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PURDUE UNIVERSITY
ALABAMA A&M UNIVERSITY
WINROCK INTERNATIONAL
THE UNIVERSITY OF NEBRASKA

NIGER APPLIED AGRICULTURAL RESEARCH PROJECT

(Contract AID 683-0256-C-00-8024-00)

PART I
FINAL ADMINISTRATIVE REPORT

June 1992

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AID Contract no. 683-0256-C-00-8024-00

Submitted by
Purdue University

in collaboration with:
Alabama A&M University
Winrock International
The University of Nebraska

To the
United States Agency
for International Development

June 30, 1992

PREFACE

The Niger Applied Agricultural Research Project (NAARP) was designed as an institutional building project to continue efforts begun under the predecessor project, the Niger Cereals Research Project. Consistent at the time with USAID's (U.S. Agency for International Development) "Plan for Supporting Agricultural Research and Faculties of Agriculture in Africa," greater emphasis was placed on strengthening the ability of INRAN (*Institut National de Recherches Agronomiques du Niger*) to better plan, manage, and conduct agricultural research. To this end, the NAAR Project attained its objectives.

Both human and material resource development were effectively implemented to undergird strengthening of the institute. The project implemented new planning, fiscal, and research management policies to effectively carry out priority research programs.

Research programs in plant breeding, agronomy, production systems, and economics, as well as new programs in irrigation and water management and research/extension liaison were successfully implemented during the life of project (LOP) through the collegial efforts on the part of the technical assistance team (TAT) and their Nigerien colleagues.

This report is administrative in nature. The principal research findings are summarized in Part II (separate edition) of the Final Report.

Certain shortcomings identified during the NAAR Project are discussed. Recommendations to overcome some of the problems encountered are found in Section 5 of this report.

Office of the Coordinator
International Programs in Agriculture
Purdue University
West Lafayette, Indiana 47907

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LIST OF ACRONYMS

ADO	Agricultural Development Officer
CCCE	*Caisse Centrale de Coopération Economique* [France]
CERRA	Regional Agricultural Research Center of Maradi
CIRES	*Centre Ivoirien de Recherche Economique et Sociologique*
CNPG	*Centre National de Perfectionnement à la Gestion*
CNRA	*Centre National de Recherches Agronomiques*
COP	Chief of Party
DAF	*Direction d'Administration et Finance* (Administration and Finance Directorate)
DECOR	*Département d'Economie Rurale* (Agricultural Economics Department)
DEP/F	*Département d'Enseignement, Programmes, et Formation* (Department of Studies, Programs, and Training)
DEPSEF	*Division des Etudes, Programmes, Suivi-Evaluation et Formation* (Study, Programs, Monitoring-Evaluation and Training Division)
DG	Director General (*Directeur Général*)
DIVAD	*Division de Valorisation et Documentation* (Dissemination and Documentation Division)
DRA	*Département de Recherches Agricoles* (Department of Agronomic Research)
DRE	*Département de Recherches Ecologiques* (Department of Ecological Research)
DS	Scientific Director (*Directeur Scientifique*)
DSI	Department of Statistics and Computer Systems
ESA	*Ecole Nationale d'Administration* (National Management School)
FAC	*Fonds d'Assistance et de la Coopération* [France] (Federal Advisory Committee)
FAO/CP	Food and Agriculture Organization/Cooperation Program [of the United Nations]
FCFA	African Financial Community francs
GDP	Gross Domestic Product
GNP	Gross National Product
GON	Government of Niger
GTAF	*Groupes de Travail Administratifs et Financiere* (Administrative and Financial Working Groups)
GTS	*Groupes de Travail Scientifiques* (see SWG for English equivalent)
HOC	Home Office Coordinator, Home Office Coordination
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDA	International Development Association [World Bank]
IITA	International Institute for Tropical Agriculture
ILCA	International Livestock Center for Africa
INRAN	*Institut National de Recherches Agronomiques du Niger* (National Agronomic Research Institute of Niger)
INTSORMIL	International Sorghum/Millet Research
IRAT	*Institut de Recherches Agronomiques Tropicales et Cultures Vivrières* (Tropical Food Crop Agronomic Research Institute)
ISNAR	International Service for National Agricultural Research [the Netherlands]
LOP	Life of project
MAE	*Ministère de l'Agriculture et l'Environnement* (Ministry of Agriculture and the Environment)
MESR	*Ministère de l'Enseignement Supérieur* (Ministry of Higher Education)
MOU	Memorandum of Understanding

NAARP	Niger Applied Agricultural Research Project
NCP	Niger Cereals Project
NCRP	Niger Cereals Research Project
NGO/PVO	Nongovernmental organization/Private voluntary organization
OCGBA	Office of Contract and Grant Business Affairs
ONAHA	*Office National des Aménagements Hydro-Agricoles*
OXFAM	Oxford Famine Relief [England]
PAC	Purdue Advisory Committee
PAWN	Purdue-Alabama-Winrock-Nebraska
PP	Project paper
REDSO/WCA	Regional Economic Development Services Office/West and Central Africa [USAID]
RELU	Research-Extension Liaison Unit
SWG	Scientific Working Groups (see GTS for French equivalent)
TAT	Technical assistance team
USAID	U.S. Agency for International Development

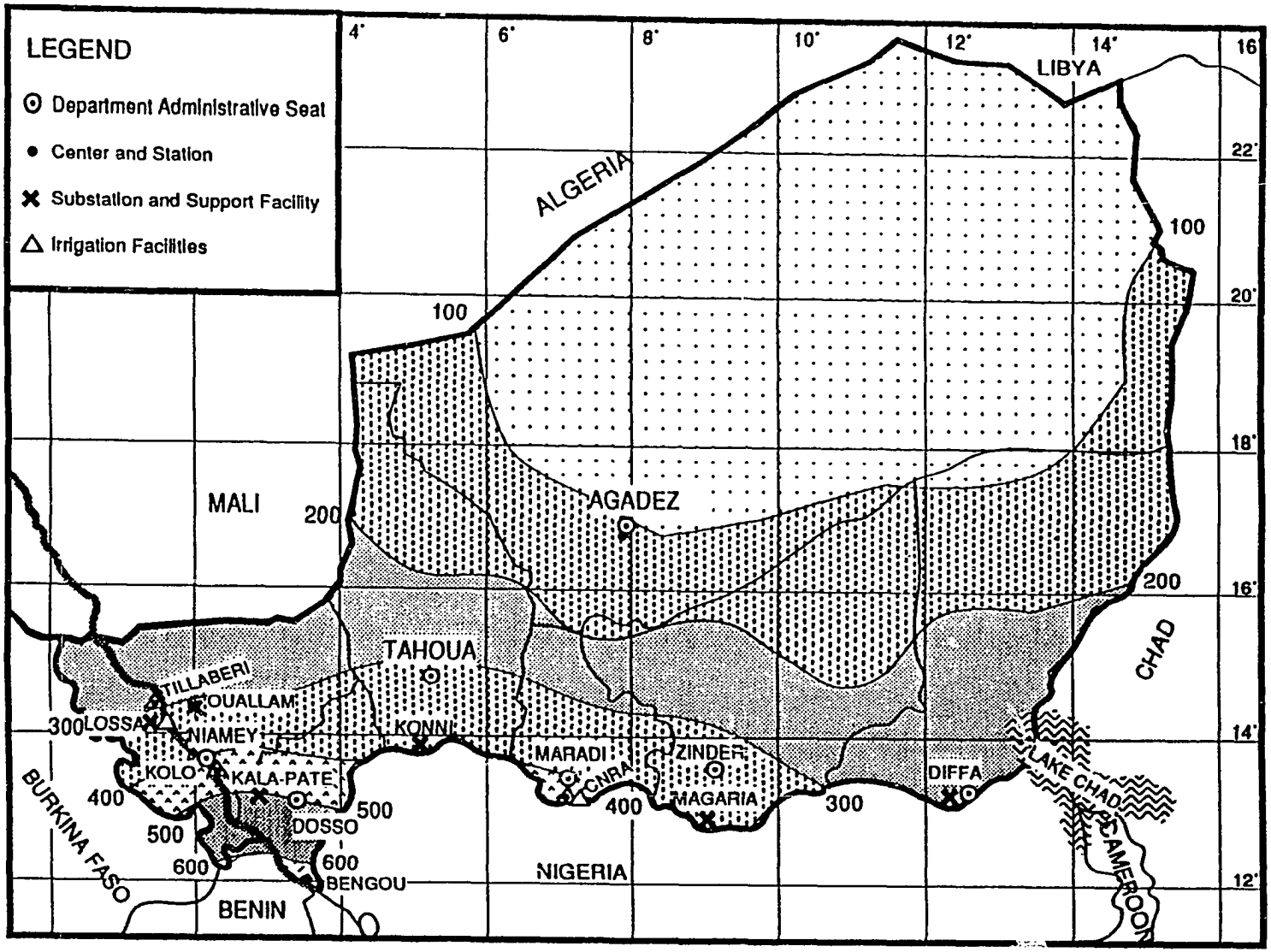

FIGURE 1–1. LOCATION OF INRAN-MANAGED RESEARCH FACILITIES WITH MEAN ANNUAL ISOHYETS (1975-1990).

PART I
FINAL ADMINISTRATIVE REPORT

In May 1988, USAID and Purdue University signed a contract to implement an institution-building project to be conducted in a collaborative assistance mode with the Government of Niger (GON) and the National Agricultural Research Institute of Niger, *Institut National de Recherches Agronomique du Niger* (INRAN). A 10-person technical assistance team was dispatched beginning in June 1988 to implement this project, the Niger Applied Agricultural Research Project (NAARP).

Purdue University, the prime contractor, was joined in the implementation process by subcontractors Alabama A&M University, Winrock International and the University of Nebraska-Lincoln in a consortium (PAWN) to assist INRAN in continued institutional development initiated under the previous Niger Cereals Research Project.

1 BACKGROUND

Niger is located in West Africa, between approximately 10°N LAT and the Tropic of Cancer and between 0° and 25°E LONG. The country consists of 490,000 sq. miles, much of which receives an annual rainfall of less than 200 mm. The majority of this rainfall occurs between June and late September/early October. In general, the country is about one-third grassland savanna and two-thirds desert and mountains. Agricultural production is, therefore, restricted to the more southern region of the country, where annual rainfall is in excess of 400 mm (Figure 1-1). Soil resources of Niger are considered moderately poor, with low organic matter and inherently low fertility. Thus, the two major constraints to agricultural productivity are soil quality and water availability.

Almost half of Niger's Gross National Product (GNP) is generated by agricultural products, mainly millet, sorghum, cowpeas, peanuts, cotton and rice, as well as livestock. Ninety per cent of the active work force of 3.54 million people is engaged in, or derives its income from, agriculture. The 1988 per capita GNP was $260 U.S., while the Gross Domestic Product (GDP) contributed by agriculture amounted to $826,000,000 or 219 billion African Financial Community francs (FCFA)[1].

1.1 *Institut National de Recherches Agronomiques du Niger* (INRAN)

Prior to 1960, agricultural research in Niger was directed by French institutions and was oriented on a regional West African basis rather than being tailored to the needs of Niger. In 1974, the GON established INRAN as the national organization responsible for providing scientific and technical support for solution of the problems of rural development and to plan and conduct research in different branches of agriculture to find those solutions. The goal of the GON at the time was self-sufficiency in food grains and was considered as a national priority.

At its creation, INRAN inherited the research programs and facilities developed by the French Tropical Food Crop Agronomic Research Institute, *Institut de Recherches Agronomiques Tropicales et Cultures Vivrières* (IRAT). IRAT research programs were not oriented toward the need of Nigerien farmers to promote increased food production for subsistence agriculture. Rather, IRAT'S main function was to increase production of export crops. Thus, since its beginning, INRAN has been faced with a need to

[1]$1.00 US = 265 FCFA

reorient the agricultural research program of Niger to meet the requirements of the rural population in basic food crop production.

Agricultural research has been conducted by INRAN at various locations throughout the country. INRAN's principal agricultural research center, the *Centre National de Recherches Agronomiques* (CNRA), is located at Tarna, near Maradi, 420 miles east of Niamey by paved road (see Figure 1-1). Established by the French, the center was nationalized as part of the INRAN organization in 1975. CNRA is sited on two locations, a main block of 260 hectares with another 10 hectares five kilometers to the south.

The Kolo Research Station is the only other independent crop research station in Niger. It is located along the Niger River, 30 km southeast of Niamey (see Figure 1-1), about 30 minutes by paved road.

Additional research is conducted on stations located at Agadez, Tillabery, Gabougoura, Tahoua, N'Dounga, Bengou, and Chical and at substations at Bengou, Ouallam, and Bonkoukou. Research is further dispersed among seven *points d'appui* (field support stations) located in various regions of the country.

In 1975 these various sites were poorly equipped and staffed. Nigerien staff, with little or no experience in research, planning and management, found it difficult to meet GON goals because of inadequate facilities and lack of training. To overcome some of these constraints, projects were designed to assist INRAN in its mission of increasing productivity of Nigerien agriculture. These projects are briefly described here.

1.2 Previous Institutional/Bilateral Projects

1.2.1 Niger Cereals Project (NCP)

The main thrust of the Nigerien agricultural research program in the mid-'70s was regional productivity projects designed to address all farm-level constraints to increased production. These productivity projects were financed by various donors, including USAID, and were carried out as a result of donor support.

The largest single project in support of Niger's agricultural research institution in the late '70s was the USAID-funded Niger Cereals Project (NCP), which was started in 1975 and completed in 1981.

The NCP was designed in 1974 in the context of the Sahelian drought. Food shortages resulting from the drought caused a heightened awareness on the part of the Government of Niger (GON) and the donor community of the fragility of food production systems. The drought also called attention to the need for food reserves. NCP was designed to increase the production of food grains by improving the institutional capacity of the GON to identify improved production technologies and to extend these technologies to Nigerien small farmers.

1.2.2 Niger Cereals Research Project (NCRP)

In 1981 INRAN still faced a number of constraints to its ability to provide meaningful research to the agricultural sector: first, the lack of several critical resources, most importantly, scientific manpower; second, a lack of ability to effectively mobilize available resources, i.e., loss of support to scientists in critical areas such as analytical laboratory analyses, statistical services, library and other information sources; third, insufficient interdisciplinary research effort; and, fourth, not focusing research efforts on

new technologies adapted to site-specific environments within agro-ecological zones. These constraints on agronomic research had profound implications for Niger's extension program.

NCRP was designed to permanently strengthen the capacity of INRAN as an institution to provide the sustained flow of research findings required to increase productivity of Nigerien agriculture.

The three principal outputs envisioned from the NCRP design strategy were:

1) Growth and development of INRAN's capacity to administer and manage its research programs, its resources, and linkages to other institutions, eg., extension and institutions such as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

2) Research support for scientific staff
   - library resources
   - plant and soil analysis
   - food grain quality analysis
   - data processing
   - in-service training for research support staff
   - expansion of available farm machinery support for research

3) Growth and development of specific research activities oriented around an integrated systematic approach.

1.3 Niger Applied Agricultural Research Project (NAARP)

The NAAR Project was designed to continue efforts begun under NCRP, building directly on progress made during the preceding five years. Consistent at the time with USAID's "Plan for Supporting Agricultural Research and Faculties of Agriculture in Africa," greater emphasis was to be placed on developing INRAN's ability to effectively manage its research programs and resources. Long-term participant training was to focus on increasing the numbers of MS- and Ph.D-level scientists. Short-term and in-country training was aimed at strengthening research support staff skills. The project was to support multidisciplinary team research on Niger's principal food crops and to strengthen, or develop, relationships with other agricultural research organizations. It was anticipated that at the end of the first five years of the project, INRAN would have begun the process of institutionalizing sound management practices and should have acquired the human and material resources needed to build a strong national applied agricultural research institute.

The project comprised three major components: 1) organizational development, 2) strengthening of research programs, and 3) development of strong research-extension linkages.

Organizational development was intended to strengthen INRAN's institutional capacity to design, administer, manage, and carry out applied agricultural research programs. This included an emphasis on research and training plans, programmatic budgeting and decentralization of program and financial management, evaluation criteria for staff and programs, and recurrent funding consideration. Human resource development and strengthening of support services were a major goal of organizational development.

Strengthening of research programs was designed to address priority constraints on the production of Niger's principal rainfed and irrigated food crops and stressed the importance of multidisciplinary research.

The development of functional linkages between INRAN researchers, extension, and other agricultural services had long needed attention. Research planning and execution were to be developed through Memoranda of Understanding (MOU) between INRAN, the Agriculture Extension Services, ONAHA (*Office National des Aménagements Hydro-Agricoles*), and Agricultural Engineering *(Génie Rural)*. INRAN would thereby provide technical recommendations for extension personnel to ultimately diffuse to farmer clientele through the Research-Extension Liaison Unit (RELU).

INRAN's role in the research-extension linkage was envisioned as

- becoming informed of important production constraints
- developing and executing research to alleviate these constraints with farmer-acceptable solutions
- synthesizing technical recommendations in a format usable by extension services
- evaluating these recommendations, as necessary.

Within INRAN, the responsibility for carrying out these actions was shared by the Research-Extension Liaison Unit (RELU), the training division, and the research departments. The NAAR Project was to assist INRAN in carrying out these actions and developing stronger extension linkages.

1.4 Inputs

According to the original conceptual design, the project paper (PP), USAID would support 29 person-years of long-term technical assistance in the following disciplines: one research management specialist, one crop breeding coordinator, one dryland cereals agronomist, one irrigation agronomist, one soils agronomist, one specialist in irrigation, one irrigation engineer, one research-extension specialist, one social economist, and one agricultural economist.

Thirty-six person-months of short-term technical assistance were to be provided in the following specific disciplines: computer science/data management (10 months), agricultural machinery repair (5 months), planning and updating training (7 months), marketing (6 months), and interim and final evaluations (8 months).

The project was to provide up to 210 person-months of short-term training to upgrade the skills of INRAN's technicians and laboratory assistants at International Agricultural Research Centers (IARCs) and African and U.S. institutions, in addition to 7 months of in-service training. The project would also fund Nigerien participation at international meetings.

Advanced professional training (MS and Ph.D.) was to be provided for up to 17 INRAN, two ONAHA, and two *Génie Rural* personnel.

Construction of storage facilities at Tarna and Kolo was to be included in the project design, and funds were to be provided for procurement of vehicles and equipment, as well as repair and rehabilitation of equipment and vehicles purchased earlier.

Finally, INRAN local project operating expenses would be supported by USAID. The Government of Niger input was to be salary support for researchers and auxiliaries and facilities for technical assistants

and their counterparts. Total U.S. and in-country five-year NAARP costs were projected to be $19,999,000 (see Table 1-1).

In summary, the NAAR Project was designed as a follow-on project for a continuation of the institution-building program initiated under NCRP in 1982. Originally, a second phase of the NAAR project was envisioned to assist INRAN in the development of the Institute.

TABLE 1-1
NAARP OVERALL PROJECTED EXPENDITURES

Expenditure categories	Project year Y1	Y2	Y3	Y4	Y5	Total
I. Technical Assistance						
A. Long-term tech asst	586,000	1,364,000	1,638,000	1,446,000	752,000	5,737,000
B. Short-term tech asst	178,000	223,000	89,000	245,000	357,000	1,093,000
Subtotal	764,000	1,587,000	1,727,000	1,692,000	1,109,000	6,880,000
II. Project Administration						
A. In-country office	90,000	205,000	223,000	211,000	183,000	911,000
B. On-campus/cont spt	143,000	143,000	143,000	143,000	143,000	714,000
C. Other	163,000	171,000	172,000	171,000	168,000	819,000
Subtotal	370,000	518,000	538,000	525,000	495,000	2,444,000
III. Training						
A. Long-term	387,000	87,000	285,000	253,000	571,000	1,584,000
B. Short-term	59,000	106,000	126,000	126,000	126,000	544,000
C. Travel for trainees	31,000	34,000	41,000	50,000	76,000	232,000
Subtotal	163,000	266,000	116,000	128,000	38,000	712,000
IV. Commodities	163,000	266,000	116,000	128,000	38,000	712,000
V. Construction	308,000	0	0	0	0	308,000

Expenditure categories	Project year Y1	Y2	Y3	Y4	Y5	Total
VI. Other costs						
A. INRAN	221,000	316,000	380,000	365,000	370,000	1,654,000
B. ONAHA/MOA	0	17,000	35,000	52,000	70,000	175,000
C. Misc. Costs	40,000	41,000	71,000	71,000	71,000	294,000
D. Financial Mgmt	60,000	30,000	30,000	30,000	30,000	180,000
Subtotal, all direct costs	2,404,000	3,004,000	3,350,000	3,292,000	2,955,000	15,006,000
Physical Contingencies (5%)	120,000	130,000	167,000	163,000	148,000	750,000
Price Contingencies (6%) [a]	144,000	371,000	640,000	864,000	999,000	3,019,000
Devaluation Contingency [b]	203,000	246,000	257,000	275,000	241,000	1,223,000
TOTAL PROJECT COSTS	2,872,000	3,772,000	4,415,000	4,596,000	4,343,000	19,999,000

[1]Source: Project Paper.

[a] Price adjustment factor applied to all direct costs. Factors are .06, .1236, .1918, .2625 and .3382 for years 1 through 5, respectively.

[b] Local costs subject to devaluation amount to the following:

1,271	1,539	1,603	1,717	1,506	7,643

The devaluation contingency amounts to .16 of such costs, reflecting an expected average exchange rate of 280 FCFA/$ over the five-year life of the project versus the present rate of 325 FCFA/$US.

2 PROJECT IMPLEMENTATION

Direct responsibility for the conduct of the NAAR project among the PAWN institutions resided in the following offices:

1. Purdue University - Office of the Director, Division of International Programs in Agriculture, School of Agriculture
2. Alabama A&M University - Office of the Director of International Programs
3. Winrock International Institute for Agricultural Development - Regional Division for Africa
4. University of Nebraska-Lincoln - Office of the Dean and Director of International Programs, Institute of Agriculture and Natural Resources.

2.1 Coordination

Coordination was provided by the NAAR Project Coordinating Committee (hereafter called the Coordination Committee) consisting of the NAAR home office project coordinator named by each PAWN institution. The Coordinating Committee met regularly and was in continuous contact in order to assure efficient operation of the project. In addition, the Coordinating Committee met once (1990) in Niger as members of the NAAR Project Council (described below).

Effective operation of the NAAR project required close cooperation among INRAN, USAID/Niamey and the Coordinating Committee. To accomplish this, the Technical Proposal called for the formation of a NAAR Project Council (hereafter called Project Council) consisting of the Director General (DG) of INRAN, the USAID/Niamey Agricultural Development Officer (ADO), the USAID Project Officer, and the Coordinating Committee.

In addition, the Purdue Advisory Committee (PAC), composed of Purdue's Department Heads and representatives of INTSORMIL (International Sorghum/Millet Research) and of the Contracting Office, advised Purdue's Project Coordinator on relevant matters important to each of their departments.

2.1.1 Home Office Coordination (HOC)

The principal function of the Home Office Coordinators (HOC) was to effectively backstop the NAARP technical assistance team (TAT) in a timely fashion. Backstopping involved administrative matters, procurement of materiel, providing and fielding consultants in response to requests from the field, and managing short-term training programs in collaboration with INRAN. In addition, the HOC assisted long-term trainees in the U.S.

Each PAWN institution Home Office Coordinator was assisted by an administrative assistant. Coordination at Purdue was initially under the direction of Drs. Robert Deuson and J.D. (Don) Paschke, with the able assistance of Ms. Jan Coleman, who had had extensive administrative experience with the previous Niger Cereals Research Project.

Similar coordination roles were played by Dr. B. Onuma Okezie, Alabama A&M University, Dr. Pierre Antoine, Winrock International, and Dr. Glen Vollmar, University of Nebraska. Table 2-1 summarizes PAWN personnel who were responsible for project administration and coordination and their duties.

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TABLE 2-1
PAWN INSTITUTION ADMINISTRATIVE STAFF

Name/Position	Institution	Dates of Service
Robert Deuson, Assoc. Coordinator	Purdue	06/01/88 - 06/30/90
J.D. Paschke, Assoc. Coordinator	Purdue	06/01/88 - 06/30/90
J.D. Paschke, Coordinator	Purdue	07/01/90 - 06/30/92
Janice Coleman, Admin. Asst.	Purdue	06/01/88 - 06/30/92
Jane (Jones) Smith, Assoc. Contract Administrator	Purdue	06/01/88 - 06/30/92
Michael Hodgson, Business Officer	Purdue	06/01/88 - 01/24/92
Greg Deason, Business Officer	Purdue	02/11/92 - 06/30/92
Elaine McMindes, Account Assistant	Purdue	06/01/88 - 06/30/92
Onuma Okezie, Coordinator	Alabama	06/01/88 - 06/30/92
Elaine P. Fails, Admin. Asst.	Alabama	06/01/88 - 06/14/90
Catherine Strother, Admin. Asst.	Alabama	01/08/90 - 03/31/91
Patsy Stevens, Admin. Asst.	Alabama	04/01/91 - 01/10/92
Carolyn Yarbrough, Admin. Asst	Alabama	02/15/92 - 05/17/92
Pierre Antoine, Coordinator	Winrock	06/01/88 - 06/30/92
Tammy Harris, Admin. Asst.	Winrock	06/01/88 - 09/06/91
Ron Hubbard, Procurement	Winrock	06/01/88 - 06/30/92
Deirdre Birmingham, Training Coordinator	Winrock	06/01/88 - 01/11/91
Glenna Howell, Training Coordinator	Winrock	01/12/91 - 06/30/92
Glen Vollmar, Coordinator	Nebraska	06/01/88 - 06/30/92
Sue Miller, Admin. Asst.	Nebraska	06/01/88 - 06/30/92

At Purdue, the Office of the Coordinator maintained close liaison with the Office of Contract and Grant Business Affairs (OCGBA) for interpretation of contract language and monitoring of financial matters. OCGBA was also responsible for settling contractual issues with each PAWN subcontractor, as well as with USAID/Niger and the REDSO/WCA (Regional Economic Development Services Office/West and Central Africa) contract office. Mrs. Jane Smith served as the NAARP contract officer during the LOP.

A number of communications linkages were implemented in networking the NAAR project. The use of FAX and CGNET electronic mail systems was employed among the PAWN institutions, in addition to the more classical telex, telephone, and postal links. Only Alabama A&M University lacked a CGNET system.

The PAWN coordinating network formed a communications network with field staff by use of FAX, telex, telephone, and CGNET, the latter through the ICRISAT Sahelian Center.

The Purdue coordination office communicated weekly by telephone with the NAARP Chief of Party (COP) to discuss matters of importance regarding project administration. Transcripts of these discussions were shared with other PAWN institutions, as well as internally at Purdue. Other shared information also included communiques such as telex and FAX messages, when appropriate, and minutes of meetings pertaining to project business.

The Purdue coordination office developed a bilingual newsletter to facilitate communication of highlights of project activities, including a reader's forum for input from INRAN, PAWN and USAID field staff on their concerns and ideas pertaining to effective implementation of the project.

Coordination was further enhanced by visits of PAWN coordination office personnel to the Niger field-based project. Table 2-2 provides the number and details of each of the respective visits.

2.2 PAWN Institutional Responsibilities

Each PAWN institution had individual responsibilities concerning personnel management and hiring of one or more of the Technical Assistance Team. Each institution maintained personnel records, was responsible for payroll, annual leave, etc., and made all arrangements for relocation of TAT family and household goods to and from post. Each institution also had responsibilities for fielding some of the short-term consultants.

Winrock International, in addition to having the above institutional responsibilities, was also responsible for materiel procurement. They later managed short-term training programs for INRAN, working in collaboration with the INRAN training officer. This required arranging for training programs, making all logistic arrangements to expedite trainees to training sites, or, in some cases, making arrangements for trainers to go to Niger to conduct specialized training.

2.2.1 NAARP Long-Term Technical Assistance Staffing

A 10-person team was fielded to provide technical assistance to the project. The eight ex-patriate positions were:

Chief of Party/Research Manager (Purdue)
Dr. Paul Hebert, a social scientist and management specialist, had spent 14 years as a professor in a graduate school of management in a developing country, where he also assumed

TABLE 2-2
PAWN ADMINISTRATIVE VISITS

Name	Inclusive Dates of Visit	Person-weeks	On-campus Responsibility
D.W. Thomas	09/28-10/09/88	1.7	Assoc. Dean., Int'l Programs, Purdue
Robert Thompson	10/02-09/88	1.0	Dean of Agriculture, Purdue
J.D. Paschke	11/06-20/88	2.0	Assoc. Campus Coordinator, Purdue
Pierre Antoine	12/07-10/88	0.4	Coordinator, Winrock
Robert Havener	12/07-10/88	0.4	President, Winrock Int'l
Total person-weeks for 1988		5.5	
Onuma Okezie	03/20-27/89	1.0	Coordinator, Alabama A&M
D.W. Thomas	05/01-06/89	0.7	Assoc. Dean., Int'l Programs,Purdue
Jane Jones	05/01-06/89	0.7	Assoc. Contract Administrator, Purdue
Pierre Antoine	08/21-30/89	1.3	Coordinator, Winrock
Robert Deuson	08/21-30/89	1.3	Assoc. Coordinator, Purdue
Pierre Antoine	10/08-15/89	1.0	Coordinator, Winrock
J.D. Paschke	10/08-15/89	1.0	Coordinator, Purdue
Larry Pherson	10/08-15/89	1.0	Contract Administrator, Purdue
Total person-weeks for 1989		8.0	
Wallace Tyner	01/22-30/90	1.1	Head, Dept. of Ag. Economics, Purdue
Govind Sharma	02/18-03/02/90	3.1	Head, Dept. of Plant & Soil Sci., Alabama A&M
Pierre Antoine	03/16/21-90	0.7	Coordinator, Winrock
Glenn Hoffman	03/24-04/07/90	2.0	Head, Dept. of Agronomy, Nebraska
R.L. Thompson	09/02-09/90	1.0	Dean of Agriculture, Purdue
J.D. Paschke	09/08-19/90	1.6	Coordinator, Purdue
Janice Coleman	09/08-19/90	1.6	Admin. Asst., Purdue
Glen Vollmar	09/08-15/90	1.0	Coordinator, Nebraska

Name	Inclusive Dates of Visit	Person-weeks	On-campus Responsibility
Onuma Okezie	09/08-16/90	1.1	Coordinator, Alabama
Pierre Antoine	09/09-17/90	1.1	Coordinator, Winrock
Total person-weeks for 1990		14.3	
J.D. Paschke	04/22-05/20/91	4.0	Coordinator, Purdue
J.D. Paschke	09/19-10/08/91	2.7	Coordinator, Purdue
Janice Coleman	09/19-10/08/91	2.7	Admin. Asst., Purdue
Pierre Antoine	09/29-10/04/91	0.7	Coordinator, Purdue
Total person-weeks for 1991		10.1	
J.D. Paschke	01/09-28/92	2.7	Coordinator, Purdue
Pierre Antoine	01/13-17/92	0.6	Coordinator, Winrock
Total person-weeks for 1992		3.3	
Total person-weeks, 1988-1992		41.2	
Total person-years, 1988-1992		0.8	

duties of Vice-President and Dean. Dr. Hebert went to Niger in June of 1988 and was posted in Niamey. In December 1990, Dr. Hebert resigned his position and returned to the United States.

Dryland Production Agronomist (Alabama A&M)
Dr. Chandra K. Reddy is an agronomist who was well-known in Niger where he had been a member of the NCR Project for four years. Dr. Reddy played an important part in developing and institutionalizing the first National Farming Systems Research in Niger during that project. Dr. Reddy assumed his Niamey post for NAARP in June 1988.

Soils Agronomist (Purdue)
Dr. Abdelfettah Berrada, another NCR project member also well-known in Niger, had a diversified background with a solid experience in soils and farming systems research work and in extension and irrigation activities. Dr. Berrada returned to Niger in June 1988 and was initially posted in Maradi at the Tarna Station. He later transferred to the Kolo Station and lived in Niamey.

Irrigation Agronomist (Nebraska)
Dr. C.R.K. Prashar joined the team in November of 1989 and was posted in Maradi at the Tarna Station. His extensive research experience as a water scientist and soil/water management specialist included research in Africa, the Middle East, India, and the United States.

Breeder (Purdue)
Dr. John W. Clark had made substantial contributions to Nigerien agricultural research as a NCRP staff member since 1982. He, therefore, was very familiar with the INRAN structure and manpower development efforts, and with management and coordination with other programs in-country (e.g., INTSORMIL). Dr. Clark remained in Niger after completing his assignment as Chief of Party for NCRP, continuing to live in Niamey and work out of the Kolo Station. He served as Deputy Chief of Party for NAARP and as interim Chief of Party after Dr. Hebert's resignation in 1990.

Agricultural Economist (Purdue)
Dr. James M. Lowenberg-DeBoer was an assistant professor at Purdue University where he had research, teaching and extension responsibilities. He was familiar with some aspects of Nigerien agriculture since he had analyzed some of the NCRP data relating to millet and cowpea production. In addition to his agricultural economist duties, Dr. Lowenberg-DeBoer was Deputy Chief of Party under Dr. Clark, and became Chief of Party in May 1991.

Irrigation/Water Management Specialist (Winrock International)
Dr. W. Ray Norman, an agricultural engineer specializing in irrigation and water management, spent the four years prior to NAARP focusing on irrigation/water management techniques and development problems in Niger. His Ph.D. research work was an analysis of technical and socioeconomic data from a field study of irrigation in Niger. He arrived in Niger in mid-September 1988 and was posted in Maradi.

Research/Extension Liaison Officer (Winrock International)
Dr. Christine Okali, an exceptional research manager and development specialist, administrator and social scientist, was Director of OXFAM (Oxford Famine Relief) America's African Program. She was well known in international centers such as ILCA (Inernational Livestock Center for Africa) and IITA (International Institute for Tropical Agriculture), the Ford Foundation and USAID

for her farming systems and on-farm research work and for her contributions to the development of linkages within or between programs and teams in Africa. She was posted in Niamey, arriving at the beginning of October 1988.

In addition to the eight ex-patriates, two Nigerien professionals were hired in-country:

Socio-economist (Purdue)
A Nigerien socio-economist, Ms. Hadiza Zarafi, had considerable field experience in designing, implementing, and evaluating socio-economic surveys. In addition to French and English, she spoke three national languages, an important asset in conducting field research. Hired in mid-November 1988, she was stationed in Maradi.

Administrative Assistant (Purdue)
Mr. Moussa Diolombi Sandi was well-known at INRAN and USAID since he had been the able administrative assistant of the NCRP Project. Mr. Diolombi was knowledgeable about INRAN's operation and management system, and was very familiar with USAID's contracts and regulations. Mr. Diolombi was posted in Niamey until his resignation in September 1991. He was replaced on a short-term basis by Mr. Maman Saidou. Following Mr. Saidou's resignation in late December 1991, the position was restructured to that of office manager and filled by Mr. Soumaila Yacouba, former NAARP accountant.

Table 2-3 summarizes long-term staff participating in the project, the length of their assignments and their posts, as well as positions they held during their tenure during the LOP. In addition to the aforementioned long-term professional staff, the NAARP local offices in Niamey and Maradi employed locally-hired personnel to carry out normal office and field functions related to project affairs. Table 2-4 summarizes, by year, job category, and location, the personnel which were employed for these purposes.

2.2.2 NAARP Short-Term Technical Assistance Staffing

In addition to long-term staff assignments to the NAAR Project, the Purdue/USAID contract stipulated that the contractor would furnish 31 man-months of short-term technical assistance as required by INRAN. The NAAR Project fulfilled this requirement with technical assistants selected from each of the PAWN institutions, or from other organizations, as requested by INRAN and/or the expatriate team. Table 2-5 summarizes those short-term participants and provides information concerning expertise and the length of time spent in the field.

Short-term consultancies not supported by NAARP funds are summarized in Table 2-6. In each consultancy, INRAN personnel were involved and gained substantially from the association.

2.3 INRAN Organizational Structure

As an administrative public enterprise, INRAN is presently under the direction of the Ministry of Agriculture and Environment (MAE), and is managed by a Director General. The DG is appointed by the President of Niger upon recommendation of the Minister of Agriculture and Environment. INRAN's operations are supervised by a Board of Governors (*Conseil d'Administration*) chaired by the Rector of the University of Niamey and composed of nine representatives of MAE, MESR (*Ministère de l'Enseignement Supérieur* - Ministry of Higher Education), Ministry of Finance, etc. There is currently no Scientific and Technical Committee to assist the Director General with the planning and implementation

TABLE 2-3
LONG-TERM STAFF

Name	Affiliation	Inclusive Dates	Person-years	Field/assignment
Paul Hebert	Purdue	06/06/88 - 12/31/90	2.5	Chief of Party
Chandra Reddy	Alabama	06/12/88 - 06/30/92	4.0	Dryland Agronomist
Abdelfettah Berrada	Purdue	06/26/88 - 06/30/92	4.0	Soils Agronomist
Christine Okali	Winrock	08/31/88 - 05/31/91	2.75	Research/Extension Liaison Officer
Jess Lowenberg-DeBoer	Purdue	09/15/88 - 06/29/92	3.75	Ag Economist; Chief of Party/Ag Economist
W. Ray Norman	Winrock	09/26/88 - 06/30/92	3.75	Irrigation Water Management Specialist
John Clark	Purdue	11/01/88 - 06/26/92	3.5	Breeder
Moussa Diolombi	Purdue	11/01/88 - 09/30/91	2.9	Administrative Assistant
Hadiza Zarafi	Purdue	11/16/88 - 06/30/92	3.6	Sociologist
Chit R.K. Prashar	Nebraska	11/29/89 - 05/04/92	2.5	Irrigation Agronomist
Maman Saidou	Purdue	10/14/91 - 12/29/91	0.2	Administrative Assistant
		Total Person-Years	33.45	

TABLE 2-4
PERSONNEL EMPLOYED BY NAARP OFFICE

Professional Category	Year				
	1988	1989	1990	1991	1992
Niamey					
Admin. & fin. asst.	1	1	1	1	1
Office manager	0	0	0	0	1
Accountant/logistics	1	1	1	1	1
Secretary	3	3	3	3	3
Chauffeur	3	3	3	3	3
Observer	0	0	0	1	1
Runner	1	1	1	1	1
Guardian	14	19	22	22	9
Total - Niamey	23	28	31	32	19
Maradi					
Socio-economist	1	1	1	1	1
Accountant/logistics	1	1	1	1	0
Secretary	0	1	1	1	0
Chauffeur	1	2	2	2	2
Technical assistant	0	0	0	1	1
Observer	0	4	4	4	1
Runner	0	0	1	1	1
Guardian	3	4	5	5	2
Laborer	0	0	5	5	5
Total - Maradi	6	13	20	21	13

TABLE 2-5
SHORT-TERM TECHNICAL ASSISTANCE[1]

Name	Inclusive dates of visit	Person-weeks	Purpose of visit
Ray Norman	07/31 - 08/14/88	2.4	Initiate irrigation design activity for three INRAN experiment stations.
Darrell Watts	07/31 - 08/14/88	2.4	Initiate irrigation design activity for three INRAN experiment stations.
Ron Hubbard	12/14-19/88	0.7	Review equipment needs and establish procurement procedures.
Total person-weeks for 1988		5.5	
Roger Sharp*	01/02-23/89	3.0	Install SAS software and develop a database at DECOR; provide training in DBase+ software.
Phil Serafini	02/02 - 03/14/89	5.7	Diagnostic study of management of INRAN Research Station system.
John Ashburner	03/20 - 05/06/89	2.4	Technical study of INRAN agricultural equipment.
Darrell Schulze	07/13-26/89	1.9	Land management and soil conservation research strategies and priorities.
Walter Stroup*	08/06-11/89	0.7	SAS training for DECOR and DSI.
Wayne Hanna	09/02-10/89	1.1	Evaluate INRAN's plant breeding program in millet & sorghum; supervise Ouendeba Botorou's dissertation research project.
Deirdre Birmingham	10/08-21/89	1.9	Elaboration of procedures for short-term training program; identification of available training programs in other countries, identification of training division equipment needs.
Total person-weeks for 1989		16.7	

Name	Inclusive dates of visit	Person-weeks	Purpose of visit
T.L. Coleman	03/11-25/90	2.0	Review and evaluation of land/soil resources and DRE data collections, especially in soils and cartography/ mapping areas; program a plan for land use study; present recommendations for acquisition of material/instruments to facilitate better usage of land/soil resources.
Ron Hubbard*	3/17-25/90	1.1	Install Commodity Tracking Software and train personnel; review status of commodity procurement and resolve outstanding procurement problems.
André Maheo	02/15 - 03/15/90	3.6	Technical inspection and evaluation of all vehicles in the INRAN motor pool; preparation of equipment inventory; identification of technical personnel and their place of assignment.
Issaka Chaïbou	02/15 - 04/15/90	8.4	Same as A. Maheo.
Vinod Bhatnagar	04/28 - 05/28/90	4.3	Pest management in intercropping.
Ellen Taylor-Powell	05/08 - 06/17/90	5.7	Determine extension techniques of working with women participating in small ruminant animal husbandry.
E. Stewart Saunders	05/16 - 06/11/90	3.7	Evaluation of recommendations made following 1984 consultancy and programming for future improvement of the Documentation Center and its sub-centers.
Deirdre Birmingham	05/14-30/90	2.3	Work with M. Ibrahim Garba, new Training Head, to implement procedures initiated in October 1989 visit.
Paresh Verma	06/08-22/90	2.0	Assessment of collaborative crop physiology research program and analyzation of 1989 data.
Philip C. Abbott*	06/29 - 07/20/90	3.0	Training in linear programming techniques to DECOR researchers; help researchers develop models of representative farms for each intervention site.

Name	Inclusive dates of visit	Person-weeks	Purpose of visit
James Ahlrichs	07/13-28/90	2.1	Assist DRE in reinforcing management of Soils Lab analysis and research.
William Aughenbaugh*	07/15 - 12/31/90	24.1	Organize and establish motor pool vehicle maintenance service system at INRAN; develop and train technical staff; establish and supervise a program of purchase/storage/inventory of spare parts.
Walter Stroup*	08/12-25/90	1.9	Continued training in SAS (statistical analysis system).
David Marx*	08/12-25/90	1.9	Continued training in SAS.
Vinod Bhatnagar	09/06 - 10/17/90	5.9	Continued assistance to INRAN in pest management in intercropping.
Deirdre Birmingham	09/08-17/90	1.3	Refinement of training policies and procedures.
Total person-weeks for 1990		73.3	
William Aughenbaugh*	01/01 - 07/14/91	27.9	Same as entry for 07/15-12/31/90.
Heather Hewitt	02/15 - 03/04/91	2.4	Assisted Dr. Christine Okali in preparation of extension training material.
Celedonio Gapasin	05/11-20/91	1.3	Assist Dr. Christine Okali in developing follow-on work plan and activities for Research/Extension liaison, including plan of activities for proposed visit by Extension Division Head to U.S. later in year.
Deirdre Birmingham	08/18-23/91	0.7	Review of May 1990 training plan with INRAN Training Officer.
Jean Marie Berthelot*	09/19-27/91	1.1	Training in survey formation and analysis of categorical data.
Total person-weeks for 1991		3.4	
Total person-weeks, 1988-1992		128.9	
Total person-months, 1988-1992		32.22	

[1]An asterisk (*) beside the consultant's name indicates that training was a part of his/her consultancy.

TABLE 2-6
MISCELLANEOUS VISITS TO NAAR PROJECT BY RESEARCHERS SUPPORTED BY CRSPS AND OTHER DONOR-SUPPORTED PROGRAMS

Name	Dates of Visit	Sponsoring Organization and Discipline
A. Felix	April-May 1989	Alabama A&M - Animal Husbandry
A. Kumar	April-May 1989	ICRISAT Sahelian Center - Millet Breeding
B. Nounguru	April-May 1989	ICRISAT Sahelian Center - Groundnut Breeding
R. Van Midde	April-May 1989	ICRISAT Sahelian Center - Agriculture
Jerry Eastin	May 1989	INTSORMIL/Univ. of Nebraska - Water Management
R. Hanchett	May 1989	USAID/REDSO, Abidjan - Water Management
R. van der Belt	May 1989	ICRISAT Sahelian Center - Forestry Management
J.O. Henry	May-June 1989	ICRISAT Sahelian Center - Agriculture
Lynn Gourley	June-July 1989	INTSORMIL/Mississippi State Univ. - Plant Breeding
Charles Wendt	July 1989	Texas A&M - Soil Science
Lloyd Hossner	July 1989	Texas A&M - Soil Science
A. Kumar	Sept.-Nov. 1989	ICRISAT Sahelian Center - Project Evaluation
B. Nounguru	Sept.-Nov. 1989	ICRISAT Sahelian Center - Project Development
Richard Frederiksen	Oct.-Nov. 1989	INTSORMIL/Texas A&M - Pathology
M. Sivakumar	Oct.-Nov. 1989	ICRISAT - Program Development
N. Solomon	Oct.-Nov. 1989	REDSO/USAID - Project evaluation
Larry Wilding	December 1989	Texas A&M - Project evaluation
Allen Kirleis	Apr.-May 1990	INTSORMIL/Purdue University - Food Science
John Axtell	August 1990	INTSORMIL/Purdue University - Agronomy
Richard Fredricksen	September 1990	INTSORMIL/Texas A&M University - Pathology
Gebisa Ejeta	October 1990	INTSORMIL/Purdue University - Plant Breeding
Larry Butler	November 1990	INTSORMIL/Purdue University - Biochemistry

Name	Dates of Visit	Sponsoring Organization and Discipline
Charles Steedman	June 1991	University of Michigan, ASDG - Economics
Richard Fredricksen	October 1991	INTSORMIL/Texas A&M University - Pathology
Peter Crawford	November 1991	Michigan State Univ. - Economics
Valentia Mazzucato	November 1991	ISNAR/MSU - Economics
Walter Butcher	November 1991	TSMM/Tropsoils - Economics
Daniel Deybe	November 1991	TSMM/Tropsoils - Economics
Roger Hanson	January 1992	Tropsoils - Soil Science
Anthony Juo	January 1992	Tropsoils - Soil Science
Charles Wendt	January 1992	Tropsoils - Soil Science
John Day	January 1992	TSMM/Tropsoils - Economics
Valentina Mazzocato	Jan.-Mar. 1992	ISNAR/Michigan State Univ. - Economics
Laurie Kitch	March 1992	Bean-Cowpea CRSP - Entomology
Larry Murdock	March 1992	Bean-Cowpea CRSP - Entomology
Michael Dingkuhn	March 1992	WARDA - Plant Breeding
Tom Randolph	March 1992	WARDA - Economics
Bruce Hamaker	April 1992	INTSORMIL - Cereal Quality
Walter Butcher	April 1992	TSMM/Tropsoils - Economics
Daniel Deybe	April 1992	TSMM/Tropsoils - Economics
Rudy Pauwels	April 1992	FED - Irrigation Engineering

of the national research program. Each year, research programs are presented for review and discussion to the different ministries on projects concerned with research. The annual budget is submitted for approval to the Ministry of Agriculture and Environment and executed under the responsibility of the Director General.

The Institute is composed of a General Directorate, three administrative/planning units (Administration and Finance, Studies and Programming, Teaching and Training), a Research-Extension Unit, a Documentation Center, a Statistics Unit, and five research departments (Agronomy, Ecology, Rural Economics, Forestry, and Veterinary and Animal Sciences). Table 2-7 summarizes 1992 INRAN scientific personnel by professional category and their current departmental assignment in the Institute. These departments have been divided into 36 sections, some of which are not yet functional, corresponding to disciplines or research themes (plant breeding, agronomy, pest and disease control, etc.). A national research center (Tarna), a laboratory center (Kolo/Niamey), three research stations, and several field support stations complement the structure of the Institute. Information regarding each of the centers, stations, and substations, their directors, types of research for which they are used, and staffing at each in 1991 is provided in Table 2-8. Some of the stations have irrigable areas, and Table 2-9 summarizes those stations where research utilizing irrigation was conducted by NAARP in the 1991-92 crop season. Research centers and stations are placed under the authority of the General Directorate, and researchers are linked by programs to the different research departments (see the INRAN organizational chart, Figure 2-1).

In addition, a full description of INRAN activities should also include all research trials associated with each of the major development projects in the country. In May 1989, there were 22 agricultural development projects under the responsibility of the Ministry of Agriculture and Environment with agricultural or natural resource research components. However, linkages between the adaptive research units on development projects and INRAN have always been weak.

Although these dispersed research endeavors may have responded to the clear needs of the projects, they have suffered from comparatively high costs, lack of continuity, and limited dissemination of results outside the projects. The performance of the national agricultural research agency (INRAN) has also been somewhat disappointing. Recognizing the need to redefine research priorities, the Government initiated a review, with assistance from ISNAR (International Service for National Agricultural Research), of the current system of agricultural research. ISNAR then assisted INRAN in establishing a long-term national agricultural research plan.

The first phase of the review involved two missions by an ISNAR team (preliminary mission, May 1986, and main mission, September/October 1986). Six working groups were then formed to work with ISNAR on the preparation of a long-term research program. These groups consisted of Nigerien staff from INRAN, the University, and the relevant Ministries, as well as a selected number of expatriate researchers. In October 1987, the long-term plan was presented to several donors, including IDA (International Development Association - World Bank), CCCE (*Caisse Centrale de Coopération Economique* - France), FAC (*Fonds d'Assistance et de la Coopération* [France] - Federal Advisory Committee), and USAID. In June 1988, a joint preparation mission (FAO/CP [Food and Agriculture Organization/Cooperation Program - United Nations] and ISNAR) visited Niger to assist the Government in identifying a national, five-year research project as an operational first tranche of the long-term research program for possible IDA financing. The proposed project was rather ambitious, given the initial time needed to strengthen and improve the management capability of INRAN; thus, the proposed project has been revised to conform with research priorities, considered complementarity with NAARP, and existing absorptive capacity.

TABLE 2-7
INRAN SCIENTIFIC PERSONNEL, 1992

Department or Division	Researchers[1]	Technicians[2]	Field Assistants & Clerks[3]
DRA	26	7	38
DRVZ	8	2	4
DRF	3	1	3
DECOR	4	6	5
DSI	1	1	5
DRE	12	4	8
CLRV	1	0	1
Total	55	21	65

Source: Personnel Service of INRAN

1 Individuals having the category A1 in the Nigerien Civil Service are considered "researchers." In addition to the 55 scientific personnel in this category, there are five other individuals in the A1 category at INRAN (the Director General, the Scientific Director, the Head of the Division of Study and Programming, the Director of Financial and Administrative Affairs, and the Advisor to the Scientific Director.) Altogether, there are 60 people in the A1 category at INRAN.

2 Individuals having the category A2 or A3 in the Nigerien Civil Service are considered "technicians" (techniciens supérieurs). In addition to the 21 scientific personnel in these categories, there are two other individuals from categories A2 and A3 occupying administrative positions: the Head of the Documentation Center and the Supervisor of the Garage. Altogether, there are 23 people in the A2 and A3 categories at INRAN.

3 Individuals in categories B, C, and D of the Nigerien Civil Service are considered to be "field assistants and clerks" (techniciens moyens). In addition to the 65 individuals from these categories that work on scientific activities, there are 15 people that work in administration. Altogether, there are 80 people in categories B, C, and D at INRAN.

TABLE 2-8
INFORMATION CONCERNING THE REGIONAL AGRICULTURAL RESEARCH CENTERS, THE EXPERIMENT STATIONS, AND THE SUBSTATIONS OF INRAN THAT WERE USED FOR NAARP ACTIVITIES

Centers	Area (ha)	Director or Supervisor	Type of Trials	Personnel in 1991		
				Res.	Tech.	Aux.
Centers						
Kolo (including N'Douga)	93	Jika Naino	Agronomy, plant breeding, soil science	9	7	57
Tarna	270	N'Diaye Ahmadou	Agronomy, plant breeding, soil science, irrigation	11	28	90
Stations						
Agadez (including Indoudou)	7.5	Mounkaila Maïguizo	Plant breeding	1	1	8
Bengou	45	Tanimou Daouda	Agronomy, soil science, plant breeding	-	3	20
Konni	31	El Hadji Illa Bawa	Agronomy, plant breeding, soil science irrigation	-	1	5
Ouallam	55	Maikoudi Abdoulaye	Agronomy	-	2	19
Tillaberi	26	Moumouni Siradji	Plant breeding, irrigation	-	1	2
Substations						
Diffa	55	Iddi Dan Yaya	Agronomy	-	1	1
Kalé Paté	11	Arzika Zamnaou	Plant breeding	-	1	4
Lossa	24	Abdou Kano	Irrigation	-	1	1
Magaria	15	Ali Timbo	Agronomy, plant breeding			
Tara	26	Mahamadou Bizo Narwa	Agronomy	-	1	4

Sources: INRAN, "Institut National de Recherches Agronomiques du Niger", 1986; ISNAR, "Programme de développement de la recherche agronomique au Niger, Tome I: Analyse du système national de recherche agronomique," 1989, p. 37; station directors and supervisors.

TABLE 2-9
IRRIGABLE AREA AND AREA IRRIGATED IN THE 1991-92 CROP SEASON AT THE REGIONAL AGRICULTURAL RESEARCH CENTERS, EXPERIMENT STATIONS AND SUBSTATIONS OF INRAN THAT WERE INVOLVED IN NAARP ACTIVITIES

Site	Area irrigable[1] 1991	Area irrigated - rainy season	Area irrigated - dry season
	(ha)		
Tarna I	4	0	0.5
Tarna II	6	4.5	1.5
Konni	11	0	2
Lossa	12	0	2
Kollo	15	15	0
Tillaberi	12	7	1
Agadez	7.5	1.5	1.5

Sources: Personal communication by Dr. Lowenberg-DeBoer, NAARP Chief of Party, with the center directors, station directors and technical assistants working in irrigation.

[1]Approximate area that could be irrigated with the sources of water and equipment now available on site. Area of rice paddy is not included.

In order for the long-term plan to be implemented, it was recommended that INRAN undergo structural organizational changes. The consideration of these changes has been an ongoing dialogue for a number of years and has yet to be formally approved by the GON. The proposed reorganizational changes entail multidisciplinary programs replacing the departments as the primary research structure. These proposed programs are: 1) Dryland crops, 2) Irrigated Crops, 3) Livestock Husbandry, 4) Natural Resources, and 5) Production Systems and Technology Transfer. Each program will be composed of subprograms with specific research activities.

Program heads will be elected by the researchers in their programs from a list of candidates that meet certain educational and experience requirements. For example, a minimum of a third cycle doctorate is to be required of program head candidates. Program heads may come from outside of INRAN, for instance, from the University of Niamey. For the 1992 crop season, program heads will be appointed, because there is not enough time before planting to organize elections. Temporary subprogram heads are being chosen by subprogram members. INRAN researchers expressed their preference of program, but the final decision on membership of each program rested with the INRAN scientific director and his advisors. Financial management is to be decentralized to the program level, with program heads making expenditure decisions.

For the time being existing departments are expected to remain to 1) supervise the disciplinary aspects of research (for instance to standardize the analysis methods used by researchers of the same disipline in different programs), 2) evaluate researchers according to the norms of their discipline, 3) coordinate researcher training in their discipline, and 4) conduct strategic research in their discipline.

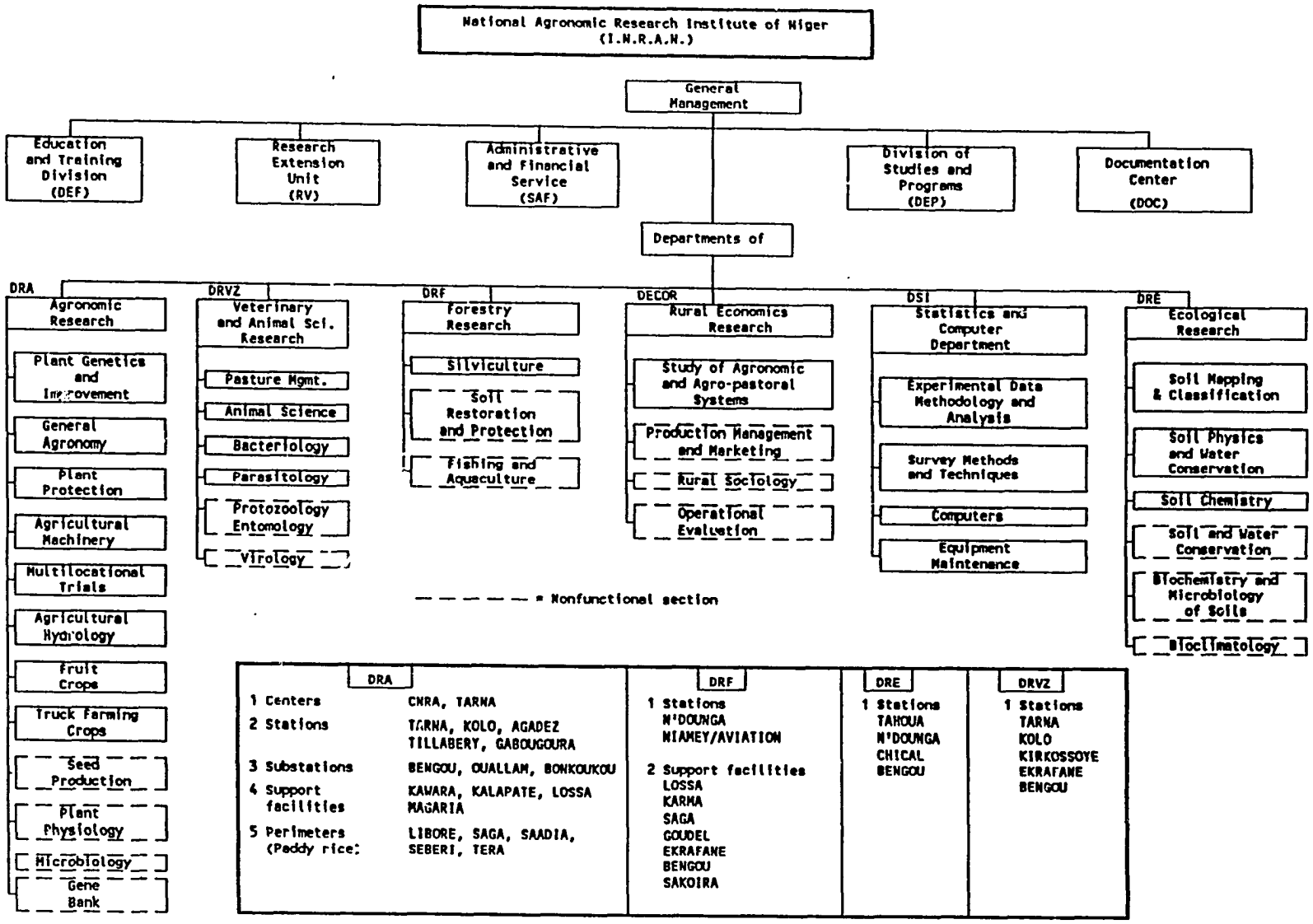

FIGURE 2-1. INRAN ORGANIGRAM (1986).

The proposed restructuring of the INRAN administration should further strengthen INRAN management of its national research program. Figure 2-2 delineates administrative responsibilities and technical research management functions as separated institutionally.

Instead of reporting directly to the Director General, the five technical departments would report to the Head of the Scientific Directorate. Similarly, the station managers would report to the Head of the Administration and Finance Directorate (DAF). Under the project, the Director General of INRAN would be assisted by an Administration and Finance Director (DAF) and a Scientific Director (DS). The DAF would be assisted by a Personnel Officer and a Materiel Resource Officer. The Scientific Directorate would be assisted by a Study, Programs, Monitoring-Evaluation and Training Division (*Division des Etudes, Programmes, Suivi-Evaluation et Formation, DEPSEF*) and a Dissemination and Documentation Division (*Division de Valorisation et Documentation, DIVAD*) for internal and external dissemination of information and for managing relations with extension services. The Department of Statistics and Computer Systems (DSI) will be transformed into a Unit and attached to the Office of the Scientific Director.

During the project, an internationally-recruited Research Management Consultant would assist the Director of INRAN and the Scientific Directorate during short-term missions, in establishing a management and monitoring system for the research program, and in preparing work programs and budgets based on submissions from Research Program Coordinators and Station Managers. The project will set up a Personnel Unit under the Administration and Finance Directorate to strengthen capability in personnel management, and a Material Resources Unit under the same Directorate that will be responsible for procurement and maintenance of the material resources of the institute. The INRAN financial management and accounting system would be strengthened through a regular consultancy contract providing short-term support missions and the recruitment of local accountants, thereby improving INRAN's capacity to operate and manage a comprehensive computerized accounting system for project expenditures. A Management Council would supervise and control INRAN, approve its budget, provide policy guidance, and ensure that INRAN's proposed annual research programs are in line with national goals and priorities.

Some of the proposed changes have been put in place, e.g., *Directeur Scientific* and *Directrice du Direction Administratif et Financier*, and it is anticipated that other changes will be made subsequent to GON approval of proposed structural changes.

2.4 Relationship of INRAN Administration to NAARP Technical Assistance Team

The NAAR Project was under the direction of Dr. Idrissa Soumana, the Director General of INRAN, from June 1, 1988, until January 1990, and of Mr. Sahadou Bawa from that point until April 1992. Mr. Bawa was subsequently replaced by Dr. Mamadou Ouattara on April 10, 1992. Under the terms of the contract, INRAN, in coordination with USAID, exercised joint management and responsibility for project implementation; however, INRAN was not burdened with the administration of the contract.

The NAARP Chief of Party (COP), a specialist in research management, advised the Director General (DG) on overall project management, realization of project goals, USAID project management procedures, and institutional contractor requirements. The COP was also to assist the DG in installing a system of research planning and program-based budgeting, while at the same time monitoring project implementation.

The technical assistance team worked primarily within the Department of Agronomic Research (*Département de Recherches Agricoles* - DRA), the Department of Ecological Research) (*Département de Recherches Ecologiques* - DRE), the Department of Economic Research (*Département d'Economie Rurale*

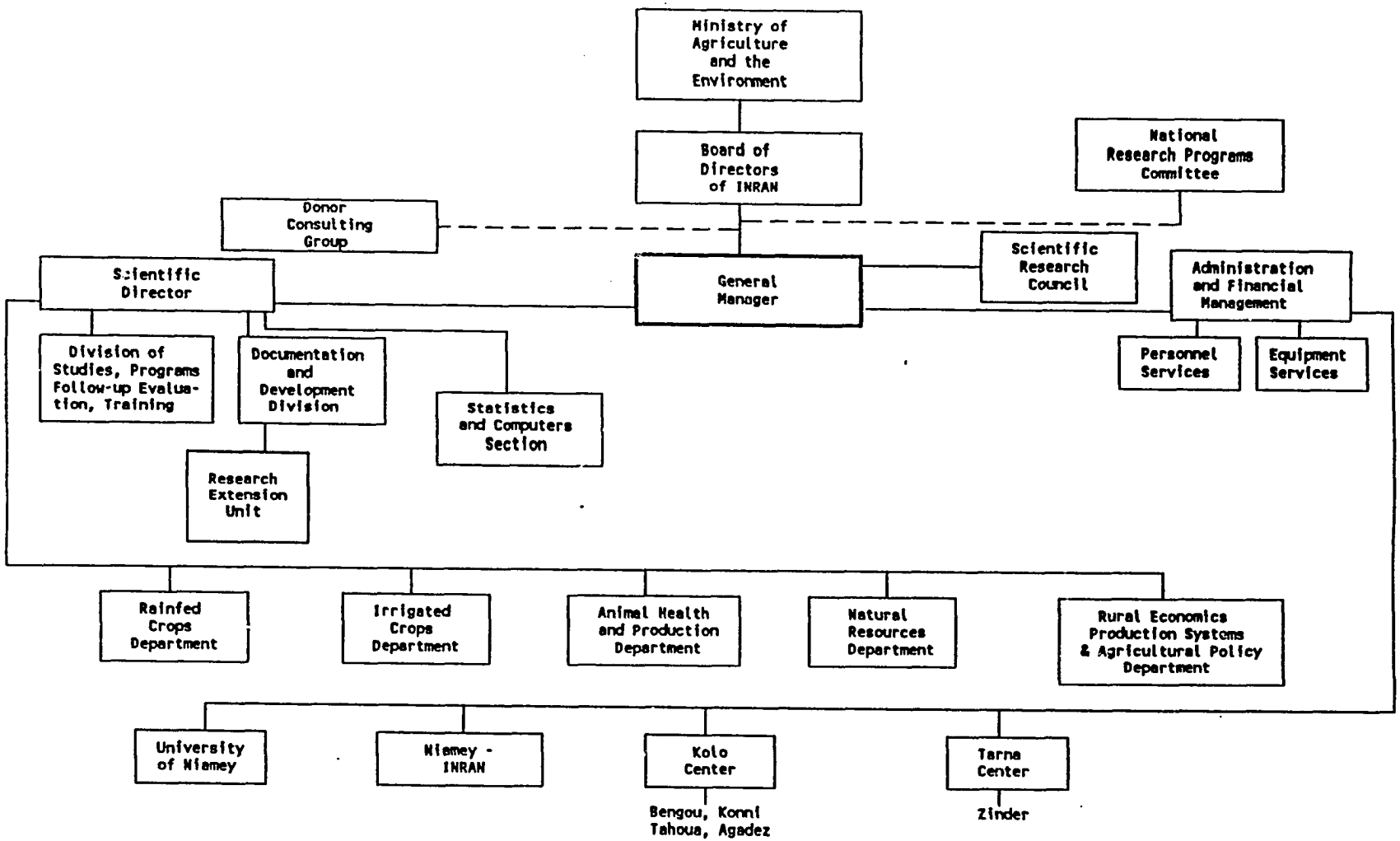

FIGURE 2-2. PROPOSED ADMINISTRATIVE STRUCTURE UNDER THE NATIONAL AGRICULTURAL RESEARCH PROJECT.

- DECOR), and the Research-Extension Unit (RELU) of INRAN. As such, each individual on the TAT was considered a member of the department to which she/he was assigned, had a formally designated counterpart, and liaised directly with the Director General (through the division heads), while at the same time being directly responsible to the COP for administrative purposes. Technical assistants worked with their co-team members and with research departments and staff to improve the overall research and institutional performance of INRAN. The U.S. staff worked collegially with their counterparts to help build INRAN staff capability.

2.4.1 Project Management

Director General Soumana scheduled quarterly INRAN staff meetings to discuss issues pertinent to project management and which served as a means of communication between department heads and their respective staffs, as well as a means of monitoring implementation of NAARP. These meetings were also attended by the USAID Project Officer, the Agricultural Development Officer (ADO), personnel from the Controller's Office, and other USAID direct-hire Nigerien employees from the ADO, Controller, and/or Training Offices. The agenda format for each meeting was much the same and covered diverse topics such as financial and personnel matters, Working Group reports, publications, consultancies, and, subsequently, diverse topics brought to the floor by the staff. Also included were reports from the NAARP Chief of Party. Minutes of a representative meeting are found in Appendix 6-1.

In addition, Dr. Hebert, the NAARP COP, scheduled periodic TAT staff meetings to discuss issues dealing with technical assistance and contract administration and problems encountered by the technical assistance team. After the resignation of Dr. Hebert, the new COP, Dr. Lowenberg-DeBoer, continued this practice.

Director General Soumana had formed working groups (*Groupes de Travail*) under the Niger Cereals Research Project. In July 1988, the DG created scientific working groups, *Groupes de Travail Scientifiques* (GTS), and administrative and financial working groups, *Groupes de Travail Administratifs et Financiere* (GTAF), to assist in the coordination of the NAARP.

The scientific working groups (GTS) were

- crop improvement
- soils and irrigation
- economics and production systems
- the working for research liaison and extension

and the administrative working groups were

- administration coordination and finances
- materiel acquisition
- training and documentation.

The scientific working groups were composed of those researchers who were involved with the specific disciplines, but they were joined by others in an interdisciplinary fashion where discipline interaction was appropriate. Thus, the crop improvement working group would include, in addition to plant breeders, a related discipline such as crop protection. The scientific work groups were responsible to the Associate Director General (*Directeur Général Adjoint*) and the department heads.

The administrative working groups included department heads and station directors and were responsible to the INRAN/NAARP DG and COP, the latter playing a supervisory role.

Each scientific working group was chaired by a member of the NAARP expatriate technical assistance team. In addition, each group had an appointed secretary, with back-up persons for each office.

The Director General spelled out terms of reference for each of the working groups, which dictated periodic meetings, research program development and monitoring, periodic research evaluation and design of new programs based on need, development of seminars and workshops, preparation of scientific reports, and the determination of training needs, as well as materiel needs such as library acquisitions.

Each group developed a support budget for scientific planning meetings, seminars, and program evaluation proceedings to defray in-country travel costs of attending scheduled meetings.

Thus, the Director General established an administrative hierarchy to take advantage of the expertise within the Institute to formulate policy, develop administrative and financial management, and develop research priorities and programs. The working groups were functional throughout the tenure of Dr. Soumana.

Initially, the new DG, Mr. Bawa, did not utilize the structure of the Scientific Working Groups (SWG) put in place by his predecessor. However, in September 1990, the USAID Project Officer requested that Mr. Bawa reinstate the committee functions because they were deemed important to multidisciplinary research planning. The DG responded by reinstating the scientific working groups as of April 10, 1991. This reorganization focused on naming a national scientist as working group coordinator with a NAARP technical assistant team member as assistant coordinator. The administrative working groups functioned only sporadically during 1991-1992; however, the communications working group functioned throughout the period from 1990-1992. In mid-1990, the training group met once, as did the materiels group.

Biennially (initiated in 1988), INRAN conducted an institute-sponsored meeting bringing research personnel from all INRAN disciplines together to present and discuss research results from the previous year's research and extension activities. These meetings were also attended by members of the USAID staff, as well as members of other donor-supported activities in Niger. The presentations of these meetings were collated into a published document, *Synthèses des Travaux de la Réunion Annuelle de la Recherche Agronomique (INRAN)*), which summarized the results and plans of each research program.

2.4.2 Administrative Changes

On January 11, 1990, a new Director General, Mr. Sahadou Bawa, was appointed by the Minister of Agriculture to carry on the functions of INRAN. As with his predecessor, the new DG was the Director of the NAAR Project and related to the Purdue team in the same fashion. Mr. Bawa visited the United States and Purdue University early in his tenure (January 1990). He was familiarized with Purdue and the Home Office coordination of NAARP, as well as having the opportunity to meet each of the PAWN coordinators.

In April 1992, Mr. Bawa was appointed Director General of ONAHA and was replaced by Dr. Mahamadou Ouattara as Director General of INRAN. Dr. Ouattara was serving as INRAN *Directeur Scientific* prior to his new appointment by the Minister of Agriculture.

Dr. Paul Hebert, NAARP Chief of Party, resigned for personal reasons as of December 31, 1990, and was subsequently replaced by Dr. John Clark as Interim Chief of Party until the appointment of Dr. James Lowenberg-DeBoer. Dr. Lowenberg-DeBoer served as Chief of Party, as well as agricultural economist in DECOR, until the end of the project.

2.4.3 Project Evaluation

A mid-term evaluation of the NAAR Project was conducted in May 1990 for the purpose of assessing the overall progress in achieving the project objective of institutionalizing a system of applied agricultural research characterized by strong functional linkages to extension activities. The evaluation team was also charged with the responsibility of providing guidance for mid-course changes in project implementation, where deemed advisable.

The evaluation team concluded that the project had made satisfactory progress towards achieving its goals and objectives, and they recommended that Phase I be extended into 1993, making use of funds unexpended thus far in that phase. They felt that this would allow more time to observe the functions and impact of the new World Bank project which was being planned for Niger. Originally, the World Bank project was designed to complement the work of the NAAR Project.

On the negative side, the evaluation team concluded that 1) both long- and short-term training programs were behind schedule, 2) INRAN still lacked adequate personnel, 3) operating funds were not being disbursed in a timely fashion (this was prior to decertification), 4) research priorities were not being addressed, and 5) problems with personnel management were still unsolved. The objectives outlined for the irrigation work were not being met due to setbacks in the proposed rehabilitation of the irrigation system.

The evaluation team made specific recommendations to overcome these identified constraints and also cited INRAN/GON and USAID/Niger, as well as the contractor, in sharing the blame for the negative aspects of the implementation process. A number of the recommendations required implementation by the GON/INRAN (evaluation and promotion criteria for INRAN employees, for example) and thus were out of the hands of the technical assistants and USAID. Of major significance was the evaluation team's recommendation that Purdue/INRAN/USAID study the best means by which the planning, coordination, and management of INRAN's research programs could be accomplished during the remainder of the life of project.

2.4.4 Project Decertification

INRAN was decertified as of June 19, 1990, by the USAID/Niger Mission as a result of financial irregularities and "serious reservations about the leadership of INRAN's financial and administrative service." The findings of the USAID Regional Inspector General's Office in Dakar, Senegal, had direct bearing on the decertification of the INRAN accounting system. However, most importantly, USAID/Niger continued to make direct payments to INRAN in order to minimize the disruption of project activities during the period in which INRAN was to "straighten out" its accounting system. USAID continued this type of financial assistance until March 1, 1992, although considerable difficulties resulted from delayed payment of temporary labor. Decertification of INRAN continued throughout the remaining LOP.

3 PROJECT ACHIEVEMENTS

3.1 Human Resource Development

Participant training funded by the NAAR Project was designed to strengthen the skills of managers, researchers, and technicians employed by INRAN and to provide minimal training to ONAHA and *Génie Rural* personnel in order to build an interagency capacity to identify problems and carry out research on Niger's jointly-managed irrigated land.

The project also provided funds for short-term training to upgrade the skills of INRAN's farm managers and field and laboratory assistants and technicians.

In addition, advanced professional training was provided by NAARP for 16 INRAN and two *Génie Rural* and two ONAHA personnel. See Appendix 6-2 for details of the training. Most advanced degree trainees were students at various U.S. universities. The long-term trainees were managed through the USAID/Niger Training Office, although the technical assistance team members played a major role in processing the students in Niger, and the Purdue Coordination Office was involved with their placement.

Dr. Lowenberg-DeBoer was involved in long-term training as a member of the thesis committee of Mr. Ly Samba, who is completing a third cycle doctorate at CIRES (*Centre Ivoirien de Recherche Economique et Sociologique*). During the 1989-90 crop season, Dr. Lowenberg-DeBoer provided on-site supervision for Mr. Ly's field research in the Tillabery area. The thesis concerns the factors determining cereals marketing decisions in the Niger River area north of Niamey.

Dr. Ray Norman assisted Mr. Mai-Moussa Chetima, an INRAN irrigation engineer studying for a Master's Degree at Utah State University (under NAARP funding), in identifying a topic and database for his thesis research. In June of 1991, Dr. Norman met with Mr. Chetima and his professor in the U.S. to discuss potential topics and to work out arrangements for the transfer of irrigation-related data from the INRAN research program. The database was subsequently prepared under Norman's direction and sent to Utah State.

At the request of ONAHA, Norman was also involved in assisting Mr. Alhadji Saminou in the selection and preparation of his thesis topic for the University of Niamey. Under Norman's direction, data were retrieved for an evaluation of surface reservoir storage losses at the Konni irrigation system. Subsequently, a methodology for analyzing the data was developed and proposed to Mr. Saminou. Mr. Saminou successfully completed his thesis. Following subsequent short-term training in Burkina Faso, he was appointed by ONAHA as the new irrigation perimeter director at Djirataoua (Maradi Department) and continues to collaborate with the Irrigation Section in applied research activities.

Originally, the USAID/Niger Training Office was going to manage the short-term training. However, this was later subcontracted to Winrock International through an amendment to the Purdue/USAID contract, which was signed December 6, 1989. Short-term training had originally been proposed in the PAWN proposal submitted in 1987, only to be deleted in the contract with Purdue.

3.1.1 Short-term Training

Winrock International employed a training manager, Ms. Deirdre Birmingham, and subsequently, Ms. Glenna Howell, both based at Winrock headquarters in the United States to handle the NAARP short-term training.

The training manager was responsible for developing procedures and systems for implementing short-term training programs, which required liaison with the INRAN Training Coordinator, Mr. Moussa Abba, in the Department of Studies, Programs, and Training (DEP/F). Mr. Abba was transferred to DECOR in 1990 and was replaced by Mr. Ibrahim Garba.

