# NIGER IRRIGATION SCHEME
# CASE STUDIES

NIGER

USAID

WATER MANAGEMENT SYNTHESIS II PROJECT
WMS REPORT 87

# NIGER IRRIGATION SCHEME CASE STUDIES

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**Niger Joint Field Study/Workshop**

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by

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# PREFACE

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

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

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

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The Joint Field Study/Workshop (JFS/W) Team greatly appreciates the cooperation it received from the various GON agencies involved and the assistance from the USAID Mission. We are especially appreciative of the support from ONAHA, INRAN and the Ministry of Plan for not only providing support in the form of team members but also providing vehicles and drivers, as well as assisting with other logistical and protocol matters.

Special thanks is due to Mr. Amadou Soumaila, Director General of ONAHA for his personal support of this activity, for allowing Mr. Idi Maman to serve as the Nigerien Team Leader, for the use of the ONAHA Conference room, and for the assistance provided by ONAHA Perimeter Managers during the Team's field visits. We also want to give special thanks for USAID's help at several critical moments which was made possible through Mr. Flynn Fuller and Mr. Hama Diallo's efforts.

The Team appreciates the African Bureau's vision in providing special project support for this JFS/W activity and believes their enthusiasm for it was important and helped lead to its success. The Team was fortunate in that most of the expatriate members had been involved with writing USAID's Nigerien Applied Agricultural Research NAAR Project Paper and/or had very recent experience in Niger. In addition, the AID Science and Technology Bureau's Office of Energy in Agriculture provided special funds to supplement the Team with experts on water lifting and energy analysis which proved most worthwhile.

Individually and collectively the Team members appreciated the confidence in and respect for each other both personally and professionally. The collaboration which was demonstrated and the working intensity of practically all of the Team members was both mutually appreciated and necessary. It was this spirit of diligently working together that was most important in the unusual success of this activity. All Team members grew personally and professionally from the experience.

The compilers of this document express their appreciation to the various contributors. We wish to acknowledge the work of Carolyn Fullmer and Sheridyn Stokes for their untiring efforts in the preparation of the drafts and final manuscript; their word processing skills and patience have been greatly appreciated. We also wish to record our thanks to JoAnn Biery and Manohar M. Sawant for bringing the text to its printed form. Thanks to Clayton Blodgett for preparing figures and to Philippe Zgheib for translating the report into French.

# FOREWORD

This Water Management Synthesis II Project activity was initiated as an effort to increase the understanding of the restraints to successful irrigation development in sub-Sahelian Africa. The Joint Field Study/Workshop (JFS/W) Team was multidisciplinary, with a set of expatriate professionals with broad international irrigation development experience, and a set of Nigerien colleagues who brought in the local perspective. The study component was designed to use a rapid appraisal approach for developing a more in-depth understanding of the successes in and constraints to irrigated agricultural development at four representative sites. The workshop component was designed as a means of learning from each other and together how successes might be extended locally as well as regionally, and developing strategies for reducing or eliminating the constraints.

Two other JFS/Ws were undertaken, Rwanda and Zimbabwe, and the respective reports produced for each provide a central focus for an international "Forum on the Performance of Irrigated Agriculture in Africa." Niger was selected as a candidate country for a JFS/W because it is representative of Central African conditions; has jointly managed small and medium irrigation and privately owned micro irrigation schemes; and as a government policy, has a keen interest in irrigation development. In addition, USAID/Niger is about to begin its Nigerien Applied Agricultural Research (NAAR) Project, which is designed to increase the needed knowledge base for improving both rainfed and irrigated agricultural performance in Niger.

The key to the development of this effective JFS/W depended on the establishment of a collaborative effort between the expatriate and Nigerien Teams. Such collaboration was necessary for two reasons. First, to identify the operational objectives and operational procedures for achieving these objectives required a collaborative effort. (An expatriate Team cannot do an adequate job of dealing with these issues on its own.) Second, in order to contribute toward the development of an effective irrigation strategy for Niger, the JFS/W aimed at enhancing the already-existing capabilities of Nigerien professionals.

