output. Breakdowns of mechanical services and fuel supply were frequent within the season. To advance seasonal crop loans under circumstances of such high levels of institutional risk was, in retrospect, a mistake. It is ironic that while the purpose of the pump irrigation project was to reduce farmers' vulnerability to naturally-caused production risks, by participating they became subject to greatly increased institutional risks.

Seventh, we see in this case how again and again staff were forced to make decisions which sidestepped the creation of an effective local capability which would have continued after the termination of project funding. The high rate of pump breakdowns was a direct consequence of farmers' lack of understanding that proper maintenance is the crucial factor for long equipment life. Pumps which should have lasted ten years were being broken in two or three. Once this began happening the field staff became preoccupied in responding to proximate demands which preempted their time and energies from creating long-run capacity. Thus, in development projects it is often true that unless measures to strengthen institutional capacity are instituted from the very beginning, project managers will become so involved resolving immediate problems that no change in effective institutional capacity will result.

In conclusion, let it be stressed that these problems are by no means unique to this project. It appears that the standard solutions which donors have access to, equipment financing, farm credit, improved inputs, etc., are an insufficient basis for stimulating rural development in isolated settings where a commercial infrastructure does not yet exist. To the credit of Mali's USAID staff, these lessons have been learned and the Mission has become much more cautious in choosing which interventions to sponsor. But for Africa as a whole the issue remains: how do governments start the process of rural development in places which because of geography and markets remain outside the mainstream of economic development as we now know it?

CHAPTER VII

SOCIAL ASPECTS OF SAHEL IRRIGATION[1]

The case studies in the preceding chapter indicate that in small-scale systems the sociological, economic and technical issues are intimately interwoven. What generalizations can be made about the likely influence of social factors upon the technical parameters in the Sahel generally?

Crops Associated with Irrigation

In the Sahel the choice of crops to irrigate differs strikingly between the "modern" and the "traditional" sectors. If one looks at the "official" large-scale schemes, towards which most external investment has been directed, rice is by far the most significant crop. The two largest producers are Mali, with 270,000 tons in 1978, and Senegal, with 127,000 tons in the same year (CILSS, 1980). Over the larger region encompassing also Chad, The Gambia, Mauritania, Niger and Upper Volta the total production came to 544,000 tons in 1978. About half came from the modern sector, but perhaps only 30 percent from schemes which claim "total" water control. This means that about half the Sahel's rice originated locally, but demand was outstripping supply even in the late 1970s and the current situation may be quite different. Important as rice is, it constitutes less than one-tenth as much as other cereals and its production reacts more sharply to fluctuations in rainfall (CILSS, 1980). After rice the next most important crop was sugar, 90,000 tons in 1978, or about one-third of Sahelian needs, followed by wheat at 12,000 tons (only 4 percent of overall consumption). It is estimated by CILSS that in a normal year the Sahel's cereals production runs at about 5.5 million tons, of which less than 5 percent comes from the modern sector, large-scale schemes. Yet to generate this modest production has required extremely high investments, up to 3 and even 4 million Franc CFA per ha (US $15 to $20,000). To protect their investments several Sahelian nations have instituted numerous controls to insure farmers grow only the designated crops and market them only through approved agencies.

In indigenous small-scale irrigation, to the contrary, the traditional grains (sorghum and millet) and horticultural crops predominate, at least insofar as areas away from the river are concerned. The physical size of gardens tends to be very small, but

---

[1]For a general introduction in English the two key works are Reyna's edited volume, Sahelian Social Development, 1980, and Hart's The Political Economy of West African Agriculture, 1982. On irrigation aspects, see CILSS' The Development of Irrigated Agriculture in the Sahel, 1980 and Vink's FAO Report, "Small-Scale Irrigation in Africa, Country Notes Upper Volta-Niger-Mali," 1983.

potential gross profits can be much higher than those usually realized from rice growing. It was amusing to be told in one of the larger schemes visited that women were earning more from spices and vegetables grown in the field drains than were the men from their official rice plots. While there is a substantial literature on rice production in West Africa,[2] much less is known about the growing of spices and market-garden crops.

It seems to be true in several areas that irrigated farming is usually not the primary enterprise upon which a family depends, but rather constitutes a supplemental source of income along with several alternatives. In Miller's survey of three villages in Senegal's middle valley not a single respondent out of 454 listed irrigated agriculture as the family's primary economic activity (1984). The predominant ethnic groups in several of the small-scale irrigation areas, the Soninke in the Bakel region of Senegal, the Sonrai in Mali's sixth region and the Hausa in southern Niger, are known throughout the region as traders. Since throughout the Sahel households are generally taxed on the basis of their production it is not surprising that traders who are involved in small-scale irrigation on a speculative basis will understate the significance of these activities when questioned about them by outsiders. A similar orientation probably also exists on the larger scale schemes and may explain why landlordism has been such a persistent problem.

Occupational Structure and Ethnicity

The Sahel's ability to support its human populations rests largely upon symbiotic relationships between different occupational traditions, which tend to be categorized according to ethnic identity, e.g., in Mali Bambara "farmers" versus Peul (Fulani) "herders." There are many studies of pastoralists, farmers and the relationships between them in the Sahel: see Aronson (1982), Barral (1967), Bernus (1977), De Garine (1978), Delgado (1977), Fieloux (1980), Franke and Chasin (1980), Gallais (1972 and 1975), Goddard (1973), Grayzel (1976 and 1977), Hill et al. (1982), Reisman (1977 and 1980), Stryker (1976), Sutter (1979), Swift (1977) and Toulmin (1983). Most authors agree that the transhumant nature of Sahelian pastoralism, with livestock coming down to the riverine zone in the long dry season, represents an ancient pattern which would be difficult to improve upon. These days, however, a buildup of agricultural populations in the South with the consequent breakdown of the vital long-term fallow period is forcing crop farmers back into the high risk pastoral zone (Toulmin, 1983:4). This threatens to repeat the 1972-73 disaster, since the severity of that drought's impact was due in large part to the sequence of wetter years in the 1960s and the

---

[2] See Pearson et al., Rice in West Africa: Policy and Economics, 1981 and also Humphreys and Scott, "Choice of Technique in Sahelian Rice Production," 1979-80.

accompanying spread of high risk peanut farming north into the pastoral rangelands (Franke and Chasin, 1980). Since the 1972-73 drought, families of both types have diversified so that "the distinction between herders and farmers is . . . not clearcut; many herders cultivate sizeable fields of millet, and some cultivators own large cattle herds" (Toulmin, 1983).

The mixed ethnic situation one often encounters on the ground in the Sahel has important implications for irrigation development, at any level of scale:

- Existing communities are often polarized along ethnic lines, so that genuine participation may be actively denied to whichever groups are not dominant. This has obvious implications for farmer recruitment and for the functioning of farmers' cooperatives.

- The degree of familiarity of different groups with particular cropping techniques can vary widely. This suggests that a substantial amount of farmer training may be necessary when introducing irrigation technologies.

- Any narrowly focused mono-crop strategy directed at the community as a whole is bound to conflict with families' own economic survival strategies, which of necessity must remain flexible and multi-enterprise in scope.

- The needs of seasonal residents (whether pastoralists or drought-stricken refugees from elsewere) should be allowed for in community planning.

Migration

The combination of a long dry season and extreme poverty within the Sahel has been for a long time the "push" factor encouraging long distance labor migration. While the sources of employment differ between countries -- people from Senegal's middle valley going to Dakar or even France; those from Mali tended to go either westward into Senegal or southward towards Abidjan; those from Upper Volta southward into Ghana; and those from Niger into neighboring Nigeria -- the effects upon the isolated, small-scale source villages are broadly similar.

On the negative side, one often finds that younger men at the prime stage of their working careers are absent, giving the more conservative village elders even greater power over those left behind. Households whose head is absent will be reluctant to make fundamental decisions about the use of compound lands, or to make the substantial capital investments typically required by irrigation development. Again, one frequently encounters temporary "stranger farmers" who have become stranded on their way through and who therefore lack any permanent claim to the lands they farm. In bad years when the rains fail there may be

nobody left with the resources to organize effective survival; indeed, the household may split at the start of a drought as men take a few animals and leave in search of food and assistance.

On the positive side, most villages today contain men who have worked in other countries and have been exposed to more advanced economic systems than their village offers. If lucky, they return with cash savings which can be reinvested in the village. They may also have special skills, such as bicycle repair or mechanics, that can be tapped to support small-scale projects. Thus, the actual levels of experience possessed by villagers may be considerably in advance of what local production could offer.

The unknown factor in recent years which may upset household survival strategies is the closing off of international borders, dividing the Sahel for the first time into its component, national units, each of which will be struggling to extend its own economic base. For the people in the poorer, landlocked Francophone nations, the removal of seasonal work opportunities in Nigeria, Ghana and other coastal states will have serious consequences. These countries have long enjoyed access to goods brought in through unofficial channels. On the other hand, the breakup of Sahel-wide population movements may make irrigation-related employment more attractive, assuming they remain viable without such ready access to spare parts and fuel.

Land and Water Rights

Sahelian farming is also characterized by various social restrictions on land and crop rights. In any system where formal rights over resources diverge from actual practice, planning based on the "official" situation may become increasingly ineffective. Dey's analysis of irrigation rights within The Gambia (1982) provides a useful case study of a widespread Sahelian problem. As she describes them, the legal principles seem quite clear: customary tenure as defined by village and clan heads is recognized, but the state may acquire land for development purposes by paying compensation to its present users. The actual situation she discovered by a survey of over a thousand irrigated rice holdings was considerably more complex and appeared to recognize six overlapping principles. These are summarized from her longer account as follows:

- Local members of a village always enjoy prior claim to its lands before outsiders, whose use of fields is temporary and by sufferance of the village leaders and/or compound heads.

- Within a village the founding clans usually enjoy better land and greater control than do later arrivals.

- Those who first clear land retain the right to its use and may pass on such claims to their children or others provided that their entry onto the land was permitted by the dominant compounds.

- Ex-slaves and artisans enjoy less freedom in choosing where to locate or in establishing lasting claims to the land they occupy.

- Male heads of household have prior claim over females who might acquire control because of continued use of a deceased husband's lands or by the clearing of their own lands.

- Land is not supposed to be rented or sold, but in fact is increasingly so treated, especially if an outsider wishes to build on it.

Given rapid population growth, the presence of outside seasonal farmers, the breakdown of long-term fallow and other factors, "traditional custom" as stated by the village elders no longer represents general practice. There are plots women and strangers control even under supposedly patrilineal compound ownership, just as there are permanent houses being built by those who cannot officially hold land rights. And, not surprisingly, Dey also found that the situations portrayed by male informants differed from what females claimed was the actual case within the rice cultivation area (1982). With minor variations, something like this is found in many countries throughout West Africa.[3]

One reason for these complications is the tradition that a man, or sometimes a woman, may invest in separate fields beyond those producing the family's food. These then become a commercial investment, whose profits are not necessarily shared within the entire family. In a polygamous society, wives typically maintain their own food-sharing units to which husbands may or may not contribute. Traditionally, rice was often a food crop and its production was left mainly to women, though here outside The Gambia there are regional and ethnic variations.[4] Often women were also traders and grew their own market-garden crops whose profits they retained separate from the husband's.

When "official" rice growing in government-initiated, large-scale schemes began (generally in the 1930s and 1940s), the civil servants in charge almost always allocated the plots to male household heads. The men were assumed to have access to "free" family labor; it would be up to them to distribute the gains as they saw fit. This explains why bureaucratic restrictions on access to plots, while justified on the basis of "customary law," in actual fact give economic force to an ideal which is no longer viable within many existing rural communities. It

---

[3]For a detailed anthrological study of changes in the control and inheritance of rice lands in Senegal's Lower Cassamance, see Snyder, 1981.

[4]Richard Miller informs us that among the Soninke of Senegal it is the husband's responsibility to fill the family grain store while a woman's production from her own plot becomes her private proceeds. For Niger, see Sutter's description of the Hausa situation (1979).

also shifts the major responsibility for rice growing from women to men. That men have come forward to take up irrigation opportunities is obvious, but it is likely those who did so were hoping for commercial gain separate from and in addition to their existing family production. Given the larger social system as just described, it should not be surprising that women have been reluctant to work in these fields in the way the "family farm" concept held by planners assumed they would.

The methods which have been adopted in Niger and Senegal for allocating plots within the small-scale perimeters represent a vast improvement upon the practices in the large-scale schemes. And, indeed, they merit consideration for general adoption throughout the region. In Niger the irrigation agency ONAHA as a matter of general practice sends a survey team into each area before perimeter development begins. This team determines the ownership and size of existing plots. Land within the new perimeter is then divided between farmers on an adjusted basis, reflecting not only previous ownership of land within the perimeter but also total land owned and farmed and family size. The 64 ha Moullelle scheme, for example, consists of 91 parcels with between one-third to 1 ha per plotholder. In SAED'S schemes within the Middle Valley of the Senegal River plots are also very small with perimeters of 10 to 25 ha being divided between 40 to 120 plots (Diemer and van der Laan, 1983). Every village household may request a plot and sometimes all families receive one. If not, plots are given out in proportion to the major social categories in the village, e.g., people of free birth, those of slave origin and those who are artisans. This is fundamental change which diminishes the dependence of the non-elite social groups on the land-owning class. Another popular innovation has been to allocate plots randomly with all those eligible having their names drawn from a hat one by one as the group progresses around the scheme layout (Diemer and van der Lann, 1983).

Impact of Irrigation Upon Women

The impact of irrigation upon women is a significant issue throughout the Sahel, where Islamic traditions influence access to resources and where particular crops or tasks may be assigned on the basis of gender. We have already noted the tendency in large schemes to assign plot rights to men, thereby altering the distribution of rice benefits within households. In addition, the allocation of land to large-scale irrigation frequently means the removal of trees (when fuel is often a woman's responsibility) and the virtual elimination of commons grazing for small stock (also under the woman's control). It may mean that no space is left for women's market-gardening, or even for a household's food crops. The human and livestock populations are then squeezed into the physical confines of the village itself, increasing problems of sanitation and household water supply. Furthermore, it is customary that the woman in a household must care for those who are sick. When irrigation permits double cropping and leaves standing water in the channels, malaria and other water borne diseases are bound to

increase. There is also the question of who will inherit the family's irrigation right should the man die. Sometimes women will even lose their claim to standing crops in the field, which may pass to a man's brothers or be reallocated with the irrigation right. This encapsulation of patriarchal "customary" codes into bureaucratic practice is totally unnecessary: the government supplies investment capital for large-scale development, not the elders; and there is little reason to believe that men would cease joining such schemes just because women hold more secure rights to plots they are farming. Similarly in regard to fuelwood supplies, garden plots and smallstock enterprises: there is no necessary reason why these cannot be made a regular feature within planned settlements, large or small.