In addition to liaising directly with the INRAN training coordinator and developing appropriate training programs, it was also the Winrock training manger's responsibility to place trainees and monitor performance of participants in courses, meetings, seminars, and international conferences in U.S., Africa, and third countries. In addition, the training manager arranged for international consultants to teach short courses and workshops in Niger. These activities required handling of financial arrangements, travel plans, and institutional arrangements by the Winrock office.

Ms. Birmingham, the Winrock training manager, visited Niger in May 1990 to work with INRAN, the TAT, and USAID to develop a work plan for short-term training. During the consultancy, she met with each of the INRAN department heads and the NAARP COP and team members, as well as the INRAN training coordinator and the USAID training officer. Documentation was provided which gave Ms. Birmingham insight into the history of training INRAN personnel, as well as INRAN's plans for continued upgrading of their skills.

One part of determining sources of training programs involved eight visits by the training manager to different local training sources to determine their usefulness in the short-term training program. For example, the *Ecole Nationale d'Administration* (ESA) is well-established (25 years) and offers both degree and nondegree training in a variety of disciplines, including English, accounting, and typing. The school can also determine training needs and develop special courses as required. The *Centre National de Perfectionnement à la Gestion* (CNPG) offers its own programs or tailors courses to the needs of the organization. They offer computer courses in word processing, financial management, and accounting, and other courses dealing with administration. These are but two examples of local institutions which were available to INRAN trainees.

The Winrock Global Directory of Non-degree Training Resources, as well as regular updates, was provided to INRAN. This directory contains information on short courses offered worldwide, including short courses by the IARCs. In addition to catalogued courses, IARCs also design courses for specialized training.

The USAID training office had a sincere interest in working cooperatively with the INRAN training office to implement both degree and nondegree programs. The USAID training office and the travel office proved to be valuable resources for INRAN trainees.

Together, the Winrock training manager and the INRAN training coordinator developed a training calendar to facilitate the timeliness of obtaining approval of training and finances before training was to be implemented. It was imperative that the training coordinator submit a budget worksheet with information on each training activity in detail for Winrock approval at least three weeks prior to the training. Unfortunately, there were numerous occasions when these submissions were not made in a timely fashion and either the training was delayed, cancelled, or in jeopardy of being cancelled at the last minute before the departure of the trainee.

Regular monthly reporting of expenditures incurred (accompanied by proper receipts) and requests from the field for financing of proposed training programs enabled Winrock to keep the in-country training revolving fund adequately supplied. The requests were made by the training officer and the NAARP COP.

All reports concerning trainees and consultancies were provided to INRAN, Winrock, and the NAARP/Purdue Coordination Office.

TAT staff also provided input into training activities. They provided on-the-job training, helped organize local short courses, facilitated short terming training activites outside of Niger, and provided support for long-term training in agricultural economics.

Dr. Lowenberg-DeBoer helped organize short courses in: Lotus 123, SAS I, SAS II, Linear Programming, Choice of Economic Analysis Methods, and Statistics for Sample Surveys. The in-country short courses have proven useful for cases in which a group of researchers required training in some basic research technique.

The SAS I course was held August 6-10, 1989, in the conference room of the Soils Laboratory in Niamey with 30 participants from all INRAN departments. The objective of the course was to teach the basics of PC-SAS, and how this software can be used for the most common statistical designs used in agricultural research. It was taught by Dr. Walter Stroup, Biometrics Department, University of Nebraska. Dr. Stroup taught largely in French, with Mr. Adam Abdoulaye and Dr. Lowenberg-DeBoer providing translation and explanation in French, where needed. The SAS I course was organized in collaboration with the late Mr. Bachir Mahamane, acting head of DSI, and Mr. Adam Abdoulaye, former head of DSI pursuing Ph.D studies in the U.S.

Training in use of Lotus 123 was conducted by Dr. Lowenberg-DeBoer in the computer room of DECOR/Niamey on Monday, Tuesday, and Wednesday afternoons from November 20 to the end of December 1989, with the exception of the week of November 27 to December 2 when the training was conducted in the computer room of the National Agronomic Research Center (CNRA) of Tarna. In Niamey, five DECOR researchers were trained in use of Lotus 123 for data entry, calculation of simple statistics and budgeting. The Tarna course covering the same topics was held in conjunction with training in DOS taught by Mr. Yahaya Dadé, DSI. The Tarna course included both DECOR and DRA researchers.

In the past, DECOR relied heavily on expatriate technical assistants and DSI computer technicians for data entry and analysis. The technicians often did not understand the information being entered and the analysis methods, and, as a consequence, the process was slow and prone to error. Now all DECOR researchers are familar with the use of Lotus 123 and the data entry bottleneck has been largely eliminated. DECOR researchers enter much of their own data, reducing entry errors. They calculate descriptive statistics with Lotus 123, speeding up the process. The computer technician helps in entry as needed, but can spend the bulk of his time on the more technical tasks of hardware maintenance, software installation, etc. Even though only two of the 10 researchers currently working at DECOR were trained in 1989, the Lotus 123 course has not been repeated because those researchers have passed their knowledge on to newly-arrived colleagues. Typically, new DECOR researchers are assigned to help a more experienced colleague in data entry and analysis, thereby learning Lotus 123 skills on the job.

The SAS II course was held August 13-17, 1990, in the INRAN documentation center at the Soils Laboratory for 30 participants. It was a follow-up to the SAS I course and dealt with more complex statistical designs. In particular, it focused on development and analysis of experimental designs that can be used to deal with the heterogeneity of Nigerien soils. It was taught by Dr. Walter Stroup and Dr. David Marx, Department of Biometrics, University of Nebraska. The course was taught primarily in English, with Mr. Adam Abdoulaye and Dr. Lowenberg-DeBoer providing translation and supplementary explanation. The week following the course, Drs. Stroup and Marx worked individually with INRAN scientists on specific statistical design and analysis problems. The SAS II course was organized in collaboration with Mr. Bachir

Mahamane, acting head of DSI, and Mr. Adam Abdoulaye. As a result of the SAS courses, this software has become the standard tool for statistical analysis at INRAN. The SAS capacity for dealing with unbalanced designs and missing data has been found particularly useful.

The linear programming short course was taught by Dr. Philip Abbott, Department of Agricultural Economics, Purdue University, at the DECOR offices in Niamey from July 2-20, 1990, for six participants, five from DECOR and one from DSI. The objective of the course was to teach the basics of linear programming. On-the-job training to reinforce skills aquired during the course was supplied by Dr. Lowenberg-DeBoer. The analysis of constraints to intensification of the production of cowpeas presented at the Farming Systems Research and Extension Symposium in 1991 was a direct product of the short course. Under the guidance of Dr. Lowenberg-DeBoer, Mr. Tahirou Abdoulaye, DECOR/Niamey, built on an example that was initially used in the short course. The resulting study has helped clarify the role of labor availability and capital constraints in the choice of cowpea production technology.

The "Choice of Economic Analysis Methods" course was taught at the National Agricultural Research Center (CNRA), Tarna, July 22-26, 1991, by Dr. Lowenberg-DeBoer. Nine DECOR researchers from Niamey and Maradi participated. The objective of the course was to provide researchers with an overview and enough knowledge of the main categories of production economics analysis methods to understand something of the advantages and disadvantages of each approach. Computer applications were shown using the NAARP project portable computers and the computer facilities of the Regional Agricultural Research Center (CERRA) of Maradi.

A short course on planning sample surveys and the analysis of categorical data was held during the week of September 23-27, 1991, in the meeting room of the Soils Laboratory in Niamey. Mr. Jean-Marie Berthelot of Statistics Canada taught the course. The 13 participants included 11 from DECOR and two from DSI.

In addition to formal short courses, Dr. Lowenberg-DeBoer helped organize three study trips for INRAN staff. In October 1989, he accompanied his INRAN counterpart, Mrs. Germaine Ibro, to the 9th annual Farming Systems Research and Extension Symposium in Fayetteville, Arkansas. Mrs. Ibro presented a paper on the risk characteristics of the millet-cowpea intercropping techniques being tested by INRAN.

In February 1990, Dr. Lowenberg-DeBoer accompanied Mr. Maliki Kadi, former head of DECOR, and Mr. Bonkula Abdoulaye, former head of DRA, to the International Symposium on Sustainable Agriculture in India at the ICRISAT Center, near Hyderabad, and to various Indian national research institutions. In addition to valuable information on research related to agricultural sustainability, the trip provided ideas on how successful agricultural research programs can be organized in a developing country.

In October 1991, Dr. Lowenberg-DeBoer traveled to East Lansing, Michigan, with Mr. Tahirou Abdoulaye, DECOR, for the 11th annual Farming Systems Research/Extension Symposium. A poster paper was presented on constraints to the intensification of cowpea production. DECOR staff have participated in five of the last seven FSR/E symposia. This participation has permitted them to stay current on FSR/E techniques and to make contact with others working in this area.

A considerable amount of Dr. Ray Norman's time and effort was devoted to informal training of Nigerien irrigation personnel during the period of NAARP. This included primarily research personnel, the technician, and the *observateurs* of INRAN's Irrigation Section, as well as technical personnel from ONAHA and *Génie Rural*. This informal training was concentrated in the following four areas:

1) Field use of research equipment.
2) Field evaluation techniques of irrigation systems.
3) Data management, analysis and interpretation.
4) Reporting and presentation of research results.

Once research equipment was received, its proper maintenance and application to field use were explained and demonstrated during field trials. Field evaluations were conducted both with inter-disciplinary teams and with individual Section personnel. Water measurement, survey, and interview techniques were practiced and developed. Correspondingly, standard evaluation procedures and related data forms were prepared to facilitate efficient and thorough data collection in the field. Once field *observateurs* were sufficiently trained and experienced, and as Section personnel gained sufficient experience to oversee field data collection, Norman's time was increasingly devoted to assisting Section personnel in the compilation and analysis of field data. Most of this effort centered around the proper and careful transcribing of data from field data forms to computer files. Methods of verifying data transcription and the use of spreadsheets for the manipulation and analysis of data were emphasized. Following a two-year period, during which a sufficient database on irrigation water use among Nigerien systems was established, work with Irrigation Section and ONAHA colleagues was initiated on the reporting and presentation of research results. Several presentations of irrigation water management research results were given in collaboration with these colleagues at INRAN meetings. A total of four papers were also prepared and presented at international meetings of the American Society of Agricultural Engineers.

In terms of informal training, perhaps one of the more important developments has been the training of a team and the establishment of a developed methodology for the evaluation of water lifting methods among small-scale irrigation systems. The team is presently capable of carrying out full performance evaluations on gasoline-powered pumpsets, manual and animal traction water lifting technologies.

Workshops which were held in conjunction with multi-disciplinary team Diagnostic Studies at the Galmi and Djirataoua perimeters were organized by Norman to train and sensitize researchers to various aspects of irrigation water management evaluation. Topics which were covered included water measurement methods, farmer survey techniques, and sensitization to the need of researchers to view operational and organizational constraints of irrigation systems as multi-disciplinary issues as opposed to single-discipline issues. At the end of NAARP, following the completion of the Water Lifting and Management field manual, Norman organized a two-day workshop among Irrigation Section personnel at Maradi to familiarize them with both the contents and the field application of evaluation methods outlined in the manual.

In the sorghum program, informal training was done principally through the use of the consultant budget. The major professor of the participants in sorghum research who did in-country thesis research visited Niger to assess the research and advise the participant. Dr. Clark, as NAARP crop breeder, also worked closely with these participants. In each case he advised the students and their major professor on the choice of research topic and experimental design and provided the plant materials, as well as general logistical support.

At the technician level, Dr. Clark gave on-the-job training in sorghum nursery management to four INRAN technicians. Two have since left the sorghum section, one to the University of Niamey and the other to head the RELU office in Maradi. Clark also worked closely with his counterpart, Mr. Issoufou Kapran, in developing the sorghum breeding program at Maradi. Mr. Kapran has matured from an inexperienced graduate student into a highly competent sorghum breeder and is fully capable of leading

the national sorghum breeding program, as well as coordinating researchers in the other disciplines of sorghum improvement.

Tables 3-1, 3-2, 3-3, and 3-4 summarize the short-term training activities during the life of project. The tables provide information regarding the programs, sites, duration, and INRAN personnel involved. A breakdown by individual is found in Appendix 6.3. See Table 2-5 for the consultants and their institutions responsible for the training. Overall, a total of 1517 person-weeks of short-term training was supported by NAARP.

The tables omit short-term training of INRAN staff which was funded from other donors or the NAARP local office budget. A substantial amount of training was funded directly through USAID/Niger out of project funds using invitational travel or travel authorization. In particular, this occurred early in the project before the Purdue/Winrock contract amendment. There were 23 such individuals reported by USAID to have benefitted from this approach.

Some training was conducted by TAT members using local office funds, e.g., Lowenberg-DeBoer conducted Lotus 123 training in November-December 1989.

A total of 2873 hours of training was provided by the NAARP office for NAARP clerical and accounting staff (72 person-weeks, assuming a 40-hour week). This training was in: secretarial skills (mainly WordPerfect) - 278 hours; computer use in accounting -15 hours; and English - 2,580 hours.

Technicians received 51% of the short-term training under the Winrock subcontract, much of which was done at IPDR Kolo for seven individuals. The technician category includes those "technicians" involved with administration.

Management training includes:

In-country - at ICRISAT and at the INRAN biennial meeting
In-Africa - training in Dakar for personnel manager
In Third Country - European training for *Directeur Scientifique*
In USA - fram managers' training trip to Indiana, Texas and Arkansas.

"Computers" includes programming and maintenance training in Niger or other African countries.

3.2 Research Programs

INRAN's *raison d'être* is to serve as a center of excellence in agricultural research. As such, INRAN is expected to provide appropriate technologies to Nigerien farmers. Appropriate technology implies that the recommended "package" is adapted to a local specific agro-ecological zone (climate, rainfall, soil type, etc.). The high variability in agro-ecological conditions dictates tailoring technologies to local situations.

The TAT of highly-qualified researchers, working with the Scientific Working Groups (SWG), was able to establish and implement a "prioritized" research agenda. The SWGs provided a forum for discussion of research plans, etc. which played a role in the setting of priority research thrusts.

However, even with inputs from the SWGs plus the INRAN *Plan à long terme* and the *Plan à moyen terme*, the TAT was unable to establish a truly prioritized research agenda based on inputs from Nigerien

TABLE 3-1
WINROCK SHORT-TERM TRAINING EXPRESSED IN PERSON-WEEKS
BY INSTITUTIONAL AFFILIATION OF TRAINEES
AND LOCATION OF TRAINING, 1989-1992

Institution	Niger	Other African Countries	USA	Other	Total, All Locations[1]
ONAHA	46	96	5	0	147
Génie Rural	38	151	0	0	189
Ministry of Agriculture	53	6	2	0	61
INRAN	758	231	116	17	1121
Total[1]	894	483	123	17	1517

[1]Because of rounding, columns may not sum exactly to the total and rows may not sum exactly to the "all locations" total.

TABLE 3-2
SHORT-TERM TRAINING OF INRAN STAFF EXPRESSED IN
PERSON-WEEKS BY PERSONNEL CATEGORY[1] AND LOCATION, 1989-1992

Personnel	Niger	Other African Countries	USA	Other	Total, All Locations[1]
Researcher	154	90	79	17	340
Technician	423	102	44	0	568
Clerical	113	39	0	0	152
Accountant	40	0	0	0	40
Mechanic	22	0	0	0	22
Total[1]	752	231	123	17	1122

[1]The category "researcher" includes staff with civil service category A1 and A2. The technicians are those in the A3, B, C, and D civil service categories who are not accountants or mechanics.

TABLE 3-3
WINROCK SHORT-TERM TRAINING OF INRAN RESEARCHERS BY SUBJECT AND LOCATION OF TRAINING EXPRESSED IN PERSON-WEEKS, 1989-1992

Subject Area	Niger	Other African Countries	USA	Other	Total, All Locations[1]
Management	57	6	25	17	104
Economics	24	2	2	0	28
Agronomy	15	18	14	0	47
Plant Breeding	0	3	0	0	3
Soil Science	0	37	9	0	46
Entomology	0	3	0	0	3
Irrigation	0	0	25	0	25
Statistics	34	0	0	0	34
Research-Extension	3	14	4	0	21
Communication	21	8	0	0	29
Total[1]	154	91	79	17	340

TABLE 3-4
WINROCK SHORT-TERM TRAINING OF INRAN TECHNICIANS BY SUBJECT AND LOCATION OF TRAINING EXPRESSED IN PERSON-WEEKS, 1989-1992

Subject Area	Niger	Other African Countries	USA	Other	Total, All Locations[1]
Management	53	39	24	0	116
Equipment Operation	14	0	0	0	14
Computers	39	61	0	0	100
Statistics	10	0	0	0	10
Soil Science	3	0	0	0	3
Agronomy	253	0	0	0	253
Irrigation	0	0	9	0	9
Research-Extension	0	2	2	0	4
English	50	0	0	0	50
Library Science	0	0	9	0	9
Total[1]	422	102	44	0	568

[1]Because of rounding, rows may not sum exactly to the "all locations" total.

decision-makers (various ministers) or the use of criteria as measures of whether particular commodities or research areas would contribute to the goals established by the GON. Examples of such criteria are commodity (or product) importance and research area. These two major criteria are subdivided and ranked in such a manner that analysis provides a priority ranking of "what is important" in agricultural research. The NAAR Project and INRAN should have solicited the assistance of ISNAR in prioritizing INRAN research programs.

3.2.1 Production Systems and Multidisciplinary Research

The formation of SWGs has facilitated an awareness of the importance of multidisciplinary research, and various groups of the TAT and their counterparts have made progress in designing multidisciplinary studies. For example, irrigation research incorporated the expertise of a socio-economist, agronomist, soil scientist, and water management specialist.

3.2.2 Intercropping Studies

Agronomists, agricultural economists, soil scientists, and crop protection specialists have collaborated on millet-cowpea intercropping studies, the results of which were given to RELU for extension. These studies provided the necessary cost-benefits information regarding the technologies recommended.

3.2.3 Crop Breeding

The breeding program solicited the participation of a pathologist and an entomologist, and on-farm trials incorporated several disciplines. However, in general, multidisciplinary studies have not been as effective as they should have been. This is mainly a result of the lack of qualified personnel. For instance, the lack of a qualified statistician exacerbates the problem of designing and implementing complex multi-variable studies, the results of which impact on data analyses and the significance of the work.

3.2.4 Crop Improvement

Sorghum crop improvement programs have been commendable, with the introduction of improved varieties. Millet has not received the attention which it should have with regard to the development of improved varieties. This area will improve with the return from training of a Ph.D millet breeder. In addition, INRAN will soon have the services of a cowpea breeder who is currently in Ph.D training and who will add another dimension to crop improvement efforts.

3.2.5 Water Management

The water management component of the NAAR project was designed and implemented for the purpose of institutionalizing a system of applied irrigation research within INRAN. Before NAARP, INRAN's experience and involvement in the field of irrigation water management was limited. The effort to institutionalize irrigation research was realized primarily through the establishment of the new Irrigation Section within the Department of Ecological Research. NAARP-related activities within the Irrigation Section concerning water management research were concentrated on staff training, equipment selection and procurement, research program design and implementation, and the establishment of effective linkages with the national irrigation parastatal organization (ONAHA) and with Rural Engineering (*Génie Rural*). The overall objectives of the water management program have been: 1) to leave in place an ongoing research program adapted to both the country's research needs and the Irrigation Section's

capacity, and 2) to leave a cadre of INRAN personnel capable of continuing and maintaining a viable research program following the completion of NAARP.

The irrigation water management research program under NAARP differed considerably from other research programs within INRAN. Previous to NAARP, little significant research in irrigation water management had been conducted, and an irrigation research program had not yet been institutionalized. Thus, NAARP's obligation to INRAN was not to improve an ongoing program, but rather to initiate the institutionalization of an entirely new program. Under the USAID/INRAN agreement for NAARP, INRAN established the Irrigation Section within DRE. NAARP technical assistance attached to the Irrigation Section, together with INRAN counterparts, then had the task of establishing a viable water management research program for the Section.

Since there was little previous groundwork laid in the water management discipline, the first months of NAARP were given to careful assessment of research priorities for the program. The first step involved an assessment of water management-related research needs in the country. This was achieved through initial field diagnostic studies of state and private irrigation systems (both large- and small-scale), literature search and reviews, and consultations with ONAHA and NGO/PVO (nongovernmental organization/private voluntary organization) personnel involved in irrigation work. Once a range of preliminary research needs had been assessed, the second step was the selection and establishment of research programs. This second step was based on several criteria; primarily, the priority and need of each research program, and the capacity of INRAN to carry out each program. INRAN's anticipated capacity, in terms of trained staff, necessary equipment and financial resources available to the Irrigation Section were evaluated, and the research programs were matched accordingly.

3.2.6 Irrigation Agronomy

Water is a major constraint to agricultural development in Niger. The needed increases in agricultural productivity will come as a result in an increase in the number of hectares of irrigated lands and the development of new horticultural and agronomic crops. The NAAR Project envisioned an increased productivity of agronomic crops with the development of a significant research effort on irrigation of sorghum, wheat, and other food crops. Water management practices were a significant part of the research effort on irrigated crops because of the need to optimize water use in an effort to conserve stored water and to maximize the number of hectares under irrigation.

Most of the agronomic research concentrated on irrigated wheat and sorghum, using differing irrigation and fertilization schemes. Additional effort was devoted to the development of the Tarna 2 (SEHA) research site, formerly an irrigation station near the Tarna CNRA station, which had been developed earlier by the French as IRAT, and later abandoned. The Tarna 2 research site was rehabilitated and was used for agronomic/irrigation studies.

3.2.7 Soils Agronomy

The soils agronomy program was designed to supplement the irrigation studies to be conducted under the NAAR Project, as well as agronomic studies to be conducted on the major rainfed cereal crops in station and on-farm trials.

The research involved diagnostic studies of the major constraints to production on irrigated perimeters to answer questions regarding soil and crop management, a comparison of methods for evaluating phosphorous (P) availability and correlation with millet production and P concentration, and studies to

determine optimal rates of NPK for sorghum production. Research on soil chemical and physical properties as they affect soil spatial variability and studies of soil management schemes on sandy soils was also a major effort in the agronomy program.

3.3 Linkages

3.3.1 Research and Extension Liaison Unit

In 1988, horizontal links between extension services and research existed largely through attendance at annual meetings, although 1986 was the first occasion on which research, ONAHA, and the MOA technical services actually met together at the same time and place. At these meetings, it was customary for the researchers to present their results and for extension representatives to voice their needs. In principle, researchers would tailor their programs to the needs expressed by the extension workers in subsequent group meetings at INRAN.

The administrators of both the research and extension services were aware that poor communication between the two had led to many problems. The approach to alleviate some of these problems was the creation of the Research/Extension Liaison Unit (RELU) in INRAN. Initially, the RELU did not integrate well with the Agricultural Extension Service and INRAN's clientele were still not receiving adequate research results for dissemination to the farmers.

Thus, research/extension linkages became a major component of the NAAR Project. Functional linkages between INRAN, Extension, and other Agricultural Services were to be developed through enhancement of the functions of the RELU.

Such enhancement was to be accomplished through activities such as:

- review research recommendations and extension materials to initiate solutions to deficiencies identified and to identify recommendations worthy of promotion;
- produce new or revised extension materials concerning INRAN research recommendations;
- develop a marketing strategy for dissemination of INRAN recommendations to extension services;
- perform liaison function between INRAN and non-INRAN organizations;
- train INRAN counterparts.

Much of what the TAT Research/Extension Specialist attempted to accomplish was inhibited by minimal support by INRAN in assigning Nigerien counterparts to the RELU. During the life of the project, there were only two counterparts, one of whom was transferred to the Ministry after a short assignment in the RELU and another who was in the unit intermittently because he was in a degree training program. Subsequently, he was also transferred to another post. By May 1991, a decision had been reached to appoint three Nigeriens to the unit, one head (A1 level) and two B1 support staff. The head of the unit was to be an academician from IPDR at Kolo while one other person was identified. None of these was in place at the end of tour of the technical assistant. Currently, there are two Nigeriens attached to the RELU, one in Niamey and one in Maradi.

3.4 Procurement

Winrock International, under the terms of its NAARP subcontract, was responsible for procurement for the project. The original budget for procurement of equipment and materiel for INRAN was $500,000. An additional $300,000 was allocated during the life of project.

Winrock furnished INRAN with a computerized system for tracking materiel and equipment from the initiation of the request through arrival and listing on inventory. This system was installed in the NAARP office by Mr. Ron Hubbard, WI purchasing agent, while on a short-term consultancy in Niger.

INRAN made requests for equipment and materiel using a system of requests from staff members processed through their respective departments and forwarded to the *Group d'acquisition de matériel* for review prior to final approval by the Director General. Presumably, such a system avoided the pitfalls of duplication of equipment. However, the system had the direct impact of delaying the processing of purchases. In addition, there were problems with inadequate descriptions and specifications for equipment, in addition to price differentials between catalogs and actual costs.

In addition, the process of noting receipt and location of equipment within INRAN, as well as the application of inventory numbers to capital equipment, was not instituted as planned. This required a follow-up program to locate and inventory the capital equipment (anything costing over $500) within the INRAN structure. This task has now been completed and the equipment identified and listed on INRAN/NAARP inventories.

Table 3.5 provides a summary of INRAN purchases made during the life of project with categorization by type and total cost per category.

TABLE 3-5
SUMMARY OF EQUIPMENT PURCHASED DURING THE LIFE OF PROJECT

Type of equipment	Year 1	Year 2	Year 3	Year 4	Totals
Computer	$34,154	$ 21,765	$38,155	$81,280	$175,354
Field/irrigation	3,807	58,514	40,509	0	102,803
Laboratory	9,628	316,534	10,773	7,861	344,796
Totals	$47,589	$396,813	$89,437	$89,141	$622,980

In addition to Winrock procurement, USAID/Niger purchased eight Toyota Land Cruisers, six Toyota pickups, one Peugeot 305, and 50 motos for the project. The Peugeot 305 was assigned to the NAAR Project Office and was under the superivision of the TAT Chief of Party.

3.5 Construction

USAID/Niger directly funded a limited number of construction projects for INRAN during the period beginning in 1988 and ending when INRAN was decertified. Construction of buildings took place at the Kolo, Maradi, Tillabery, Konni, and Bengou stations. Additional construction involved irrigation work at Tarna station and fencing was put in place at Kolo and N'Dounga.

3.6 Publication

Dr. Lowenberg-DeBoer has been a member of the INRAN communications committee since it was started in 1989. He participated in the development of the publications agreement between INRAN and

the PAWN institutions which was signed by the Director General of INRAN, Mr. Sahadou Bawa, on February 8, 1990. This agreement sets out a review procedure for communications produced by the INRAN-PAWN collaboration. Under the agreement, publication of results cannot be blocked, but INRAN must be informed of proposed publications and given the chance to comment on them before publication. This agreement has facilitated an impressive growth in scientific publications involving INRAN staff. NAARP team members and their Nigerien colleagues have produced 10 articles accepted in refereed scientific journals. Three of these articles are in French, and seven are in English. The two most recently-accepted articles are to be published in newly created regional journals: *l'Agronomie Africaine* and *Systèmes Agricoles en Afrique*, which are logical outlets for INRAN applied research results.

A list of INRAN publications and presentations may be found in Appendix 6-4.

As a communications committee member, Dr. Lowenberg-DeBoer has been involved in the ongoing process of reviewing INRAN documents proposed for publication and screening articles for the extension-research liaison publication, *Echange Plus*.

The second issue of the INRAN journal, *La Revue de la Recherche Agronomique*, was published in February 1992. It included five articles (57 pages): three agronomy articles, one soil science article, and one interdisciplinary article involving agricultural economics and agronomy. The articles were submitted to a rigorous in-house review before publication. A more attractive two-color cover was designed, and printing was handled by a Niamey firm.

As associate editor for the *Sorghum Newsletter* from 1988 to 1992, Dr. John Clark's responsibility with this international publication was to solicit and edit contributions from West Africa.

Dr. Lowenberg-Deboer contributed to the formulation of the new INRAN bylaws by providing a draft for the section covering publications policy. The current draft of the publications section incorporates a review committee to help INRAN staff improve the quality of its publications. Approval by the Scientific Director is necessary for publication under INRAN auspicies; however, researchers are allowed the option to publish documents which have been refused approval if they specify that the views expressed are those of the authors and not of INRAN as an institution. Publications coming out of collaborative research with other institutions may be governed by different review procedures if they are specified in the memorandum of agreement establishing the collaboration. All publications are to mention INRAN, and they are all to bear the name of the authors. To become effective, these bylaws must be approved by the INRAN Administrative Counsel.

4 BUDGET SUPPORT

4.1 USAID/INRAN In-Country Expenditures

During the Life of Project, both USAID and the Government of Niger (GON) supported INRAN/NAARP, with USAID providing both in-country and U.S. funding of implementation, operation, and administrative management of the project, and with GON providing researcher and technician salaries, as well as office, laboratory, and field accommodations for the technical assistance team.

Table 4-1 provides an overall summary of USAID/Niger disbursements made to INRAN/NAARP through 13 April 1992. Presumably, some additional funding was to be provided to INRAN to support the 1992 research initiative. Thus, USAID disbursed $2,699,367 for support of INRAN up to April 1992.

4.2 NAARP/PAWN

The total estimated budget for the performance of the work specified in the contract between USAID and Purdue University was $10,720,999. This was subsequently increased by amendments to the contract to cover short-term training and additional procurement. Extension of the long-term technical assistance team in Niger during the fourth year of the project was a no-cost extension. Table 4-2 provides the details of the original approved (1988) budget for the NAARP/PAWN effort.

Table 4-3 summarizes expenditures for the NAARP during the life of project. We have provided data on expenditures during years 1,2, and 3 of the project and the best estimate of expenditures for year 4 for the prime contractor, Purdue University, and each of its subcontractors. The fourth year estimate is based on expected costs to be incurred during the remainder of the LOP and current pricing data.

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TABLE 4-1
USAID-INRAN NAARP IN-COUNTRY DISBURSEMENTS TO 13 APRIL 1992

INRAN LOCAL COSTS[1]		
INRAN local costs (salaries, etc.)		1,789,860
Admin-Finance study (ENA)		8,873
To accounting firms for payment		16,013
	SUBTOTAL	1,814,746
CONSTRUCTION[2]		
Irrigation		147,114
Experiment station infrastructure		190,370
Fences (Kolo and N'Dounga)		28,410
	SUBTOTAL	365,894
VEHICLES		
8 Toyota Land Cruisers		185,126
6 Toyota Pickups		164,461
1 Peugeot 305 (NAARP office)		12,492
50 motorbikes		82,995
	SUBTOTAL	445,074
EVALUATION AND MANAGEMENT OF NAARP		
Mid-term evaluation		82,463
Price-Waterhouse audit		15,849
Seidou Amadou		12,559
	SUBTOTAL	110,871
TRAINING AND TRAVEL[3]		
Long-term training		350,341
Invitational travel (23 persons)		57,069
	SUBTOTAL	407,410
	GRAND TOTAL	2,699,367

Source: USAID/Niger, Comprehensive Pipeline Report, 13 April 1992

[1]Approximately $25,000 in local costs are unjustified from before decertification.
[2]Construction of buildings took place at the stations of Kolo, Maradi, Tillabery, Konni, and Bengou.
[3]Division between long-term and invitational travel based on report and supplemented by personal knowledge of Dr. Lowenberg-DeBoer, NAARP Chief of Party.

TABLE 4-2
1988 ESTIMATED COST FOR PERFORMANCE OF WORK, SPECIFIED IN NIGER APPLIED AGRICULTURAL RESEARCH PROJECT CONTRACT

Category	Est. Amount
Salaries and Wages	$ 1,163,171
Fringe Benefits	333,593
Allowances	451,345
Travel, Trans., & Per Diem	414,311
Other Direct Costs	943,001
Sub-Contracts	
Winrock International	2,290,079
University of Nebraska	757,800
Alabama A&M University	729,301
Overhead	775,205
Local Cost Financing	2,863,193
TOTAL ESTIMATED COST	$10,720,999

TABLE 4-3
ON-CAMPUS NAARP EXPENDITURES FOR THE LIFE OF PROJECT[1]

Institution	Expense Category	Year 1	Year 2	Year 3	Year 4	Total[2]
	Salaries/Wages	$ 72,875	$ 63,072	$ 68,096	$ 60,288	$ 264,331
	Fringe Benefits	12,964	18,072	18,435	20,514	69,985
	Allowances	17,898	28,959	27,078	59,061	132,996
	Travel & Shipping	51,027	14,536	33,689	12,322	111,574
Alabama	Supplies	667	1,116	655		
	Other Direct Costs	1,403	1,128	2,787	35,754	43,510
	Indirect Costs	59,074	42,012	49,662	61,428	212,176
	Subtotal	215,909	168,896	200,403	249,366	834,574
	Salaries/Wages	$ 78,324	$ 129,716	$ 170,011	$ 88,087	$ 466,137
	Fringe Benefits	20,778	33,546	35,470	25,764	115,557
	Allowances	31,361	52,757	53,096	60,924	198,138
	Travel & Shipping	51,115	45,848	30,969	37,585	165,517
Winrock	Other Direct Costs	8,742	10,396	14,453	31,465	65,056
	Procurement	17,409	330,341	201,577	249,979	799,305
	S-T Training	-0-	53,645	275,237	260,517	589,399
	Indirect Costs	49,551	94,749	113,015	62,618	319,932
	Subtotal	257,279	750,997	893,829	816,940	2,719,045
	Salaries/Wages	$ 16,085	$ 52,018	$ 88,997	$ 121,511	$ 278,611
	Fringe Benefits	2,283	10,353	16,702	18,112	47,450
	Allowances	-0-	11,334	15,915	(9,550)	17,699
Nebraska	Travel & Shipping	10,718	14,908	21,931	42,645	90,202
	Supplies	116	37	-0-		
	Other Direct Costs	319	11,109	2,169	2,932	16,682
	Indirect Costs	6,588	18,578	28,728	31,269	85,163
	Subtotal	36,109	118,337	174,441	206,921	535,808
	Salaries/Wages	$ 278,661	$ 329,704	$ 327,927	$ 310,732	$ 1,247,024
	Fringe Benefits	77,641	94,548	95,533	87,720	355,442
	Allowances	68,515	122,767	111,765	92,697	395,744
	Travel & Shipping	74,953	71,428	91,855	126,322	364,558
	Other Direct Costs	101,059	50,951	72,316	205,509	429,835
Purdue	Subcontracts:					
	Alabama	215,909	168,896	200,403	249,366	834,574
	Winrock	257,279	50,997	893,829	816,940	2,719,045
	Nebraska	36,109	118,337	174,441	206,921	535,808
	Indirect Costs	152,833	130,267	139,374	174,263	596,737
	In-country	364,253	425,670	60,245	1,757,485	2,607,653
	Grand Total	$1,627,212	$2,263,567	$2,167,688	$4,027,953	$10,086,420[2]

[1]Actual expenditures for years 1-3; best estimate of expenditures for year 4.
[2]Discrepencies in totals are due to rounding of dollar amounts.

5 PROBLEM AREAS AND RECOMMENDATIONS

5.1 Problem Areas

5.1.1 Problems in Africa[1]

Overall institutional development of a viable national agricultural reseach system (NARS) requires deliberate political will, serious interest, and genuine commitment on the part of the national government and senior administrators of the institution in order to bring about change. Too often, African governments have a biased view of the role of agriculture in national development, and this attitude is translated into weak support that is given to the institution and to agricultural research. Political support for agriculture research has declined at precisely the time when greater support has been needed.

In sub-Saharan Africa (SSA), an actual decline in production is judged as a shameful indicator of managerial incompetance and poor governance.

The major constraint in SSA is the lack of the right attitude in the highest levels of the decision-making processes to recognize the importance of agricultural research in economic recovery, long-term progress, and future prosperity of countries of the region.

A significant number of national agricultural research systems exist only through donor activities. However, it is questionable if this is an advantage or a disadvantage to self-reliance and development. Many times, assistance is not requested by recipient countries, but is undertaken at the insistence of the donor(s). Furthermore, such programs are many times "modeled" after what the donor(s) perceive of as the recipient's needs and, therefore, may be irrelevant. As a consequence, the administrators of NARS find it easy to turn to donors--governments in turn not only withhold, but refuse, support to their *own* NARS.

Other problems can be identified such as: the number of foreign assistance efforts in a particular country which is often beyond the management capability of the national system; project designs of such scale that they are unmanageable; and non-integrated projects which distort program balance when they cease. Other examples such as over-financed projects, short-term projects, and quick impact generating activities (buildings and vehicles) have been or are recognized by those persons who have critically evaluated the role of donor support to the NARS.

Then there is the matter of obvious NARS-recognized failures of donor-supported projects (millions of dollars). Half of the World Bank's research and development projects in SSA are known to have totally failed (World Bank, 1988).[2]

Drought-related food crises have resulted in massive donor-assisted food aid and a disincentive for governments to sponsor and support agricultural resarch. The demand for research and the support for enhancing research capability are lacking, as a result.

[1]Nwanze, Kanayo F. 1991. Sustainable Food Production in Africa: The Challenge to National Agricultural Research Systems (NARS), *Insect Sci. Applic.* 12:615-625.
[2]World Bank. 1988. Rural Development: World Bank Experience, 1965-1986. World Bank, Washington DC.

Three major issues impact on the success of the national agricultural research service. First, support from the highest level of government is required for building an effective institutional capacity and capability for adaptive research and technology. Second, a long-term commitment from the national government and donors, both in capital and human resource development, is necessary for sustained development. Third, actual donor involvement in institution building through training, research, and extension should receive equal priority.

5.1.2 Problems in Niger Relating to NAARP Management

Some of the problems alluded to above are, or have been, important to the administration and the conduct of the NAAR Project and INRAN. These issues can be easily recognized in a critical evaluation of the NARS. Furthermore, a continuation of activities in support of INRAN and its agricultural research mission should consider some of the points made by Nawanze (1991) which bear on the success of the initiatives of INRAN.

Initiatives by the NAAR Project were hampered by administrative changes in the office of Director General of INRAN. The lack of continuity in this office greatly affected the carrying out of INRAN research programs.

The Chief of Party acting for the contractor was a qualified, trained management specialist (MBA) as required under the terms of the USAID contract and by the INRAN Director General. Even though the Contractor (Purdue University) explicitly recommended that an experienced agricultural research scientist with management experience in an agricultural experiment station environment would be better qualified to act as COP to advise the DG in research management, USAID required the employment of a "management specialist" as COP.

The resignation of the Purdue Chief of Party was also responsible for some disruption in the working relationship between the INRAN DG and the NAAR Project office. However, this issue was resolved with the appointment of Dr. Lowenberg-DeBoer, who served admirably as COP during the remainder of the life of project.

Decertification of INRAN financial assistance by USAID introduced significant constraints to INRAN programs, despite continued direct payment to INRAN upon presentation of required vouchers. This was particularly important in the timely payment of temporary laborers, and continued to be a problem during the remaining period of the LOP. Responsibility for these constraints due to decertification has to be shared by both USAID and INRAN.

Resolution of problems between the Contractor and USAID with regard to disallowances of expenditures at times became tedious, with the same claims by the Contractor being submitted three times before charges were eventually allowed.

Administrative issues which were to be resolved in INRAN where addressed, but not successfully solved during the LOP, were:

- Materiels management system (initiated)
- Personnel management (awaits GON action)
- Financial management system (program-based budgeting issues, etc. as yet unresolved)
- Inadequate professional/scientific capacity jeopardized indigenous and TAT efforts in institutional development

- Failure to initiate MOUs between INRAN, ONAHA, etc., even after lengthy discussion

Some of these issues await approval of INRAN reorganization before they may finally be settled.

5.1.3 Technical Problems

RELU - Linking of INRAN and the Extension Services using the multi-locational trial program generated conflict between the two services. The expatriate RELU specialist spent much of her time in 1989 monitoring these trials, and she worked with the Extension Service to reorganize the trials. Due to changes in the INRAN Directorship, the process became disrupted, and RELU was not involved in 1990, even though it was evident that the process initiated in 1989 was a valid one. A lack of INRAN counterparts was also a critical constraint to progress in the RELU.

The RELU specialist departed Niger early in 1991, and USAID/Niger made the decision not to employ a replacement to continue the work of the Unit until the end of project.

Irrigation - Both the lack and dilatory nature of staff assignments to the Irrigation Section served as a major setback to the program. Other major obstacles included: lack of funding for the Irrigation Section through NAARP/INRAN budgeting (throughout LOP), late arrival of research equipment (a reflection on materiel acquisition in INRAN management), and administrative responsibilities of the technical assistant.

5.2 Recommendations

In the future, the COP for technical assistance teams should not only have managerial experience, but she/he should be technically competent in the discipline appropriate for the donor-assisted project.

INRAN (or other Nigerian organization) has to identify proper counterparts for technical assistants in order to achieve the required level of technical competence on the part of the Nigerien staff and also to assist the TAT in becoming totally familiar with the technical and administrative facets of the Nigerien organization.

Technical assistants need to spend more of their time interacting with their counterparts as trainers. They also need to interact significantly as members of the institute and administrative unit to which they are attached. This is a most significant element of institution building and is a means to achieving evolutionary change in the institution.

USAID has to devise, with the contractors, a better means to handle reimbursement of costs incurred by the contractor. Some headway was made in the late stages of NAARP through an early review of vouchers by the USAID controller's office and the NAARP accountant. The problem of value-added tax charges was never fully resolved and needs to satisfactorily be resolved for all future contracts.

USAID, when dealing with training issues and academic standing, should rely on the opinion and action taken by the academic institution regarding academic matters and not take issue with the academic institution in their resolution.

USAID, in light of progress made in institution building projects, should continue to support such activities for a long enough period to reach the desired conclusion. Institution building does not occur in any specified period of time nor with a given amount of dollar input. For example, the Land Grant

University Experiment Station System was not built over a 10-15 year time span and, as a matter of fact, is still undergoing evolutionary change, albeit with a different mechanism for research support.

Better research linkages should be established in-country between ICRISAT, the University of Niamey, and the Collaborative Research Support Projects.

Better and more functional linkages should be established between INRAN research programs and Extension Services and farmers. The reverse linkage is also critical to the research community in order for them to become familiar with the problems of the farming constituents.

Better programmatic linkages should be established between the NARS of Sahelian countries to avoid duplication of research effort, on the one hand, but adding complementarity to research, on the other. Linkages infer communication on research issues between countries working on similar problems and could promote annual or biennial regional research conferences.

6 APPENDICES

6.1 Minutes of Representative INRAN Staff Meeting

EPUBLIQUE DU NIGER

ISTERE DE L'AGRICULTURE
ET DE L'ENVIRONNEMENT

TITUT NATIONAL DE RECHERCHES
AGRONOMIQUES DU NIGER

I. N. R. A. N. /

Niamey, le 5 Avril 1989

-:-:-:-:-:-:-

PROCES VERBAL DE LA 3e REUNION TRIMESTRIELLE

DU PROJET DE RECHERCHE AGRICOLE APPLIQUEE AU

NIGER (PRAAN)

L' an mil neuf cent quatre vingt neuf et le jeudi 30 mars s'est tenue, dans salle de réunion du Laboratoire des Sols de l'INRAN, la troisième réunion trimes- elle d'évaluation du Projet de Recherche Agricole Appliquée au Niger (PRAAN).

Ont participé à cette réunion :

MM.	IDRISSA SOUMANA	Directeur Général de l'INRAN
"	MOUSSA OUMAROU	D.G.A./INRAN
"	FLYNN FULLER	USAID/ADO
"	SEIDOU AMADOU	USAID/ADO
"	MOUNKAILA SOUMAILA	USAID/CONT
"	GASTON KABA	USAID/GDO/ET
"	PAUL HEBERT	CDE/PURDUE/INRAN
"	JIKA NEINO	Chef Station Kolo/INRAN
"	JOHN CLARK	INRAN/DRA
Mme	SABO AMINA	INRAN/DRVZ
MM.	IDRISSA DAOUDA	INRAN/PTV
"	TOUKOUA DAOUDA	INRAN/BEI/F
"	MAHAMANE BACHIR	INRAN/DSI
"	OUSMANE MAITAGOUA	MP/PR/DEPP
"	ABOUBACAR ISSA	INRAN/DRF
"	MOUSSA DIOLOMBI	INRAN/SFM
"	CHANDRA REDDY	INRAN/DRA
"	MOUMOUNI OUSSEINI	INRAN/CRV
"	BONKOULA ABDOULAYE	INRAN/DRA
"	CHRISTINE OHALI	INRAN/CRV
"	J. LOWENBERG DEBOER	INRAN/DECOR
"	MAHAMANE ISSAKA	INRAN/DRE

L'ordre du jour proposé a été le suivant :

1) Situation Financière

2) Situation du Personnel du Projet
3) Situation des Groupes de Travail
4) Situation de la Rehabilitation des Systèmes d'Irrigation
5) Publications
6) Missions d'Appui Technique
7) Missions de Travail àl'Etranger
8) Divers

La réunion était présidée par Monsieur Idrissa SOUMANA, Directeur Général de l'INRAN.

Après avoir souhaité la bienvenue aux participants, le Président a demandé s'il y a des points nouveaux à inscrire à l'ordre du jour.

N'ayant enregistré aucune intervention, l'ordre du jour ci-dessus a été adopté.

I - SITUATION FINANCIERE

Le Directeur Général de l'INRAN a demandé au Chef du Service Financier et du Materiel de présenter la situation financière du Projet.

- La période couverte par ce rapport se caractérise par un net ralentissement des opérations.

- L'approbation du budget de l'exercice 1989 et la mise en place des crédits ont accusé un retard considérable dû essentiellement à l'introduction d'une budgétisation par programme de recherche.

A. Financement des coûts locaux (INRAN)

- La situation a été résumée dans trois documents :

Document N°1 : Financement des coûts locaux (INRAN)

- L'ouverture des crédits budgétaire 1989 reste la préoccupation majeure à cette date (i. e. ; 10 mars)

- Programmation bugétaire de la gestion 1988 :

141. 075.000 CFA

- Budget approuvé	141. 075. 000
- Total des avances.....	119. 788. 872
- Paiement direct.....	7. 359. 629
	127. 148. 501
- Justifications.....	99. 875. 561
- Avances non Liquidées.....	27. 222. 940

.../...

B. L'assistance technique (PRAAN)

Document N° 2 : L'Assistance Technique

- L'assistance technique est subdivisée en deux parties :

Budget PRAAN - Bureau Local

Budget PRAAN - Campus

- Budget PRAAN - Bureau Local - Année I (en CFA)

- Budget approuvé.....	215. 968. 800 CFA
- Total des avances.....	85. 905. 618 CFA
- Justifications.....	63. 069. 493 CFA
- Avances non liquidée.....	22. 836. 125 CFA

- Budget PRAAN - Campus - Année I (en $)

- Budget approuvé	$ 3. 036. 301. 00
- Dépenses.....	$ 726. 429. 35
- Engagements.....	$ 228. 437. 15
- Reservation.....	$ 1. 339. 541. 48
- Total dépenses engagés...	$ 2. 294. 377. 98
- Disponible au 31/1/89	$ 741. 923. 02

- M. Bonkoula Abdoulaye (INRAN/DRA) a demandé que la ventilation des procédures pour le nouveau budget (1989) se fasse aussitôt que possible.

- Le DGA a demandé le déblocage des fonds pour le budget des groupes de travail scientifiques.

- M. Jika (INRAN/KOLLO) a demandé des éclaircissement au sujet des fonds du trésor.

.../...

II SITUATION DU PERSONNEL DU PROJET

a) EQUIPE D'ASSISTANCE TECHNIQUE

- Le Chef d'Equipe de PURDUE/PRAAN a expliqué que le poste d'Agronome en Irrigation est encore vide. Cependant l'USAID-Niger est entrain d'évaluer le CV d'un candidat pour remettre à la Direction Générale de l'INRAN.

b) PERSONNEL ADMINISTRATIF DU SIEGE DU PRAAN

- Le personnel administratif du siège de Maradi est en place depuis le 1er Janvier 1989. Pour le siège un personnel temporaire a été engagé. Un concours est en préparation pour un personnel permanent.

III SITUATION DES GROUPES DE TRAVAIL SCIENTIFIQUE ET ADMINISTRATIF

- Le DGA a présenté un aperçu général des activités des Groupes de Travail Scientifique.
- Le Dr. CLARK a présenté un bref rapport des activités du Groupe Amélioration des Plantes.

- Le Dr. REDDY a présenté un rapport sommaire pour le Groupe Economie et système de production.

- M. Issaka MAHAMANE a présenté le rapport pour le Groupe Sols et Irrigation.

- Le Dr. OKALI a présenté le rapport pour le Groupe Liaison Recherche-Vulgarisation.
- M. Issaka Mahamane a présenté un rapport sommaire pour le Groupe Acquisition du Matériel.

- M. Toukous DAOUDA a présenté un rapport pour le Groupe Formation

- Le DG a présenté un compte-rendu oral des activités du Groupe de Coordination Financière et Administrative.

IV SITUATION DE LA REHABILITATION DES SYSTEMES D'IRRIGATION

- Le DGA et M. Issaka Mahamane ont présenté la situation pour les différentes études qui sont en marches. L'appel d'offre pour la confection des forages à KONNI et TARNA a été lancé pour la date limite du 20 Avril 1989.

- Le Dr. NORMAN et M. DJIDO (ONAHA) ont visité Abidjan, Côte-d'Ivoire pour identifier des fournisseurs de l'équipement requis.

- Le Comité de Pilotage du Volet Irrigation doit se réunir prochainement sous la présidence de l'ONAHA.

V PUBLICATIONS

- M. Idrisse Daouda a présenté les activités du Groupe Communication depuis son lancement au mois de Février. La préparation des articles scientifiques pour publication par l'INRAN est en marche.

.../...

- Le DG a demandé que le Chef du Département d'Information du MAE soit invité à se joindre au Groupe Communication

- L'Université de Purdue est entrain d'imprimer pour l'INRAN la synthèse des cinq dernière année d'activitée provenant de la Réunion Annuelle de Maradi en Septembre 1988.

VI MISSIONS D'APPUI TECHNIQUE

- Le CDE de Purdue/PRAAN a présenté la liste des consultants qui ont entrepris des missions d'appui technique à l'INRAN. Les objectifs et les termes de référence pour ces missions ont été discutés. Ces missions ont été effectuées par les Messieurs HUBBARD (Winrock), SHARP (Purdue), SERAFINI (Winrock), ASHBURNER (Winrock), Gilliver (ICRISAT), et VAN MIDDE (ICRISAT).

- Le DG a encouragé chaque Département de discuter de ses besoins en matière de mission d'appui technique et d'en faire la demande à la Direction Générale.

VII MISSIONS DE TRAVAIL A L'ETRANGER

- Le CDE de Purdue/PRAAN a présenté une liste des cadres de l'INRAN qui ont entrepris des missions de travail à l'étranger. Un total de trente-et-une (31) missions ont été effectuées. L'USAID/PRAAN ont subventionné sept (7) de ces missions.

- Bachir Mahamane (INRAN/DSI) a suggéré que de telles missions soient mieux organisées pour minimiser de graves soucis et des embarras.

- Le DG a ajouté que souvent de tels difficultés provenaient d'un manque de planification serieux ou un changement de plans inattendus de la part des participants.

VIII DIVERS

- L'USAID a confirmé que les fonds pour la clôture à KOLLO n'étaient plus disponibles. Le DGA a exprimé l'espoir que les fonds du PRAAN pourraient être utilisés à cette fin. M. Seidou (USAID/ADO) a suggeré que le dossier de ce projet soit discuté encore avec l'INRAN.

- Les plans pour le projet magasin/bureau à l'INRAN est encore à finaliser par l'USAID. M. SOLOMON, Ingénieur de l'USAID, a proposé quelques changements.

- M. Moumouni Ousseini (INRAN/CRV) a présenté un rapport sommaire sur le voyage qu'il a récemment completé avec D. OKALI au Maroc, Sénégal, et Mali.

.../...

- Le DG a réitéré à l'USAID que le manque de personnel local à l'INRAN demeure un problème très grave pour le PRAAN. Dans la perspective que le PRAAN est surtout un projet d'appui et de renforcement de l'INRAN en tant qu'institution de recherche nationale, ce problème exige qu'il ait une réflexion approfondie de la part de l'USAID et l'INRAN.

- La date de la quatrième réunion d'évaluation trimestrielle du PRAAN a été fixé pour le jeudi 29 juin 1989 à 09hoo au Laboratoire des Sols de l'INRAN.

- L'ordre du jour étant épuisé, le Président a levé la séance à 12 heures 15 minutes.

LES RAPPORTEURS :

Dr. Paul HEBERT
M. Seidou AMADOU

6.2 Long-Term Training

The following tables show the individuals who received, or are presently receiving, long-term training under the auspices of USAID long-term NAARP training funds.

TABLE 6-1
LONG-TERM TRAINING IN THE U.S.

Name	Degree	Suject	University
Aboubacar Adam	MS[1]	Food Technology	Purdue
Bio Maman Dodo	MS	Agronomy	Purdue
Raphiou El Ibrahim	MS	Agronomy	North Carolina State
Ouendeba Botorou	PhD[1]	Plant Breeding	Purdue
Adam Abdoulaye	PhD	Statistics	Iowa State
Mai Moussa Chetima	MS	Irrigation	Utah State
Seyni Sirifi	MS	Agronomy	Nebraska
Mahamadou Ibrahim	MS	Seed Technology	Mississippi State
Boukary Hama	MS	Seed Technology	Mississippi State
Ouattara Mahamadou	PhD[1]	Soil Science	Texas A&M
Diallo Soumana	MS[1]	Soil Science	Univ. of Arizona
Sabiou Mahamane	MS[1]	Agronomy	Univ. of Arizona
Issaka Mahamane	PhD	Soil Science	Purdue
Moussa Goubé Gaoh	PhD	Soil Science	Texas A&M
Alou Abdourhamane	MS[1]	Plant Science	Univ. of Arizona
Kedidia Mossi[2]	BS	Plant Physiology	Nebraska

[1]Degree completed.
[2]Early termination.

TABLE 6-2
LONG-TERM TRAINING IN THIRD COUNTRIES

Name/Organization[1]	Degree	Subject	Institution/Country
Issa Mahamane, INRAN	3rd cycle doctorate	Agricultural Economics	Inst. Nat. Agro. Tunis, Tunisia
Amadou Attikou, INRAN/DRE	Maîtrise	Soil Science	Univ. of Benin, Benin
Moussa Hamma Boureima, INRAN	Licence	Sociology	Univ. of Benin, Benin
Ousmane Taher, ONAHA	Ingénieur	Hydrology Engineering	Ecole Nat. Trav. Pub., Chad
Boukari Ari[2], ONAHA	Ingénieur	Agronomy	Inst. Agro. Bouaké, Côte d'Ivoire
Chaidou Mahamane, Génie Rural	Diplôme d'Ingénieur des travaux	Agricultural Engineering	Ecole Nat. Trav. Pub., Chad
Chetima Assane[2], Génie Rural	Ingénieur	Civil Engineering	Ecole Nat. Ing., Mali

[1]No attempt has been made to translate into English the degrees received at African institutions, since there is no comparable degree in the U.S.
[2]Early termination.

TABLE 6-3
LONG-TERM TRAINING OF INRAN STAFF FUNDED THROUGH
THE SAHEL HUMAN RESOURCES DEVELOPMENT PROJECT DURING NAARP

Name	Degree[1]	Subject	Institution/Country
Ly Samba Abdoulaye	3rd cycle doctorate	Agricultural Economics	CIRES, Abidjan, Côte d'Ivoire
Moussa Adamou	PhD	Plant Breeding	Mississippi State, U.S.

[1]See note 1 above.

6.3 Breakdown of NAARP Short-Term Training Activities Through Winrock by Individual

TABLE 6-4
BREAKDOWN OF SHORT-TERM TRAINING BY INDIVIDUAL

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year	Length in weeks	Location
Mounkaila Maiguizo	INRAN/DRA/Agadez	Res	Mali, Bamako	Entomology	Jan. 90	1	Africa
Amadou N'Diaye	INRAN/DRA/Tarna	Res	Mali, Bamako	Entomology	Jan. 90	1	Africa
Diamheidou Seyni Maïga	INRAN/DRA/Kollo	Res	Mali, Bamako	Entomology	Jan. 90	1	Africa
Bonkoula Abdoulaye	INRAN/DRA	Res	India	Res. Mgmt.	Feb. 90	3	Other
Maliki Kadi	INRAN/DECOR	Res	India	Res. Mgmt.	Feb. 90	3	Other
Issoufou Kapran	INRAN/DRA	Res	Bamako	Agronomy	Oct. 89	1	Africa
Moumouni Ousseini	INRAN/CLRV	Res	USA	Research-Extension	Oct. 89	2	USA
Alou Ibrah	INRAN	Acc	Niger (Centre Kolo)	Accounting	Oct. 89	10	Niger
Maiga Boubacar Harouna	INRAN	Acc	Niger (Centre Kolo)	Accounting	Oct. 89	10	Niger
Idi Mairakouma	INRAN	Acc	Niger (Centre Kolo)	Accounting	Oct. 89	10	Niger
Abdoulaye Rahila	INRAN	Acc	Niger (Centre Kolo)	Accounting	Nov. 89	2	Niger
Seydou Kallam	INRAN	Acc	Niger (Centre Kolo)	Accounting	Nov. 89	2	Niger
Sani Alpha	INRAN	Acc	Niger (Centre Kolo)	Accounting	Nov. 89	2	Niger
Sanoussi Garba	DSI/Tarna	Tech	Niger (Min. of Plan)	Computers	Oct. 89	39	Niger
Mme Assia Dari	INRAN	Clerical	Niger (Willie)	Wordperfect	Feb. 90	1.5	Niger
Moussa Goubé Gaoh	INRAN/DRE	Res	Nigeria (IITA)	Res. Stat. Mgmt.	Feb. 90	3	Africa
Idi Maria Kollo	INRAN/DSI	Tech	Tunisia	Computers	June 90	8	Africa
Iddi Ousmane	INRAN/DSI	Tech	Tunisia	Computers	June 90	8	Africa

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Abdou Harouna	INRAN/DIRECTION	Tech	USA	Management	June	90	9	USA
Dine Sadikou	INRAN/CLRV	Res	Burkina Faso	Research-Extension	April	90	1.5	Africa
Illa Baoua	INRAN/Konni	Tech	Burkina Faso	Research-Extension	April	90	1.5	Africa
Amadou Moutari	INRAN/Kollo	Res	Burkina Faso	Research-Extension	April	90	1.5	Africa
Mahattan Cheterou	MAE, SAA Madaoua	MAE	Burkina Faso	Research-Extension	April	90	1.5	Africa
Souley Mahamadou	MAE, SAA Konni	MAE	Burkina Faso	Research-Extension	April	90	1.5	Africa
Amani Halidou	MAE, Section Elevage	MAE	Burkina Faso	Research-Extension	April	90	1.5	Africa
Idé Yayé	INRAN/Kollo	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Seydou Saley	INRAN/Kollo	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Amadou Idoum	INRAN/Konni	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Tahirou Elhadji	INRAN/Konni	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Farsante Magagi	INRAN/Tarna	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Gandah Madé	INRAN/Tarna	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Oumarou Soumaila	INRAN/Tillabery	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Aouta Mahamane	INRAN/Ouallam	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Gambo Garba	INRAN/Bengou	Tech	Niger (ICRISAT)	Equip. Operation	May	90	1.5	Niger
Moussa Soumaila	INRAN/Matériel	Mech	Niger (CPTP)	Vehicle Maint.	June	90	2	Niger
Idé Issaka	INRAN/DRE	Tech	Niger	Soil Science	May	90	1.5	Niger
Seydou Amadou	INRAN/DRE	Tech	Niger	Soil Science	May	90	1.5	Niger
Konda Issaka	ONAHA	ONAHA	Niger (CEFIGRE)	Water Mgmt.	May	90	3	Niger
Sami Abdou	ONAHA	ONAHA	Niger (CEFIGRE)	Water Mgmt.	May	90	3	Niger

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Moussa Indja	ONAHA	ONAHA	Burkina Faso	Water Managment	April	90	10	Africa
Moussa Abba	INRAN/DECOR	Res	Niger	Linear Programming	July	90	3	Niger
Maman Issa	INRAN/DECOR	Res	Niger	Linear Programming	July	90	3	Niger
Ibro Germaine	INRAN/DECOR	Res	Niger	Linear Programming	July	90	3	Niger
Maliki Kadi	INRAN/DECOR	Res	Niger	Linear Programming	July	90	3	Niger
Tahirou Abdoulaye	INRAN/DECOR	Res	Niger	Linear Programming	July	90	3	Niger
Yahaya Dadé	INRAN/DSI	Tech	Niger	Linear Programming	July	90	3	Niger
25 researchers	INRAN	Res	Niger	SAS II	Aug.	90	25	Niger
5 DSI technicians	DSI	Tech	Niger	SAS II	Aug.	90	5	Niger
Dine Sadikou	INRAN/CLRV	Res	Senegal	Research-Extension	Aug.	90	1	Africa
Sidi Aboubacar	MAE	MAE	Senegal	Research-Extension	Aug.	90	1	Africa
Yahaya Dadé	INRAN/DSI	Tech	Morocco	Computers	Sept.	90	6	Africa
Jika Naino	INRAN/Kollo	Res	USA	Res. Farm Mgmt.	Sept.	90	3	USA
Oumarou Soumaila	INRAN/Tillabery	Tech	USA	Res. Farm Mgmt.	Sept.	90	3	USA
N'Diaye Ahamdou	INRAN/Tarna	Res	USA	Res. Farm Mgmt.	Sept.	90	3	USA
Siradji Moumouni	INRAN/Tillabery	Tech	USA	Res. Farm Mgmt.	Sept.	90	3	USA
Tanimoun Daouda	INRAN/Bengou	Tech	USA	Res. Farm Mgmt.	Sept.	90	3	USA
Illa Bawa	INRAN/Konni	Tech	USA	Res. Farm Mgmt.	Sept.	90	3	USA
Farsante Magagi	INRAN/Tarna	Tech	USA	Res. Farm Mgmt.	Sept.	90	3	USA
Ibrahim Garba	INRAN/Formation	Res	USA	Res. Farm Mgmt.	Sept.	90	3	USA
Ibrahim Garba	INRAN/Formation	Res	USA, Tunis, Paris	Tng. Opportunities	Sept.	90	4	USA
Saidou Bawa	INRAN/DG	Res	Niger	English	Oct.	90	0.25	Niger
Moussa Goubé Gaoh	INRAN/DRE	Res	USA	Agronomy (ASA)	Oct.	90	3	USA
Moussa Adamou	INRAN/DRA	Res	Eygpt	Seed production	Oct.	90	1	Africa
Issoufou Kapran	INRAN/DRA	Res	Eygpt	Seed production	Oct.	90	1	Africa
Ousseni Sidibé	INRAN/DRA	Res	USA	Res. Mgmt.	Nov.	90	4	USA
Mahamadou Gandah	INRAN/DRE	Res	USA	ASAE	Nov.	90	5	USA
Abdou Sami	ONAHA	ONAHA	USA	ASAE	Nov.	90	5	USA
Ibrahim Djido	ONAHA	ONAHA	Burkina Faso	Computer	Oct.	90	8	Africa

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Samionou El Hadji	ONAHA	ONAHA	Burkina Faso	Irrigation	Oct.	90	39	Africa
Aboubacar Djibo	ONAHA	ONAHA	Burkina Faso	Irrigation	Oct.	90	39	Africa
Mahamadou Ouattara	INRAN/DRE	Res	Senegal, Burkina, Morocco	Soil Science	March	91	3	Africa
Mme. Beidari Fatouma	INRAN/DRE	Res	"	Soil Science	March	91	3	Africa
Issaka Mahamane	INRAN/DRE	Res	"	Soil Science	March	91	3	Africa
Salou Moussa	INRAN/DRE	Res	USA	Soil Science	April	91	6	Niger
Researchers	INRAN	Res	Niger	Biennial meeting	May	91	57	Niger
Technicians	INRAN	Tech	Niger	Biennial meeting	May	91	29	Niger
Mahamane Issa	INRAN/DECOR	Res	Nigeria	On-Farm Trials	Sept.	90	2	Africa
Mme. Beidari Fatouma	INRAN/DRE	Res	Togo (IFDC)	Soil Science	Oct.	90	2	Africa
Dine Sadikou	INRAN/CLRV	Res	Nigeria	Research-Extension	Jan.	91	1	Africa
Ibrahim Garba	INRAN/Formation	Res	Nigeria	Research-Extension	Jan.	91	1	Africa
Dine Sadikou	INRAN	Res	Nigeria	Research-Extension	Feb.	91	1.5	Africa
Assoumane Moussa	INRAN	Res	Nigeria	Research-Extension	Feb.	91	1.5	Africa
Cherif Ali	INRAN	Res	Nigeria	Research-Extension	Feb.	91	1.5	Africa
Jika Naino	INRAN	Res	Nigeria	Research-Extension	Feb.	91	1.5	Africa
Moutari Adamou	INRAN	Res	Nigeria	Research-Extension	Feb.	91	1.5	Africa
Issoufou Kapran	INRAN	Res	Niger	Research-Extension	March	91	1	Niger
Mamane Nourri	INRAN	Res	Niger	Research-Extension	March	91	1	Niger
Cherif Oumarou	INRAN	Res	Niger	Research-Extension	March	91	1	Niger
Hassane Djingarey	INRAN	Tech	Niger	Research-Extension	March	91	1	Niger
51 (42 CDA, 5 SAA Adj., 4 DDA)	MAE	MAE	Niger	Research-Extension	March	91	51	Niger
15 INRAN researchers	INRAN	Res	Niger	Agronomy	March	91	15	Niger
4 INRAN drivers	INRAN	Mech	Niger (CPTP)	Mechanics	April	91	8	Niger
Hadiza Adamou	INRAN/DOC	Tech	USA	Library Science	June	91	8.7	USA
Ibrahim Moussa	INRAN Direction	Mech	Niger	Vehicle Maint.	June	91	4	Niger
Adamou Bourima	INRAN Direction	Mech	Niger	Vehicle Maint.	June	91	4	Niger
Zakou Gandah	INRAN Direction	Mech	Niger	Vehicle Maint.	June	91	4	Niger

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Amadou Sidikou	ONAHA	ONAHA	Niger	Vehicle Maint.	June	91	4	Niger
Alidou Dodo	ONAHA	ONAHA	Niger	Vehicle Maint.	June	91	4	Niger
Abdou Moussa	ONAHA	ONAHA	Niger	Vehicle Maint.	June	91	4	Niger
Djibrilla Kourma	ONAHA	ONAHA	Niger	Vehicle Maint.	June	91	4	Niger
Issoufou Kollo	INRAN/DRA	Res	Kenya	Parasitic Weeds	June	91	2	Africa
Illa Ado	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Gregroire Robert Mamoudou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Rabe Kane	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Maman Sani Dan Fari	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Tassiou Garba	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Issoufou Hassane	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Boubacar Amadou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Abdou Madougou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Paraiso Tahirou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Ousmane El Seydou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Mahaman Sani Amadou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Awache Mamane	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
[illegible]ou Niandou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Ali Adamou Mahaman	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Manzoul Mohamed	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Mamane Mato Tawaye	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Seini Daouda	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Assane Oumarou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Mo[illegible]uni Djibo Moussa	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Abdou Bori	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Mossi Amadou	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Falalou Tari Bako	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Amadou Djibo	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Alhassan Bonkano	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger
Laouan Saley	Génie Rural	GR	Niger	Construction Tech.	June	91	1.5	Niger

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Moussa Adamou	INRAN/DRA	Res	USA	Research Mgmt.	July	91	1.5	USA
Issoufou Kapran	INRAN/DRA	Res	USA	Research Mgmt.	July	91	1.5	USA
Moussa Oumarou	INRAN/DRA	Res	USA	Research Mgmt.	July	91	3	USA
Hamey Kadi Kadi	INRAN/DRA	Res	USA	Research Mgmt.	July	91	1.5	USA
Ahmadou N'Diaye	INRAN/CNRA	Res	India	Research Mgmt.	July	91	3	Other
Moussa Abba	INRAN/DECOR	Res	Niger	Prod. Economics	July	91	1	Niger
Tahirou Abdoulaye	INRAN/DECOR	Res	Niger	Prod. Economics	July	91	1	Niger
Addo Azahidou	INRAN/DECOR	Res	Niger	Prod. Economics	July	91	1	Niger
Moussa Bokar	INRAN/DECOR	Res	Niger	Prod. Economics	July	91	1	Niger
Germaine Ibro	INRAN/DECOR	Res	Niger	Prod. Economics	July	91	1	Niger
Mahamadou Malam Abdou	INRAN/DECOR	Res	Niger	Prod. Economics	July	91	1	Niger
Marou Assane Zarafi	INRAN/DECOR	Res	Niger	Prod. Economics	July	91	1	Niger
Hadiza Zarafi	INRAN/DECOR/PRAAN	Res	Niger	Prod. Economics	July	91	1	Niger
Ahmed Abdoulaye	INRAN/DECOR	Res	Niger	Prod. Economics	July	91	1	Niger
Ibrahim Garba	INRAN/Training	Res	Morocco, Ivory Coast	Tng. Opportunities	July	91	2.5	Africa
Amadou Harouna	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Ali Alzouma	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Alidou Dodo	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Abdoulaye Fonda	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Abdou Amadou	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Oumarou Adamou	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Oumarou Mamane	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Issoufou Adamou	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Kangay	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Soumana Amankaye	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Hamadou Manou	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Chaibou Souleymane	ONAHA	ONAHA	Niger	Literacy	August	91	1	Niger
Moussa Manzo	INRAN/DECOR	Tech	Niger	On-Farm Trials	August	91	1	Niger
Mahamadou Mahamane	INRAN/DECOR	Tech	Niger	On-Farm Trials	August	91	1	Niger

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Idrissa Mamoudou	INRAN/DECOR	Tech	Niger	On-Farm Trials	August	91	1	Niger
Shama Kantou	INRAN/DRE	Tech	Niger	On-Farm Trials	August	91	1	Niger
Hamma	INRAN/DRE	Tech	Niger	On-Farm Trials	August	91	1	Niger
Oumarou	INRAN/DRE	Tech	Niger	On-Farm Trials	August	91	1	Niger
Matto Maman	INRAN/DRE	Tech	Niger	On-Farm Trials	August	91	1	Niger
Issoufou	INRAN/CNRA	Tech	Niger	On-Farm Trials	August	91	1	Niger
Inoussa	PEN	MAE	Niger	On-Farm Trials	August	91	1	Niger
Issaka	PEN	MAE	Niger	On-Farm Trials	August	91	1	Niger
Issa Nouma	ONAHA	ONAHA	Niger	On-Farm Trials	August	91	1	Niger
Moussa Abba	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Tahirou Abdoulaye	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Addo Azahidou	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Moussa Bokar	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Germaine Ibro	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Mahamadou Malam Abdou	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Marou Hassan Zarafi	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Mohamed Abdoulaye	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Ly Abdoulaye Samba	INRAN/DECOR	Res	Niger	Survey Statistics	Sept.	91	1	Niger
Iddi Ousemane	INRAN/DSI	Tech	Niger	Survey Statistics	Sept.	91	1	Niger
Iddi Maria Kollo	INRAN/DSI	Tech	Niger	Survey Statistics	Sept.	91	1	Niger
Toukoua Daoudé	INRAN/DEP	Res	Netherlands	Research Mgmt.	Sept.	91	4	Other
Inusah Hamani	INRAN/DSI	Tech	Benin	Computer	Oct.	91	39	Africa
Mme. Kadi Seybou	INRAN	Clerical	Benin	Secretarial	Oct.	91	39	Africa
Mamane Nourri	INRAN/DRA	Res	USA (ASA)	Agronomy	Oct.	91	6	USA
Fatouma Beidari	INRAN/DRE	Res	USA (ASA)	Agronomy	Oct.	91	3	USA
Mahamadou Gandah	INRAN/DRE	Res	USA (ASA)	Agronomy	Oct.	91	2	USA
Seyni Maïga	INRAN/DRA	Res	USA (ASA)	Agronomy	Oct.	91	3	USA
Tahircu Abdoulaye	INRAN/DECOR	Res	USA (FSR)	Economics	Oct.	91	2	USA
Rene Jolly Abdel-Kader	INRAN/Chef de Personnel	Tech	Sengal (CESAG)	Management	Oct.	91	39	Africa

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Illiasou Mossi Maiga	Génie Rural	GR	Burkina Faso	Hydraulics	Oct.	91	39	Africa
Hamidou Seydou	Génie Rural	GR	Burkina Faso	Hydraulics	Oct.	91	39	Africa
Assako Imolen	Génie Rural	GR	Burkina Faso	Hydraulics	Oct.	91	39	Africa
Sabiou Mahaman	INRAN/DRE/Irrig.	Res	USA (Colorado)	Irrigation	Oct.	91	10	USA
Souleymane Mounkaila	INRAN/DRE/Irrig.	Tech	USA (Colorado)	Irrigation	Oct.	91	9	USA
Ibrahim Souley	INRAN	Tech	Niger (IPDR)	Agronomy	Nov.	91	35	Niger
Djibo Morou	INRAN	Tech	Niger (IPDR)	Agronomy	Nov.	91	35	Niger
Tankary Hassane	INRAN	Tech	Niger (IPDR)	Agronomy	Nov.	91	35	Niger
Moussa Barke	INRAN	Tech	Niger (IPDR)	Agronomy	Nov.	91	35	Niger
Abdoulaye Garba	INRAN	Tech	Niger (IPDR)	Agronomy	Nov.	91	35	Niger
Hadiza Boukari	INRAN	Tech	Niger (IPDR)	Agronomy	Nov.	91	35	Niger
Ali Kanta	INRAN	Tech	Niger (IPDR)	Agronomy	Nov.	91	35	Niger
Jada Gonda	INRAN/DRA	Res	Togo	Communication	Nov.	91	2	Africa
Haougui Adamou	INRAN/DRA	Res	Togo	Scientific	Nov.	91	2	Africa
Kapran Issoufou	INRAN/DRA	Res	Togo	Scientific	Nov.	91	2	Africa
Basso Adamou	INRAN/DRA	Res	Togo	Scientific	Nov.	91	2	Africa
Diallo Soumana	INRAN/DRE/Irr	Res	USA (ASAE)	Irrigation	Dec.	91	10	USA
Mme. Diori, née Aissata Mahamadou	INRAN	Clerical	Niger	Office Assistant	Dec.	91	30	Niger
Mme. Oumarou, née Haoua Gado	INRAN	Clerical	Niger	Office Assistant	Dec.	91	30	Niger
Mme. Bachir, née Oussenia Boukary	INRAN	Clerical	Niger	Wordperfect	Jan.	92	8	Niger
Mme. Moussa, née Zara Seybou	INRAN	Clerical	Niger	Wordperfect	Jan.	92	8	Niger
Mme. Seydou, née Maïmouna Mabeye	INRAN	Clerical	Niger	Wordperfect	Jan.	92	11	Niger
Mme. Hadiza Bissala	INRAN	Clerical	Niger	Wordperfect	Jan.	92	11	Niger
Aichatou Bouremia	INRAN	Clerical	Niger	Wordperfect	Jan.	92	11	Niger
Idé Alirou Maïga	INRAN/DRE	Res	Burkina Faso	Remote Sensing	Jan.	92	26	Africa

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Alassane Chetima	Génie Rural	GR	Burkina Faso	Remote Sensing	Feb.	92	22	Africa
Salifou Nouhou	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Abdourahamane Aissa	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Mamane Nansouba	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Moussa Mariama	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Madé Garba	INRAN	Tech	Niger	English	Feb.	92	2.1	Niger
Mourima Issoufou	INRAN	Res	Niger	English	Feb.	92	2.1	Niger
Traoré Syrau	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Boubacar Harcuna	INRAN	Tech	Niger	English	Feb.	92	2.1	Niger
Sani Alfa	INRAN Acctg.	Tech	Niger	English	Feb.	92	2.1	Niger
Maman Matto	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Gourouza Mounkaila	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Boubacar Idrissa	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Iddi Maria Kollo	INRAN/DSI	Tech	Niger	English	Feb.	92	2.1	Niger
Mahamadou Zeinabou	INRAN/DRE	Res	Niger	English	Feb.	92	2.1	Niger
Maidagi Mamane	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Sadi Aichatou	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Amadou Moustafa	INRAN/DRE	Res	Niger	English	Feb.	92	2.1	Niger
Chaibou Sodé	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Seydou Ramatou	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Aboubacar Halidou	INRAN/Kolo	Tech	Niger	English	Feb.	92	2.1	Niger
Adamou Hadiza	INRAN/DOC	Tech	Niger	English	Feb.	92	2.1	Niger
Adamou Moutari	INRAN/Kolo	Res	Niger	English	Feb.	92	2.1	Niger
Azia Amadou	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Beidari Fatouma	INRAN/DRE	Res	Niger	English	Feb.	92	2.1	Niger
Yahaya Dadé	INRAN/DSI	Tech	Niger	English	Feb.	92	2.1	Niger
Farmo Amadou	INRAN/DRE	Res	Niger	English	Feb.	92	2.1	Niger
Ibrahim Zanguina	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Kaka Saley	INRAN/DRE	Res	Niger	English	Feb.	92	2.1	Niger
Maliki Aissata	INRAN/DOC	Tech	Niger	English	Feb.	92	2.1	Niger

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in weeks	Location
Maman Nourri	INRAN/Kolo	Res	Niger	English	Feb.	92	2.1	Niger
Oumarou Idrissa	INRAN/DRE	Res	Niger	English	Feb.	92	2.1	Niger
Ousmane Iddi	INRAN/DSI	Tech	Niger	English	Feb.	92	2.1	Niger
Tahirou Abdoulaye	INRAN/DECOR	Res	Niger	English	Feb.	92	2.1	Niger
Daouda Moussa	INRAN/DRE	Tech	Niger	English	Feb.	92	2.1	Niger
Maikoudi Abdoulaye	INRAN/Ouallam	Tech	Niger (ICRISAT)	Experiment Station	Feb.	92	4	Niger
Mahaman Hamza	INRAN/Tarna	Tech	Niger (ICRISAT)	Experiment Station	Feb.	92	4	Niger
Bawa Illa	INRAN/Konni	Tech	Niger (ICRISAT)	Experiment Station	Feb.	92	4	Niger
Moumouni Siradji	INRAN/Tillabery	Tech	Niger (ICRISAT)	Experiment Station	Feb.	92	4	Niger
Idrissa Soumana	INRAN/Bonkoukou	Tech	Niger (ICRISAT)	Experiment Station	Feb.	92	4	Niger
Tanimou Daouda	INRAN/Bengou	Tech	Niger (ICRISAT)	Experiment Station	Feb.	92	4	Niger
Mahamadou Ouattara	INRAN/DS	Res	Netherlands	Res. Mgmt.	March	92	2	Other
Moussa Oumarou	INRAN/CERRA Niamey	Res	Netherlands	Scientific	March	92	2	Other
Salissou Aboubacar	INRAN/CLRV	Res	USA	Research-Extension	March	92	2	USA
Djingarey Hassane	INRAN/CLRV	Tech	USA	Research-Extension	March	92	2	USA
Djibo Banaou	MAE/DPA	MAE	USA	Research-Extension	March	92	2	USA
Kaminou Mallam Sidi	ONAHA	ONAHA	Niger (CPTP)	Mechanics	March	92	1	Niger
Harouna Yayé	ONAHA	ONAHA	Niger (CPTP)	Mechanics	March	92	1	Niger
Adamou Soumana	ONAHA	ONAHA	Niger (CPTP)	Mechanics	March	92	1	Niger
Harouna Alou	ONAHA	ONAHA	Niger (CPTP)	Mechanics	March	92	1	Niger
Sani Yahaya	ONAHA	ONAHA	Niger (CPTP)	Mechanics	March	92	1	Niger
Harouna Abdou	ONAHA	ONAHA	Niger (CPTP)	Mechanics	March	92	1	Niger
Eugene Kpeloussi	INRAN Direction	Clerical	Niger	Secretarial	April	92	1	Niger
Mariama Mahamane	INRAN Maradi	Clerical	Niger	Secretarial	April	92	1	Niger
Ali Yayé	INRAN Direction	Acc	Niger	Inventory Mgmt.	April	92	1	Niger
Mounkaila Tourouza	INRAN/CERRA Niamey	Acc	Niger	Inventory Mgmt.	April	92	1	Niger

Name	Affiliation	Personnel Category	Training Location	Subject	Start Date Month/Year		Length in Weeks	Location
Chekna Mohamend	INRAN/Maradi	Acc	Niger	Inventory Mgmt.	April	92	1	Niger
Gandah Madé	INRAN/Kolo	Acc	Niger	Inventory Mgmt.	April	92	1	Niger
Amadou Harouna	ONAHA	ONAHA	Niger (CPTP)	Mechanics	April	92	1	Niger
Moussa Abdou	ONAHA	ONAHA	Niger (CPTP)	Mechanics	April	92	1	Niger
Halidou Dodo	ONAHA	ONAHA	Niger (CPTP)	Mechanics	April	92	1	Niger
Amadou Sidikou	ONAHA	ONAHA	Niger (CPTP)	Mechanics	April	92	1	Niger
Mahamdou Soumaïla	ONAHA	ONAHA	Niger (CPTP)	Mechanics	April	92	1	Niger
Haogui Adamou	INRAN/DRA	Res	Morocco	Plant Pathology	April	92	8	Africa
Basso Adamou	INRAN/DRA	Res	Morocco	Plant Pathology	April	92	8	Africa
Boureima Monkaila	Génie Rural	GR	Burkina Faso	Const. Mgmt.	May	92	3	Africa
Souley Alou	Génie Rural	GR	Burkina Faso	Const. Mgmt.	May	92	3	Africa
Boubacar Akassa	Génie Rural	GR	Burkina Faso	Const. Mgmt.	May	92	3	Africa
Gregoire Mahamadou	Génie Rural	GR	Burkina Faso	Const. Mgmt.	May	92	3	Africa

6.4 Publications and Presentations

6.4.1 Publications

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THE UNIVERSITY OF NEBRASKA

NIGER APPLIED AGRICULTURAL RESEARCH PROJECT

(Contract AID 683-0256-C-00-8024-00)

PART II
FINAL TECHNICAL REPORT

June 1992

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AID Contract no. 683-0256-C-00-8024-00

Submitted by
Purdue University

in collaboration with:
Alabama A&M University
Winrock International
The University of Nebraska

To the
United States Agency
for International Development

June 30, 1992

PREFACE

During the life of the Niger Applied Agricultural Research Project (NAARP), a major goal was to strengthen INRAN's capacity to improve and implement multidisciplinary applied research programs. The NAAR Project attained this goal.