The JFS/W was carried out between February 2, and March 5, 1987. The Team was made up of the following eight Nigeriens and six expatriate Team members:

A. Nigerien Team Members.

Idi Maman, Team Leader, Agricultural Economist, ONAHA
Algabit Assadel, Economist, Ministry of Plan
Ibro Germaine, Agricultural Economist, INRAN
Mahaman Issa, Agricultural Economist, INRAN
Abdoul Aziz Oumar, Agronomist, ONAHA
Mamhdou Madon, Agricultural Engineer, Genie Rural
Chetima Mai Moussa, Agricultural Engineer, INRAN
Oumarou Naawa, Perimeter Director, ONAHA

## B. Expatriate Team Members.

Jack Keller, Co-Team Leader, Agricultural Engineer
Eric Arnould, Co-Team Leader, Rural Sociologist
Terrence Hart, Mechanical Engineer
Donald Humpal, Irrigation Agronomist
Ray Norman, Agricultural Engineer
Thomas Zalla, Agricultural Economist

All Team members participated in developing the four case studies. Different individuals and assemblages of individuals representing different expertise were responsible for writing the various sections of each study. In order to organize the analysis and writing assignments and to facilitate the assemblage of the case studies (see Chapters II, III, IV, and V) the "Case Study Outline" (presented on the following page) was adopted by the Team. The same numbering system and general sub-titles are used in each case study.

The Team discussed the general conclusions and recommendations derived from each case study but these were not written up and included in the individual case studies. However, they are summarized in Chapter I (see General Conclusions and Recommendations).

# CASE STUDY OUTLINE

## 1.0 Project/System Description

1.1 Physical Features
1.2 Farm characteristic
1.3 Crop calendar and rotation (crop areas and timing, etc.).
1.4 Irrigation system costs (main and on-farm works).

## 2.0 Operational Overview

2.1 Institutional and social structure.
2.2 Irrigation systems (main and on-farm works).
2.3 System (main) management.
2.4 On-farm irrigation and crop management.
2.5 Training/extension.
2.6 Cost of operation and maintenance.
2.7 Farm enterprise and institutional functioning.

## 3.0 Evaluation of Performance

3.1 Irrigation system (main) operation.
3.2 System (main) management (and maintenance).
3.3 On-farm irrigation and crop management.
3.4 Irrigated agricultural productivity.
3.5 Irrigated system (main) economics.
3.6 On-farm (micro) economics.
3.7 Enterprise and institutional performance.
3.8 Training/extension.
3.9 Equity issues and social parameters.

## 4.0 Specific Constraints and Recommendations

4.1 Institutional and social.
4.2 Economic (system and on-farm).
4.3 System design.
4.4 System management and O&M.
4.5 Cropping program.
4.6 On-farm management.
4.7 Research (action and experimental).
4.8 Training and Extension.

## General Conclusions and Recommendations

For extending system in Niger without major modifications.
For extending system in Niger with major modifications and recommended modifications.

# NIGER IRRIGATION SCHEME STUDIES
## EXECUTIVE SUMMARY

Niger has four predominant types of irrigation systems, namely: jointly managed river pumping systems; jointly managed reservoir storage surface systems; jointly managed groundwater pumping systems; and individually managed micro and small irrigation systems. (Jointly managed means that a government agency as well as the users are responsible for managing the irrigation system.) The jointly managed river pumping systems account for approximately 6,000 of the roughly 13,000 hectares of irrigated land in Niger. Most of these perimeters are located in the depressions and floodplains adjacent to the Niger River. The jointly managed reservoir storage surface dam systems are found in and near the Maggia Valley. They account for about 3,800 hectares of Niger's developed irrigated area. Niger has developed its first medium-scale jointly managed groundwater pumping system at Djirataoua, on the Goulbi-Maradi. The well field provides water for approximately 500 hectares. The remaining 3,000 to 4,000 hectares of fully irrigated land is in individually managed micro and small irrigation systems. The water supply for this area is from 20,000 unlined hand-dug wells and perhaps 2,000 permanent concrete lined hand-dug wells.

The JFS/W Team conducted rapid appraisals on four different irrigation schemes. The four principle cases studied were:

1. Community Managed River Lift Irrigation Scheme (13 ha) near Say, Niger.

2. Djirataoua Electrified Multiple Deep Well Irrigation Scheme (500 ha) and the Safo Diesel Powered Ruwana Perimeter (9 ha) near Maradi, Niger.