However, it does seem that the negative impacts are minimized on small-scale projects. Fuel and grazing are left undisturbed. Small projects can be managed flexibly, permitting greater adjustment to individual family circumstances. Those assisting the village are less likely to insist that food crops cannot be grown on irrigated land. And the environmental and health impacts may be easier to contain, though not necessarily so; the spread of disease from a small focal point is a frequent occurrence in the tropics. The major difference is simply that in small-scale schemes the production system is less likely to be treated as the determining factor overriding considerations of members' welfare.

Labor Constraints

Labor availability is fundamental to successful irrigation development, for several reasons. First, non-mechanized irrigation farming of the types we see in the tropics are usually very labor intensive, especially so if the crops are rice or cotton, two favorites in many African countries. Second, the labor demand is more than doubled when the planned program aims at two or even three irrigated crops per year, something technically feasible because of the absence of a winter season. The qualification "more than" must be added in the Sahel because of overlap between the double-cropped cycles, as well as competition with the arable, rainfed crops. Third, some irrigation tasks must be precisely timed or else they will be ineffective. Fourth, work by farmers on the primary and secondary canal systems comes at unpredictable times and requires a community response. Even on the tertiary channel, unless all farmers cooperate, the efforts of any one or two farmers down the furrow will be wasted. In the tropics weed growth is rapid and the drains soon become clogged, leading to unanticipated flooding when rains occur. Fifth, in many schemes the final leveling of fields and sometimes the construction of the tertiaries may be left to farmers' own initiative. Sixth, sometimes irrigation occurs at extremely uncongenial times, e.g., at night or during Ramadan when Muslim farmers are forbidden to drink or eat during the daylight hours. And seventh, the field tasks themselves may require intense physical effort in a moist, hot environment where just to be near or in the water increases one's risks of contacting various enervating diseases. Add these aspects together

and it becomes clear why irrigation demands well-timed, disciplined and coordinated work, three attributes which are seldom encountered from a peasant labor force within lowland Africa.

This demand situation would itself suggest that "free" labor is not likely to be forthcoming to assist irrigation development, at least not over the longer run once farmers have learned how much work is required. In the short run many farmers can draw upon "stranger farmers" or other reciprocal labor-exchange institutions to start off the irrigated farming cycle. Unfortunately, within the Sahel project appraisal exercises have usually found that unless labor enters as an unpriced "free" input, the farmers will have inadequate returns to repay scheme costs; similarly in regard to imposing a double cropping cycle even when for environmental and health reasons this is not desirable.

Let us turn, therefore, to the household labor supply situation, since this is where project plans assume "free" labor will be forthcoming. An immediate obstacle for some families is the labor migration tradition already discussed above. Wallace suggests that in Northern Nigeria among the Hausa, who are by tradition traders, freedom to be absent from farming during the dry season is highly valued (Wallace, 1981 and 1983). In Niger and Mali seasonal involvement with livestock trading can be very important, just as livestock exports are of crucial significance within the respective national economies. There are also other types of "traditional" trading to consider: dried onions, spices and so forth, some of which are themselves produced by traditional irrigation.

Then there are those constraints upon labor supply related to the woman's role in the peasant system. A number of African studies suggest that women's time is more constrained than the men's, in large part because of their heavy responsibility in meeting routine domestic obligations (cooking, childcaring, etc.). When women are denied a fair share of the profits from irrigation production, they have added reason to minimize their input into what they see as their husband's commercial undertaking. With modernization, children begin to attend school -- further reducing the woman's field activities, since older girls could otherwise substitute for their mothers within the household. And, finally, if development does begin to take root locally, by definition people will begin to attach a monetary value to their work.

The one safe prediction we can make about large-scale irrigation development is that labor pricing will be a dynamic factor responsive to changes in the economic environment. In this situation, models of farm response which assume "free" labor inputs are bound to lose their predictive validity over the longer run, as indeed they have in the Sahel to date. Wallace is almost surely right to argue that unrealistic labor expectations are possibly the single most defective aspect of the engineering projections which have guided irrigation investments in West Africa. A main reason this is not yet recognized has been the lack of integrated, on-farm analysis of irrigation within the Sahel, where

instead each discipline has been left to treat its own concerns separately.

Recognition of an acute labor bottleneck might explain several puzzling features of farm-level performance, such as farmers' persistent failure to weed their crops and maintain their furrows. Any plans to move to a double cropping cycle of an irrigated, labor-intensive crop like rice should be very carefully checked since competition with the farmers' food crop cycle is bound to occur. Labor demand also explains why the adoption of large plot sizes of say, 10 ha in a scheme like the Office du Niger, is bound to be accompanied by landlordism. With irrigated rice, family holdings should probably be less than one or two hectares.

Unanticipated Social Costs and Benefits

Other unanticipated social costs/benefits arise out of the routine application of bureaucratic procedures during perimeter development. These need to be identified more clearly so that in the future irrigation projects, be they large or small, can avoid the mistakes of the recent past. It has been customary for civil engineers to do the basic design of perimeter layout, since they alone command the technical specifications needed in drawing up construction contracts. At stake are many vital interests, some of them of little concern to the average design engineer. Perimeter layout affects the size and shape of fields, the kind of irrigation technology adopted, where people can build houses, their domestic water supplies, the distances to their fields, the ease of movement with the perimeter and many other considerations. Unfortunately, the social impacts of land planning do not become visible until several years have elapsed, long after the engineers have left. The danger is that key impacts which are necessarily linked to physical layout will be ignored, while narrow technical considerations or even sometimes standard design solutions will be adopted without adjustment to suit local conditions. Similarly, the routine procedures which accompany perimeter development after the design phase can also have a large and detrimental effect upon the people in an area: procedures for determining existing land use and ownership, for allocating fields to particular claimants, for locating village sites and determining which families can belong, for deciding upon and then paying compensation, etc. These matters are often decided on the basis of the administrator's immediate convenience, and in ignorance of their likely effect upon the existing population.[5]

Some genuinely horrifying examples of well-intended projects gone wrong can be found in Northern Nigeria's recent irrigation schemes --

---

[5] Useful papers on non-agricultural uses of water in arid areas and the implications for alternative designs are by Yoder (1983) and Horst (1983), both circulated by London's Overseas Development Institute (ODI) irrigation network.

here see descriptions given in Wallace (1981), Griffith (1983), Bird (1983), Adams (1983) and Wallace (1983). For the sake of brevity, let us use the Bakolori Scheme as our illustration. Built in 1974-79, it was intended to irrigate 27,000 ha of river terrace lands and flood plain using water drawn from the Sokoto River. Much of the design work was done in Italy. The rectilinear layout necessitated a complete change in farmers' fields, as is generally the case in African irrigation schemes. Large drains were positioned to discharge onto valuable low lying land, already under intensive use. The irrigation network was superimposed over existing settlements and completely disrupted communication between villages. No provision was made for either livestock, of which villagers had many, or domestic water supplies (which could have been cheaply provided if initially anticipated). The number of people on the land proved substantially more than pilot surveys had estimated, leading to inadequate compensation and the irony that post-scheme beneficiaries were outnumbered by pre-scheme claimants for compensation. Expropriation of farmers' fields began in 1977, but compensation had still to be paid in December of 1980. Eventually the local farmers began to blockade the project's construction teams and the Federal Government ordered force employed. Twenty-five people (23 of them farmers) were reported killed, and several villages burned. An observer concluded that for the people of the Sokoto Valley, "irrigation development" caused circumstances of acute hardship similar to those during a time of drought, and for many the only recourse was to move out of the valley (Adams, 1983).

It is pleasant to report that new irrigation perimeters can be established in a much more harmonious fashion provided that people's needs are anticipated in advance. In fairness to Nigeria, it could be noted that the procedures which caused such hardship are little different from those being employed in several other African countries. Local farmers will also know the high and low water levels over a longer period than official records document. We do not feel that a professional sociologist must be present before civil engineers dare to ask farmers some direct questions about local water resources. Again, ONAHA has begun to involve farmers from an area in the initial construction phase, as paid employees doing the initial leveling and channel layout. This practice provides local families with a cash income during the difficult period before their new fields come into production. It may also have the effect of leaving behind workers with the skills needed for maintaining the canal system, and perhaps a greater understanding of the technical aspects of water management within the scheme area. Almost certainly it will mean that farmers know how to level their fields. Another commendable practice within ONAHA's system is the adjustment of land parcels to fit each family's actual labor force. ONAHA's small plot sizes (usually less than 1 ha each) maximize the distribution of plots within the community, minimize the impact of farm-level labor constraints and make landlords unnecessary. These are only a few of many examples where relatively minor procedural adjustments can have a significant impact on farmers' well-being.

Entrepreneurial Tradition

Another socio-economic feature which merits special notice vis-a-vis small-scale irrigation is the vigorous entrepreneurial tradition which flourishes throughout the Sahel. Agricultural marketing for subsistence producers is seldom a simple task, as Harriss' (1982) review substantiates. In the Sahel it is complicated by national efforts to intervene through statutory marketing boards, which at an earlier phase were given a monopoly over the handling of particular crops (Berg, 1980). Then there is the problem of illicit movement of food and goods across national frontiers, a long-standing aspect of the Sahelian economies (Collins, 1976). One way or another small-scale traders have been able to maintain a flow of commodities into the Sahel from both North (across the desert) and South. This attests to there being a remarkable reservoir of commercial skills within the zone. Provided demand exists, it is really quite unnecessary for the government to intervene within the marketing chain. Local traders have proved themselves capable of moving crops out and spare parts in even when confronted with the adverse circumstances that sometimes defeat even the government's own efforts at organizing trade. Sahelian traders' existing skills should be viewed as a resource which small-scale irrigation projects can tap.

We were impressed in our field visits by the extent to which Sahelian peasants already make use of animal power and small engines. Since oxen, camels, horses, bicycles and lightweight mobylettes are already in regular use throughout the zone, there should be no intrinsic reason why these sources of power cannot be harnessed for small-scale irrigation, as indeed animal power is within traditional irrigation. We have already pointed out that the bottleneck seems to lie in a lack of suitable technology. Dan Jenkins of the Regional Economic Development and Services Office (REDSO)/Abidjan convinced us that existing technologies for small-scale water supplies have not paid adequate attention to the yield realized per unit of energy input, an absolutely critical relationship if the energy source is either a person or an animal, or, for that matter, the "mobylette" engine. If better pumps could be devised which use these sources the maintenance of the energy supply would not be a problem, since they will continue to be significant for other farming operations irrespective of their use for irrigation purposes. In our concluding chapter we recommend that the development of such technologies might warrant USAID support.

Cooperatives

Farmers' cooperatives have a long and mixed history in the Sahelian countries, going back to French colonial experiments. In Senegal the legacy of bureaucratic bungling associated with the cooperative movement was so strong that in recent years irrigation associations have usually been called instead "groupement de producteurs" (Miller, 1984). Irrespective of what they are called, an obvious way of bringing water

user associations into the larger national system is to have them incorporated legally as cooperatives. In Niger, for example, ONAHA representatives work hand in hand with those of the Union Nationale de Crédit et des Coops (UNCC) to establish cooperatives within each perimeter, a process which is targeted as requiring roughly four years to bring the local organization into full operation. As a rule of thumb, there is one ONAHA agent and one UNCC official for every 60 ha of command area. The ONAHA perimeter director works directly with the various cooperatives in arranging seasonal water distribution plans for each one.

In much of the Sahel farmers are accustomed to shared financial responsibilities (Diemer and van der Laan, 1983): "Koranic schools are found in every Halpulaar village. As a result every Halpulaar village has men who are sufficiently proficient in Arabic script to be able to register the payment of subscriptions. Collective funds are so common that there are well-established rules about how they should be managed." This tradition of village-level contributions and record-keeping has been reinforced in literacy campaigns ("alphabétisation") which have emphasized functional skills needed by farmers (Belloncle, 1982). Belloncle's own work over the past decade in Niger stands as a model of how simplified field training can be used to strengthen cooperative organization.

The fact that schemes are locally controlled does not guarantee that they follow a participative mode of decision-making. In much of the Sahel village matters are controlled by a small circle of elders whose word is seldom challenged. Note how Diemer and van der Laan (1983) describe decision-making in one of Senegal's small schemes:

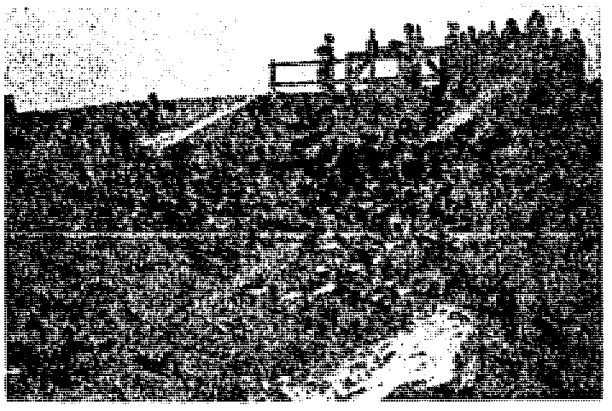
> Most participants are kept out of the decision-making process. For example, in one scheme it was decided not to grow maize during a given year, as the leading participants preferred to migrate. They communicated their decision to the other participants. Many of these, in particular those with large households, strongly opposed the decision but did not succeed in having it revised . . . If an individual receives an order from a person invested with some kind of relevant authority he will most probably do as he was told.

Again, during our visit to Mali's Bandiagara Plateau, we encountered a small dam where, although the rains were beginning, villagers had refused to shut the gates to start impounding water. It was explained that the land which would be flooded or which would be needed for irrigation belonged to three families whose continuing opposition was strong enough to prevent use of the dam. This example is a reminder that conflict may occur at any level of scale. Unless there are accepted procedures for resolving disputes and ensuring participatory management, small-scale projects can evidence the same difficulties which large-scale schemes do.