Part II of the final report summarizes the research results of collaborative work between INRAN research scientists and their NAARP technical assistant counterparts. Part II is technical in nature; administrative details of the project are found in Part I, which is a separate volume.

The NAAR Project was successful in assisting INRAN in the prioritizing, planning, and implementation of research programs in crop improvement, soil science, production systems, farming systems, irrigation water management and agronomy, and research-extension liaison. The results of studies in each programmatic area are summarized here. Some unpublished results are in more detail, while formal publications resulting from this and other programs, or from information previously published under this project, are provided. A list of published works may be found in Appendix 6.4 of the Final Administrative Report.

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Drs. Lowenberg-DeBoer and Norman, and to a lesser extent, Dr. Hebert, contributed to Section 2, while Dr. Clark was the sole contributor to the section on crop improvement. Dr. Berrada reported on the soils research and Dr. Reddy was responsible for the section concerning production systems.

The section dealing with farming systems research and the related sociological aspects were contributions of Dr. Lowenberg-DeBoer and Mme. H. Zarafi, respectively.

Drs. Norman and Prashar contributed the information concerning irrigation and water use management and agronomy, and Dr. Christine Okali presents the results of her extension liaison studies.

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LIST OF ACRONYMS

APS	Agricultural Production Support
ARDETEC	Agricultural Equipment and Rural Technologies Workshop
CARE (Niger)	Cooperative for American Relief Everywhere
CEC	Cation exchange capacity
CFDT	*Compagnie de développement des textiles* (Textile Development Company)
CRSP	Collaborative research support project
CV	Coefficient of variation
DAP	Days after planting
DCB	Diothionite-Citrate-Bicarbonate
DDA	*Direction départementale de l'agriculture* (Department of Agriculture Headquarters)
DECOR	Department of Agricultural Economics
DRA	*Département de recherches agronomiques* (Department of Agronomic Research)
DRE	*Département de recherches écologiques*(Department of Ecological Research)
DSI	*Département de statistique et l'informatique (*Statistical Information Services)
ECEC	Effective cation exchange capacity
FAO	Food and Agricultural Organization (United Nations)
FCFA	African Financial Community francs
GERDAT	*Groupement d'études et de recherches pour le développement de l'agriculture tropicale* (Research Group for the Development of Tropical Agriculture)
GMP	*Groupe mutuel de production* (Mutual production group)
GON	Government of Niger
GRET	*Groupe de recherche et d'échange technologique* (Research and Technology Exchange Group)
GTZ	German International Aid Program
ICRISAT	International Crops Research in the Semi-Arid Tropics
IFDC	International Fertilizer Development Center
IIMI	International Irrigation Management Institute
INRAN	*Institut national de recherches agronomiques du Niger* (National Agronomic Research Institute of Niger)
INTSORMIL	International Sorghum/Millet Research
IPDR	*Institut pratique pour le développement Rural* (Institute for Rural Development)
IRAT	*Institut des recherches agronomiques tropicales*
LGS	Length of growing season
LSD	Least significant difference
NAARP	Niger Applied Agricultural Research Project
NCRP	Niger Cereals Research Project
NGO/PVO	Nongovernmental organization/private voluntary organization
ONAHA	*Office national des aménagements hydro-agricoles* (National Office of Irrigated Agricultural Improvement)
PEN	*Programme engrais nigérien* (Nigerien Fertilizer Program)
PRSAA	*Programme de renforcement des services d'appui à l'agriculture* (Agricultural Extension Support Project)
REDSO	Regional Economic Development Services Office (USAID)
RELU	Research-Extension Liaison Unit
SAFGRAD	Semi-Arid Food Grain Research and Development
SD	Standard error of the mean

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SEHA	*Station expérimentale hydro-agricole* (Irrigated Agriculture Experimental Station)
SNV	Dutch development agency
SSP	Super simple phosphate
TA	Technical assistant
TAT	Technical assistance team
TROPSOILS	Soil Management Collaborative Research Support Program
TRP	Tahoua rock phosphate
TSMM	Technology for Soil Moisture Management
TSP	Triple super phosphate
ULV	Ultra low volume

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PART II
FINAL TECHNICAL REPORT

1 INTRODUCTION

1.1 Limited Resources for Agricultural Productivity

Niger is a land-locked country which includes and borders a large part of the Sahara Desert. Bordered on the south by Nigeria and Benin, it is located some 600 kilometers from the Atlantic Ocean. The FAO (Food & Agricultural Organization of the United Nations) divides the estimated 126.7 million ha constituting Niger as in Table 1-1. Arable land is estimated to be less than 11 million ha (Ancey *et al.*, 1987). In theory, agriculture could be practiced in the regions of 300 mm of rainfall or more; however, constraints due to soil quality limit effective agricultural practices to considerably less area than that receiving nonlimiting rainfall.

TABLE 1-1
MAJOR ECOLOGICAL ZONES OF NIGER AND THEIR EXTENT ('000 ha)[1]

Ecological zones	Annual rainfall (mm)[2] (probability=90%)	Area ('000 ha)	Percent of total
Saharian	less than 200	82.35	65.0
Saharo-sahelian	200-300	15.40	12.2
Sahelian	300-350	15.34	12.1
Sahelo-soudanian	350-600	12.37	9.8
Soudanian	more than 600	1.24	0.9
Niger total		126.70	100.0

[1]Ancey *et al.*, 1987
[2]Rainfall likely to occur with probability greater than 90%.

Table 1-2 provides a distribution of the various soil types in Niger, based on regional research conducted by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Seventy-three per cent of the arable lands are arenosols, which are characterized as mostly sandy and light textured. For the most part, agriculture practiced on these soils is rainfed.

The potential for irrigation is limited to areas along the Niger River, ponds, and dallols (fossil river valleys). This potential is provided in Table 1-3 and given by department (Ancey *et al.*, 1987). While the potential for expanding irrigation is considerable, the costs for such endeavors appears to be quite high.

Irrigated agriculture (less than one per cent of arable land) remains a minor part of Nigerien agriculture and affects only a limited number of Nigerien farmers. However, if Nigerien agricultural productivity in both agronomic and horticultural crops is to increase, irrigation of suitable lands offers a

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means to accomplish the objective. Thus, the two major constraints to agricultural productivity in Niger are considered to be soil and water.

TABLE 1-2
MAJOR SOIL UNITS AND THEIR APPROXIMATE EXTENT ('000) IN AGRI-ECOLOGICAL ZONES OF NIGER, DEFINED IN TERMS OF LENGTH OF GROWING SEASON (LGS)[1]

Soils	Southern Sahelian LGS = 60-100 days	Sudanian LGS = 100-150 days
Arenosols	8710	28
Fluvisols	145	-
Gleysols	295	-
Luvisols	900	118
Vertisols	410	38
Cambisols	380	-
Planosols	23	-
Regosols	808	85
Total	11671	269

[1]Sivakumar 1988.

TABLE 1-3
THE IRRIGATED SECTOR IN NIGER, BY DEPARTMENT ('000 ha)[1]

Department	Potential		Developed and Rehabilitated ('000 ha)
	Total ('000 ha)	Identified ('000 ha)	
Niamey (River)	140	32.5	6.8
Dosso (Dallols)	40	7.6	3.0
Tahoua (Ader Maggia)	28	5.3	1.1
Maradi (Goulbis)	11	10.4	1.8
Diffa (Komadougou)	50	3.0	0.5
Agadez (Aïr Mountain)	3	2.5	0.5
Total	272	61.3	12.9

[1]after Ancey *et al.*, 1987.

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1.2 The Niger Applied Agricultural Research Project (NAARP) and INRAN

The Niger Applied Agricultural Research Project (NAARP) was designed as phase two of the Niger Cereals Research Project (NCRP), authorized in 1982 and scheduled to be completed in 1988. The purpose of the NCR Project was to develop the Nigerian National Agronomic Research Institute's (INRAN) capacity to undertake cereals research programs whose results can be effectively disseminated to farmers through existing extension and cooperative systems. NCR project activities focused on three broad areas: 1) growth and development of INRAN's capacity to manage its research programs,resources and linkages to other institutions; 2) growth and development of INRAN's ability to support its research efforts through support service functions, i.e., soil and plant analysis, food grain quality analysis, data handling and statistical analysis, library and documentation services; and 3) growth and development of specific activities oriented toward the development of a comprehensive, integrated and systematic approach to research. With NCR project support, INRAN began to develop the strong foundation upon which an effective national research institute must be built.

The purpose of the Niger Applied Agricultural Research Project was to institutionalize a system of applied agricultural research with strong functional linkages to extension. NAARP continued NCRP efforts, building directly on progress made under NCRP. Under NAARP, greater emphasis was placed on strengthening the Institute's overall management capability. Institutional cross linkages with technical services, cooperatives and other agricultural research organizations were reinforced. The creation of strong linkages with extension services was a major objective. The project continued to support research programs initiated under NCRP and to further develop research support services. Whereas NCRP limited its research efforts to rainfed crops, this project also helped develop INRAN's capacity to conduct applied research on priority problems in irrigated agriculture.

Project activities focused on the following three areas:

1) Development of INRAN's capacity to design, administer, manage, and carry out applied agricultural research programs through the development of improved planning and management practices, carefully programmed human resource development and further strengthening of research support services.

2) Development of specific multidisciplinary research programs designed to address priority constraints on production of Niger's principal rainfed and irrigated food crops. Technical themes were within these four interrelated areas:

   a) **Crop Improvement.** Multidisciplinary team research built upon ongoing research efforts to explore classical plant, soils, water, climate relationships for the principal rainfed and irrigated crops grown in Niger. Breeders, entomologists, agronomists, agro-economists, and cereals quality experts worked to clarify constraints to expanding productivity in each crop and to develop knowledge and plant materials designed to overcome these constraints.

   b) **Production Systems.** Multidisciplinary team research developed crop and site-specific systems of cultural practices and appropriate technological innovations for dryland and irrigated crop production in at least three distinctive agro-ecologic zones. Work focused on the development of recommendations for crop rotation, intercropping, fertilizer use, time of planting, seeding techniques, plant density and spacing, weeding, pest control, and included agro-economic analyses of cost and efficiency.

c) **On-farm Research.** A modified on-farm research program which built on the considerable work of the Rural Economics Department (DECOR) became an increasingly important part of project activities.

d) **Water Management.** The Irrigation Section of the Division of Ecological Research (DRE) of INRAN worked closely with ONAHA's (*Office National d'Aménagement Hydo-Agricole* - National Office for Irrigated Agricultural Development) Applied Research Unit and the Rural Engineering Service to initiate a multi-disciplinary attack on the priority problem areas of irrigation water quantity and quality control, water application methods and water application efficiency. Systems and farm level efficiencies in each of these areas were a central focus of research.

3) Development of functional linkages between INRAN, Extension, and other agricultural services by promoting increased participation of the extension services in the planning and execution of research and in the development, delivery, and evaluation of technical recommendations. The project helped develop the capacity of INRAN's Research-Extension Liaison Unit (RELU) to provide extension services with timely, acceptable and useful information.

2 DEVELOPMENT OF INRAN'S CAPACITY TO IMPROVE AND IMPLEMENT RESEARCH PROGRAMS

2.1 Research Management and Planning

Most recently, the NAARP Chief of Party, Dr. Jess Lowenberg-DeBoer, represented NAARP at the series of meetings (January, February 1991) which determined how the INRAN reorganization plan was to be implemented. He then participated in the INRAN biennial meeting May 6-10, 1991, making a presentation on project resources available for the 1991 crop season on May 9. An important objective of the biennial meeting was to introduce and explain the reorganization plan to INRAN researchers. See Section 2.3 of the administrative portion of this report for a fuller explanation of this reorganization.

He also participated in the workshop on implementation of the Niger long- and medium-term agricultural research plans at Tillabery, from late January-early February, and at the follow-up workshop to implement the recommendations of the Tillabery meeting.

Dr. Lowenberg-DeBoer's predecessor, Dr. Paul Hebert, served as an advisor to the Director General with regard to both long-term and annual research plans for INRAN. The Government of Niger (GON) Ministry of Agriculture assumes responsibility for the establishment of the long-term (Five-Year National Development Plan) and annual research plans of the Ministry. The latter plans were developed during the course of annual week-long meetings of key personnel of the Ministry, including senior INRAN administrators and department heads. INRAN, as the national agronomic research institute, is responsible for implementation of these plans.

Dr. Hebert also played a role in the INRAN annual/biennial long-term research planning meetings.

As COP, Dr. Hebert and Dr. Lowenberg-DeBoer advised the INRAN Director General on administrative matters dealing with budgeting, fiscal integrity, procurement, special studies concerned with logistical support for research as well as the preparation of INRAN and NAARP research documentation.

2.2 Irrigation Water Management Research Programs and Planning Process

The irrigation water management research program under NAARP differed considerably from other research programs within INRAN. Previous to NAARP, little significant research in irrigation water management had been conducted, and an irrigation research program had not yet been institutionalized. Thus, NAARP'S obligation to INRAN was not to improve an on-going program, but rather to initiate the institutionalization of an entirely new program. Under the USAID/INRAN agreement for NAARP, INRAN established the Irrigation Section within DRE (Department of Ecological Research). NAARP technical assistance attached to the Irrigation Section, together with INRAN counterparts, then had the task of establishing a viable water management research program for the Section.

Since there was little previous groundwork laid in the water management discipline, the first months of NAARP were given to careful assessment of research priorities for the program. The first step involved an assessment of water management-related research needs in the country. This was achieved through initial field diagnostic studies of state and private irrigation systems (both large- and small-scale), literature search and reviews, and consultations with ONAHA and NGO/PVO (nongovernmental organization/private voluntary organization) personnel involved in irrigation work. Once a range of preliminary research needs had been assessed, the second step was the selection and establishment of research programs. This second step was based on several criteria; primarily, the priority and need of each research program, and the capacity of INRAN to carry out each program. INRAN's anticipated capacity, in terms of trained staff,

necessary equipment and financial resources available to the Irrigation Section were evaluated and the research programs were matched accordingly.

The principal research programs in water management carried out under NAARP are listed in the order of priority in which they were pursued.

1) Irrigation Water Use Database Collection Program.
2) Water Lifting Studies Among Microsystems.
3) Water Use and System Diagnostic Studies.
4) Water Scheduling Program For Irrigated Perimeters.

Once these programs were established, the ability of NAARP to pursue them in full was dependent on the availability of INRAN staffing, a sufficient Section budget allocation, and the timely procurement of research equipment. As each of these programs were initiated and carried out, they were adjusted and refined in a continual effort to adapt to various constraints encountered during the life of the project. (Each of these programs is discussed in greater detail in Section 3.5 of this report.)

Another aspect of research planning was to establish a number of long-term research programs and activities, matched to the developed capacity of the Irrigation Section, which could be continued during the post-NAARP period. The Irrigation Water Use Database program was established in order to acquire several years worth of baseline data on irrigation water use in the country, in order to characterize the county's irrigation systems. After three years the field data retrieval aspect of this program was halted and the data was compiled and put on file at the Irrigation Section. This database will thus serve in a supportive role to on-going research endeavors, as well as to others initiated in the years ahead. The Water Lifting program was very successful under NAARP and an evaluation team from the Section has been trained and left in place. It is, thus, anticipated that as new microsystem activities and developments occur in Niger, the Irrigation Section can provide evaluation services for water management among irrigated microsystems. It is also anticipated Water Use and Diagnostic Studies will continue, particularly within the larger ONAHA perimeters upon request and/or as the need arises. However, this program will likely be continued in close collaboration with the new International Irrigation Management Institute (IIMI) program, recently established in Niger. Efforts during the last months of NAARP were made to strengthen this linkage in anticipation of continued pursuit of diagnostic work among perimeters. The Water Scheduling program was initiated under NAARP and all of the baseline research and data collection needed for calibration of the program has been completed. The Irrigation Section presently has the trained capacity developed under NAARP (in terms of staff) and the necessary equipment and data (also acquired under NAARP) to continue and eventually complete this program in the years ahead. Its functional continuation is dependent on the future means of the Section (primarily financial) and on continued cooperation and collaboration with ONAHA personnel. (Frequent changes in ONAHA personnel during the NAARP period often hampered the progress of this program.)

2.3 Financial Management/Irrigation Section Budgeting

With the establishment of the Irrigation Section, the new staff assigned to the Section had little exposure to irrigation research programs and their related costs. Time was devoted on several occasions to working with Section and DRE personnel in establishing the Irrigation Section's annual operating budget. Effort was given to helping staff evaluate means of reducing overall costs by combining field activities of different research programs.

2.4 Equipment Procurement and Inventory for the Irrigation Section

During the first year of NAARP, Dr. Norman worked together with the Head of DRE, the Irrigation Section Head, and Dr. Berrada to develop a comprehensive list of research material needed to implement the anticipated irrigation research program. This involved the identification of various sources of research equipment and the matching of that equipment to specific field needs. A full range of computer-related equipment was also selected for the Irrigation Section, as well. This effort was completed within the first months of in-country arrival, however, considerable delays were experienced in both the process by which the equipment order was expedited and the process by which it was received and distributed (to Maradi) by INRAN. Although efforts were repeatedly made to reduce these delays, they were effectively beyond the control of the Irrigation Section personnel located in Maradi. The delay of more than a year in actually obtaining the equipment, however, did result in setbacks in initiating several components of the research program. Once the equipment was received in Maradi, a careful inventory of the equipment was made and is presently kept on file within the Section. The need for sufficient storage room for much of the field and computer equipment was negotiated with the INRAN station director at Maradi, and was eventually granted. In addition to storage facilities, a small computer room/facility was also established at the same location for the exclusive use of the Irrigation Section.

2.5 Irrigation Rehabilitation Activity

During the first 28 months significant time was devoted to the organizational and engineering aspects of the anticipated irrigation rehabilitation of INRAN's experiment stations. As mentioned, Norman's primary role was that of serving on the Comité de Pilotage as the primary spokesman for this activity and that of serving as a liaison between INRAN and *Génie Rural* (Agricultural Engineering) in overseeing the engineering design aspects of the activity. Several months were spent working with engineers Mr. Moussa Seyni (*Génie Rural*) and Mr. Ibrahim Djido (ONAHA) in preparing the design specifications and blueprints. This aspect was also coordinated with Mr. Solomon Atiase of USAID/REDSO (Regional Economic Development Services Office), Abidjan and involved a reconnaissance trip to Abidjan to inventory the local availability of irrigation equipment and construction materials. Norman then worked with *Génie Rural* and USAID in the bidding process for tubewell construction. Once the contractor was selected, Norman oversaw the siting, well-drilling, and well testing activities with the drilling firm (SOREIS) and "Hydraulique". Subsequent to this the rehabilitation activity was put on hold by USAID. About 10-20% of Norman's time was devoted to this activity during the first two years of NAARP.

3 DEVELOPMENT OF SPECIFIC MULTIDISCIPLINARY RESEARCH PROGRAMS

The following is a presentation of the technical accomplishments under the auspices of the NAAR Project. Each presentation covers the three plus years of activities by each member of the technical assistance team.

3.1 Crop Improvement

3.1.1 Sorghum Breeding

Due largely to the long-term training component of NCRP and NAARP, INRAN has a well-trained team of researchers working in sorghum improvement. A list of national staff involved with some aspect of sorghum research is found in Table 3.1-1. Except for the plant breeder, who works full-time on sorghum, most of the other staff devote about half their time to sorghum research and half to another crop, usually millet. This group, plus the head of RELU, Mr. Salissou, and NAAR plant breeder, Dr. John Clark, met at Kolo in April 1992 to plan research activities for the 1992 crop season. Under the chairmanship of DRA head, Dr. Moussa Adamou, research proposals were presented, discussed, amended, and approved by the group.

TABLE 3.1-1
RESEARCH PERSONNEL OF SORGHUM IMPROVEMENT PROGRAM

Research Area	Name	Degree (Location)
Breeding:	Moussa Adamou	PhD (Kolo)[2,3,4,5]
	Issoufou Kapran	MS (Tarna)[1,3,4,5]
Agronomy:	Cherif A. Oumarou	MS (Tarna)[3,4,5]
	Mamane Nouri	MS (Kolo)[5]
Entomology:	Seyni Maiga	PhD (Kolo)[5]
	Hame Kadi Kadi	MS (Tarna)[3,5]
Plant Pathology:	Abdourhamane I. Kolo	MS (Kolo)[3,5]
	Adamou Basso	MS (Tarna)
Cereal Quality:	Moussa Oumarou	MS (Niamey)[5]
	Adam Mamoudou	MS (Niamey)[3,4]
DECOR:	Abdoulaye Tahirou	BS (Niamey)[5]
DRE:	Fatima Beidari	MS (Niamey)[5]

[1]Sorghum program coordinator.
[2]Head of DRA; should be considered as a resource person, not an active breeder.
[3]Long-term U.S. degree training under NCRP or NAARP.
[4]Did in-country thesis research.
[5]Received one or more short-term training courses under NAARP.

Certain research programs in sorghum improvement have been well institutionalized, particularly in plant breeding, cereal quality, and resistance to *Striga* and long smut. INRAN's sorghum program has

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been designated as one of five advanced centers for research by the 17 member-country SAFGRAD Sorghum Research Network for Central and West Africa. INRAN receives modest financial support from the Network to reinforce research in cereal quality and resistance to long smut.

INRAN has contributed entries to ICRISAT's regional variety trials (short cycle and long cycle), hybrid trial disease, and *Striga* resistance nurseries. The two hybrids provided by INRAN represent the only contributions by a national program in the regional network. All other hybrids in the regional trial were produced by ICRISAT's Regional Sorghum Center in Kano, Nigeria. INRAN has provided, by request, sorghum breeding lines to the national programs of Nigeria, Mali, Togo, the Cameroon, and Mauritania, as well as to the ICRISAT Centers in Mali and Nigeria.

The 1992 work plan for the sorghum breeding section developed by Clark, Kapran, and Moussa Adamou is found in Table 3.1-2. The number of activities of the overall program is approximately the same as in past years, although the number of pedigree selections at Kolo will be reduced because of Clark's impending departure. It was felt that the two Kolo technicians were capable of continuing the program at Kolo with periodic visits by Mr. Kapran and assistance from Dr. Adamou, when needed. It would be extremely helpful if INTSORMIL (International Sorghum/Millet Research) could send a sorghum breeder from the U.S. prior to harvest to take notes on the trials and make selections at Kolo.

The sorghum research program was not drastically reduced in 1991, as were many of INRAN's research activities, because some financial and logistical support was received from the NAARP local office. The sorghum program also benefitted from its collaboration with INTSORMIL, which provided a modest amount of financial assistance that was both useful and timely.

TABLE 3.1-2
INRAN/DRA SORGHUM BREEDING WORK PLAN FOR 1992 CROP SEASON

A. SELECTIONS (Sites: Kolo, Tarna)
- new crosses on A lines and by plastic bag, including a pollen freezing test.
- pedigree: F1 - Fn.
- populations: random mating of SPK, SPT, followed by S1 testing.
- maintenance: maintain varietal purity: A4D4, L-30, 1/2 MSB, MM, MG, DK, HB, MDK, MDW, Sepon 82, SRN39, MR-732, 90SN-7, various A/B lines.
- maintenance and morphological description of 407 Nigerien varieties from ICRISAT in India.

B. TRIALS.
- observation collection of improved varieties from Tarna (COVAT): 60 F5s derived from SRN39. Sites: Kolo, Konni, Tarna.
- observation collection of elite TAMU lines (Miller): 40 lines (TX2818 - TX2857) Site: Tarna.
- observation collection of lines resistant to shootfly (ICRISAT-India) 60 lines. Site: Tarna (Entomology and Breeding).
- observation collection of lines resistant to stem borers (ICRISAT-India): 69 lines. Site: Tarna (Entomology and Breeding).

- observation collection of lines resistant to grain mold (ICRISAT-India): 156 lines. Site: Tarna (Pathology and Breeding)
- observation collection of lines resistant to midge (TAMU): 25 lines. Sites: Tarna, Konni (Entomology and Breeding).
- observation collection of lines resistant to head bugs (TAMU): 18 lines, 14 derived from MALISOR84-7. Sites: Tarna, Konni, Bengou (Entomology and Breeding).
- preliminary local variety trial: retest 9 varieties from 1991. Sites: Kolo, Tarna.
- advanced local variety trial: retest 7 varieties from 1991. Sites: Kolo. Tarna, Tillabery, Bengou, Konni, Diffa.
- preliminary improved and introduced variety trial: 34 lines, including 91 TF-8, 2 checks, and 31 best lines of EPVAI91. Sites: Kolo, Tarna.
- advanced improved and introduced variety trial: retest 11 lines from 1991. Sites: Kolo, Tarna, Bengou, Tillabery, Konni, Diffa.
- hybrid observation collection: 84 new F1s, including 47 from Tarna and 37 from Kolo. Sites: Kolo, Tarna.
- preliminary hybrid trial: 5 hybrids tested in EPH91. Sites: Kolo, Tarna.
- cooperative trials:
  a) INRAN Entomology: entomological evaluation of new pedigree selections; varietal performance vis-à-vis midge and headbugs (see observation collections).
  b) INRAN Plant Pathology: pathological evaluation of new pedigree selections; evaluation of descendants of SRN39 (see observation collections); performance against long smut.
  c) INRAN General Agronomy: determination of agronomic practices adapted to improved material.
  d) INRAN Irrigation/Agronomy: trial on influence of planting dates and supplemental irrigation on improved varieties.
  e) INRAN DECOR: follow up of demonstrations in the Maradi region; test of SRN39, SEPON82 and demonstration with NAD-1 in the Konni zone.
  f) INRAN Cereal Quality: seed production of elite lines from sorghum network (6), 90SN-1 to 90SN-5, NAD-1 for food quality tests.
  g) Demonstrations: SEPON-82, NAD-1. In cooperation with RELU and interested DDA's; for NAD-1 large plots on Tarna station, large plots on Konni perimeter (in charge: INRAN Konni head); on-farm trial of 5 lines in advanced trial (90SN-1 to 90SN-5) in cooperation with Maradi DDA and others.
  h) INTSORMIL: adaptation test of elite lines, grain yield and quality; study on drought resistance to *Striga*, others (see Observation Collections).
  i) ICRISAT: variety trials with WASIP-Kano (Tarna); CCRN trial of ecological site characterization (Tarna); ISVHAT (Bengou).
  j) ROCARS/SAFGRAD: variety trials WASVAT (cc and cm); WASHAT.

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3.1.1.1 Main Research Results

The principal outputs of a plant breeding program are not abstract technical reports replete with statistical analyses, data tables, graphs, and figures, but tangible products of plant material. Among the end products of the NAARP sorghum breeding activity, which promulgated the NCRP effort, are three new sorghum varieties recommended for Nigerien farmers. They are:

SEPON-82 - a high yielding variety suitable for either rainfed or irrigated production systems.

SRN-39 - a *Striga*-resistant variety for production in those areas where *Striga hermonthica*, a very serious parasitic weed pest of sorghum, is a constraint to sorghum production.

ATx632xMR732 F1 - a F1 hybrid for rainfed and irrigated production systems with both stable and high yield characteristics.

A limiting factor in the future production of seed of NAD-1 is the lack of a commercial seed industry in Niger. The governmental seed production effort at the Lossa Foundation Seed Farm is inadequate to produce significant quantities of hybrid seed. The Seed Farm lacks both sufficient trained personnel, as well as sufficient land area, to produce a hybrid sorghum, in addition to seed of open pollinated sorghum, plus millet and cowpea varieties.

In the on-farm trials of DECOR in the Birni N'Konni region, where the variety SRN39 would be most advantageous, farmers have expressed concern about a problem of poor emergence with this variety. Farmers at the test sites readily recognized the *Striga* resistance of this variety expressed by a highly visible reduction in numbers of *Striga* plants on plots of SRN39, compared to plots of other varieties. Additional on-farm tests, including other villages and departments, are needed to determine if poor emergence will be a continuing disadvantage of this variety. At a half dozen sites in different regions of Niger during seven previous years of testing, poor emergence was not found to be a significant problem affecting the performance of SRN39. These test sites included the INRAN station at Konni and a farmer's field on the Konni perimeter. Variety SRN39 has one intrinsic characteristic rendering it susceptible to factors which reduce germination, a relatively soft, floury endosperm.

Seed with a soft endosperm seems to receive greater damage from headbugs and grain mold than seed with a hard endosperm. The NAARP and INRAN sorghum breeders have never maintained that variety SRN39 was superior to most local varieties, except where *Striga* was a limiting factor. Among nine resistant varieties in a regional ICRISAT trial throughout the Sahel, SRN39 was consistently the most resistant to *Striga*, but lowest in yield. The NAARP and INRAN sorghum breeders began a pedigree selection program in 1988 between SRN39 and elite varieties, and a hybrid evaluation program in 1989, to improve on the productivity of SRN39, while maintaining strong *Striga* resistance.

Variety Sepon-82 does not appear to have similar limitations on its production and adoption by farmers. The Ministry of Agriculture's Seed Production Service has requested 80 kg of breeder's seed of this variety for 1992 (sufficient to plant 8-10 ha). INRAN will only be able to supply approximately 40 kg of high-quality breeder's seed because of severe bird damage to a seed production field at the Tillabery station during the 1991-92 off-season. Still, at a lower plant density, this quantity of seed could plant 6-8 ha of seed multiplication fields. The Lossa Seed Farm produced nearly 4 tons of Sepon-82 seed in 1991. Test results for seed germination and purity of M-1 sorghum seed produced in 1991 follow:

Variety	Date of Test	% Seed Purity	% Normal Germination
Sepon-82	Dec. 14, 1991	94.70	92.75
SRN39	Dec. 31, 1991	93.30	77.50
NAD-1	Dec. 31, 1991	94.70	88.50

These test figures are within an acceptable range by most seed industry standards, except for the germination rate of SRN39. The germination rate of this early variety could be improved by treatment for head bugs and/or later planting (August), with supplemental irrigation to avoid late rains and grain mold.

The stability of crop yields is an appropriately abiding concern of plant breeders, seed producers, and farmers alike. Mr. Piet Visser, of INRAN's General Agronomy Section, statistically analyzed the yield stability of Sepon-82, SRN39, and NAD-1 in comparison with local variety checks. He used data from both on-station and on-farm yield trials from 1986 to 1991. The number of different environments (a combination of years and locations) analyzed was 67 for Sepon-82, 36 for SRN39, and 27 for NAD-1. He found that on average, Sepon-82 and NAD-1 were both higher yielding and at least as stable as the local checks. He also found that the yield of SRN39 was equal to the local checks in fields without *Striga* and significantly better in *Striga*-infested fields. This paper will be published in the 1992 issue of the *Sorghum Newsletter*.

The on-going sorghum breeding program will reap future benefits in terms of improved sorghum varieties with high, stable yields of good grain quality and resistance to various diseases and insects. The current program involves three breeding techniques or strategies: pedigree selection, F1 development and evaluation, and recurrent selection with two random mating populations. In breeding for resistance to various stresses, the sorghum improvement team is screening for resistance to drought, long smut, head bugs, midge, shootfly, and *Striga*. Germplasm introduction and evaluation remain an important component of the breeding program.

New techniques in cultural practices and disease and insect control, which will enhance yields and yield stability, can be expected from the agronomy and plant protection specialists.

The strong emphasis of NCRP and NAARP on participant training has provided the sorghum research program with new, well-trained personnel. The addition of new research staff in plant protection increases the likelihood that new varieties will be produced that are resistant to important pests (see Table 3.1-2 for a list of new, resistant germplasm to be screened in 1992). After experimenting with different techniques for three years, the U.S.-trained plant pathologist at Kolo, Mr. Issoufou Kolo, has recently perfected an inoculation technique for long smut. Previously, breeders had to select for resistance under erratic natural infestations, a very uncertain undertaking at best. There is now a very realistic chance that a long smut-resistant variety or varieties will be produced in Niger in the near future. In his initial screening, Mr. Kolo found that a local variety, Tera, previously thought to be resistant was, in fact, susceptible. This very early variety, which had shown very little or no signs of smut during the past five years, had apparently escaped the disease inoculum because of its earliness. A more positive finding was that the new variety Sepon-82 has somewhat more resistant to long smut than local varieties.

3.1.1.2 Recommendations and Final Comments

The first, and most compelling, recommendation is that the talented national sorghum breeder, Mr. Issoufou Kapran, be permitted to return to the U.S. to pursue a PhD degree in the very near future.

Although the size and quality of the sorghum research program would undoubtedly suffer in his absence, in the long term the additional knowledge and experience to be gained from PhD training would greatly benefit INRAN as a research institute in general, and the sorghum program in particular.

A second recommendation is that INRAN's sorghum program should continue its collaboration with INTSORMIL, ICRISAT, and the regional sorghum network. They are excellent sources of high quality technical assistance, valuable germplasm, and information. INTSORMIL should be encouraged to continue its technical assistance visits in order to assist Mr. Kapran and the Kolo technicians in nursery evaluation and in making selections prior to harvest. Such visits by INTSORMIL sorghum breeders would be needed even more in the event of Mr. Kapran's departure for PhD study. The value of INTSORMIL and ICRISAT cooperation is not limited to breeding, but encompasses all areas of research in sorghum improvement.

The third recommendation is that INRAN reactivate the scientific working groups. The groups performed a useful function for the evaluation and monitoring of research activities, as well as stimulating scientific interest and debate. An alternative is to formalize the recently established commodity groups (like those in sorghum and millet) and assign them the tasks formerly given to the working groups. The best-qualified and dedicated individual should be appointed as coordinator to lead the group, whether Nigerien or expatriate.

Despite the misgivings of administrators, extension workers, economists, sociologists, and fellow plant breeders, the INRAN and NAARP sorghum breeding team of Dr. Adamou, Mr. Kapran, and Clark have maintained a reasonable and constant proportional effort to hybrid development since the mid 1980s. The technical and economic constraints to hybrid seed production and the socio-economic issues of farmer acceptance of hybrids in a developing country are real and important, but so are the advantages of hybrids. There is no doubt that, on average, hybrids are superior to open-pollinated varieties, both in terms of yield and yield stability. The yield stability of hybrids is especially valid and relevant where severe stresses occur, as they do in Niger. An emerging hybrid sorghum seed industry already exists in Nigeria and Côte d'Ivoire. That is more than a premonition. Hybrids are the wave of the future, even in the Sahel and other regions, where harsh climates and resource-poor, developing-country conditions prevail.

3.2 Soil Science

3.2.1 Diagnostic Study of the Perimeters

3.2.1.1 Djiratawa Perimeter

The irrigated perimeter of Djiratawa was started in 1981. It occupies about 512 ha of land, divided into 48 blocks. Each block has a deep well, which provides water for an area of 8 to 13 ha. Only 44 wells were in working condition at the time of the survey. Each well is equipped with a submersible pump, which receives its power from an electric grid. Water is conveyed to the fields through open channels. The basic land unit is made up of two plots of 0.16 ha each.

The perimeter has about 1300 farmers grouped into four co-operatives. Each farmer exploits a minimum of two 0.16-ha plots. Farmer selection is based on a set of criteria such as age, marital status, and place of residence. Farmers do not own the land, but they can pass it on to their heirs when they die.

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Average annual rainfall is about 500 mm in the region, and mean temperature is about 27°C. The rainy season usually lasts four months (June-September). The period from November through February is called the cool, dry season, and from March through May, the hot, dry season. The lowest temperatures (≤ 5°C) are usually recorded in December and January. The maximum temperatures in April and May can exceed 40°C.

The irrigated perimeter of Djiratawa is located in the Goulbi valley, and, thus, most of its soils are of alluvial nature. The dominant soils are sandy loams and loamy sands, with limited areas of sandy-clay loams. They may be classified as Alfisols, Fluvents, and Psamments in the U.S. system. There is no precise soil map of the perimeter.

Crops grown during the rainy season are mainly cotton and sorghum. Each 0.32 ha holding is divided into two equal soles. Crop rotation within each sole is as follows:

Sole 1: Sorghum (June-October) - Wheat (November-February) - Cotton
Sole 2: Cotton (June-February) - Sorghum

Farmers used to grow peanuts after cotton during the dry hot season, but not anymore, because of the excessive cost of electricity for pumping water.

Sorghum is sometimes replaced with millet on sandy soils. Other crops, e.g., corn and onions, may be grown along the waterways or in tiny patches of land. Wheat is irrigated once a week during the vegetative growth stage and twice a week during the reproductive stage. Cotton and sorghum receive supplemental irrigation during dry periods.

An important consideration in "leasing" land to farmers is whether or not they pay their dues regularly. Land can be taken away from any farmer who did not pay his dues and be given to a potential applicant. This is one reason why there is a high turnover in land "ownership", given the high cost of electricity. This may also explain why a number of plots are abandoned by farmers each year.

Fertilizers and wheat seeds are provided to the farmers by the local cooperative as a loan payable after crop harvest. Cotton seeds are provided by the cotton processing plant in Madaoua. Seeds for most other crops (sorghum, millet, cowpea, etc.) are produced by the farmers themselves.

This report deals mainly with the agronomic constraints to crop production. Other constraints are discussed in reports by other members of the multi-disciplinary team which carried out the diagnostic study.

Crop yields obtained at Djiratawa are high, compared with similar crops, e.g. sorghum and millet, grown on nonirrigated soils. But these yields are often below potential. For example, sorghum yield averaged about 2000 kg/ha in 1987, while the potential yield was over 3000 kg/ha. Several constraints may be responsible for this discrepancy. The most important ones are:

- The sole occupied by cotton is not freed until March or later. Farmers continue to irrigate and harvest cotton for several weeks after the recommended cut-off date (end of November). No study has been done to evaluate the consequences of extending the cotton cycle for nine to ten months, on crop yield, soil fertility, etc. Some of the consequences may be: less time for land preparation, higher demand on soil fertility and moisture, and more opportunity for the proliferation of diseases, insects, and weeds.

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- There is very little information on wheat varieties used at Djiratawa or elsewhere in Niger. This is because there is no wheat breeding, or at least variety screening program. Some varieties, e.g. Florence Aurore and Pranquel, have been used since 1981, but their yield potential is limited. Others varieties have been introduced recently from neighboring countries. In 1989, several farmers were surprised to see that the wheat they planted did not seem to grow. The origin of the variety was not known.

- The fertilizers used on the perimeter were mainly urea, 15-15-15, and Single Super Phosphate. Cotton received the highest rate of chemical fertilizers, followed by wheat. Very few farmers interviewed applied fertilizer on sorghum fields. The rates of fertilizers used varied a great deal from one field to another. They were about 50% of the recommended rates. In several fields visited in 1989, urea was applied on the soil surface without incorporation. The farmers we talked to were not aware that substantial urea losses could occur by volatilization.

- Most of the chemical fertilizers used were purchased from Nigeria, since they cost less there. Unfortunately, there is no control on the quality of these fertilizers. There have been instances in the past where the quality of fertilizers purchased from Nigeria, i.e., for experimentation purposes, was found to be very poor.

- The use of manure on the perimeter is very limited. One of the problems is transportation, since most of the Djiratawa farmers live a good distance away from their fields.

- All the crop residues are burned or removed from the fields, which contributes to soil degradation.

- Soil, irrigation, and crop management do not take into account the great variety of soils found on the perimeter. For instance, repeated shallow tillage increases soil compaction and decreases water infiltration on soils with high clay content.

Other constraints:

- The cost of electricity for pumping water is very high. Consequently, there is a high rate of turnover in land ownership, due to the inability of farmers to pay all their dues. This also limits the number of crops which can be grown in one year.

- To make things worse, water management is very poor. It was estimated that the quantity of water used in Djiratawa was about twice that required by the crops (Ray Norman, 1990, Personal Communication).

- Several plots were abandoned for one or more of the following reasons: water shortage and/or cost, soil texture (too much sand or too much clay), defective levelling, damaged water canals. The sandy soils have very high infiltration rates, and, consequently, require frequent irrigations. After several years of poor management, the productivity of these soils decreases dramatically. The soils with high clay contents have low infiltration rates and are prone to flooding during the rainy season, especially in the absence of adequate drainage or levelling. During the dry season, these soils may develop large cracks, which can damage the roots and drain too much water. They are also hard to work.

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3.2.1.2 Galmi Perimeter

This perimeter of 245 ha first began operation in 1983-84. Rain water and runoff from a nearby watershed are collected in a reservoir of 7,200,000 m^3 total capacity. Average annual rainfall is about 450 mm and mean temperature about 28°C.

Water is discharged from the reservoir into a primary canal, approximately 6.3 km in length, which services 25 secondary canals. The primary and secondary canals were built with concrete, and the tertiary canals with compacted soil.

The basic field unit or plot is 25 m x 100 m or 0.25 ha. Each farmer holds one or more plots. The total number of farmers is about 854, organized into 26 GMPs (*Groupe mutuelle du production* - smallest organized unit within the irrigated perimeter).

The soils of the perimeter are dominated by the clay loams and sandy clay loams. Light-textured soils (sandy loams) are located in the northeast sections, e.g. S7, and the heavy soils (clay loam) are found in sections S24 to S26. There is no soil map of the perimeter.

The crops cultivated during the rainy season are: cotton, millet and sorghum. Cotton takes up about half the acreage of each holding, and millet and sorghum, the other half. In 1989, there were apparently more plots in millet than in sorghum. Cowpea acreage was less than 1 ha. Crop rotation is similar to that practiced at Djiratawa.

During the dry season, the crops planted are, by order of importance: onions, wheat and corn. The total crop acreage during the dry season is dependant on the volume of water in the reservoir. Crop calendar is approximately:

Wheat:	November to March
Onions:	November to March
Corn:	March to June

The mode of acquisition of plots and inputs is quite similar in Galmi and Djiratawa. The main difference is the lower rate of turnover of plot holders in Galmi.

Several of the constraints identified in Djiratawa were also found in Galmi. Important differences concern water cost and availability and crop performance. In Galmi, the cost of water is much lower than in Djiratawa. However, it is less available, except during years of high rainfall. More disease and weed problems were seen in Galmi than in Djiratawa in 1989. For example, *Striga* associated with sorghum was more widespread in Galmi. Farmers switch to millet when *Striga* infestation is too high. Nutgrass (*Cyperus sp.*) was also more present in Galmi than in Djiratawa. The rates of urea used in Galmi varied from about 30 to 300 kg/ha. Sometimes, farmers apply excessive amounts of urea to onion fields, and maybe too much water. This, in turn, leads to storage problems. Nevertheless, the region of Galmi is famous for its onion production.

More detailed surveys were conducted in Djiratawa and Galmi in 1990 under the supervision of the NAAR Project Sociologist. Unfortunately, the results of these surveys are not yet available.

3.2.2 Soil Test Correlation and Calibration

3.2.2.1 Evaluation of Phosphorus Availability in Several Soils of Western Niger

A good soil test is one which gives the best index of availability to the plants of the nutrient(s) tested. In the case of phosphorus, which is one of the most limiting nutrients to plant growth in Niger, several chemical extraction methods have been developed. The efficiency of a soil test for predicting the P status of a soil can be evaluated by correlating the P extracted with plant growth parameters such as yield, % yield, P uptake, and P concentration (Fitts and Nelson, 1956). On the other hand, values can be correlated with estimates of labile P such as A or L value (Larsen, 1967).

The National Soil Laboratory of Niger, after using the Truog P extraction method [(0.002N H_2SO_4 at pH 3.0 + $(NH_4)SO_4$]) for about 10 years, adopted the Bray-1 method in 1987, based on a quick comparison between Bray 1 and Olsen. No study was conducted to determine how well each of these methods correlate with crop yield and P uptake, and which one gives the best estimates of P availability in Nigerien soils.

It has been established that the chemical nature and amount of P extracted varies among soils, and the factors affecting the results are those that influence the degree of agitation or mixing of soil and solution, e.g., type and size of the extracting vessel in relation to the extract volume, soil-to-solution ratio, rate and time of extraction, and the ambient temperature. The suitability of a P extraction method can sometimes be improved by changing the soil-to-solution ratio (Kamprath and Watson, 1980). Smith *et al.* (1957) found a much better correlation between Bray P-1 and plant response to added P on calcareous soils when the soil-to-solution ratio was changed from 1:7 to 1:50. Similarly, a much better correlation was obtained with the North Carolina P extraction method on clayey Oxisols from Brazil when the soil-to-solution ratio was 1:25 instead of 1:8 (Cajuste and Kussow, 1974).

The objectives of this evaluation were:

1. To compare four extraction methods (Bray 1, Olsen, Mehlich 1, and Mehlich 3) for evaluating P availability in 31 soils of western Niger;
2. To investigate the effect of four soil-to-solution ratios on the amount of P extracted with Bray 1, Mehlich 1, and Mehlich 3;
3. To make recommendations as to which P extraction methods and soil-to-solution ratios are best suited to the main soils of western Niger.

Soils from 31 locations in south-central and western Niger (Figure 3.2-1) were sampled to a depth of 45 cm in 1990, air dried, and ground to pass a 2-mm screen. Routine soil analyses included pH, CEC (cation exchange capacity), exchangeable bases, organic C, DCB-Fe (Diothionite-Citrate-Bicarbonate-Iron), and texture. These soils ranged from strongly acid to alkaline, and from sandy to clay loam. They were generally low in organic carbon (Table 3.2-1). Several of these soils were previously analyzed and described in detail as part of a benchmark study. An attempt will be made to classify the soils used in this study according to the U.S. soil classification system.

The four methods used for P extraction are presented in Table 3.2-2. Mehlich 1 is also known as the "North Carolina" method. The soil-to-solution ratios used with each method are shown in Table 3.2-2.

On 13 (#1, 2, 3, 11, 12, 13, 14, 16, 21, 23, 24, 27, 28) of the 31 soils sampled, four soil-to-solution ratios were used (1:7, 1:10, 1:50, and 1:100) to test their effect on P extracted with Bray 1, Mehlich 1, and

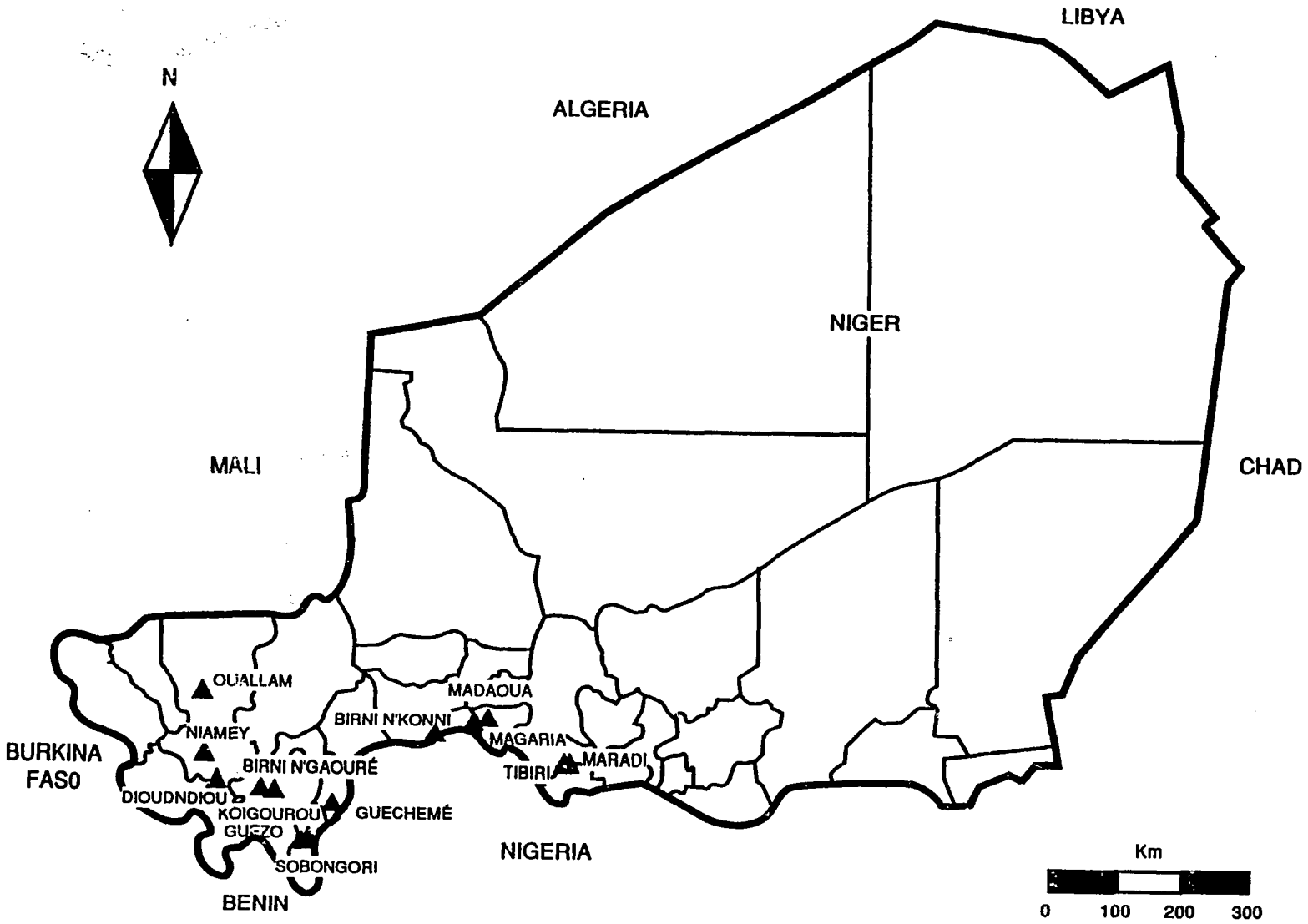

FIGURE 3.2-1. SOIL SAMPLING LOCATIONS IN 1990, NIGER, WEST AFRICA

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TABLE 3.2-1
SELECTED PROPERTIES OF THE SOILS USED IN THE P CORRELATION STUDY

Soil sample no.	pH H_2O	CEC[1] $cmol_c$	DCB-Fe[2]	Organic carbon	Clay	Sand
	1:2.5	kg^{-1}	------g/kg------		------%------	
1	6.8	2.0	10.8	9.5	27	44
2	[illegible]	9.5	10.9	11.2	22	47
3	7.0	2.9	1.8	2.9	5	90
4	6.0	1.3	3.2	0.8	5	89
5	7.0	21.7	27.0	3.9	39	27
6	7.2	14.8	23.5	4.0	24	55
7	7.1	1.6	4.2	1.5	3	92
8	6.1	1.3	2.5	2.5	4	91
9	6.5	1.1	1.8	1.6	3	91
10	5.0	1.5	3.1	1.3	4	93
11	9.1	13.1	15.6	3.1	19	70
12	7.1	1.4	2.6	0.7	2	96
13	7.1	3.9	3.1	1.8	7	87
14	7.1	2.3	4.5	1.3	5	90
15	7.3	6.6	19.8	2.0	12	71
16	7.7	7.2	24.8	2.4	11	65
17	7.0	1.3	1.3	1.3	4	89
18	6.1	1.3	16.6	1.0	5	91
19	7.0	7.8	16.8	4.7	15	57
20	6.1	1.0	3.7	0.6	4	94
21	5.9	1.0	5.0	0.7	4	95
22	5.6	2.4	5.5	1.1	13	81
23	6.0	1.3	2.4	1.7	4	93
24	5.4	3.2	9.9	2.9	10	81
25	6.5	12.9	14.3	5.3	33	43
26	6.2	1.4	1.9	1.7	3	91
27	8.3	7.1	7.4	3.5	15	53
28	7.9	5.9	22.0	4.8	12	39
29	7.9	17.8	27.9	6.0	34	11
30	7.7	1.4	2.5	0.9	3	93
31	7.2	1.3	2.9	1.0	3	93

[1]CEC = cation exchange capacity. [2]DCB - Diothionite-Citrate-Bicarbonate.

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TABLE 3.2-2
SOIL P EXTRACTION METHODS

Method	Extractant	Soil/ Solution Ratio	Reference
Bray I	0.025N HCl + 0.03N NH_4F	1:7	Bray & Kurtz (1945)
Olsen	0.5M $NaHCO_3$ at pH 8.5	1:20	Olsen *et al.* (1954)
Mehlich 1	0.05N HCl + 0.025N H_2SO_4	1:4	Sabbe & Breland (1974)
Mehlich 2	0.02N CH_3COOH + 0.25N NH_4NO_3 + 0.015N NH_4F + 0.013N HNO_3 + 0.001M EDTA	1:10	Mehlich (1984)

Mehlich 3. The clay content and pH values of the 13 soils used in this study ranged from 1.6 to 26.0% and 5.0 to 8.9, respectively. (Table 3.2-1).

Soil extract P was determined by the ascorbic-molybdate blue colorimetric method with Bray 1, Olsen, and Mehlich 3, and by the vanadate-molybdate yellow method with Mehlich 1.

The P extracted with these methods was correlated with millet dry matter and P concentration.

Millet (*Pennisetum glaucum* (L.) R. Br.) variety CIVT was grown in plastic pots in a screen house for five weeks. Each pot contained 6 kg of soil, and was watered daily to two-thirds of field capacity. The soil in each pot received the equivalent of 50 kg N/ha, 30 kg K_2O/ha, 10 kg Mg/ha, and 16 kg S/ha one week after planting. The pots were arranged in three randomized complete blocks. There were a total of 31 pots in each block, corresponding to each of the soils sampled.

At the end of five weeks, millet plants were harvested, washed with P-free soap, weighed, dried for 72 hours at 60°C, and weighed again. They were finely ground and then digested with the sulfuric acid-hydrogen peroxide procedure described by Nelson and Sommers (1973). P was determined by the Molybdate blue method.

Total soil P content was determined on all 31 soils. In addition, soil P sorption-desorption characteristics were studied by using the method described by Kamprath and Fox (1970). The results of this study are being analyzed.

Soil P test levels varied from 0.8 to 48 mg kg^{-1} with Bray 1, 0 to 23 mg kg^{-1} with Olsen, 0 to 229 mg kg^{-1} with Mehlich 1, and 0.7 to 262 mg kg^{-1} with Mehlich 3 (Table 3.2-3). If we exclude soil no. 27, the maximum amount of P extracted with Mehlich 1 and Mehlich 3 was 66 and 69 mg kg^{-1}, respectively (soil no. 3). Most of the sandy soils had P values below 6 mg kg^{-1} with all four methods. Mehlich 1 was the least sensitive, since it extracted virtually no P from the soils which had between 1.4 and 3.5 mg kg^{-1} Bray P-1.

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TABLE 3.2-3
AVERAGE SOIL TEST P, MILLET DRY WEIGHT AND P CONCENTRATION

	Bray 1	Olsen	Mehlich 3	Mehlich 1	Millet	
		---------- mg/kg ----------			Dry wt. g/pot	P. conc. g/kg
Minimum	0.8 (11)	0.0 (17)	0.6 (11)	0.0 ( )[1]	0.2 (18)	0.5 (23)
Maximum	48.2 (27)	26.1 (1)	261.5 (27)	228.8 (27)	14.2 (1)	3.5 (3)
Average	10.2	7.9	20.8	17.8	3.9	1.3
SD[2]	10.8	8.5	47.3	43.2	4.3	0.6

[1]Soil no. 11, 17, 18, 22, 23, 25, and 30.
[2]Standard error of the mean

Correlations between Bray P-1 and the other methods were highly significant, as was the correlation between Mehlich 1 and Mehlich 3 (Table 3.2-4). All four methods were highly correlated with exchangeable K (Table 3.2-5). There was also a good correlation between Olsen and soil texture, CEC, organic carbon, and free iron oxide (DCB-Fe).

TABLE 3.2-4
CORRELATION COEFFICIENTS[1] BETWEEN P EXTRACTION METHODS

Methods	Bray 1	Olsen	Mehlich 3	Mehlich 1
Bray 1	-	0.67**[2]	0.84**	0.80**
Olsen	0.67**	-	0.51**	0.43*[3]
Mehlich 3	0.84**	0.51**	-	0.96**
N. Carolina	0.80**	0.43**	0.96**	-

[1]Pearson correlation coefficients calculated with SAS.
[2]** = significant at P = 0.01.
[3]* = significant at P = 0.05.

Overall, Bray P-1 was the most correlated with millet dry matter and P concentration. This was particularly true for the sandy soils (Table 3.2-6) on which millet (*Pennisetum glaucum* (L.) R. Br.) is usually grown. Mehlich 1 and 3 were also highly correlated with millet P concentration for the same group of soils. In contrast, the best correlation between Olsen and millet dry matter was found for soils with more than 11% clay.

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TABLE 3.2-5
CORRELATION COEFFICIENTS[1] BETWEEN P EXTRACTED WITH FOUR METHODS AND SOIL PROPERTIES

Soil properties	Bray 1	Olsen	Mehlich 3	Mehlich 1
pH H_2O	0.40*[2]	NS	0.36*	0.43*
pH KCl	0.53**[3]	0.51**	0.36*	0.45*
Clay	NS	0.71**	NS	NS
Silt	0.42*	0.73**	NS	0.38*
Sand	-0.37*	-0.76*	NS	NS
CEC	NS	0.76**	NS	NS
K	0.68**	0.72**	0.74**	0.67**
DCB-Fe	NS	0.72**	NS	NS
Organic C	NS	0.68**	NS	NS

[1]Pearson correlation coefficients calculated with SAS.
[2]* = significant at P = 0.05.
[3]** = significant at P = 0.01.

TABLE 3.2-6
CORRELATION COEFFICIENTS BETWEEN P EXTRACTED WITH FOUR METHODS AND MILLET DRY MATTER AND P CONCENTRATION

	Bray 1	Olsen	Mehlich 3	Mehlich 1
		All soils (31)		
Dry weight	0.79**[1]	0.77**	0.47*[2]	0.37*
P conc.	0.69**	0.37*	0.55**	0.59**
		Sandy soils (Clay ≤ 11%)		
Dry weight	0.93**	NS[3]	0.77**	0.69**
P conc.	0.89**	NS	0.95**	0.93**
		Other soils (Clay > 11%)		
Dry weight	0.63*	0.86**	NS	NS
P conc.	NS	NS	0.55*	0.61**

[1]** = significant at P = 0.01.
[2]* = significant at P = 0.05.
[3]NS = nonsignificant.

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As the volume of the extraction solution was increased from 7 to 100 ml, the amount of Bray P-1 increased in a linear fashion (Table 3.2-7). The linear regression explained 77-99 % of the total variation in the amount of P extracted by this method.

TABLE 3.2-7
BRAY P-1 AT FOUR SOIL:SOLUTION RATIOS, AND THE ADJUSTED R-SQUARE OF THE LINEAR REGRESSION BETWEEN P AND EXTRACTION SOLUTION VOLUME

Soil sample No.	Soil:solution ratio				Adjusted r^2
	1:7	1:10	1:50	1:100	
	---------- mg/kg^{-1} ----------				
1	25.4	29.3	80.4	110.6	0.95
2	8.5	16.6	101.2	128.5	0.88
3	34.2	35.8	68.5	78.6	0.85
11	0.9	0.7	3.2	10.9	0.86
12	18.7	17.6	22.9	27.9	0.80
13	4.9	4.8	7.5	13.2	0.79
14	11.1	10.9	17.0	22.9	0.98
16	13.9	15.8	50.2	84.8	0.99
21	3.9	3.5	7.8	9.4	0.77
23	2.0	2.3	5.0	11.7	0.90
24	2.8	2.9	8.4	12.6	0.98
27	55.4	66.9	229.2	313.9	0.95
28	9.8	11.5	37.0	59.3	0.98
Mean	14.7	16.8	49.1	68.0	-

With Mehlich 3, only six of the 13 soils analyzed exhibited a linear relationship between P extracted and the volume of the extraction solution (Table 3.2-8). The other soils (no. 3, 11, 13, 14, 21, and 24) showed very little increase in the amount of Mehlich P-3 as the volume of the extraction solution was increased. All these soils, except no. 3, had low P values. Apart from these soils, the maximum amount of Mehlich P-3 was reached at about 1:50.

Similar results were obtained with Mehlich 1 (Table 3.2-9). P extracted at the recommended soil-to-solution ratio of 1:4 was 32.4 mg kg^{-1} on the average.

The average amount of P extracted by each method was in the order: Mehlich 1 > Mehlich 3 > Bray 1. The three methods were highly correlated with exchangeable K (R = 0.77 to 0.90) at all four soil-to-solution ratios. The only other significant correlations with soil properties are shown in Table 3.2-10.

TABLE 3.2-8
MEHLICH P-3 AT FOUR SOIL:SOLUTION RATIOS, AND THE ADJUSTED R-SQUARE OF THE LINEAR REGRESSION BETWEEN P AND EXTRACTION SOLUTION VOLUME

Soil sample No.	Soil:solution ratio				Adjusted r^2
	1:7	1:10	1:50	1:100	
	---------- mg/kg^{-1} ----------				
1	37.6	46.3	98.2	117.5	0.89
2	10.4	25.5	105.0	118.6	0.82
3	69.5	69.4	109.7	89.3	NS
11	0.7	0.5	1.63	3.5	NS
12	16.5	16.6	19.9	19.8	0.57[1]
13	4.7	4.0	5.2	2.8	NS
14	9.9	10.1	12.4	14.8	NS
16	19.5	26.0	95.5	119.1	0.88
21	2.8	3.4	2.4	3.5	NS
23	0.7	1.8	1.3	0.9	NS
24	2.1	2.4	2.9	3.5	NS
27	206.6	198.8	371.4	364.7	0.70
28	12.5	16.8	60.3	66.5	0.81
Mean	30.3	32.4	68.1	71.1	-

[1]Significant at P = 0.05. All other r-squares are significant at P = 0.01, except those indicated by NS.

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TABLE 3.2-9
MEHLICH P-1 AT FOUR SOIL:SOLUTION RATIOS, AND THE ADJUSTED R-SQUARE OF THE LINEAR REGRESSION BETWEEN P AND EXTRACTION SOLUTION VOLUME

Soil sample No.	Soil:solution ratio				Adjusted r^2
	1:7	1:10	1:50	1:100	
	---------- mg/kg^{-1} ----------				
1	41.5	58.4	102.7	113.5	0.81
2	20.2	29.6	63.3	63.7	0.73
3	81.8	81.3	72.0	78.2	NS
11	0.0	4.8	2.4	4.2	NS
12	8.2	15.8	12.3	27.2	0.49[1]
13	6.9	13.1	17.3	14.4	NS
14	7.1	15.2	14.3	20.8	NS
16	106.9	138.9	159.7	230.7	0.72
21	0.8	10.6	11.0	7.7	NS
23	1.0	10.2	12.3	10.4	NS
24	3.3	9.8	7.2	19.3	0.44[1]
27	317.3	366.4	340.2	408.5	NS
28	10.0	62.7	88.3	99.0	0.55
Mean	46.5	62.8	69.5	84.4	-

[1]Significant at P = 0.05. All other r-squares are significant at P = 0.01, except those indicated by NS.

TABLE 3.2-10
CORRELATION COEFFICIENTS BETWEEN P AND SOIL PROPERTIES

Soil property	Bray 1		Mehlich 1	
	1:50	1:100	1:50	1:100
Fine silt	0.60[1]	0.60[1]	NS	NS
Coarse silt	NS	NS	0.59[1]	0.58[1]
Coarse sand	NS	NS	-0.58[1]	-0.58[1]
Sand	-0.55[1]	-0.58[1]	-0.55[1]	-0.52NS

[1]Significant at P = 0.05. All other r-squares are significant at P = 0.01, except those indicated by NS.

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Highly significant correlations were obtained between Bray P-1 and millet dry weight at 1:7 and 1:10 soil-to-solution ratios (Tables 3.2-11 and 3.2-12). The amount of P extracted at these two ratios was practically the same for most of the 13 soils used in the study (Table 3.2-7). Mehlich 1 was the least correlated to millet growth, and P uptake at all four soil-to-solution ratios.

At this stage of our investigation, Bray 1 at the recommended soil-to-solution ratio (1:7) appears to be the best method for evaluating P availability in a wide range of soils from central and western Niger. It is even more suited to sandy soils on which millet is usually grown. The next best method is Mehlich 3 at 1:7 or 1:10 ratio. This method should also be investigated for its multiple-nutrient (P, K, Ca, Mg, Mn, Zn, Cu) extraction potential, to make it cost effective.

Olsen showed a good correlation with millet dry matter on soils with more than 11% clay, but not with millet P concentration. Further testing is needed to assess the suitability of this method for the evaluation of P availability on Nigerien soils.

TABLE 3.2-11
CORRELATION COEFFICIENTS BETWEEN SOIL P EXTRACTED WITH THREE METHODS AT FOUR SOIL:SOLUTION RATIOS, AND MILLET DRY MATTER

Extraction method	Soil:solution ratio			
	1:7	1:10	1:50	1:100
Bray 1	0.82**[1]	0.80**	0.66*[2]	0.64**
Mehlich 3	0.63**	0.66*	0.64*	0.63*
Mehlich 1	0.52	0.52	0.56*	0.49

[1] ** = significant at P = 0.01.
[2] * = significant at P = 0.05.

TABLE 3.2-12
CORRELATION COEFFICIENTS BETWEEN SOIL P EXTRACTED WITH THREE METHODS AT FOUR SOIL:SOLUTION RATIOS, AND MILLET P CONCENTRATION

Extraction method	Soil:solution ratio			
	1:7	1:10	1:50	1:100
Bray 1	0.71**[1]	0.69**	0.56*[2]	0.53
Mehlich 3	0.54	0.57*	0.58*	0.55
Mehlich 1	0.48	0.49	0.51	0.48

[1] ** = significant at P = 0.01.
[2] * = significant at P = 0.05.

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3.2.2.2 Sorghum Response to Nitrogen and Phosphorus

A series of experiments has been conducted since 1989 on research stations and farmers' fields. The overall objectives of these experiments were:

1. To determine the optimal rates of nitrogen and phosphorus for sorghum production on dunar and valley soils.
2. To study the response of several sorghum varieties to nitrogen.
3. To calibrate soil test data with sorghum yield.

Sorghum response to nitrogen on valley soils

Experimental design: split-plot with the varieties in main plots and fertilizer rates in sub-plots.

Number of replications: 4

Plot size
sub-plots: 6.0 m x 5.6 m
main plots: 5.6 m x 36 m

Treatments
Sorghum varieties
V1 : SEPON 82
V2 : SST 731-11
V3 : L-30
V4 : S-35
V5 : Local variety, e.g. Mota Maradi

Fertilization
F1 : Check without fertilizer
F2 : 100 kg/ha of SSP
F3 : 100 kg/ha of SSP + 30 kg N/ha
F4 : 100 kg/ha of SSP + 60 kg N/ha
F5 : 100 kg/ha of SSP + 90 kg N/ha
F6 : 100 kg/ha of SSP + 120 kg N/ha.

Source of P: Single Super Phosphate (SSP)
Source of N: Urea

Planting density: 80 cm x 30 cm, which amounts to approximately 42,000 seed pockets/ha.

Location of the experiment: Tarna, Konni, and Tillabery research stations. The experiment at Tarna did not succeed.

Duration: The sorghum variety x nitrogen rate experiment was conducted in Konni in 1989 and 1990, and in Tillabery in 1990 and 1991.

Measurements: At most locations, the following parameters were monitored:

- Dates of field operations
- Number of plant hills after emergence and at harvest
- Head and grain weight
- In a few instances, plant height, date of 50% flowering, and stover yield were also monitored.

The soil on which the experiment was installed in Konni has been classified as fine, mixed, isohyperthermic, typic chromustert. It had the following characteristic in the top 30 cm: 30-40% clay, 35% silt, pHw = 7.1, effective CEC: 30-35 meq/100g, Bray P-1 = 25-35 mg/kg, and O.M. = 0.7 - 0.9%.

The soil in Tillabery was slightly acid to neutral (pHw=6.2), had a coarser texture (20% clay and 60% sand), lower CEC (total bases = 19 meq/100g), and less available phosphorus (14 mg/kg) than the soil in Konni.

Konni experiment - 1989 results

The analysis of variance did not show any significant effect of the interaction "variety x fertilization" on grain or head yield, at the 5% type I probability level (Table 3.2-13).

Similarly, there were no significant differences among the varieties tested. The local variety, El Mota Maradi, produced as much, or even a little more, grain than the so-called improved varieties. The varieties, El Mota and L-30, produced the highest number of heads.

On the contrary, the effect of N&P fertilization on sorghum head and grain yields was highly significant. There was a substantial increase in sorghum yield as nitrogen rate was increased from 30 to 60 kg/ha (Figure 3.2-2). Further increase in nitrogen rate did not cause an increase in sorghum yields (Table 3.2-13). The application of 100 kg/ha of SSP alone did not increase yields, as compared to the zero-fertilizer treatment. This lack of response to phosphorus may be due to the relatively high soil test level (Bray P-1 = 20 mg/kg in 0 to 30 cm of soil).

The highest [crop value/fertilizer cost] ratio (3.2) was obtained with 60 kg N/ha, which is equivalent to approximately 133 kg urea/ha (Table 3.2-14).

Konni experiment - 1990 results

In 1990, sorghum was planted very late. In addition, the amount of rain which fell from planting through the end of the crop season was very low. Sorghum received only one or two supplemental irrigations because of low storage in the water reservoir. These droughty conditions probably favored the heavy sorghum midge infestation during flowering and grain formation. All these factors led to very low and highly variable grain yields (data not shown).