3. Galmi Reservoir Gravity-Fed Irrigation Perimeter (245 ha) at Galmi, Niger.

4. Private Irrigation Small Dug Well Perimeters (0.1 to 0.3 ha each) in the Tarka Valley (300+ ha) near Madaoua, Niger.

The same .format was used for each of the case studies (which are reported separately in Chapters II, III, IV, and V). A summary of each case study and the important findings are presented in Chapter I.

Each of the four case studies analyzed the situation in an interdisciplinary mode, giving attention to a range of factors: agronomic; engineering; economic; social; organizational; and institutional. Included in each case study is the identification of policy and research issues, some for immediate action, and others for subsequent discussion at the African Irrigation Forum mentioned in the Foreword. Before appraising any irrigation schemes, the expatriate JFS/W Team members held a four-day orientation and team building workshop for the Nigerien Team members.

## General Conclusions

The cost of developing one hectare of medium-scale irrigation perimeter in Niger is high, even by Sahelian standards, amounting to from U.S. $10,000 to over $25,000 per hectare. Key factors accounting for the relatively high cost include: difficult topography and site conditions; unnecessarily high design standards; and lack of local competition in bidding for design and construction contracts. Inadequate water supplies and/or management difficulties appear to be problems on virtually every jointly managed perimeter. Reduced rainfall has lowered the flow of the Niger River and reduced the inflow into the inland reservoirs. At the same time, heavy siltation has reduced the storage capacity of the reservoirs, and greatly reduced their ability to provide adequate water for dry season irrigation.

In general, cultural practices on irrigated perimeters are adequate to good by West African standards, though there is room for improvement. Farmers generally plant improved varieties and apply close-to-recommended level of fertilizers. The principal agronomic constraints on increasing yields of irrigated crops include heterogenous soils that prevent plant water needs from being uniformly met; poor seed quality; lack of varieties that are resistent to disease in the case of vegetables; difficulties with weeding practices and weed control; inappropriate fertilizer recommendations; non-uniform planting dates that lead to inappropriate applications of water on some of the crops; and lack of availability and use of insecticides.

In spite of these problems, available evidence suggests and the JSF/W Team found that private returns per day of labor in irrigated farming exceeds those of rainfed agriculture. Onions, improved sorghum and peanuts are consistently among the highest, and cotton and sorghum among the lowest income producers of the field crops. The principal vegetables grown under irrigation in Niger are onions, tomatoes, peppers, and to a much less extent, carrots, lettuce and cabbage. Onion yields, which average in the neighborhood of 30 to 40 tons/ha, are good by any standards.

Farmers traditionally prepare their plots for irrigation by constructing small (2 to 25 $m^2$) basins interconnected by a channel network. The basins are quite carefully prepared and leveled (smothered) with elevations differences no greater the + or - 3 to 5 cm. Farmers size their channels and basins according to the flow rate available, the soil texture and the topography. Where flow rates are very small, as with hand lifting from 3 or 4 m giving flows of less than 0.5 lps, 2 to 4 $m^2$ basins are common. Where flows produced by hand lifting from shallower depths or by motor-pumps was in the neighborhood of 1 to 2 lps, 8 to 12 $m^2$ basin are common, and where flows from siphon tubes were over 4 lps basins up to 32 $m^2$ were being used.

The irrigation perimeters of Djiritaoua and Galmi were leveled and designed for using (80 or 100 m) long furrows fed from 1 or 2 siphon tubes. However, farmers elected to modify the applications system to conform to their traditional small basin or short (10-12 m) furrow approach of applying water. The Team feels the farmers were right in doing this as they simply don't have the means by which to develop long furrows capable of acceptable application efficiencies. This is because they use manual farming techniques and have only limited access to machinery.

We were also impressed by the ability of farmers to organize (with GON assistance) and manage their irrigation systems (water distribution and maintenance) at the tertiary level where this was required (except in cases where cultural diversity was too extreme). However, we were not favorably impressed by the level of extension expertise, especially in the areas of irrigation scheduling; plant protection; and the operation and maintenance of the public irrigation infrastructure. These shortcomings appear to result from the lack of properly trained personnel and relevent information and not from their lack of interest.