1.
Shadcuf irrigation of vegetable gardens in the Goulbi n' Maradi, Niger.

2.
Calabash irrigation in the vicinity of Dire', Mali.

3.
The Inland Delta of Mali showing the growing of floating rice through natural flood irrigation.

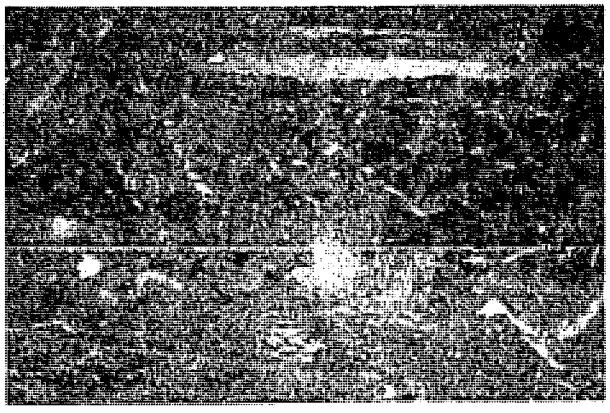


4.
Headgate of one of the perimeters at Operation Riz-Mopti, Mali.

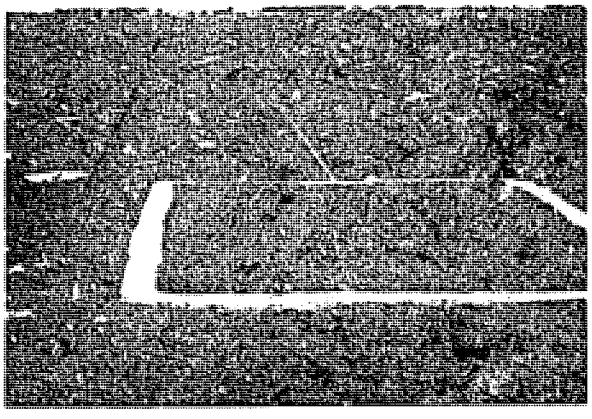
5.
Cattle grazing in a rice perimeter at Operation Riz-Ségou, Mali.

6.
Cattle trampling dikes of an irrigation perimeter in Niger.

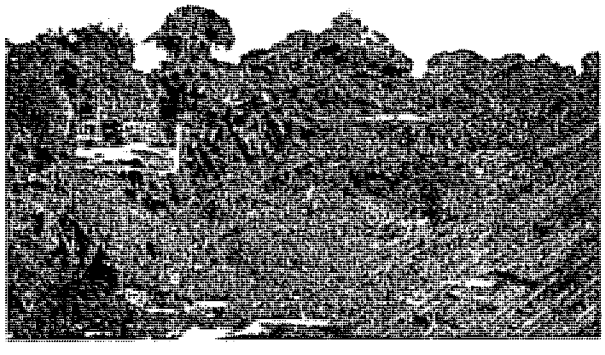
7.
Water guard and farmer explaining why canal is weed choked.



8.
Dogon vegetable garden built with soil transported to the water source and irrigated by calabash.



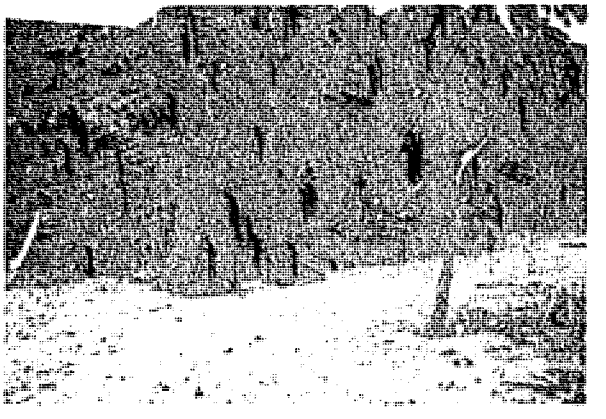
9.
Dogon vegetable garden where water is hand pumped to storage tanks and irrigated by gravity flow.



10.
Small barrage in Dogon Country with gates open. Villagers had been unable to agree on closing gates despite the start of the rainy season.

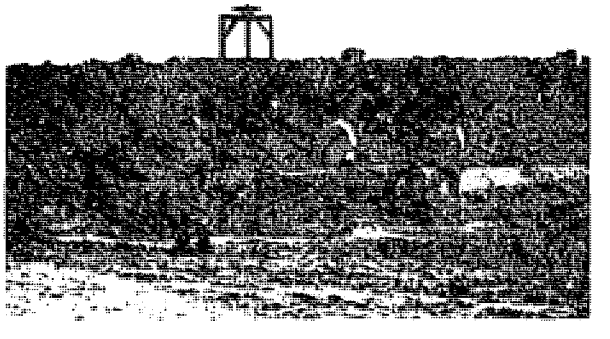
11.
Small barrage in Dogon Country where water storage also constitutes the household's supply.

12.
Pump on a float on the margins of the Inland Delta at Diré, Mali.



13.
Pumps purchased from India by USAID for Action Blé-Diré.

14.
Chinese-built pump station at headworks at a perimeter near Niamey, Niger.



15.
Diversion gate on the 1,500 ha Namarigouagu perimeter, Niger.

CHAPTER VIII

IMPLICATIONS

Sahelian Irrigation in General

To conclude this report we return to an overview of the general issues affecting irrigation in the Sahel and then to the specific needs of the small-scale subsector.

The Economic Environment

While our field team did not include an economist, we could not fail to note that economic issues obtruded at almost every point within our itinerary. In this regard, three main observations stand out:

First, some of those interviewed went so far as to insist that pricing decisions alone will "make or break" irrigation policy in the Sahel. A primary difficulty is that while Sahelian producers operate in a marginal environment under conditions of high risk and poor transport, so do their support services, and as a consequence the unit costs of production are inherently high. A secondary difficulty which may vary from country to country and over time is the tendency for state intervention to protect urban consumers, a pan-African tendency, but one which especially affects high cost irrigation production (see Eicher, 1982; Harriss, 1982; Wilcock, 1978; and CILSS, 1977). The Sahel's marketing parastatals are renowned across Africa for their large size and low efficiency, a perhaps inevitable consequence of trying to market low value, low volume crops over a vast territory. A tertiary difficulty is that the main irrigated crops, rice and wheat, are the very commodities donors are likely to supply as food aid in the bad yers, while providing stiff competition by subsidized European or American producers in the good years. These economic factors, combined with transport costs, influence the local viability of Sahelian irrigation to an extent beyond what we have considered in this report (Sparling, 1981).

Second, this same paradox is repeated within each of the countries we visited, wherein the isolated regions which suffer food deficits are also where the unit costs and risks of production may be highest. In such areas it is often assumed that irrigated farming is the only viable solution which offers the prospect for stabilizing food supplies. Such ideas might be termed "privileged solutions," because they are accepted as a matter of faith and used to support lavish investments which rarely perform as expected. In truth, modern irrigation, whether large-scale with its dams and cement-lined canals or small-scale with pumps and spare parts and fuel, becomes institutionally risky in those very environments where reliability and self-sufficiency are most desired. The Action Blé case incorporated in Chapter VI makes this point clearly and indicates the need for unusually astute economic analysis in advance of irrigation projects which will be located in peripheral regions.

Third, we enter a plea for real world, behavioral economics: a kind of analysis which is shorn of unnecessary assumptions and which is based upon actual costs and benefits derived from local research. There is an enormous exchange of high value traditional commodities flowing across the Sahel: spices, livestock, dried onions, gum arabic, etc. Any micro-analysis which ignores such transactions, as many have, is bound to generate misleading conclusions and ones which adversely affect estimation of the benefits from small-scale irrigation. Similarly, the actual on-site costs of different services required by farmers can be vastly different from what project designers assume. In irrigation there are many opportunity costs to consider: water denied to downstream users, scarce capital diverted to low-productivity projects, and so forth. On the larger projects there is a wide divergence between projected schedules, costs and returns and what eventually materializes. All of this argues that while further economic analysis of irrigation is greatly needed, it must be an informed, situationally anchored type of analysis, which is difficult to obtain.

Irrigation Strategy

As currently being implemented, irrigation development is usually capital intensive and foreign exchange intensive. Even if irrigation schemes were highly productive, which in Africa they usually are not, their high costs raise fundamental questions about timing, location and alternatives. These strategic implications are even more salient when the country concerned is poor, in debt, unable to pay recurrent costs and incapable of supplying inputs or paying attractive prices to farmers. USAID Missions within the Sahel are continually involved in decision-making which impinges upon strategic issues: whether to emphasize rainfed or irrigated agriculture, advice on pricing policies and project locations, data acquisition investments and the redesign of existing projects.

At several places in this report there are warnings that AID's present commitments to the river basin authorities are unlikely to pay off in the ways specified in project documents. We have also questioned why USAID Missions shoud accept "off-the-shelf" European planning for the irrigation components in these large schemes. The project proposals for large-scale irrigation which we looked at briefly were riddled with inconsistencies, grossly overestimated benefits, failures to weigh likely implementation capacity, naive political assumptions and optimistic assumptions about revenues. Given the fact that irrigation is likely to continue as a component in any food production stragegy for the Sahel, it is critical that the USAID Missions begin to develop their own capacity to review irrigation sector decisions more adequately. Whether such capacity should be housed in the STDP office in Mali or in REDSO/Abidjan is a question beyond our purview, but at least some additional irrigation expertise is needed.

Improving Large-Scale Irrigation

Irrespective of cost-effectiveness, it is likely that there will be further investments in large-scale irrigation schemes within the region. The reasons are threefold. First, some large perimeter irrigation areas already exist, notably the Office du Niger in Mali and schemes in the Senegal Delta, and represent substantial investment which a poor country is unlikely to abandon. Second, the major dams under construciton or in the planning stages involve further resettlement and linked irrigation development, e.g., the Manantali Dam in Mali and USAID's involvement in planned resettlement. Third, there appear to be still other sites along the major rivers where medium-sized perimeters might be constructed once river levels have been stabilized, although we did not investigate these estimates in detail.

If, then, inefficient large-scale schemes continue, and perhaps will be expanded, a key issue becomes the opportunity cost of water which is being squandered. In a desert environment badly managed irrigation involves large evaporation losses and often a consequent buildup of salinitysalinity on valuable alluvial soils. On the Niger River water withdrawn for the Office du Niger is taken at the expense of users farther downstream in the Inland Delta and Lacustrine Zones. One suspects that this has been a factor contributing to the 100-year lows in river level which the zone to the north has been experiencing. For this reason, despite the low cost-effectiveness of irrigation as an economic investment, there is an urgent need to increase the productivity of "main system" management in schemes which already exist. The problems may be partly technical in origin, reflecting poor design or poor agronomy. However, enough is known about the Office du Niger to state that it problems are largely bureaucratic and sociological in nature (De Wilde, 1967; Kamuanga, 1981; and Kamuanga and Spencer, 1981).

One promising approach would be to adopt a subunit within a larger system and then work with local farmers and scheme staff to discover how productivity can be improved, as the Dutch have done in the Office du Niger. A second would be to exchange experience between the Sahel and other areas such as the Sudan and India. A third would be to tap the WMS Project's previous experience with diagnostic analysis in Egypt and Pakistan to identify empirically where productivity bottlenecks occur.[1] We strongly recommend that all three approaches be employed as part of a concerted attempt to increase scheme productivity within the large scale irrigation sector. This alternative should take precedence over the further physical expansion of the large-scale schemes, an expansion which perpetuates present errors and accelerates the waste of the region's scarce water resources.

---

[1]We find it somewhat ironic that the WMS-II Project is giving technical assistance on irrigation management to a country like India, which has tens of thousands of irrigation engineers, but not to Sahel's large-scale schemes.

Irrigation Impacts

The above remarks suggest that adequate assessment of environmental impacts becomes particularly important when irrigation interventions are at issue in semiarid, tropical environments like those of the Sahel. Of course, since the early 1970s virtually all larger projects include advance review of environmental impacts. Nevertheless, as one reads such reports it is apparent they are often of a perfunctory nature or else their findings are not integrated meaningfully into the larger project design. This report has stressed the extraordinary complexities of Sahelian environmental relationships. We have suggested that some of the larger projects are already having unanticipated negative impacts on downstream users. Negative impacts are not limited, however, to large-scale interventions; a small-scale project can have just as pronounced an effect on the health of a nearby village as does a large dam.

In relation to potential negative impacts, three topics merit further analysis. First, there is the whole question of the hydrologic, economic and sociological relationships within Mali's Inland Delta (see Chapter IV in this report). This area is much more densely utilized than outsiders have assumed and its human and animal populations are large enough that even small changes can make a large difference. At a minimum, the excellent work Gallais has initiated on broad patterns of land use should be supplemented by detailed investigation of hydrological balances, both spatially over the area and temporally over a complete water season. The likelihood of negative impacts is so high that a prudent course of action would be to delay further large-scale interventions on the Niger River until impacts of the current developments on the Senegal River can be assessed from actual experience. Because of the Senegal River's potential for power generation it is virtually certain that it will receive additional investment in large-scale projects. This makes the Senegal system a potential laboratory from which other areas of the Sahel can learn, particularly in regard to improving large-scale irrigation efficiency and minimizing negative impacts.

Two other kinds of impact also assume special importance in the Sahel. Health impacts must be monitored in any irrigation interventions, large or small. People appear to be generally aware of this need but the means for carrying it out remain unclear.[2] There is also the continuing issue of how pastoral access to water and forage can be guaranteed when land use near the water is shifted into irrigation. Rather than treating these aspects as invariable costs associated with all irrigation, policy makers should be assisted in exploring technological and procedural innovations that would minimize the adverse tradeoffs. For example, in African conditions sprinkler irrigation might permit easier control of

---

[2]For preliminary work on this aspect see Leslie Small, "Irrigation and Human Welfare: a Workshop Report," 1984, International Agricultural and Food Program, Cook College, Rutgers University.

disease vectors than flood basin irrigation affords; and again, rights of easement are well known in law and could be used as a safeguard traditional pastoral rights. One way or another the requirements of multiple use of both land and water must be incorporated into future engineering designs for irrigation projects, whether they be large or small (Yoder, 1983).

The Maintenance Crisis

In moving through parts of Mali and Niger one sees many examples of older schemes where the physical system for water distribution is not being adequately maintained. Again and again one is told that maintenance is the farmers' duty. If so it is an obligation they are not honoring throughout most of Africa, and Asia too, if the literature is any indication of the true state of affairs. Earlier WMS-I and -II studies have suggested that scheme rehabilitation might be conceptualized as "deferred maintenance," an engineering solution to deficit labor inputs which have accumulated over several years. By labeling scheme reconstruction as a "rehabilitation project," donors and local governments are in effect substituting future hard currency debt burdens in place of local costs which on-site "beneficiaries" ought to have paid had the system been working as planned. Yet while virtually all field engineers admit maintenance is a "problem" that reaches almost crisis proportions, nobody has studied schemes to demonstrate empirically why lack of maintenance occurs.