Tillabery experiment

The effect of the interaction [variety x fertilization] was not significant in 1990, as well as in 1991. In 1990, the improved varieties, Sepon82 and S-35, produced the highest grain yields (Figure 3.2-2 and Table 3.2-15). The local variety, Himo Kire (HK), was the least productive in both years. The effect of N&P fertilizer on grain yield was significant in 1990 (alpha=10%) and highly significant in 1991 (alpha=1%). Figure 3.2-5 shows the relationship between N rates and grain yield in 1990 and 1991, respectively. It

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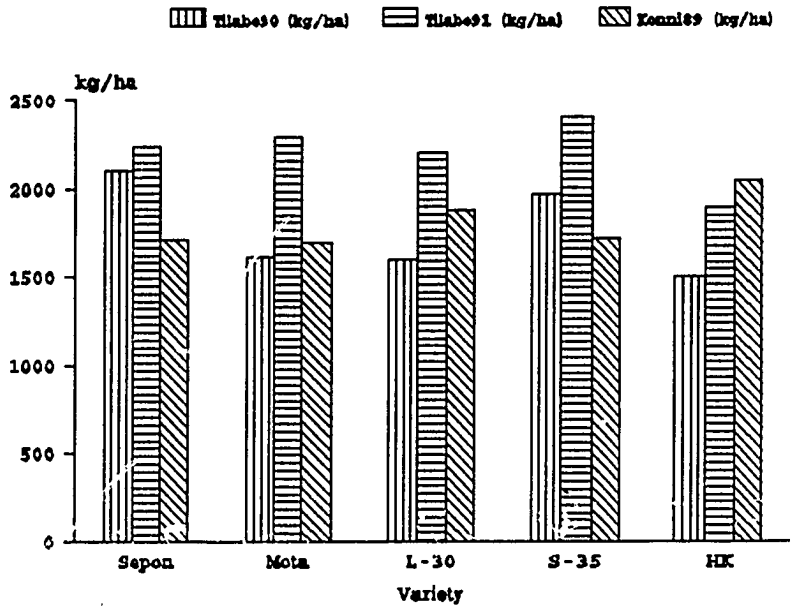

FIGURE 3.2-2. SORGHUM GRAIN YIELD, 1989-1991.

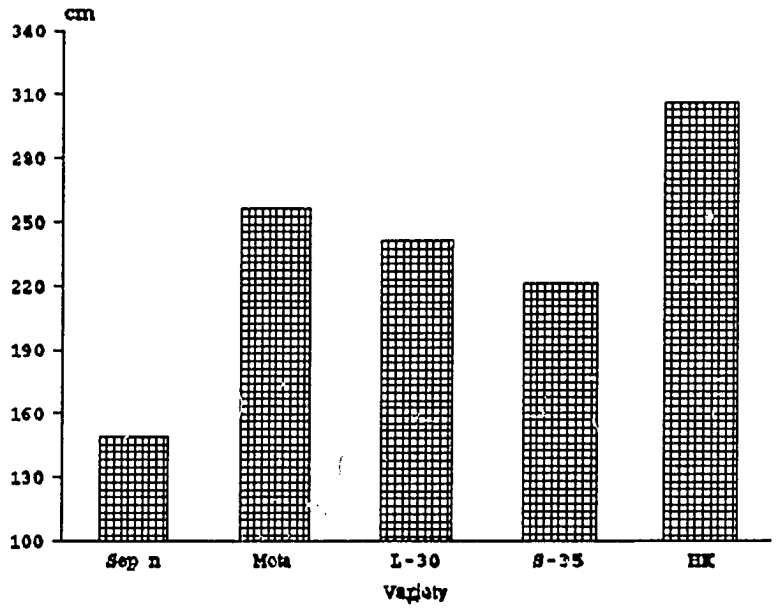

FIGURE 3.2-3. PLANT HEIGHT OF FIVE VARIETIES. TILLABERY, 1991.

TABLE 3.2-13
RESULTS OF THE 1989 SORGHUM TRIAL IN KONNI[1]

Factor/ level	No. of sorghum hills at		No. of sorghum heads harvested	Sorghum yield	
	Emergence	Harvest		Heads	Grain
				(kg/ha)	
Variety (A)					
Sepon 82	113	69	98	2726	1713
SST 731-11	106	67	97	2591	1700
L-30	114	67	134	2782	1879
S-35	109	69	99	2448	1720
El Mota	104	65	134	2881	2039
P > F	NS[2]	NS	0.02	NS	NS
N & P fertilization (B)					
F1 (00-00-00)	111	68	116	2433	1714
F2 (00-20-00)	111	69	102	2290	1469
F3 (30-20-00)	108	66	107	2273	1469
F4 (60-20-00)	111	70	111	2969	2017
F5 (90-20-00)	108	66	122	3098	2110
F6 (120-20-0)	106	64	117	3049	2054
P > F	NS	NS	NS	HS[2]	NS
Interaction AxB (P>F)	NS	NS	NS	NS	NS
Overall average	109	67	113	2685	1810
CV (%)	13	18	25	26	32

[1]Planting date: July 7; total rainfall: 431 mm; rainfall since July 7: 365 mm.
[2]NS = nonsignificant; HS = significant at P = 0.01.

TABLE 3.2-14
ADDITIONAL REVENUE FROM UREA APPLICATION, KONNI, 1989

Urea[1]	N	Yield[2]	Yield increase		Cost of urea (b)	(a) - (b)	Ratio (a)/(b)
kg/ha	Equiv. kg/ha	kg/ha	kg/ha	FCFA (a)		FCFA	
0	0	1469					
67	30	1469	0	0	4355	-4355	-
133	60	2017	548	27400	8645	18755	3.17
200	90	2110	641	32050	13000	19050	2.47
267	120	2054	585	29250	17355	11895	1.69

[1]Cost of urea = 65 FCFA/kg. [2]Sorghum grain value: 50 FCFA/kg

TABLE 3.2-15
VARIETAL AND N&P FERTILIZATION EFFECTS
ON SORGHUM GRAIN YIELD IN TILLABERY IN 1990 AND 1991[1]

Variety	1990	1991
	Grain yield (kg/ha)	
Sepon 82	2104	2240
SST 731-11[2]	1615	2291
L-30	1601	2205
S-35	1966	2404
KG	1498	1895
P > F	HS[3]	S

N&P	1990	1991
	Grain yield (kg/ha)	
00-00	1578	1615
00-20	1682	1993
30-20	1696	2211
60-20	1895	2247
90-20	1916	2601
120-20	1775	2574
P > F	0.09	HS
Var. x NP	NS	NS
Grand mean	1757	2207
CV (%)	24	21

[1]

	1990	1991
Planting date:	July 9	June 6
Harvest date:	October 26	October 15
Total rainfall:	356 mm	410 mm
Rainfall after planting:	306 mm	342 mm

[2]In 1991, the variety SST 731-11 was replaced by El Mota Maradi.
[3]HS = significant at P = 0.01; S = significant at P = 0.05; NS = nonsignificant.

appears from these figures that the maximum grain yield would be reached at about 75 kg N/ha in 1990 and ≥ 90 kg N/ha in 1991. The higher yields in 1991 were probably due to earlier planting and slightly higher rainfall.

In economic terms, the application of urea in 1990 was not profitable (Table 3.2-16). In 1991, the gross return from the application of urea ranged from 8220 FCFA/ha to 22400 FCFA/ha. The highest return was obtained with 200 kg/ha of urea or 90 kg N/ha (Table 3.2-17). The sharp drop in the price of urea, and the higher yield increases accounted for the "gains" made in 1991.

In 1991, in addition to grain yield, the dates of 50% flowering and plant height were also monitored. The tallest variety was by far the local HK, followed by El Mota Mdi and L-30 (Table 3.2-18 and Figure 3.2-3). The improved variety, Sepon82, was the shortest. The effects of N&P fertilization and of the interaction [variety x NP] on sorghum height were not significant.

The local variety, HK, reached 50% flowering in about 109 days after planting (DAP), or 21 days later than the early maturing variety, El Mota Mdi. The varieties, Sepon82 and L-30, reached 50% flowering in about 94 DAP (Table 3.2-18).

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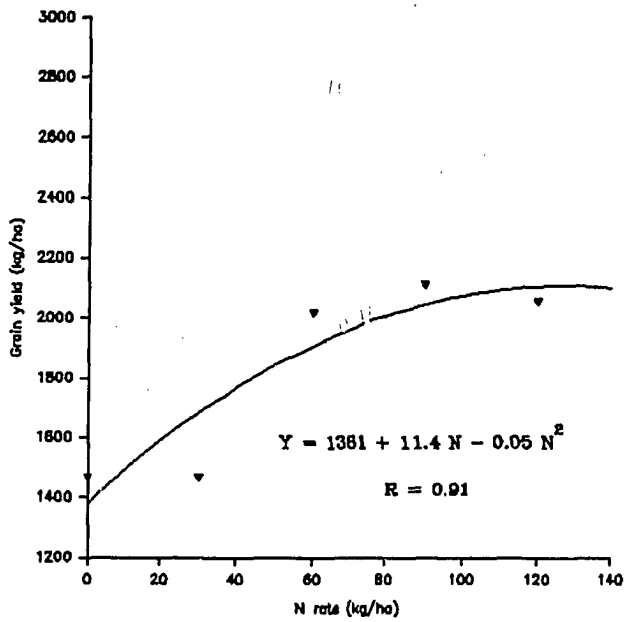

FIGURE 3.2-4. SORGHUM RESPONSE TO N RATE. KONNI, 1989.

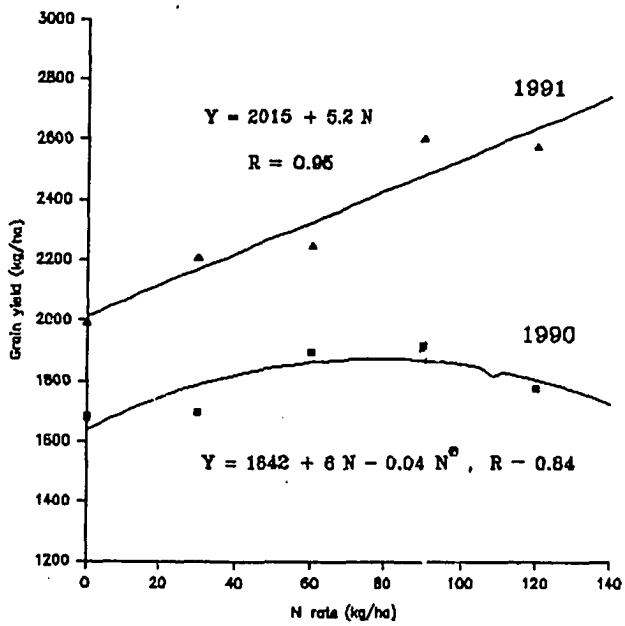

FIGURE 3.2-5. SORGHUM RESPONSE TO N RATE IN TILLABERY.

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TABLE 3.2-16
ADDITIONAL REVENUE FROM UREA APPLICATION, TILLABERY, 1990

Urea[1]	N	Yield[2]	Yield increase		Cost of urea (b)	(a) - (b)	Ratio (a)/(b)
kg/ha	Equiv. kg/ha	kg/ha	kg/ha	FCFA (a)		FCFA	
0	0	1681					
67	30	1696	15	975	4355	-3380	0.22
133	60	1895	214	10700	8645	2055	1.24
200	90	1916	235	11750	13000	-1250	0.90
267	120	1775	94	4700	17355	-12655	0.27

[1]Cost of urea = 65 FCFA/kg.
[2]Sorghum grain value: 50 FCFA/kg.

TABLE 3.2-17
ADDITIONAL REVENUE FROM UREA APPLICATION, TILLABERY, 1991

Urea[1]	N	Yield[2]	Yield increase		Cost of urea (b)	(a) - (b)	Ratio (a)/(b)
kg/ha	Equiv. kg/ha	kg/ha	kg/ha	FCFA (a)		FCFA	
0	0	1993					
67	30	2211	218	10900	2680	8220	4.07
133	60	2247	254	12700	5320	7380	2.39
200	90	2601	608	30400	8000	22400	3.80
267	120	2574	581	29050	10680	18370	2.72

[1]Cost of urea = 40 FCFA/kg.
[2]Sorghum grain value: 50 FCFA/kg

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TABLE 3.2-18
FLOWERING DATE AND PLANT HEIGHT, TILLABERY, 1991[1]

Variety	Flowering DAP	Height cm
Sepon82	94 c	194 e
Mota Mdi	88 d	256 b
L-30	93 c	241 c
S-35	97 b	221 d
HK	109 a	306 a
P > F	HS	HS
Var. x NP	NS	NS
CV (%)	1	6

Treatment N&P rate	Flowering DAP	Height cm
00-00	98	229
00-20	97	235
30-20	95	235
60-20	96	234
90-20	95	237
120-20	95	237
P > F	HS	HS

[1]HS = significant at P = 0.01. Means followed by the same letter are not significantly different.

Sorghum response to N & P fertilization on dunar soils

Experimental design: Randomized Complete Block

Number of replications: 4

Plot size: 6 m x 6 m

Variety: A_4D_4 in 1989 and Mota Maradi in 1990

Sowing density: 20,000 seed holes/ha at 1.00 m x 0.50 m spacing

Treatments

Nitrogen:	0, 30, 90 Kg N/ha
Phosphorus:	0, 20, 40, 60 Kg P_2O_5/ha
N source:	Urea
P source:	SSP

Location of the experimental: Tarna (1989), Konni (1989, 1990), and Bengou (1990)

The experiments installed at Tarna and Konni in 1989 produced very low and variable yields because of soil heterogeneity and poor performance of the sorghum variety, A_4D_4.

In Konni in 1990, there were no significant effects of nitrogen, phosphorus, or of their interaction on grain yield. In Bengou, there was a significant effect of nitrogen on grain yield at alpha = 10%. However, the high CVs at both locations makes it difficult to draw valid conclusions.

On-farm trials

Sorghum is the third largest crop of Niger, after millet and cowpea. In the Konni "district," sorghum acreage was estimated at 50,802.00 ha in 1990, for a total grain production of 28,732.00 tons.

Sorghum is cultivated as a sole crop or in association with millet and/or cowpea. It is mainly found in relatively high rainfall areas (≥350 mm), in lowlands, or where irrigation is available. Grain sorghum is used as a staple food, its leaves for feeding animals and its stalks for building fences, among other things.

In the Birni N'Konni region where the calibration trials were conducted, sorghum is the main cereal in the irrigated perimeter. The government agency, which overseas the management of the irrigated perimeters in Niger (ONAHA), recommends that half the acreage of each "holding" be cultivated during the rainy season to sorghum and the other half to cotton. Nevertheless, some farmers may prefer millet to sorghum. In 1990, the acreage sown to sorghum and cotton was 900 and 1200 ha, respectively. The rest of the total acreage of the Konni perimeter (2440 ha) was sown to millet, cowpea, and a few other crops.

The soils on which the calibration trials were installed were mainly Haplustalfs, Haplustolls, and Chromusterts. On the outskirts of the irrigated perimeter, the predominant soil type is Psammentic haplustalf.

Few experiments have been conducted in the past in the Konni region to test sorghum response to NPK. Two of these experiments were installed on the INRAN research station in 1989 and 1990. The varieties tested responded to nitrogen (up to 60 kg N/ha) but not to phosphorus, since soil P test levels were fairly high (20-30 mg/kg) on the research station.

The FAO's Niger Fertilizer Program carried out a number of experiments on farmers' fields, but no soil test data are available for these experiments, except in 1990.

The objectives of this study were to:

1. test the response of sorghum to N and P rates on farmers fields, and under various soil conditions;
2. calibrate soil test data with sorghum grain yield.

In 1990, an experiment with 10 N-P-K and treatment combinations was conducted on five farmers' fields by the Niger Fertilizer Program (PEN) in collaboration with INRAN. INRAN researchers took soil samples from these fields at 0 to 15 and 15 to 30 cm depths before fertilizer application, and ran chemical analyses (pH, exchangeable cations, Bray P-1, total N, and Organic C) on them. The plots were laid out in randomized complete blocks. The number of replications was four in each trial. Sorghum variety, IRAT204, was planted in three of these trials, and SEPON82 in two trials. Total rainfall was 357 mm at the INRAN research station.

In 1991, it was decided to slightly modify the experimental design and increase the number of trials. Two similar experiments were designed: one for the irrigated perimeter, and the other one for the drylands of the Konni region. A well-adapted sorghum variety was chosen for each of these two experiments.

A total of 31 trials were installed on farmers' fields between May and July 1991. Seventeen of these trials were installed in fields equipped for gravity irrigation, and the rest (15) in non-irrigated fields. INRAN and PEN provided the seeds and fertilizers for these trials. In addition, several *observateurs* from INRAN (3), PEN (1), and ONAHA (1) were based in the region to collect data from these trials and advise farmers on their management.

A composite soil sample was taken from each replication at 0-20 and 20-40 cm depths before the application of P fertilizer. Of the 31 trials planted in 1991, 23 were harvested. Four trials were abandoned by the ONAHA technician near harvest time for no valid reason, and another one was abandoned by the farmer who emigrated to a neighboring country. Five other trials did not succeed because of drought, diseases, or neglect. Among the 23 trials harvested, seven had very high CVs and were not included in this report.

Total rainfall was generally above average and decreased from east to west. The rainiest month was August in all locations, followed by July and September. June was fairly dry, particularly during the first 19 days, which created a stressful condition for the trials which were planted in May or early June.

1990 trial results

The five trials produced 4063 kg/ha of grain sorghum on the average (Table 3.2-19). The highest yields were obtained with the INRAN improved variety, Sepon82. The effects of N and P fertilizers on

TABLE 3.2-19
AVERAGE GRAIN YIELDS, 1990 TRIALS

Trt. No.	N	P_2O_5	K_2O	Variety / Test No.					
				IRAT 1	IRAT 2	SEPON 3	SEPON 4	IRAT 5	Avg.
				kg/ha					
1	0	0	0	3052	1867	2865	2698	2281	2552
2	0	46	0	3750	2156	3406	3240	2781	3067
3	23	46	0	3875	2698	3875	3635	2990	3415
4	46	46	0	4490	3063	6364	5135	4615	4733
5	69	46	0	4802	3438	6615	5323	4948	5025
6	46	0	0	3855	2260	3563	3656	2792	3225
7	46	23	0	4188	2594	4625	4000	3146	3710
8	46	29	0	4875	2990	6959	5479	5125	5085
9	46	46	30	4292	3469	6240	5032	4656	4738
10	46	59	0	4688	3323	6834	5458	5115	5083
Avg.				4187	2785	5134	4366	3845	4063
CV (%)				6	10	5	7	5	6
F test				HS[1]	HS	HS	HS	HS	

[1]Significant at P = 0.01.

grain yield were highly significant in all the trials. The finely-ground Tahoua Rock Phosphate (TRP) applied at 30 kg P/ha had a similar effect on sorghum grain yield, as did the Triple Super Phosphate (TSP) applied at the same P rate (Table 3.2-20). This is an important result, although the availability of TRP is questionable, since the TRP deposits have not been exploited for several years. The application of 25 kg K/ha, in addition to 46 kg N/ha and 20 kg P/ha, did not have a significant effect on grain yield.

TABLE 3.2-20
ORTHOGONAL CONTRAST MEAN COMPARISON,
SORGHUM GRAIN YIELDS, KONNI, 1990

		Test no.					
		1	2	3	4	5	All
Contrast	Effect	P > F					
T1 vs others	NP	HS[1]	HS	HS	HS	HS	HS
T1 vs others-6	P	HS	HS	HS	HS	HS	HS
T2 vs T3+4+5	N	HS	HS	HS	HS	HS	HS
T6 vs T4+7+8	P (STP)	HS	HS	HS	HS	HS	HS
T6 vs T4+7+8+9+10	P+PNT	HS	HS	HS	HS	HS	HS
T4 vs T9	K	NS	0.06	NS	NS	NS	NS
T8 vs T10	P(PNT)	NS	NS	NS	NS	NS	NS

[1]HS = significant at P = 0.01; NS = nonsignificant.

Figures 3.2-4 and 3.2-5 show a strong linear correlation between N or P rates and grain yield. These figures suggest that higher N and P rates may be needed to reach maximum yields.

1991 trial results

Sepon82. The eight trials, whose results are reported here, produced 2486 kg/ha of grain sorghum on the average. Two tests (6 and 11) produced about 1220 kg/ha, three tests (1,3,7) around 2000 kg/ha, while tests no. 4 and 5 produced over 4000 kg/ha of grain sorghum (Table 3.2-21). Overall, the treatment effect on grain yield was highly significant. However, the effect of the interaction between site and treatment was also significant. In all the tests, except two (7 and 11), the effect of N and P treatments on grain yield was significant. Orthogonal contrast comparisons showed a significant effect of N in five tests (2, 3, 4, 5, 6), of P in three tests (2, 4, 6), and of N+P in six tests (2, 3, 4, 5, 6, 11).

Figures 3.2-6 through 3.2-9 show the regression lines or trends of sorghum grain yield versus N or P rate. Cate and Nelson's graphical method was used to determine critical P levels. On valley soils, it may be estimated at 10-12 mg/kg (Figures 3.2-16 and 3.2-17). The R-square method will be used to confirm these values. In Figure 3.2-15 (Sepon82), the points are too scattered, which makes it difficult to estimate a critical P level.

El Mota Maradi. The tests planted to the sorghum variety, El Mota Mdi, produced 1200 to 2000 kg/ha of grain on the average (Table 3.2-22). The treatment effect was significant in every one of the eight tests

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TABLE 3.2-21
SEPON82 GRAIN YIELDS, 1991 TRIALS

Trt. No.	N kg/ha	P_2O_5	Test no. 1	2	3	4	5	6	7	11	Avg.
			---------- kg/ha ----------								
1	0	0	1938	1688	1400	3688	3400	888	2400	913	2039
2	0	46	2163	2213	1275	4138	3575	1475	1838	475	2144
3	23	46	2163	1850	2288	4488	4088	913	2250	975	2377
4	46	46	2100	2075	2438	4938	4413	925	2500	1763	2644
5	69	46	2475	1863	2188	5163	4388	988	2450	1450	2621
6	92	46	2450	1750	1675	5538	4800	950	2325	1238	2591
7	46	0	1963	1663	2438	4413	4600	988	1963	1663	2461
8	46	23	2288	2375	1900	4575	4650	1850	2150	1225	2627
9	46	69	2813	1900	1913	5263	4875	1738	1938	1275	2714
10	46	92	2538	1763	2413	5400	4763	1500	1450	1350	2647
Average			2289	1914	1993	4760	4355	1221	2126	1233	2486
CV (%)			13	9	11	2	2	20	33	33	13
F test[1]			NS	S	HS	HS	HS	S	NS	NS	

[1]NS = nonsignificant; S = significant at P = 0.05; HS = significant at P = 0.01.

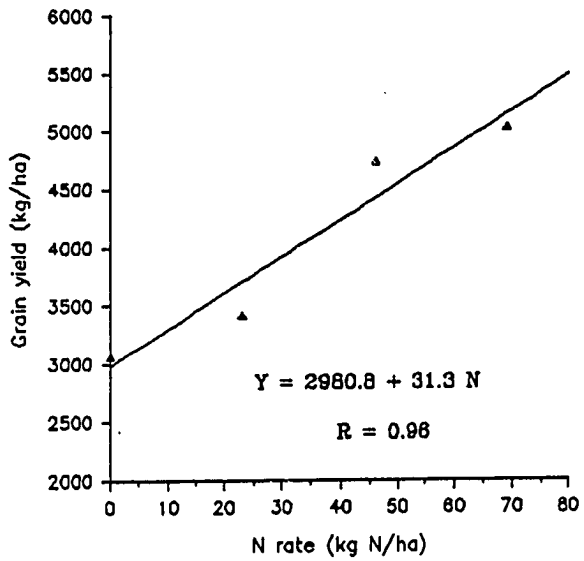

FIGURE 3.2-6. SORGHUM RESPONSE TO N RATES, 1990 TRIALS.

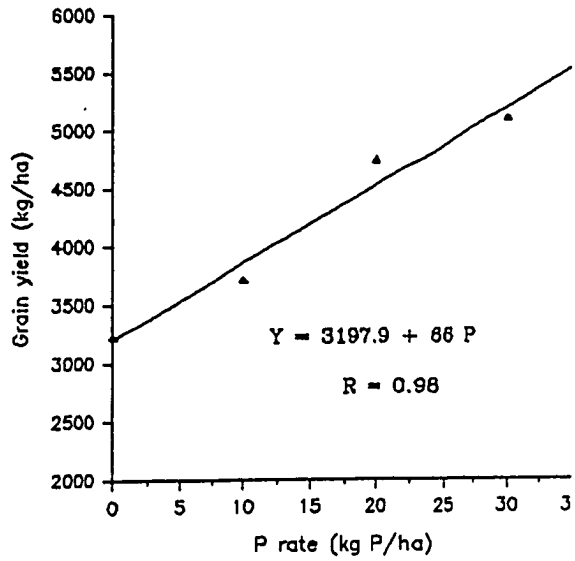

FIGURE 3.2-7. SORGHUM RESPONSE TO P RATES, 1990 TRIALS.

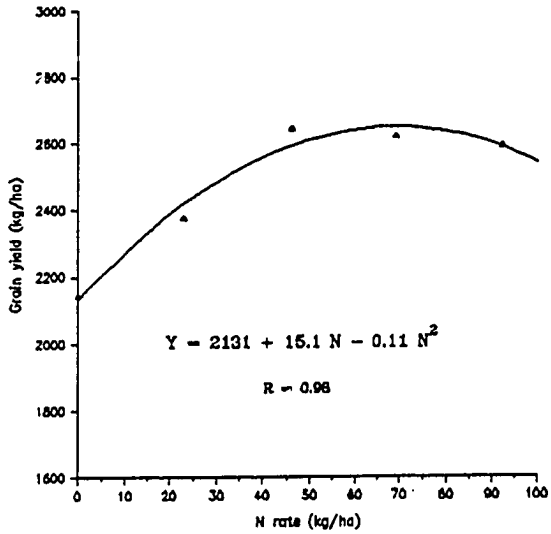

FIGURE 3.2-8. SEPON82 RESPONSE TO N RATES, 1990 TRIALS.

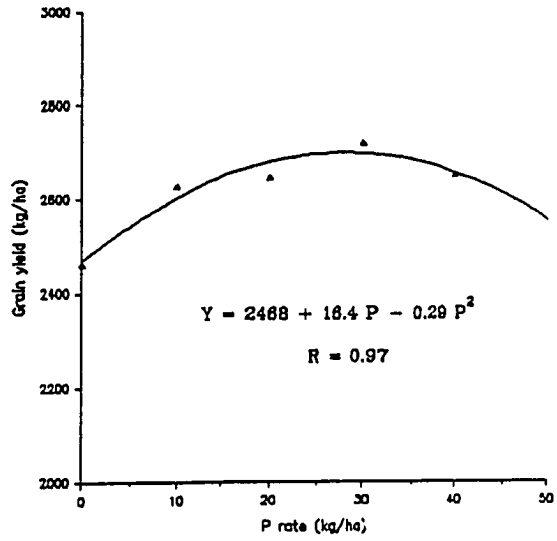

FIGURE 3.2-9. SEPON82 RESPONSE TO P RATES, 1990 TRIALS.

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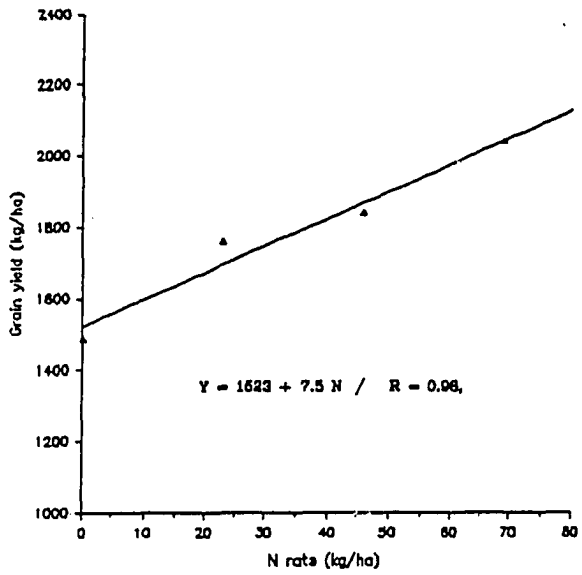

FIGURE 3.2-10. MOTA RESPONSE TO N RATES. AVERAGE OF 8 TRIALS (1991).

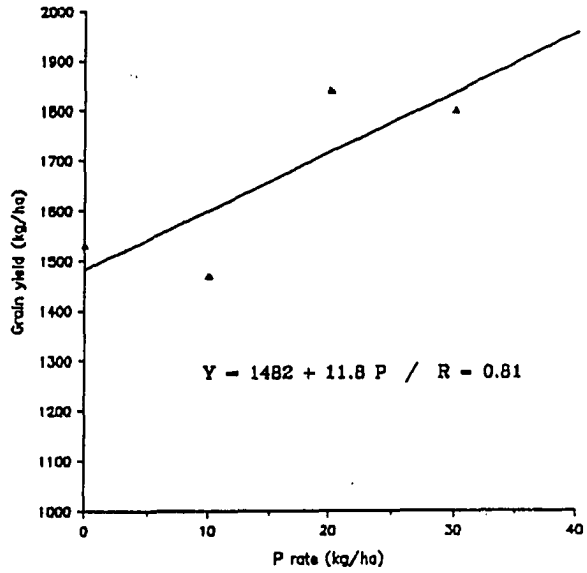

FIGURE 3.2-11. MOTA RESPONSE TO P RATES. AVERAGE OF 8 TRIALS.

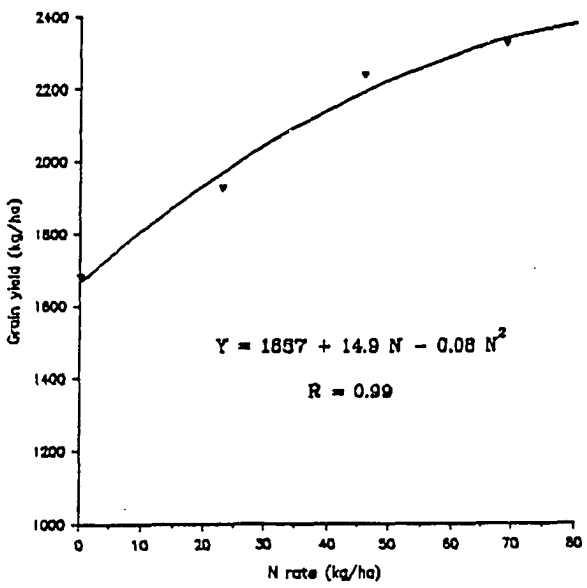

FIGURE 3.2-12. MOTA RESPONSE TO N RATES. TRIALS 1-4 (1991).

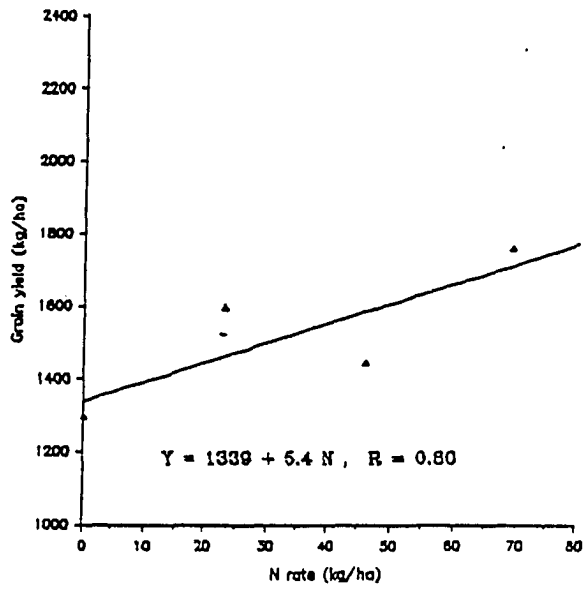

FIGURE 3.2-13. MOTA RESPONSE TO P RATES. TRIALS 7, 9, 10, 11.

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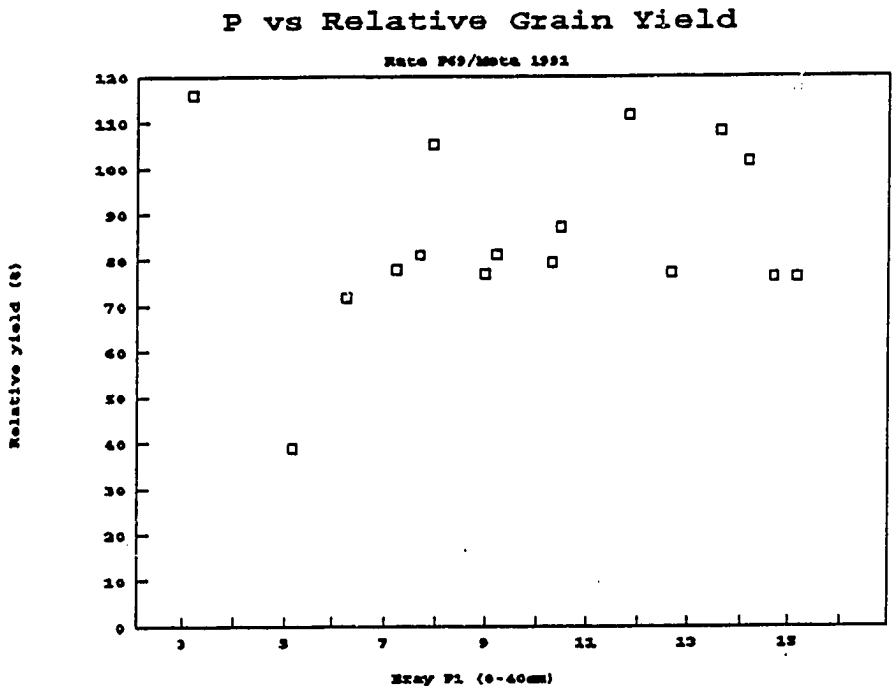

FIGURE 3.2-14. CATE AND NELSON GRAPHICAL METHOD FOR ESTIMATING P CRITICAL LEVEL. P RATE = 69 kg P_2O_5/ha. SANDY SOILS, 1991.

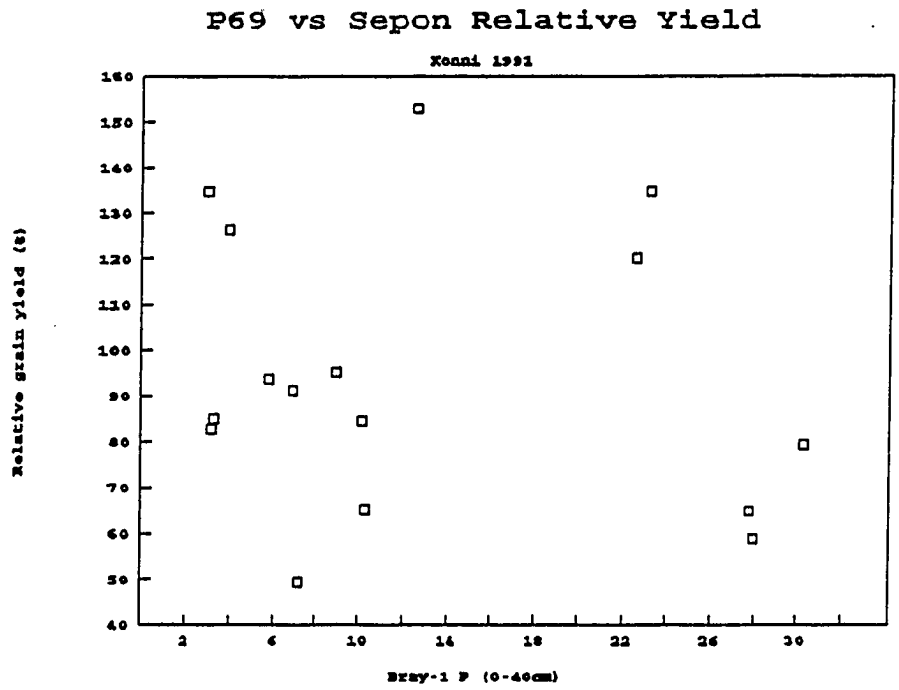

FIGURE 3.2-15. CATE AND NELSON GRAPHICAL METHOD FOR ESTIMATING P CRITICAL LEVEL. P RATE = 69 kg/P_2O_5/ha. VALLEY SOILS, 1991.

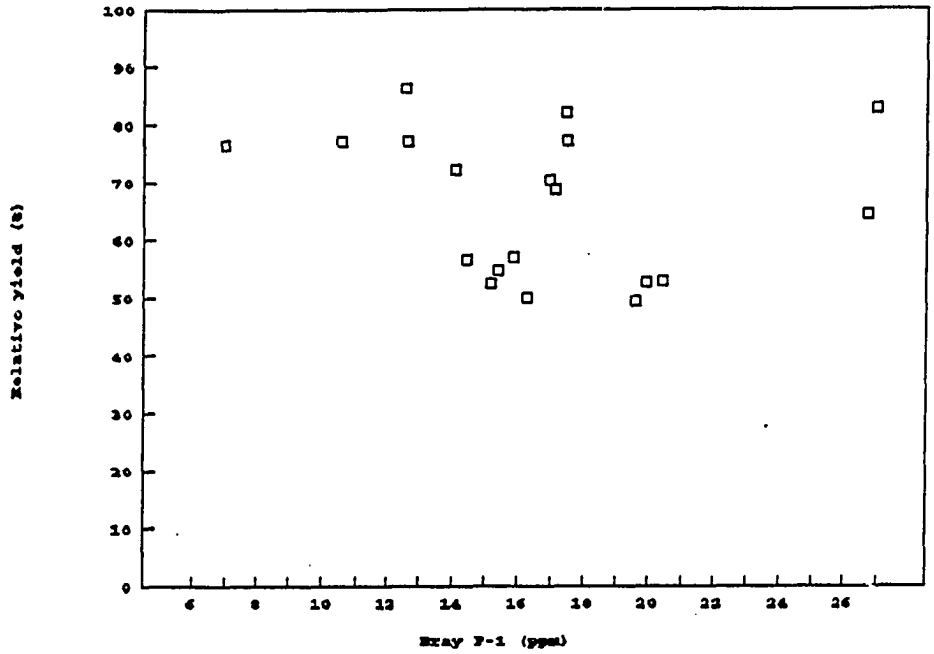

FIGURE 3.2-16. CATE AND NELSON GRAPHICAL METHOD FOR ESTIMATING P CRITICAL LEVEL. P RATE = 46 kg P_2O_5/ha. VALLEY SOILS, 1990.

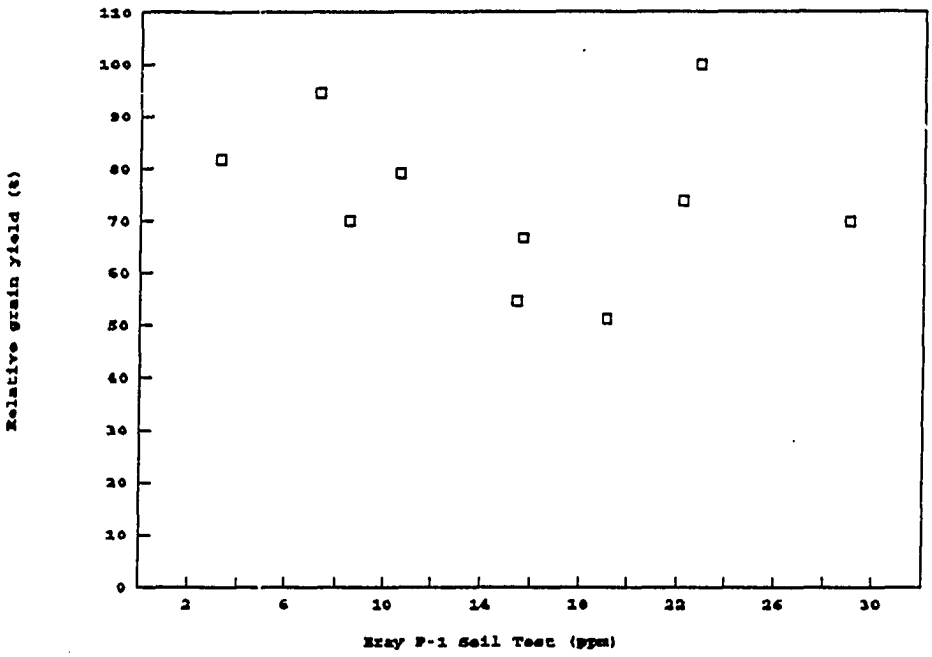

FIGURE 3.2-17. CATE AND NELSON GRAPHICAL METHOD FOR ESTIMATING P CRITICAL LEVEL. VALLEY SOILS, 1990 AND 1991 TRIALS (AVERAGES).

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TABLE 3.2-22
MOTA GRAIN YIELD, 1991 TRIALS

Trt. No.	N	P_2O_5	Village / Test No.								Avg.
			Cerassa Mangou				Kaku	Dagarka		Dibissou	
			1	2	3	4	7	9	10	11	
			kg/ha								
1	0	0	1713	1638	1575	1538	1275	938	888	1163	1341
2	0	46	1813	1750	1563	1600	1300	1550	1075	1263	1489
3	23	46	1950	1950	2000	1800	1925	1425	1638	1400	1761
4	46	46	2275	2225	2250	2188	1075	1700	1313	1688	1839
5	69	46	2413	2313	2350	2200	1900	1538	1738	1863	2039
6	46	0	1813	1713	1625	1713	1250	1300	900	1925	1530
7	46	23	1925	1750	1550	1850	838	1400	863	1575	1469
8	46	69	2213	2113	1838	2200	1288	1363	1538	1838	1798
Average			2014	1931	1844	1886	1356	1402	1244	1589	1658
CV (%)			6	2	9	4	20	26	21	22	14
F test[1]			HS	HS	HS	HS	S	NS	S	NS	

[1]HS = significant at P = 0.01; S = significant at P = 0.05; NS = nonsignificant.

TABLE 3.2-23
ORTHOGONAL CONTRAST COMPARISONS, SORGHUM GRAIN YIELDS, 1991[1]

Sorghum variety: Sepon82

Contrast	Test No.								
	1	2	3	4	5	6	7	11	All
T1 vs T2	NS	0.08	NS	HS	S	S	NS	NS	NS
T1 vs T7	NS	NS	HS	HS	HS	NS	NS	NS	HS
T1 vs others	NS	NS	HS	HS	HS	0.08	NS	NS	NS
T2 vs T3+4+5+6	NS	S	HS	HS	HS	S	NS	S	HS
T7 vs T8+4+9+10	0.07	S	NS	HS	NS	S	NS	NS	S

Sorghum variety: Mota

Contrast	Test No.								
	1	2	3	4	7	9	10	11	All
T1 vs T2	NS	S	NS	NS	NS	NS	NS	NS	0.09
T1 vs T6	NS	NS	NS	S	NS	NS	NS	0.07	S
T1 vs others	HS	HS	S	HS	NS	NS	0.08	NS	HS
T2 vs T3+4+5	HS	HS	HS	HS	NS	NS	0.06	NS	HS
T6 vs T4+7+8	HS	HS	NS	HS	NS	NS	NS	NS	S

[1]NS: Not significant.
S: Significant at P = 0.05.
HS: Significant at P = 0.01.

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retained for analysis. Orthogonal contrast comparisons (Table 3.2-23) showed a significant effect of N on grain yield in five tests (1, 2, 3, 4, 5), of P in three tests (1, 2, 4), and of N+P in four tests (1, 2, 3, 4).

Figures 3.2-10 to 3.2-13 show the regression lines of sorghum grain yield versus N or P rate. On sandy soils, critical P level was approximately 7-8 mg/kg (Figure 3.2-14).

Conclusion: Further data analysis is needed to draw valid conclusions from the results of the on-farm trials.

3.2.3 Spatial Variability

3.2.3.1 Causes and Effects of Spatial Variability of Millet Growth in South-central Niger

It is not unusual to see a great deal of variability in millet fields in Niger. Substantial variations in millet population, growth, and/or development may be found within short distances (2-20 m). This micro-variability generally becomes apparent one to three weeks after plant emergence. Millet growth in low productive areas of the field is suppressed or reduced considerably. Several millet plants eventually die, and the remaining ones may or may not produce heads, depending on the severity of the problem.

In general, spatial variability may result from the combined action of several factors, such as: 1) those related to soil formation, e.g., topography and parent material, whose variations in time and space can cause differences in soil depth, and its chemical and physical properties (intrinsic soil variability); 2) the climatic factors, e.g., rain and wind, which can have direct or indirect effects (erosion) on soils and crops; and 3) the biological factors: trees (e.g. *Acacia albida*), termites and other insects, diseases, etc.

To these natural factors, one should add the actions of humans and other animals: cultivation, grazing, field management practices, etc. These actions can cause great variability, especially under low-input farming.

The variability induced by these factors can be characterized at different scales. Moorman and Kang (1978) proposed a surface of $4m^2$ as a minimum area for the characterization of spatial variability in soil properties. They defined soil microvariability as being the variability within a field which has a permanent character, or which, at least, persists over several years and has an effect on cultivated plants. This definition excludes variations due to field management, except if they lead to permanent changes in soil properties.

Although spatial variability is widespread in millet fields throughout Niger, very few studies have been conducted to assess its importance, and to quantify its effects on millet production. Pfordresher *et al.* (1989) estimated an average of 14% of the area surveyed in the Dallol Bosso to be nonproductive to millet. The soil of nonproductive zones had higher levels of exchangeable Al and lower pH values than did adjacent productive zones at 0-10 cm and 10-30 cm soil depths. In addition, the soils of the productive zones were less crusted and had a thicker surface horizon than the soils of the nonproductive zones.

In a previous study, Wendt (1986) analyzed 26 soil samples (0-15 cm) taken along a 15-m-long transect in a millet field located at the ICRISAT Sahelian Center, about 40 km southeast of Niamey, Niger. He was able to link the low productivity of parts of the transect with low pH (pH 1:1 = 4.5), high percent saturation in Al + H, and decreasing amounts of exchangeable K, Ca, and Mg, as compared to the soil

of the productive parts. In a pot study using soils from the transect, Wendt also found a strong correlation (r^2 = 0.81) between the dry weight of millet plants harvested 37 days after sowing and their Al concentration. The critical concentration of Al in millet plants was estimated at about 600 µg/g.

The objectives of the present study, which was conducted in 1988 and 1989 in south-central Niger (*Département de Maradi*), were (1) to identify the causes of spatial variability in millet fields, and (2) to evaluate its effects on millet production.

Figure 3.2-18 shows the localization of the sites selected for this study and the isohyets in the department of Maradi. Fifteen millet fields and one cowpea field were selected in 1988, and 20 millet fields in 1989. Site selection was done much earlier in the season (early July) in 1989 than in 1988 (end of August). Hence, the distinction between productive and unproductive areas of the fields was more difficult in 1989 than in 1988. Only a few of the fields selected in 1988 were also surveyed in 1989.

In 1988, two 5 m x 5 m plots were delineated in two adjacent areas of contrasting productivity in each millet field. The productive areas typically had more millet plants, and healthier ones, than the less productive areas.

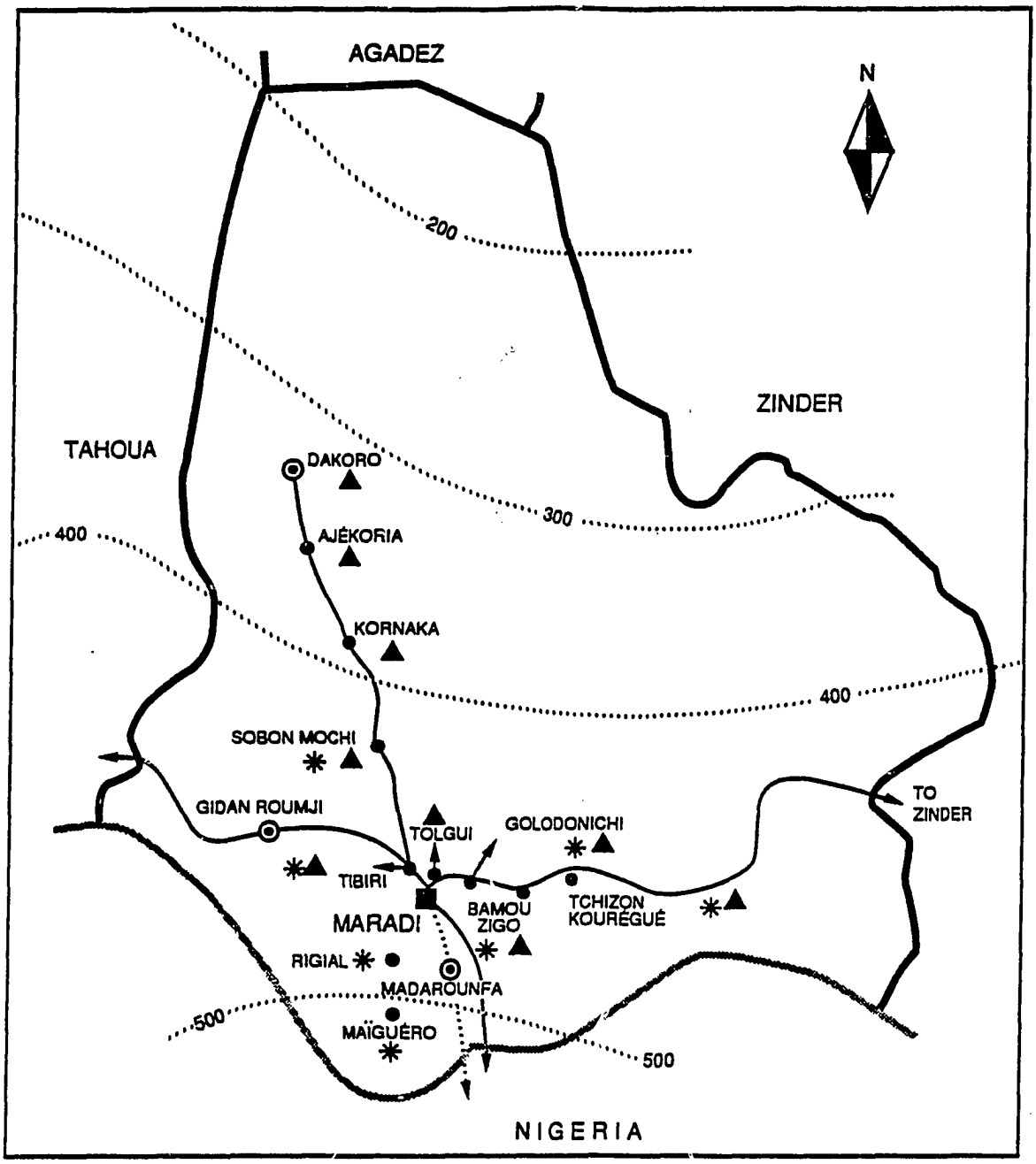
In 1989, the number of plots was doubled in each area, and their size was increased to 6 m x 6 m for a better representation of the spatial variability within each millet field.

Soil samples were taken from the productive and less productive plots shortly after their delineation. The number of plots sampled was 32 (16 x 2) in 1988 and 28 (14 x 2) in 1989. The depth of soil sampling was 0-20 cm in 1988 and 0-5, 5-10, 10-15, and 15-20 cm in 1989. In 1988, each soil sample was divided into two homogeneous sub-samples. Half of the sub-samples were sent to Purdue University in Lafayette, Indiana, and the other half to the INRAN Soil Laboratory in Niamey for analysis. In 1989, all the soil samples were analyzed at the INRAN laboratory.

The following analyses were done on the 1988 and 1989 samples at the INRAN Soil Laboratory:

- Particle size distribution by the hydrometer method (Day, 1965).
- pH in water and 1N KCl at the soil-to-solution ratio of 1:2.5.
- Exchange acidity (Al + H) measured by titration after extraction in 1N KCl solution (Thomas, 1982). Aluminum was complexed with sodium fluoride and measured by titration with HCl.
- Available phosphorus was determined by using the Bray-1 extraction solution (0.003M NH_4F + 0.0025M HCl), and the ascorbic acid for color development (Olsen and Sommers, 1982).
- Exchangeable bases were extracted by ammonium acetate, and measured by atomic absorption (Ca and Mg) and flame emission (K and Na). The sum of exchangeable bases and exchangeable acidity is called effective (ECEC).
- Organic carbon was determined by the Walkey-Black procedure (Nelson and Sommers, 1982). The soil organic matter content was obtained by multiplying the C concentration by 1.724.
- Total nitrogen was measured by the wet oxidation procedure of Kjeldahl (Bremmer and Mulvaney, 1982).

The fixing capacity of the soils sampled in 1988 was studied by John Scott-Wendt at Purdue University as part of his Ph.D research. He added 0, 0.5, 10.9, 21.8, and 43.7 µg of P, or the equivalent of 0, 30, 60, 120, and 240 Kg P_2O_5/ha, to 50 g of each soil. The soils fertilized in this way were brought to 10% humidity and incubated at 35°C during 30 days. They were then air-dried, humidified again at



✱ 1988

▲ 1989

·····300 Isohyte 1961–1990 (in mm)

■ Department Administrative Seat

◉ District

SCALE
1/1,500,000
0 50 km

FIGURE 3.2-18. SOIL SAMPLING SITES IN 1988 AND 1989.

10%, and incubated during 24 hours before proceeding to the extraction of the soil solution by centrifugation.

The concentration of P in the soil solution was measured by using the blue molybdate method (Olsen and Sommers, 1982). Labile P was determined by a modified version (Scott-Wendt, 1989) of the resin extraction procedure described by Olsen and Sommers (1982).

Exchangeable Al was extracted with 0.5N $BaCl_2$ and measured by the catechol violet procedure (Mosquera and Mombiela, 1986). Free iron oxides (DCB-Fe) were extracted with Dithionite-Citrate-Bicarbonate (DCB-Fe), and amorphous and weakly crystalline iron (AO-Fe) was extracted with ammonium oxalate (Olsen and Ellis, 1982) and determined by atomic absorption.

In addition to soil analyses, information on soil and crop management in each field was obtained, and *in-situ* differences between the productive and less productive areas were carefully monitored and recorded. At maturity, millet hills and ears in each plot were counted. Millet ears were then harvested, threshed, and the grain weighed. In 1989, several (6 out of 20) millet fields were harvested by the farmers before we were able to get to them.

The majority of fields investigated in 1988 (9 out of 15) and in 1989 (15 out of 20) were cultivated to millet as the main crop, in association with cowpea and/or sorghum. Most of these fields were cultivated with the same crops for at least the last four years. Some farmers have noticed the decrease of productivity of their fields and the apparition of unproductive areas after ten years of cultivation.

Few millet fields were fertilized with P fertilizers (SSP) and organic manure, and even fewer fields were side-dressed with urea. In 1989, four farmers among those (7/20) who used the Single Super Phosphate (SSP) received it through a research project sponsored by IFDC. Phosphorus and nitrogen fertilizers were broadcasted by hand over the whole field without any tillage, and without distinction between productive and less productive areas of the field.

During the investigation, we noticed very few crop residues, e.g., millet stalks on the soil surface, though the majority of farmers (29/35) asserted having left the whole or part of the crop residues in the field. The combined action of grazing, termites, and climatic factors have probably destroyed or removed a large part of the crop residues left in the field after harvest of the previous crop. Only one farmer declared to have knowingly placed crop residues on the low productive zones of his field.

Apart from the cultivated vegetation, the most apparent differences between productive and low productive zones of the millet fields investigated in 1988 and 1989 were:

- the low productive zones were often, but not always, located in the lower parts of the field;
- the soil of these zones was sometimes eroded and more compact than the soil of the more productive zones;
- on a large number of fields, bush stumps were found in the productive areas. It is likely that the leaves and brushwood of these shrubs, which are often cut and left on-site, contribute to enhance soil fertility and reduce erosion;
- in 1988, termite activity was noticeable in the productive parts of three out of 16 fields;
- in one field surveyed in 1989, we found small pieces of pottery, which can be an indication that the site was inhabited previously.

Soils which are completely unproductive are commonly called "gueza" in the region of investigation. According to the farmers, these soils are located where *Combretum micranthum* has spread out, then disappeared.

In 1988, productive plots had substantially more millet plants and ears than their unproductive counterparts, which resulted in much higher grain yields in all the fields surveyed (Table 3.2-24).

TABLE 3.2-24
NUMBER OF MILLET HILLS, MILLET EARS, AND GRAIN YIELD
OF PAIRED PRODUCTIVE AND UNPRODUCTIVE SITES IN 1988

Parameter	Productive	Unproductive	P > F
No. hills (25 m^2)			
Mean	13.9 a[1]	5.5 b	< 0.01
SD	4.0	3.5	
No. ears (/25 m^2)			
Mean	57.4 a	2.4 b	< 0.01
SD	30.3	4.3	
Grain yield (k/ha)			
Mean	694.3 a	10.8 b	< 0.00
SD	313.1	23.1	

[1]Means followed by the same letter are not significantly different at P = 0.05.

TABLE 3.2-25
NUMBER OF MILLET HILLS, MILLET EARS, AND GRAIN YIELD
OF PAIRED PRODUCTIVE AND UNPRODUCTIVE SITES IN 1989

Parameter	Productive	Unproductive	P > F
No. hills (36 m^2)			
Mean	17.6	17.3	NS
SD	5.2	16.4	
No. ears (/36 m^2)			
Mean	37.5 a[1]	20.2 b	< 0.01
SD	24.7	17.5	
Grain yield (k/ha)			
Mean	270.9 a	140.8 b	< 0.01
SD	251.5	141.7	

[1]Means followed by the same letter are not significantly different at P = 0.05.

In 1989, there were also significant differences in the number of millet plants and ears, and grain yield between productive and unproductive plots (Table 3.2-25). These differences were less pronounced than

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in 1988, but were probably more representative of the spatial variability within millet fields in south-central Niger. Millet yields were generally poor and much more variable in 1989 than in 1988, because of the drier conditions and wider geographic area covered by millet fields surveyed in 1989 (Figure 3.2-18).

There were no significant differences in the clay, silt, and sand contents of the soils of the productive and less productive plots in 1988, as well as in 1989 (Tables 3.2-26 and 3-27). The majority of soils sampled had more than 90% sand and less than 10% clay in the 0-20 cm depth.

In 1988, the soils of low productive plots were slightly more acid and had much higher levels of exchangeable Al and iron oxides than the soils of adjacent productive plots (Table 3.2-28). The same trends were noticed in 1989. In addition, it was possible to show that soil acidity increased slightly with depth (Table 3.2-29).

Effective CEC of the soils sampled in 1988 and 1989 was extremely low, regardless of their productivity level. These soils were also very poor in organic carbon (<0.2%) and available phosphorus. Data from the 1989 laboratory analyses seem to indicate that Bray-1 P content was higher near the soil surface (0-5 cm) than below (5-20 cm).

TABLE 3.2-26
SOIL TEXTURE (0-20 cm) OF PAIRED PRODUCTIVE AND UNPRODUCTIVE PLOTS IN 1988

Parameter	Productive	Unproductive	P > F
Clay (%)			
Mean	2.2	2.7	NS[1]
SD	1.2	1.0	
Fine sand (%)			
Mean	43.8	45.6	NS
SD	6.6	6.4	
Coarse sand (%)			
Mean	50.5	47.3	NS
SD	7.0	6.6	

[1]NS = not significant.

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TABLE 3.2-27
SOIL TEXTURE (0-20 cm) OF PAIRED PRODUCTIVE AND UNPRODUCTIVE PLOTS IN 1989

Site	Depth (cm)				Mean	SD[1]
	0-5	5-10	10-15	15-20		
	% Clay					
Productive	2.5	3.6	4.6	4.8	3.9	3.1
Unproductive	3.9	4.5	4.8	5.5	4.7	2.8
	% Fine sand					
Productive	40.0	40.8	42.9	42.2	41.5	6.4
Unproductive	42.2	41.2	40.9	42.3	41.6	6.3
	% Coarse sand					
Productive	54.6	53.1	49.9	49.6	51.8	6.1
Unproductive	50.5	51.1	50.6	49.3	50.4	5.6

	P > F		
Source	% Clay	% Fine sand	% Coarse sand
Productivity	NS[2]	NS	NS
Depth	< 0.01	NS	0.02
Productivity x depth	NS	NS	NS

[1]Standard error of the mean.
[2]NS = nonsignificant.

TABLE 3.2-28
SOIL CHEMICAL PROPERTIES OF PAIRED PRODUCTIVE AND LESS PRODUCTIVE PLOTS IN 1988 (0-20 cm)

Plots	Productive		Less productive		P > F
	Mean	SD	Mean	SD	
pH water (1:2,5)	6.0	0.2	5.8	0.1	< 0.01
pH KCl (1:2,5)	5.0	0.4	4.4	0.2	< 0.01
ECEC[1] (col/kg)	0.61	0.12	0.58	0.16	NS
Exch. Al (cmol/kg)	0.03 a[2]	0.04	0.15 b	0.06	< 0.01
DCB[3]-Fe (µg/g)	45.4 b	18.2	64.8 a	26.7	< 0.01
AO-Fe[4] (µg/g)	1259 b	893	1672 a	953	< 0.01
Bray P-1 (mg/kg)	2.5	0.8	2.5	1.3	NS

[1]ECEC = effective cation exchange capacity.
[2]Means followed by the same letter are not significantly different at P = 0.05.
[3]Dithionite-Citrate-Bicarbonate.
[4]Weakly crystalline Fe extracted with amonium oxalate.

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TABLE 3.2-29
SOIL CHEMICAL PROPERTIES OF PAIRED PRODUCTIVE AND LESS PRODUCTIVE PLOTS IN 1989 (0-20 cm)

Plot	Depth (cm)				Mean	SD[1]
	0-5	5-10	10-15	15-20		
	pH (H_2O)					
Productive	6.7	6.5	6.3	6.3	6.4 a[2]	0.3
Unproductive	6.2	6.1	5.9	5.9	6.0 b	0.5
	pH (KCl)					
Productive	5.8	5.5	5.35	5.2	5.5 a	0.4
Unproductive	5.1	4.9	4.8	4.3	4.9 b	0.5
	Exchangeable Al ($cmol_c$/kg)					
Productive	0.00	0.00	.001	0.01	0.01	0.01
Unproductive	0.02	0.06	0.09	0.15	0.08	0.08
	Exchangeable acidity ($cmol_c$/gk)					
Productive	0.03	0.05	0.06	0.08	0.06 b	0.04
Unproductive	0.08	0.14	0.21	0.26	0.17 a	0.17
	Effective CEC ($cmol_c$/kg)					
Productive	1.44	1.83	1.98	2.23	1.87	1.39
Unproductive	1.84	1.97	2.13	2.20	2.04	1.41
	Bray P-1 (mg/kg)					
Productive	3.9	2.5	1.9	1.6	2.5	1.9
Unproductive	2.4	1.6	1.6	1.5	1.8	1.0

[1]Standard error of the mean.
[2]Means followed by the same letter are not significantly different at P = 0.05.

Figure 3.2-19 shows an exponential increase in P concentration of the soil solution of the productive plots with each addition of phosphorus. Phosphorus concentration of the soil solution was much higher for the productive than the less productive plots at all P fertilization rates.

Without any addition of phosphorus, soil solution P concentration of the productive and less productive plots was well below the critical level of 0.2 µg P/ml necessary for an optimal growth of millet (Fox and Kamprath, 1970). Half of the soils of the productive plots released at least 0.2 µg P/ml at 5.5µg P/g of soil, or the equivalent of 30 Kg of P_2O_5 /ha. At the same fertilization rate, P concentration of the soil solution of all the low productive plots was ≤ 0.07µg P/ml. It was necessary to apply more than 60 Kg P_2O_5/ha for the majority of the soils of the nonproductive plots to reach the critical level of 0.2µg P/ml.

Unlike soil solution P concentration, there were only small differences in the amount of labile P between the soils of the productive and less productive plots (Figure 3.2-20). With no addition of phosphorus, the amount of labile P was very low (about 0.8µg/g) in all the soils. Since soil sampling was

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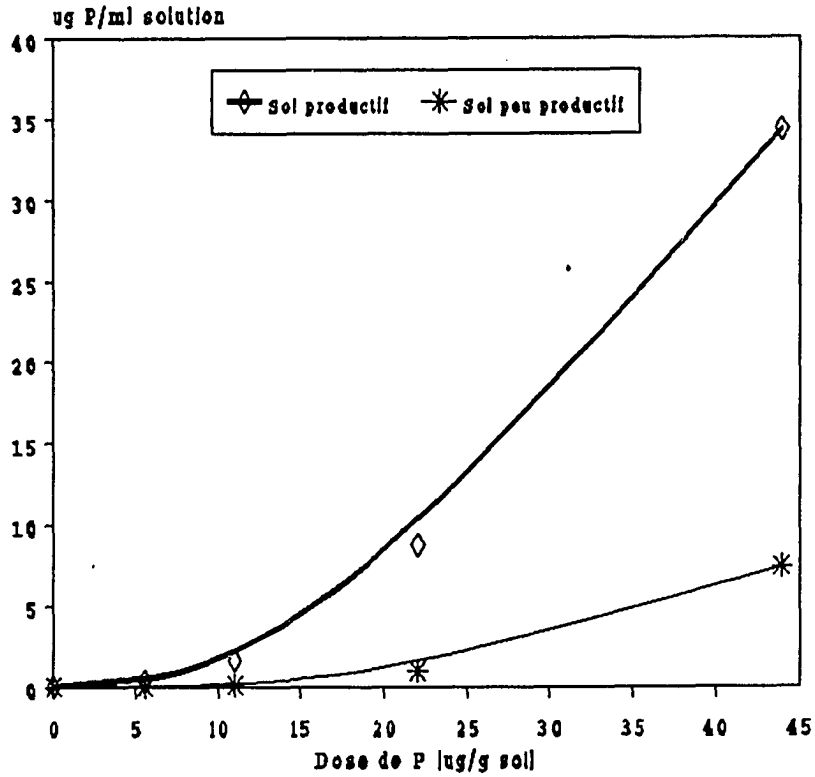
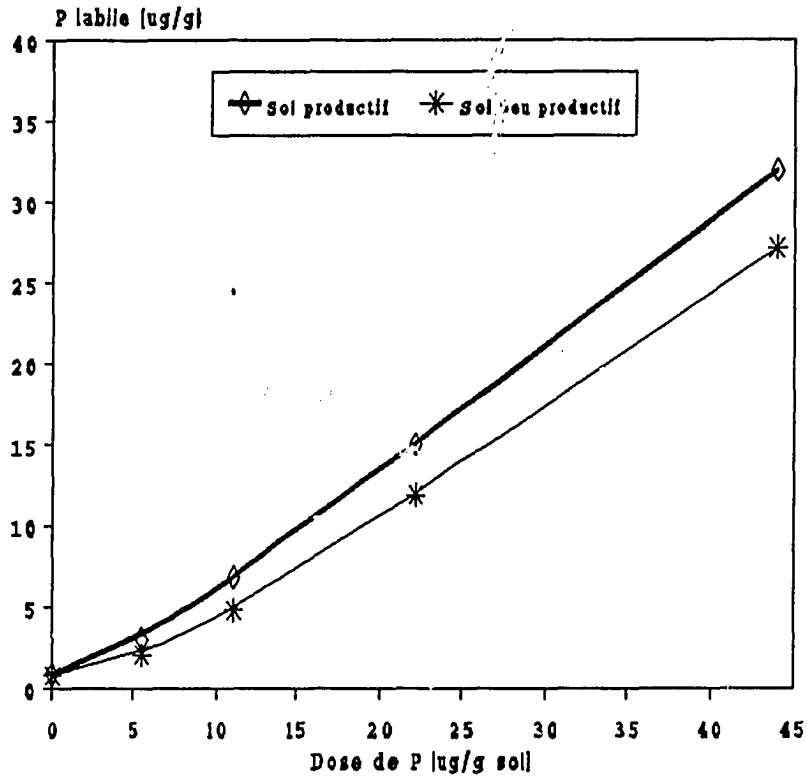


P rate µg P/g soil	Productive soil		Unproductive soil	
	Average	SD	Average	SD
	---- µg/ml ----		---- µg/ml ----	
0.0	0.02	0.04	0.01	0.01
5.5	0.38	0.44	0.03	0.03
10.9	1.66	1.84	0.13	0.11
21.8	8.71	8.04	0.96	0.80
43.7	34.30	24.04	7.39	5.66

FIGURE 3.2-19. SOIL SOLUTION P CONCENTRATION OF PRODUCTIVE AND LESS PRODUCTIVE PLOTS AT VARIOUS P FERTILIZATION RATES.



P rate µg P/g soil	Productive soil		Unproductive soil	
	Average	SD	Average	SD
	---- µg/ml ----		---- µg/ml ----	
0.0	0.87	0.16	0.77	0.35
5.5	3.06	0.74	2.04	0.67
10.9	6.77	1.37	4.78	0.99
21.8	15.03	2.02	11.85	1.78
43.7	31.92	3.184	27.14	3.11

FIGURE 3.2-20. LABILE P OF PRODUCTIVE AND LESS PRODUCTIVE SOILS AT VARIOUS P FERTILIZATION RATES.

done toward the end of the crop season, soil P reserves may have been used up by millet, particularly in the productive plots.

These results indicate that the low productive soils fix more phosphorus than their productive counterparts. This may be linked to the levels of exchangeable Al and iron oxides in these soils. As a matter of fact, low productive soils had considerably more exchangeable Al, free iron (DCB-Fe), and amorphous or poorly crystalline iron (AO-Fe) oxides than the more productive soils (Table 3.2-30). Furthermore, there were significant correlations between the levels of these parameters and P labile or in solution, mainly at the highest P fertilization rates (Table 3.2-31).

TABLE 3.2-30
EXCHANGEABLE Al, NH_4-OXALATE EXTRACTABLE Fe (Feo) AND DCB-EXTRACTABLE Fe (Fed) OF PAIRED PRODUCTIVE AND UNPRODUCTIVE SOILS IN 1988

Parameter	Productive	Unproductive	P > F
Exchangeable Al (cmol(+)/kg)			
Mean	0.032 b[1]	0.152 a	< 0.01
SD[2]	0.036	0.064	
Feo (µg/g)			
Mean	45.375 b	64.813 a	< 0.01
SD	18.162	26.681	
Fed (µg/g)			
Mean	1259.375 b	1671.875 a	< 0.01
SD	893.312	952.850	

[1]Based on LSD values at P = 0.05. Means followed by the same letter are not significantly different at P = 0.05. (Adapted from Scott-Wendt *et al.*, 1990).
[2]Standard error of the mean

The study conducted in 1988 and 1989 in the Department of Maradi illustrates the great spatial variability which exists within millet fields in south-central Niger. The most visible features of this variability were the clear differences in millet yield and its components between productive and low productive areas of the same field. On the contrary, there was very little variation in the soil texture of these areas, at least on a depth of 0-20 cm. The soils of all the fields surveyed were sandy, and had very low effective CEC, and low P and organic carbon contents. Davis-Carter (1989) suggested that the low buffering capacity of the millet-producing soils of Niger may explain that slight variations in their chemical properties can cause large variation in their productivity.

The soils of low productive plots had slightly lower pH values and much higher levels of exchangeable Al than the soils of the more productive plots. This confirms the results obtained by Scott-Wendt *et al.* (1988) in western Niger.

The analyses of the soils sampled in 1988 showed a good correlation between P concentration of the soil solution and exchangeable Al, and between P concentration and free iron oxides. The low

TABLE 3.2-31
PEARSON CORRELATION COEFFICIENTS (r) BETWEEN SOIL SOLUTION P, LABILE P, AND EXCHANGEABLE Al AND DCB-Fe AND AO-Fe IN 1988

P rate	Parameter	P in solution		Labile P	
(µg P/g)		r	P>|r|	r	P>|r|
0.0	Al	-0.36	0.04	-0.36	0.04
	DCB-Fe	-0.33	0.07	0.28	0.12
	AO-Fe	-0.31	0.09	0.37	0.04
5.5	Al	-0.55	0.00	0.58	0.00
	DCB-Fe	-0.49	0.00	0.09	0.64
	AO-Fe	-0.47	0.01	-0.02	0.92
10.9	Al	-0.57	0.00	-0.68	0.00
	DCB-Fe	-0.53	0.00	-0.29	0.10
	AO-Fe	-0.50	0.00	-0.22	0.21
21.8	Al	-0.64	0.00	-0.84	0.00
	DCB-Fe	-0.59	0.00	-0.53	0.00
	AO-Fe	-0.55	0.00	-0.48	0.00
43.7	Al	-0.72	0.00	-0.82	0.00
	DCB-Fe	-0.67	0.00	-0.57	0.00
	AO-Fe	-0.65	0.00	-0.54	0.00

productive soils had more exchangeable Al and iron oxides, and, consequently, fixed more P. Thus, the common recommendation of 20-30 kg of P_2O_5/ha for millet production in Niger is far below the rate of P needed for optimum millet growth on low productive soils, and does not take into account the great soil variability in millet fields. Other nutrients may become limiting once P is supplied to the soil in sufficient quantity.

This is an important result, since previous research has rather favored the thesis of aluminum toxicity (Scott-Wendt *et al.*, 1988), which was unlikely in our study, given the relatively high pH values (>5.5) and the moderate Al saturation (<30%) of the soils of the low productive plots. Furthermore, Alhrichs *et al.* 1989) showed the high tolerance of several millet varieties to aluminum toxicity.

3.2.3.2 Characterization of Spatial Variability in Two Millet Fields in Western Niger

The study of spatial variability initiated in 1988 by the Soils Agronomist was continued in 1990 and 1991 in western Niger.

The objectives of the 1990-1991 study were:

1. to evaluate the spatial relationships among soil properties, and between these properties and millet yield;
2. to test ways of reducing spatial variability in millet fields in western Niger.

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In order to achieve these objectives, the following steps have been completed:

- Characterization of spatial variability of soil properties and millet yield in two fields near the capital city of Niger.
- Laboratory analyses and pot studies to determine the most limiting nutrients in these fields.
- One year (1991) of field experiments to test the effect of these nutrients, and other soil amendments, on millet yields.

The two millet fields selected for this study were located at about 8 km NW of Niamey.

Six pits were dug in each field for soil description. Soil samples were taken from each horizon and analyzed at the INRAN Soil Laboratory. In addition, bulk density measurements were made with the cylinder method ("anneau") in the first three horizons. In general, the soil of the two millet fields can be described as silicious, isohyperthermic, psammentic haplustalf.

The areas sampled were 40 m x 40 m in field #1 and 120 m x 60 m in field #2.

Contour maps (Figures 3.2-21 and 3.2-22) were drawn for each field. They show differences in elevation within each field.

Soils were sampled at depths of depth 0-20, 20-40, 40-60, and 60-80 cm.

Laboratory soil analyses were conducted to determine pH, (Al+H), Exch. Bases, CEC, Bray P-1, DCB-Fe, Organic C, and Total N.

In addition, plant measurements (4m x 4m) were made to determine the number of hills and ears, yield of grain and stover weight of millet. Also determined was the weight of volunteer millet and localization and number of bushes and *Sesbania* sp.

Selected soil properties of the two millet fields are presented in Tables 3.2-32 and 3.2-33. The soils of these fields were fairly acid, had very low organic carbon content and relatively high DCB-iron content. What we did not expect to see were the relatively high P contents: 19-20 mg/kg on the average. According to the farmers, no P fertilizer was applied during the last three to four years. Similar soils in the area do not have more than 3-4 mg/kg. Further investigation will be necessary to verify the farmers' claim. In field #2, Bray P-1 values were highly variable at all depths. This was also true for Al+H values in both fields.

Tables 3.2-34 and 3.2-35 show the extreme variations in millet yield in the areas sampled in field #1 and #2, respectively. Highly significant positive correlations were found between soil elevation in field #1 and the number of millet hills and ears, total millet yield, the number of *Sesbania* plants, soil pH, Bray P-1 (Table 3.2-36). In the second field, grain yield and Bray P-1, in particular, were highly correlated with soil elevation (Table 3.2-37). This means that millet yields and soil P content were higher in the elevated parts of the field.

Variograms were built to show the range of influence, or the distance beyond which there is little spatial correlation, of various parameters in field #1. As a first estimate, the range of influence was about 20 m for grain yield (Figure 3.2-25), 15 m for soil phosphorus (Figure 3.2-24), and 15-20 m for soil pH (Figure 3.2-23). More data were collected in 1991 in the second field to come up with better estimates of range values. These data are being analyzed with GeoEas.