Most of the irrigation potential in Niger does and will continue to require water lifting. Therefore, minimizing the capital plus operating costs of lifting water is extremely important for the economic development of Niger's irrigation potential. In addition, much of the irrigation potential must also be supplied from wells. Thus, improving the efficiency and cost effectiveness of well development is also of major importance.

After the problems associated with water lifting and well development, the two next most important irrigation system related problem areas are efficiently conveying the water and scheduling the deliveries. While both conveyance and scheduling efficiencies are relatively high, each being in the neighborhood of 75 to 85 percent, there is still room for improvement. Thus, even with application efficiencies as high as 75 percent, the overall irrigation efficiencies are between 40 and 50 percent under full irrigation. Even though this is quite good, because of the high cost of lifting water (or storing it), maintaining even higher overall irrigation efficiencies is very important to the economic viability of irrigated agriculture in Niger.

Plant protection is perhaps the most important near and medium term agronomic problem. It affects crop choice (excludes peanuts and cowpeas), yields (cotton, onions), and poses multiple management problems (build-up and transference of pests from cotton). As the irrigated area increases plant protection problems will increase as well. Scheme managers, farmers and researchers need to concentrate their efforts in this area as a first priority. As economic analysis has shown, perimeter production become much more attractive when higher value cowpea and peanut crops can be grown in place of sorghum.

Very limited applied work has been done on the response of existing crop varieties to irrigation. Crop establishment, density, stress management and charges in production inputs, especially fertilizer, have barely been touched by research. The research that has been done in Niger has not been collated and synthesized. Furthermore, the practical experience of perimeter managers and farmers has been only lightly tapped. Experience and research on crop varieties used in Niger and neighboring counties has not been systematically compiled and reviewed. Even the older research results from Niger itself are under utilized.

Most irrigation systems are designed with a specific cropping pattern and rotation in mind. Many irrigation perimeters in Niger seem to attempt major shifts in cropping pattern on a system wide basis with little reference to the individual grower. As Nigerien policy shifts greater operating responsibility to cooperatives, government management and marketing agencies should be careful to spread production and marketing among a broader range of crops. The irrigation requirements of most of the annual crops that can be produced in Niger do not vary so significantly that system operating efficiencies would be much affected by crop diversification. Planting dates on most of the perimeters are spread so largely that truly homogeneous water rotation blocks do not exist anyway.

Of the four case studies, three required water lifting. The cost of irrigation to the farmers was considerably higher for all of these as compared to the gravity-fed irrigation perimeter at Galmi. This is because farmers on all schemes, both public as well as private, are responsible for paying the recurring cost for operating and maintaining the irrigation water delivery system. But they are not expected to pay the major capital costs associated with developing the public infrastructures.

Even though the profitability to farmers at Galmi was the highest, from an overall economic (world economic account) point of view, the internal rate of return is zero, even with relatively high value crops. This is considerably better than at the Djirataoua deep well scheme which the Team estimates has an internal rate of return in the neighborhood of a negative 7 percent. But it is much lower than for the less sophisticated developments involving community lift irrigation or dug wells, and possibly individual community operation drilled wells like the Ruwana system at Safo.

Hand lifting water from dug wells, where the lift is less than 3 m, is still profitable for irrigating high value crops such as onions, but is considerably less (only about half as) profitable as using motor-pumps for lifting the water. For hand-lifting to remain economically viable, new hand pumping technologies are needed. Hand-lifting is important economically because it provides employment, but without improvement in lifting technologies it will eventually be replaced by small motor-pumps.

At the present, small motor-pumps supplied from concrete-lined dug wells (or natural surface supplies such as lakes and rivers) are the most economic water supply systems in Niger. This is especially true where import taxes on fuel and the motor-pump units are avoided (by direct purchases from commercial sources in Nigeria). Such irrigation systems, if optimized, can even be operated profitably for growing relatively low value crops (such as oil seeds, and some grains).

## General Recommendations

In the Team's view, the gravity-fed schemes, like at Galmi, have a viable place in Niger's irrigation development. But, this is only true where donors are willing to subsidize development. This is also true for the more elaborate rice irrigation schemes which require pumping water from the Niger River; and it is possibly true for the individual drilled well perimeters like the Ruwana at Safo. But we were not favorably impressed by the scheme at Djirataoua where an electric power grid supplies a group of wells. Consequently, we do not recommend further investment in this type of development unless a more economic electric mini-grid system were available.