We suggest this would constitute an excellent topic for collaborative work between main system engineers, farm economists, sociologists and managerial analysts. Maintenance problems can occur when a double crop cycle competes with rainfed cultivation because of the "free rider" problem (i.e., unless everyone does it the effort is wasted), because of inequity in plot allocations, because of alienation towards the irrigation agency, because of family problems and for several other reasons. We believe it has been the weakest link in project implementation and merits recognition as a topic for scientific research in its own right.

Small-Scale Irrigation

The key issue underlying our visit to the Sahel was whether there is more scope within the region for development of small-scale and community-managed irrigation systems. For the Water Management Synthesis Project there was also the question of what lessons the Sahel's existing small-scale irrigation might offer to other areas of Africa, i.e., the "lessons learned." Let us therefore conclude this report by summarizing its main findings in regard to the small-scale subsector in irrigation development.

Community-Managed Systems

Within Mali and Niger where our field visits were concentrated there were few existing examples of viable, communally-managed irrigation systems. The reported instances of these systems almost all come from Senegal where for the past decade the Senegalese parastatal SAYED has been trying to initiate such projects (Miller, 1984; Diemer and van der Laan, 1983; and Adams, 1981). As we did not undertake field visits in Senegal, this report may underestimate the extent and significance of the communal element in the SAYED and Bakel schemes. From the literature it seems that migrant workers returning from France have played a key role and that access to off-scheme savings accounts for the success farmers in these perimeters have had in repaying loans even during bad crop seasons. It is obvious that the main pool of existing experience on small perimeter management exists in Senegal, but we would also stress our favorable impression of ONAHA's system in Niger.

Within Mali, Niger and Upper Volta the opportunity for community-managed systems arises in connection with the new, smaller-scale irrigation perimeters which all three countries are presently developing. Because these are limited to river terraces or what can be irrigated from a small dam, they tend to be in the range of 5 to 100 ha, although a few along the Niger may be larger. Those below 100 ha are too small for efficient operation by a large irrigation authority even if the authority is responsible for their initial development. There is every reason to encourage localized mangement for such perimeters, either through the community or through formation of users' associations.

To activate such schemes two additional components are needed, one physical and the other organizational: (1) an operational delivery system to transport water onto farmers' fields; and (2) an acceptable model which outlines for villagers how a water users' association can be formed and will function. Whether this organization is labeled a "water users' association" is immaterial; the critical aspect is that there should be a corporate body which enjoys villagers' support and which will take responsibility to manage the perimeter. We saw from the case studies that having village control of a small-scale project does not automatically insure equity or smooth operation. People need help in learning how to do irrigation, especially those who come from a pastoral or other background without previous irrigation experience. Where external assistance has financed improved water supplies within the Sahel efforts have tended to become concentrated on the purchasing of pumps or the building of dams -- leaving unresolved how field delivery of water and perimeter operations will be accomplished. Until these additional aspects are routinized within the community system, farmers themselves will not enjoy the benefits from their "improved" supply no matter how imposing the water storage structure may look. We believe there is a large potential for more exchange of managerial experience on small-scale projects within the Sahel.

Small-Scale Technology Development

If the participative management approach can supply the "software" required by small-perimeter irrigators, what about the quality of the existing "hardware": the actual technologies being used in field applications? At first glance small-scale irrigation appears to be well served by existing technologies. The need is ancient and has been met by a spectrum of traditional water-lifting devices ranging from "persian wheel" to "archimedes screw." Modern versions of pump and pipe combinatons abound. There are several manuals on small-scale irrigation on the market (Stern, 1979; and Griffin et al., 1983). And, of course, "high technology" options such as drip irrigation are coming into more widespread use.

The view from the field suggests, to the contrary, that there is still a considerable gap to be bridged. Farmers using plastic pipe in the hot tropical sunlight are experiencing cracking, split pipes, leaking couplings and outright pipe failure because of faulty installation. The existing small pumps require a relatively large energy input to move a small amount of water (e.g., requiring a reciprocal motion for each powered stroke). Drip installation requires sediment-free water which is often not available. The very fact that farmers continue to employ extremely labor-intensive traditional methods for water lifting and conveyance, such as the shaduf and dallou systems described in Chapter VI, indicates an absence of effective alternatives at the micro end of the technological scale. To be sure, the small-scale manuals incorporate pictures of quaint water-lifting devices; but they do so in a condescending fashion which fails to show how simple systems within the farmers' reach can be extended and improved by application of modern materials and knowledge. Even with regard to platform mounted pumpsets there remain many technical lessons which have not become consolidated into general practice.

The development of any new technology generally requires a long-term commitment, something which donor agencies can rarely provide. However, in this instance there are individuals scattered across Africa who have already accumulated much of the experience such a program would need to draw upon. It is a need nobody else is filling and that has a large potential benefit to the private sector in the Sahel nations. What is required are exchanges of expertise between countries, a pooling of ideas from those existing specialists who know small-system engineering first hand and some help in training and concept dissemination. Such initiative need not be very expensive and once launched might be handed over to a large donor like FAO. At the initial stages, however, they require careful planning and much personal contact, a vital catalytic input which we feel the WMS-II Project, the sponsor of this report, ought to undertake. At the moment, despite thousands of smallholders trying to irrigate without help and literally hundreds of small PVO schemes, there are few sources of good expertise to draw upon in designing new projects or troubleshooting existing ones.

Related to the above assistance might also be a small research component designed to tap NGO and PVO managerial experience with projects currently in operation. There is substantial literature on the bigger irrigation systems, but hardly anything to warn about comparable difficulties being encountered in small-scale interventions. Where margins are tight because of budgetary, skill or supply constraints, as they often are in small-scale irrigation, even a "small" project can pose difficult technical problems, the main point made from our case studies. If the Peace Corps or other voluntary agencies are intending to get involved in such activities, as we were told they were in Mali, then there is a need to consolidate the existing PVO experience. Once again, the experience already exists but those who possess it are unlikely to draw out the general implications which would give their localized knowledge wider currency.

Traditional Systems

During the field visits a number of particular land-use systems were encountered which we believe would repay further scientific study. There is the Inland Delta system of traditional irrigation in Mali, a complex and interesting case whose hydrologic aspects need to be more fully understood. Again, as we described briefly in Chapter VI, the Air Mountains in Niger contain a unique form of arid-land irrigation where farmers rely on shallow wells recharged from uncultivated slopes. It would be interesting to learn how farmers estimate the water reserves so as to govern the withdrawal rates from their wells. An analogous situation occurs where sand dunes form a collecting slope that makes oasis settlement possible, but which forces its eventual relocation. Here the danger is that too rapid withdrawal of water can upset the hydrologic balance and thereby destroy the entire group of oasis wells, a real possibility now that farmers are individually buying motorized pumps. These small-scale types of oasis irrigation have special problems which ought to be better understood from a technical standpoint. Probably marsh or "bas fond" depressional farming of rice is another, similar case where analysis from a multidisciplinary perspective is needed.

On-Farm Water Management

Perhaps because Sahelian peasants are used to animal or hand-lifted water delivered for short distances into individual basins they appear to lack experience with land leveling and all the associated skills for managing water conveyance. We saw many examples of leaking canals, unlined furrows in sandy soils, extremely uneven fields, weed-choked canals and other conditions, creating maximum water losses. On both large- and in small-scale schemes the water losses are very high, an ironic fact given that water is so expensive to obtain. There are a number of steps which could be taken to greatly reduce the amount of water being used in Sahelian irrigation. Without going into detail,

since we were not in a position to perform field measurements we would stress the need for on-site diagnosis of Sahelian systems, followed by an intensive cycle of training for farmers and their "fonctionaires" alike. Had this been primarily an engineering report, we might have devoted an entire chapter to this topic. The situations we observed seemed to cry out for the kind of on-farm, interdisciplinary analysis of water mangement which the WMS Project has already provided in other countries.

Land-and-Water Relationships

Our concluding observation is not specific to irrigation, but concerns instead an urgent need to come to a better understanding of soil/water relationships in Africa's semi-arid and arid plateau lands, such as on the Bandiagara Plateau in Mali or in much of southern Niger. In the Dogon area the soil has in three centuries been stripped down to expose bare rock. Over much of the Sahel zone, when land is misused or even because of a few seasons of cultivation an ironstone "cap" forms which renders the land surface unusable for agricultural production. One sees instances of sheet erosion so severe that the root systems of growing plants are left exposed for several centimeters by the end of each season. There is research being done, but one comes away from the Sahel with the impression that time is running out. Human and animal populations continue to rise, yet few of the many plans formulated after the 1968-73 droughts have come to fruition, and the opportunities for taking action are slipping away. If this report can constitute a small step in a more positive direction, we shall be satisfied.

APPENDIX A

WORKING BIBLIOGRAPHY

Previous Page Blank

APPENDIX A

WORKING BIBLIOGRAPHY

Ackerman, W.C., G.B. White and E.D. Worthington (eds.) 1973. Man-Made Lakes: Their Problems and Environmental Effects. Washington, D.C.: American Geophysical Union.

Adams, W.M. 1983. "Irrigation as Hazard: Farmers' Responses to the Introduction of Irrigation in Sokoto, Nigeria." Paper presented for the Workshop: Irrigation in Tropical Africa, Problems and Problem Solving. Cambridge, England: African Studies Centre, Univ. of Cambridge, 6 pp. (mimeo).

Adams, Adrian. 1981. "The Senegal River Valley," pp. 325-353. In: Heyer, Judith et al. (eds.) Rural Development in Tropical Africa. New York: St. Martin's Press.

Adams, Adrian. 1977. Le Long Voyage des Gens du Fleuve Sénégal. Paris: Francois Maspero.

Adams, Adrian. 1977. "The Senegal River Valley: What Kind of Change?" Review of African Political Economy, No. 10 (Sept.-Dec.), pp. 33-59.

Africare, Inc. 1982. Revised Tara Hydro-Agricultural Project, Tara, Niger. Washington, D.C.: Africare.

Amn, Samir, Mark and Sow and Samba. 1975. La Planification du Sous-Développement: Critique de l'Analyse de Projets. Paris: Editions Anthropos for IDEP, Dakar, 404 pp. Critical review of project appraisal and World Bank planning; includes detailed materials on the Senegal Basin.

Aronson, Dan R. 1982. Toward Development for Pastoralists in Central Niger. A Synthesis Report of the Work of the Niger Range and Livestock Project. Niamey: USAID (Contract 683-0000-C-2012-00), for Livestock Service, Ministry of Rural Development, Republic of Niger, 121 pp.

Baak, B.C.P.H. van (compiler). 1976 onwards. Land and Water Development: Selected Literature, 1976. Wageningen, The Netherlands: International Institute for Land Reclamation and Improvement; published annually, covers technical topics.

Bah, Boubacar. 1982. "La Participation Dans Les Projets de Cultures Irriguées." Bamako: CILSS, Bureau d'études, de Conseils et d'intervention au Sahel, 60 pp.

Baker, Kathleen. 1982. "Structural Change and Managerial Inefficiency in the Development of Rice Cultivation in the Senegal River Region." African Affairs, Vol. 81, No. 325, pp. 499-510.

Previous Page Blank

Baldwin, Kenneth. 1957. The Niger Agricultural Project: An Experiment in African Development. Cambridge, Mass.: Harvard Univ. Press.

Barral, Henri. 1967. "Les populations d'eleveurs et les problémes pastoraux dans le nord-est de la Haute-Volta...1963-1964." Cahiers de L'ORSTOM, Série Sciences Humaines, Vol. 4, No. 1, pp. 3-30.

Bell, Clive and Hazell, P.B.R. 1980. "Measuring the Indirect Effects of an Agricultural Investment Project on Its Surrounding Region," American J. of Agricultural Economics, Vol. 62, No. 1 (Feb.), pp. 75-86.

Belloncle, Guy. 1981. Structures Villageoises et Stratégies de Développement Projets Éducatife en Afrique Noire. Paris: Bureau d'Etudes Coopératives et Communantaires.

Berg, Elliot. 1980. "Reforming Grain Marketing Systems in West Africa: A Case Study of Mali," pp. 147-172. In: ICRISAT, Proceedings of the International Workshop on Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture, Pantacheru, India: ICRISAT, 435 pp.

Berg, Elliot. 1975. The Recent Economic Evolution of the Sahel. Ann Arbor, Michigan: Center for Research on Economic Development, Univ. of Michigan, 247 pp. Overview of situation up to 1975 with chapters on economic impact of drought, world inflation, food subsidy impact, etc.; pp. 165-230 give country statistics synthesized from many sources; pp. 231-247 give a select bibliography.

Bernus, Edmond. 1974. "L'évolution récente des relations entre éleveurs et agriculteurs en Afrique tropicale. L'exemple du Sahel Nigerien," Cahiers de l'ORSTOM, Série Sciences Humaines, Vol. 11, No. 2, pp. 137-143.

Bernus, Edmond. 1974. "Possibilities et limites de la politique d'hydraulique pastorale dans le sahel nigerien," Cahiers de l'ORSTOM, Serie Sciences Humaines, Vol. 11, No. 2, pp. 119-126.

Bernus, Edward. 1977. "Les Eleveurs face à la Sécheresse en Afrique Sahelienne: Exemples Nigériens," In: Dalby, David et al. (eds.) Drought in Africa. African Environment Special Report, No. 6. London: International African Institute.

Berry, Leonard, Richard Ford and Richard Hosier. 1980. The Impact of Irrigation on Development: Issues for a Comprehensive Evaluation Study. AID Program Evaluation Discussion Paper No. 9. Washington, D.C.: USAID, 70 pp.

Bird, Alan. 1983. "The Land Issue in Large Scale Irrigation Projects: Some Problems from Northern Nigeria." Paper for the Workshop: Irrigation in Tropical Africa, Problems and Problem Solving. Cambridge, England: African Studies Centre, Univ. of Cambridge, 10 pp. (mimeo).

Bottrall, Anthony. 1978. "The Management and Operation of Irrigation Schemes in Less Developed Countries," pp. 309-322. In: Widstrand, Carl (ed.), The Social and Ecological Effects of Water Development in Developing Countries. New York: Pergamon Press.