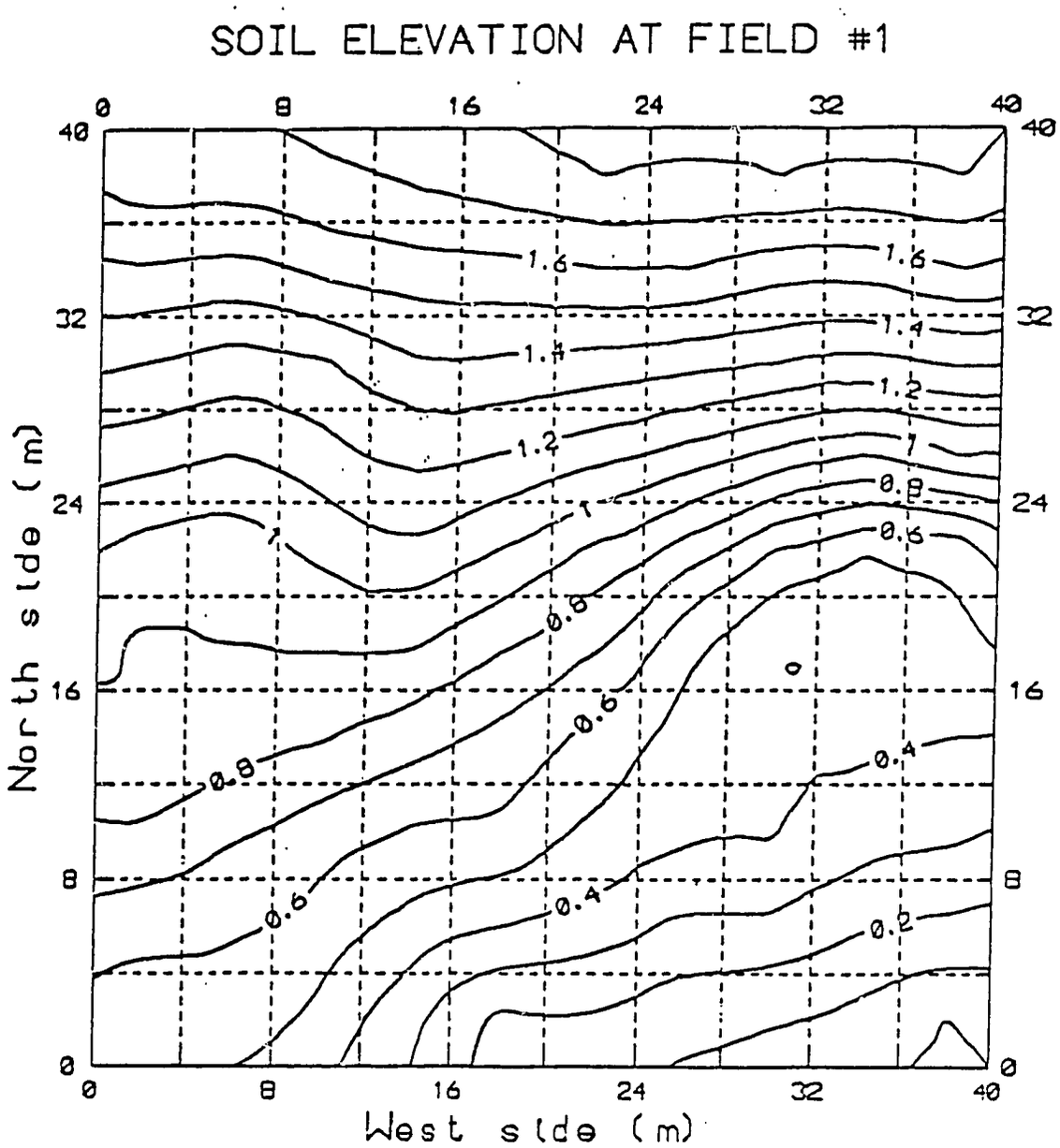

FIGURE 3.2-21. CONTOUR MAP OF SOIL ELEVATION IN FIELD #1.

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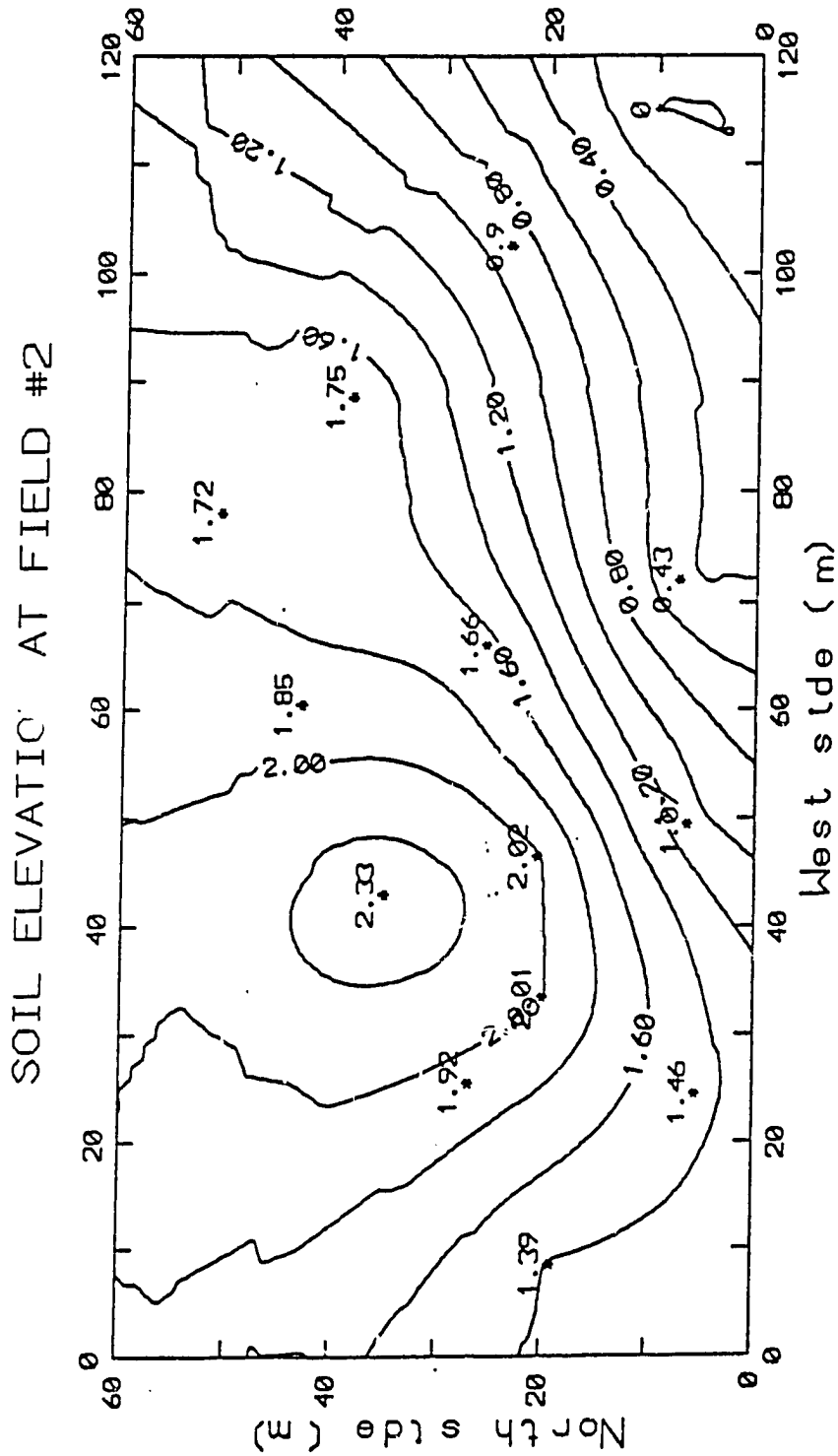

FIGURE 3.2-22. CONTOUR MAP OF SOIL ELEVATION IN FIELD #2.

TABLE 3.2-32
SELECTED SOIL CHEMICAL PROPERTIES AT FIELD #1.
SAMPLING DATE: JUNE 1990

Soil property	Soil depth					
	0-20 cm		20-40 cm		40-60 cm	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
pH H2O (1:2.5)	5.6	7	5.6	8	5.4	8
pH HCl (1:2.5)	4.8	10	4.6	10	4.4	9
(Al+H) $cmol_c$/kg	0.2	97	0.3	102	0.5	89
CEC[1] $cmol_c$/kg	1.1	23	1.1	28	1.2	27
Organic C (g/kg)	1.2	33	0.9	25	0.7	20
Bray-1 P (mg/kg)	21.0	21	19.8	27	19.2	25
DCB[2]-Fe (g/kg)	8.0	27	8.3	39	8.6	27

TABLE 3.2-33
SELECTED SOIL CHEMICAL PROPERTIES AT FIELD #2.
SAMPLING DATE: JUNE 1990

Soil property	Soil depth					
	0-20 cm		20-40 cm		40-60 cm	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
pH H2O (1:2.5)	5.4	4	5.2	7	5.0	4
pH HCl (1:2.5)	4.7	6	4.3	9	4.1	5
(Al+H) $cmol_c$/kg	0.2	109	0.5	91	0.9	60
CEC[1] $cmol_c$/kg	1.3	30	1.4	32	1.7	31
Organic C (g/kg)	1.3	26	1.1	23	1.0	30
Bray-1 P (mg/kg)	19.6	75	19.7	88	18.5	92
DCB[2]-Fe (g/kg)	5.0	57	5.8	58	6.9	48

[1]Cation exchange capacity.
[2]Dithionite-Citrate-Bicarbonate.

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TABLE 3.2-34
MILLET PERFORMANCE IN 1990 IN FIELD #1

Growth parameter	Minimum	Maximum	Average	CV (%)
No. hills/m^2	0.1	1.2	0.6	35
No. heads/m^2	0.0	2.2	0.8	65
Grain yield (g/m^2)	0.0	53	19	68
Stover yield (g/m^2)	0.0	325	142	59
Total yield (g/m^2)	0.0	392	179	56

TABLE 3.2-35
MILLET PERFORMANCE IN 1990 IN FIELD #2

Growth parameter	Minimum	Maximum	Average	CV (%)
No. heads/m^2	0.0	3.8	1.6	54
Grain yield (g/m^2)	0.0	74	29	57
Stover yield (g/m^2)	6.2	625	227	58
Total yield (g/m^2)	6.2	736	284	54

TABLE 3.2-36
PEARSON CORRELATION COEFFICIENTS, FIELD #1

	Elevation	pHw	(Al+H)	CEC	Bray-1	DCB-Fe
Soil depth	-	-0.28	0.37**[1]	0.23**	-0.14*	NS
Elevation	-	0.68**	-0.70**	-0.25**	0.54**	-0.56**
No. hills	0.53**	0.35**	-0.47**	-0.15**	0.17**	-0.37**
No. heads	0.47**	0.34**	-0.44**	-0.18**	0.13*	-0.23**
Grain yield	0.29**	0.20**	-0.29**	-0.15*	NS	-0.15**
Total yield	0.50**	0.30**	-0.44**	-0.21**	0.13*	-0.25**
Sesbania	0.73**	0.52**	-0.49**	-0.13*	0.36**	-0.42**

[1]* and ** = significant at the P = 0.05 and 0.01 levels, respectively.

TABLE 3.2-37
PEARSON CORRELATION COEFFICIENTS, FIELD #2

	Elevation	pHw	(Al+H)	CEC	Bray-1	DCB-Fe
Soil depth	-	-0.61**[1]	0.60**	0.47**	NS	NS
Elevation	-	0.38**	-0.32*	-0.27*	0.67**	-0.42**
No. heads	0.46**	NS	-0.45**	-0.32*	NS	NS
Grain yield	0.69**	NS	NS	-0.40**	0.50**	-0.50**
Total yield	NS	NS	-0.48**	NS	NS	NS

[1]* and ** = significant at the P = 0.05 and 0.01 levels, respectively.

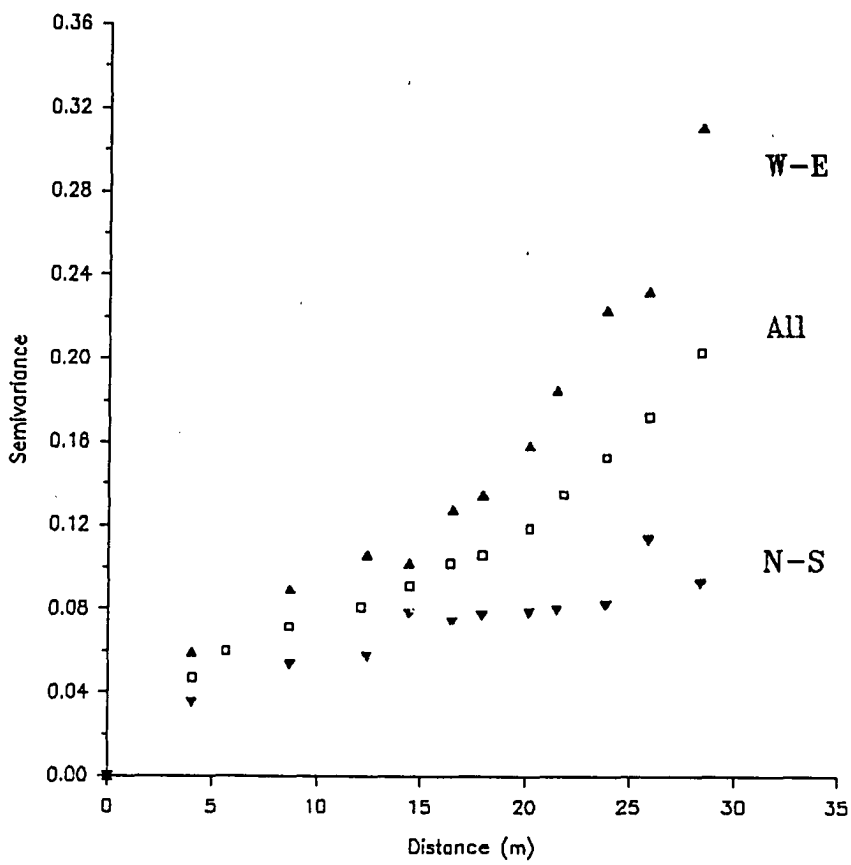

FIGURE 3.2-23. SEMIVARIOGRAM OF SOIL pH IN FIELD #1 IN 1990.

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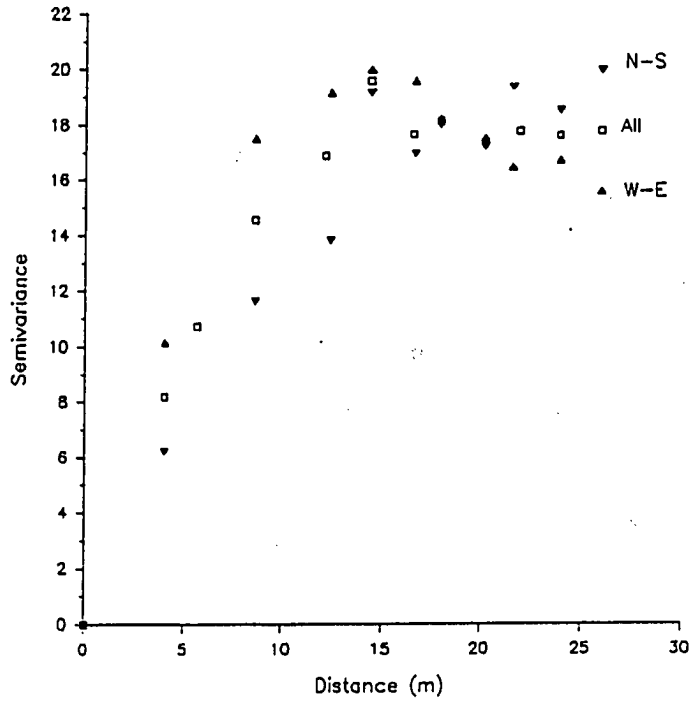

FIGURE 3.2-24. SEMIVARIOGRAM OF BRAY P-1 IN FIELD #1 IN 1990.

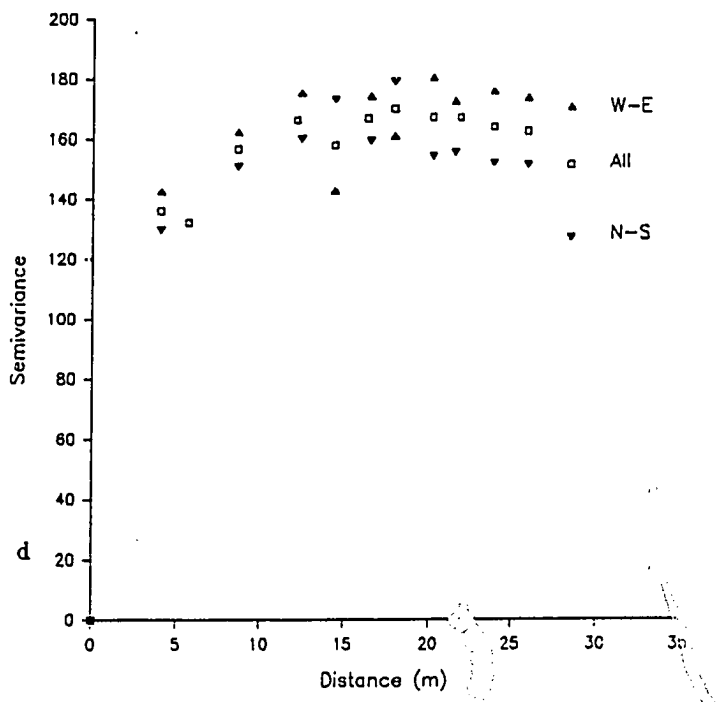

FIGURE 3.2-25. SEMIVARIOGRAM OF GRAIN YIELD IN FIELD #1 IN 1990.

Pot experiments

The main objective of these experiments was to test nutrient deficiencies in the soils of productive and unproductive areas of field #1, and their effect on millet growth.

Pot experiment #1:

Millet variety:	CIVT
Planting date:	11/28/90
Harvest date:	12/26/90
Experimental design:	Randomized complete block design, 2 factors, 3 reps
Factor A:	Productive and unproductive soil

Pot experiment #2:

Millet variety:	CIVT
Planting date:	2/23/91
Harvest date:	3/23/91
Experimental design:	Randomized complete block design, 2 factors, 3 reps
Factor A:	Productive and unproductive soil

The soils used for pot experiments 1 and 2 were taken from the productive and nonproductive areas of field #1. They were air-dried, and passed through a 4-mm screen. Plastic pots labeled 1 to 16 (experiment #1) or 1 to 24 (experiment #2) were filled with 6 kg of each soil, and watered to 75% field capacity. Half of the pots, e.g., 1-8 (or 1-12) were filled with soil from productive areas, and the other half, with soil from nonproductive areas. After two days, the soil in the pots was fertilized according to each treatment combination (Tables 3.2-38 and 3.2-39) and the corresponding pot number. Only 50% of nitrogen was applied at this time. The other half was applied 8-10 days after planting. All the nutrients, except manure, were diluted in distilled water and applied with plastic syringes.

Twenty-four hours after fertilizer application, 15-20 seeds of millet (CIVT) were planted in each pot at about 1.5 cm soil depth. The number of millet plants in each pot was reduced to eight plants one week after emergence.

Each pot was weighed daily and brought up to 75% field capacity with distilled water. During the last two weeks of the experiment, it was necessary to water the pots twice a day.

The following were made to determine measurements:

Plant height before harvest
Millet dry weight: tops only (experiment #1), tops and roots (experiment #2)

Laboratory analyses were conducted to determine the concentrations of millet N, P, K, Ca, and Mg.

Pot experiment #1. The main effects of soils and nutrients and the effect of their interaction on millet height and dry matter were highly significant (Tables 3.2-40 and 3.2-41).

TABLE 3.2-38
NUTRIENTS ADDED (FACTOR B), EXPERIMENT 1

Nutrient	N	P_2O_5	K_2O	S+MG+ZN+CU+B
	---------- kg/ha ----------			
Check	0	0	0	0
N	46	0	0	0
P1	0	50	0	0
NP2	46	50	0	0
P2	0	100	0	0
NP2	46	100	0	0
NP2K	46	100	30	0
All	46	100	30	12+10+5+2+1

TABLE 3.2-39
NUTRIENTS ADDED (FACTOR B), EXPERIMENT 2

Nutrient[1]	N	P_2O_5	K_2O	S	Mg	Zn	B	Cu	Manure
	---------- kg/ha ----------								t/ha
Check	0	0	0	0	0	0	0	0	0
NP	46	50	0	0	0	0	0	0	0
NPK	46	50	45	0	0	0	0	0	0
NPKS	46	50	45	16	0	0	0	0	0
All	46	50	45	16	10	5	1	2	0
All-Mg	46	50	45	16	0	5	1	2	0
All-Zn	46	50	45	16	10	0	1	2	0
All-B	46	50	45	16	10	5	0	2	0
All-Cu	46	50	45	16	10	5	1	0	0
M5	0	0	0	0	0	0	0	0	5
M10	0	0	0	0	0	0	0	0	10
M5NP	46	50	0	0	0	0	0	0	5

[1]Reagent-grade nutrients.

TABLE 3.2-40
PLANT HEIGHT AS AFFECTED BY SOIL AND NUTRIENTS, POT EXPERIMENT #1

Soil nutrients	Productive	Unproductive	Average
	Height (cm)		
Check	26.7	15.3	21.0
N	29.7	18.3	24.0
P1	29.3	16.7	23.0
NP1	33.0	36.0	34.5
P2	33.7	17.7	25.7
NP2	33.3	38.0	35.7
NP2K	36.3	41.7	39.0
All	43.7	45.0	44.3
Average[1]	33.2	28.6	30.9

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean squares	F value	P > F
Rep	2	2.67	1.333	0.18	
Soil (A)	1	256.69	256.688	35.11	.000
Nutrients (B)	7	3102.98	443.283	60.63	.000
AB	7	844.81	120.688	16.51	.000
Error	30	219.33	7.311		

[1]Coefficient of variation = 8.7%.

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TABLE 3.2-41
MILLET DRY WEIGHT AS AFFECTED BY SOIL AND NUTRIENTS, POT EXPERIMENT #1

Soil nutrients	Productive	Unproductive	Average
	Height (cm)		
Check	1.34	0.08	0.71
N	2.48	0.50	1.49
P1	1.78	0.50	1.14
NP1	3.36	3.67	3.52
P2	2.10	0.20	1.15
NP2	3.75	4.49	4.12
NP2K	4.36	4.66	4.51
All	9.44	7.37	8.40
Average[1]	3.58	2.68	3.13

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean squares	F value	P > F
Rep	2	0.05	0.027	0.17	
Soil (A)	1	9.57	9.568	61.87	.000
Nutrients (B)	7	283.49	40.499	261.90	.000
AB	7	14.10	2.014	13.03	.000
Error	30	4.64	0.155		

[1]Coefficient of variation = 12.6%

Figure 3.2-26 illustrates the effect of added nutrients on millet dry matter. It is apparent from this graph that the application of 50 or 100 kg of P_2O_5/ha alone to the productive and unproductive soils did not cause an increase in millet dry matter, as compared to the check. On the contrary, the combination of N and P increased millet yield significantly. The increase was more important on the "unproductive" soils, which produced as much as the productive ones with the addition of N and P. The addition of potassium (30 kg K_2O/ha) did not give rise to a substantial increase in millet yield, as compared to the N&P treatment combinations.

The maximum yield was obtained with treatment #8, which received all the nutrients (N, P, K, S, Mg, Cu, Zn, and B), on the productive, as well as the less productive, soil.

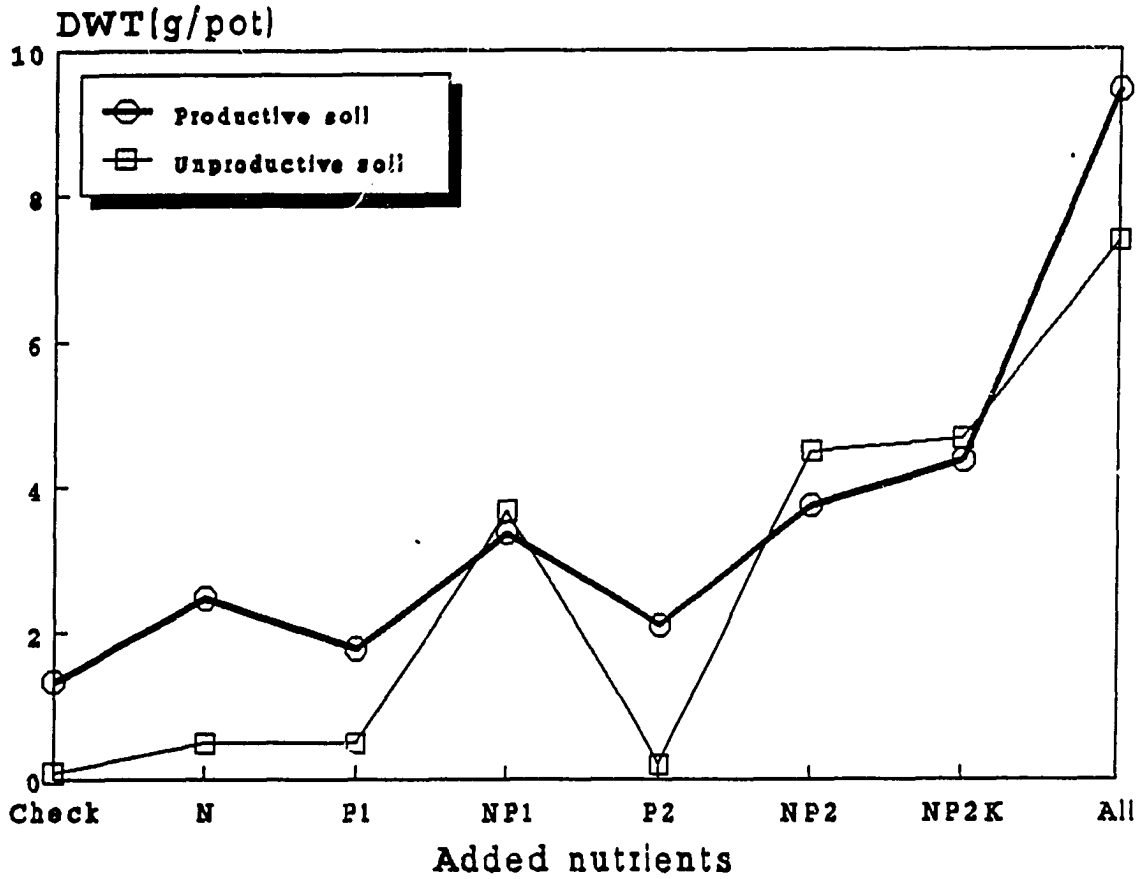

FIGURE 3.2-26. THE EFFECTS OF ADDED NUTRIENTS ON MILLET DRY WEIGHT. POT EXPERIMENT #1.

Pot experiment #2. This experiment was carried out during a period (February 23-March 23) of relatively high air temperatures, which explains the higher millet yields obtained, in comparison with the first experiment.

The effects of soil productivity, nutrients, and their interaction on millet height and yield (tops and roots) were highly significant (Tables 3.2-42 and 3.2-43). The micronutrients Zn, Cu, and B did not seem to have a significant effect on millet dry matter (Figure 3-27). It appears from the figure that the treatment combination, NPKS, gave the highest millet dry matter yield. There was a substantial increase when both N and P were applied, almost no increase when K was added, and a big boost when sulfur (S) was added to NPK. This confirms the results of the first experiment, plus it shows that the best treatment combination is probably NPS. Sulfur had less effect on millet growth on low productive soil than it did on the productive one. The addition of micronutrients to NPKS did not cause any noticeable increase in millet dry matter. The application of manure at the rate of 5 or 10 t/ha did not have any effect on millet yield.

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Manure at 5 t/ha + N + P had a similar effect on millet yield than N+P alone. It may be that the effect of manure would take longer to show up than what was allowed by the experiment.

Similar trends were observed of the effects of nutrients on millet root dry matter (Figure 3.2-28).

The results of the two pot experiments indicate that a combination of N, P, and S on the productive soils, and N and P on the less productive ones, would ensure optimum millet growth, assuming that other factors (e.g., water) are not limiting.

TABLE 3.2-42
MILLET DRY WEIGHT OF THE TOPS AND ROOTS
AS AFFECTED BY SOIL AND NUTRIENTS, POT EXPERIMENT #2

Soil/ Nutrients	Tops		Roots	
	Prod.	Unprod.	Prod.	Unprod.
1. Check	2.11	0.43	1.73	0.66
2. N + P	5.67	5.26	4.14	5.03
11. N + P + K	5.87	5.36	4.14	4.81
12. N + P + K + S	10.51	7.33	9.41	5.18
3. N+P+K+S+Mg+Zn+B+Cu	10.67	5.77	7.98	4.59
4. Treatment No. 3 - Mg	10.52	7.84	6.56	5.32
5. Treatment No. 3 - Zn	10.65	7.13	6.61	5.28
6. Treatment No. 3 - B	11.18	8.97	7.16	6.40
7. Treatment No. 3 - Cu	10.59	8.12	7.34	6.96
8. Manure at 5 t/ha	2.16	0.38	1.91	0.64
9. Manure at 10 t/ha	2.15	0.48	2.17	0.74
10. Manure at 5 t/ha+N+P	7.37	6.02	6.48	5.85
Average	7.45	5.26	5.47	4.29

ANALYSIS OF VARIANCE

Source	F value	P > F
Soil productivity	27.35	0.0001
Nutrients	44.37	0.0001
Interaction	6.31	0.0001
CV (%)	8.53	

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TABLE 3.2-43
MILLET HEIGHT AS AFFECTED BY SOIL AND NUTRIENTS,
POT EXPERIMENT #2

Soil nutrients	Plant height (cm)	
	Productive	Unproductive
1. Check	34	22
2. N + P	42	45
11. N + P + K	44	46
12. N + P + K + S	55	49
3. N+P+K+S+Mg+Zn+B+Cu	53	49
4. Treatment No. 3 - Mg	53	55
5. Treatment No. 3 - Zn	55	52
6. Treatment No. 3 - B	57	55
7. Treatment No. 3 - Cu	53	49
8. Manure at 5 t/ha	39	19
9. Manure at 10 t/ha	38	21
10. Manure at 5 t/ha + N+P	48	51
Average	47.6	42.8

ANALYSIS OF VARIANCE

Source	F value	P > F
Soil productivity	27.35	0.0001
Nutrients	44.37	0.0001
Interaction	6.31	0.0001
CV (%)	8.53	

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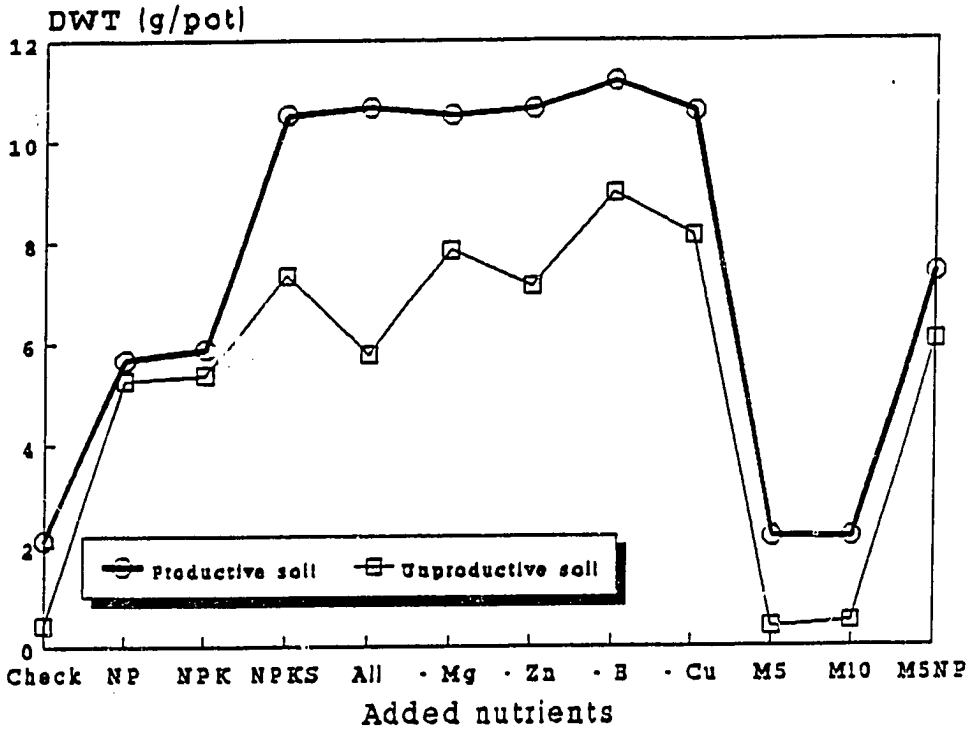

FIGURE 3.2-27. THE EFFECTS OF ADDED NUTRIENTS ON MILLET ABOVE-GROUND DRY WEIGHT. POT EXPERIMENT #2.

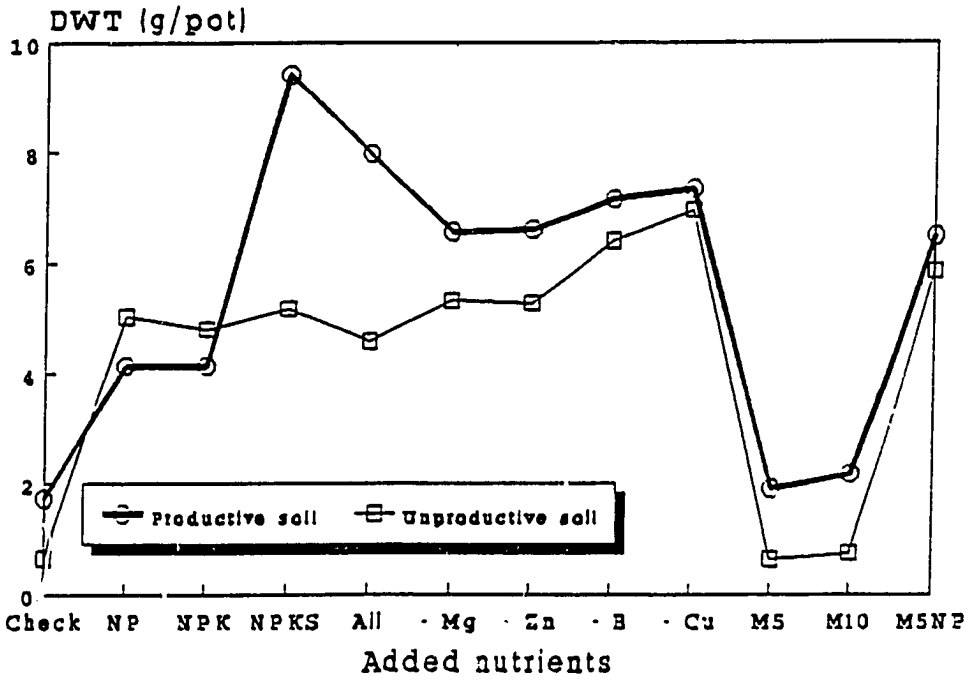

FIGURE 3.2-28. THE EFFECTS OF ADDED NUTRIENTS ON MILLET ROOT DRY WEIGHT. POT EXPERIMENT #2.

3.2.3.3 On-farm Trials

The results of the pot experiments showed that a combination of N, P and, possibly, S would increase millet yields substantially on both productive and less productive soils of the spatial variability study area. Field observations also indicated that erosion was an important factor in explaining soil variability. Elsewhere, Scott-Wendt *et al.* (1988) and others showed that leaving crop residues in the field can enhance soil fertility through decomposition, and by entrapping soil particles.

Therefore, it was decided to design a simple experiment to test these hypotheses.

In 1991, an experiment was conducted in field #1 and in four locations of field #2 to tests the effects of N and P and crop residues on millet yield.

The treatments were:

T1: Check with no fertilizers added
T2: 100 kg/ha of Urea + 200 kg/ha of SSP
T3: T2 + 2 t/ha of millet stalks

The experimental designs were:

Test 1 (field 1): randomized complete block design with 6 replications
Plot size: 8m x 12m

Tests 2 to 5 were located in field #2 on soils of varying productivity and were set up as follows:

Test 2 (relatively productive soil): randomized complete block design with 4 reps
Plot size: 6m x 6m;
Test 3 (unproductive soil): complete randomized design with 4 reps
Plot size: 6m x 6m;
Test 4 (relatively productive soil): randomized complete block design with 5 reps
Plot size: 6m x 8m; and
Test 5 (relatively unproductive soil): randomized complete block design with 5 reps
Plot size: 6m x 8m.

Millet variety HKP was planted on May 26 at 1m x 1m spacing. Single Super Phosphate at 200 kg/ha, or approximately 16 kg P/ha (SSP also contains sulfur), and 50 kg/ha urea were applied on plots T2 and T3. Immediately after fertilizer application, all the plots were "tilled" with a hand tool (small sweep) to control weeds and mix urea and SSF with the topsoil. The next day, millet stalks were spread over the T3 plots. A more natural situation would have been to leave millet stalks in the designated plots after harvest. Unfortunately, all the details (treatments, design, etc.) of the experiment were not worked out at that time. There was also the risk that millet stalks would be displaced, removed, or grazed.

The second urea application (50 kg/ha) on plots T2 and T3 was done one month later. A total of three weedings was necessary to keep the plots clean. Millet was treated with Sulfuron®. However, this was not enough to prevent a heavy "Raghuva" (spike worm) infestation, which caused excessive ear and grain damage. Consequently, grain yields were very low.

Total rainfall in 1991 was 444 mm, of which 377 mm fell after sowing. August was by far the rainiest month (190 mm), while July (49 mm) and September (24 mm) were fairly dry.

The following parameters were monitored in these experiments:

1. Grain and straw yield
2. Number of millet hills and millet ears harvested
3. Extent of drought and ear worm damage
4. Regular soil moisture measurements with the neutron probe in plots which received N and P (T2).

Because of the heavy spike worm damage, we will only present straw yield data in this report. Other results, e.g., soil moisture data, are being analyzed.

Table 3.2-44 shows significant differences between the check and treatments 2 and 3 in four out of five sites. Crop residues (millet stalks) did not result in a yield increase, in comparison with NP alone, except in site #3, which was the least productive. In 1990, millet grain and stover yield on this site was practically zero. In 1991, even the check plots produced something. This may be due to differences in rainfall, millet variety, planting density, cultural practices, etc.

TABLE 3.2-44
MILLET STRAW YIELD AT FIVE SITES IN MALLALEY IN 1991

Treatment	Site No.				
	1	2	3	4	5
	kg/ha				
Check	1372 b[1]	1684 b	486 c	1153	906 b
N+P	2118 a	2934 a	1441 b	2278	1813 a
T2+CR	2196 a	2569 a	2049 a	2181	1760 a
Average	1895	2396	1325	1870	1493
CV (%)	20	18	0	50	24
P > F	HS	S	HS	NS	HS

[1]Means followed by the same letter were not significantly different at P = 0.05 (Duncan). HS = significant at P = 0.01; S = significant at P = 0.05; NS – nonsignificant.

3.2.4 Soil Management

3.2.4.1 Effect of Carbofuran and Phosphorus on Groundnut

ICRISAT researchers found that a major source of spatial variability of peanut growth at the Sahelian Center were nematodes. In order to verify this result at other locations, a joint ICRISAT-INRAN experiment was set up at Tarna in 1989. Carbofuran was used as a nematode suppressant. Another objective of this experiment was to test the effects of several P sources on groundnut yield.

The soil on which the experiment was conducted in 1989 and 1990 was a Psammentic Haplustalf. It had the following characteristics at the 0-30 cm depth: % sand = >90%, pHw = 6.4, effective CEC = 1.8 meq/100g, Bray P-1 = 12.3 mg/kg, and % O.M = O.13.

The experimental design was a split-split plot design with three replications.

The following treatments were incorporated into the design:

With and without carbofuran 5G (Furadan®) at a rate of 1 kg of active ingredient/ha
Groundnut varieties
1.55 - 437
ICGS (E) 30 (in 1989)
Phosphorus
1. Check
2. Phosphate of Tahoua at 20 kg P_2O_5/ha
3. Phosphate of Tahoua at 40 kg P_2O_5/ha
4. STP at 20 kg P_2O_5/ha
5. STP at 40 kg P_2O_5/ha
6. SSP at 20 kg P_2O_5/ha
7. SSP at 40 kg P_2O_5/ha
8. Phosphate of Parc-W partly acidulated at 20 kg P_2O_5/ha
9. Phosphate of Parc-W partly acidulated at 40 kg P_2O_5/ha
10. Phosphate of Parc-W at 20 kg P_2O_5/ha
11. Phosphate of Parc-W at 40 kg P_2O_5/ha
12. Check

Superimposed was treatment or no treatment with Carbofuran 5G (Furadan®)

The plot sizes were 3.6 m x 3.0 m in 1989 and 6.0 m x 4.0 m in 1990, with a spacing of 50 cm x 10 cm.

Tables 3.2-45 and 3.2-46 show that only the carbofuran had a significant effect on groundnut yield in 1989. The plots which were treated with carbofuran produced an average of 500 to 600 kg/ha more groundnuts than the plots which were not treated. The nematode population was significantly reduced by the use of carbofuran (ICRISAT/SC, 1989 Annual Report). Carbofuran has been frequently reported to act as a growth stimulant.

In 1990, the carbofuran was apparently responsible for an increase in groundnut pod and stover yields (Tables 3.2-47 and 3.2-48). The effects of phosphorus source and rate on groundnut yields were not significant in 1989 and in 1990. This may be due to the relatively high P soil test level (Bray P-1= 12 mg/kg). It should be noted that the yields of the groundnut variety 55-437 were much higher in 1989 than in 1990, probably because of the higher rainfall in 1989.

3.2.5 Soil and Crop Residue Management

A long-term experiment was installed in 1989 at Tarna to test the effects of cropping system, soil tillage, crop residues, N&P fertilization, and their interactions on millet and cowpea yield and soil chemical and physical properties.

The soil on which the experiment was installed had been cropped to millet for the last few years (the exact number of years is not known). It had the following characteristics at the 0-30 cm depth: % sand = 94.0, % clay = 3.7, pHw = 6.3, Effective CEC = 1.2 cmol/kg, Bray P-1 = 4-13 mg/kg, and % O.M. = 0.13. This soil has been classified as a Psammentic Haplustalf.

The experimental design was a split-split-split plot with four completely randomized blocks on plots 7 m x 6 m in size.

TABLE 3.2-45
GROUNDNUT POD YIELDS IN 1989

Treatment	Pod yield (kg/ha)			
	Without carbofuran		With carbofuran[1]	
	55-437	ICGS(E)	55-437	ICGS(E)
Check	1735	1951	2143	1854
P-Tahoua 20	1782	1600	2460	2224
P-Tahoua 40	2203	1951	2141	2338
STP 20	1745	1717	2328	2241
STP 40	1619	1375	2500	2389
SSP 20	1950	1604	2437	2237
SSP 40	1725	1465	2015	2373
PPA-W 20	1720	1374	2127	1987
PPA-W 40	1666	1848	2006	2258
P-W 20	1657	1327	2456	1888
P-W 40	1775	1200	2417	2041
Check	1494	1436	2409	2285
	1760	1571	2287	2176
Average	1665		2231	
Overall average: 1948		CV (%) = 18		

TABLE 3.2-46
GROUNDNUT STOVER YIELD IN 1989

Treatment	Stover yield (kg/ha)			
	Without carbofuran		With carbofuran[1]	
	55-437	ICGS(E)	55-437	ICGS(E)
Check	2866	2728	2999	2837
P-Tahoua 20	2506	2350	3159	3261
P-Tahoua 40	2943	2344	2660	3119
STP 20	2660	2118	2752	2961
STP 40	2127	2438	2241	2964
SSP 20	2476	2286	2918	2946
SSP 40	2388	2212	2645	2791
PPA-W 20	2366	2363	3043	2520
PPA-W 40	2556	2834	2593	2725
P-W 20	2506	2237	2989	2600
P-W 40	2530	2260	2260	2655
Check	2154	2371	2237	3156
	2506	2378	2928	2878
Average	2442		2903	
Overall average: 1948	CV (%) = 14			

[1] 1 kg active ingredient/ha

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TABLE 3.2-47
GROUNDNUT POD AND STOVER YIELDS IN 1990

Treatment	Yields (kg/ha)			
	Pods		Stover	
	W/o C[1]	With C	W/o C	With C
Check	718	1650	581	1240
P-Tahoua 20	799	1608	600	1280
P-Tahoua 40	896	1561	692	1312
STP 20	1015	1695	825	1421
STP 40	885	1545	694	1292
SSP 20	808	1611	634	1173
SSP 40	809	1564	724	1230
PPA-W 20	780	1581	627	1213
PPA-W 40	796	1709	688	1421
P-W 20	689	1563	540	1232
P-W 40	792	1720	624	1343
Check	745	1581	657	1275
Average	811 b	116 a	657 b	1286 a
Overall average	1213		972	
CV (%)	2048		2206	

[1]C = carbofuran (Furadan®) at 1 kg active ingredient/ha

TABLE 3.2-48
GROUNDNUT POD AND STOVER YIELDS IN 1990

Treatment	Pods	Stover
	Yield (t/ha)	
Check	1184	910
P-Tahoua 20	1204	940
P-Tahoua 40	1229	1002
STP 20	1355	1123
STP 40	1215	993
SSP 20	1210	903
SSP 40	1186	976
PPA-W 20	1181	920
PPA-W 40	1252	1055
P-W 20	1126	886
P-W 40	1256	984
Check	1163	966

The following treatments were imposed on the design:

Cropping system:
- Monocropped millet
- Millet-Cowpea intercropping

Tillage
- W0: Check (no-till)
- W1: Soil tillage after harvest and before sowing
- W2: Soil tillage before sowing only

Crop residues
- R0: All crop residues are taken out of the field after harvest
- R1: All crop residues are left in the field after harvest

N and P fertilization
- F0: Check with no fertilizer
- F1: 100 kg of SSP/ha
- F2: 50 kg of urea/ha
- F3: 100 kg of SSP/ha + 50 kg of urea/ha

The millet and cowpea varieties used in this experiment were CIVT and TN 5-78, respectively. Tillage was done with an offset disk. In 1990, 5 t/ha of manure were applied on all the plots before soil preparation to enhance soil fertility. Total rainfall was highest in 1989 (504 mm) and lowest in 1991 (379 mm) at Tarna.

Measurements were the number of millet hills harvested, ear, grain, and stover weight, and number of *Striga* plants. The pod and grain weights on cowpea were determined.

Composite soil samples were taken each year from selected plots before fertilizer application and after harvest. In addition, gravimetric soil moisture measurements were made four to six times during the crop season in selected treatments. The results of soil analyses and moisture measurements are not presented in this report.

Statistical analyses: Although the experiment was designed as a split-split-split plot, the analysis of variance was done as if there were two experiments instead of one: one experiment with millet/cowpea intercropping, and the other with millet only. This is because SAS (or rather the computer used) could not handle the four-way interaction.

1989 results

Millet yields were very low and highly variable (Table 3.2-49). Several factors may have been responsible for the low yields: late planting, grass hoppers, *Striga*, and diseases such as downy mildew. It should also be mentioned that the field had been cropped to millet for a number of years. In contrast, cowpea yields were fairly high (Table 3.2-49).

Soil tillage did not have a significant effect on millet or cowpea yields during the first year of the experiment. On the contrary, plots where millet stover was left on the soil surface after harvest produced significantly more cowpea grains than the plots from which crop residues were removed.

TABLE 3.2-49
MILLET AND COWPEA YIELDS IN 1989

Factor/ Level	Average yield (kg/ha)					
	Cowpea		Millet 1[1]		Millet 2[2]	
	Pods	Grain	Ears	Grain	Ears	Grain
Tillage (A)						
Check	813	672	97	58	180	103
Two diskings	792	640	108	79	196	139
One disking	807	637	200	151	119	87
P > F	NS[3]		NS		NS	
Crop residues (B)						
Removed	774	618	107	75	192	131
Left	835	681	109	75	192	131
P > F	NS	S	NS		NS	
N and P fertilizer (C)						
Check	808	658	53	33	86	59
SSP	837	682	39	33	71	58
Urea	776	632	161	106	289	186
SSP + Urea	496	625	178	128	320	222
P > F	NS		HS		HS	
Interactions						
AB	0.09	NS	NS			
AC			NS		NS	
BC				.09		
ABC				.09		
Overall average	804	649	108	75	192	131
CV (%)	19	20	83		66	

[1]Millet intercropped with cowpea.
[2]Monocropped millet.
[3]NS = nonsignificant; HS = significant at P = 0.01.

Similarly, urea applied at the rate of 100 kg/ha (45 kg N/ha) increased millet yields substantially.

1990 results

The effect of manure on millet yield was dramatic (Table 3.2-50). In contrast, cowpea yields were lower in 1990 than in 1989, but still above the region's average (2 to 300 kg/ha). There were no significant effects of the two- or three-way interactions on millet or cowpea yields at the 5% type I probability level. The effect of tillage on millet and cowpea yields was highly significant in millet-cowpea intercropping, and significant in monocropped millet (Table 3.2-50). No-till seemed to produce the best results with cowpea. In contrast, soil tillage, after harvest or before, produced the highest millet yields. The effect of crop residues was significant in monocropped millet only.

The effect of N&P fertilizer on cowpea yield was highly significant, although differences between fertilized and nonfertilized plots were less or equal to 60 kg/ha. It appears from Table 3.2-50 that nitrogen was responsible for the increase in millet yields, regardless of the cropping system.

1991 results

In 1991, grain yields of millet and cowpea were very low; therefore, only stover yields were measured. Tillage increased cowpea stover yield significantly (Table 3.2-51). The effect of tillage on millet yield was not significant, although there was a difference of 260 to 360 kg/ha between the no-till and tillage treatments. Nitrogen and/or phosphorus increased both millet and cowpea stover yields significantly. Nitrogen was responsible for most of the increase in stover yield. It should be noted that the coefficients of variations were high for cowpea and intercropped millet.

The effect of the interaction between tillage and crop residues on intercropped millet was highly significant (P>F: 0.006). Table 3.2-52 shows that millet intercropped with cowpea produced more stover when the crop residues were not removed and the soil was tilled after harvest.

Millet yields were extremely low in 1989 and 1990 and substantial in 1990. Without the application of manure (5 t/ha) in 1990, millet yields may have been as low as those of 1989 and 1991, except that in 1991, rainfall was low and erratic. Urea and Single Super Phosphate did allow an increase in millet grain (1989 and 1990) and stover (1991) yields. Soil tillage after harvest or before sowing also increased millet yields significantly in 1990. In general, millet grew poorly on the soil of the experimental site.

In contrast, the grain yield of cowpea intercropped with millet was highest in 1989 and lowest in 1991, despite the application of manure. The design adopted for this experiment does not permit to test the effect of cropping system (millet vs. millet/cowpea) with enough precision.

These preliminary results indicate that the soil on which the experiment was conducted for three years cannot sustain a reasonable production of millet and/or cowpea without an organic amendment. Furthermore, the problems (diseases and *Striga*, in particular) encountered during the course of this experiment indicate that it may be necessary to rotate the crops or introduce a new cropping system, e.g., one with a fallow period, to maintain soil productivity.

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TABLE 3.2-50
MILLET AND COWPEA YIELDS IN 1990

Factor/ Level	Average yield (kg/ha)					
	Cowpea		Millet 1[1]		Millet 2[2]	
	Pods	Grain	Ears	Grain	Ears	Grain
Tillage (A)						
Check	661	501	477	326	731	502
Two diskings	522	396	1196	850	1114	801
One disking	518	397	1271	906	1333	964
P > F	HS[3]		HS		S	
Crop residues (B)						
Removed	573	434	898	632	1028	734
Left	561	428	1066	755	1091	778
P > F	NS		S		NS	
N and P fertilizer (C)						
Check	571	437	886	614	924	630
SSP	553	422	903	633	831	602
Urea	612	463	1014	706	1218	861
SSP + Urea	532	402	1122	822	1266	929
P > F	HS	S		HS	HS	
Interactions (P > F): all the interactions were NS						
Overall average	567	431	981	694	1060	756
CV (%)	14	16	28	31	22	27

[1]Millet intercropped with cowpea.
[2]Monocropped millet.
[3]HS = significant at P = 0.01; S = significant at P = 0.05;
NS = nonsignificant.

TABLE 3.2-51
MILLET AND COWPEA STOVER YIELDS IN 1991

Factor/ Level	Average yield (kg/ha)		
	Cowpea	Millet 1[1]	Millet 2[2]
Tillage (A)			
Check	1636	981	922
Two diskings	2740	1440	913
One disking	2469	1244	983
Pr. > F	HS[3]	NS	NS
Crop residues (B)			
Removed	2145	1168	893
Left	2418	1275	986
Pr. > F	NS	NS	0.06
N and P fertilizer			
Check	1699	890	852
SSP	1661	1054	853
Urea	2745	1359	991
SSP + Urea	3021	1583	1063
Pr. > F	HS	HS	HS
Overall	2282	1222	939
CV (%)	34	36	22

TABLE 3.2-52
MILLET[4] STOVER YIELD OF THREE
TILLAGE METHODS AT TWO CROP RESIDUE LEVELS

Tillage	Stover yield (kg/ha) Crop residues	
	Zero	All
No-till	925	1038
One disking	1230	1649
Two diskings	1348	1139

[1]Millet intercropped with cowpea.
[2]Monocropped millet.
[3]HS = significant at P = 0.01; S = significant at P = 0.05;
NS = nonsignificant.
[4]Intercropped with cowpea.

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3.3 Production Systems

3.3.1 Millet and Cowpea Cropping Systems

The preliminary research on millet/cowpea cropping systems was started under NCRP. Detailed analysis and publication of NCRP results were carried out under NAARP. Several new experiments were conducted to solve some of the identified constraints in extending the millet and cowpea technologies proposed toward the end of NCRP.

3.3.1.1 Cropping Systems

As mentioned earlier, traditionally, millet is grown both in sole and intercrop systems, whereas cowpea is almost always grown in association. Based on IRAT research, the Niger extension service tried in vain to spread sole crop systems of both cereals and legumes, as it was seen as a pre-requisite for yield gains. Under NCRP, through a multi-disciplinary team rapid reconnaissance survey, it was determined that farmers are not willing to shift to sole cropping, because they see intercropping as a strategy against climatic risk and as a way to spread the labor resource. Under NCRP, the production systems research group, headed by Dr. Reddy, tried to understand the biological validity of these farmers' arguments. A series of sole and intercrop system comparisons were made across the country to coincide with different planting dates, fertilizer regimes, densities etc.

The water use efficiency of each of the systems was calculated through soil-water measurements. These results indicate that when these crops are sown in the month of June, the water use efficiency of the millet/cowpea improved intercrop system is significantly greater than either the sole millet or cowpea system. These details are published in the International Conference Proceedings of Soil Water Balance in the Sudano-Sahelian Zone (Nouri and Reddy, 1991). The southern belt of Niger, such as the Maradi, Dosso, and Niamey areas, receive first rains in the month of June. However, in late planting situations, such as when crops are sown in the month of July or early August, the current intercrop technologies average was less efficient than the sole cowpea system. Much of the northern part of the country, such as the Diffa, Zinder, Tillabery regions (above 14° N) receive first rains in the month of July. The agronomic trials conducted at the Ouallam, Diffa, Chikal, and Kouka agricultural research stations of INRAN provided ample evidence in this regard. These results are published in the international Conference Proceedings of Challenges in Dryland Agriculture (Reddy *et al.*, 1990).

3.3.1.2 Planting Methods

Based on some of the initial research station results on THE millet/cowpea intercrop system, large-scale (100 farmers/year) on-farm research was initiated under NCRP. The feedback from that on-farm research identified the relatively higher labor requirements in cowpea planting as one of the major bottlenecks in adopting the improved millet/cowpea intercrop or cowpea sole crop technologies. To offset this constraint, a joint research project with Agricultural Equipment and Rural Technologies Development Workshop (ARDETEC) was initiated by the Production Systems Research Group under NAARP. This research resulted in the development of efficient cowpea planters. Field experiments involving manual planting and new planters drawn by bullocks indicated up to five-fold improvement in planting efficiency. For instance, in 26 hours, only 1 ha of cowpea interplanting can be conducted manually, whereas with the animal-drawn planters, 5.2 ha can be planted. These results are published in *La Revue de la Recherche Agronomique* (Buckner *et al.*, 1992). However, it is important to note that animal power is rarely used at this time in Nigerien agriculture. Some more discussion on this general subject is provided in the Farming Systems/Economics part of this report.

3.3.1.3 Genotypes

In traditional systems, tall, partly-photoperiod-sensitive, relatively late-maturing local pearl millet genotypes are mainly sown both in sole and intercrop systems. Photoperiod-sensitive and indeterminate cowpea genotypes are usually planted in millet or millet/sorghum association. From the research conducted at the INRAN Kolo agricultural research station, it is proven that early maturing and spreading cowpea genotypes such as cv TN 5-78 are better and more productive, both in sole and intercrop systems. All cowpea genotypes yielded more when planted in association with dwarf, rather than traditional, tall pearl millet genotypes because they received more light. The details of this research are published in the Experimental Agriculture Journal (Reddy *et al.*, 1990).

To quantify the shading effects of millet on cowpea, an artificial shading experiment was conducted at Kolo research station, in collaboration with International Sorghum Millet Collaborative Research Support Program (INTSORMIL CRSP). The net assimilation rate of the cowpea canopy was highest under full sunlight, compared to reduced light levels when the crop was vegetative. Transpiration, which was not significantly different before flowering, was highest under 57% light, and not under full sunlight as expected, after canopy started to flower. Therefore, the ratio of photosynthesis to transpiration, and total dry weight yield, was higher under 100% sunlight, compared to other reduced light levels. The details of these results are being prepared for publication in the *Agronomy Journal* (Verma *et al.*, 1992).

In a separate study at Kolo agricultural research station, IITA-introduced cowpea genotypes were compared with top INRAN cv, TN 5-78, and Nigerian local cv., Sadoré local, and Burkina Faso local cv, Gorom, for four years for various types of yields. In this study, cvs. TN 5-78, TVx 3236, KVx 183-1, Kvx 61-74, and Gorom produced the highest grain yields, while cv. Sadoré local produced the highest forage yield. Cultivars TN 5-78 and Gorom showed better nodulation, higher leaf area index (LAI), and root weight/unit area, indicating better adaptation to the local environment. These details are presented in the combined 1989/1990 INRAN agronomy report (Nouri *et al.*, 1991).

While the ideal cowpea genotypes are available for farmers, the ideal dwarf pearl millet genotypes are not currently available from the millet breeding program. This aspect needs the special attention of the millet breeders.

3.3.1.4 Densities/Geometries

The research carried out on this subject at Tarna agricultural research station during NCRP proved that millet density can be greatly varied without greater yield variation as millet tiller production gets adjusted by the planting density. Also, identified in that research was the fact that farmers' densities in the traditional system are indicative of the soil fertility level. Based on these results, the millet row spacing of 1.5 m was standardized, and it is widely accepted, both by researchers and farmers. The hill spacing is varied in response to fertility level, planting time, and cropping system. These details are published in the INRAN extension bulletin (Reddy *et al.*, 1990).

Unlike millet, traditional cowpea density is very low. Research conducted under NCRP has identified appropriate cowpea planting densities, both under sole and intercrop systems (Reddy *et al.*, 1990-INRAN extension bulletin). Several-fold increase in the cowpea density of improved intercrop systems is recommended as a result of these trials.

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3.3.1.5 Planting Dates

In Niger, millet planting starts with the first rains in May and continues for several weeks. Late planting usually results in poor grain yields. As there is limited or no use of mechanized power to sow crops, it is almost impossible for small families of 2-3 active workers to complete millet planting with the first rains on relatively large holdings of 4-8 ha.

A study was conducted at the Bengou agricultural research station to identify the appropriate millet genotypes for early and late plantings. The results indicate that the early and partially photosensitive cv., HKB, produced significantly higher grain yield than the late and photosensitive cv., Somno, when planted with the first two seasonal rains. With delayed plantings, HKB's crop growth rate (CGR) and harvest index (HI) decreased significantly and led to poor grain yields, even though it maintained similar growth periods and had similar rainfall, radiation, and temperature available at all five planting dates. Contrary to this, cv. Somno maintained low, but stable, HI over various planting dates. From this study, it seems logical to use photosensitive millet genotypes, such as cv. Somno for late July plantings in the Sudano-Sahelian zone. The detailed results of this study are being published in the Experimental Agriculture Journal (Reddy and Visser, 1992).

As stated earlier, cowpea, as a general rule, is cultivated in association with millet in Niger. In the associative systems, millet is planted first, and cowpea is interplanted later with subsequent rains. As the rainy season length is very limited (about 100 days), it is extremely important to choose an appropriate date of planting for cowpea. A study was conducted at Kolo agricultural research station to achieve this objective. Results indicate that the cowpea growth period decreased by the same number of days as the delay in planting and the light interception level of same stage cowpea decreased with the delay in planting. This led to significantly lower crop growth rates (CGRs), lower grain, and dry matter yields of cowpea by delaying planting from the same time as millet to seven weeks after millet. In general, maximum overlapping time with millet was best for cowpea yields. Contrary to cowpea, millet grain yields didn't vary with different cowpea interplanting times. The overall systems analysis indicated 62% land use efficiency with cowpea interplanting around 15 days after millet planting in rainy seasons without major droughts. The details of these results were submitted to *Agronomy Journal* for publication (Reddy and Visser, 1992).

3.3.1.6 Weeding

It is well established that weeding on time is essential to efficiently use plant resources, particularly in dryland agriculture. Farmers in Niger are well aware of this. However, again due to lack of appropriate or efficient tools, year after year thousands of hectares of crop land in Niger is abandoned after initial plantings. Krause *et al.* (1990) identified that shortage of labor reaches a very critical level at the weeding time, as it is also often the time of cowpea planting in intercropping. To alleviate this constraint, as in the case of cowpea planting equipment, a joint research project was initiated with ARDETEC. This program evaluated the existing weeders and developed a prototype for weeding in the improved millet/cowpea intercrop systems. The field evaluations showed that it is feasible to mechanically weed in the improved millet/cowpea systems, and it would only take about 30% of the time of manual weeding. The details of these data are being published by *Agronomie Africaine* Journal (Reddy and Buckner, 1992).

3.3.1.7 Fertilization

Research in this area was initiated under NCRP. Niger soils are extremely poor for almost all the crop nutrients with the exception of potassium. Phosphorus (P) and nitrogen (N) fertilizer effects on millet

and sorghum and P effects on cowpea were studied, both on-station and on-farm. Highly significant P effects on millet and cowpea were established from the on-farm trials. The data from the on-station research on this aspect is not appropriate, as most of INRAN stations' P levels exceed the crop critical levels. On-farm research on N effects indicates a high economic risk for N fertilizers. These results are discussed from an economic point of view in the Farming Systems/Economics part of this report and are also published in *La Revue de la Recherche Agronomique* (Ibro *et al.*, 1992).

Given the economic risk with the application of N fertilizers, a study was undertaken jointly with INTSORMIL CRSP to understand the contribution of cowpea to millet during intercropping and after intercropping/sole cropping. This study also included N response of millet in sole and intercrop systems. The results indicate that at a no commercial N application level, the cowpea intercropped millet yielded 60 kg ha^{-1} additional grain and obtained 5 kg ha^{-1} additional N from the soil. Also, cowpea produced about 670 kg ha^{-1} grain. However, this trend was not maintained when commercial N is applied to the millet. The residual effects of cowpea sole and cowpea intercrop on the test crop millet were significantly positive, compared to sole millet in no nitrogen applied plots. Harvesting cowpea at flowering or maturity didn't change associated millet performance. Commercial nitrogen application at a rate of 46 kg N ha^{-1} had a positive effect on sole millet, but not on intercrop millet, possibly due to competition with cowpea for water and N. In summary, it seems risk prudent for Nigerien farmers to adopt the improved millet/cowpea intercrop system with no nitrogen application. The details of these results are being prepared for publication in *Agronomy Journal* (Reddy *et al.*, 1992).

Similarly, a millet/cowpea rotation experiment was initiated at Konni Agricultural Research Station of INRAN in collaboration with the International Crops Research Institute for Semi-Arid Tropics (ICRISAT). The rotation of millet with cowpea consistently doubled millet grain yields to 1.4-1.9 t ha^{-1}, which would otherwise require considerable and risky N-fertilizer input. The details of this research project are being prepared for publication in *Experimental Agriculture Journal* (Klaij *et al.*, 1992).

Similarly, in a study to determine non-monetary inputs to boost soil fertility, a crop residue trial was conducted at Ouallam agricultural research station in collaboration with INTSORMIL CRSP. The results indicate that 1 t ha^{-1} of residue increased grain yield by 306%, 2 t ha^{-1} by 458%, and 3 t ha^{-1} by 545%, while total dry weight yield increased by 253%, 347%, and 382%, respectively, in 1988. The increases in yield in 1989 were not as great as in 1988, but followed the same general trend, especially in the case of total dry weight yield. Details of these results are being prepared for publication in *Agronomy Journal* (Verma *et al.*, 1992).

3.3.1.8 Plant Protection

Plant protection research has been conducted by the INRAN Plant Protection Division for a number of years. It has been established that insect pest control on cowpea is one of the major plant protection issues in Niger. Since cowpea is susceptible to several insect pests, and often the damage on grain yield can reach 100%, it has been proposed to apply preventive insecticidal measures at flowering and pod filling stages.

To estimate the economically viable number of preventive measures on cowpea, an on-farm trial was conducted in different locations. The results indicate significant differences between control (no insecticide spray) and a single spray with deltamethrine (Decis®) or cypermetrin (Cymbush®). The type of spraying equipment (backpack sprayer, electrodyne or ULV) didn't have any effect on cowpea grain yield. However, based on the initial investment needs and the types of crops grown, one can choose between these three types of equipment. An economic analysis of these results is presented in the

Farming Systems/Economics part of this report. More in-depth analysis of this data is also being published by *Système Agricole en Afrique* (Ibro *et al.*, 1992).

As in the case of fertilizer applications, farmers in Niger rarely apply insecticides. Under serious grasshopper infestations, the Government of Niger intervenes with aerial insecticidal spraying. For isolated insect damage, no such provision exists.

Insect pest control on cowpea was investigated with the objective of providing a sustainable, no-cost ecological control strategy of the key cowpea pests. A study comparing sole and millet intercropping on cowpea insect pests was conducted, both on-station (Kolo) and on-farm (20 farms, Kouka village) under NAARP in collaboration with INRAN entomologists and economists and the University of Niamey students. The trials indicated major differences in the populations and infestation of one major cowpea pest, thrips (*Megalurothrips sjostedti*), between different cropping systems. Thrips is one of the two major cowpea insect pests in West Africa whose damage on cowpea flowers/buds can result in 100% grain yield loss. Thrips infestation of cowpea was greatly reduced by millet intercropping. Under heavy thrips infestation (under natural conditions, i.e., no chemical control), the cowpea grain yield in 1990 at Kolo in the sole crop system was 20 kg ha^{-1}, whereas it produced 130 kg ha^{-1} as an intercrop with millet. Two University of Niamey students (Altini, 1990, and Atindehou, 1991) presented these data in theses. Since thrips are considered a major cowpea pest, and there are no significant differences between the populations of other pests between cropping systems, it would be beneficial to grow cowpea as an intercrop. This ecological manipulation, combined with insect-resistant varieties and one preventive insecticidal spray, might offer an immediate integrated cowpea pest management strategy. In the long run, release of natural parasites and predators may offer another option.

3.3.1.9 Long-Term Effects (Sustainability)

In traditional agriculture, as explained above, millet sole or millet/cowpea intercrop or millet/sorghum/cowpea intercrop are grown year after year. In the intercrop systems, the cowpea population is usually very low (it ranges between 2-3 thousand/ha). Farmers believe that intercropping helps to provide the longevity of their soils. To understand the long-term effects of the sole millet and traditional millet/cowpea compared to improved intercrop and sole cowpea, two different studies were initiated under NAARP.

In the first study, the improved millet/cowpea intercrop system (18,000 hills/ha of cowpea) was compared with sole cowpea and millet at Kolo. All the systems received 9 kg P ha^{-1}. After three years, the after-effects of these systems were measured, both on soil and on a test crop millet. Soil analysis at the beginning of 1989 crop season indicated significantly higher organic matter (29%) and magnesium in the previous cropping system cowpea sole compared to other treatments. Test crop millet N uptake and yield were better in the previous cowpea-based cropping systems, compared to millet sole. Details of these results are published in the *Field Crops Research* journal (Reddy *et al.*, 1992). Also, Mr. Buckner (1991) submitted a MS thesis to the University of Montpellier, France, on this study.

In the second study, the traditional millet/cowpea intercrop system (3000 hills/ha of cowpea) was compared with sole cowpea and millet at Konni Agricultural Research Station in collaboration with ICRISAT scientists. After three years, the after-effects of these systems were measured on both soil and test crop millet, as in the previous study. The continuous cowpea sole system significantly reduced the carbon/nitrogen ratio of the soil (7.5) compared to the continuous millet sole (13.6) and the traditional intercrop (11.9). A soil C/N ratio of 12 and below is considered advantageous to crop plants as soil mineralization would increase. The grain yield data of the test crop indicated that the continuous cowpea

sole had an effect on the test crop equivalent to the application of 205 kg N ha^{-1}. These results are prepared as a journal article and are being reviewed for publication in *Experimental Agriculture* (Reddy *et al.*, 1992).

These long-term trial results reconfirm that increasing cowpea cultivation, either as in the improved intercrop systems or as sole crop, would be a risk-prudent strategy for Nigerien farmers.

3.3.2 Millet and Sorghum Cropping Systems

In Niger, sorghum is principally grown on sandy soils in association with millet and cowpea (millet/sorghum/cowpea, about 1.4 m ha, and sorghum/cowpea, 0.194 m ha in 1990). As millet and sorghum are somewhat similar, many of the above-mentioned millet/cowpea results/strategies can be applied in these associations. This is even clear to farmers, as they already began to substitute sorghum for millet in sorghum-growing areas in the application of the millet/cowpea alternative production strategies. However, sorghum is also grown as a pure crop in lowlands or ancient river beds (0.2 m ha in 1990) and in association with millet in the Soudanian zone (0.581 m ha). Therefore, some attention was given to the last two cropping systems under NCRP and NAARP.

Traditionally, sorghum is grown as a pure crop on heavy soils with high clay content (about 20%). The sorghum breeding program has developed several appropriate varieties and hybrids for these soils. Among these, SEPON 82 (a high grain yielding variety), SRN-39 (a *Striga*-resistant variety), and NAD1 (a high grain yielding hybrid), are noteworthy. These elite materials showed grain yield superiority and stability under many environments. These results are being prepared for publication in *Echange Plus* and *Sorghum Newsletter* by Mr. Visser. Also, other details concerning these are provided in the breeding section of this report.

In sorghum areas, soil surface erosion/rain water runoff is a major problem. Farmers traditionally make ridges after crop establishment to avert this problem. To overcome this constraint, several water conservation techniques were compared, both at Kolo and Maradi INRAN research stations under NCRP. The Kolo trial was continued until 1988. These results were analyzed under NAARP. The results indicate that sorghum plants benefitted from the soil conservation techniques of ridging and tied-ridging and produced higher grain and dry matter yields compared to plants grown on flat-tilled plots. The farmers' practice of late erection of ridges was less productive in terms of plant establishment, growth rate, and final grain and dry matter yields, compared to pre-plant ridging and tied ridging. The details of these results are published in the Proceedings of the International Conference on Challenges in Dryland Agriculture (Van der Ploeg and Reddy, 1990).

At Bengou Agricultural Research station, a package of millet/sorghum technologies was developed for the Gaya region of Niger, based on the millet/sorghum association trials conducted under NCRP and NAARP. In collaboration with Semi-Arid Food Grain Research and Development (SAFGRAD) and DECOR/INRAN, on-farm trials were initiated in the region. These results indicated that a total of more than 1.5 t/ha cereal could be produced in the intercrop system. Improved millet varieties (as in the millet/cowpea trials) and increased millet densities had no effect on the millet grain yield. However, application of nitrogen improved millet grain yield by 60%. Sorghum grain yield improved up to 50% by using improved densities and 1.25 times by improving densities and N and P fertilization (the fertilized plots received 45 kg N ha^{-1} and 9 kg P ha^{-1} together for millet and sorghum). Details of these results are reported by Nouri *et al.* (1992).

3.3.3 Technology Diffusion

By the end of NCRP, the preliminary millet/cowpea cropping systems technologies were developed by Dr. Reddy and his colleagues (Reddy, 1988). These technologies were packaged into now-established millet/cowpea dryland production strategies. The uniqueness of these technologies was their flexibility or responsiveness to the farmers' constraints. This is in contrast to the nationwide crop production recommendations that Niger, and other neighboring countries in the Sahel, are used to. These technology recommendations took into account time of planting, fertilization, and the preference of cropping system. In total, 26 packages were developed and diffused (Reddy *et al.*, 1990).

The Niger extension service began to test these recommendations across the country with no donor funding in 1989. Later on, the World Bank funded the Agricultural Extension Support Project (PRSAA) in the Dosso department, the German International Aid Program (GTZ) funded the Tillabery agro-forestry project, and Care International Agricultural Extension Project in Maradi began to fund more and more of these demonstrations. In the NAAR project, Dr. Christine Okali, Research/Extension Liaison Specialist, took considerable interest and followed up these activities with the Niger Extension Service. Details of these activities are included in the Research/Extension liaison part of this report.

While these technologies are being demonstrated on farmers' fields, DECOR/INRAN continued to monitor the modified millet/cowpea on-farm tests in the Maradi and Filingué regions of the country. The Tropical Soils CRSP in Niger began to test these technologies on their watershed program at Hamdalaye. Dr. Jess Lowenberg-DeBoer and colleagues carried out detailed risk and adoption analyses on these technologies, based on the data collected on 100 farms/year during NCRP and NAARP. These analyses particularly discouraged Nitrogen fertilizer application and proved beyond doubt that the improved millet/cowpea intercrop and cowpea sole crop technologies have a better future in Niger dryland agriculture and often can offer greater returns, with no outside investments. However, these analyses also identified labor as the most important infrastructural constraint for large-scale farmer adoption of the technologies.

Also, simultaneously, the initially identified millet/cowpea technology adoption constraints were addressed on research stations. Significant findings of this new research are providing an alternative single-line cowpea intercrop geometry, in addition to the two-line geometry; development of cowpea planting and intercrop weeding equipment; and proving beyond a doubt that the millet/cowpea intercrop and sole cowpea's extremely favorable effects on soil and crop productivity, compared to the current farmer practices of traditional millet/cowpea intercrop and cowpea sole crop.

Because some of the millet/cowpea intercrop technologies are completely new and against farmers tradition, a video film from planting to harvesting operations with expert comments was developed by Dr. Reddy and his colleagues. This film was diffused by Niger National Television on January 1 and March 12, 1992. Currently, this tape, originally in French, is being dubbed into the popular Hausa and Djerma languages of Niger. These versions of the film also need to be diffused at the beginning of the agricultural season. The PRSAA is showing interest in using these local language tapes more extensively in their farmer training activities. INRAN and USAID should encourage and promote these technology diffusion activities so as to avoid losing current interest and gains after the end of the NAAR Project.

The adoption of part of these technologies, such as cowpea cultivar TN 5-78, reached 8% in the on-farm trial sites (Lowenberg-DeBoer *et al.*, 1992) and 5% in the rest of the country (Valentine, MSU - personal communication) on a surface area basis, which are respectable adoption levels for the Sahel region. Details of these works are presented in the Farming Systems/Economics section of this report.

Millet/cowpea technology perfection and diffusion was achieved with extraordinary co-operation between the Production Systems Research Program and Rural Economics Department and the Research/Extension Liaison Unit of INRAN.