Hand-lifting from shallow wells to irrigate high value crops not only provides a significant source of employment, it is also one mean for enterprising farmers with little access to credit to get started with irrigated farming. But, for hand-lifting to be viable, the lift must be small (less than 3 or 4 m) and crop returns to water high. Thus, any development efforts, such as subsidizing large numbers of small motor-pumps for use on dug wells should be pursued with extreme caution. This is because they could easily displace the hand-lifting by lowering the water table and/or greatly increasing commodity supplies causing prices to fall. Therefore, the Team recommends that small motor-pump development be left entirely in the private sector without any subsidies.

In review of the delicate economic balance which keeps water lifting by traditional hand-methods viable, the Team recommends that USAID's Nigerien Applied Agricultural Research (NAAR) Project concentrate on finding and testing improved hand (and possibly animal) lifting technologies. There is also considerable room for improving motor-pumping. What are needed are pumping units which are better suited for the flow and lift conditions in Niger and improved sales and both private and public service networks.

The hand-dug wells are costly and the depth to which they can be dug is limited. In order to more fully develop the rather extensive groundwater resources in Niger, improved low cost well drilling technologies are needed. The Team recommends concentrating on technologies for constructing both very low cost small diameter wells (75 to 100 mm) which can be installed by indigenous means (like in Bangladesh) to tap shallow aquifers; and lower cost larger diameter wells to tap the deeper aquifers like at Djirataoua. The small wells could serve individual farmers using hand or centrifugal pumps and the larger wells could be used for community operated irrigation perimeters like at Safo using turbine pumps.

It has been suggested that there may be considerable potential for irrigation from groundwater in Niger. To better understand this potential a country wide reconnaissance level groundwater survey would be very useful. But, the Team recommends that instead of conducting costly detailed surveys, groundwater development should be allowed to proceed in incremental steps and carefully monitored. Development should be curtailed wherever either the quantity or quality of the groundwater appears to be unsustainable. While the present irrigation from groundwater in Niger is probably still sustainable, the needed monitoring of both the groundwater levels and water quality is not being done. Therefore, the Team recommends making a countrywide reconnaissance level groundwater survey and carefully monitoring important existing developments such as in the Tarka Valley and at Djirataoua area.

The Team also recommends that efforts be made to improve irrigation scheduling, especially for the larger perimeters. While traditional water conveyance channels are satisfactory for the small flows produced by hand-lifting, they are not adequate for the larger flows from motor-pumps. In order to take better advantage of the larger flows, and/or optimize motor-pump efficiency, improved water conveyance techniques are needed. Such techniques might involve the use of lined channels or pipes. Assisting with improved irrigation scheduling and water conveyance technologies are two areas in which the Team recommends the NAAR Project concentrate.

The priority irrigation system and irrigated crop research needs in Niger are very applied ones. Finely tuned variety trials, precise water balance studies, and basic research should not be placed at the head of programming needs. Broad screening of advanced lines and stable crop varieties, simple three to four step fertilization trials and broad screening of herbicides and pesticides is far more important to irrigation in Niger. Much of this work can be done on existing perimeters by a relatively small group of researchers and technicians with skilled and strong central supervision. Currently there is no sustained irrigation research all within any government agency capable of handling on-perimeter trials or demonstrations of new technologies and synthesizing yearly experience on the principal perimeters. As Niger has already expended large sums of money to build and operate irrigation perimeters, a small and agile applied research unit offers substantial promise in improving return to irrigation investment.

Because irrigation is quite costly in Niger, to be financially feasible at the farm and scheme or perimeter level, it must be focused on relatively high return crops. This requires having production packages available which give high yields with low input costs as well as focussing on high value crops. Finding suitable high value crops requires spotting and working with those who have local, regional and/or international "market niches."

Rather than undertaking a new series of trials, an important effort should be made to sift through research already documented in Niger and from neighboring Sahelian countries on irrigated crop management as well as water development and application technologies. Such a review would help greatly to focus research programming and to orient on-farm adaptive testing. It may also provide directly usable technology overlooked to date by irrigation schemes growing crops other than rice.