Boutillier, J. L. 1980. "Irrigated Farming in the Senegal River Valley." In: Purdue University. Workshop on Sahelian Agriculture, May 1980. Lafayette, Ind.: Dept. of Agric. Economics, Purdue University.

Boutillier, J. L. et al. 1962. La moyenne vallée du Sénégal; Etude socioeconmique. Paris: Ministere de la Cooperation et INSEE, République Française.

Brinkerhoff, Derick W. 1980. "Realities in Implementing Decentralization, Coordination, and Participation: The Case of the Mali Rural Health Project." Development Discussion Paper No. 105. Cambridge, MA: Harvard Institute for International Development, Harvard University, 40 pp.

Brokensha, D.W., D.M. Warren and O. Werner (eds.) 1980. Indigenous Knowledge Systems and Development. Landau, MD: Univ. Press of America.

Brokensha, David, M. Horowitz and T. Scudder. 1977. The Anthropology of Rural Development in the Sahel: Proposals for Research. Binghampton, N.Y.: Institute for Development Anthropology.

Brokensha, David and Thayer Scudder. 1968. "Resettlement," pp. 20-62. In: Warren, W.M. and N. Rubin (eds.) Dams in Africa. London: Frank Cass; key review of poorly planned resettlement efforts which generally accompany the building of large dams in Africa.

Buignicourt, James. 1976. Senegal River Valley: A Threatened Environment and Landscape. Dakar: ENDA, 28 pp.

Cairncross, S. and R. Feachem. 1978. Small Water Supplies. Bulletin No. 10. London: Ross Institute and Advisory Service.

Camboulives, Marguerite. 1967. L'Organisation Coopérative au Sénégal. Paris: Pedone.

Carruthers, Ian. 1978. "Contentious Issues in Planning Irrigation Schemes," pp. 301-308. In: Widstrand, Carl (ed.) The Social and Ecological Effects of Water Development in Developing Countries. New York: Pergamon Press.

Caughman, Susan. 1981. "Women at Work in Mali: The Case of the Markala Cooperative." Working Paper No. 50, African Studies Center. Boston: Boston University, 35 pp.

Charlick, R.B. 1974. "Power and Participation in the Modernization of Rural Hausa Communities." Ph.D. Thesis, University of California, Los Angeles.

CILSS. 1981. The Recurrent Costs in the Countries of the Sahel. How to Evaluate, Finance and Control Them. Acts of the Ouagadougou Symposium, 11-15 January 1982. Paris: Club du Sahel/CILSS, 592 pp. A key reference on this topic; in addition to the Symposium resolutions, it reprints 17 specialized papers and documents (Part IV, pp. 181-537), some on specific countries and other of general relevance.

CILSS. 1980. Le developpement des cultures irriguées dans le Sahel. Bilans et perspectives (c. 330-2-136). Paris: Club du Sahel, 40 pp.

CILSS. 1980. The Development of Irrigated Agriculture in the Sahel. Sahel D(80)75. Paris: Club du Sahel/CILSS, 35 pp.; crucial report synthesizing the CILSS country-by-country reviews of irrigated agriculture in 1979.

CILSS. 1979. Development of Irrigated Agriculture in Mali. Sahel D (79)42. Paris: Club du Sahel/CILSS, 128 pp.

CILSS. 1979. Development of Irrigated Agriculture in Mauritania. Sahel D (79)45. Paris: Club du Sahel/CILSS, 86 pp.

CILSS. 1979. Development of Irrigated Agriculture in Niger. Sahel D (79)46. Paris: Club du Sahel/CILSS, 51 pp.

CILSS. 1979. Development of Irrigated Agriculture in Senegal. Sahel D (79)43. Paris: Club du Sahel/CILSS, 108 pp.

CILSS. 1979. Development of Irrigated Agriculture in Upper Volta. Sahel D (79)44. Paris: Club du Sahel/CILSS, 55 pp.

CILSS. 1978. Cultures Irriguees. Consultation sur les projets de production vegetable, 19-22 Septembre 1978. Paris: Club du Sahel/ CILSS.

CILSS/Club du Sahel. 1977. Marketing, Price Policy and Storage of Food Grains in the Sahel: A Survey. Vol. 1. Synthesis with Statistical Compilations and Annotated Bibliography. Vol. 2. Country Studies. Paris: CILSS/Club du Sahel.

Cocheme, J. and P. Franquin. 1967. An Agroclimatology Survey of a Semi-arid Area in Africa South of the Sahara. WMO Technical Note 86. Geneva: WMO, 136 pp.

Collins, John D. 1976. "The Clandestine Movement of Groundnuts Across the Niger-Nigeria Boundary." Canadian J. of African Studies, Vol. 10, No. 2, pp. 259-276.

Crawford, Paul R. 1982. AID Experience in Agricultural Research: A Review of Project Evaluations. AID Program Evaluation Discussion Paper No. 13. Washington, D.C.: U.S. Agency for International Development, 257 pp.

Crow, John E. et al. 1977. L'Environment Economique, Social, et Physique du Département de Ziner, la République du Niger. La plannification des ressources naturelles au Niger. Tucson, Arizona: University of Arizona (Natural Reources Project, Preliminary Working Paper), 123 pp.

Crystal, C. 1981. "An Analysis of the Socio-Economic Factors which Distinguish Innovators from Traditional Farmers in the Action Blé Diré Project," (unpublished report). Bamako: USAID/Mali. 83 pp.

Davis, Lenwood G. 1976. Irrigation and Water Systems in Africa: An Introductory Survey. Council of Planning Librarians Exchange Bibliography #1206. Monticello, Ill.: Council of Planning Librarians, 24 pp.; mostly geographical references with coverage of Gezira, Aswan and Volta.

De Garine, Igor. 1978. "Population, Production and Culture in the Plains Societies of Northern Cameroon and Chad: The Anthropologist in Development Projects." Current Anthropology, Vol. 19, pp. 42-54.

Delgado, C. 1978. The Southern Fulani Farming System in Upper Volta. Ann Arbor, Michigan: CRED, Univ. of Michigan.

Delgado, C. 1977. "Economic Interactions between Peasants and Herders in the West African Savannah: A Case Study from Teu Kodogo, Upper Volta." Ann Arbor, Michigan: CRED, University of Michigan.

Derman, William. 1980. "Cooperatives, Initiative, Participation and Socio-Economic Change," pp. 605-702. In: Reyna, Stephen P. (ed.) Sahelian Social Development. Abidjan: REDSO/USAID.

Des Bouvrie, C. and J.R. Rydzewski. 1977. "Irrigation," pp. 161-193. In: Leakey, C.L.A. and J.B. Wills (eds.) Food Crops of the Lowland Tropics. Oxford, England: Oxford Univ. Press.

Deutsches Institut fur Afrika Forschung. 1975. Drought in Africa. A Selected Bibliography. Hamburg: Deutsches Institut fur Afrika Forschung, Dokumentations-Leitstelle; about 200 annotated titles indexed in English, French and German.

Development Alternatives, Inc. 1982. Agricultural Sector Assistance Strategy for Upper Volta. Washington, D.C.: Development Alternatives, Inc., 204 pp.

De Wilde, John C. 1967. "Mali: The Office du Niger--An Experience with Irrigated Agriculture," pp. 245-300. In: Experiences with Agricultural Development in Tropical Africa. Vol. 2, Case Studies. Baltimore: Johns Hopkins Univ. Press.

Dey, Jennie. 1982. "Development Planning in the Gambia: The Gap Between Planners' and Farmers' Perceptions, Expectations and Objectives." World Development, Vol. 10, No. 5, pp. 377-396.

Dey, Jennie. 1980. "Women and Rice in The Gambia: The Impact of Irrigated Rice Development Projects on the Farming Systems." Ph.D. Thesis, Univ. of Reading, England, 381 pp.; shows negative impact of schemes on women's traditional rice growing through increased workload and channeling of benefits and inputs through male heads of household.

Diagne, P.S. 1974. La Delta du Fleuve Sénégal: Problèmes de Développement. Doctoral Thesis, Univ. of Paris; description of the delta and history of SAED's efforts, by its former Secretary General (74-78).

Diallo, M. 1980. "Comparative Analysis of Capital Intensive and Labor Intensive Rice Irrigation Perimeters in the Senegal River Valley." M.S. Thesis, Michigan State University.

Diemer, Geert and Ellen C.W. van der Laan. 1983. "Using Indigenous Skills and Institutions in Small-Scale Irrigation: An Example from Senegal." ODI Irrigation Management Network Paper 8b. London: Overseas Development Institute, 11 pp.

Doherty, V.S. an N.S. Jodha. 1977. "Conditions for Group Action Among Farmers." Occasional Paper No. 19. Hyderabad: ICRISAT.

Dunsmore, et al. 1976. The Agricultural Development of The Gambia: An Agricultural, Environmental and Social Economic Analysis. Land Resources Study, 22. Surviton, Surrey, England: Land Resources Division, Ministry of Overseas Development.

Dupire, Marguerite. 1962. Peuls Nomades. Etude descriptive des Wo 'daa'be du Sahel Nigérien. Travaux et Memoires de l'Institut d'Ethnologie LXIV. Paris: Institute d'Ethnologie.

Easter, William K. 1980. Issues in Irrigation Planning and Development. Staff Paper P80-5. St. Paul, Minn.: Dept. of Agric. and Applied Econ., Univ. of Minnesota, 32 pp.

Eddy, Edward D. 1979. Labor and Land Use on Mixed Farms in the Pastoral Zone of Niger. Vol. 3. Livestock Production and Marketing in the Entente States of West Africa. Ann Arbor, Michigan: Center for Research on Economic Development. Univ. of Michigan (for USAID), 492 pp.

Eicher, Carl K. 1983. "West Africa's Agrarian Crisis." Paper for the Fifth Bi-Annual Conference of the West African Association of Agricultural Economists, Abijan, Ivory Coast, Dec. 7-11. 71 pp.

Eicher, Carl K. and Doyle C. Baker. 1982. Research on Agricultural Development in Sub-Saharan Africa: A Critical Survey. MSU Int. Dev. Paper No. 1. East Lansing, Mich.: Dept. of Agric. Econ., Michigan State University.

Elmendorf, M. 1976. "Bura Irrigation Settlement Scheme--Tana River District, Kenya." Washington, D.C.: The World Bank.

Family Health Care, Inc. (Victor Barbiero). 1979. Health Impact Guidelines for the Design of Development Projects in the Sahel. 2 Vols. Washington, D.C.: Family Health Care, Inc.--Vol. 1, Sector specific reviews and methodology, 116 p. (includes as its model for assessing health impacts a 2,500 ha irrigation project in Mali); Vol. 2, Reference Manual, 188 p.; gives disease by disease review, pp. 129-181 has 273 item bibliography.

Feachem, R., M. McGarry and D. Mara (eds.). 1977. Water, Wastes and Health in Hot Climates. New York: John Wiley.

Fieloux, M. 1980. "A Socio-Economic Study of a Toucouler Village, Bow (Senegal)." In: Purdue University: Workshop on Sahelian Agriculture, May 1980. Lafayette, Inc.: Dept. of Agric. Econ., Purdue University.

Food and Agriculture Organization. 1982. Farmers' Participation and Organization for Irrigated Water Management. Rome: FAO Land and Water Division.

Food and Agriculture Organization. 1982. Guidelines--Women in Land and Water Development. Rome: FAO Land and Water Development Division.

Food and Agriculture Organization. 1977. Les Systèmes Pastoraux Saheliens. Rome: FAO.

Food and Agriculture Organization. 1974. Tree Planting Practices in African Savannas. FAO Forestry Series No. 14. Rome: FAO.

Food and Agriculture Organization. 1973. The Sahelian Zone. A Selected Bibliography for the Study of its Problems. Rome: FAO library occasional bibliographies.

Food and Agriculture Organization. 1973. Bibliography of FAO Documents on Senegal. Rome: FAO (microfiche), B. 105.

Food and Agriculture Organization. 1972. Bibliography of FAO Documents on Upper Volta. Rome: FAO (microfiche), B. 040.

Food and Agriculture Organization. 1972. Bibliography of FAO Documents on Mali. Rome: FAO (microfiche), B. 035.

Food and Agriculture Organization. 1972. The Employment of Draught Animals in Agriculture. Rome: FAO, 249 pp.; reissue in English of French work prepared in 1968.

Food and Agriculture Organization. 1971. Bibliography of FAO Documents on Niger. Rome: FAO (microfiche), B. 021.

Food and Agriculture Organization. 1981. Man's Influence on the Hydrological Cycle. Irrigation and Drainage Paper, Special Issue 17. Rome: FAO, 71 pp.

Franke, Richard W. and Barbara Chasin. 1980. Seeds of Famine. Totowa, N.J.: Allanheld, Osmun, 167 pp.

Fresson, Sylviane. 1978. Village Participation in Pump Irrigation Areas in the Matam Zone in Senegal. Paris: OECD, 130 pp.

Fresson, Sylviane. 1978. "Public Participation in Village Level Irrigation Perimeters in the Matam Region of Senegal," Experiences in Rural Development, Occ. Paper No. 4. Paris: OECD Development Paper (CD/R 78 12).

Gall, Pirie M. 1982. Range Manaement and Livestock Development in the Sahel. Washington, D.C.: Chemonics, 85 pp.

Gallais, Jean. 1978. "Traditional Stragegies, Modern Decision-Making and Management of Natural Resources in the Sudan-Sahel," pp. 11-33. In: Management of Natural Resources in Africa: Traditional Stragegies and Modern Decision-Making. MAB Technical Notes 9. Paris: UNESCO, 81 pp.

Gallais, Jean. 1975. Pasteurs et Paysans du Gourma. Paris: Editions du Centre National de la Recherche Scientifique, 239 pp.

Gallais, Jean. 1975. "Traditions pastorales et développement: problèmes actuels dans la region de Mopti (Mali)," pp. 354-366. In: Monod, Theodore (ed.) Pastoralism in Tropical Africa. London: Oxford Univ. Press.

Gallais, Jean. 1972. "Essai sur la situation actuelle des relations entre pasteurs et paysans dans Sahel ouest-africain," pp. 301-313. In: Etudes de geographie tropicals offertes a Pierre Gourou. Paris/The Hague: Mouton.

Gallais, Jean. 1967. Le Delta Interieur du Niger: Etude de Géographie Regionale. Memoires de l'Institute Fondamental d'Afrique Noir, No. 79.