3.4 Farming Systems Research

DECOR farming systems research is structured as a three-step process: 1) diagnostic survey to determine the potential and constraints of an agro-ecological area, 2) on-farm trials to test candidate technologies proposed by on station researchers, and 3) follow-up surveys to determine what (if anything) farmers retained from the researcher's proposals. The NAARP technical assistant (TA), Dr. Jess Lowenberg-DeBoer, participated in all three steps of this research process. He helped develop research plans and participated in rapid reconnaissance surveys, as well as helping to supervise field observers, verify information, and enter data. In particular, the TA helped DECOR researchers to identify and implement appropriate analyses.

3.4.1 Threshold Profitability Levels

To be adopted by farmers, new agricultural technologies must provide profitability levels comparable to the farmer's other alternatives. The initial DECOR efforts in economic evaluation of new technologies took into account the opportunity cost of family labor, but did not look in detail at the opportunity cost of capital, in part because of a lack of benchmark returns to serve as a point of reference. Capital markets are not well-developed in Niger, so it is not possible to use financial returns (interest rates, stock market returns, etc.). The general 40% per crop season proposed by Perin *et al.* (1976) was used, but without specific information that confirmed this level of opportunity cost for Niger.

In this context, the TA collaborated with his DECOR colleagues, in particular, Mr. Mahamadou Malam Abdou, Mr. Ly Samba. and Mr. Tahirou Abdoulaye, in collecting and analyzing data on the non-agricultural activities of farmers. This data was collected in conjunction with DECOR diagnostic surveys and the thesis research of Mr. Ly Samba. Data collection focused on legal activities (not related to smuggling) that are not considered hereditary. Activities such as being a butcher or a blacksmith can be quite profitable, but they are generally open only to certain families. Thus, they are not open to just anyone and their returns cannot serve as a point of reference for opportunity cost of capital.

These non-agricultural activities are often transitory. Individuals try to take advantage of opportunities that come their way. Often the opportunity is related to information or commercial contacts. Thus, people often are reluctant to talk about their non-agricultural activity. These characteristics make data collection difficult. Until now, data complete enough to permit the calculation of rates of return has been collected on only a few activates. Often this was possible after repeated personal contact. In consequence, the results reported here (Table 3.4-1) must be treated as case studies. They fit into the general pattern observed in Niger, but they do not have significance in a statistical sense. The estimation methods are explained in detail in the materials for the short course entitled "*Choix des Méthodes d'Analyse Economique.*"

The rates of return on non-agricultural activities differ substantially between activities and, for some activities, greatly exceed the 40% per crop season rule of thumb. The seller of kola nuts has an opportunity cost of roughly 500% per crop season, assuming a four-month crop season (1500/(12/4)).

TABLE 3.4-1
INVESTMENT LEVELS AND ANNUALIZED RATES OF RETURN
FOR SELECTED NON-AGRICULTURAL ACTIVITIES
DRAWN FROM CASE STUDIES, NIGER, 1989 AND 1990

Activity	Investment (FCFA)	Rate of return[1] (percentage)
Seller of kola nuts	1500	1512
Seller of condiments	1250	805
Maker of traditional beds	600	386
Roadside seller of bread and coffee	7100	95
Fisherman	10250	75
Miller	487100	66

[1]The rate of return calculation assumes an opportunity cost of off-season labor of 50 FCFA/hr.

The rate of return appears to be related to the amount of the investment, with small investments having very high returns. Effectively, the small investments of the kola seller and the maker of traditional beds is the key to permitting the profitable use of off-season family labor and other resources (for example, sorghum stalks used in making beds). The high returns on these activities are protected by the high transactions cost of investment and the small total return. For example, a large-scale merchant would not be interested in being the village kola seller who makes only about 2250 FCFA per week. Similarly, the large-scale merchant would be reluctant to invest in retail kola selling in the villages (though he might be quite interested in the wholesale trade) because of the transactions cost of dealing with large numbers of individual sellers. Thus, individuals with more capital seek out enterprises that can profitably absorb more capital and provide higher total returns, and the small-scale activities are left to the poorest individuals, for whom even the small total gain would be attractive.

It should be noted that even the lower return investments in Table 3.4-1 provide high returns to capital by developed country standards. This is consistent with the capital scarcity in Niger. As a general rule, scarce resources command high prices.

The tentative conclusions to be drawn from this exercise are:

1. Threshold profitability levels differ substantially among individuals.
2. For the poorest individuals, the opportunity cost of capital is probably too high to permit profitable use of any purchased inputs.
3. Use of most purchased inputs should be targeted to the group with annual opportunity costs of capital in the 50% to 100% range.
4. Nigerien farmers are unlikely to make voluntary investment in long term soil conservation and improvement.

A corollary to conclusion 2 is that credit programs are unlikely to encourage use of purchased inputs among the poorest group. They may be eager to take loans, but their self interest would tend to lead them to divert the funds to non-agricultural investments.

Livestock ownership may offer a way to identify the farmers who are likely candidates for use of purchased inputs. Cattle, sheep and goats are the most common non-crop investment made by Nigerien farmers. Informal data on production and costs collected in diagnostic surveys suggest that returns to cattle do not exceed about 50% annually, and that returns to small ruminant production are around 100%. Thus, if a farmer owns cattle, his opportunity cost is probably in the 50% annual category. If he owns small ruminants, but no cattle, his opportunity cost of capital may be around 100% annually. If he owns no livestock, his opportunity cost of capital may be too high to permit profitable use of purchased inputs. Research in this area could help researchers and extension target technologies to those who are most likely to use it.

The rates of return in Table 3.4-1 are roughly comparable to the financial rates of return used in discounting; thus, they can be used to obtain an idea of the value placed on future returns. At the highest rates of return in Table 3.4-1, returns beyond one year have virtually no value. Even at the 50% rate, returns are heavily discounted. At the 50% rate, a return of 1000 FCFA in two years has a present value of only 444 FCFA. This high opportunity cost of capital places a premium on quick returns. Soil conservation and improvement has a notoriously slow return. Even at relatively low opportunity cost of capital found in developed economies, farmers have been reluctant to invest in conservation. Only conservation practices that offer almost immediate benefits (like reduced tillage) have been widely adopted without subsidies or regulation.

The implication for forestry and soil conservation research is, that for widespread adoption, techniques will have to be devised that require very little investment and offer almost immediate benefits. Subsidization of conservation practices could encourage their use, but in the current situation, the government of Niger has little money to invest in such subsidies, and donors are unlikely to maintain a long-term interest. As a consequence, subsidization of conservation practices is not likely to be a long-term solution.

3.4.2 Diagnostic Surveys

3.4.2.1 Gaya Diagnostic Survey

The Gaya area is the fourth region in Niger to be studied by INRAN farming systems researchers. Previously-studied areas are: Filingué *arrondissement*, 1980; Madarounfa *arrondissement*, 1982, 1984, 1985; and the Niger River region (Kolo and Tillabery *arrondissements*), 1984-85. The Gaya area is the only part of Niger south of the 600 mm isohyte (Figure 3.4-1) and, therefore, presents unique opportunities in terms of agricultural potential. The objective of the study was to identify the potential and the constraints of the area in order to better plan INRAN research strategy, in particular, for research at the Bengou Station.

From 1989, the Gaya survey has been the responsibility of Lowenberg-DeBoer's counterpart, Mrs. Germaine Ibro. The NAARP TA participated in the 1989 rapid reconnaissance survey at the village level, the supervision of the detailed farm survey, and the preliminary analysis of the data. In-depth analysis of the data is in progress. Preliminary results are reported by Ibro (1990, 1991).

The diagnostic survey in the Gaya *arrondissement* was started in 1988 prior to the arrival of the TA in Niger. It began with 15 volunteer farmers in three villages near the Bengou Experiment Station: Rountoua, Koira Tagui, and Garin Malam. In 1989, a rapid reconnaissance survey was conducted to select two additional villages representative of the area. The villages of Sokondji Birni and Kaliguidé in the area southeast of the city of Gaya were selected. A random sample of 16 farmers was selected in

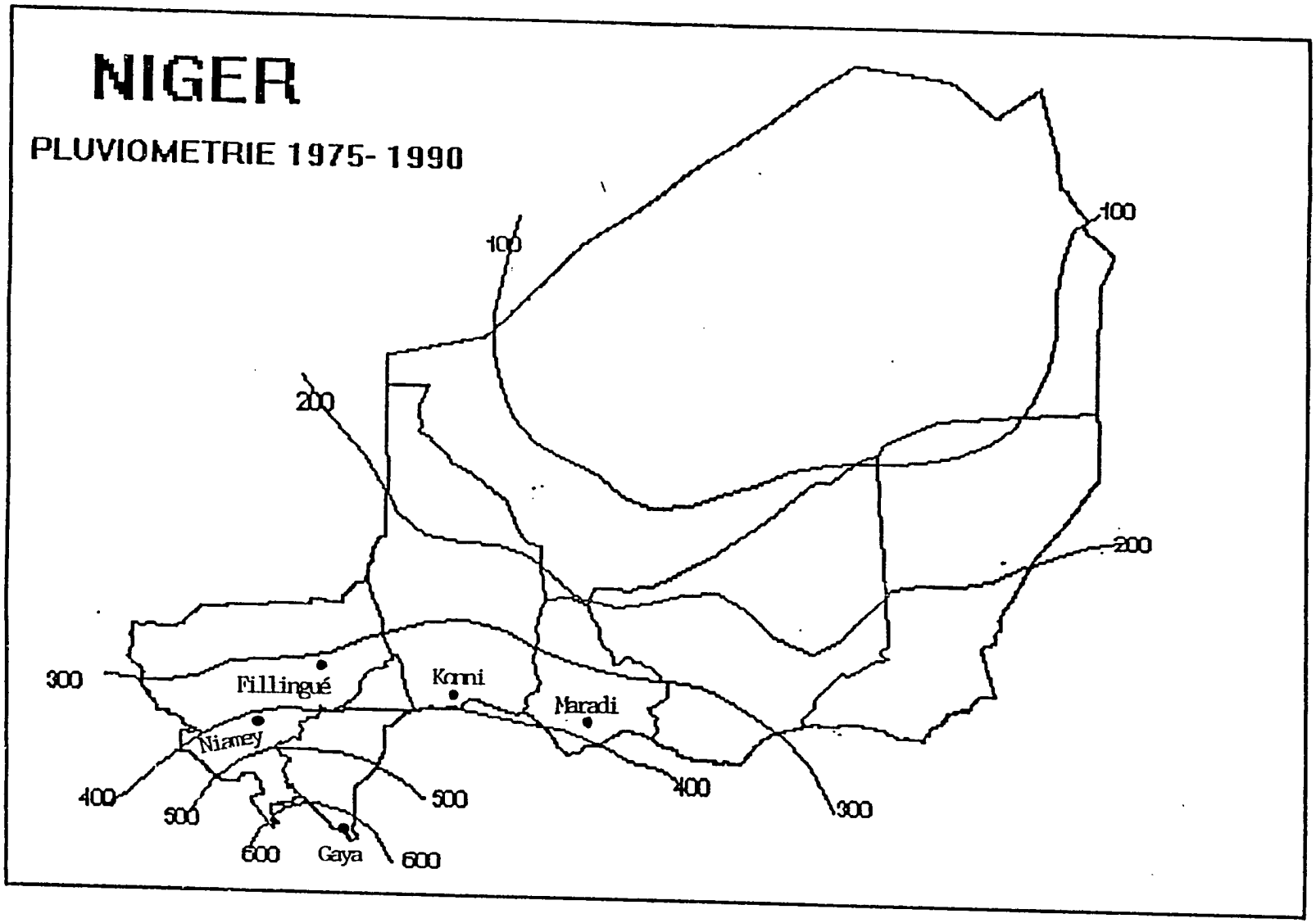

FIGURE 3.4-1. ISOHYTE MAP SHOWING ON-FARM TRIAL LOCATIONS.

the two additional villages. As is typical of many farming systems studies, the DECOR surveys involve relatively small sample size. The complexity of the data needed to understand the interrelations among farming systems components and the limited resources available at DECOR prevent the use of larger sample sizes.

The higher rainfall in the Gaya area permits a wider range of crops than is found in the other areas of Niger. Millet and millet-cowpea intercrop are widely planted, but sorghum and sorghum intercrops are very important. For example, in 1990 17% of the cultivated area at Sokondji Birni was planted to monocrop sorghum, and another 53% was planted to sorghum intercrops. Other important crops include cotton, groundnuts, maize and rice.

The average farm family includes 10 persons, of which six help in agricultural activities. Women work in the fields mainly at planting time and harvest, in particular, the harvest of cowpeas. The average family cultivates 5 ha.

In most of Niger, the peak period for labor demand is the first weeding, which usually takes place in July.

In the Gaya area, the labor demand is bimodal. There is a peak at first weeding and also at the time when harvest of millet coincides with the second and third weeding of sorghum and maize, usually in late August and early September. Most weeding is done by hand with a *daba* (hoe) by adult men. The average farm operation includes two adult men. Animal traction is widely used in the Gaya area for soil preparation, but it has not been adopted for weeding. One objective of the in-depth analysis of the Gaya data will be to better understand constraints to use of animal traction for weeding.

So-called modern inputs are seldom used in the study villages. Improved millet and sorghum seed is not readily available locally. In addition, INRAN improved varieties are not well-adapted to the longer crop season at Gaya. Chemical fertilizer is well-known, but little used. Manure is widely used.

The average farm family in the study villages has about 182,000 FCFA ($US 674) invested in livestock. All the farms in the sample owned livestock, and 85% owned cattle. In contrast to the Birni N'Konni area, most of the livestock are owned by male members of the household, in particular, the head of the household. In principle, some of this capital could be drawn into crop production if it could be shown that the proposed technologies were substantially more profitable than current practices. Women own primarily small ruminants.

3.4.2.2 Konni Diagnostic Survey

The Birni N'Konni area is the fifth region to be studied by INRAN farming systems researchers. The choice of the Konni area was primarily related to the presence of crust-forming soils and research results showing that animal traction could increase productivity there. In addition, the presence of the Konni perimeter raised issues of integration of dryland and irrigated cropping systems.

The NAARP TA was responsible for initiating the work in the Konni area in 1989. In 1990, this responsibility was turned over to Mr. Tahirou Abdoulaye, but the TA continued to take an active part in the Konni research, in particular, the animal traction survey conducted in collaboration with Mr. Fred Kruit of the INRAN animal traction project, which is financed by the Dutch Development Agency (SNV). Preliminary results of the survey are reported by Lowenberg-DeBoer (1991).

The Konni area research was initiated in 1989. After a rapid reconnaissance survey, three villages were selected for further closer study: Dagarka, located on the west edge of the Konni irrigated perimeter; Ambouta, about 19 km southwest of Konni on the Nigerian border; and Kaku, about 20 km northeast of Konni on the National Highway 27 to Tahoua. A random sample of 20 farmers was selected.

The dryland cropping system is millet-based, but with a substantial sorghum component. For example, in 1989 millet-sorghum-cowpea intercrop occupied 38% of the dryland area at Dagarka, 88% at Kaku, and 24% at Ambouta. There were small areas of monocrop sorghum on dryland fields at Dagarka and Kaku.

The irrigated cropping pattern follows ONAHA (*Office National des Aménagements Hydro-Agricole*) recommendations. ONAHA is the Nigerien governmental organization that manages all the large perimeters in the country. In general, each field is divided into two equal parts. In the rainy season, one-half is planted to cotton and the other half to sorghum. Supplemental irrigation is applied to cotton and sometimes to sorghum. During the dry season, if there is enough water in the reservoir, the half that was planted to sorghum is planted to wheat. Usually, there is not enough water for all the farmers on the perimeter to grow wheat. The profitability of wheat production depends on use of cheap off-season labor. Survey records show adult men being paid 200 FCFA ($US 0.74) plus a meal for a day's heavy labor preparing the soil for wheat in November. During the rainy season, at first weeding, wages range from 700 FCFA to 1200 FCFA per day with a meal.

The average farm in the study villages includes 3.9 ha. In the villages without irrigation, the average was about 5 ha. At Dagarka, the average was about 3 ha, with 0.75 ha irrigated.

The average farm had 126,000 FCFA ($US 467) invested in livestock and 26,500 FCFA ($US 98) in non-agricultural activities. In the sample as a whole, about 55% of the sample families owned cattle, and about 6% owned no livestock.

On average, almost 60% of the livestock investment belongs to women. In Dagarka and Kaku, the percentage belonging to women is about 75%. In the sample as a whole, about 28% of heads of households owned cattle, and 22% owned no livestock. Given the fact that the production of cereals and legumes is a male activity in Niger, it is not clear that the capital invested in livestock can be considered a potential source of funds for financing new crop technologies (no matter how profitable). Farm women in the Konni area have their own objectives and responsibilities, which often require that their investments remain in the form of livestock.

The average family size in the sample is six persons. Of those six persons, four participate actively in agriculture. The average farm has two adult men. The literacy rate in the sample is 12%, including Arabic. Seven porcent of the population has attended public school, with instruction in French. Some 17% of the school-age children currently attend school. The peak labor demand period is weeding. Women participate in field work, mainly for planting and harvest. Virtually all children over the age of five work in the fields.

So-called modern inputs are little used in the Konni area. In 1989 and 1990, no fertilizer use was observed on dryland fields. On the perimeter, fertilizer is often limited to the cotton fields. In 1989, only one of the eight sorghum fields on the perimeter received fertilizer (urea). Improved sorghum varieties are used on the perimeter, primarily IRAT 204. Improved millet, sorghum, and cowpea varieties are not used on dryland fields.

A few farmers in Dagarka own animal traction equipment and draft animals. They use them for soil preparation on the irrigated perimeter, but they do not use animal traction on dryland fields for soil preparation or weeding. In Kaku, there is no animal traction use by the sample farmers; there are five donkey carts in the village, but no animal traction tillage equipment. There is no animal traction use in Ambouta.

3.4.3 The Gidan Roumdji Animal Traction Study

In an effort to better understand the factors which lead to profitable use of animal traction, DECOR further collaborated with Mr. Fred Kruit of the Animal Traction Project (*Project Machinisme Agricole*, a part of INRAN/DRA). The Animal Traction Project was based at the INRAN Konni experiment station. Preliminary results are reported by Lowenberg-DeBoer, Abdoulaye and Kruit (1991).

After a rapid reconnaissance survey of the Maradi department north of National Highway 1, the northern part of the Gidan Roumdji was chosen for closer study. Unlike many areas in the Sahel where animal traction declined after development projects ended, the use of animal traction in Gidan Roumdji is increasing. Currently about 60% of farms in the four villages studied use animal traction. The objective of this study was to determine how farmers have profitably incorporated workbulls and donkeys into their farming system. The farming practices of 48 randomly-selected farmers were studied in the 1990 crop season.

The way in which farmers profitably use animal traction varies from area to area. In the Gidan Roumdji area, the profitability of animal traction is linked to three factors: 1) availability of relatively good quality land that can be brought into production, 2) local blacksmiths who make low-priced equipment that is well-adapted to the area, and 3) good quality grazing in the nearby pastoral zone (Goulbi Kaba).

Yields on fields tilled with animal traction and those cultivated manually are not significantly different. The main benefit of animal traction use is time savings. Users of both workbulls and donkeys save about 10 workdays per hectare compared to their neighbors who use traditional manual methods. The time saved is used primarily to cultivate more land. Average farm areas by traction type are: manual, 5 ha; donkey, 7 ha; and workbull, 16 ha. Owners of animal traction equipment cultivate over 90% of their land with animal power. Clearing bush for new fields was reported only by animal traction users. Sustainability of the system may be limited by the need for large areas for cultivation and pasture.

Benefits other than expanding cultivated area play a minor role in animal traction profitability in the Gidan Roumdji area. Personal transportation is important for cart owners and makes their lives easier, but in the villages studied, transportation is not what pays the bills (Figures 3.4-2 and 3.4-3). Paid transportation provides a source of liquidity, but it is not a major source of revenue for animal traction users. The sale of bulls at the end of their working life provides farmers with a savings mechanism, but on an annualized basis, it does not play a major role in profitability. Paid custom work is not a major source of income.

Donkey traction is increasingly important in the Gidan Roumdji area. Many farmers who sold bovine traction equipment during the 1984 drought repurchased donkey equipment in the late 1980s. The investment required for donkey traction is substantially less than that needed for bovine traction. The average investment by traction type is: donkey without cart, 25,000 FCFA ($US 93); donkey with cart, 60,000 FCFA ($US 222); workbulls without cart, 90,000 FCFA ($US 333); and workbulls with cart, 180,000

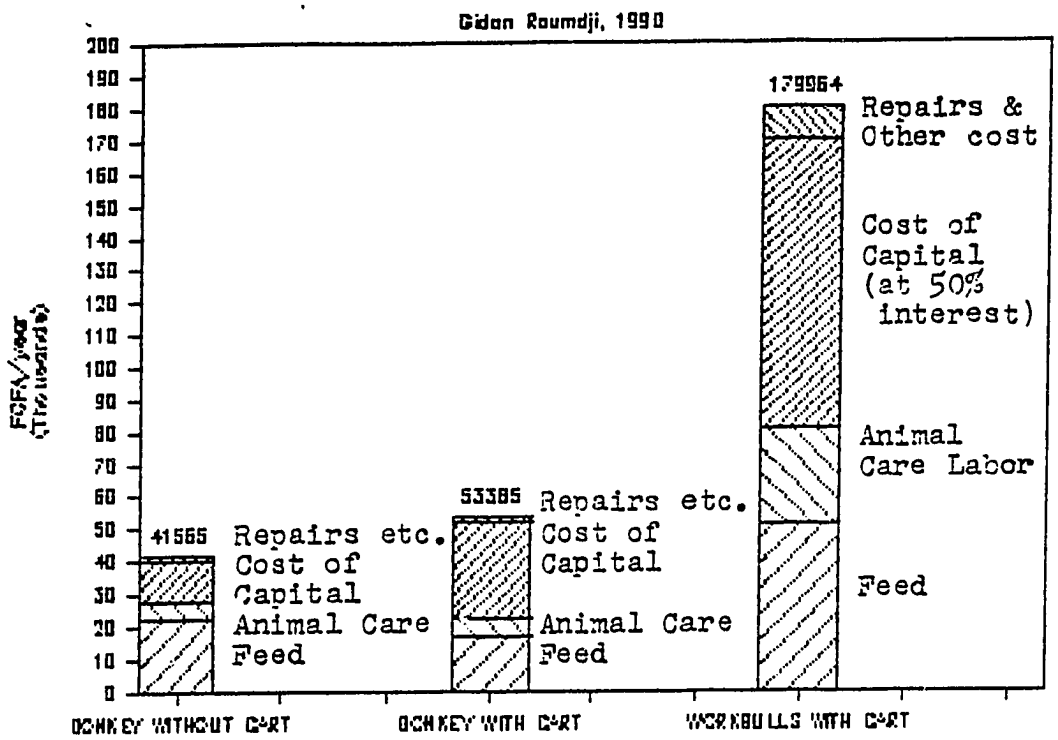

FIGURE 3.4-2. ANIMAL TRACTION COSTS, GIDAN ROUMDJI, 1990.

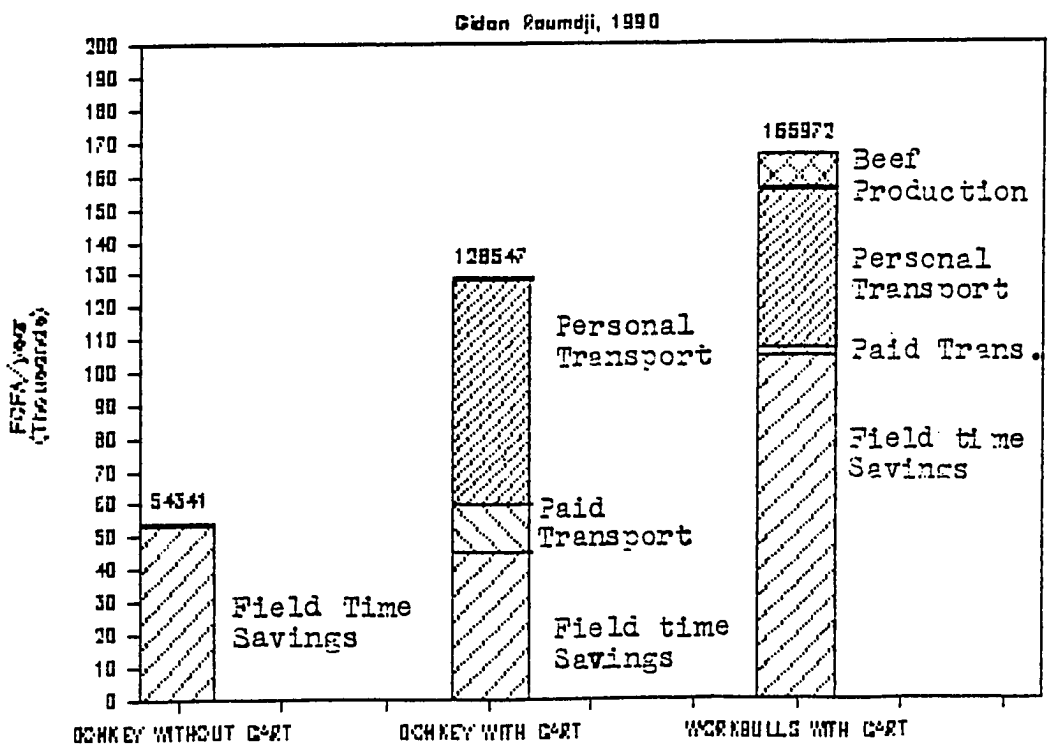

FIGURE 3.4-3. ANIMAL TRACTION BENEFITS, GIDAN ROUMDJI, 1990.

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FCFA ($US 667). For cart owners, the opportunity cost of capital is the largest single category in the cost of animal traction use (Figure 3.4-2).

Workbulls are used mainly on farms that raise cattle for other purposes. Bovine traction is a way to increase the profitability of the existing cattle enterprise. In the sample, donkey traction users were drawn almost entirely from the group that owned no cattle.

In the sample, users of both types of animal traction exclusively use equipment fabricated by local blacksmiths. The most common tool is a modified peanut lifter using one wide shovel. The modified tool imitates the traditional hoe, the *hilaire*, and is well-adapted to the sandy soil. The farmers readily acknowledge the fact that the blacksmith tools are less durable than those made by the so-called modern workshops, which were created by development projects in various departmental capitals. If the tools made by the workshops sold at the same price as those fabricated by the blacksmiths, farmers would certainly choose the workshop equipment. But blacksmith-made tools sell for one-half to one-third of the workshop price, in spite of the substantial subsidy received by the workshops. For example, a donkey cultivator made by a blacksmith sells for about 7,600 FCFA ($US 28). The comparable workshop-made tool sells for about 20,000 FCFA ($US 74). Given the high opportunity cost of capital, the farmers would prefer to pay the relatively high repair costs associated with blacksmith-made tools than to make the larger investment. A farmer with a blacksmith-made donkey cultivator can expect to spend about 1500 FCFA ($US 6) on repairs in a year. In the initial years of use, the repair cost on workshop-made tools is negligible.

Animal traction was introduced to the area before independence, but was not widely used until the late 1970s when the Maradi Project promoted animal traction. The most obvious result of the project activities comes out of training and tools provided for local blacksmiths. The project provided training and credit for animal traction equipment to a few farmers who may have acted as role models for their neighbors. Most farmers purchased their equipment for cash in the market, and report that they have never had contact with the extension service concerning animal traction.

The Gidan Roumdji study shows that animal traction can be profitable in the Sahel. The modification of the peanut lifters is a classic case of farmer innovation. Unfortunately, the combination of the availability of relatively good quality bushland, good grazing, and low-cost tools is not easily found in Niger. It is unlikely that animal traction can be made profitable in the Konni area by the approach used by the farmers of Gidan Roumdji. Konni blacksmiths could rapidly learn to make animal traction tools, but Konni area farmers do not generally have large areas of relatively good soils that could be cleared and farmed using animal traction, nor do they have access to the good grazing land that lowers feed cost at Gidan Roumdji. The economics of the use of animal traction in intensification of Nigerien agriculture is not yet well-understood. A study in Madarounfa, where the rural population is the most dense in Niger and where animal traction is widely used, might shed some light on use of animal traction for intensive farming.

3.4.4 On-farm Trials

During the period 1988-1991, the initial INRAN on-farm trial series focusing on millet and cowpeas was completed, and new trials were started (Table 3.4-2). INRAN on-farm trials started in 1984 and typically involved the same technologies tested at two or more widely differing sites. The new trials more closely match the specific problems of the site and, thus, involve a wider variety of crops and intercrop systems. On-farm trials were started on two new sites (Gaya and Konni) and ended at one of the initial sites (Liboré, near Niamey). In 1991, DECOR collaborated in on-farm trials with DRE, DRA, SAFGRAD,

TABLE 3.4-2
THE NUMBER OF FARMERS PARTICIPATING IN ON-FARM TRIALS
IN WHICH DECOR COLLABORATED[1], BY AREA AND TYPE OF TRIAL FOR 1988-1991

Type of trial	Filingué	Maradi	Liboré	Konni	Gaya
1988					
Millet-cowpea	13	35	10		
Dwarf millet	1	1			
Raghuva	1				
Insecticide application	1	1			
Peanut varieties		6			
N application methods		1			
1989					
Millet-cowpea	17	42	11		
Dwarf millet	1	1			
Raghuva	1				
Insecticide application	1	1			
Peanut varieties		6			
1990					
Millet-sorghum					11
Millet-peanut		30			
Sorghum varieties					
Peanut varieties				13	
Millet/cowpea rotation	20				
1991					
Millet-sorghum					11
Millet-peanut		30			
Sorghum varieties				2	
Millet-cowpea rotation	20				
Sorghum fertilizer				10	
Soil fertility	14				

[1]INRAN departments sometimes conduct researcher-managed, on-farm trials without DECOR collaboration. Trials near Maradi, in collaboration with the International Fertilizer Development Center (IFDC), were not included.

INTSORMIL, and TROPSOILS in nine villages in four *arrondissements*: Filingué, Birni N'Konni, Gaya and Madarounfa (Figure 3.4-1). Madarounfa is an *arrondissement* directly south of Maradi.

Virtually all DECOR researchers have been involved in the on-farm trials. Typically, each site has a supervisor who follows DECOR activities (Table 3.4-3). The TA's role in these trials was mainly to provide technical advice in terms of economic data collection and analysis. In particular, he was involved in the effort to summarize and draw conclusions based on the millet and cowpea trials.

Because of weather variability, at least three years of data are usually needed to draw conclusions based on agronomic trials in Niger. For this reason, the focus of this report is on the millet and cowpea

TABLE 3.4-3
DECOR SITE SUPERVISORS AND COLLABORATING DEPARTMENTS
FOR ON-FARM TRIALS BY AREA AND TYPE OF TRIAL FOR 1988-1991

1988		
Millet-cowpea, Kouka	Germaine Ibro	INRAN/DRA/Gen. Agron.
Millet-cowpea, Maradi	Assane Zarafi	INRAN/DRA/Gen. Agron.
Millet-cowpea, Liboré	Mahamane Issa	INRAN/DRA/Gen. Agron.
Dwarf millet, Kouka	Germaine Ibro	INRAN/DRA/Gen. Agron. & Millet Section
Dwarf millet, Maradi	Assane Zarafi	INRAN/DRA/Gen. Agron. & Millet Section
Raghuva	Germaine Ibro	INRAN/DRA/Gen. Agron. & Entomology
Insecticide, Kouka	Germaine Ibro	INRAN/DRA/Gen. Agron., Ent., & Cowpea Breeding
Insecticide, Maradi	Assane Zarafi	INRAN/DRA/Gen. Agron., Ent., & Cowpea Breeding
Peanut varieties	Assane Zarafi	INRAN/DRA/Peanut Section
N application	Assane Zarafi	INRAN/DRE
1989		
Millet-cowpea, Kouka	Gilbert Numa	INRAN/DRA/Gen. Agron.
Millet-cowpea, Maradi	Assane Zarafi	INRAN/DRA/Gen. Agron.
Millet-cowpea, Liboré	Mahamane Issa	INRAN/DRA/Gen. Agron.
Dwarf millet, Kouka	Gilbert Numa	INRAN/DRA/Gen. Agron. & Millet Section
Dwarf millet, Maradi	Assane Zarafi	INRAN/DRA/Gen. Agron. & Millet Section
Raghuva	Gilbert Numa	INRAN/DRA/Gen. Agron. & Entomology
Insecticide, Kouka	Gilbert Numa	INRAN/DRA/Gen. Agron., Ent., & Cowpea Breeding
Insecticide, Maradi	Assane Zarafi	INRAN/DRA/Gen. Agron., Ent., & Cowpea Breeding
Peanut varieties	Assane Zarafi	INRAN/DRA/Peanut Section
1990		
Millet-sorghum	Germaine Ibro	INRAN/DRA/Gen. Agron., SAFGRAD
Millet-peanut	Assane Zarafi	INRAN/DRA/Gen. Agron., SAFGRAD
Sorghum varieties	Tahirou Abdoulaye	INRAN/DRA/Sorghum Section, INTSORMIL
Peanut varieties	Assane Zarafi	INRAN/DRA/Peanut Section
Millet-cowpea rotation	Issa Mahamane	INRAN/DRA/Gen. Agron. & Entomology
1991		
Millet-sorghum	Germaine Ibro	INRAN/DRA/Gen. Agron., SAFGRAD
Millet-peanut	Assane Zarafi	INRAN/DRA/Gen. Agron., SAFGRAD
Sorghum varieties	Tahirou Abdoulaye	INRAN/DRA/Sorghum Section, INTSORMIL
Millet-cowpea rotation	Moussa Abba	INRAN/DRA/Gen. Agron. & Entomology
Sorghum fertiiizer	Tahirou Abdoulaye	INRAN/DRE
Soil restoration	Addo Azahidou	TROPSOILS

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results. The tentative results of the on-going trials can be found in the annual DECOR progress reports (Maliki *et al.*, INRAN/DECOR document 20F, and INRAN/DECOR document 22F). Issues raised by work at the Liboré site and an outline of the new trials will be described before going on to the millet-cowpea results.

3.4.4.1 Liboré

The village of Liboré is located in the Kolo *arrondissement* south of Niamey. It was one of the three original INRAN on-farm trial sites. In spite of promising agronomic results, farmer response to the on-farm trials and to the proposed millet and cowpea technologies was not favorable. Each year it became more difficult to find on-farm trial volunteers.

The 1989 adoption survey found that at Liboré no on-farm trial participant used any part of the tested technologies on his fields outside of the trial. At other sites, farmers used certain parts of the technologies on their fields outside the trial. For example, at Kouka in 1990, 80% of on-farm trial participants questioned the use of the TN578 cowpea variety on their fields outside the trial.

There are two main hypotheses concerning the problems encountered at Liboré. One hypothesis focuses on the high opportunity cost of labor and capital in this essentially suburban area (Shapiro, 1990). In spite of the promising agronomic results, the technologies were not profitable enough to compete in the suburban economy. The initial diagnostic survey in the area only considered the agricultural activities; thus, the opportunity costs created by nonagricultural activities were not taken into account in designing the technologies to be tested.

The second hypothesis suggests that social problems were created by the intervention of several organizations in the rural development of this area. Each organization has its own approach. In particular, some organizations typically pay farmers for work in on-farm trial fields. The farmers at Liboré had difficulty understanding why DECOR did not pay them for their work.

The approach used by DECOR does not allow such payments, because the trial is regarded as a collaboration between farmers and researchers. The researchers supply the technologies (improved seed, fertilizer, insecticide, etc.) and the farmers supply their land and labor. The opinions of the farmers are as much a part of the results of an on-farm trial as the yields or the physical observations. Payment for work on trial fields would tend to bias results by making the interaction between farmer and researcher one of boss and worker, rather than collaboration.

Given the lack of interest in the millet-cowpea intercrop technologies and the problems in obtaining farmer cooperation, it was decided in 1990 to drop the site. A new, more representative on-farm-trial site in the Niger River zone of the Tillabery department had been discussed, but work on site selection was not initiated because of the transformation of INRAN into the program structure. In the discussion at the INRAN biennial meeting in 1991, it was deemed unwise to start new activities the last season under the old departmental structure of INRAN.

3.4.4.2 Kouka Rotation Trial

The objective of the new Kouka trials is to determine the long-term effects of certain technologies, including soil changes and insect population dynamics. The previous millet-cowpea trials showed that increasing cropping intensity without purchased inputs had certain economic benefits, but the long-term

effects of these practices were not well understood. Continuation of this trial is planned with World Bank funds under the National Agricultural Research Project (PNRA) (see INRAN, 1992).

The trials involve testing the traditional millet-cowpea intercrop, a higher density intercrop using improved varieties, and a millet/cowpea rotation. The higher density intercrop is a promising technology for the area that emerged from the previous millet-cowpea intercrop trials. Economic analysis of the previous trials suggested that annual use of fertilizer did not pay in the Kouka area. In the new trials, the only fertilizer is phosphate applied to the cowpea portion of the millet/cowpea rotation. The logic behind this fertilizer application is that while N can be produced by legumes in the rotation, phosphate will eventually have to be added to maintain the productivity of the system. The cowpeas, as a cash crop, were thought best suited to providing the cash flow necessary for fertilizer purchase. The insect studies involve close collaboration with Dr. Seyni Maïga, DRA/Entomology.

In research related to the Kouka trials, Dr. Lowenberg-DeBoer collaborated with Mr. Tahirou Abdoulaye, Dr. K.C. Reddy, and Dr. Philip Abbott of Purdue on a linear programming analysis of the constraints on use of high density intercrops or rotation approaches (Abdoulaye *et al.*, 1991). Analysis indicates that animal traction could reduce the labor constraint during first weeding, but if additional arable land were available, farmers would tend to expand cultivated area rather than use the time saved with animal traction to intensify.

3.4.4.3 Hamdalaye Watershed

For the first time, an economic perspective is being brought to the TROPSOILS activities in the watershed at Hamdalaye. Economic data is being collected for the on-farm millet-cowpea trials. Mr. Addo Azahidou is responsible for DECOR activities at the site, in collaboration with Dr. Andrew Manu of TROPSOILS. In the 1992 season, DECOR will collaborate with TSMM and TROPSOILS in socio-economic surveys in the area, in addition to the on-farm trials.

3.4.4.4 Gaya and Konni Sorghum Trials

Diagnostic surveys showed that sorghum and sorghum intercrops were important parts of the cropping system in the Gaya and Konni areas. Existing INRAN experiment station results related to sorghum varieties and agronomic practices allowed researchers to respond quickly to some farmer concerns.

In the diagnostic survey, farmers indicated that *Striga* is an important problem for them. A series of trials in 1990 and 1991, in collaboration with the DRA Sorghum Section, tested the INRAN *Striga*-resistant sorghum variety, SNR39. Farmer response to the *Striga* resistance was encouraging, but yields have not been comparable to local varieties. Seed quality, stand establishment, and insect attacks have been problems. This trial is planned for the 1992 season with INTSORMIL financing.

A second series of trials started in 1991 at Konni involved fertilization of monocrop sorghum. These were in collaboration with the DRE Soil Chemistry and Fertility Section. Trials were planted in fields on the Konni perimeter and on sandy uplands at Dagarka and Kaku. The continuation of this trial is not yet decided.

The Gaya trials at Sokondji Birni focus on the millet-sorghum intercrop. Mr. Mamane Nourri, DRA/General Agronomy Section, is responsible for the trials. Mrs Germaine Ibro of DECOR has been responsible for the economic analysis of results. Preliminary results indicate that the INRAN millet variety,

CIVT, does not adapt well to the longer rainy season in the Gaya area. The trials were begun with SAFGRAD financing. They will continue in 1992 within the context of the PNRA (INRAN, 1992).

3.4.4.5 Maradi Millet-Peanut Intercrop Trials

Diagnostic surveys in the Madarounfa area indicate that the millet-peanut intercrop is an important part of the farming system. The millet-peanut trials conducted in 1990 and 1991 test experiment station results concerning variety, density, and planting date. These trials were started with SAFGRAD financing and will be continued in 1992 (INRAN, 1992).

3.4.4.6 Millet-Cowpea Technologies

The millet-cowpea intercrop technologies tested in on-farm trials were: T1, traditional practices; T2, improved seed cultivated using traditional agronomic practices; T3, improved seed with increased plant density; T4, improved seed, increased density and fertilizer; and T5, improved seed, increased density, fertilizer and insecticide. The treatments were the same in both Kouka and Madarounfa, except for the millet variety. HKP was used in Kouka and CIVT in Madarounfa.

The millet-cowpea on-farm trials were conducted from 1985 to 1989, but the economic analysis depends mainly on the period 1986-88. Unfortunately, no TN578 cowpea seed was available in 1985, and all treatments used local varieties. Given the economic importance of cowpea, the 1985 results cannot be considered representative of the tested technologies. In 1989, the most promising of the technologies were tested on larger scale plots (up to 0.5 hectare), but data is not available on all options.

3.4.4.7 Rates of Return

In the annual DECOR reports, the on-farm trial results were analyzed from many different perspectives: grain yields, cash income, net income, rate of return, etc. (Ly *et al.*, 1986; Issa *et al.*, 1987; Maliki *et al.*, 1989). Each measure of performance has its usefulness. The rate of return to capital is used here to provide a general perspective on the profitability of the technology in relation to other activities of the farmers (Table 3.4-1). As the ratio of net returns to the investment in seed, fertilizer, insecticide, and preharvest labor, it takes into account both cash costs and in-kind expenses (labor and farm capital). The marginal rates of return are calculated on returns and investment over and above traditional practices.

The rate of return for T2 is undefined because on-average costs were not increased by using improved seed (Table 3.4-4). During this period, the Niger government set seed prices at expected market prices at planting time. Sometimes prices for improved seed were slightly lower than actual market prices, and sometimes they were slightly higher. The improved seed, particularly the cowpea variety TN578, regularly provided higher yields than traditional seed. Because traditional agronomic practices are used in T2, the only increase in labor demand is for harvest. Thus, higher returns were obtained without increasing investment or preharvest labor.

In both Filingué and Madarounfa, the use of improved seed at increased planting density is modestly profitable (Table 3.4-4). It may be an appropriate alternative for wealthier farmers with an opportunity cost of capital of 48% to 120% on an annual basis. Of the increased investment of 5600 FCFA/ha, about 1800 FCFA is for increased seed used to plant at the higher density, and as such, represents a cash flow problem. Because of cowpea storage problems, many farmers buy cowpea seed each year. For farmers

TABLE 3.4-4
MARGINAL RATES OF RETURN TO INVESTMENTS IN IMPROVED SEED, FERTILIZER, INSECTICIDE AND ADDITIONAL LABOR FOR MILLET-COWPEA TECHNOLOGIES TESTED IN ON-FARM-TRIALS, 1986-88, BY *ARRONDISSEMENT*

Treatment	Average marginal investment	Filingué	Madarounfa
	(FCFA/ha)	(Percent)	
Improved seed with traditional agronomic practices (T2)	-100	undefined	undefined
Improved seed at increased density (T3)	5600	16	40
Improved seed at increased density with fertilizer (T4)	13800	-37	33
Improved seed at increased density with fertilizer and insecticide (T5)	21100	-41	12

with family labor available, the remaining 3800 FCFA represents an investment in kind that may be profitable. As is pointed out by the linear programming studies of labor constraints by Tahirou *et al.* (1991) and Krause *et al.* (1987), the increased density adds to the labor requirement in the crucial planting and first weeding periods when most family labor is already fully employed. Weeding labor can usually be hired, but this usually requires cash.

At Kouka (Filingué), technologies T4 and T5 were not profitable on average (Table 3.4-4). That is to say, 100 kg/ha of phosphate fertilizer (SSP) in combination with 50 kg/ha of urea and insecticide treatment of cowpea at flowering and 10 days after flowering were not profitable. It may be possible to identify other fertilizer rates and alternative pest control plans that are profitable. Low doses of phosphate may be profitable without nitrogen fertilizer in this cereal legume intercrop. Intercropping naturally reduces cowpea pest problems, because the millet forms physical barriers to insect movement. Thus, chemical pest control is less profitable on intercrop than on monocrop. Alternative approaches to maintaining soil fertility and insect control are being investigated in the new series of millet-cowpea trials at Kouka.

In Madarounfa village, T4 (application of fertilizer) could be profitable for wealthier farmers with an opportunity cost of capital of about 100% annually. Detailed analysis indicates that application of phosphate is quite profitable, but that the returns to nitrogen application are unstable and often low. T5 has positive returns on average, but profitability is substantially below the other options open to most farmers.

In short, the average rates of return in both Filingué and Madarounfa villages indicate that only T2, the use of improved seed with traditional cultural practices, is likely to interest a broad spectrum of farmers. T3 might interest wealthier farmers. In the Filingué *arrondissement*, the application of fertilizer and insecticide on millet-cowpea intercrop were not shown to be profitable. In Madarounfa, the use of phosphate fertilizers may interest wealthier farmers, but nitrogen use does not have a profitability that is comparable to other rural enterprises.

3.4.4.8 Risk Analysis

Averages can hide important characteristics of cropping system changes. For example, a higher average can be achieved by sacrificing stability. At DECOR, cumulative distributions of various measures of technology performance have been compared, using stochastic dominance analysis. The details of the analysis are described by Ibro *et al.* (1989). The detailed results by village are reported by Ibro *et al.* (1992) and Lowenberg-DeBoer (1992).

These distributions indicate the probability of results falling at or below any given level. For example, in Figure 3.4-4, the cumulative probability curve for T1 at 500 kilocalories is about 32%. That is to say that with traditional practices, there is a 32% probability of producing 500 kilocalories or less.

Cumulative distributions can be estimated for any quantifiable result (yields, revenues, etc.) by adding up the probabilities at all levels below the one of interest. The two indices of performance used here, yield in kilocalories and net revenue, relate to the two main concerns of many Nigerien farmers--food self-sufficiency and monetary income.

Graphically, the cumulative distribution to the right is preferred, because it has a lower probability of "bad" (low) outcomes and a higher probability of "good" outcomes. The steeper the slope of the cumulative distribution curve, the more stable the results. Estimated cumulative distribution curves that are close together and criss-cross may, in fact, be different estimates of the same distribution.

Figure 3.4-4 of millet and cowpea grain yields in terms of kilocalories is a good example of what agronomic research can do. With each additional input, the cumulative distribution is pushed to the right. Thus, the curve for T2 is to the right of T1, T3 is to the right of T2, etc. With increased inputs, the slope of the cumulative distribution curve is reduced, indicating greater variability, but this is "good" variability in that it gives the chance to produce large crops in good conditions and reduces the probability of low yields. In terms of food production, any of the proposed technologies would be preferred to the traditional approach. It should be noted that most of the rightward shift can be attributed to the cowpea variety TN578 (Ibro *et al.*, 1992). The improved millet improves yields mainly when fertilizer is added.

In terms of net revenue (gross value of production minus cash costs minus the opportunity cost of family labor), the picture is very different (Figure 3.4-5). The "high" input technologies (T4, T5) are at the left because their increased productivity is not great enough to cover the increased costs. At low yields, T2 is at the right, but under better conditions, T3 is at the right. T1 has the steepest slope, but it does not outperform T2 under the low yield conditions. Up to about 5000 FCFA/ha, T1 and T2 have virtually identical distributions; but beyond 5000 FCFA/ha, the slope of the T2 curve is reducing, indicating a chance for higher returns under high yield conditions. The T3 curve is to the left under low yield condition. This occurs primarily because, with the higher T3 investment, greater losses are possible in low rainfall years. In risk terms, T2 would be acceptable to a wide spectrum of farmers, because it does not increase risk in low yield seasons, but offers the chance of higher profits when conditions are right. Because of its profitability in higher rainfall seasons, T3 cannot be eliminated on a risk basis; certain farmers may wish to take the chance involved with T3 (especially on small areas) in return for the higher profitability when conditions are good.

In Madarounfa, the results in terms of kilocalories show the clear effect of fertilizer and insecticide (Figure 3.4-6). The cumulative distribution curves for T1, T2, and T3 are virtually identical. In terms of food self-sufficiency, T4 and T5 are clearly preferred to the others.

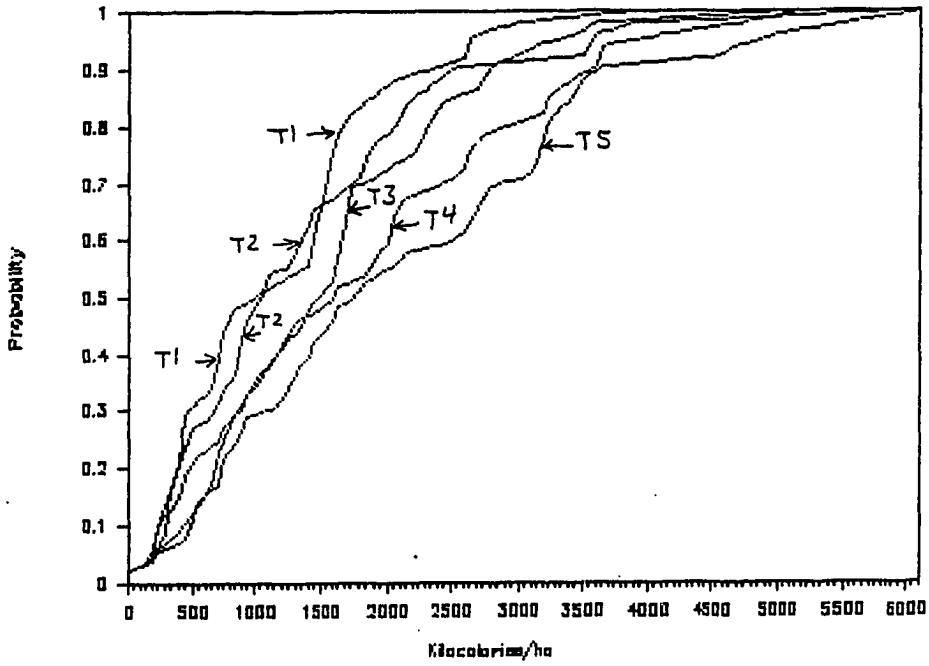

FIGURE 3.4-4. CUMULATIVE DISTRIBUTIONS, TREATMENTS 1-5, KOUKA, 1986-88.

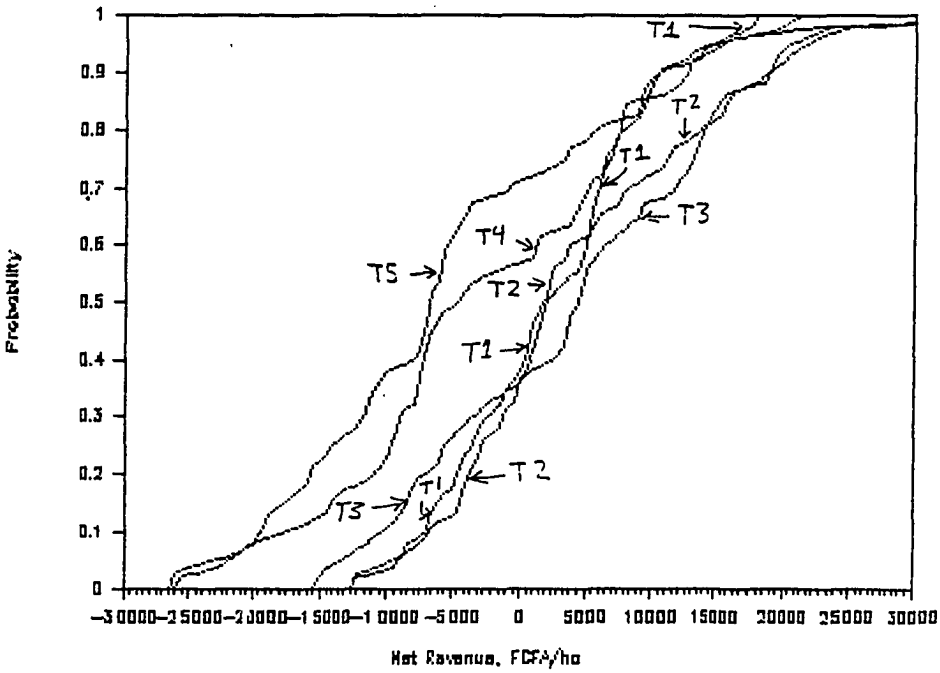

FIGURE 3.4-5. CUMULATIVE DISTRIBUTIONS, TREATMENTS 1-5, KOUKA, 1986-88.

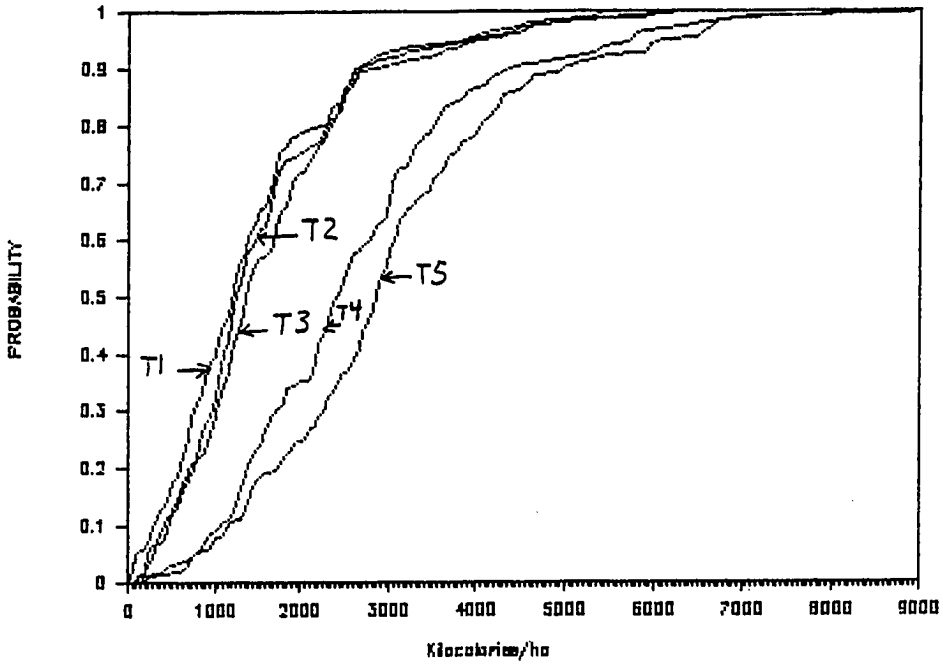

FIGURE 3.4-6. CUMULATIVE DISTRIBUTIONS, TREATMENTS 1-5, MADAROUNFA, 1986-88.

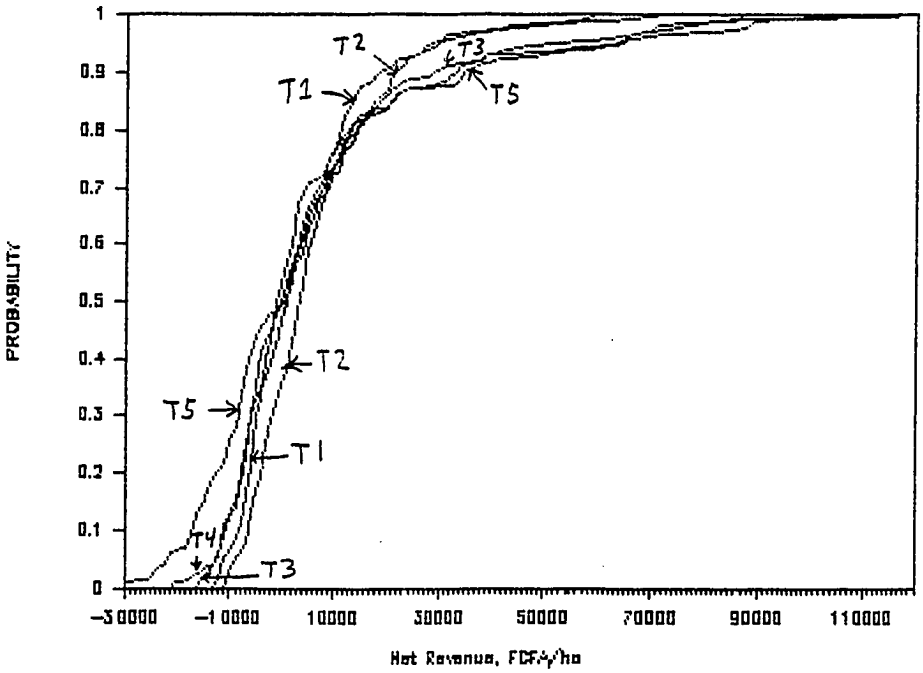

FIGURE 3.4-7. CUMULATIVE DISTRIBUTIONS, TREATMENTS 1-5, MADAROUNFA, 1986-88.

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In terms of net revenue, it is harder to distinguish the preferred distribution (Figure 3.4-7). The T2 curve is at the right up about 75% probability, but it peaks at a much lower level than T4 or T5. T3 and T4 have very similar distributions, but T3 peaks at 86,000 FCFA/ha and T4 at 118,000 FCFA/ha. T5 has higher loss probabilities than the other technologies. Detailed analysis indicates that T5 losses are related to nitrogen applications.

The risk analysis reinforces results derived in the annual reports. In both Filingué and Madarounfa, the use of improved seed with traditional cultural practices (T2) offers some benefit to a broad range of farmers. Increased density increases risk, but also allows the farmer to reap increased revenues in good rainfall seasons. In Madarounfa, phosphate applications do not greatly increase risk, but offer the potential for higher yields and revenues during seasons of good rainfall.

3.4.4.9 Insecticide Application

Insect damage is one of the main constraints in increasing the production of cowpeas in Niger. Insecticide treatment is recommended, but much of the research on cowpea insect control has been done in more humid coastal areas, where insect problems differ substantially from those of Niger. The objective of this study was to evaluate the agronomic and economic performance of the number of insecticide applications and three types of spray equipment. This evaluation is based on data from on-farm trials of monocrop cowpea in four villages in the Madarounfa *arrondissement* during the period 1986 to 1989 and in the Filingué *arrondissement* in 1988 and 1989. Details can be found in Ibro *et al.* (1991).

The treatments tested were:

1. The control, no insecticide.
2. One treatment at flowering with an Electrodyne® sprayer using Cymbush® (cypermethrine) at a rate of 0.55 l/ha.
3) One treatment at flowering with a Fontan® sprayer using Decis® (deltamethrine) at a rate of 1 l/ha.
4. One treatment at flowering with a ULV (ultra low volume) sprayer using Decis® at a rate of 1 l/ha.
5. One treatment at flowering and one 10 days later with an Electrodyne® sprayer using Cymbush® at a rate of 0.55 l/ha.
6. One treatment at flowering and one 10 days later with a Fontan® sprayer using Decis® at a rate of 1 l/ha.
7. One treatment at flowering and one 10 days later with a ULV sprayer using Decis® at a rate of 1 l/ha.

The Fontan® is a backpack sprayer powered by gasoline. It uses insecticide mixed with water. The ULV and Electrodyne® are powered by batteries and do not use additional water. The Electrodyne® can only be used with Cymbush®. The others can be used with a wide range of products.

Yield results show:

1. Yields with insecticide treatment are almost always higher than those of the control and about 50% of the time, this difference is statistically significant.
2. There is rarely a difference between yields on parcels treated once and those treated twice.
3. There is not a systematic difference related to the sprayer type; therefore, the sprayer can be chosen on the basis of cost.

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Labor required for spraying is not a major constraint, but it is important to note that the Electrodyne® requires about twice as much time per hectare as the other sprayers. The Electrodyne® requires on average four hours and 48 minutes per hectare, while the average for the Fontan® is two hours and 31 minutes, and for the ULV, two hours and 51 minutes. This difference is not surprising because the Electrodyne® can treat only one or two rows at a time, but the ULV and the Fontan® can spray a band up to 5 meters wide.

Estimation of sprayer costs indicates that there is not a major difference in sprayer operation costs per hectare. The range is from 62 to 200 FCFA/ha, but there is a major difference in the initial investment. At the *Central d'Approvisionnement* in Niamey in 1990, the Fontan® cost 165,000 FCFA, while the ULV was priced at 18,000 FCFA and the Electrodyne® at 13,500. If only cowpeas are to be treated, the Electrodyne® is a good choice, but it can only be used with the Cymbush® insecticide. If a variety of products are to be sprayed, the ULV offers a relatively low initial cost and a high capacity compared to the Electrodyne®.

Insecticide treatment of monocrop cowpeas offers rates of return that are comparable to other rural enterprises (Table 3.4-5). The marginal return to the second treatment is highly variable. At Kouka, the average marginal rate of return to the second treatment is -107%, but rates range from -521% to +141%, with negative rates for four of the six cases. In the Madarounfa villages, the average marginal rate of return to the second treatment is 129%, and rates range from -508% to +1094%, with negative rates for 10 of the 26 cases.

In short, the results indicate that among the options tested, one insecticide application to monocrop cowpea at flowering is the most profitable approach. A second treatment might be profitable if it could be used only when conditions favor insect infestations. Research is needed to better target multiple applications toward conditions where they can be profitable. The sprayer types tested appear to be equal in technical efficiency, but if new equipment is to be purchased cost considerations favor the ULV. It has a relatively low initial cost and a relatively large capacity.

TABLE 3.4-5
AVERAGE INVESTMENT IN INSECTICIDE, SPRAYER OPERATION COSTS, AND APPLICATION LABOR FOR PEST CONTROL IN MONOCROP COWPEA, AND AVERAGE RATES OF RETURN TO THIS INVESTMENT BY *ARRONDISSEMENT*, TYPE OF SPRAYER AND NUMBER OF APPLICATIONS, 1986-89

Type of sprayer and number of applications	Investment (FCFA/ha)	Fiiingué	Madarounfa
		(percent)	
One application at flowering:			
Electrodyne®	1500	714	719
Fontan®	1900	118	390
ULV	2200	706	319
One application at flowering and a second 10 days later:			
Electrodyne®	2900	215	493
Fontan®	3800	94	229
ULV	4400	316	141

3.4.4.10 Adoption Survey in Filingué and Madarounfa

The objective of an "adoption survey" is to determine what (if anything) from the technologies tested in on-farm-trials is adopted by farmers for use in their fields outside the trials. Such surveys are necessary because farmers can often find many nice things to say about innovations proposed by scientists, and yet do not adopt these practices in their own fields. In many cases, when adoption does occur, they adopt only part of the package proposed. The survey serves as a final check in the research process. If a technology is widely adopted in on-farm trial villages, it can more confidently be passed on to extension for broader distribution. An adoption survey can also provide feedback for researchers. Knowing what is adopted and attempting to understand why it is adopted can help researchers in planning the next steps.

Two adoption surveys have been conducted in the millet-cowpea on-farm trial villages. A general survey was conducted in 1989 at all three of the millet-cowpea on-farm trial sites under the supervision of Mrs. Hadiza Zarafi and Lowenberg-DeBoer. The 1989 survey involved only on-farm trial participants and used a single interview with each farmer to collect the information. The results of this survey are reported by Zarafi and Lowenberg-DeBoer (1991).

The most striking result of the 1989 survey is that virtually all the farmers interviewed said that availability of inputs was a major problem. Fungicide for seed treatment is the only "modern" agricultural input available in most local markets. Because of transportation problems, the farmers preferred to have the inputs available in the village itself. Transportation is especially important for fertilizer, because it is heavy and bulky.

A more detailed survey was done in 1991 by Mrs. Zarafi, Mr. Mohamed Abdoulaye, DECOR, Maradi, and Lowenberg-DeBoer. This survey used a stratified random sample of on-farm trial participants and nonparticipants in Filingué (Kouka) and the three Madarounfa villages. It involved repeated contact with the farmers during the crop season, measuring field areas and estimating yields. The economic aspects of the 1991 survey are reported by Lowenberg-DeBoer *et al.* (1992).

The 1991 survey shows once again that Nigerien farmers are very selective in their choice of agricultural practices. In Kouka, the farmers were especially interested in technologies for increasing cowpea production, TN578 and monocrop cowpea production practices. TN578 was the only improved cowpea used in Kouka, and it represented about 11% of all cowpea seed used (Table 3.4-6). For on-farm trial participants, TN578 was 55% of all cowpea seed used. Five of the 20 farmers in the Kouka sample had fields of monocrop cowpea, but because the fields were small (0.5 ha on average), monocrop cowpea represented only 2% of cultivated area.

The farmers at Kouka do not use fertilizer (Table 3.4-7) or insecticide. Relatively little improved millet seed is used (Table 3.4-6). The analysis of Ibro *et al.* (1992) suggests that this may be related to the fact that the yield distribution for HKP at Kouka without fertilizer is almost identical to the distribution for the local varieties.

In the Madarounfa villages, use of so-called modern inputs is widespread. Use of improved millet varieties is at about the same level as it was when the diagnostic survey in the area was done in the early 1980s. TN578 is about 7% of cowpea seed used in the three villages. It was unknown to farmers in the earlier survey. Farmers say that lack of TN578 seed has limited the area planted to this variety. Since the seed production in Niger has been privatized, quantities grown and sold have plummeted.

TABLE 3.4-6
USE OF IMPROVED SEED ON COLLECTIVE FAMILY FIELDS (GANDU)
IN ON-FARM-TRIAL VILLAGES IN FILINGUE AND MADAROUNFA,
EXPRESSED AS A PERCENTAGE OF ALL SEED USED, 1991 CROP SEASON

Input	Filingué	Madarounfa[1]
	(percent)	
Millet		
All improved millet seed	3	52
CIVT	0	28
P3Kolo	0	13
HKP	3	3
Cowpea		
All improved cowpea seed	11	9
TN578	11	7

TABLE 3.4-7
USE OF FERTILIZER ON COLLECTIVE FAMILY FIELDS (GANDU)
IN ON-FARM-TRIAL VILLAGES, 1991 CROP SEASON

Item	Filingué	Madarounfa[1]
Percentage of cultivated area receiving fertilizer	0	60
Percentage of cultivated area receiving phosphate	0	45
Average fertilizer application, kg/ha	0	32
Average phosphate application, kg/ha SSP	0	44
Average nitrogen application, kg/ha urea	0	8
Average fertilizer cost, FCFA/ha	0	1200

[1]Madarounfa figures are the average of Rigial and Maïguéro values. Comparable data was not available for Kandamo.

Fertilizer is widely used in the Madarounfa villages, especially phosphate (Table 3.4-7). Insecticide treatment of cowpea was used by four of the 60 farmers in the Madarounfa sample. Fertilizer applications rates are substantially lower than those used in the on-farm trials. Average SSP application is half of that used in the trials. The average nitrogen application is about 16% of the rate used in the trials. It should be noted that urea is purchased by farmers only in small quantities by the *tiya* (bowl), while phosphate is purchased by the sack. Use of low fertilizer application rates is a common way for farmers throughout the world to make the most of their limited resources. The low rate reduces the investment required and limits the financial risk. In general, the initial units applied have a larger effect than those added when yields are nearing their maximum; thus, the low rates can have a more than proportional effect on yields.

The fertilizer use in Madarounfa is frequently in conjunction with manure from corralling of animals in the field (*parcage*) or from livestock kept in the family compound. About 35% of the fields received manure in 1991.

In general, the users of fertilizer and other purchased inputs have more land, more family labor, and more capital (as indicated by livestock value) than their neighbors. For example, in the Madarounfa villages, the average value of cattle owned by users of fertilizer and insecticide was 195,000 FCFA. The average value of cattle owned by nonusers was 55,000 FCFA.

The increase in planting density proposed by researchers has not been accepted by farmers. The densities observed in the on-farm trial villages are much lower than the proposed densities and approximately the same as those observed in the early 1980s. For monocrop cowpea, the observed density is only about 10% of the 55,000 hills proposed by researchers. Farmers have consistently commented on the increased labor required at the higher planting densities. They also have pointed out that they generally do not have the family labor or the funds to hire labor needed to use these higher densities.

3.4.4.11 Sociological Aspects of Farming Systems Research

According to the three main activity plans proposed for 1989-90, 1990-91, and 1991-92, the NAARP socio-economist conducted various research studies which yielded interesting results and which will be useful to agricultural research, or just to agriculture, in Niger.

1989 New Technology Acceptance Survey

A survey of the acceptance of new technologies tested by DECOR was conducted on the sites of Filingué (Liboré, Kouka) and Madarounfa (Maiguéro, Rigial Oubadawaki and Kandamao) beginning in June 1989. A number of collaborators were involved with this study, namely: Dr. James Lowenberg-DeBoer, Dr. Chandra Reddy, Mr. Gilbert Numa, Mr. Hassane Zarafi, and Mme. Ibro Germaine. The objective of this survey was to understand the reasons for the adoption or rejection of these new technologies.

This survey shows that there are some aspects connected to farmer acceptance or rejection of a new technology, such as low literacy level, low income (despite non-agricultural activities), older age, etc. In addition, the trial fields were bush fields with low fertilization levels.

The perceived aspects and the problems encountered during the trials are as follows: early and fast growth of the improved varieties and good cowpea yield on the one hand, and nonavailability of inputs, attack by disease and insects, plus the problem of cowpea storage, on the other. Unfortunately, in every village, innovative farmers were not questioned by neighboring farmers. In short, acceptance was not widespread.

1989 Basic Survey

During the 1989 cropping season, the social aspects of a basic survey at Gaya and Konni were collaboratively studied with DECOR investigators. The objective of this study was to understand the social realities of those two sites.

The results of this study can be summarized as follows: the data collected shows that villages on both sites, Gaya and Konni, had common characteristics such as their degree of contact with the outside world. Family members were the main source of field labor. Hired labor was mostly used in villages of the irrigated perimeters or where different field tasks frequently overlapped.

The results of this survey revealed that farmers may find another source of work through collective work. It should be noted that this (family) labor is essentially without cost, and that the quality of the work performed depends on the relations between the participating workers and the benefitting farmer. The land system of the villages is generally a community of family farms. The control that the head farmer holds over what crops are grown and their income is rather high in Sokondji Birni and Kalidjindé. However, this control has started to lose some of its weight in Ambouta, Daggarta, and Kaku.

Areas suitable for cultivation have become scarce in Konni, thus encouraging farmers to practice "*suffari*," the renting of land. This applies to most of the irrigated land. More detailed studies would be able to show the effects of scarce cultivated land and the *suffari* practice on the dynamics of family farms and the search for better productivity.

Therefore, any initiative, especially in the agricultural field, should take into account such aspects as:
- social hierarchy within the villages,
- agricultural credit, including everything it implies, and
- land use patterns.

1989 Irrigation Diagnostic Study

An irrigation diagnostic study was conducted in Galmi and Djiratawa in 1989 with personnel from the Irrigation Section. The objectives of the study were to understand the realities of the forementioned perimeters and to identify the constraints in order to conduct more detailed studies. Constraints were found in water management and in the marketing of produce.

Adoption monitoring survey

During the 1990-91 period, an adoption-monitoring survey was conducted with DECOR investigators in Madarounfa. The objectives of this survey were to follow up on farmers' statements made during the first adoption survey in 1989 and to estimate the adoption rate of the technologies.

Not all farmers kept the promises they made during the first survey. However, there was a remarkable effort towards adoption, despite the persistence of problems (fertilizer availability, pests). The farmers' purchasing power was a cause for rejection of new technologies.

1990-91 Dissemination of Information Study

A study on the dissemination of information on the Djiratoua and Galmi perimeters was carried out in 1990-91 in collaboration with Irrigation Section investigators. The objectives of this study were to identify the constraints to communication on the perimeter level and to contribute to the improvement of water management.

Given that only the first part of the study was completed, results are purely theoretical.

1990-92 Adoption Survey

An adoption survey was conducted in Madarounfa and Filingué during the 1990-92 season. The objectives were 1) to identify, in collaboration with Dr. Lowenberg-DeBoer and Mr. Mohamadou Abdoulaye, the farmers' cropping practices, 2) to understand the influence of certain factors, such as farm income or other sociological variables such as sex, age, social status, training, supervision, information, migration, etc., on the adoption of new technologies, and 3) to determine the reasons for their behavior.

The new technologies were mostly tested in the villages of Maiguéro, Rigial Oubandawaki, and Kandamao. These included improved seeds and the use of draft animals and chemical fertilizers. Innovation was low in Kouka. Neither the recommended pesticide applications nor the planting densities were accepted and adopted by the farmers. The factors influencing adoption or rejection were of several types. The psycho-sociological factor held considerable weight since adoption is an issue which depends on the farmer himself.

1991-92 Dissemination of Information Study

A study of the dissemination of information was conducted in 1991-92. The problems noted in communication resulted from the bases on which the perimeters were established. Farmers misunderstood the objectives set by the ONAHA Irrigation Section, which caused irresponsible use of the perimeters, thereby leading to poor maintenance of the installations, increasing debt, etc. Another problem was the lack of confidence by the farmers in the perimeter territory administration.

A study on the causes and consequences of bilharzia in villages within the Galmi Perimeter was conducted with Dr. Ray Norman and members of the Irrigation Section in 1991-92.

This study showed that half of the individuals questioned were affected by the illness. Furthermore, a great majority of those affected received some sort of medical treatment, and this treatment varied. The farmers stated that it had an impact on their work time at the perimeter level.

1991-92 Traditional Weather Forecasting Methods Study

A study of traditional weather forecasting methods was conducted at Gaya and Konni in 1991-92. Collaborators in this preliminary study were Mr. Mohamadou Abdoulaye from DECOR, agri-meteorologists from DRE, and DECOR investigators. The objectives of the study were to determine the traditional weather forecasting methods used by farmers and how these methods could contribute to improving agri-meteorological forecasts.

The main elements traditionally used by farmers on those two sites are characteristics related to nature (atmosphere, fauna, and most of all, vegetation); others are related to current social practices within their communities (mostly religious). These traditional meteorology methods are still used by farmers. For the most part, they ignore modern meteorology.

General Conclusions

In conclusion, in light of the various activities performed by the NAARP socio-economist during the four years of the project, two aspects are noteworthy. The great majority of tasks planned in the annual programs were completed, and the proposed studies that were cancelled were because of poorly managed collaboration. The duration of the research studies led to the present results, thanks to the one-

year extension of the NAAR Project until June 30, 1992. It is hoped that the sociological data obtained through these studies will be of use to agronomic research, and that INRAN researchers will take the opportunity to use this type of information in the conduct of future studies.

3.4.5 General Perspective on Nigerien Agriculture

The on-going research efforts at DECOR reinforce the conclusion that Nigerien farmers are economically dynamic. They are always looking for ways to improve their condition. When they find a technological innovation that is to their benefit, they are willing to modify their farming systems to make full use of its possibilities. The adoption of animal traction in Gidan Roumdji, with the modification of the implements and the extension of cultivated area per farm, is a case in point.

The alternate perspective is still all too common at INRAN and elsewhere. This is the view of Nigerien farmers stuck in their traditions, too stubborn to recognize the good things offered by research. The DECOR work clearly indicates that when Nigerien farmers do not adopt a given innovation, it is for good reason, and very often those reasons are economic. For example, many Nigerien farmers recognize the benefits of increasing cowpea planting density, but they also recognize that it is not profitable in most cases, given their labor resources. Most Nigerien farmers are familiar with fertilizer, and in the low rainfall areas, they recognize that it is rarely as profitable as investments in livestock or non-farm activities. They also realize that without fertilizer the improved millet varieties do not show their advantage and, thus, they are sometimes reluctant to replace their traditional varieties. Nigerien farmers cling to their traditional agricultural practices because those practices have served them well. The amazing thing is not that Nigerien farmers do not produce more; it is a miracle that they produce anything at all under the extremely adverse conditions of the Sahel.

The challenge for agricultural research is to develop technologies that are profitable in the farmer's context. To do that, it is necessary to understand their constraints. One of objectives of production systems research at INRAN has been, and will continue to be, understanding the farmer's problems and helping other scientists understand, so that they can then develop improved technologies that fit those conditions.

3.4.6 Future Research Directions

The initial contribution of social science researchers to the INRAN effort has been focused on cropping systems. This is, and will remain, an important area of concentration, but INRAN capacity in economics and sociology has developed to the point where it is logical to think of expanding the effort to other parts of the farming system, in particular: 1) livestock and crop-livestock interaction, and 2) marketing.

Most Nigerien farmers own livestock or incorporate use of livestock owned by nomadic herders in their farming system. Livestock provide food and income. They serve as the farmer's savings account. They provide the manure needed to maintain soil fertility. The way in which livestock are incorporated into the farming systems differs substantially between the pastoral north and the sedentary farmers of the south of Niger, but it is important in both contexts. A farming systems study near the new station to be built in the Tahoua area might be a logical point to start this effort. Close working relationships with animal scientists will be needed. Development of human resources at INRAN in animal science will be essential.

Farmers often talk about marketing problems. In adoption surveys, they often complain that agricultural inputs are not readily available, and that products are difficult to sell. It does little good to develop improved production practices if farmers cannot obtain the inputs needed or sell the product. The marketing research will require an approach substantially different from that used in cropping systems work. INRAN needs one or two economists trained in the marketing area. Virtually all farmers have marketing problems, so the marketing work could be started in any region, but it might be easiest to begin in an area with a marketable surplus of cereals or legumes, such as Maradi or Gaya. The production systems for these products are relatively well understood, so the marketing work could build that foundation.

Much remains to be done in the cropping systems area. A large part of eastern Niger has never been studied by INRAN farming systems researchers. The Gidan Roumdji animal traction study and the adoption surveys are examples of the importance of studying what farmers do with introduced technologies. A study of the use of animal traction in intensification of agriculture in the Madarounfa area would be useful.

INRAN economists and sociologists will continue to be involved in on-farm trials, but the new program structure should make it possible for them to focus on the analysis of the economic and social implications, while their colleagues from the biological sciences are more involved with the physical conduct of the trial. In their effort to start on-farm work at INRAN, DECOR economists were involved in every aspect of the trials, from planning, to laying out the plots, to weighing the harvest. Their colleagues in other departments were not always convinced of the usefulness of these trials. In some cases, other scientists associated with the trial only visited the site once in the crop season. It is useful for social scientists to be acquainted with the mechanics of agronomic trials. It helps them interact with their colleagues at the institute. But it is questionable if they should be using the bulk of their time to supervise these efforts, while the economic and sociological analysis for which they are trained is left undone. In recent years, INRAN economists have been able to focus more on the economic aspects of on-farm trials. A good example of the new approach is the millet-sorghum intercrop trials at Gaya, where Mr. Mamane Nourri, DRA, has taken the lead on trial execution, and Mrs. Germaine Ibro, DECOR, has concentrated on determining profitability and farmer reaction.

3.5 Irrigation and Water Management

Water management research activities of a multi-disciplinary nature were carried out under the following four principal research programs: 1) Irrigation Water Use Database Collection Program, 2) Water Lifting Studies Among Microsystem, 3) Water Use and System Diagnostic Studies, and 4) Water Scheduling Program For Irrigated Perimeters. The participatory involvement of research personnel from INRAN departments (other than DRE) and from ONAHA and *Génie Rural* were maintained at various stages of each of these programs.

3.5.1 Irrigation Water Use Database Collection Program

3.5.1.1 Program Summary

This program was established in order to acquire a long-term database on water management practices among irrigation systems in the country. The retrieved data would serve to characterize different irrigation practices and would provide necessary baseline data for the Water Use and Diagnostic Studies Program and the Water Lifting Program. Long-term monitoring was initiated at several representative

systems, including ONAHA-managed perimeters and small, private irrigated microsystems. Monitoring activities among the perimeters was done in collaboration with ONAHA and *Génie Rural*.

Several sites for long-term monitoring were selected, using two basic criteria: representation and reasonable accessibility by researchers from the Irrigation Section in Maradi. Following reconnaissance of the region, the following sites were selected:

1) ONAHA-Managed Systems Sites:

- Galmi Perimeter - 250 ha, 850 parcel holders, reservoir-fed system, Ader-Doutchi-Maggia region.	Monitored During: Dry Seasons 89/90 & 90/91 Wet Seasons 90 & 91
- Moullela Perimeter - 65 ha, 110 parcel holders, reservoir-fed system, Ader-Doutchi-Maggia region.	Monitored During: Dry seasons 89/90 & 90/91 Wet Seasons 90 & 91
- Djiratawa Perimeter - 450 ha, 1500 parcel holders (approx.), tubewell system, Maradi Goulbi region.	Monitored During: Dry Seasons 89/90 & 90/91 Wet Seasons 90 & 91

2) Private, Irrigated Microsystems Sites:

- Koumassa, Tarka Valley - four individual systems monitored (2 hand-lift, 2 motorpump), approx. 0.10 ha each.	Monitored During: Dry Season 89/90 Wet Season 90
- Soumarana, Maradi Goulbi - Two individual systems monitored (1 chadouf, 1 motorpump).	Monitored During: Dry Season 90/91 Wet Season 91

Long-term collection of field data included the following information.

Data specific to both perimeters and microsystems:

- Flow rates, volumes, and timing of daily irrigation throughout each season.
- Daily rainfall and pan evaporation rates.
- Seasonal cropping area.
- Soil moisture regime.
- Seasonal crop yields.
- Regular monitoring of crop market prices, redevance rates, and land tax payments.

Data specific to perimeters only:

- System water distribution and rotation scheduling among perimeter sub-units (GMPs) and farmer parcels.
- Reservoir releases and levels (among Ader-Doutchi-Maggia perimeters).

- Pumping hours and electrical consumption (within tubewell perimeter at Djiratawa).
- Reservoir sedimentation rates (Ader-Doutchi-Maggia perimeters).

Data specific to microsystems only:

- Labor allocation for water lifting and distribution.

3.5.1.2 Methodology

Several *observateurs* were hired and trained to monitor the selected systems. During each monitored season, an *observateur* was placed full-time at each site and charged with monitoring water management-related activities on a daily basis. Data forms were prepared to facilitate organized data collection. At the end of each month, *observateurs* were required to make one copy of the past month's data and send the original to the Irrigation Section for computer compilation and filing. The Section technician was charged with making regular, monthly visits to each site to troubleshoot and collect data. The technician was frequently accompanied on these site visits by Dr. Norman, NAARP Irrigation Specialist, and/or other INRAN staff from the Section. Between seasons when there was little field monitoring, the technician and *observateurs* were charged with reviewing and copying relevant ONAHA records of water usage from other non-perimeters, as well as the monitored perimeters.

At the perimeters, several sub-units (GMPs) were selected for individual monitoring at the head, middle and tail-end sections of the perimeters. This was done in an effort to assess the equity of water distribution, as well as to examine farmer water management on the GMP level, in contrast to system level management.

All data retrieved under this program were compiled on microcomputers and filed at the irrigation Section for future use. Most of the data was analyzed in conjunction with one or more of the other irrigation research programs of the Section.

3.5.1.3 Summary of Primary Results

One of the first constraints that was recognized at the outset of the water management program under NAARP was the lack of sufficient long-term baseline data, which characterized ongoing irrigation activities in Niger. As previously mentioned, the data retrieved under this program was analyzed and used as input to several of the other research programs of the Section. The principal result of this effort, however, was the establishment of a database of several years of irrigation water management-related measurements and findings, which otherwise did not exist. These data may now serve as foundational input to future studies in irrigation water management in the region.

3.5.2 Water Lifting Studies Among Microsystems

3.5.2.1 Program Summary

The purpose of this program was to conduct an examination and performance evaluation of the principal water lifting technologies in use among microsystems throughout Niger. Such an evaluative survey would provide an assessment of appropriate water lifting technologies in accordance with varying, regional and site-specific constraints (geophysical, hydraulic, and agronomic).

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In order to sample representative microsystems and water lifting technologies throughout the country, letters were sent to the agricultural offices (DDA) of each department in Niger requesting a list of recommended sites of microsystem activities within their departments. Upon receipt and review of the responses from each department, the following site areas were selected for evaluation:

Tahoua Department - Lower Tarka Valley
Agadez Department - Aïr Plateau
Maradi Department - Goulbi Maradi
Zinder Department - Cuvette Systems
Diffa Department - Komadougou River and N'guigimi Cuvettes.

At these sites, over a two year period, 144 microsystems using manual and animal traction lifting methods were evaluated, and 37 microsystems using gasoline-powered pumpsets were evaluated. Collaboration on the evaluation of small pumpsets was established with the Paris-based *Groupe de Recherche et d'Echange Technologique* (GRET), which had carried out some similar evaluations in other Sahelian countries. The pumpset evaluation used a revised datasheet form provided by GRET. GRET also participated in the analysis of the retrieved data.

Typical data retrieved during each of these evaluations, for each type of lifting technology, included:

- Lifting frequencies.
- Sustained pumping and/or flow rates.
- Water table levels and fluctuations.
- Labor and energy/fuel requirements for pumping.
- Initial and operational costs of technologies.

3.5.2.2 Methodology

Several months were spent by Norman in training the 2-3 man evaluation team, which was lead by the Irrigation Section technician, Mr. Souleyman Mounkaila. Also, data forms to facilitate the recording of data were developed during this period. At each site, microsystems were selected for monitoring, which offered the widest possible range of lifting heights (pumping heads) to which the particular water lifting method was adapted. Following water flow measurements, farmers were then interviewed and survey forms filled out.

3.5.2.3 Summary of Primary Results

Based on long-term data retrieved under the Water Use Database Collection program and from initial results of water lifting tests, it was determined that, in most cases, the highest single cost component of production among microsystems, and, thus, the principal production constraint, is that of water lifting (i.e., labor and/or energy costs).

Water lifting studies among microsystems have indicated that the cost of removing water from the ground (i.e., labor and/or energy costs) is by far the largest constraint to production in these systems. Many traditional technologies are well-adapted to certain regional and/or geophysical conditions. At present, the Section is in the process of classifying and matching these conditions to appropriate traditional water lifting technologies of these constraints.

A standard methodology and set of procedures for evaluating manual, animal traction, and pumpset water lifting for small-scale irrigation were developed. INRAN's Irrigation Section should be able retain this capability to conduct such evaluations in the future, as long as present staffing is maintained.

A technical performance function, relating discharge (liters per second) to lift (meters) for the primary traditional water lifting methods used in Niger, was developed. Furthermore, performance envelopes and the operational ranges for manual and animal traction methods were established. The function to derive the discharge-lift relationship and the upper discharge envelope can also be applied to other similar water lifting technologies, as they are introduced or developed within the region.

The performance of the principal pumpsets used in the region were evaluated according to make (brand), power rating, age, and lifting conditions. Most important was the assessment of water deliveries per unit volume of fuel consumed, over a range of operational lifts. GRET also participated in the analysis of the pumpset data and a report by GRET on this activity is forthcoming.

A field manual was compiled in which the evaluation methodologies developed under this program are detailed in a step-wise manner. Additionally, the performance characteristics of all evaluated water lifting technologies is listed. It is anticipated that these performance measures for manual and animal traction systems, together with those generated from the fuel-powered pumpset data, will serve to facilitate an accurate selection and evaluation process for appropriate water lifting technologies used in small-scale irrigation development for the region.

3.5.3 Irrigation Water Use and System Diagnostic Studies

3.5.3.1 Program Summary

The overall purpose of this program was to provide an in-depth evaluation on water use performance among irrigated systems through a series of intensive, diagnostic studies at each site. This involved testing for engineering constraints to effective water management, as well as an examination of other nontechnical factors which affect how water is used. Furthermore, these studies were aimed at examining how farmers respond to both technical and nontechnical constraints within their irrigated systems. Field water use measurements involved application rates, operational and non-operational system water losses, delivery schedules, and farmer parcel deliveries and losses. Equity of water distribution between head and tail-end sections of perimeters was examined. Also, the contrasting roles of ONAHA and the farmer cooperative in perimeter water management were studied. In both perimeters and microsystems, the seasonal soil moisture budget (involving irrigation applications, plant uptake, evaporative losses, and deep percolation) was evaluated. Evaluations of irrigation costs were also conducted regularly.

In the first year of NAARP, potential participants from various disciplines within INRAN, ONAHA, and *Génie Rural* were identified for participation in the irrigation diagnostic studies. Several attempts were made at simultaneous mobilization of this entire team for concurrent field studies at specific sites. It soon became evident, after the first diagnostic studies were held (at Galmi and Djiratawa), that various logistical constraints precluded the effective mobilization of the entire multi-disciplinary team at the same time. (These constraints were primarily that of conflicting work calendars, budgeting constraints, and conflicting per diem rates between INRAN and ONAHA.) The diagnostic work was continued, however, by smaller groups of 2-3 researchers at the sites and at different times. These continued diagnostic efforts were usually organized and led at various times by Dr. Norman (engineering), Mme. Zarafi (socio-economy), and Dr. Berrada (agronomy). Norman devoted most of his field efforts in the Water Use and Diagnostic Studies program to collaborating with both Irrigation Section staff and ONAHA/*Génie Rural* personnel

(both engineering and agronomy disciplines). This effort was spent not only in the conducting of field research and the retrieval of data, but in the training of counterparts in effective diagnostic evaluation, particularly in the engineering discipline. Norman also worked with Berrada on an irrigation parcel abandonment study at the Djiratawa perimeter, and with Mme. Zarafi, who conducted a farmer survey examining farmer organization and water management (at the Galmi and Djiratawa perimeters), and a survey to examine the effects of Bilharzia (schistosomiasis) among farmers at the Galmi perimeter.

At the request of CARE-Niger, which was engaged in a watershed management program among perimeters, the NAARP water management program undertook a three-year study of sedimentation rates in two perimeter reservoirs, Galmi and Moullela. CARE supported the effort financially, and ONAHA and *Génie Rural* collaborated with the Irrigation Section in the placement of several hundred metal stakes in the dry reservoir basins. The Irrigation Section took the responsibility of annual field measurements during reservoir depletion and of the data analysis.

The Water Use and Diagnostic Studies were also supported by long-term data retrieved under the Irrigation Water Use Database Collection program. A major aspect of the Water Use and Diagnostic Studies was the analysis of this long-term data, in conjunction with the more multi-disciplinary data retrieved during the diagnostic surveys.

3.5.3.2 Methodology

Sites for these studies were the same systems selected for long-term evaluation under the Database Collection Program (both perimeters and microsystems). Regular visits were made to each of these several times during each cropping season, usually for 1-3 days. During these site visits, most of the time was devoted to making direct field water measurements: calibrating flow gates and offtakes, measuring canal seepage, operational losses, water pumping rates, reservoir sedimentation rates, etc. Additionally, each site visit involved extensive formal and informal interviews with farmers regarding their own perceptions of operational constraints to system functioning. When lengthy field measurements or farmer surveys were necessary, the responsibility was generally turned over to the *observateur* following several days of working with him during the site visit. At the perimeters, time was usually spent during each visit in evaluating water use and interviewing farmers in both a selected head GMP and a selected tail-end GMP.

3.5.3.3 Summary of Primary Results

The primary research results from completed studies under this program during NAARP are summarized as follows:

Studies of storage losses in the reservoir system at the Konni perimeter indicate that, before water is ever used for irrigation in the dry season, 37% and 32% are lost to surface evaporation and seepage losses, respectively. Thus, only 32% of the original volume stored is delivered to the perimeter for irrigation.

Reservoir sedimentation studies over a three-year period have shown that annual storage losses are on the order of 2-3% of the original reservoir storage volume within several systems.

Studies of water losses within perimeter delivery systems indicate that operational losses account for the greater portion. Proportionally, losses due to the delivery infrastructure are considerably less. The indication is that improved organization and monitoring of water deliveries, rather than improved

infrastructure, would better serve to reduce delivery losses. The largest portion of overall irrigation losses occur within the parcel as seepage below the root zone, indicating a need for better water scheduling.

Water rotation and distribution studies indicate that, in the design and planning of systems, labor availability is often overestimated (and the off-perimeter competition for labor is often underestimated). It was found that farmers frequently substitute water for unavailable labor, which, in turn, may reduce irrigation efficiency marginally, but it tends to increase overall perimeter operational performance.

Water distribution and rotation studies revealed that unlimited availability and access to water within the system may serve to reduce system operational efficiency. On the contrary, it was found that where access to water is controlled or limited, the incentive is created for farmers to organize functional irrigation rotation among themselves.

Water distribution and rotation studies also revealed that farmer management units of 20 farmers or less tend to have the capacity for self-management, particularly in terms of organizing water deliveries. On the other hand, there is clearly the need for better outside support (e.g., by the state) for system-level management among farmer management units.

Among all systems and perimeters studied, irrigation efficiencies were found to be highest among small, private microsystems. Among perimeters, the reservoir-fed systems of the Ader-Doutchi-Maggia region had the highest irrigation efficiencies (50-70%, the older systems tending to have the higher efficiencies), with the electrical-powered Djiratawa perimeter having the lowest (50% or less).

Water use studies at the Djiratawa perimeter indicated that little incentive exists among farmers to conserve water, since farmers are not individually (or by farmer management units) taxed on the basis of water use. The electrical tariff is averaged for the entire system, and each farmer is required to pay the average. As a result of this study, the Irrigation Section was asked to work with ONAHA to restructure the water taxation system, so that each farmer management unit (GMP) is directly accountable for the water it consumes, thus increasing the incentive to conserve water. Mr. Alhadji Saminou, the new ONAHA director of the Djiratawa perimeter and recently returned from NAARP short-term training, has implemented this new method of redevance calculation using electrical consumption rates for each tubewell sector.

The total cost to the farmer for irrigation water was evaluated among eight representative systems (four perimeters and four microsystems) and found to vary significantly among systems. The cost of water to the farmer, from highest to lowest, was found to be in the following order: manual-lift microsystems, gasoline-powered pumpset microsystems, electrical-powered perimeters, reservoir-fed perimeters. However, it was also found that systems which incur the highest costs, and which allow for greater direct farmer control over system water management, tend to exhibit the highest performance characteristics.

Parcel abandonment studies in the Djiratawa perimeter indicated that the availability of irrigation water (in terms of delivery, scheduling and volume of supply) was not a major constraint and, thus, did not serve as a major incentive to abandon parcels. Rather, parcels having soils which were poorly drained and not suited to the principal crops grown tended to be the principal reason for abandonment. In most cases, this problem was often compounded by high redevance rates due to the uniform water tariff rate among all parcel holders, regardless of water consumption.

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3.5.4 Water Scheduling Program For Irrigated Perimeters

3.5.4.1 Program Summary

This program was initiated in order to assist ONAHA perimeters in planning and budgeting the use of scarce reservoir water reserves during dry season irrigation. In addition to usually scarce water reserves following the wet season, multiple cropping is often practiced and serves to further complicate water budgeting. It was, thus, determined that ONAHA perimeters could benefit from assistance in a water budgeting plan, which would minimize the difficulties involved in making seasonal water budgeting assessment by utilizing measured system characteristics of water losses and irrigation efficiencies of each perimeter, as well as specific crop water requirements of each irrigated crop.

Fieldwork for the retrieval of water use data needed for the calibration and validation of this program was completed under the Water Use Database Collection program and the Diagnostic Studies. From these data, preliminary water loss and system efficiency coefficients for each perimeter were developed. Some crop water requirement studies for crops in the region have been conducted in the past. These data, coupled with water requirements studies of certain crops conducted under NAARP by the irrigation agronomist, can be used in the budgeting program, as well.

3.5.4.2 Methodology

Meetings were held between Norman and Irrigation Section personnel to discuss the conceptualization and the development time frame of this program. As a result, five principal steps were developed in order to carry out the program to completion:

1. Meet with ONAHA personnel to review past policies and models used for water scheduling within perimeters, to assess ONAHA's felt needs for assistance in water scheduling, and to develop a tentative list of concept guidelines for the structuring of the water budgeting program for ONAHA.

2. Develop performance characteristic coefficients for each perimeter from data retrieved under previous NAARP-INRAN studies--evaporative and seepage losses from reservoir storage, operational and seepage losses in canal delivery networks and parcels, irrigation efficiencies. Also, obtain crop water requirement estimates for irrigated crops.

3. Based on the input from ONAHA (Step #1) and performance characteristics developed in Step #2, develop and calibrate a preliminary water budgeting program for reservoir-based perimeters.

4. Test and validate the program over a one- to two-year trial period, in collaboration with ONAHA, within selected perimeters.

5. Make appropriate changes, adjustments, and upgrades to the final program, and adapt it to site-specific characteristics of individual perimeters.

Due to several unforseen and unavoidable constraints (e.g., the arrival of computer equipment and the irrigation agronomist late in the NAARP program, and changes in Irrigation Section and ONAHA personnel), it was decided that Steps #1-3 would be completed by the end of NAARP, while Steps #4-5

would be carried out later by Section personnel, in collaboration with ONAHA during the post-NAARP period.

3.5.4.3 Summary of Primary Results

A preliminary reservoir water budgeting program was developed for use on a computer spreadsheet to facilitate multiple crop water budgeting for the dry season in reservoir-fed perimeters managed by ONAHA. The budget uses system performance characteristics obtained from NAARP-INRAN studies, and serves to reduce the complex task of assessing water needs in an multiple-crop reservoir system, where water losses are significant.

3.5.5 Recommendations

In spite of the many, unanticipated setbacks in the implementation of NAARP, it is felt a viable program in irrigation water management was been set in motion. The success of a continuation of this program during the post-NAARP period will be highly dependent on future financial and moral support allotted to the Irrigation Section by INRAN at the Directorate and Departmental levels.

Most of the major impediments to the rapid and effective establishment of the research program in water management, which were experienced during the NAARP period, were both unavoidable and unplanned. Both the lack and dilatory nature of staff assignments to the Irrigation Section served as perhaps the major setback in the program. Other major obstacles included: the lack of funding for the Irrigation Section through NAARP-INRAN budgeting (throughout the life of NAARP, the irrigation research program was financed entirely through the NAARP-Purdue office budget), the late arrival of research equipment, and the time which Norman had to devote to administrative matters as the NAARP-Maradi office supervisor.

Potential constraints which the Irrigation Section will face in the post-NAARP period are not only financial. Due to the lack of budget allocations, the Section has had to release the three *observateurs* (previously hired under the NAARP-Purdue budget) who received extensive field training in water management field data collection methods. Such trained field assistance is crucial to any research program. Another constraint the Section will continue to face is the logistical problem of being located in Maradi near field irrigation activity, but being attached to the DRE, which is located in Niamey. The resultant problem is that the Section has little influence in Niamey when various administrative and/or bureaucratic needs arise.

In addition to the need of financial and moral support from Niamey, in order to continue a viable program, Irrigation Section personnel should be encouraged to exert the effort necessary to maintain close, functional ties with ONAHA and IIMI, as well as with other development institutions (e.g., NGOs) involved in irrigation. Finally, and perhaps above all else, Section personnel should be encouraged to maintain a genuine curiosity about how water, farmers, and crops interact and work, in order to help guarantee a continuing and progressive research effort.

3.6 Irrigation Agronomy

3.6.1 Background

The irrigation research program was designed to address soil and water management programs in the Ader-Doutchi-Maggia valley, the Taraka valley, the Maradi Goulbi, and the irrigation research stations of INRAN as related to crop production.

According to the 1987-91 Niger Economic and Social Development Plan, there are 23,000 ha of irrigated land in the country. Out of this, 12,000 ha are under modern irrigation in 47 perimeters. The total irrigated area is about 1% of the arable land. The cost of development of irrigation perimeters in Niger is high to very high.

The potential for further irrigation development is rather limited because of a lack of available water and financial resources. As such, emphasis was on investigations leading to an optimal use of the very limited water resource.

Irrigation research was rather new in Niger. A French company, CFDT, tried different cotton varieties under irrigation. At the Lossa irrigation research station, which was also managed by technical expertise from France (GERDAT), trials were carried out on some wheat varieties. During 1963 and 1970, studies were carried out by Tropical Agriculture Research Institute (in France) at the SEHA station in Maradi on evapotranspiration of wheat, corn, sorghum, cotton, onions, tomatoes, and cowpeas. The main emphasis was on establishing correlation of evapotranspiration with the empirical formula of Blaney-Criddle and evaporation from a Pitch evaporimeter.

Water supplies in different irrigation perimeters were based on the recommendations contained in the feasibility study reports. Because of the lack of available data on evapotranspiration from field studies, a number of assumptions were made in irrigation schedules. In the Konni irrigation perimeter developed in 1980, use was made of the revised Penman method for calculating crop water requirements. However, the crop coefficients used were not the ones recommended in the document. Therefore, the estimates cannot be considered precise. These schedules proposed during the design phases of the perimeters, and followed by ONAHA, needed revision and updating during the operation phases of the projects.

INRAN did not have a well-defined research program. INRAN researchers carried out experiments with supplemental irrigation, but had no well-designed irrigation experiments.

The NAARP priority research activities dealt with INRAN'S irrigation research program, field studies on responses of crops to irrigation, improvement of water management programs in irrigation perimeters in the Ader-Doutchi-Maggia valley, water losses in storage reservoirs, water balance in 10 regions in Niger, water requirements of main crops, irrigation water quality, and development of Tarna 2 as INRAN's irrigation research station.

Studies were carried out jointly with INRAN researchers and those responsible for water management in the ONAHA irrigation perimeters. Mr. Mohamadou Gandah worked very closely with the NAARP irrigation agronomist as a counterpart and maintained an accelerated pace of all activities. Later, Mr. Mahamane Sabiou was named as the INRAN counterpart. All the research and management staff in the ONAHA perimeters in the Ader-Doutchi-Maggia valley played a very active role in the successful completion of the programs.

3.6.2 Soil Characteristics

Soils considered for irrigation in Maradi Goulbi are of recent alluvium. These are deep, over 1.5 meters, well-drained and free of salt hazard. Soil characteristics at Tarna are given in Tables 3.6-1 and 3.6-2.

TABLE 3.6-1
TYPICAL SOIL PROFILE, VALLEY SOIL, MARADI AREA, NIGER

0 - 17cm	Brown (10YR 5/3) wet, clay loam, slightly developed polyhydric sub-angular blocks, medium and coarse elements, steady, many fine and medium pore spaces, many fine roots, clear boundary, pH 6.9.
17 - 49cm	Dark yellowish brown (10YR 3/6) wet, gley medium and coarse polyhydric sub-angular blocks, steady, very fine pore spaces, many fine roots, clear boundary, pH 6.2.
49 - 68cm	Dark yellowish brown (10 YR 4/6) wet with reddish yellow (7.5YR 6/8) mottles, loamy clay, bulky compact structure, steady, very fine pore spaces, very fine roots, clear boundary, pH6.0.
68 - 90cm	Brown to dark brown (10YR 4/3) to very pale brown (10YR 7/4) wet with strong brown (7.5YR 5/8) to very dark grey (10YR 3/1) mottles, clay loam, bulky compact structure, steady, many fine and medium pore spaces, fine roots, clear boundary, pH 5.5.
90 - 111cm	Grayish brown (10YR 5/2) wet with strong brown (7.5YR 4/6) mottles, sandy clay, bulky compact structure, steady, very fine medium and large pore spaces, moderate fine roots, clear boundary.
111 - 131cm	Brown (10YR 5/3) wet with yellowish red (5YR 4/6) mottles, sandy loam, bulky compact structure, slightly steady, many fine pore spaces, few roots, clear boundary.
131 - 147cm	Light yellowish brown (10YR 6/4) wet with dark yellowish brown (10YR 4/6) mottles, loamy sand, bulky structure with fine medium and coarse polyhydric sun-angular blocks, slightly steady, moderate fine pore spaces.

These soils are located in the lowland of the Goulbi alluvial plain and are deep and fairly levelled. The soil color is homogeneous and ranges from brown at the top to yellowish brown at lower depths. Reddish to yellow-brown mottles appear below the 50 cm soil depth. On the whole, the soil texture of the profile is fine, with a clay content of 36% to 50%. Polyhydric structure is slightly developed in the top layers, but becomes bulky at lower depths. Soil consistency is steady. Porosity is good, and the soil boundaries are clear. The soils have a good soil moisture holding capacity.

The soils have a moderate cation exchange capacity, with a high base saturation. These soils are essentially saturated with calcium (70%) and magnesium (30%). The soils have a moderate amount of potassium and phosphorus, but they are, however, low in organic carbon and very low in nitrogen.

TABLE 3.6-2
SOIL PHYSICAL AND CHEMICAL ANALYSES, TARNA RESEARCH STATION, MARADI, NIGER

Soil depth cm	Texture					pH		EC[1] S m^{-1}	Organic carbon			
	Coarse > 2 mm	Sand %		Silt %	Clay % < 0.002	H_2O	KCL		% C	% N	C/N	OM
		Coarse	Fine									
0-22	LA	2.4	21.9	39.4	36.3	6.9	6.1	0.03	0.91	0.48	19.0	1.57
22-41	A	1.8	10.1	37.5	50.7	6.2	5.2	0.04	0.63	0.38	16.6	1.09
41-61	AL	1.3	6.9	46.4	45.4	6.0	4.9	0.05	0.83	0.36	23.1	1.42
63-91	LA	3.5	26.7	33.4	36.4	5.5	4.7	0.04	0.90	0.25	36.0	1.56

Soil depth cm	Exchangeable cations				Total bases	CEC[2]	% Base saturation	Phosphorus ppm
	Ca	Mg	Na	K				Total available P
	meg/100 g							
0-22	14.6	4.93	0.61	0.45	20.59	20.64	99.7	9.8
22-41	18.6	6.21	0.94	0.31	26.06	26.22	99.4	3.9
41-63	17.6	5.39	0.86	0.24	24.09	24.24	99.4	6.0
63-91	13.4	4.08	0.70	0.21	18.39	18.45	99.7	

Depth cm	Moisture retention			Water retention (mm)		
	PR 2.5	PF 3.0	PF 4.2	Capillary	Available	Total
0-22	28.3	28.3	12.8	9.9	15.9	32.4
22-41	33.3	28.5	17.6	10.5	15.7	60.3
41-63	34.6	27.8	16.0	11.8	18.6	42.5
63-91	28.6	23.0	12.7	10.3	15.2	14.9

[1]Electrical conductivity.
[2]Cation exchange capacity.

3.6.3 Climatic Data

Climatic data for 1990 and 1991 for INRAN's center at Tarna are given in Figure 3.6-1. Data show the mean maximum, mean minimum, and total monthly rainfall during 1990 and 1991 and also the long-term (1961 to 1990) average values. There are two periods of maximum temperature, first during April and May, and then in September and October. During 1990 and 1991, total rainfall in Maradi was 392 and 495 mm. The climate is typical Sahelian, with a rainfall average of 700 mm at Maradi. There is a wide variation in different years and even within a season. The rainy season is from May to September.

During the rainy season, the winds are very strong and attain a speed of 80 km/hr. During the dry season, the wind direction is from northeast to southwest. The season is marked by strong winds during February-March.

The annual evaporation from the US standard open pan is about 2,800 mm.

The mean solar radiation value was 20.3 Mj/cm^2. High solar radiation, coupled with low humidity level, was responsible for higher evaporation during November to February. Evaporation from open pan ranged between 8-9 mm per day.

3.6.4 Objectives

The objectives of irrigation agronomy research program included:

Long-term objectives:

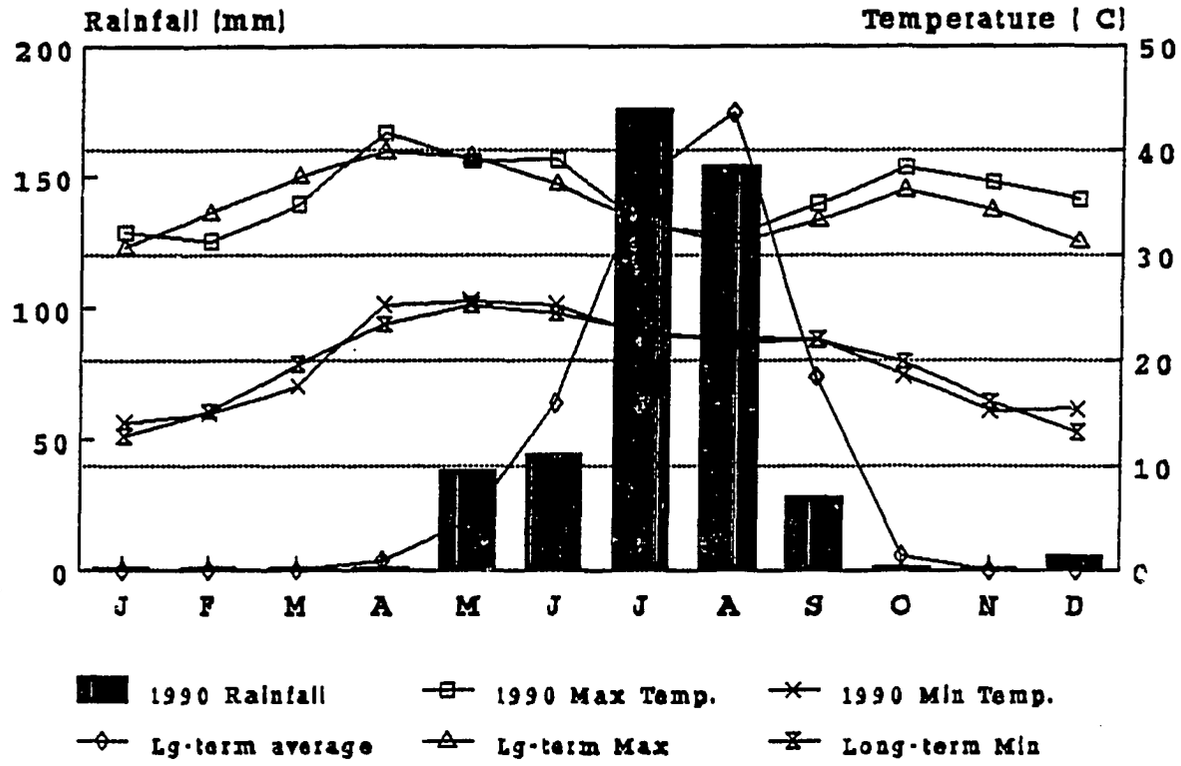
1. Improvement and maintenance of agricultural lands under irrigation by providing a strong base for applied research program.
2. Adoption and use of modern agricultural technology for self sufficiency in food and export of specialized crops.
3. Strengthening of technical services, research and development teams for optimum use of land and water.

Immediate objectives:

1. Determining water requirements of main crops in different agroclimatic regions in Niger.
2. Developing cropping patterns in irrigated agriculture giving the highest returns per unit area per unit quantity of water.
3. Water management in relation to improved cropping practices and technology in different agroclimatic regions.
4. Monitoring water quality: its effects on soils, management of salt-affected soils, fluctuation of the ground water table at selected sites.
5. Establishment and maintenance of fully-automated weather stations.
6. Training Nigerien counterparts and local staff through in-service training and studies or training abroad.

3.6.5 Coordinated Program in Water Management

ONAHA is the principal organization for water management in Niger; however, this organization does not have a strong research program. Water management schedules practiced in the perimeters are per



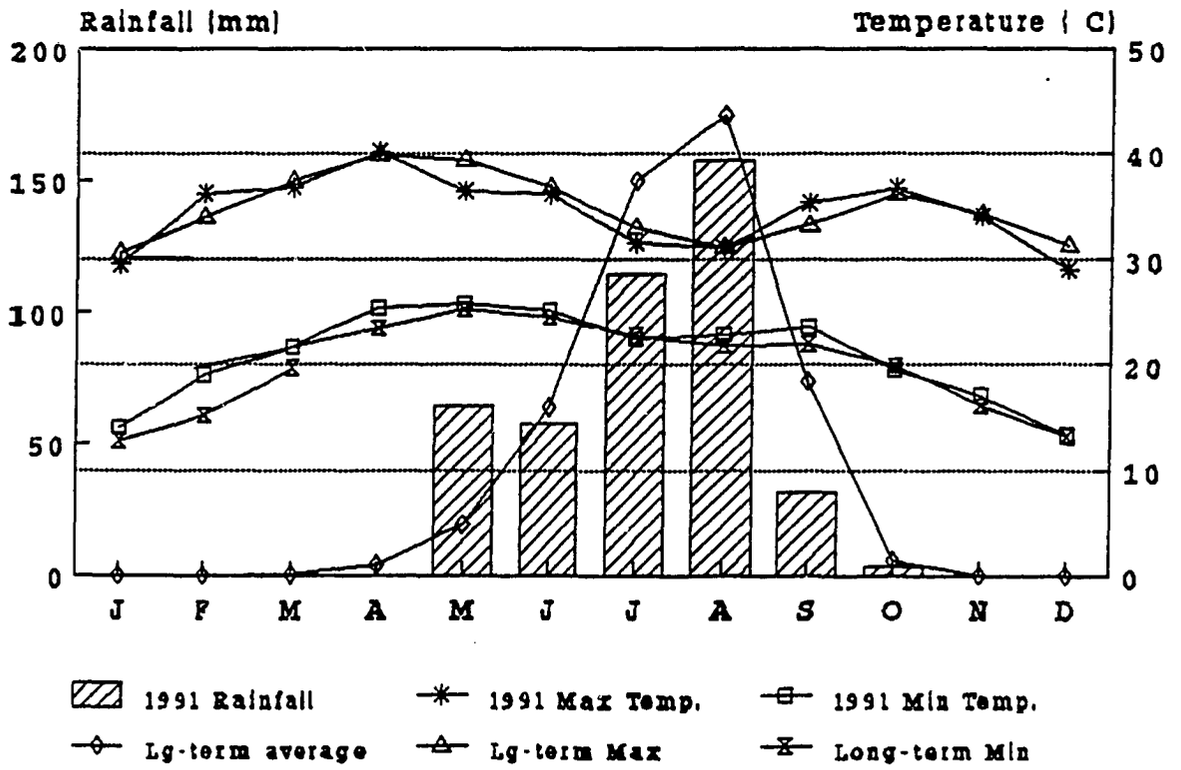


FIGURE 3.6-1. MONTHLY MEAN AIR TEMPERATURE, MONTHLY TOTAL RAINFALL AND LONG-TERM AVERAGE, MARADI, NIGER

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the recommendations in the feasibility study reports. INRAN has the potential for irrigation research, and a good beginning was made in 1989 under PRAAN project.

The construction phases of perimeters is handled by the Department of Rural Engineering in the Ministry of Agriculture. There is no effective coordination among ONAHA, INRAN, and the Department of Rural Engineering in the same ministry. The case of proposed new irrigation perimeters in the Ader-Doutchi-Maggia valley may be mentioned as a recent example. Feasibility studies are in progress for new perimeters between Keita and the Galmi catchment. At present, only the Department of Rural Engineering is associated with the investigations, with no input by ONAHA or INRAN.

3.6.6 Water Use in Irrigation Perimeters

3.6.6.1 Water Use

Evaluation of water use in perimeters in Ader-Doutchi-Maggia, i.e., Ibohamane, Konni and Galmi, showed that there was an excessive use of water. In the Konni irrigation perimeter, 12-15 irrigations were applied for the wheat crop from November to late January. In the Galmi irrigation perimeter, 22-24 irrigations were applied to onion crops from October to the third week of January (Table 3.6-3).

TABLE 3.6-3
WATER USE IN PERIMETERS IN ADER-DOUTCHI-MAGGIA VALLEY, NIGER

Perimeter	Period 1989-90	No. of days	Main crop	No. of irrigations	Quantity of water applied (m^3/ha)
Galmi	Oct-Jan 20	108-110	Onions	22-24	21,000
Konni	Oct-Jan 28	100-110	Wheat	12-15	15,000
Ibohamane	Sept-Oct 20	30-35	Cotton	5-9	8,500

Both the frequency and the amount of water applied to crops were high. Excessive water application was also evident from tensiometer readings at Galmi and Konni (Table 3.6-4).

In these perimeters, irrigations were scheduled by ONAHA staff when tensiometer readings were 0.04 to 0.48 bar for wheat and onions.

The soil moisture tension prior to irrigations, shown in the table, indicate that the soil profile was almost wet before irrigation.

In the 1990 crop growing season, tensiometers were fixed at six different sites at 30, 45, and 60 cm soil depths in cotton and sorghum fields in the Konni irrigation perimeter. The object of the observations was to trace moisture status in the soil *in situ* before irrigations. The data are presented in Figures 3.6-2 and 3.6-3.

In general, the sorghum crop was irrigated when the soil moisture tension at the 0-30 cm soil depth was 0.7 bar. During the late stages of crop growth, the soil moisture tension at the 0-30 cm soil depth

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TABLE 3.6-4
MOISTURE TENSIONS AT WHICH IRRIGATIONS WERE SCHEDULED, 1989-90, KONNI AND GALMI IRRIGATION PERIMETERS, ADER-DOUTCHI-MAGGIA VALLEY, NIGER

Perimeter	Crop	Soil depth	Tensiometer reading (bar)[1]
Konni	Wheat	0 to 15 cm	0.48
		15 to 30 cm	0.06
		30 to 45 cm	0.4
Galmi	Onions	0 to 15 cm	0.12
		15 to 30 cm	0.08
		30 to 45 cm	0.04

[1]bar = 10^6 dynes/cm^2.

was around 0.2 bar. Irrigations at such low soil moisture tensions amounted to a waste of water, without any effect on crop yields.

3.6.6.2 Need for an Optimum Use of Water

A total of 12,000 ha of land is under modern irrigation in 47 perimeters. The cost of land development under irrigation in different perimeters is high to very high. The cost of development of the Konni irrigation perimeter, completed in 1980, was about $20,000 per hectare. Data show that of 47 perimeters established during 1965-1980, 15 were rehabilitated. The life of perimeters appeared to be 14 years. The high initial cost of development of the land and then rehabilitation in about 14 years necessitates that water resources are used optimally. Water is one of the most expensive limiting factors in crop production in Niger.

Problems associated with pumping ground water for irrigation perimeters are the high cost of electrical pumping and the falling ground water table. Inability of the irrigation cooperatives to pay power bills resulted in shutoff of power supply and, consequently, crop production was affected. During the 1991-92 crop growing season, serious power cutoffs were experienced by the farmers in the Dijaratawa perimeter.

The falling ground water table appeared to be a direct consequence of the limited recharge of the aquifer and excessive withdrawals of water.

3.6.6.3 Water Use Planning

ONAHA staff considered that 36,000 m^3 of water stored in the barrage were needed for irrigation of one hectare. This is a rule of thumb for adjusting irrigated areas in relation to the amount of available water stored in barrages.

Water stored in the barrages and the area irrigated in the Konni irrigation perimeter in different years is shown in Table 3.6-5.

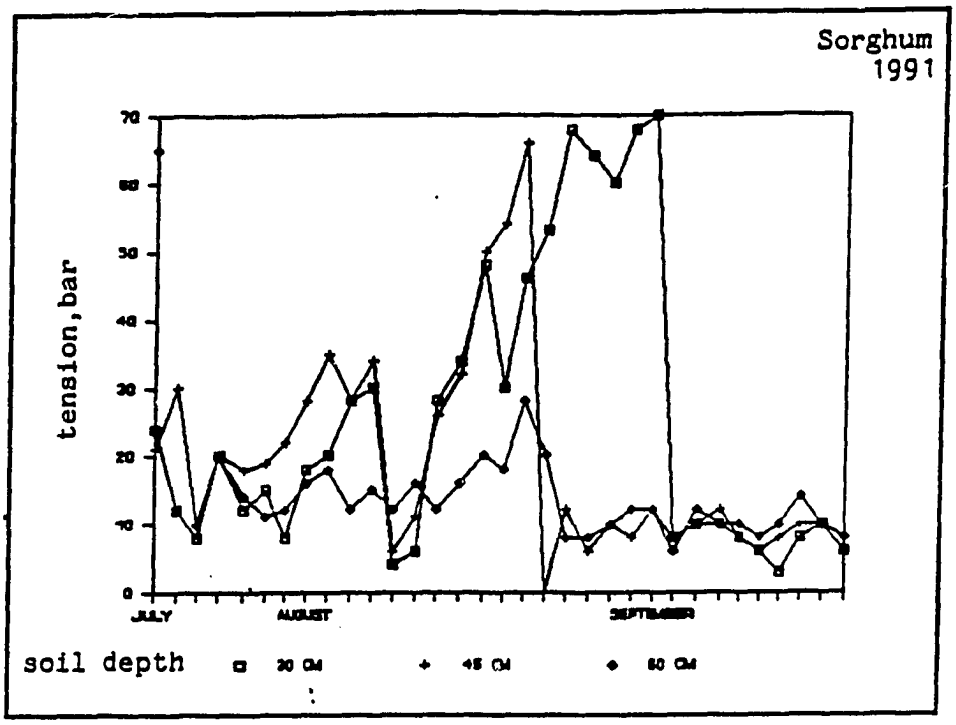

FIGURE 3.6-2. SOIL MOISTURE TENSION IN SORGHUM FIELDS, KONNI IRRIGATION PERIMETER, ADER-DOUTCHI-MAGGIA VALLEY, NIGER

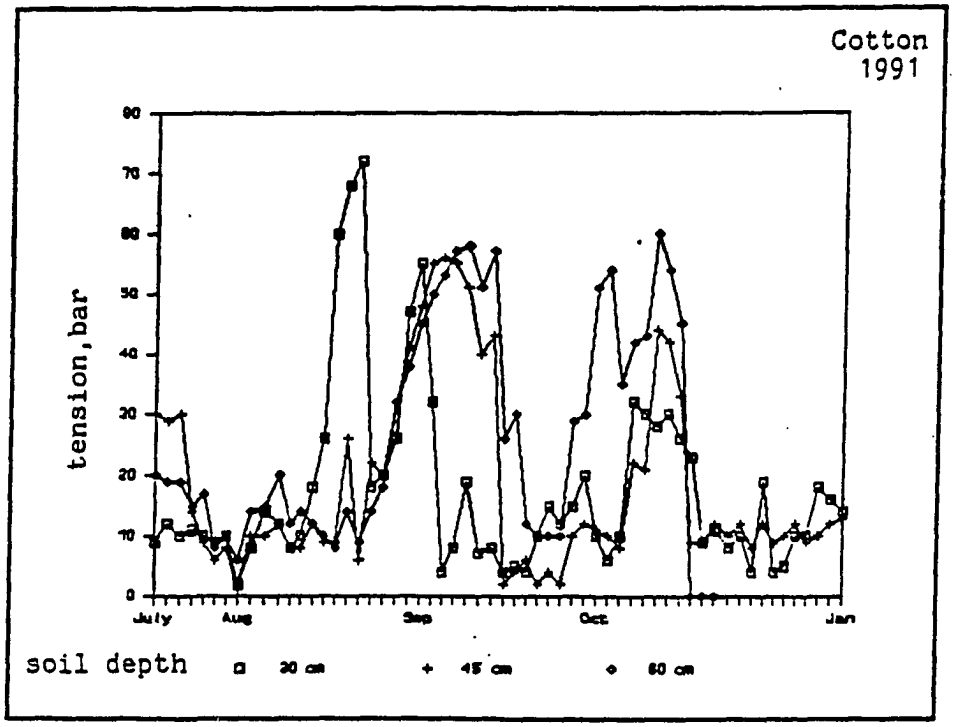

FIGURE 3.6-3. SOIL MOISTURE TENSION IN COTTON FIELDS, KONNI IRRIGATION PERIMETER, ADER-DOUTCHI-MAGGIA VALLEY, NIGER

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TABLE 3.6-5
WATER STORED IN KONNI IRRIGATION BARRAGES AND AREA CULTIVATED

Year	Volume stored, thousands of m^3	Area cultivated ha	Volume of water used per ha (m^3)
1991-92	29,105	606	48,020
1990-91	14,160	359	39,443
1989-90	28,911	644	44,893
1988-89	24,504	600	40,840
Mean			43,301

Water used per hectare varied from year to year. With about 14 million m^3 of water stored in the dry season, 359 hectares were cultivated, with a record production of the wheat crop. On average, about 43,000 m^3 of water stored in the reservoir was sufficient to irrigate one hectare.

Planning for optimum use of water resources in agricultural production necessitates information on water resources, soils, and cropping schedules. The Konni irrigation perimeter has been operational since 1981 in the Ader-Doutchi-Maggia valley in Niger. The water from the Maggia River is stored in two dams, Zango and Mozague, which have a live storage of 40M m^3 (million cubic meters). A 15-km lined feeder canal delivers water to a compensation pool at Tyerassa for supply and distribution to the perimeter. About 2,440 ha are actually under cultivation. The entire perimeter is divided into smaller units and each unit (farmer) has 0.75 hectare; therefore, there are about 3,000 family farms.

The climate is typical of the Sudano-Sahelien area. The dry season (without rain) lasts from October to May. The average rainfall is about 500 mm per annum, but is subject to wide fluctuations. Initially, the cropping pattern in the perimeter was two-thirds sorghum and one-third cotton. But at present, each crop occupies 50% of the area. Sorghum is followed by a wheat crop in the dry season.

Wheat is raised during the dry season (November to March). The crop is planted after two irrigations, the first for land preparation and the second mainly for control of termites. At times, only one irrigation is scheduled. Some farmers apply 60 kg N per hectare for the wheat crop. This treatment is applied at tillering or at the ear emergence stage of crop growth.

The perimeter has a potential for production of 3,150 tons of cereals (mainly sorghum and wheat), 800 tons of cotton, and 700 tons of legumes (cowpeas). However, the production, especially for wheat, is subject to the water stored in the reservoirs and the area cultivated. Consequently, water use planning and irrigation scheduling are necessary every year to ascertain acreage which can be cultivated in relation to the water supply.

In 1989-90, water storage at the beginning of the wheat growing season was 29M m^3 and, as per the prevailing water scheduling system in the perimeter, about 640 ha were cultivated. The average yield was 2.5 tons per hectare.

In 1990, the rainfall was subnormal. As a result, the maximum water reservoir capacity after the rainy season was 27M m^3 as against a storage capacity of 42M m^3 in 1989, including two million cubic meters in the compensation pool at Tyerassa. Accounting for supplemental irrigations of cotton and sorghum

for 1990, the water stored at the beginning of the wheat growing season was estimated to be about 17M m^3. The dead storage capacity of the reservoirs is 2M m^3. Using a flexibility factor of 1.1, the total volume of water available during the wheat growing season was calculated to be 13.6M m^3. The existing water supply schedules in the perimeter comprised the delivery of 7-8 m^3 of water per second for seven hours per day for six days in a week for one irrigation. The Director of the Konni irrigation perimeter calculated that 250 ha of wheat could be cultivated during 1990-91, but there would be no water by January 1991. During January, the wheat attained the peak period of water requirements. Accordingly, the wheat yield under these conditions may have been less than one ton per hectare.

In the present study, an analysis was presented on water use planning and irrigation scheduling for the 1990-91 wheat growing season. This model could be used in the following years with some modifications, including different cropping patterns. The model provided information on water allowance, supply days, and supply intervals for a maximum production of wheat per hectare.

The methodology included (1) calculation of net irrigation requirements, (2) project acreage in relation to the water supply, and (3) water allowance, supply days, and supply intervals in the Konni irrigation perimeter. The supply interval was established by considering the prevailing water supply system to meet the requirements of the irrigation cooperatives.

Crop water requirements (ET crop) are the depth of water needed to meet water loss through evapotranspiration of a disease-free crop growing in large fields under non-restricting soil conditions, including soil water and fertility, and achieving full production potential under a given environment.

The effect of the climate on crop water requirements is given by reference crop evapotranspiration (ETo). ETo is the rate of evapotranspiration from an extensive surface of 8-15 cm tall green grass cover of uniform height, actively growing, completely shading the ground, and no shortage of water. ETo was established by the modified Penman method and expressed as mm of water per day.

The effects of crop characteristics on crop water requirements were evaluated through crop coefficients (kc). These coefficients relate ETo to crop evapotranspiration (ET crop).

$$\text{ET crop} = kc \times \text{ETo}$$

In this study, crop coefficients for the wheat crop were adapted from FAO irrigation and drainage paper No. 24. The wheat growing season was divided into four stages (reference Figure 3.6-4). Crop coefficients (kc) for different stages were worked out.

Net irrigation requirements (In) were calculated as the depth of water required for meeting evapotranspiration minus contribution by rainfall (R), ground water (Ge) and stored soil moisture (Wb).

$$In = \text{ET crop} - (R + Ge + Wb).$$

All the above variables were expressed in mm depth of water.

To establish irrigation requirements in addition to net irrigation requirements, allowance was made for the losses during conveyance and application of water. Project irrigation efficiency was expressed in the fraction of net irrigation requirements. The acreage of wheat which could be grown in an irrigation perimeter at Konni during the 1990-1991 growing season was calculated from the peak period requirements (critical period of growth) and the available water supplies.

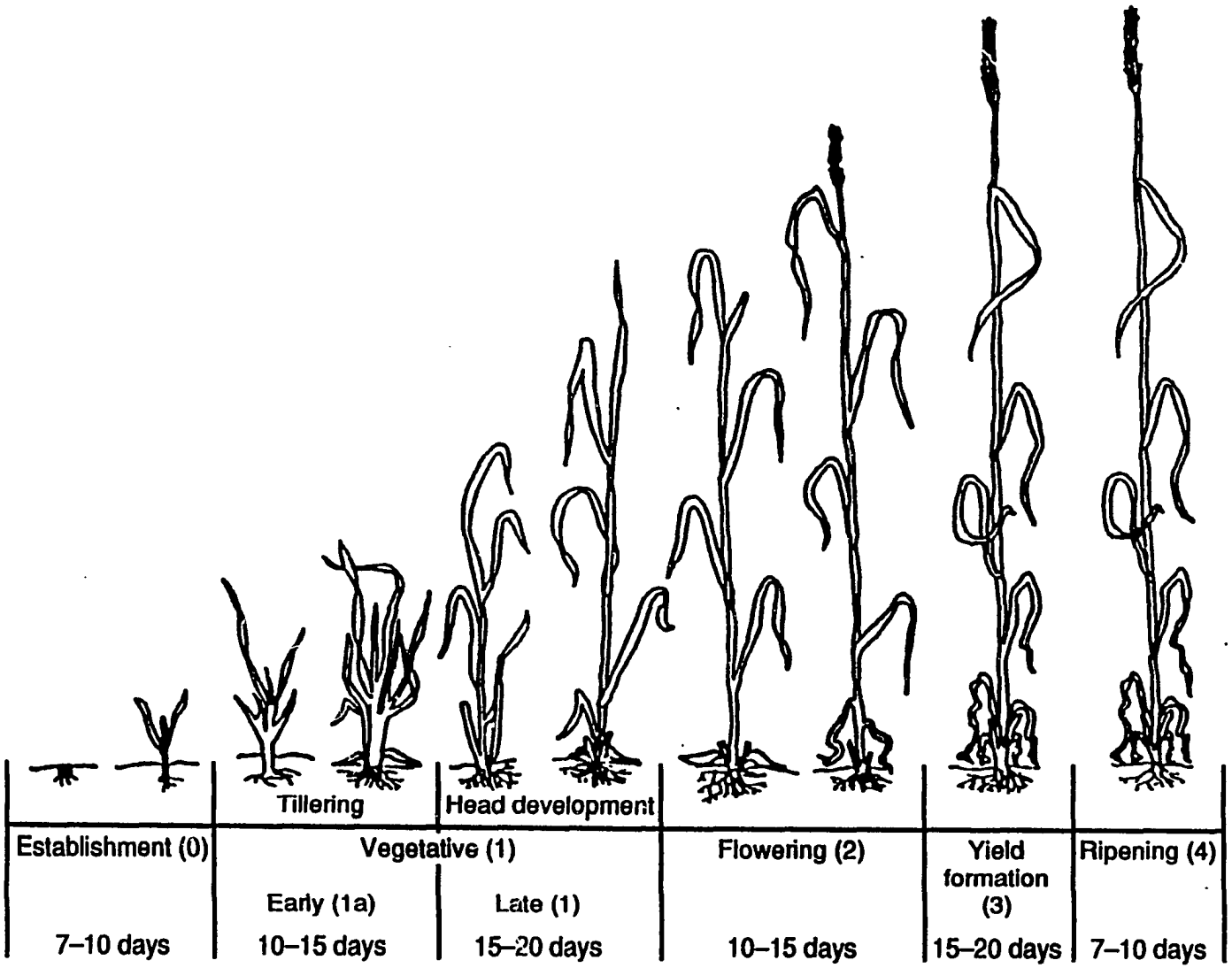

FIGURE 3.6-4. WHEAT GROWTH STAGES, KONNI, ADER-DOUTCHI-MAGGIA VALLEY, NIGER.

$$A = Ep\ (1\text{-}LR)\ V/10 \times In,$$

where

A = acreage of wheat, ha
Ep = project irrigation efficiency, fraction
LR = leaching requirements, fraction
V = water supply requirements, m^3 per month
In = net irrigation requirements, during peak period, for the season.

The factor 10 appears due to conversion of mm per month to m^3 per month.

Other factors considered for establishing ET crop were (1) effective rainfall, (2) ground water table contribution, (3) leaching requirements, and (4) stored soil moisture.

The effective rainfall during the wheat growing season at Konni is nil. Also, the ground water table is below five meters and, as such, no contribution was considered in this study.

As referred to earlier, the field irrigation application was 60%. Accordingly, leaching requirements were not included in the estimation of the net irrigation requirements.

The wheat crop was grown after the harvest of sorghum. The sorghum crop received the last supplemental irrigation during September. Consequently, the contribution of the stored soil moisture was negligible.

Irrigation application efficiency in the Konni irrigation perimeter was calculated for the following conditions:

Reservoir storage efficiency (Es). Although no accurate data are available for the water storage efficiency, the management authority suggested that the storage reservoir efficiency was 0.5. This included the deep percolation losses, as well as the evaporation losses. The magnitude of the evaporation is high because of the vast surface and shallow depth of the reservoirs.

Conveyance efficiency (Ec) is the ratio of the water received at the outlet from the Tyerassa reservoir into the primary, secondary, and tertiary canals and the water released at the inlet of fields from the tertiary canals. The value for the Konni irrigation perimeter is 0.73 (Gandah and Prashar, 1990).

Field application efficiency (Ea) is the ratio between water made available to the crop and that received at the field inlet. For the Konni irrigation perimeter, the value is 0.6.

Konni perimeter irrigation efficiency (Ep) is the ratio of the water available in the storage reservoir and the water available to the crop.

$$Ep = Es \times Ec \times Ea = 0.5 \times 0.73 \times 0.6 = 0.219$$

In the perimeter, wheat is the principal crop. As such, area which could be irrigated during the 1990-1991 season (November to March) was based on the water requirements of wheat during the critical period of growth and the water in the reservoir at the beginning of planting. The water stored in the Konni reservoirs is 17M m^3. There are 2M m^3 dead storage; therefore, available water is 15M m^3.

For the Konni irrigation perimeter, a flexibility factor of 1.1 was considered. As such, effective water storage was calculated to be 13.6M m^3.

The total area which can be irrigated, as referred to earlier, was calculated to be:

$$A = Ep\ (1\text{-}LR)\ V/10 \times In$$

$$A = 10 \times 0.219/10 \times 224.4 \times 4 = 332\ Ha$$

The operation schedules proposed in this study are in line with the existing schedules and fully accommodate the interests of the irrigation cooperatives in the perimeter.

Operations and water supply schedule for 332 ha of wheat in the 1990-91 cropping season in the Konni Irrigation Perimeter is shown in Table 3.6-6.

TABLE 3.6-6
OPERATIONS AND WATER SUPPLY SCHEDULES FOR WHEAT, 1990-91, KONNI IRRIGATION PERIMETER, ADER-DOUTCHI-MAGGIA VALLEY, NIGER

	Nov.	Dec.	Jan.	Feb.	Mar.
Net irrigation requirements, mm per month	73.8	99.2	224.4	142.2	26.5
Water allowance, M m^3	1.77	2.38	5.38	3.41	0.64
Supply days	12	12	24	15	3
No. of irrigations	3	3	4	4	1[1]
No. of weeks/no. of days	1st/6 2nd/3 3rd/3 4th/nil	1st/6 2nd/3 3rd/3 4th/nil	1st/6 2nd/6 3rd/6 4th/6	nil 2nd/6 3rd/6 4th/3	1st/3 nil nil nil
Schedule for each irrigation (duration in hrs., stream size per sec.)					
First	6 hrs 7 m^3	6 hrs 7.5 m^3	7.5 hrs 8 m^3	- -	7.5 hrs 8 m^3
Second	5 hrs 8 m^3	5 hrs 6.5 m^3	7.5 hrs 8 m^3	7 hrs 8 m^3	- -
Third	5 hrs 8 m^3	5 hrs 6.5 m^3	7.5 hrs 8 m^3	7 hrs 8 m^3	- -
Fourth	- -	- -	7.5 hrs 8 m^3	7 hrs 8 m^3	- -

[1]if needed.

Water supply schedules suggested in this study were based on achieving full production potential of the wheat crop for the Konni irrigation perimeter. The model provided assured water supply for 332 ha, excluding a flexibility factor of 1.1. Details were worked out on stream size, supply duration, and irrigation interval during the 1990-91 wheat growing season.

A flexibility factor was used, and this accounted for fluctuations in water supply in excess to those required in the wheat growing season. This factor could also account for an additional irrigation to meet a special situation such as termite control or conditions of high evapotranspiration during February.

The proposed model also considered the major interests of the irrigation cooperatives. The model provided a methodology for water use planning in the succeeding years for acreage and a cropping pattern in relation to the available water supplies in the reservoirs.

3.6.6.4 Water Losses in Barrages

Water losses in the barrages are assumed to be 50%. The experience in the perimeters showed that the water supply schedules planned with 50% losses invariably fall short of expected length of time.

In 1990, a water use planning and supply schedule for the Konni irrigation perimeter was prepared. The water losses in the barrage were considered to be 50%, as suggested by ONAHA staff. The water in the barrage was supposed to last until the end of February 1991; however, there was no water in the barrage by the end of January 1991. Among other factors, it is suggested that water loss in the barrage was already partially responsible for the water supply running short by four weeks.

Ader-Doutchi-Maggia valley, Niger

One of the basic requirements in irrigation project planning is an inventory of the amount of available water. In the Ader-Doutchi-Maggia valley, water available for a given barrage depends on the rainfall falling directly on the area plus, inflows into the barrage. All the irrigation perimeters were built as low-cost irrigation projects. The rain water and the runoff from adjoining areas is collected in barrages and later used for water supply in the irrigation perimeters. The volume of water stored in the barrage is evaluated from the gauge readings located at convenient points. The gauge reading for a given barrage is referred to a rating table for total volume stored.

There are no documented reports or studies on the water losses in the barrages in the Ader-Doutchi-Maggia valley in Niger. Even in the feasibility studies of the perimeters, the data are lacking. The feasibility study of the Konni irrigation perimeter referred to an anticipated loss of 53% per annum, and out of this, the evaporation losses were considered to be about 18%.

In one of the water management and irrigation scheduling programs in the Konni irrigation perimeter, where the water losses were considered as 50%, the water supply fell short by one month.

Thus, the objectives of this investigation were to evaluate:

1. water losses in the barrages in the Ader-Doutchi-Maggia valley in Niger,
2. magnitude of the evaporation and seepage loss.

TABLE 3.6-7
WATER LOSSES IN BARRAGES, KONNI IRRIGATION PERIMETER
ADER-DOUTCHI-MAGGIA VALLEY, NIGER

Year	Volume of water in the beginning of dry season (Aug)	Volume of water released in the season	Volume at the end of rainy season (Oct)	Water losses (Aug-Oct)	Volume of water in the beginning of dry season	Volume of water released in dry season (Nov-Feb)	Volume of water at the end of dry season	Water losses (Nov-Feb)
	"000" m^3							
1984-1985	27290	1295	20080	5915 21.7%	19000	3941	4040	12099 63.7%
1985-1986	39000	5335	29267	4398 11.3%	26890	8601	998	19668 73%
1986-1987	38860	6137	29313	3410 8.8%	26932	10048	1455	20191 75%
1987-1988	39200	11096	19400	8704 22.2%	19400	7023	2950	13421 69.2%
1988-1989	38660	5546	29401	6713 17.3%	24504	7529	3836	17036 69.5%
1989-1990	37476	4677	2981	3888 10.4%	28911	8954	2000	17957 62.1%
1990-1991	27850	4029	14160	11661 41.9%	14160	4242	2250	9668 68.3%
Mean				19.1%				68.7%

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The investigations were carried out for three typical irrigation perimeters, i.e., Konni, Moulella, and Ibohamane. Daily gauge readings of the barrages were used to calculate the total volume of water stored in a given barrage. A daily water balance account was maintained, which included increases in the volume stored through rainfall and/or inflows from adjoining areas and a decrease in the volume stored through water releases for irrigation. For ease of presentation, the data were presented per 10-day period. For the Konni irrigation perimeter, data were used for seven years from 1984 to 1991. For the Ibohamane and Moulella irrigation perimeters, data were used for four years from 1988 to 1991. The results are presented in Table 3.6-7.

Data for 1991-92 were treated separately because the rainfall during the season was above normal and well-distributed. This resulted in water reservoirs which were full to almost full until the end of August and September, despite some water releases for irrigation.

Water loss from a barrage for a given period was the difference in the volume at the beginning and at the end of a given period, minus the water released for irrigation during that period.

For the Konni irrigation perimeter, water losses were established separately for the rainy season (June to September) and for the dry season (November to March). The water losses during the rainy season ranged between 9% to 42%. The wide variation is due to rainfall and inflows from the catchment area. The water losses for the dry season were 62-75%. The average water losses during the dry season were 69%.

In 1991 in the Konni irrigation perimeter, the water reservoirs were full to capacity with 42 million cubic meters until October 10.

Between October 11, 1991, and February 27, 1992, out of 35.5M m^3, only 10.7M m^3 were released for irrigation. Water losses in the reservoir were 64%. The losses per 10-day period ranged from 45-100%.

For the dry season (the wheat growing period from November 15, 1991, to February 27, 1992), water losses were 60%.

In the Ibohamane and Moulella irrigation perimeters, irrigation scheduling and water supply for crop production lasts mainly up to December. Data on the water losses showed that there were wide variations in different months. In general, the losses increased from July onward. However, when there was sufficient stored water in June, losses were higher in June.

In the Ibohamane irrigation perimeter, water losses in the barrage ranged from 55% to 87% during 1988, 1989, and 1990. A loss of 87% during 1989 was due to the fact that the main gate valve could not operate during August and September. Water losses in the Ibohomane perimeter during September and October 1991 were 55.2%. The data show that from September 11 to October 31, 1991, 2.8 million cubic meters of water were lost to the barrage.

In the Moulella irrigation perimeter, water losses ranged between 76 to 82% during 1988, 1989 and 1990. Water losses in the Moulella barrage were 360,046 cubic meters from October 1, 1991 to January 14, 1992, showing a loss of 81%.

From the daily and 10-day water balance budgets, it was interesting to note that the total water supply actually useable was more than the maximum capacity of the reservoirs.

It was also observed that in a given year when rainfall in July was normal, the barrages were full to capacity, and there was an overflow of water. With a normal rainfall in July, water could be released early for supplemental irrigation.

The Moulella irrigation perimeter is much smaller compared with the Konni and Ibohamane perimeters. Water losses in Moulella were high, because the volume of water released per irrigation from the barrage is 4,000 to 20,000 cubic meters. Both in the Ibohamane and Konni irrigation perimeters, water released per irrigation is much higher.

Water losses in barrages differ from one perimeter to another. These also depend on the volume of water released from the barrage per irrigation. At present, ONAHA staff consider water losses in the barrage as 50% in all the perimeters. ONAHA should consider 69% water losses in the Konni barrage, 55% in Ibohamane, and 77-80% in the Moulella perimeter barrage. This will provide a more realistic approach in evaluating the areas which can be commanded for cultivation with the volume of water stored in the reservoirs.

Evaporation and seepage losses

The evaporation losses for the Konni area from a free water surface were calculated by the Penman (1948) formula, using long-term weather data records (1961 to 1990) on temperature, wind speed, sunshine hours, rainfall, and humidity.

The evaporation losses for the period from June to October were 20.5 cm per month. For the period from November to February, these losses were 24.4 cm per month. On an annual basis, the evaporation from class A open pan was 30.7% higher than that calculated by the Penman method.

A further analyses was made of the water losses in the Ibohamane perimeter barrage to establish evaporation and seepage losses separately. Detailed weather data were not available for the Ibohamane perimeter, but Keita station represents conditions typical at Ibohamane.

Evaporation losses from a large water surface were calculated by the Penman (1948) original formula for 1990 and 1991 per 10-day period.

For a given 10-day period, the following were calculated:

1. the difference in the depth of water in the barrage, cm
2. evaporation loss, as depth, cm
3. change in the depth of water in the reservoir due to volume of water diverted for irrigation (if any), cm.

Seepage losses were established as the difference in water level in the barrage for a given period, minus the evaporation losses and the lowering in water depth due to water releases for irrigation (if any).

A reference was made to the bore hole data across the barrage bed (Barrage bed, 1966). The surface soil texture was silty clay, which afforded an excellent sealing effect against seepage losses. At lower depths, the clay content was reported to be high.

In one section of about 100 meters on the left bank, the soil texture was fine, medium, and coarse sand. The permeability coefficient was 10^{-5} cm sec^{-1}. In the center and in the right bank of the reservoir, the clay content was high. The permeability coefficient in the center of the barrage bed, at different depths, was:

at 2.0 m	6.10^{-6} cm sec^{-1}
at 3.2 m	$3.6.10^{-6}$ cm sec^{-1}
at 7.0 m	$1.7.10^{-6}$ cm sec^{-1}

On the right bank, there was very fine sand at the surface, but down below at 2 meters, the clay content was high. The permeability was 3.8×10^{-6}.

Permeability data showed that there was good sealing against the seepage losses. However, toward the left bank, there were sections with high permeability. The permeable section is almost in the center, which is a source of major sink in the reservoir bed and, hence, the losses due to seepage were high to very high.

In the literature, several references are available (use of chemicals, floating material) for reducing evaporation losses. However, these techniques have had very limited success. Under field conditions in perimeters in the Ader-Doutchi-Maggia valley in Niger, water supply schedules will have to be readjusted to minimize losses. Consideration should be given to 1) avoiding application of water to the cotton crop in the late stages, thus saving more water for the dry season, 2) planting early in the dry season, no later than November 1, and 3) releasing water in larger quantities over a shorter period during the dry season.

3.6.6.5 Siltation of Water Barrages

Siltation of water reservoirs is a major problem in the Ader-Doutchi-Maggia valley. In the Ibohamane irrigation perimeter, data showed that reservoir storage capacity has been diminishing by 200,000 cubic meters per annum for the past four years. In the Ibohamane perimeter, it is almost a practice to excavate 200-300 m^3 of soil around the main gate valve in the barrage. In the 1991 season, about 30 proclain-days of work were done to remove soil. Erosion in the Ibohamane watershed was reported to be about 2,250 tons per hectare per year. It was, thus, not surprising that the barrage capacity of 5.2 million cubic meters (m^3) was reduced to 2.5M m^3 in about 13 years. The perimeter was rehabilitated in 1987.

In the Konni irrigation perimeter, ONAHA staff claim that the reservoirs are silting by 5 cm per year, although no accurate records are available.

Siltation is accelerated, among other factors, by cultivation of major parts of the reservoirs during the dry season. As the water recedes in the barrage, the crops are grown on the barrage floor on residual moisture. The crops grown include tomatoes, squash, and sweet potatoes. With the onset of rains in June, the soil from the disturbed (cultivated) area, especially under sweet potatoes, is washed down into the lower parts of the barrage. At present, ONAHA is allowing this practice of cultivation of parts of the barrage, but it is technically highly questionable.

3.6.6.6 Conveyance Water Losses in Primary and Secondary Canals, Konni Irrigation Perimeter

Water distribution and supply involves conveyance losses below any given outlet in a water supply system. The project water distribution system must convey water from the head gate without excessive conveyance losses and duly account for any such losses. These losses are compensated for by providing additional water supply in the distribution system. Often these losses increase because of inadequate maintenance. As such, measuring of conveyance losses is necessary, especially in the working irrigation systems. These losses depend on soil characteristics of the canal bed, length of time the canal operates, depth to groundwater, sediment load in the water, depth of water in the canal, and maintenance of the distribution system. The Konni irrigation perimeter has been operational since 1981, and there are a number of canals which are a source of concern because of their water losses. Irrigation design in the Konni perimeter is based on lined primary, secondary, and tertiary canals operating water upstream regulation by using a control structure (Neyrtec Modules) for appropriate discharges.

Studies were carried out to determine water conveyance losses in primary and secondary canals in the Konni irrigation perimeter in the Ader-Doutchi-Maggia valley in Niger in 1990. The canals were selected in consultation with the water management authority in the Konni perimeter.

Conveyance losses were measured by the inflow-outflow method, using a water current meter. Two primary canals, Primary A and Primary B, and one secondary canal, Secondary 2PA, were studied. The length of the canals studied ranged from one kilometer to one and a half kilometers. The secondary canal was also studied in sections of 100 to 300 meters to delineate lengths causing excessive losses.

Inflow-outflow of water was measured at pre-selected stations. The diversions of water from the specific sections of canals under study were considered in the calculations. The cross-section of the canals and the lengths of the canals were measured. The net percent losses in the canals were calculated. The canals had a constant flow depth during the course of investigations. This was facilitated through the control structures in the irrigation canals.

A portable water flow meter (model 201, Marsh-McBirney, Maryland, USA) was used in the study. This unit measured water velocity in one direction. The velocity was recorded at 0.6 times the depth (from the top) in the running water. The electronic sensor of the flow meter was placed in the water against the water flow. The sensor was attached to a digital readout meter, giving velocity in meters per second. The data were recorded *in situ*.

Water losses in primary canal A and primary canal B were 11% to 13% and in the secondary canal, 2PA, 10%. Water losses in the secondary canal ranged between 1% to 4% in different sections along 1.4 km lengths of the canal. The sections between 500 m and 1000 m had 2-4% of the losses.

The field data on water measurements at the beginning of the canals (canal head) were compared with the rated water releases from the control structures (Neyrtec modules). The data showed that the measured water flow at the canal head was in close agreement with the regulated flow from the control structures, the variation being +1.9% to -2.5%.

The Konni irrigation perimeter was designed for 85% water conveyance efficiency. The project was commissioned in 1980-81 and the water losses in the canals were still considered to be the same as at the beginning of the project. It was observed that the tail end water users had a genuine problem of a shortage of water supply, receiving water as late as four hours from its release at the head gate. Both

the primary and secondary canals were built as prefabricated slabs. A 15-km-length feeder canal from Zango and Mozangeé reservoirs delivers water into a compensation pool at Tyerassa. The feeder canal is constructed from poured concrete and as such, the magnitude of water losses is less. Likewise, the tertiary canals are also built from poured concrete.

In the Konni irrigation perimeter, losses of 11-13% in the primary and 10% in the secondary concrete-lined canals are high. The major losses were through the slab joints, cracks in the canals, and inadequate cleaning and maintenance. The water losses in the primary and the secondary canals at the beginning of the project were assumed to be 5% and are still considered as such.

The Konni perimeter has a network of 26 km of primary and 25 km of secondary canals. These canals carry about 0.25 million cubic meters of water daily. Even a small increase in conveyance efficiency will result in benefits to the water users and the project.

The results on water losses reported in this study brought out a need for compensation and additional water supply to water users for an equitable distribution of water and also a scope for further investigations to isolate sections causing excessive losses.

The management authority and the director of the perimeter agreed to augment water supply in the canals for end users.

3.6.6.7 Water Losses Due to Operational Management

Water losses in the storage reservoirs for a 2-4 week period during October-November were high to very high. This period represents the end of supplemental irrigations in the rainy season to the beginning of irrigations in the dry season. The magnitude of these losses depended on the total water stored. Management operational losses in the Konni irrigation perimeter are given in Table 3.6-8.

TABLE 3.6-8
MANAGEMENT OPERATIONAL LOSSES, KONNI IRRIGATION PERIMETER, ADER-DOUTCHI-MAGGIA VALLEY, NIGER

Year	Volume, thousands of m^3 stored		
	End of rainy season	Beginning of dry season	Water lost between seasons
1985	29,267	26,890	2,377
1986	29,313	26,932	2,381
1987	19,400	19,400	nil
1988	28,401	24,504	3,897
1989	28,911	28,911	nil
1990	17,000	14,160	2,840
1991	32,090	29,150	2,985
Mean			2,896

About one million cubic meters of water is used for one irrigation in the entire perimeter. There is a need to reduce these losses between the two irrigation seasons. This could be facilitated through 1) planting earlier in the dry season (by the first of November) and 2) releasing water in the perimeter just after harvest of the sorghum crop as a pre-irrigation and/or building up of soil moisture storage. This practice, as seen from data in Table 3.6-8, was practiced during 1987 and 1989.