Gannett, Flemming and Carpenter, Inc. (n.d.) Assessment of Environmental Effects of Proposed Developments in the Senegal River Basin. Synthesis: Final Report. Harrisburg, PA in association with Orgatec Societe Africaine d'Etudes Techniques, Dakar, Sénégal for OMVS, 195 pp.

Gellar, Sheldon. 1982. Senegal. Boulder, Colo.: Westview Press, 145 pp.

Gellar, Sheldon. 1981. Planning, Management and Participatory Development Issues in Irrigation Projects: A Select Annotated Bibliography. Paris: CILSS/Club du Sahel, OECD (Sahel D (81)147), 64 pp.; excellent source.

Gil, N. 1979. Watershed Development with Special Reference to Soil and Water Conservation. FAO Soils Bulletin 44. Rome: FAO, 257 pp.

Gilbert, E.H., D.W. Norman and F.E. Winch. 1980. Les Recherches sur les Systèmes d'Eploitation Agricole: Une Evaluation Critique. Developpement Rural Cahier MSU No. 6. East Lansing, Michigan: Dept. of Agric. Economics, Michigan State University; contains useful French language description (pp. 97-138) of the various international agricultural research institutes.

Goddard, A.D. 1973. "Changing Family Structures Among the Rural Hausa." Africa, Vol. 43, pp. 207-218.

Gray, Clive and André Martens. 1982. "The Political Economy of the 'Recurrent Cost Problem' in the West African Sahel." Development Discussion Paper No. 128. Cambridge, MA: Harvard Institute for International Development.

Grayzel, John Aron. 1977. "The Ecology of Ethnic-Class Identity Among an African Pastoral People: The Doukoloma Fulbe." Ph.D. Thesis, anthropology, Univ. of Oregon.

Grayzel John Aron. 1976. "Cattle Raisers and Cattle Raising in the Doukoloma Forest Area, October 1974-September 1975." Bamako: USAID/OMBEVI (mimeo.).

Griffin, Richard E., George H. Hargreaves, Gary Z. Watters, R. Kern Stutler and LeRoy Salazar. Pumps and Water Lifters for Irrigation. Handbook No. 3. Logan, Utah: Agricultural and Irrigation Engineering Department, Utah State University. University, Logan, Utah. 158 pp.

Griffith, W.J. 1983. "Madness of Fowl, Marriage with Cat?" Paper for the Workshop: Irrigation in Tropical Africa, Problems and Problem Solving. Cambridge, England: African Studies Centre, Univ. of Cambridge, 12 pp. (mimeo).

Grove, A.T. 1970. Africa South of the Sahara. London: Oxford University Press, 280 p.

Guillaume, M. 1960. "Les Aménagements Hydro-Agricoles de Riziculture et de Culture de Décrue dans la Vallée du Niger." L'Agronomie Tropicale, Vol. 15, Nos. 1-4 (1:73-79; 2:133-187; 3:273-174; 4:390-413).

Haissman, I. 1970. "Skilled Manpower Planning for Irrigation Projects in Developing Countries." Ph.D. Thesis, Univ. of California, Berkeley.

Hammond, Peter B. 1960. "Management in Economic Transition," pp. 109-122. In: Moore, W.G. and A.S. Feldman (eds.) Labor Commitment and Social Change in Underdeveloped Areas. New York: Social Science Research Council.

Harriss, Barbara. 1982. Agricultural Marketing in the Semi-Arid Tropics of West Africa. Development Studies Occasional Paper No. 17. Norwich, England: School of Development Studies, University of East Anglia, 133 pp.

Harriss, Barbara. 1980. "Going Against the Grain," pp. 265-288. In: ICRISAT, Proceedings of the International Workshop on Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture. Pentancheru, India: ICRISAT.

Hart, Keith. 1982. The Political Economy of West African Agriculture. Cambridge, England: Cambridge Univ. Press, 226 pp.

Hautaluoma, Jacob E. et al. 1980. Development Process for Improving Irrigation Water Management on Farms. Project Implementation Manual. Water Management Technical Report No. 65 D. Fort Collins, Colo.: Colorado State University, 111 pp.

Hewitt, W.H. 1977. "Land Resources Appraisal of Gambia River Basin." New York: UNDP (mimeo.).

Heyer, Judith et al. (eds.) 1981. Rural Development in Tropical Africa. New York: St. Martin's Press, 375 pp.; contains three irrigation case studies, including the Kano and Gezira schemes and small-perimeters in Senegal.

Hill, Alan G., Sara Randall and Oriet Sullivan. 1982. The Mortality and Fertility of Farmers and Pastoralists in Central Mali 1950-1981. CPS Research Paper No. 82-4. London: Centre for Population Studies, London School of Hygiene and Tropical Medicine, Univ. of London, 54 pp.

Holloran, Susan et al. 1982. Sederhana: Indonesia Small-Scale Irrigation. AID Project Evaluation Report No. 29. Washington, D.C.: U.S. Agency for International Development.

Hopfen, H.J. 1969. Farm Implements for Arid and Tropical Regions. FAO Agricultural Development Paper, No. 91. Rome: FAO, 159 pp.

Horowitz, Michael M. 1975. "Herdsman or Husbandman in Niger: Values and Strategies," pp. 387-405. In: Monod, Theodore (ed.) Pastoralism in Tropical Africa. London: Oxford Univ. Press.

Horst, L. 1983. "Irrigation Systems - Alternative Design Concepts." ODI Irrigation Management Network Paper 7c. London: Overseas Development Institute, 18 pp.

Hoskins, Marilyn and Fred Weber. 1982. "Evaluation of Lutheran World Relief Projects, Niger," (unpublished report). Niamey: Lutheran World Relief. 73 pp.

Hughes, Francine. 1983. "Fuelwood Needs on Irrigation Schemes: The Case of Bura Irrigation Settlement Project, Kenya." Paper for the Workshop: Irrigation in Tropical Africa, Problems and Problem Solving. Cambridge, England: African Studies Centre, Univ. of Cambridge, 18 pp. (mimeo).

Hughes, Charles C. and John M. Hunter. 1970. "Diseases and 'Development' in Africa," pp. 443-493. Social Science and Medicine, Vol. 3. Pergamon Press.

Humphreys, Charles P. and Scott R. Pearson. 1979-80. "Choice of Technique in Sahelian Rice Production." Food Research Institute Studies, Vol. 17, No. 3, pp. 235-77.

Interafrican Committee for Hydraulic Studies. 1977. Catalog du Centre de Documentation, 2 Vols. Boston: G.K. Hall; contains 27,000 entries held by the Comité Interafricain d'Etudes Hydrauliques documentation center in Quagadougou, Upper Volta, heavily oriented to technical materials.

Jobs and Skills Programme for Africa. 1980. Dynamique de L'Empoi dans un Système Sahelien le Niger. Addis Ababa: JASPA, International Labour Office, 301 pp.

Jones, Christine W. 1983. "The Mobilization of Women's Labor for Cash Crop Production: A Game-Theoretic Approach." Ph.D. Thesis, Economics, Harvard University, 183 pp. An important source based on field work in Cameroun.

Jones, Christine W. 1983. "The Impact of the SEMRY I Irrigated Rice Production Project on the Organization of Production and Consumption at the Intra-household Level." USAID Contract No. PTR-0096-00-2232-00, 112 p.

Jones, William. 1976. Planning and Economic Policy: Socialist Mali and Her Neighbors. Washington, D.C.: Three Continents Press; Chap. 4 has case study of the Office du Niger up to the mid-1960s.

Joseph, Stephen and Stanley Scheyer. 1977. A Strategy for Health as a Component of the Sahel Development Program. Washington, D.C.: Family Health Care, Inc. for USAID (AID/afr-C-1138, w.o.8), 99 pp.

Joyce, Charles L. (ed.) 1978. Towards a Rational U.S. Policy on River Basin Development in the Sahel. (Proceedings of a Colloquium, March 31-April 1, 1978.) Washington, D.C.: Agency for International Development.

Joyce, Stephen and Françoise Beudot. 1976. Elements for a Bibliography of the Sahel Drought. (French and English) Paris: Development Center, OECD. Updated issues by Françoise Beudot, 1977-1982.

Kamuanga, M. 1981. "Farm Level Study of the Rice Production System at the Office du Niger in Mali: An Economic Analysis." Ph.D. Dissertation, Michigan State University, East Lansing.

Kamuanga, M. and D.S.C. Spencer. 1981. Losses of Rice in West Africa: The Case of the Office du Niger in Mali. WARDA Occ. Paper No. 5. Monrovia, Liberia: WARDA.

Katz, R.W. and M.H. Glantz. 1977. "Rainfall Statistics, Droughts and Desertification in the Sahel," pp. 81-102. In: Glantz, M.H. (ed.) Desertification: Environmental Degradation In and Around Arid Lands. Boulder, Colo.: Westview Press.

Keller, Jack et al. 1982. Project Review for Bakel Small Irrigated Perimeters, USAID/Senegal Project No. 685-0208. WMS Report 9. Logan, Utah: Agricultural and Irrigation Engineering Department, Utah State University. 107 pp.

Kloth, T.I. et al. 1976. "Sahel Nutrition Survey, 1974." American J. of Epidemiology, Vol. 103, No. 4, pp. 383-390.

Kostinko, Gain and Josue Dione. 1980. Rural Development in Senegal: An Annotated Bibliography Since 1975. African Rural Economy Paper No. 22. East Lansing, Mich.: Dept. of Agric. Econ., Michigan State University.

Kowal, J.M. and A.H. Kassam. 1978. Agricultural Ecology of Savanna: A Study of West Africa. Oxford: Oxford Univ. Press.

Langley, P. 1977. "A Self-Reliant Environment? The Possibility of a Technological Alternative." African Environment: Technological Relay Series. Dakar: IDEP; review of large-scale projects vs. small-scale alternatives.

Lateef, Noel V. 1980. Crisis in the Sahel: A Case Study in Development Cooperation. Boulder, Colo.: Westview Press, 287 pp.

Leonard, David C. 1983. Traditional Field Crops. Washington, D.C.: Information Collection and Exchange, Peace Corps, 176 p. (Appropriate Technology for Development Manual No. M-13); a handbook of simplified agronomy techniques.

Litzenberger, S.C. (ed.) 1974. Guide for Field Crops in the Tropics and Subtropics. Washington, D.C.: Agency for International Development.

Lowdermilk, Max K. 1978. "Farm Water Management in Irrigation Systems: The Crucial Role of Farmer Organizations," pp. 1-59 (Chap. 7). In:

Joyce, Charles (ed.) Towards a Rational U.S. Policy on River Basin Development in the Sahel. Washington, D.C.: Agency for International Development.

McJunkin, F.E. 1975. Water, Engineers, Development and Disease in the Tropics. Washington, D.C.: Agency for International Development; basic source, with emphasis upon schistosomiasis.

McJunkin, F.E. 1970. Engineering Measures for Control of Schistosomiasis. Chapel Hill, N.C.: Dept. of Environmental Sciences and Engineering, School of Public Health, Univ. of North Carolina (for USAID), 66 pp.

McNetting, Robert et al. 1980. "Interior Niger Delta of Mali," pp. 373-454. In: Reyna, Stephen (ed.) Sahelian Social Development. Abidjan: Regional Economic Development Services Office (REDSO), West Africa, USAID, 702 pp.

Maiga, Mahamadou. 1976. Capitalisme, Exploitation des Resources Hydrauliques du Fleuve Sénégal et Developpement des Pays Riverains (Guinee, Mali, Mauritanie, Senegal). Ph.D. Thesis, Univ. of Paris.

Maiga, Mahamadou. 1976. "The Policy of Rice Import Substitution: The Case of the Senegal River Valley and Delta." African Development, Vol. 7, No. 2, pp. 44-57.

Mali, Republic of. 1983. Mali Land and Water Resources. Vol. 1, Atlas. Vol. 2, Technical Report. Vol 3, Annexes. New York: TAMS for the Ministry of Rural Development, Republic of Mali.

Manteuffel, H.M. and W.E. Tyner. 1980. "Benefit-Cost Analysis of Small Irrigated Perimeters--A Sahelian Case Study." In: Purdue University. Workshop on Sahelian Aglriculture, May 1980. Lafayette, Ind.: Dept. of Agric. Econ., Purdue University.

Mattern, David. 1981. "Final Report, Action Blé-Diré," (unpublished report). Bamako: USAID/Mali.

Meillasoux, Claude (1974). "Development or Exploitation: Is the Sahel Famine Good Business?" Review of African Political Economy, Vol. 1, pp. 27-33.

Mensching, Horst G. with V. Haarmann (eds.) 1982. Problems of the Management of Irrigated Land in Areas of Traditional and Modern Civilization. IGU Working Group on Resource Management in Drylands. Hamburg: IGU, 174 pp.

Miller, Richard P. 1984. "Peasant Autonomy and Irrigation: Innovation in the Senegal River Basin." Ph.D. Thesis, Northwestern University. A key study on water users' associations in Senegal (1980-81).

Montgomery, John D. 1983. "When Local Participation Helps." Journal of Policy Analysis and Management, Vol. 3, No. 1, pp. 90-105.

Nelson, Gary and Fred M. Tileston. 1977. "Irrigation: A Paradox for Sahelian Development." Washington, D.C.: Agency for International Development.

Newman, M., I. Ouedraogo and D. Norman. 1980. "Farm-Level Studies in the Semi-Arid Tropics of West Africa," pp. 241-263. In: ICRISAT, Proceedings of the International Workshop on Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture. Pantancheru, India: ICRISAT.

Nicholson, Sharon E. 1982. The Sahel: A Climatic Perspective. Paris: CILSS/OECD (Sahel D (82)187), 80 pp.

Niger, République, Ministère du Plan. 1981. Les Aménagements Hydro-Hydro-agricoles. Etude Comparative des coûts d'investissements et de fonctionnement. France: SOGREAH: Ingenieurs Conseils, 146 pp. (For Republic of Niger, Ministry of Planning.)

Niger, République. 1981. ONAHA, Fiches Signaletiques, Naimey: ONAHA.

Obeng, Letitia E. 1978. "Starvation or Bilharzia?--A Rural Development Dilemma," pp. 343-351. In: Widstrand, Carl (ed.) The Social and Ecological Effects of Water Development in Developing Countries. New York: Pergamon Press.

Office de La Recherche Scientifique et Technique Outre-Mer. 1979. Maitrise de L'espace Agraine et Développement en Afrique Tropicàle. Actes du Colloque du Ouagadougou. Paris: Editions de l'office de La Recherche Scientifique et Technique Outre-Mer, 600 pp.