3.6.6.8 Efficient Water Use Through Redesigned Rotational Water Supply System, Konni Irrigation Perimeter

The Konni perimeter is 2,440 ha and is divided into a number of farms, each being 0.75 ha; therefore, there are about 3,000 family farms. A rotation water supply system is said to be operational, but with respect to the method of water supply in the canal system, it amounted to a continuous water supply system because the rotation occurred only between three adjoining family farms. The prevailing water distribution system had inherent water management problems and resulted in excessive water losses. An analyses of the water supply in the perimeter showed that the water was running in the entire canal system in the perimeter, although only one-third of the farmers were entitled to use it on a given day. It took about three to four hours for the canal system to be full before releasing water for the farmers. There were problems with the farmers opening the sluice valves during this period. This problem was discussed with the director of the Konni irrigation perimeter, and collaborative efforts were made to redesign water allocation on a zone basis.

The object of this study was to find an efficient rotational water supply system without involving any structural changes in the supply system.

After considering the different options, the entire perimeter was divided into two zones, zone A and zone B.

Economy and efficiency of water use in the redesigned system is shown in Table 3.6-9. The data in the table demonstrate that there was a 50% economy in water use on a zone basis.

Each zone was irrigated for three days, compared to water supplied in the entire perimeter for six days. Economy in water use resulted from the fact that the water circulated in 60% of the canal system in zone A and 40% in zone B, compared to the entire system for the same number of days. With the zone basis, there was a more equitable distribution of water to the major advantage of the tail-end water users. The redesigned system also afforded ease of management operations for the authority. Average time taken for water from the supply source to reach the tail end of the system was reduced by about one hour.

The proposed zone approach was accepted by the water management authority and water is now distributed on the basis of zones.

3.6.7 Water Balance for 10 Different Regions in Niger

Potential evapotranspiration, minus effective rainfall per 10-day period, was established to work out a water balance for 10 different regions in Niger. These stations were Agadez, Birni N'Konni, Gaya, Maine Soroa, Maradi, N'Guigmi, Niamey, Tahoua, Tillabery, and Zinder. Data in Table 3.6-10 give the bearings of the stations and the number of years for which weather data were used for a given station.

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TABLE 3.6-9
ECONOMY IN WATER USE THROUGH REDESIGNED ROTATIONAL WATER SUPPLY SYSTEM, KONNI IRRIGATION PERIMETER, ADER-DOUTCHI-MAGGIA VALLEY, NIGER

Flow in zone A (primary canals A+D) =	4.7 m^3/sec
Flow in zone B (primary canals B+C) =	3.1 m^3sec
Case A: Using the existing system	
For one irrigation, duration of water release =	8 hrs.
Water released per day =	224,640 m^3
Water released per irrigation cycle (6 days) =	1,347,840 m^3
Case B: Using the zone basis	
For zone A:	
For one irrigation, duration of release =	8 hrs.
Water released per day =	135,360 m^3
Water released per irrigation cycle (3 days) =	406,080 m^3
For zone B:	
For one irrigation, duration of release =	8 hrs.
Water released per day =	89,280 m^3
Water released per irrigation cycle (3 days) =	267,840 m^3
Total water released for zones A and B =	673,920 m^3
Economy in water released on zonal basis =	673,920 m^3

TABLE 3.6-10
STATIONS USED FOR WATER BALANCE STUDIES IN NIGER

Station	Latitude (N°)	Longitude (E°)	Altitude (m)	Database	Missing years
1. Agadez	16 58	7 59	498	1921-90	84
2. Birni-Konni	13 48	5 15	272	1933-90	-
3. Gaya	11 59	3 30	160	1931-90	-
4. Maine Soroa	13 14	11 59	338	1936-90	-
5. Maradi	13 28	7 25	368	1931-90	75-78
6. N'Guigmi	14 15	13 07	286	1921-90	-
7. Niamey-ville	13 30	2 08	216	1905-90	-
8. Tahoua	14 12	1 27	209	1923-90	-
9. Tillabery	14 12	1 27	209	1923-90	-
10. Zinder	13 48	8 59	451	1905-90	75-78

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Probability analyses were completed for potential evapotranspiration (PE) and rainfall for all the stations, and values were established at 100%, 80%, 60% and 40% levels. Standard methods were used in probability analyses of weather data.

One typical analysis for the Maradi station is shown in Table 3.6-11.

A given probability level can be selected for calculation of crop water requirements and other studies. An 80% probability level for potential evapotranspiration and rainfall was selected for establishing water balance zones in Niger.

Effective rainfall was calculated from total rainfall as per the FAO empirical method (1974). This formula for calculation of effective rainfall is specially applicable when 80% probability level is selected. Effective rainfall is the part of the total rainfall which meets the crop water requirements. It does not include deep percolation, surface runoff and interception. As such the data on average rainfall is less useful. According to the formula,

Effective rainfall = 0.6 total rainfall- 10 for total rainfall less than 70 mm and
= 0.8 total rainfall - 25 for total rainfall more than 70 mm

Water balance for a given region was expressed as effective rainfall (ER) minus potential evapotranspiration. Based on these values, a deficit (minus) or surplus (plus) was worked out for a given station per 10-day period. Thirty-six maps were prepared for different regions in Niger. The details are presented in a separate report (Prashar *et al.*, 1992).

3.6.8 Water Quality in Niger with Special Reference to the Ader-Doutchi-Maggia Valley

In assessing water supply in irrigation projects, there is a need to have information, both on the quantity and the quality of irrigation water. Specific uses of water have different quality criteria. Water used in agriculture invariably has measurable quantity salts. The suitability of a given water for irrigation depends on the amount and type of salts present in the water.

Irrigation water quality refers to its intended use. Good quality irrigation water has the potential to allow maximum crop yield under good soil and management practices.

In the Ader-Doutchi-Maggia valley, as elsewhere in Niger, only limited references are found on the quality of water. These are in the Niger River basin. Elsewhere, quality references are made indicating that the water quality is good.

The main analytic source for detailed analyses of water in Niger is INRAN's soils laboratory in Niamey.

Investigations on irrigation water quality were carried out from January 1990 to February 1992. Water samples were collected from storage reservoirs, deep wells, and open wells from 11 different sites. These were in Maradi Goulbi, the Taraka Valley, the Ader-Doutchi-Maggia valley, and INRAN stations at Tarna and Konni. One-liter water samples were collected in plastic bottles and taken to INRAN's Soils Laboratory in Niamey.

TABLE 3.6-11
DECADAL VALUES OF POTENTIAL EVAPOTRANSPIRATION AND RAINFALL
AT DIFFERENT LEVELS OF PROBABILITY, MARADI, NIGER

Decade	Probability							
	40%		60%		80%		100%	
	PE	Rain	PE	Rain	PE	Rain	PE	Rain
1	44.10	0.00	49.90	0.00	53.92	0.00	58.00	0.00
2	46.48	0.00	49.90	0.00	58.26	0.00	71.10	0.00
3	54.98	0.00	60.68	0.00	65.38	0.00	78.90	0.00
4	53.12	0.00	57.04	0.00	65.26	0.00	76.50	0.00
5	54.68	0.00	58.68	0.00	68.94	0.00	82.40	0.00
6	50.02	0.00	54.90	0.00	60.46	0.00	79.20	0.00
7	59.06	0.00	64.40	0.00	76.58	0.00	91.80	0.00
8	59.62	0.00	67.04	0.00	76.78	0.00	97.10	0.00
9	68.16	0.00	77.58	0.00	83.16	0.00	101.20	5.50
10	62.98	0.00	72.94	0.00	77.94	0.00	88.00	5.50
11	65.10	0.00	68.10	0.00	71.10	0.00	92.00	7.40
12	65.80	0.00	69.80	0.00	76.20	1.88	94.00	37.00
13	63.04	0.00	68.26	0.26	71.90	5.64	90.70	29.50
14	65.32	0.00	69.78	1.30	74.94	5.32	87.40	44.00
15	70.06	2.96	76.06	11.96	78.64	25.16	80.00	48.40
16	62.22	5.36	67.18	11.28	69.72	20.46	76.80	47.40
17	62.90	19.56	66.60	29.46	69.46	43.84	105.00	86.60
18	58.02	13.44	61.22	30.80	64.76	45.60	71.20	71.50
19	54.92	29.16	60.18	35.54	62.76	48.62	65.00	119.00
20	50.82	47.78	55.60	59.60	60.10	75.24	67.90	117.80
21	53.08	53.40	57.26	77.16	59.46	98.34	64.30	176.30
22	47.14	50.00	49.76	69.02	52.12	92.28	56.70	105.80
23	44.86	44.68	46.94	68.62	[illegible].38	82.02	57.80	100.70
24	49.52	40.72	53.14	54.84	55.28	104.30	59.90	161.20
25	47.64	29.40	49.86	38.68	50.82	62.64	52.60	114.10
26	47.10	3.38	49.84	20.78	53.60	44.38	58.00	87.20
27	48.16	4.42	49.34	11.52	51.40	19.92	56.70	47.30

Decade	Probability							
	40%		60%		80%		100%	
	PE	Rain	PE	Rain	PE	Rain	PE	Rain
28	48.42	0.00	51.40	0.00	54.30	4.74	62.50	67.0
29	49.28	0.00	51.40	0.00	58.72	0.00	69.90	6.90
30	57.08	0.00	63.32	0.00	65.22	0.00	77.70	11.70
31	49.22	0.00	54.96	0.00	59.98	0.00	74.80	0.00
32	49.24	0.00	53.06	0.00	60.70	0.00	65.60	0.00
33	46.58	0.00	51.70	0.00	54.40	0.00	61.30	0.00
34	46.16	0.00	49.94	0.00	56.14	0.00	66.90	0.00
35	44.20	0.00	51.44	0.00	55.56	0.00	63.30	0.00
36	48.60	0.00	53.34	0.00	56.48	0.00	64.90	0.00

Analyses were made for pH, electrical conductance, Ca, Mg, K, Na, CO_3, HCO_3, Cl, and SO_4. Standard methods were used for analytical purposes. The suitability of irrigation water was considered in relation to the guidelines for interpretation of water quality given in FAO irrigation and drainage paper No. 29, 1976. The chemical analyses of water from the different sources studied in this project showed that the water from most sites was of excellent quality.

Electrical conductivity values of water were very low; 0.11 to 0.46 for storage reservoirs, 0.15 to 0.7 for deep wells, and 0.28 to 0.5 S m^{-1}. In general, the values were minimum in October and November.

The pH value varied from 6.8 to 8.0. The mean value was about 7.5. On the whole, sodium adsorption ratio (SAR) values were very low, less than 0.2 in all the samples. In general, the water quality was excellent for irrigation purposes and does not warrant any soil hazard through its continuous use.

However, analyses of water from deep wells at the Konni irrigation perimeter showed that the water was of a poor quality. The electrical conductivity of water was 1.6 S m^{-1}. This concentration indicated high to very high saline water, with a chance of sodium hazard.

Suitability of water for irrigation depends on its quality as well as the other factors, i.e., soil, evapotranspiration, and crops selected.

Irrigation water contains a considerable amount of salts in varying degrees, depending on the source of the water. This means that with every irrigation, a certain amount of salt is added to the soil. Salts can easily be leached from the soils, but at Konni, the soils are vertisols (clay content of 26-56%) at different depths. The permeability of soil is about 1 cm/hr. Below the 70 cm soil depth, there is a heavy concentration of gypsum. As such, internal drainage is very limited. The evapotranspiration is high, and there is no crop from March to June. Under these conditions, re-salinization continues to take place in the soil profile.

In 1990, soil profiles were studied at the Konni Research Station in irrigated and unirrigated areas. Salt concentration in the unirrigated area was at one meter depth, but there was a much higher concentration at the 75 cm depth in the irrigated area.

Considering irrigation water from deep wells at Konni with electrical conductivity of 1.6S m^{-1} and assuming that about 1,500 mm of water is applied per year, the amount of salt added to the soil will amount to about 15.4 t ha^{-1}. With limited to no leaching, it is calculated that salts added with water may accumulate in 50 cm soil depths and raise the salt content by 0.512% every year. At this rate, within three years the level of salinity in the surface soil will not permit cultivation of most crops. The water from the wells at Konni is not being used for irrigation.

3.6.9 Irrigation/Agronomy Studies

3.6.9.1 Intensity of Cropping in Perimeters

The cropping intensities envisaged in the design phases of the perimeters were 150% to 200%. This considered the first crop in the rainy season with supplemental irrigation and the second crop in the dry season with irrigation. The cropping records during the past six years showed that the maximum cropping intensity was 125% in the Konni irrigation perimeter. In other perimeters, it was less than 110%.

3.6.9.2 Water Requirements of Crops in the Maradi Region

Crop water requirements are a natural consequence of the environment under which the crops are grown. These requirements are defined as the depth of water required by a crop, or a diversified pattern of crops, to meet evapotranspiration during a given growing period. Data on water requirements of crops are essential in project planning, design, and operation, and to refine water supply schedules in the ongoing irrigation projects.

Ideally, crop water requirements need be based on sound field experiments. This method has constrains of time, resources, and necessary manpower. Invariably, data on water requirements of crops are applied under climatic and agronomic conditions which are quite different from those where they were originally developed. The data are also needed on very short notice. Attempts were made to develop a methodology which could be applied under wider soil and climatic conditions. After group consultation, the Food and Agriculture Organization of the United Nations (FAO) published FAO Paper No. 24, entitled "Crop Water Requirements." This document gives details on establishing water requirements of crops, water supply schedules, and project planning. Despite the general assumptions made in the paper, the methodology is very reasonable to establish water requirements of crops in different parts of the world.

The objectives of this project were to:

1. estimate water requirements of main crops in different regions in Niger from weather data, using the methodology given in the FAO Irrigation and Drainage paper No. 24,
2. compare the estimates of crop water requirements from weather data and those obtained from field investigations.

Using the water balance investigation presented in Section 3.6.7, water requirements of the wheat crop in Maradi were established. Estimates of water requirements from weather data were compared with actual field data. Estimated data were further used for field supply schedules.

The data used on wheat crop growth stages and soil conditions are shown in Table 3.6-12

TABLE 3.6-12
WHEAT CROP GROWTH STAGES AND SOIL CONDITIONS,
MARADI, NIGER

Phase	Init.	Dev.	Mid	Late	Total
Crop stage (days)	15	30	40	25	110
Crop coefficient (coeff.)	0.60---	---->	1.20	0.70	
Rooting depth (m)	0.30---	---->	1.00	1.00	
Depletion level (fract)	0.60---	---->	0.60	0.90	
Yield response F. (coeff.)	0.20	0.60	0.50	0.40	1.00

Utilizing the data in Table 3.6-12 the following were worked out:

1. evapotranspiration of wheat crop (ET crop),
2. irrigation requirements, and
3. irrigation requirements per 10-day period during the crop growing season.

The results are shown in Table 3.6-13.

TABLE 3.6-13
WHEAT CROP EVAPOTRANSPIRATION AND IRRIGATION REQUIREMENTS,
MARADI, NIGER

Month	Dec	Stage	Coeff	ET crop mm/day^{-1}	Tot. ETC mm/dec	Eff. Rain mm/dec	Irr. req. mm/day^{-1}	Tot. irr req. mm/dec
Nov	1	init	0.60	3.46	34.6	0.0	3.46	34.6
Nov	2	in/de	0.65	3.75	37.5	0.0	3.75	37.5
Nov	3	dev	0.80	4.54	45.4	0.0	4.54	45.4
Dec	1	dev	1.00	5.58	55.8	0.0	5.58	55.8
Dec	2	de/mi	1.15	6.31	63.1	0.0	6.31	63.1
Dec	3	mid	1.20	6.68	66.8	0.0	6.68	66.8
Jan	1	mid	1.20	6.71	67.1	0.0	6.71	67.1
Jan	2	mid	1.20	6.77	67.7	0.0	6.77	67.7
Jan	3	mi/lt	1.15	7.05	70.5	0.0	7.05	70.5
Feb	1	late	1.00	6.72	67.2	0.0	6.72	67.2
Feb	2	late	0.80	5.77	57.7	0.0	5.77	57.7
Total					633.2	0.0		633.2

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For the gravity irrigation system as practiced at Tarna 2 irrigation research station and in the Dijaratawa irrigation perimeter, an irrigation efficiency of 70% was used.

In this example of calculation of water requirements of wheat in Maradi, three timing options were selected:

1. irrigating at a fixed interval of one week
2. irrigating at a moisture depletion level of 40%, and
3. irrigating at a moisture depletion of 60%.

Water requirements for wheat were 607 mm, calculated from field determinations made previously.

The water requirements of wheat determined from field studies at the Tarna 2 irrigation research station during 1990-91 and those calculated from weather data are shown in Table 3.6-14.

The values of wheat water requirements from field determination at Tarna 2 irrigation research station and those calculated for irrigating at 40% and 60% soil moisture depletion levels were very close.

TABLE 3.6-14
WATER REQUIREMENTS OF WHEAT CROP AT MARADI
FROM FIELD DETERMINATIONS
AND THOSE CALCULATED FROM WEATHER DATA

Field determinations:	
1990-91	607 mm
1991-92	612 mm
Estimated from weather data with an option of:	
Irrigating at a weekly interval	630 mm
Irrigating at 40% moisture depletion level	610 mm
Irrigating at 60% moisture depletion level	568 mm

3.6.9.3 Tarna 2 Irrigation Research Station

The Tarna 2 irrigation research station is a new name for the old IRAT station SEHA which is now a part of the Tarna Research Station at Maradi. SEHA was a center of major irrigation research from 1963 to 1973, but was abandoned afterwards. The present development program centered around establishing Tarna 2 as a principal national irrigation research station in Niger, with proper records for each block, a well-defined cropping pattern, and a cropping schedule.

Tarna 2 has a total surface area of 15 hectares and is well fenced. The station has one deep well for irrigation, two power generators, two open wells, office buildings, and a water reservoir. There are 30 2m x 2m x 1m drainage-type lysimeters for detailed investigations on evapotranspiration of crops. There is a flood protection dike on the southern end of the station. As the area has not been cultivated since 1973, the station was covered with local grasses and Acacia trees.

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The 15-ha station area was divided into 12 blocks, each block being 1.05 ha (Figure 3.6-5). Blocks numbers 1, 2, 3, 7, 8, and 9 were cleared in 1991 and used for experiments.

On the whole, the soils at the station are fertile. The organic carbon and nitrogen contents were 0.68% and 0.37%. Available phosphorus content was very high, 22.5 ppm.

Crop yields during 1990 to 1992 were very high (wheat 3.0 t ha^{-1}, onions 32.5 t ha^{-1}). The excellent crop stands and yields were a good demonstration for the farmers in the Dijaratawa irrigation perimeter.

The layout design and database system were developed for the whole station so that long-term programs can continue with all the required details on cropping patterns, fertilizer use, crop rotations, and water use. A three-year crop rotation, i.e., cotton, cereal (sorghum, wheat), legumes (cowpea, groundnut), will be followed on blocks 7 to 12. Other blocks are reserved for horticultural tree crops (citrus, mangoes, guava), vegetables, and forages. An area along the flood protection dike is also reserved for agroforestry.

The station needs the development of an irrigation system to increase 15 ha under irrigation. At present, about 1.5 ha can be irrigated during the dry season and about 4.5 ha in the rainy season.

There is a need to have two more deep wells and the irrigation distribution system. This will assure irrigation of the whole station. A sum of about $100,000 is needed for that purpose.

The present facility of irrigating 1.5 ha in the dry season can be doubled by importing pipe fittings, costing about $9,000, and using the available pipes at the Tarna station.

Field Crop Responses to Irrigation and Fertilization

In 1990 and 1991, field studies on irrigation responses to sorghum, wheat, onions, and groundnut were conducted at the Tarna 2 irrigation research station in Maradi. Four to six lysimeters were used for each crop. Alfalfa was used as a reference crop for determining crop evapotranspiration. The soil texture at the experimental site was loam to clay loam. The field moisture capacity was found to be 28% and the wilting point 11.5%. Irrigation water was conveyed to the field through aluminum pipes and delivered at the plot intake. The station is yet to have elaborate arrangements to monitor the depth of water applied per irrigation. However, determinations were made on the amount of water applied per plot through water flow and time records per plot. The average depth per irrigation was 6-7 cm. Soil moisture determinations were made before each irrigation. Soil moisture samples were collected from 0-15 cm, 15-30 cm, 30-60 cm, 61-90 cm and 90-120 cm depths. These data were used to determine the amount of water retained in the soil profile. Water use efficiency referred to in this report is the ratio of dry matter produced per unit quantity of water.

Wheat irrigation and fertilizer experiment

Irrigation and fertilizer responses of the wheat variety Pranquel were studied in 1990-91 and 1991-92 in an experiment comprising three irrigation intervals and four nitrogen levels. All the treatment combinations were accommodated in a factorial experiment in four replications. The crop was planted in rows on December 4, 1990. The seed was dropped uniformly by hand in 30-cm rows. A seed rate of 100 kg/ha was used. Irrigation intervals were every week, after two weeks, and after three weeks. Four common irrigations were applied to all the plots before starting differential irrigations. In 1991-92, irrigations were scheduled when 40%, 60% and 80% of the available moisture was depleted at the 50 cm soil depth. Four nitrogen levels consisted of: no fertilizer, and 40, 80, and 120 kg nitrogen per hectare

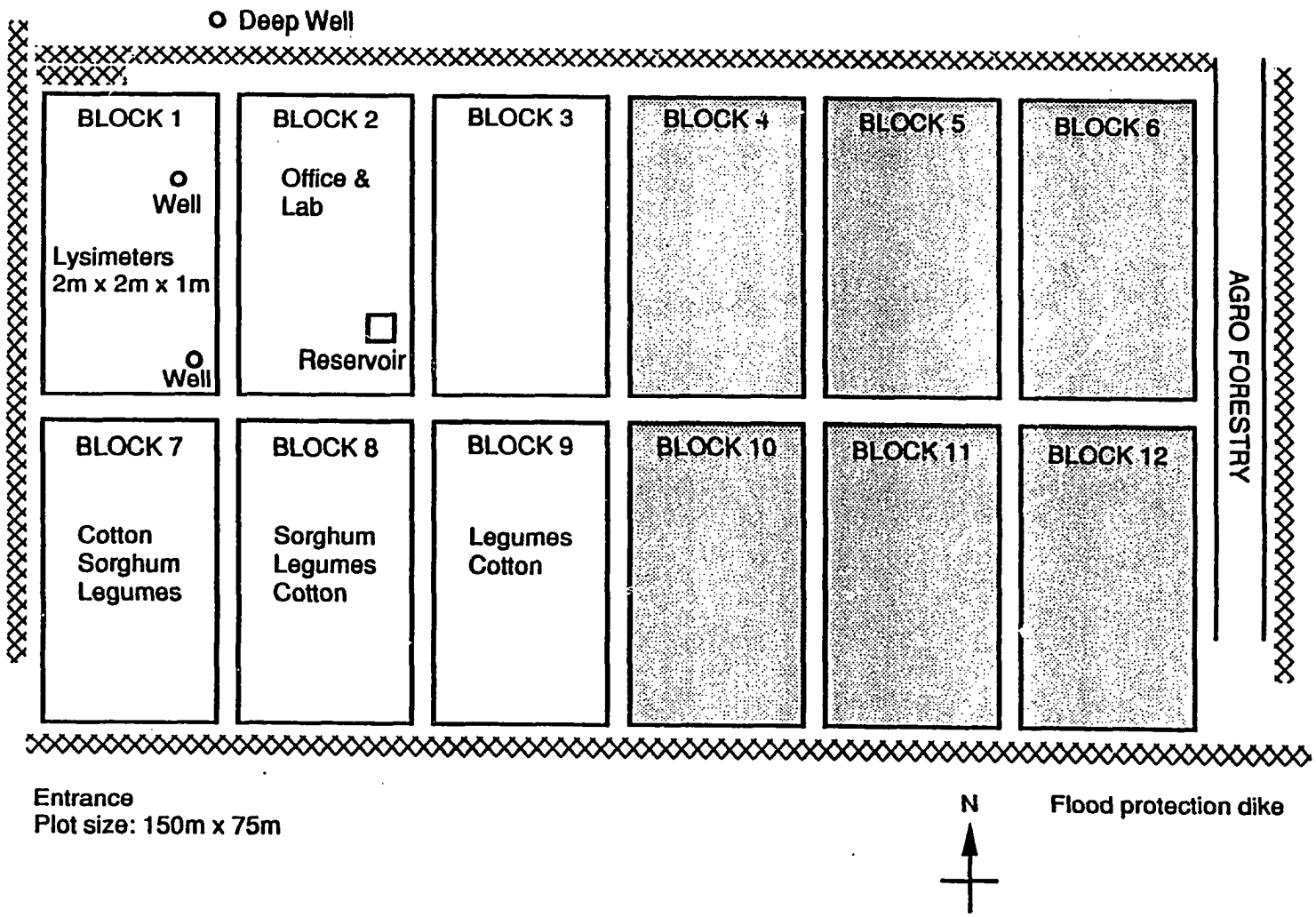

FIGURE 3.6-5. TARNA 2 IRRIGATION RESEARCH STATION, MARADI, NIGER.

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applied as urea. Half the fertilizer application was applied at planting with a second application 45 days after planting. Harvesting was done by hand. Thrashing of each plot was done through a small power thrasher. Wheat grain yield under different treatments is shown in Table 3.6-15.

TABLE 3.6-15
WHEAT[1] YIELD (t ha^{-1}) UNDER DIFFERENT IRRIGATION AND NITROGEN FERTILIZER LEVELS, TARNA 2 IRRIGATION RESEARCH STATION, MARADI, 1990-91

Irrigation frequency	Nitrogen (kg N/ha)[2]				Average yield/ t ha^{-1}
	None	40	80	120	
One week	1.50	1.65	1.82	1.40	1.59
Two weeks	1.00	0.95	0.95	1.06	0.99
Three weeks	0.73	1.03	0.73	0.62	0.78
Mean	1.08	1.21	1.17	1.03	LSD 5% 0.18

[1]Variety - Pranquel, planted on 12/4/90, harvested on 3/4/91.
[2]Nitrogen applied as Urea.

In 1990-91, application of more frequent irrigations on weekly intervals significantly increased the wheat grain yield over delayed irrigations at a two- or three-week interval. The wheat crop was planted late in the first week of December in 1990, and the planting date was apparently responsible for the reduced yields.

Responses to different levels of nitrogen did not show significant differences in grain yield. Irrigation and fertilizer interaction was also not significant.

In 1991-92, a similar experiment was repeated, but planting was done in the first week of November 1991. Irrigations were scheduled on a soil moisture regime when the soil moisture at the 50 cm soil depth was depleted by 40%, 60% and 80% during the crop growing season. The interval of irrigation in number of days ranged from 4-7, 6-9, and 10-12 days for the three irrigation regimes, respectively. Three common irrigations were given to all the plots before starting the differential irrigations. The results are presented in Table 3.6-16.

The mean grain yield was 3.01 t ha^{-1}. This was almost three times the yield compared with the previous year's experiment. The main factor was the timely planting in November, compared to the later planting in December in the preceding year.

Application of irrigations at 4-7 and 6-9 days during the wheat growing season gave significantly higher grain yield, compared with irrigations at a 10-12 day interval.

Irrigation and nitrogen interaction was significant. The wheat yield was highest with more frequent irrigations, but a high level of production could be maintained with nitrogen applications at 7-9 and 10-12 day intervals, with higher levels of nitrogen. Main effects of nitrogen fertilizer did not show significant differences in wheat grain yield.

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TABLE 3.6-16
WHEAT[1] GRAIN YIELD (t ha^{-1})
UNDER DIFFERENT IRRIGATION AND NITROGEN FERTILIZER LEVELS,
TARNA 2, IRRIGATION RESEARCH STATION, MARADI, 1991-92

Irrigation frequency	Nitrogen (kg N/ha)[2]				Average yield/ t ha^{-1}
	None	40	80	120	
4-7 days	3.48	3.62	3.27	2.86	3.31
6-9 days	2.86	2.85	3.50	3.60	3.18
10-12 days	2.57	2.33	2.89	2.98	2.69
Mean	2.97	3.15	3.27	2.86	LSD 5% 0.31

[1]Variety - Pranquel, planted on 11/7/91, harvested on 3/12/92.
[2]Nitrogen applied as Urea.

Data in Tables 3.6-17 and 3.6-18 show the amount of water applied under different irrigation treatments in 1990-91 and 1991-92.

The data in Table 3.6-18 show that the water use efficiency in 1991-92 was much higher as compared with the results in 1990-91. Grain yield was much higher though the amount of water applied was not very high.

TABLE 3.6-17
WHEAT[3] WATER USE UNDER DIFFERENT IRRIGATION TREATMENTS, 1990-91,
TARNA 2, IRRIGATION RESEARCH STATION, MARADI, NIGER

Irrigation frequency	No. of irrigations	Amount of water applied (m^3)	Average Grain yield (t ha^{-1})	Water use efficiency
One week	9	6075	1.59	0.262
Two weeks	6	4600	0.99	0.215
Three weeks	5	3875	0.78	0.201

[3]Variety - Pranquel, planted on 12/3/90, harvested on 3/4/91.

Observations on wheat planting dates

In 1991-92, observations were made on planting date and the yield of variety Pranquel in non-replicated trials at the Tarna 2 irrigation station. Plantings were made in the first weeks of November, December and January.

The results (Table 3.6-19) showed that the grain yield (3.3 t ha^{-1} planted in November and 1.30 t ha^{-1} planted in December) was highly affected by planting date. The observation indicated that wheat needed

TABLE 3.6-18
WHEAT[1] WATER USE UNDER DIFFERENT IRRIGATION TREATMENTS, 1991-92, TARNA 2, IRRIGATION RESEARCH STATION, MARADI, NIGER

Irrigation at depletion of 50 cm soil by:	No. of irrigations	Amount of water applied (m^3)	Average Grain yield ($t\ ha^{-1}$)	Water use efficiency
40% (4-7 days)	14	7075	3.31	0.468
60% (7-9 days)	10	6400	3.18	0.497
80% (10-12 days)	8	4875	2.69	0.552

[1]Variety - Pranquel, planted on 11/7/91, harvested on 3/12/92.

TABLE 3.6-19
WHEAT[2] GRAIN YIELD FOR DIFFERENT PLANTING DATES[3], TARNA 2 IRRIGATION RESEARCH STATION, MARADI, NIGER

Planting date	No. of irrigations applied	Harvest date	Grain yield ($t\ ha^{-1}$)
11/4/91	14	10/3/92	3.31
12/7/91	10	20/3/92	1.30
1/8/92	8	—	no grain

[2]Variety - Pranquel.
[3]Nonreplicated trial.

be planted in early November. This was also confirmed from results of investigations in 1990-91 and 1991-92 experiments.

Wheat varietal responses under irrigation

In a separate experiment, an evaluation was made of three wheat varieties, Pranquel, Sette Cerrose, and Kalvik RS 4. These varieties were accommodated in a randomized block in six replications.

Under the conditions of the experiment, there was no significant difference in the grain yield of Pranquel, Sette Cerrose, and Kalvik RS4. The mean grain yield was 1.45 t/ha. The yield was rather low, but the crop was planted in the last week of November 1990 and harvested during the second week of February 1991. The wheat straw yield also did not show significant difference in yield for different varieties.

During 1991-92, there was also no significant difference in the grain yield of three varieties. However, the absolute yield level was high. The mean grain yield was 2.98 t ha^{-1}. This was due to planting early in the first week of November.

The performance of wheat varieties was also evaluated at INRAN's Konni station and from the farmers' fields in the Konni irrigation perimeter. Data were collected on the growing period, plant height, effective number of tillers per plant at harvest, grain weight per ear, 1,000 grain weight, and grain yield. The results are presented in Table 3.6-20.

TABLE 3.6-20
PERFORMANCE OF WHEAT VARIETIES IN 1990-91
UNDER IRRIGATION AT INRAN'S MARADI AND KONNI STATIONS, NIGER

Variety	Growing period (days)	Plant height (cm)	Effective no. of tillers	1,000-grain weight (g)	Average yield (t ha^{-1})
Florance	90	135	2.93	46.5	2.69
Sette cerrose	85	90	2.65	45.7	2.53
Maxipack	95	85	2.91	42.5	2.33
Super X	94	80	1.89	37.5	1.99
Kalyan	92	80	1.93	41.2	2.50
Pranquel	90	135	1.85	42.3	2.56
Kalvik RS4	82	75	3.15	43.6	2.67

Observations on the above varieties are the means of six different sites. Varieties Pranquel, Sette Cerrose, and Kalvik RS4 were planted during the last week of November, which was late. From the viewpoint of acceptability to the users, variety Kalvik RS 4 was highly attractive because of its bold size and the light brown color of the grain.

Onion irrigation and variety experiment

In 1990-91 and 1991-92, the response of three onion varieties to three levels of irrigation were studied in a replicated factorial experiment (N=3). Six-week-old seedlings were transplanted in rows 20 cm apart; the plant-to-plant distance was 15 cm. The varieties included in the experiment were Galmi violet, Galmi white, and Soumarana violet. Irrigation regimes were comprised of irrigating after 4, 8, and 12 days. Eight common irrigations were given before starting differential irrigations. Samples were collected from each plot for volume weight relationship of bulbs under different treatments.

Data in Table 3.6-21 show onion yields under different irrigation levels.

Onion yield was highly affected by the irrigation interval. Irrigating at a four-day interval increased the onion yield significantly over delayed irrigations. The mean yield from plots receiving frequent irrigations was 32.5 t ha^{-1} (Table 3.6-22).

Among the three onion varieties, Galmi violet, Galmi white and Soumarana violet, there was no significant difference in the crop yield. The mean yield for the three varieties was 22.8 t/ha. From the market acceptability point of view, Galmi violet was preferred over other two varieties.

Onion water use under different irrigation treatments is shown in Table 3.6-22.

TABLE 3.6-21
YIELD (t ha^{-1}) OF THREE VARIETIES OF ONION SUBJECTED TO FOUR DIFFERENT FREQUENCIES OF IRRIGATION, TARNA 2 IRRIGATION RESEARCH STATION, MARADI, NIGER

Irrigation frequency	Variety and average yield		
	Galmi violet	Galmi white	Soumarana violet
Four days	32.95	29.64	34.88
Eight days	19.67	20.17	22.03
Twelve days	16.08	17.52	15.70
Mean	22.90	22.44	24.20

TABLE 3.6-22
ONION WATER USE UNDER DIFFERENT IRRIGATION TREATMENTS, TARNA 2 IRRIGATION RESEARCH STATION, MARADI, NIGER

Irrigation frequency	No. of irrigations	Amount of water applied (m^3)	Onion yield (t ha^{-1})	Bulb volume/weight ratio
Four days	26	17,550	32.49	3.52
Eight days	15	10,500	20.62	3.80
Twelve days	11	7,975	16.43	4.18
				LSD 5% 0.5

Application of 17,550 cubic meters of water in 26 irrigations increased onion yield significantly over fewer irrigations.

The bulb volume:weight relationship under different irrigation treatments showed significant differences. This relationship was low with more frequent irrigations. The mean volume:weight ratio was 3.43. Average weight per bulb was 235 grams.

Sorghum responses to irrigation and fertilizer

The response of sorghum variety Mota Maradi was studied in relation to irrigation and nitrogen and phosphorous treatments in a balanced group of sets of a 3^3 factorial experiment in blocks of nine plots, each replicated twice. As per Yates' (1937) notation, the 'Y' group was confounded. There were two replications. The experiment was carried out in the rainy season of 1991. Supplemental irrigations were scheduled when the available soil moisture at the 50 cm of soil depth was depleted by 40%, 60% and 80%. Moisture depletion levels were interpreted in the number of days between irrigations every month. Two common irrigations were applied to all the plots for crop establishment. Nitrogen treatments were 0, 60, and 120 kg N/ha. Phosphorous treatments were 0, 40, and 80 kg P/ha. All treatments of phosphorus

were applied at planting. Nitrogen was applied in two doses, one at planting and the second five weeks after planting.

The main effects of irrigation, nitrogen, and phosphorus were not significant. Among the two way-interactions, there was a strong combined effect of nitrogen and phosphorus, but the interaction fell short of significance level.

Application of five to eight supplemental irrigations to the sorghum crop did not show significant differences in grain yield. The mean yield was 0.975 t ha^{-1}. The rainfall during the sorghum growing season was 495 mm and was well distributed during July, August, and September. The water use efficiency was high, with less number of irrigations.

Groundnut responses to irrigation and fertilizer

Irrigation and phosphorus responses to groundnut variety 55-437 were studied during the 1991 rainy season. Three irrigation levels and four phosphorus levels were accommodated in a factorial experiment in four replications. Irrigations were scheduled when the available soil moisture at the one meter depth of soil was depleted by 40%, 60% and 80%. Four common irrigations were applied to all the plots for crop establishment before considering differential irrigations. Phosphorus levels were comprised of 0, 40, 80, and 120 kg P/ha. All the fertilizer treatments were applied at planting. A basal dose of 20 Kg N/ha was applied to all the plots. Plot-to-plot yield was registered separately. Treatment effects were observed on the groundnut kernel yield, shelling percentage, and oil content.

Under the conditions of the experiment, there was no difference in the groundnut kernel yield, both under the irrigation and the fertilizer levels. The coefficient of variation was 18.3%.

The rainfall during the groundnut growing season was 495 mm and was fairly well distributed; consequently, the irrigation responses were masked. The experimental site had been fallow for over 17 years and, as such, there were no fertilizer responses. Mean kernel yield was 1.03 t ha^{-1}. There was no significant difference in the shelling percentage under different irrigation and phosphorus levels. Mean shelling percentage was 59.4 per cent.

The per cent of oil produced under different irrigation and phosphorus levels was not significant. Mean oil content was 48.5.

Alfalfa responses to irrigation

Alfalfa was used as a reference crop in the lysimeters. In the buffer area around the lysimeters, alfalfa response to irrigation was studied. Alfalfa seed, variety Agadez, was dropped uniformly by hand 30 cm apart in rows. Three irrigation levels were after 4, 8, and 12 days. Five common irrigations were applied to all the plots before starting differential irrigations. The first cutting of alfalfa was made about 90 days after planting. Subsequent cuttings were made at 25-day intervals. Dry matter content of the alfalfa plants was determined at each cutting. The results are presented in Table 3.6-23.

The first cutting of hay gave a higher yield of fresh and dry weights than the second and third cuttings. There was a tendency for the yields to taper off with each cutting.

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TABLE 3.6-23
ALFALFA YIELD (t ha^{-1}) UNDER DIFFERENT IRRIGATION TREATMENTS,
TARNA 2 IRRIGATION RESEARCH STATION, MARADI, NIGER

Frequency of irrigation	Number of cuttings/days after planting					
	1st - 90		2nd - 115		3rd - 138	
	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.
Four days	51.2	4.1	43.6	4.01	39.8	3.7
Eight days	54.5	4.8	44.6	3.92	36.6	3.03
Twelve days	39.8	3.30	35.7	3.00	32.8	2.66
LSD 5%	5.67	0.81	2.51	0.26	3.75	0.76

Application of irrigation after four and eight days resulted in significantly higher fresh and dry weight yield than watering after 12 days. Total production and water used under each irrigation treatment is given in Table 3.6-24.

TABLE 3.6-24
ALFALFA WATER USE UNDER DIFFERENT IRRIGATION TREATMENTS,
TARNA 2 IRRIGATION RESEARCH STATION, MARADI, NIGER

Frequency of irrigations	No. of irrigations	Amount of water applied (m^3)	Fresh weight (t ha^{-1})	Dry weight (t ha^{-1})	Water use efficiency
Four days	35	23,625	134.5	12.47	0.528
Eight days	18	13,600	135.7	11.94	0.878
Twelve days	12	10,800	108.3	8.88	0.822

Application of irrigations after eight days gave the highest dry matter production per unit quantity of water. The water use efficiency was 0.88.

3.6.9.4 Drought and Millet Yield Relationship

In the Sudano-Sahelian region, crop production is limited by too little rain and stored soil moisture. The only rainy season is from late June to mid September, with an annual rainfall of 200 mm (18°N latitude) to about 1,200 mm (12°N latitude). The rainfall over the years has shown marked fluctuations, including severe drought conditions in 1904, 1909, 1916, 1974, and 1984. Excluding these atypical years, crop production is highly affected with variations within the seasonal rainfall.

The relative uncertainty of successful crop production without special adaptive land and water use is the outstanding characteristic of the Sudano-Sahelian region in Niger. More than 90% of the cultivated area in Niger is rainfed. This area lies south of the 350 mm isohyet and extends from the borders with

Burkina Faso and Mali in the southwest corner of the country in a band of about 200 to 250 kilometers width to the Chadian border on the east. Within this zone, 65% of the cultivated area lies in the 500-800 mm rainfall isohyet. Because of the erratic rainfall pattern in time and space, food production in the country is low, especially in years with low rainfall when massive food aid is needed.

The objectives of these particular studies were to determine:

1. effectiveness of rainfall with different probabilities on production of millet and sorghum,
2. relationship between rainfall in the season and millet and sorghum crop yields,
3. evapotranspiration of millet and sorghum under different moisture regimes.

In 1990 and 1991, drought and millet yield relations were studied in thirty 2mx2mx1m drainage-type lysimeters. The design for the experiment was suggested by Drs. David. B. Marx and Walter W. Stroup, Department of Biometry, University of Nebraska, Lincoln. Twenty-nine treatment combinations, comprised of three levels of rainfall probabilities (normal, 60% and 40% of normal), and three different periods (July 1-15, July 16-31, and August 1-15) were used. Lysimeter number 30 was a control, providing drought and yield relationship for the current season rainfall.

The lysimeter area was covered with plastic sheet and soil, leaving space for plants to pass through. Different rainfall probabilities were simulated by applying the exact predetermined quantity of irrigation water under the plastic cover. Care was taken to assure that water was applied uniformly. Timing of application of water during the three periods was selected in relation to the generalized rainfall characteristics for Maradi (Sivakumar *et al.*, 1992). Table 3.6-25 provides a summary of generalized characteristics of annual daily rainfall.

TABLE 3.6-25
GENERALIZED CHARACTERISTICS OF DAILY RAINFALL
AT MARADI, NIGER (SIVAKUMAR *ET AL.*, 1992)

Month	No. of rainy days	Amount of rain/rainy day	Average interval between rainy days
January	0	0.0	-
February	0	0.0	-
March	0	0.0	-
April	1	4.0	19.4
May	3	9.0	16.6
June	6	10.0	6.1
July	10	15.3	2.4
August	13	17.2	1.6
September	8	11.9	5.1
October	1	10.0	20.1
November	0	0.0	-
December	0	0.0	-

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Millet (variety CIVT) was planted on June 22 and harvested on September 26, 1990. All 30 lysimeters had a buffer area of 1.4 hectares. Detailed records were maintained on (1) water balance of each lysimeter, (2) growth and development of millet crop, (3) soil moisture determination through neutron probe access tubes, and (4) post-harvest measurements, i.e., yield per lysimeter/per plant, number of total and grain bearing heads, grain weight per ear, and the plant height. These investigations were carried out in collaboration with the NAARP dryland agronomist.

Analyses of grain yield per plant showed that there was no significant difference under the treatments tried in the experiment. From a practical point of view, the results were significant because even with 40% of the normal rainfall in the Maradi area in each of the periods, i.e., July 1-15, July 16-31, and August 1-15, the millet yield was not reduced. The experiment was run under controlled conditions, and it was expected that the results were not likely to be different if rerun with the same treatments. The soil moisture stress experienced by the millet crop was not sufficient to result in a reduction in crop yield. As for the 1991 rerun of the experiment, the probability level of rainfall was reduced to 16% to bring about a high soil moisture stress during the millet growth period.

There were marked differences in grain yield per plant under different treatments. However, the statistical analyses of data were not yet available for presentation in this report.

3.6.9.5 Changes in Soil Fertility

The soils at the Tarna 2 station were reported to have deteriorated from 1963 to 1973. Consequently, the research station was abandoned. A survey of the farm land use in 1990 showed that some blocks were cultivated in sorghum from 1973 to 1984. The cultivated area was limited to blocks demarcated by the old irrigation canals and pipe layout. On the whole, the area was overgrown with a combination of either local grasses or *Acacia albida*.

Areas were identified with continuous grass fallow and fallow for four, six, and eight years. Just outside the farm fenced area, similar soils had less intensive cropping since 1973. Areas were also characterized by *Acacia albida* for four, six, eight, and 12 years.

Considering the available soil analyses data of 1973 as the base, it was planned to investigate the following:

1. improvement in the soil physical and chemical characteristics, and
2. movement of nutrients within the soil profile, especially that of phosphorus.

Investigations were planned to be studied under the following treatments:

a. Under grass fallow:
   1. Control - soil analyses of 1973.
   2. plots under continuous cropping outside the farm area
   3. uncultivated grass fallow since 1988
   4. uncultivated grass fallow since 1986
   5. uncultivated grass fallow since 1984
   6. uncultivated grass fallow since 1973.

b. Under Acacia albida:
   1. Control - soil analyses of 1973

2. uncultivated fallow since 1973
3. area under four years of *Acacia albida*
4. area outside the canopy of 4-year-old *Acacia albida*
5. area under 6 years of *Acacia albida*
6. area outside the canopy of 6-year-old *Acacia albida*
7. area under 8 years of *Acacia albida*
8. area outside canopy of 8-year-old *Acacia albida.*

Ten soil profiles were studied. About 500 soil samples were collected under different treatments referred to above. Soil samples were taken from 0-15, 15-30, 30-60, 60-90, and 90-120 cm depths. These samples were analyzed in the Soils Laboratory in Niamey.

A detailed report is being prepared by the head of the INRAN Soils Laboratory. The report will highlight the dynamics in soil fertility under different fallow systems. Data were obtained for total nitrogen, total organic carbon, and available phosphorus concentrations at the 15 cm soil depth for land under continuous cropping, grass fallow for six years, and that fallowed under *Acacia albida*.

The data showed that there was no measurable difference in the total nitrogen and organic matter content under the three cropping systems, but the phosphorus content was about six times higher under *Acacia albida*, as compared with the area under intensive cropping.

The mean electrical conductivity values of 400 soil samples was less 0.95 S m^{-1}, thus indicating that there was a soil salinity hazard at the station.

3.6.9.6 Water Management Dynamics and Enhanced Wheat Production, Konni Irrigation Perimeter

As mentioned above, the rainfall during 1990 was about 60% the normal and so the total water stored in reservoirs was about 29 million cubic meters (M m^3), as against a normal storage of 42M m^3. After accounting for supplemental irrigations for cotton and sorghum, about 15M m^3 of water was left for irrigation during the dry season (November to February) for the wheat crop.

Adhering to the established water supply schedules, the Director of the Konni irrigation perimeter estimated that 250 ha could be planted to wheat, but due to nonavailability of water from January onward, the total production may be a maximum of 50 tons.

INRAN proposed a new water supply schedule and discussed it with the water management authority. This new schedule provided irrigation for a maximum of 368 ha, with an anticipated production of 800 tons in the perimeter. The proposed schedule was accepted and followed in the perimeter.

At the end of the wheat growing season in March 1991, the Director of the perimeter confirmed the following: 1) about 1,200 peasants were benefitted; 2) a total of 359 hectares were cultivated; and 3) the wheat production in the perimeter was 937 tons.

3.6.9.7 Water Balance Method of Irrigation for Sorghum at the Ibohamane Irrigation Perimeter

In 1991, a water balance method for irrigation was followed in the Ibohamane irrigation perimeter. Irrigations were scheduled when 60 mm of the soil moisture was used from the soil. The effective rainfall was considered as follows:

Total rainfall (mm)	Effective rainfall (%)
1-10	nil
10-20	100
20-40	90
40-60	80
60-80	70
80 and above	50

The sorghum crop growing season was divided into stages in relation with the number of days after planting. The rate of water use by crop was expressed per five-day period. Data in Table 3.6-26 show the crop stages, duration of the stage, and water use.

TABLE 3.6-26
SORGHUM STAGES OF GROWTH AND RATE OF WATER USE, IBOHAMANE IRRIGATION PERIMETER, IBOHAMANE, NIGER

Crop stage	No. of days after planting	Water use/5 days (mm)
1st	1-20	15
2nd	21-40	20
3rd	41-100	30

A typical water budget sheet for scheduling irrigation for the sorghum crop during 1991 is shown in Table 3.6-27.

The system maintained a record of accumulated evapotranspiration and useable water depletion. This can be adjusted with more precise information on evapotranspiration, effective rainfall, and useable available water. By following the water budget system, seven irrigations were applied to the sorghum crop during the entire growing season. The sorghum yield was 1.31 t/ha.

The water balance method of irrigation permits irrigation scheduling based on plant water needs at different stages of crop growth, against the arbitrary fixed intervals during the crop growing season.

TABLE 3.6-27
WATER BUDGET SHEET FOR SCHEDULING IRRIGATIONS,
IBOHAMANE IRRIGATION PERIMETER, IBOHAMANE, NIGER

Period	Stage of crop growth, days	Available soil moisture, mm	Irrigation, mm	Rainfall, mm	Crop E.T.	Water balance
5/25	-	39.0	0	0	0	39.0
5/26-30	1-5	39.0	0	58.4	15	82.4
5/31-6/4	6-10	60.0	0	0	15	45.0
6/5-9	11-15	45.0	0	0	15	30.0
6/10-14	16-20	30.0	0	17.0	15	32.0
6/15-19	21-25	32.0	0	12.5	20	24.5
6/20-24	26-30	24.5	0	0	20	4.5
6/25-29	31-35	4.5	50	0	20	34.5
6/30-7/4	36-40	34.5	0	0	20	14.5
7/5-9	41-45	14.5	50	0	30	34.5
7/10-14	46-50	34.5	0	15.4	30	19.9
7/15-19	51-55	19.9	50	0	30	39.9
7/20-24	56-60	39.9	0	0	30	9.9
7/25-29	61-65	9.9	0	42.3	30	22.2
7/30-8/3	66-70	22.2	0	17.0	30	9.2
8/4-8	71-75	9.2	0	18.6	30	37.3
8/9-13	76-80	37.3	0	18.6	30	25.9
8/14-18	81-85	25.9	0	60.0	30	55.9
8/19-23	86-90	55.9	0	22.5	30	48.4
8/24-28	91-95	48.5	0	0	30	18.4
8/29-9/2	96-100	18.4	0	31.6	30	20.0
9/3-7	101-105	20.0	0	0	30	0
9/8-12	106-110	0	30	20.3	30	0

4 DEVELOPMENT OF FUNCTIONAL LINKAGES BETWEEN INRAN, EXTENSION, AND OTHER AGRICULTURAL SERVICES

Throughout the period of the assignment of the NAARP Research/Extension Specialist, only one INRAN staff member was allocated to the Liaison Unit. The counterpart, Ousseini Moumouni, a seed production specialist trained at the University of Missouri, had worked within the Unit for a number of years. In December 1989, he was transferred to the Ministry of Agriculture as Assistant Secretary General to the Minister. A second counterpart, Dine Sadikou, who was to complete his studies at Montpellier at the end of 1990, was identified. He returned to Niger in April 1990 to complete his field work and finally began full-time work in INRAN in November 1990. In February 1991, Dine Sadikou was also transferred to another post. By May 1991, an internal INRAN decision had been reached to appoint three people to the Unit, one head (Level A1) and two support staff (Level B1). None of these people were in place before the RELU specialist left her assignment in Niamey, and only two of the three had been identified. The head of the Unit was to be a former head of the Department of Socio-Economic Studies at the Institute for Rural Development (IPDR) at Kolo.

Under the APS (Agricultural Production Support) project, a second Liaison Unit, also with one staff member, was established within the extension services of the Ministry of Agriculture. During the first year of the RELU program, attempts were made to establish strong links with this Unit in order to enlarge the number of direct counterparts with full-time liaison responsibilities. However, this liaison person largely assumed the role of a participant in meetings and missions etc. rather than that of an active facilitator and coordinator of liaison activities. In addition, with the introduction of the PRSAA Project (*Programme de Renforcement des services d'Appui à l'Agriculture)* within the extension services in 1988, his responsibilities were enlarged.

Under NAARP, it was assumed that this Research Extension Liaison Unit would play a role in facilitating research-extension links with INRAN. In fact, the initiative and responsibility for these linkages, other than participation at meetings, remained within INRAN. It was proposed that both liaison units function as a single unit, with joint work programs. However, this will only be possible if personnel are allocated full time to each unit.

Given the lack of direct counterparts in both liaison units during this period of technical assistance (1988-91), a strategy was developed to widen the involvement of other INRAN and non-INRAN staff in liaison activities. In particular, the participation of the heads of INRAN substations was facilitated, and, in 1991, it was proposed that two of these people be assigned as the B1 staff to the INRAN Unit. On the side of extension, a number of agriculture department *arrondissement* heads have participated in liaison training activities.

4.1 Institutional/Departmental Linkages

The RELU Specialist was expected to work especially closely with INRAN's Department of Rural Economy (DECOR), the Documentation Center, the irrigation component of NAARP, and ONAHA extension personnel, as well as with the APS project and the extension services in general.

4.1.1 DECOR

The links with DECOR were based on two assumptions. The first assumption was that the Liaison Unit would only be extending information which had been tested in INRAN's on-farm trials. The second

assumption was that the Liaison Unit would facilitate the "handing over" of these on-farm trials to the extension services during the project term.

While the first assumption is valid, the Liaison Unit should not be restricted to working solely with DECOR results; the Unit should be responsible for disseminating all information, regardless of its source. The second assumption, that the extension services should take over the on-farm trial program, did not seem to be appropriate, given the intensive data collection involved and, therefore, resources needed to both collect and analyze the data. It was also not clear what extension was expected to gain from taking over such tightly organized trials. This "handing over" was not, therefore, initiated.

Considerable time was spent during the first few months of the NAARP technical assistant's assignment in INRAN in planning a closer link between the Liaison Unit and DECOR. However, the head of the Liaison Unit showed little interest, and DECOR staff made no independent moves towards forming closer linkages. Well-defined links between the Liaison Unit and DECOR were not, therefore, established during the three-year technical assistance. However, by the end of 1989, a proposal for a restructuring of the Liaison Unit and operational procedures for liaison activities, which included DECOR, in addition to other INRAN departments, was prepared. The proposal involved the formation of a Working Group which would essentially be responsible for reviewing research recommendations and for developing a detailed strategy for marketing research recommendations (tasks defined for the Liaison Unit under NAARP). These proposals were made in order to provide a logical framework within which linkages between all INRAN departments and the Liaison Unit might be defined. Presently, both DECOR and the Liaison Unit are able to define their own program of work; that is, DECOR can be propositioned or can proposition any researcher to present his/her research findings for on-farm trial evaluation. Likewise, staff of the Liaison Unit can decide which research results to market and with whom to cooperate.

4.1.2 INRAN Documentation Center

The link with the INRAN Documentation Center was logical, since both the Liaison Unit and the Center are concerned with communications. Nevertheless, technical assistance to the Center has been organized under the project independently from the RELU. The focus of this RELU technical assistance has been to increase research user access to worldwide documentation. At the INRAN restructuring meetings held in February 1991, it was proposed that the Liaison Unit, the Documentation Center, and the Unit responsible for Statistical Information Services (DSI), be merged to form a single unit responsible for the extension of research results (*Unité de Valorisation des Résultats de Recherche*). During the last two years, attempts were made to promote especially close links with the INRAN Documentation Center, and this structural change, if implemented, should have a positive impact on the Liaison Unit.

4.1.3 ONAHA

The proposed links with ONAHA were based on the assumption that research results would be available from the joint ONAHA/INRAN research program during the NAAR project life. For various reasons, which were not directly connected with the RELU technical assistant, this did not happen. It should be noted that the two NAARP technical assistants directly connected with the irrigation program are based in Maradi. The technical team sociologist, who is also based in Maradi, has participated in the irrigation research and has addressed some of the issues which might have been addressed by staff of the Liaison Unit.

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4.1.4 APS Project

Since the APS project was the extension support program at the time when the NAARP project was initiated, close working relationships between the Liaison Unit and the APS program were considered to be very important. However, prior to 1988, no links had been established between the technical assistants within the APS program and the head of the INRAN Liaison Unit. It should be noted, however, that links between the two liaison units and the Audio Visual Unit, both of which were established under the APS program, were comparatively strong. Links with the PRSAA World Bank-funded extension support program, which started in 1988 and succeeded the APS program, have also been strong from the outset.

The APS project ended in 1989 and during that year, only one technical assistant remained. Contact by the RELU specialist was made with the APS technical staff upon her arrival in Niamey, and discussions with two staff who remained in Niger were profitable. One of these technical assistants, Romero Gonzalo, was the technical assistant responsible for liaison activities.

The Media/Audio Visual Unit established under the APS project is well-equipped, has a staff of four and, therefore, has a potential which should be exploited. Presently, the staff of this Unit spend most of their time assembling video material and taking photographs at seminars and meetings. In 1990, the INRAN RELU facilitated the filming of the *Journée Commentée* which took place at Birni N'Konni. Dine Sadikou was to assist in the production of the video, but, unfortunately, this work was not completed before his departure. The head of the Audio Visual Unit has been made responsible for the coordination of the liaison bulletin, *Echanges Plus*, initiated during the tenure of the RELU specialist.

4.2 Training Programs

Most of the documentation covering the staffing of the INRAN Liaison Unit does not directly address the question of skills required for liaison activities. While it is clear from the terms of reference for this technical assistance that communication skills were considered essential, these skills have yet to be developed within INRAN. In 1989, a short computer training program was organized for Moumouni Ousseini, INRAN RELU counterpart, and the NAARP contractors were requested to identify possible training in preparation and editing, etc. of material for publication. No such training was identified, because no course was available similar to the one requested by the TA (technical assistant).

The new liaison bulletin, *Echanges Plus*, was first published in January 1990. Since this bulletin is prepared, for the most part, in-house, those participating are gaining some experience in the design and layout of publication. The publication was originated jointly by the RELU technical assistant and Nigerien staff in the Extension Liaison Unit.

To date seven issues of *Echanges Plus* have been published. While most of the contributions have come from INRAN staff, the majority of the editing work has been completed by headquarters extension staff, who earlier participated in the production of *Manomi*. The person now responsible for coordinating the production of *Echanges Plus* was not, however, involved in the publication of *Manomi* and would profit from further training. It was proposed that he participate in a short training course in Senegal. It was also proposed that staff of the Audio Visual Unit, along with INRAN Liaison Unit staff, visit communication departments in the NAARP institutions.

One of the overall objectives of the RELU technical assistant has been to strengthen the general understanding of, and participation in, liaison activities, both within INRAN and the extension services.

Since training programs in liaison are not available, the following activities were organized and designed to "train" INRAN and non-INRAN staff in liaison. Beginning with a visit to Senegal, Morocco, and Mali in February 1989, other visits were organized to two other West African countries, Burkina Faso in 1990, and Nigeria in 1991, specifically with the objective of identifying liaison issues and proposing means of addressing them. Following the Nigeria mission, Dine Sadikou prepared proposals to identify individuals within INRAN technical departments who would be responsible for liaison activities.

The Liaison Unit has also been responsible for coordinating more conventional training of extension staff in technical matters. In 1988-89, a number of short training sessions for extension personnel were organized at the request of extension. These sessions covered, for example, millet varieties, pests and diseases, and tree establishment, all of which could presumably have been taught by IPDR staff or extension personnel. It has since been argued that this is not an appropriate use of INRAN researchers, who should concentrate their training activities on new information and new techniques. Following this argument, the RELU technical assistant coordinated INRAN researcher participation in training in the use of the millet/cowpea *fiche* in March 1991, and in the subsequent preparation of a training manual. At the same training session, the INRAN sorghum program staff presented information on new sorghum varieties.

4.3 Evaluation of Technical Information

The evaluation of technical information was viewed as a key task of the Liaison Unit, given its communication role vis-à-vis other established procedures for such evaluations. Early on, a strategy document was prepared, with proposals for the establishment of a working group which would be responsible, both for identifying interesting technology which might be at various stages of development and extension, and for preparing a detailed work plan and follow-up activities. It was proposed that the working group be comprised of permanent members from both research and extension, including liaison personnel, and of temporary members who would vary, depending on the technology under consideration. The proposal took into consideration the paucity of qualified personnel in Niger and, therefore, did not suggest the setting up of a series of committees for the different departments or regions which would inevitably involve overlapping membership.

While the working group was not established, a process of evaluation was initiated with respect to INRAN's millet/cowpea production recommendations and sorghum varieties.

4.3.1 Millet/Cowpea Production Recommendations

One of the more interesting documents available for extension was the booklet describing alternative strategies for the production of millet and cowpea during the main cropping season (Reddy, 1988). This small booklet differed significantly from earlier technical recommendations in terms of both its form and content. Specifically, it presented a series of six alternative production strategies, taking into consideration the expected length of the cropping season and the levels of fertilizer input. Within each of these strategies, alternative cropping patterns, including sole crop options, were offered. As is described in the booklet, these recommendations represented an attempt by research to respond to the demand by extension for recommendations which take into account the farmer's need for flexibility in dealing with the between- and within-season climatic variation which has become the established pattern within the region over the last 15 years. This document was sent to the extension services for comment, and it was agreed that RELU, along with Dr. Reddy, would facilitate its distribution and coordinate the feedback of reaction from extension. This agreement initiated a program of work which occupied considerable time over the next three years and which only ended in March 1991 with the training of extension staff in Zinder and Maradi departments, referred to above.

The program covered activities directly linked with key Liaison Unit tasks: to identify and evaluate technical theses and to facilitate their extension amongst rural communities. The work highlighted a number of communication issues relating to extension staff training (the presentation of technical information and the provision of feedback to research) and reinforced the arguments made in the strategy paper for a detailed calendar of work with clearly allocated responsibilities. Before leaving Niger, the RELU technical assistant presented two seminars, one within USAID and one within INRAN, based on this experience. The objective of the seminars was to widen the understanding of the liaison process, to emphasize the multiple tasks involved, and to highlight the role of different institutions and departments necessarily involved. The key message was that while a liaison unit might play a key role in coordinating activities and even in completing certain tasks connected with the evaluation and extension of technology, such liaison work cannot be the sole responsibility of such a unit. Since this work was one of the major tasks completed during the three-year tenure of the RELU specialist, more details are provided below.

The task of evaluating and extending technical themes involves, firstly, the organization of joint programming meetings between research, extension, and other services working within rural areas in order to define tasks and to allocate responsibilities. Starting in December 1988, the Liaison Unit, therefore, facilitated discussions between staff of INRAN's agronomy program and extension personnel. These discussions of the millet/cowpea recommendations continued until February 1989, when, at a final meeting held in Dosso, working agreements were reached on all INRAN's off-station activities, including multilocational and on-farm trials; and a formal request was made by INRAN to the extension service to incorporate the millet/cowpea recommendations into their demonstrations.

This was the first time that INRAN had actually requested the extension services to initiate specific demonstrations. In principle, it went against current extension philosophy which gives extension agents the task of identifying demonstration themes based on a diagnostic of the farmers' situations. At the Dosso meeting, staff of the Liaison Unit distributed a document which drew clear distinctions between multilocational and on-farm trials and demonstrations, and the different roles of the various parties involved. Considerable attention was given to INRAN's multilocational trial program, which had been a source of considerable friction for some time.

The second task in the extension of technical themes by research is to communicate the required information to field personnel and farmers. Following the Dosso meeting, INRAN organized a training program which largely focused on the multilocational trial program. The training was conventional, and individual INRAN scientists made presentations on millet, cowpea, sorghum, and groundnut varieties, in addition to presentations on plant diseases and pests. The Agronomy Section briefly presented the millet/cowpea booklet.

The third task of coordinating the implementation and monitoring of these joint INRAN/extension activities fell to the two liaison units in research and extension. Monitoring and reporting procedures for the multilocational trials were already outlined, and the principal objective during the cropping season was to assess the feasibility of these procedures. Hence, the INRAN Liaison Unit TA visited each of the 35 multilocational trial sites three times in 1989, while, at the same time, assessing the interest shown in the millet/cowpea demonstrations.

The response from extension to the request by INRAN for demonstrations was overwhelming; well over 200 demonstrations were recorded. Over 150 of these were located within Zinder Department, and a proposal was made to the INRAN Agronomy Section for a joint visit with research staff. Up to this point, no researchers had been involved in the monitoring process. While agreement was reached, the main problem of joint monitoring of field activities became evident. Each institution, department, section, and

individual has a set of activities programmed for each year. Time for joint activities is rarely allocated in advance, and frequently has low priority. Thus, while the responsibilities of the various institutions had been discussed at the Dosso meeting, a detailed work calendar was not set up.

It should be noted that until this point, little discussion of the recommendations within the booklet had taken place between INRAN and the extension personnel. In addition, clear distinctions had always been drawn between research and extension activities, and, therefore, although researchers were on farms, extension personnel were seen as the most important and essential link with the wider farm population. Feedback to researchers in the form of general research guidelines was generally, therefore, provided at an annual general meeting of senior Ministry of Agriculture personnel. Rarely had researchers themselves been directly involved in detailed follow-up of technology under demonstration by extension staff. For more detailed feedback on such activities as INRAN's multilocational trials, which were carried out by extension staff, INRAN largely relied on the return, by mail, of data, and while both agronomic information and farmer evaluations were requested, conventionally, only agro-climatic data was returned.

While the experience from the multilocational trials had been a source of friction for some time, with researchers complaining about extension personnel inefficiencies and extension complaining about inadequate rosearcher monitoring and supervision in what was, essentially a research activity, more extension training and increased researcher visits had conventionally been viewed as the solutions. There was no serious questioning of the expectations of either side, and while some additional extension staff training was given, no systematic analysis of the situation had been made. The request for feedback from extension made in the millet/cowpea booklet followed the pattern of expectations established in the past between research and extension.

Key findings from the limited demonstration monitoring by the Liaison Unit in 1989 were that the booklet did not appear to have reached all field staff, and/or had not been read; that appropriate varieties, given the timing of the rains, were either not available or were not used; and that planting densities, particularly for cowpea, were not followed. Overall, it was not clear that the different options were understood.

As a result of this first year of demonstration monitoring, a decision was made to present the information in the booklet in a different form, such that all the various options could be seen at the same time. The original booklet consisted of over 40 pages of text, tables, maps, diagrams, annexes, and literature references. While the original booklet was prepared by Chandra Reddy, the NAARP agronomist, the task of coordinating the preparation of technical extension documents had conventionally fallen to the INRAN Liaison Unit since its formation in 1982. Therefore, the preparation of a technical *fiche* was facilitated by the TA.

In November 1989, therefore, INRAN's Research-Extension Liaison Unit took the millet/cowpea booklet and attempted to produce a shorter, more practical tool, which could easily be taken to the field and used by extension personnel. This involved the Unit in facilitating a process of "unpacking" the booklet through a detailed evaluation of the information completed jointly with the technical scientists. During this process, missing and vague information, as well as several errors, were identified. Gaps in researcher knowledge were also highlighted.

The unpacking first included the clear identification of the key decision points. The information was then organized along the lines of a decision tree, with period of planting (six periods), use of fertilizer (yes or no) and cultural system (pure stand or intercrop) providing the key decision points. By following a particular set of branches, one arrives at one of 26 alternative millet/cowpea production strategies. The

new four-page document, published by INRAN in 1990, became more comprehensive than the earlier booklet in that it incorporated a greater number of alternatives, for example, the inability or unwillingness of some farmers to use chemical fertilizers, or the availability of alternatives such as manure. Among the 26 alternative strategies are recommendations which represent some present farmer practice.

The *fiche* was distributed in time for the 1990 cropping season and the training program was repeated. A tool was also designed for the more systematic collection of information from the Zinder Department in order to monitor the actual options selected by extension staff for demonstration.

Further, more detailed monitoring in Zinder Department in 1990 revealed continued problems of interpretation of the technical information, in addition to problems connected with the way in which civil service institutions communicate amongst themselves and organize a number of activities, such as the central production and distribution of improved seed for demonstrations each calendar year. It also became clear that many extension staff need more specific training in the design of extension tools, in particular in the design of demonstrations based on the analysis of particular situations, and in the collection, analysis, and interpretation of data from such demonstrations.

Following these results, and in cooperation with Zinder departmental staff, IPDR and extension headquarters staff, another training program was organized. However, the specific objective of this activity was to receive feedback directly from extension staff in the field on their understanding of the technical information, and on their ability to implement the strategy. The training was designed as an interactive process, and a training specialist in using these techniques was brought in from CARE (Cooperative for for American Relief Everywhere) Niger. The training, which took place in February 1991, demanded considerable input from research personnel. A draft of a training manual based on this experience was prepared.

Overall, the role of the Liaison Unit, other INRAN researchers, and IPDR staff in extension training needs to be carefully reviewed. Certainly, both the research and extension staff profited from the kind of training that was organized in Zinder, and perhaps what is needed is for IPDR and other involved parties to consider the way in which training programs are presently designed. The director of the DDA (*Direction Départementale de l'Agriculture)* of Zinder, who actively participated in this training, is now the Director of the IPDR.

The training itself demonstrated the key role which researchers have to play in the extension of new technology or ideas, and the importance to the researchers of the direct exchange with actual field personnel at this stage of the transfer of new ideas and practices. This is a particularly important point, given the present extension strategy of limiting contact between extension staff and researchers to the level of extension specialists.

With reference to the points on feedback made earlier, it is noteworthy that over the three-year period, INRAN had received no detailed automatic feedback from extension on the documentation, nor on the demonstrations themselves. Information on the demonstrations was, nevertheless, included in the routine reports submitted by extension field staff to extension headquarters through the *arrondissements*. One of the tasks assigned to the NAARP technical assistant was the design of tools to enable extension staff to provide feedback. The reporting forms used for the multilocational trials provided a basis for the forms assembled for the millet/cowpea demonstration monitoring. In most instances, these were returned to INRAN in the same way as all other extension reports, including those covering INRAN's multilocational trials–via the *arrondissement*. As noted, this documentation is used by the administration when compiling reports to headquarters for final discussion at the annual general meeting. Consequent delays in the

receipt of these forms, and problems in the interpretation of much of the recorded data, suggest that alternative procedures need to be found. Certainly extension staff are required to submit all reports on their activities through official channels, and it may not be possible to change this procedure. Unfortunately for the millet/cowpea work, the reporting forms were not prepared in time to be covered during the training program before the season started. In future work, this training must be done. In the end, however, detailed feedback of the kind required to redesign a technology requires the direct involvement of researchers themselves in the field activity.

While it is clear that research and extension personnel have different roles to perform, it is also clear from this experience that these roles should not be used to limit the scope of activities of each of these services. For each activity in which both are involved, it is, therefore, essential that roles are defined, the time required is clearly specified, and commitments are made. The actual tasks which each institution, etc. will perform will partly be determined by the resources available, as well as the stage of development of the information under consideration. This subject was discussed in the strategy paper referred to earlier. Here, it was proposed that the liaison working group have the responsibility for defining roles and reaching agreements.

4.3.2 Improved Sorghum Varieties

In 1990, with the sorghum breeders, the NAARP RELU technical assistant initiated a limited program of extension demonstrations in order to facilitate feedback on new varieties, particularly comments from the farmers themselves, which were not forthcoming from multilocational trials. This work was based on proposals made following the monitoring of INRAN's multilocational trials in 1989. The demonstrations were planned to cover a limited number of sites and varieties. Unfortunately, insufficient planning led to misunderstandings of the objectives of the trials by extension staff, who assumed that they were implementing yet another multilocational trial. Again, it was impossible to organize joint monitoring between the NAARP TA, the sorghum breeders, and departmental staff, because no agreement of specific time allocations had been made for this program at the start of the season. These sorghum demonstrations are discussed in more detail in the Liaison Unit biannual report.

4.4 Evaluation of Extension Techniques

As was noted in the millet/cowpea example, time was spent looking at and evaluating extension techniques. While this task was not specifically listed in the terms of reference for the TA position, it forms part of the logical framework used for the six monthly reports.

Two extension activities in particular have been considered: the use of diagnostic surveys and demonstrations.

4.4.1 Diagnostic Surveys

In 1990, a study was designed to assess the diagnostic needs of extension staff whose principal extension tool is the demonstration. This work was completed with a consultant and focused on small ruminant production by women producers. The program was completed jointly with extension staff in two *arrondissements*. Unfortunately, no feedback was received on the draft report produced, and a final document, which might be used for training, has yet to be produced. However, the information put together during this activity formed the basis for the training in Zinder described above. The Zinder training covered the use of agronomic and village diagnostic survey data in the development of an

extension work plan, in addition to the technical underpinnings of the alternative strategies for millet and cowpea production.

4.4.2 Demonstrations

The use of demonstrations as extension tools was also considered during the Zinder training, and this forms part of the training manual in preparation.

4.5 Distribution of Technical Information

4.5.1 Technical *Fiches*

INRAN's Liaison Unit has played a key role, since its inception, in the dissemination of research results. As noted above, a series of technical *fiches* were prepared during Fournier's consultancy, and these remain the principal extension documents available within INRAN. They are also almost the only documents available to extension. The extension services have not, in general, developed extension material for their own staff or for farmers.

During the first year of her assignment, the NAARP TA assisted in the further distribution of material remaining in stock within INRAN. In response to demands from extension, it was also planned to facilitate the update of the technical information available on dry season vegetable production. However, INRAN does not have a strong research program in this area. With Moumouni Ousseini, a workshop of individuals and institutions actively involved in vegetable production programs was organized in 1989. The objective of the workshop was to bring together people who might participate in updating this information. With the departure of the NAARP counterpart, this work was not completed, and since his departure, the use of information from the Center for Horticultural Research in Senegal has been advocated. This information was first made available to the extension services following the training visit referred to above and is now widely used.

Four new technical *fiches* were prepared during the last eight months. The first two cover sesame and *vouandzou*. The sesame *fiche* material updates an existing *fiche*, whereas INRAN has not previously distributed information on *vouandzou*. These were prepared at the request of a technical assistant to the crop diversification program of INRAN. The intention was to prepare information specifically for crops produced by women.

Two other recently-completed *fiches* cover two new sorghum varieties, SRN 39 and SEPON-82. All four *fiches* have been prepared in a new format, and it is proposed that these be distributed individually.

4.5.2 Information Exchange

While it is the role of the Liaison Unit to prepare and extend technical information, the Unit also has a role of facilitating the exchange of information in general. Attempts were made to organize activities within which an exchange of information between research and extension staff could take place in a sustainable manner. It is this exchange which facilitates the applied research process, in addition to building respect between the different institutions and individuals concerned. These activities have included *Journées Commentées* focusing on research and extension activities both in and around INRAN sub-stations, in addition to the publication of *Echanges Plus*. The bulletin is now in its eighth edition. A plan of work to be used by the extension staff person identified as the bulletin coordinator was prepared before the departure of the RELU technical assistant.

4.5.3 Seed Availability

One constraint on the extension of much of INRAN's "improved" technology is the seed component. While seed production has been a major focus of agricultural development activity in Niger, the main focus of this activity has been the production of high quality "certified" seed, and it has met with little success. While there are continuing attempts to focus on the production of high quality seed, this time within the private sector, there is also some discussion of wider issues connected with seed, including increasing farmer consciousness of the importance of good seed and seed storage. As part of an attempt to address these issues, a visit to Winrock International's on-farm seed program in Senegal was organized in 1990. This visit took place jointly with a representative from a non-governmental organization, CARE Niger, and subsequently, a similar program was included as an integral part of a research-extension liaison program being funded by CARE Niger in the Maradi Department. It has been proposed that the INRAN Liaison Unit play an active role in this work, and that continued support be provided by the Winrock Program in Senegal, in addition to a seed specialist from Alabama A&M University who has similar interests.

4.6 Improvement of Existing Liaison Activities

One of the most important activities linking INRAN and the extension services at the time of the NAARP TA assignment was the INRAN multilocational trial program. As has already been noted, there was conflict between the two services. During 1989, much time was spent monitoring these trials and providing proposals for future trials. A series of reports was prepared and decisions were taken in November 1989 to reorganize the trials. Unfortunately, following changes in departmental heads in 1990, the liaison process was disrupted, and the Unit was not involved in the 1990 trials. Little information exists on the 1990 trials, but overall, it is clear that the process initiated in 1989 was a valid one and needs further development.

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