Office de La Recherche Scientifique et Technique Outre-Mer. 1979. Monographie Hydrologique du Bassin du Niger. 3 Vols. Paris: Office de La Recherche Scientifique et Technique Outre-Mer.

Olsen, Edwin C. 1983. "On-Farm Water Management of Small Irrigated Perimeters, USAID/Mali." Logan, Utah: International Irrigation Center (unpublished paper), 18 pp.

OMVS. 1980. Interpretation of Results and Recommendations in the Field of Rural Development. General Report, Part E: Social and Economic Study of the Senegal River Basin. Saint Louis: O.M.V.S.

OMVS. 1971 onwards. Aménagement et Mise en Valeur du Bassin du Fleuve Sénégal. Saint-Louis, Senegal: OMVS Documentation Center; published index of OMVS holdings, serial.

Ouedraogo, Ismal, Mark D. Newman and David W. Norman. 1982. The Farmer in the Semi-Arid Tropics of West Africa: A Partially Annotated Bibliography. ICRISAT Research Bulletin No. 4, Vol. 2. Andra Pradesh, India: ICRISAT, 122 pp.

Painter, James E. et al. 1982. The On-Farm Water Management Project in Pakistan. AID Project Impact Evaluation Report No. 35. Washington, D.C.: U.S. Agency for International Development.

Parnell, Theodore and Albert E. Utton. 1976. "The Senegal Valley Authority: A Unique Experiment in International River Basin Planning." Indiana Law Journal, Vol. 52, No. 2, pp. 235-256.

Pasternak, Burton. 1968. "Social Consequences of Equalizing Irrigation Access." Human Organization, Vol. 27, No. 4, pp. 332-343.

Patterson, William McClinton. 1984. "Village Irrigation Systems Along the Senegal River: A Comparative Analysis." Ph.D. Dissertation, Cornell University, Ithaca, New York.

Paylore, Patricia. 1976. Desertification: A World Bibliography. Tucson, Arizona: Office of Arid Land Studies, Univ. of Arizona, 271 pp.

Pearson, Scott R., J. Stryker and Charles P. Humphreys. 1981. Rice in West Africa: Policy and Economics. Stanford: Stanford Univ. Press.

Peter, Dominique et al. 1979. Development of Irrigated Agriculture in Gambia: General Overview and Prospects, Proposals for a Second Programme 1980-85. Paris: CILSS/Club du Sahel for Republic of Gambia (Sahel D (79)48), 60 pp.

Pollard, Nigel. 1981. "The Gezira Scheme--A Study of Failure." The Ecologist, (Jan.-Feb.), Vol. 11, No. 1, pp. 21-31; emphasizes aggregate negative impacts, particularly upon health.

Rafols, W. de 1982. "Economic Analysis Update," (unpublished report). Bamako: USAIDéMali. 37 pp.

Rajogopalan, S. and M. Shiffman. 1974. Guide to Sanitary Measures for the Control of Enteric Diseases. Geneva: World Health Organization.

Raulin, Henry. 1976. "Organized Cooperation and Spontaneous Cooperation in Africa (Niger Republic)," pp. 35-43. In: Nash, J., J. Dandler and N.S. Hopkins (eds.) Popular Participation in Social Change. The Hague: Mouton Publishers.

Raynaut, C. 1977. "Circulation Monetaire et Evolution des Structures Socio-Economique chez les Haoussas du Niger," Africa, Vol. 47, No. 2, pp. 160-71.

Reisman, Paul. 1980. "The Fulani in a Development Context," pp. 71-186. In: Reyna, Stephen P. (ed.) Sahelian Social Development. Abidjan: REDSO/USAID West Africa.

Reisman, Paul. 1977. Freedom in Fulani Social Life. Chicago: Univ. of Chicago Press.

Reynaut, E. 1969. "Quelques Donées de l'Horticulture dans la Valée de Maradi." Etudes Nigériennes, No. 26, pp. 1-164.

Republique Française, Ministère de la Coopération. 1979. Etude des Charges Recurrentes Des Aménagements Hydroagricoles au Niger. Analyse des Principaux Résultats Économiques. Parisç Sedes (84 rue de Lille 75007), 155 pp.

Rippstein, G. and B. Peyre de Fabregues. 1972. Modernisation de la Zone Pastorale du Niger: Etude Agrostologique, No. 33. Maisons-Alfort: Institut d'Elevage et de Medecine Veterinaire des Pays Tropicaux.

Royal Tropical Institute. 19 . Sahel Documentatie. Amsterdam, The Netherlands: Royal Tropical Institute; detailed bibliographic series on Sahelian development issues.

Rural Development Unit. 1979. Agriculture Policies of the Five Entente Countries. Abidjan: Rural Development Unit, Ivory Coast, 227 pp.; review of Niger, pp. 127-167.

Sahel Documentation Center. 1977 onwards. Sahel Bibliographic Bulletin. East Lansing, Mich.: Sahel Documentation Center; published quarterly, best single bibliographic resource, entrees by topic and country with several sections on irrigation and river basin management.

Scudder, Thayer. 1980. "African River Basin Development and Local Initiatives in Savanna Environments," pp. 383-405. In: Harris, David R. (ed.) Human Ecology in Savanna Environments. New York: Academic Press.

Shaw, Margaret. 1979. Administrative Structures and Civil Service in the Sahel Countries. Washington, D.C.: Agency for International Development (Contract afr-c-1454, Aid Project 625-0929).

Shear, D. and B. Clark. 1976. "International Long-Term Planning for the Sahel." International Development Review, Vol. 4, pp. 15-20.

Sisson, Andrew B. and Theodore Ahlers. 1981. The Socio-Economic Impact of SEMRY I: Economic Aspects. Research Report No. 1. Yaounde: CRED.

Skogerboe, Gaylord V. et al. 1980. Development Process for Improving Irrigation Water Management on Farms. Executive Summary. Water Management Technical Report No. 65 A (AID/ta-C-1411). Fort Collins, Colo.: Water Management Research Project, Engineering Research Center, Colorado State University, 22 pp.

Small, Leslie. 1984. "Irrigation and Human Welfare: A Workshop Report," (unpublished report). New Brunswick, N.J.: International Agricultural and Food Program, Cook College, Rutgers University.

Smith, Linda. 1983. "Survey of Sixth Region Pump Farmers--1982-83 Wheat Campaign," (unpublished report). Bamako: USAID/Mali. 18 pp.

Snyder, Francis G. 1981. Irrigation and Human Welfare: A Workshop Report. New Brunswick, N.J.: International Agricultural and Food Program, Cook College, Rutgers University, 29 pp.

Southwest Research Institute (n.d.) 1982. A Technical Guide to Water Management on Small Farms. San Antonio, Texas: Southwest Research Institute for USAID, 91 p.; illustrated introductory treatment.

Sow, Samba. 1965. Intégration de l'Elevage et des Eleveurs dans la Zone Pionnière du Delta. Dakar: Collège d'Aménagement du Territoire, Memoire de Stagiaire.

Sparling, Edward W. 1981. "A Survey and Analysis of Ex-Post Cost-Benefit Studies of Sahelian Irrigation Projects." Fort Collins, Colo.: Colorado State University, Dept. of Economics (draft ms.).

Sparling, Edward W. et al. 1980. Development Process for Improving Irrigation Water Management on Farms. Development of Solutions Manual. Water Management Technical Report No. 65 C. Fort Collins, Colo.: Colorado State University, 95 pp.

Stanley, N.F. and N.P. Alpers (eds.) 1975. Man-made Lakes and Human Health. New York: Academic Press.

Stann, J.M. 1983. "Labour Constraints in the Promotion of Irrigation Projects." Paper for the Workshop: Irrigation in Tropical Africa, Problems and Problem Solving. Cambridge, England: African Studies Centre, Univ. of Cambridge, 10 pp. (mimeo).

Steedman, C. et al. 1976. Mali: Agricultural Sector Assessment. Ann Arbor: Center for Research on Economic Development, Univ. of Michigan.

Stern, P.H. 1979. Small-Scale Irrigation. London: Intermediate Technology Ltd./Bet Dagan, Israel: Int. Irrigation Infor. Center; standard reference.

Storm, R. 1976. "Government Cooperative Groundnut Marketing in Senegal and Gambia." Journal of Rural Cooperation, Vol. 5, No. 1, pp. 29-42.

Stryker, Dirk J. 1978. Food Security, Self-Sufficiency, and Economic Growth in the Sahelian Countries of West Africa. Palo Alto, Calif.: Food Research Institute, Stanford Univesity.

Stryker, Dirk J. 1978. "Rainfed Farming and Irrigation Options in West Africa." In: Joyce, Charles (ed.) Towards a Rational U.S. Policy on River Basin Development in the Sahel. Washington, D.C.: Agency for International Development.

Stryker, Dirk J. 1976. "Population Density, Agricultural Technique, and Land Utilization in a Village Economy," American Economic Review, Vol. 66, pp. 347-358.

Suret-Canale, Jean. 1971. French Colonialism in Tropical Africa, 1900-1945. New York: Pica Press.

Sutter, John W. 1980. "Subsistence Strategies and Monetary Pressures: The Hausa of Zinder Department, Niger." Ph.D. Thesis, Cornell University, Ithaca, New York.

Sutter, John W. 1979. "Social Analysis of the Nigerial Rural Producer, "Part D. In: Niger Agricultural Sector Assessment, Vol. II. Naimey: USAID/Niger.

Sutter, John W. 1979. "Commercial Strategies, Drought and Monetary Pressures: Wo 'daa'Be Nomads of Tanout Arrondissement, Niger." Ithaca, N.Y.: Cornell University (mimeo).

Swift, Jeremy. 1979. "The Economics of Traditional Nomadic Pastoralism: The Twareg of the Adrar N Iforas (Mali)." Ph.D. Dissertation, Univ. of Sussex.

Swift, Jeremy. 1977. "Sahelian Pastoralists: Underdevelopment, D sertification, and Famine." Annual Review of Anthropology, Vol. 6, pp. 457-478.

Tillman, Gus. 1981. Environmentally Sound Small-Scale Water Projects Guidelines for Planning. New York: CODEL/VITA, 142 pp.

Tillman, Robert E. 1981. Environmental Guidelines for Irrigation.

Toulmin, Camilla. 1983. "Herders and Farmers or Farmer-Herders and Herder-Farmers?" ODI Pastoral Network Paper 15 d. London: Overseas Development Institute, 22 pp.

Traore, B. 1980. "Socioeconomic Field Assessment of Prospective Technologies in the SAT of Mali: A Case Study in an OACV Zone," pp. 125-146. In: ICRISAT, Proceedings of the International Workshop on Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture. Patancheru, India: ICRISAT.

UNESCO. 1978. World Water Balance and Water Resources of the Earth. Paris: UNESCO, 663 pp.

United Nations. 1977. Water Resources, Planning and Management: A Select Bibliography. New York: United Nations (Dag Hammarskjold Library), 117 pp.; overall biblio. organized geographically and topically.

United Nations Development Programme. 1980. Development of the Gambia River Basin. Multidisciplinary Multidonor Mission. Final Mission Report, Chapters I-IV. New York: UNDP.

Uphoff, Norman T., John M. Cohen and Arthur Goldsmith. 1979. Feasibility and Application of Rural Development Participation: A State-of-the-Art Paper. Ithaca, N.Y.: Center for International Affairs, Cornell University, 338 pp.

U.S. Agency for International Development. 1982. U.S. Development Objectives in the Senegal River Basin. Dakar: River Basin Development Office, USAID/Senegal, 50 pp.

U.S. Agency for International Development. 1976. Niger Livestock Field Survey. Washington, D.C.: USAID.

U.S. Agency for International Development. 1976. Proposals for a Long-Term Comprehensive Development Program for the Sahel. Part II. Technical Background Papers. Washington, D.C.: Agency for International Development, 239 pp; see esp. "Water Resources," pp. 173-212.

U.S. Agency for International Development. 1976. Report to the United States Congress: Proposals for a Long-Term Comprehensive Development Program for the Sahel. Part II. Technical Background Papers. Washington, D.C.: Agency for International Development.

U.S. Agency for International Development. 1975. Development Assistance Program: Central West Africa Region, Annex E: Niger. Washington, D.C.: USAID.

U.S. Agency for International Development. 1975. Health in Africa. Washington, D.C.: Office of Development Services, Bureau for Africa, USAID, 91 pp.

USDA. 1980. Food Problems and Prospects in Sub-Saharan Africa. The Decade of the 1980s. Washington, D.C.: International Economics Division, USDA for USAID, 414 pp.

Van Hoey, L. 1968. "The Coercive Process of Urbanization: The Case of Niger," pp. 15-32. In: Greer, S.A. et al. (eds.) The New Urbanization. New York: St. Martin's Press.

Vermeer, D.E. 1981. "Collision of Climate, Cattle and Culture in Mauritania during the 1970s." Geographical Review, Vol. 71, pp. 281-297.

Vincent, Linden. 1980. Irrigated Farming: Debt or Profit? Under-Utilization of Water in the Medjerda Scheme, Tunisia. Development Studies Discussion Paper No. 69. Norwich, England: Development Studies Group, East Anglia University, 64 pp.

Vink, N. 1983. Small-Scale Irrigation in Africa. Country Notes: Upper Volta, Niger, Mali. Rome: Land and Water Development Division, FAO.

Vlachos, Evan. 1972. "Socio-Economic Aspects of Irrigated Agriculture." Paper for Seminar on Prospects for Irrigation in West Africa, held at Ibadan, Nigeria (Oct. 23-27, 1972). Ibadan, 113 pp. (Jointly sponsored by Ford Foundation, L'Institut de Recherches Agronomiques Tropicales et des Cultures Vivriès, and IITA.)

Wagner, E.G. and J.N. Lanoix. 1959. Water Supply for Rural Areas and Small Communities. Geneva: WHO.

Waldstein, Abraham S. 1980. "Development for Whom?" pp. 507-603. In: Reyna, Stephen P. (ed.) Sahelian Social Development. Abidjan: REDSO/USAID.

Waldstein, Abraham S. 1978. Government Sponsored Intensification Schemes in the Sahel: Development for Whom? Abidjan: REDSO/USAID, 114 pp.

Wallace, Tina. 1983. "Non-Farming Occupations in Chiromawa: Their Significance for the Running of the Irrigation Scheme, and the Impact of the Scheme on These Occupations." Paper for the Workshop: Irrigation in Tropical Africa, Problems and Problem Solving. Cambridge, England: African Studies Centre, Univ. of Cambridge, 18 pp.

Wallace, Tina. 1981. "The Kano River Project, Nigeria: The Impact of an Irrigation Scheme on Productivity and Welfare," pp. 281-305. In: Heyer, Judith et al. (eds.) Rural Development in Tropical Africa. New York: St. Martin's Press.

Wiegel, J.Y. 1980. "Irrigation and Socio-Economic Systems of the Sonolé in the Bakel Region (Senegal River Valley)." In: Purdue University. Workshop on Sahelian Agriculture, May 1980. Lafayette, Inc.: Dept. of Agric. Econ., Purdue University.

Weiler, E.M. 1979. "Social Cost-Benefit Analysis of the Nianga Pilot Project." M.S. Thesis, Agricultural Economics, Purdue University, 291 pp.

White, G.F. 1978. Environmental Effects of Arid Land Irrigation in Developing Countries. MAB Technical Notes, 8. Paris: UNESCO.

Whyte, Anne V.T. 1977. Guidelines for Field Studies in Environmental Perception. MAB Technical Notes 5. Paris: UNESCO, 117 pp.

Wilcock, D.A. 1978. The Political Economy of Grain Marketing and Storage in the Sahel. MSU African Rural Economy Program, Working Paper No. 24. East Lansing, Michigan: Michigan State University.

Yansane, A.Y. 1976. "An Evaluation of Socialist Experiments in African States of French Colonial Legacy." Nigerian Journal of Economic and Social Studies, Vol. 18, No. 3, pp. 363-407.

Yoder, Robert. 1983. "Non-Agricultural Uses of Irrigation Systems: Past Experience and Implications for Planning and Design." ODI Irrigation Management Network Paper 7e. London: Overseas Development Institute, 24 pp.

Zimmermann, Robert C. 1982. Environmental Impact of Forestry. Guidelines for its Assessment in Developing Countries. FAO Conservation Guide No. 7. Rome: FAO, 85 pp.

Zondervan-Droz, L. 1978. Choices in Irrigating Smallholdings in Sub-Humid Areas. Washington, D.C.: USAID (AFR/DR, AID/W), 20 pp.

APPENDIX B

OPERATION RIZ-MOPTI (ORM)

Previous Page Blank

APPENDIX B

OPERATION RIZ-MOPTI (ORM)

Introduction

Operation Riz-Mopti was organized in 1972 with assistance from the World Bank. The objective is to control the natural flooding of the Niger and Bani Rivers in the region of Mopti and increase rice production through the establishment and maintenance of six "casiers" -- Mopti Nord, Mopti Sud, Karbaye, Ibetemi, Diabocourou and Sarantomo. The total area of controlled irrigation is 38,000 ha, of which 29,000 ha are presently occupied.

Objectives

The overall objectives of ORM include:

1. Controlling the flood waters of the Niger and Bani Rivers;

2. Increase the cultivated area of rice, thereby increasing production of rice;

3. Increase yield of rice; and

4. Provide greater reliability of production through flood control.

These objectives have been attained through:

1. Creation of an infrastructure to control flooding and redistribution and awarding of parcels of land to villagers within the nearby vicinity;

2. Maintenance and management of the casiers, buildings and equipment; and

3. Collection from the rice cultivators rent, duties and taxes that have been legally instituted.

ORM has a responsibility toward the participants to:

1. Furnish them with extension services for all phases of production;

2. Provide selected seeds;

3. Organize agricultural credit;

4. Land equipment either collectively or individually (tractors; threshers);

Previous Page Blank

5. Organize marketing; and

6. Training in rice cultivation techniques through distribution of information, demonstrations, trials and experiments.

Financing

Fonds d'Aide et Coopération (FAC) has provided funding for the services of expatriates and represents 8 percent of the costs. The Malian government has provided 19 percent of the costs with the International Bank for Reconstruction and Development (IBRD) providing loans for 73 percent of project costs.

Organization

ORM is part of the Ministry of Production and is under the Office for the Coordination of Rice Operations. With headquarters of ORM located at Sevaré just outside Mopti several divisions have been organized:

1. Administration and Accounting Section;

2. Génie Rurale Section;

3. Agricultural Equipment Section;

4. Maintenance Workshop;

5. Supplies and Marketing Section;

6. Agricultural Research Section;

7. Extension Division; and

8. Statistical Division.

Perimeter Organization

The administration of ORM is carried out through the establishment of zones which are subdivided into casiers, sub-casiers and cells.

1. Zone

   Four zones, each comprising several casiers, are under the direction of a Chief of Zone, who has an Engineer Certificate in Applied Sciences (ITA). The size of a zone varies from 5,000 to 10,000 ha.

2. Casier

Each casier is directed by a Chief of Casier, an agricultural technician charged with overseeing 500 to 5000 ha. His staff includes surveyors and workmen to assist in maintenance. The role of the Chief of Casier is to assure the coordination of activities from a technical, economic and human perspective.

3. Sub-casier

Each casier is subdivided with a sub-casier chief supervising the operations of 200 to 300 plots. The total area for which the sub-casier chief is responsible is 500 to 1000 ha. He is assisted by agents who are responsible for the cells.

4. Cells

Cells are subdivisions of the sub-casiers and represent plots of 12 ha. Each cell may be subdivided into 3 to 4 ha plots cultivated by individual farmers.

The administrative structure is a classic example of large scale irrigation top-down approach with very little input from the individual farmer, although extension agents have close contact.

Criteria for Participant Selection

Selection of participants is based upon four criteria:

1. The principal occupation of the participant. Preference is given to those who are exclusively farmers.

2. The size of the family and number of working men.

3. The equipment owned by the farmer with preference being given to those with draft animals and plow.

4. The distance of the farmer's village to the perimeter, with preference given to those located the closest.

Flood Control

Through the building of dikes to protect the perimeters and the construction of control gates to control the flooding and protect against rice-eating fish, greater reliability for a successful crop has been achieved. Construction is based upon sufficient floodwater being available 99 out of 100 years for 96 percent of the rice fields within the project area. For the remaining 4 percent it is estimated that sufficient water will be available for 9 out of 10 years. Unreliability

of rains, however, creates a problem in that the rice is planted with the beginning of the first heavy rains and is dependent on the rains for the first month to month-and-a-half before the arrival of the floods. Floodwaters are controlled to 5 cm per day for floating rice and 3 cm per day for "riz dressé."

APPENDIX C

THE DALLOU IRRIGATION SYSTEM

by

Ralph A. Royer
Church World Service

APPENDIX C

THE DALLOU IRRIGATION SYSTEM

by

Ralph A. Royer
Church World Service

The Dallou is a small-scale irrigation system appropriate to Sahel conditions. It exists in north Africa, Yemen, Chad, Niger and possibly other places. We shall be discussing it as it exists in the Air Mountains of north central Niger (also known as the Agadez region). The Dallou arrived in Niger from the north and predates colonial penetration.

1. Description

The Dallou uses animal power (most commonly from an ox) to draw water from a well between 2 and 12 m deep. The water is released into a trough and then flows by gravity to irrigate small beds approximately 1 m x 2 m. The well is dug near the middle of the garden or at its highest point. Its wall above and below the water table is protected from cave-ins by using sticks or small logs laid more or less square, with straw and grass stuffed in behind the wood to hold back the sand. A framework with two pulleys is built over the well. The leather bag is made with a tail some 50 cm long, attached to the bottom of the bag to empty it. A large rope is attached to the bag and a smaller one to the tail. The large rope is pulled over the upper pulley and the smaller one over the lower pulley. As the full bag is lifted, the lower pulley guides the tail into the trough and while the bag is suspended by the upper pulley the water drains into the trough and then into a small holding basin. From the holding basin it flows in channels to a series of beds.

The bag contains between 40 and 50 litres of water. From a depth of 4 to 5 meters, it can be pulled up and emptied twice a minute (thus easily producing 3 to 4 m^3 per hour). One person is required to manage the ox as it walks back and forth, and to make sure the bag is full each time. This person's major effort is expended in keeping tension on the bag once it has reached the desired height while it takes a few seconds to empty. During this time the ox turns around. A second person, usually a small boy or girl, is required to control the water following a rotation system from one bed to another as the water follows a well defined system of channels. The channels are all earthen. Soil is removed and replaced, opening and closing the beds to the water flowing by.

Channels and beds are laid out by eyesight alone. Most of the gardeners have become adept at doing this with a large, long handled

Previous Page Blank

hoe. The garden, usually about one hectare in size, is fenced by cutting thorny branches. Only one-half to three-quarters of the surface is irrigated at any one time. Rotation is regularly practiced. The beds are fertilized using cow, sheep and goat dung as well as soil from under a local tree (Salvadora persica). The variety of crops grown include wheat, maize, millet, potatoes, tomatoes, onions, garlic, pumpkins, peppers and various condiments. Wheat is grown over the winter, while maize is grown in the summer. It is the practice to allow grass to grow in the beds, which when weeded provides food for the ox. Cornstalks, straw, etc. are also fed to the ox, since with only 75 to 150 mm of rainfall per year there is little pasture. Gardening is limited to certain valleys, which store the runoff in the sandy river bed and thereby permit gardening on the banks.

2. Typical Constraints

a. Wells. As traditionally dug, these last only a couple of years and then collapse due to the sandy nature of the soil. A collapsed well leaves a large hole, using up precious space. The amount of wood destroyed in this fashion is a great waste in this desert region. In addition, considerable labor is required to dig and keep up a well.

b. Infiltration. The sandy soil leads to a significant amount of infiltration in the main channels, which are sometimes 50 m in length. No lining of the channels is presently practiced.

c. Ox Harness. The harness tends to be very crude. This often leads to a rubbing off of the hair and/or sores on the animal's back and sides -- thus certainly affecting its output.

d. Water Table Depths. For practical purposes, depths less than 2 m or more than 10 to 12 m are not recommended. For the shallow depths it takes too much turning around of the ox; for greater depths, the length of time between loads of water means that there is not enough volume to keep up the flow and infiltration takes an increasing proportion of the water.

3. Potential Improvements

One of the advantages of the Dallou system is that it is possible to erect it using 100 percent local materials. Nevertheless, there are a number of areas where improvements are possible. Some of these are listed below.

a. Wells. A cement lined well of 1.4 m diameter improves the system immensely: (i) provides a permanent orientation of the garden, where fruit trees, dates, etc. can be planted along the water channels; (ii) saves yearly work on the well and the use of scarce resources (i.e., garden space and wood); and (iii) provides good quality water for family use. The method for putting in such wells is relatively simple. When moulds are supplied to areas or to cooperatives, only a few lessons are

required to be able to help each other put in their wells. The cost of cement and reinforcing rod (Niger prices) comes to US $32.00 to $36.00 per meter. A practical maximum depth for this type of well is 10 to 12 m, which corresponds very well with the general limits of the system as mentioned above.

b. Water Infiltration. Reduction of infiltration by the use of cement lined channels would permit the same cultivated area using less water or an extension of the area using the same amount of water. Several methods of casting joinable transportable pieces of ferocement or fibre reinforced cement seem good possibilities. These channels would be especially useful for the long distances.

c. Ox Harness. Animal efficiency could no doubt be increased by improving the harness, particularly if cows are in use (cows and camels are sometimes employed in addition to oxen).

d. Holding Basin/Reservoir. Since children are increasingly being sent to school, some system to provide a reservoir which one person using an ox could fill is needed. This same person could then go later and open the channels, thus doing more of the work himself.

e. Synthetic Water Bags. The leather bags, while constituting a significant expense, seem to last a year or less. Possibly some synthetic materials (recycled from other uses?) could make longer lasting water bags.

f. Live Hedges and Fencing. At present, thorns are cut and placed around the garden to serve as a fence. Live fencing using a variety of species would reduce the present destruction of the environment. A few fast growing eucalyptus could be planted to provide replacement poles for the framework over the well. Tall trees could be planted to provide windbreaks on particularly exposed sides.

4. Summary

The Dallou System would seem to provide a relatively simple means for an individual to practice intensive gardening, allowing production both for family needs and for sale. It would require a minimum of outside investment and credit. The system can be entirely independent of outside inputs, but it would benefit from at least the provision of a cement well. Numerous other improvements are possible, and can be adopted as the gardener's financial situation or resources permit.

WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

Executive Summary
Appendix A: The Indian Subcontinent
Appendix B: East Asia
Appendix C: Near East and Africa
Appendix D: Central and South America

WMS 2 Nepal/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 3 Bangladesh/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 4 Pakistan/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 5 Thailand/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 6 India/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 7 General Asian Overview

WMS 8 Command Area Development Authorities for Improved Water Management

WMS 9 Senegal/USAID: Project Review for Bakel Small Irrigated Perimeters Project No. 685-0208

WMS 10 Sri Lanka/USAID: Evaluation Review of the Water Management Project No. 383-0057

WMS 11 Sri Lanka/USAID: Irrigation Development Options and Investment Stragegies for the 1980's

WMS 12 Ecuador/USAID: Irrigation Sector Review

WMS 13 Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand

WMS 14 Peru/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 15 Diagnostic Analysis of Five Deep Tubewell Irrigation Systems in Joydebpur, Bangladesh

Previous Page Blank

WMS 16 System H of the Mahaweli Development Project, Sri Lanka: 1980 Diagnostic Analysis

WMS 17 Diagnostic Analysis of Farm Irrigation Sysems on the Gambhiri Irrigation Project, Rajasthan, India: Volumes I-V

WMS 18 Diagnostic Analysis of Farm Irrigation in the Mahi-Kadana Irrigation Project, Gujarat, India

WMS 19 The Rajangana Irrigation Scheme, Sri Lanka: 1982 Diagnostic Analysis

WMS 20 System H of the Mahaweli Development Project, Sri Lanka: 1983 Diagnostic Analysis

WMS 21 Haiti/USAID: Evaluation of the Irrigation Component of the Integrated Agricultural Development Project No. 521-0078

WMS 22 Synthesis of Lessons Learned for Rapid Appraisal of Irrigation Strategies

WMS 23 Tanzania/USAID: Rapid Mini Appraisal of Irrigation Development Options and Investment Strategies

WMS 24 Tanzania/USAID: Assessment of Rift Valley Pilot Rice Project and Recommendations for Follow-on Activities

WMS 25 Interdisciplinary Diagnostic Analysis of a Work Plan for the Dahod Tank Irrigation Project, Madhya Pradesh, India