Groups of farmers served from individual outlets (or wells) do appear to cooperate quite well in operating and maintaining their collective part of the irrigation system. However, they still need management, financial and technical assistance in order to improve irrigation performance. This is particularly important in Niger considering the high cost of developing irrigation water supplies.

As with this study Team, a multidisciplinary diagnostic approach should be taken by the NAAR Project to determine the priority problems to be addressed by an applied-adaptive research program. Perimeter-wide studies and research should concentrate on tne restraints to irrigated agricultural production. In addition the micro or on-farm irrigation needs of individual farmers (such as how best to lift, convey and apply water to their fields) should also be researched and extended.

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# CHAPTER I

# BACKGROUND, STRATEGIES, AND GENERAL CONCLUSIONS

The JFS/W Team conducted rapid appraisals on four different irrigation schemes. The same format was used for each of the case studies (which are reported separately in Chapters II, III, IV, and V). A summary of each case study and the important findings are presented in this Chapter (I). The high level of output of the JFS/W was possible because during the field studies time was devoted for discussing the information being collected and attempting to integrate the facts being gathered. At the completion of each case study, time was allocated for synthesizing the results of that analysis.

Each of the four case studies analyzed the situation in an interdisciplinary mode, giving attention to a range of factors: agronomic; engineering; economic; social; organizational; and institutional. The case studies utilized a variety of techniques for obtaining information, including field observations and interviews with farmers, irrigation leaders and agency staff, as well as the use of secondary information such as reports, maps and agency information. Included in each case study is the identification of policy and research issues, some for immediate action, and others for subsequent discussion at the African Irrigation Workshop mentioned in the Preface.

Before appraising any irrigation schemes, the expatriate JFS/W Team members held a four-day orientation and team building workshop for the Nigerien Team Members. During this period, the Joint Team (which will be referred to as the Team hereafter) conducted a rapid appraisal of the Say Community Managed River Lift Irrigation Scheme as a "practice" exercise. The results of this rapid appraisal were so interesting it was decided (by the Team) to include this as one of the four irrigation schemes (or cases) studied.

During this Team building and learning workshop, the itinerary and plans for carrying out the four case studies was codified. The Team received very good cooperation from the various GON agencies involved. For example, ONAHA, INRAN, and the Ministry of Plan each provided a field vehicle in addition to the services of their professionals who were Team Members.

## Irrigation in Niger

Responsibility for irrigated agriculture in Niger is divided principally between the Genie Rural, the Office Nationale des Amenagements Hydro-Agricoles (ONAHA), the Ministry of Hydrology and the Environment (MHE) and the Institut Nationale de Researches Agronomiques du Niger (INRAN). The Genie Rural is responsible for design and supervising construction; ONAHA for implementation, management and maintenance of irrigated perimeters; and the MHE for collecting and analyzing information on surface waters and groundwater. INRAN is responsible for all agricultural research. INRAN carries out limited amounts of research related to irrigated agriculture at its two principal stations at Kolo and Tarna and most of its other substations. A principal effort of USAID's Nigerien Applied Agricultural Research (NAAR) Project is to strengthen INRAN's capability to carry out irrigated agricultural research and to coordinate these research efforts with ONAHA's irrigated perimeter implementation and management efforts.

Niger has four predominant types of irrigation systems, namely: jointly managed river pumping systems; jointly managed reservoir storage surface systems; jointly managed groundwater pumping systems; and individually managed micro and small irrigation systems. (Jointly managed means that ONAHA as well as the users are responsible for managing the irrigation system.)

The jointly managed river pumping systems account for approximately 6,000 of the roughly 13,000 hectares of irrigated land in Niger. Most of these perimeters are located in the depressions and floodplains adjacent to the Niger River, which are called cuvettes. These cuvette perimeters usually produce a double crop of rice and have a typical size between 100 and 400 hectares, with the largest being a 1,350 hectare perimeter at Mamaregoungou. Currently, the cuvette perimeters serve approximately 5,600 hectares. The remaining river pumping systems are on terrace lands producing upland field and vegetable crops.

The jointly managed reservoir storage surface dam systems are found in and near the Maggia Valley. They account for about 3,800 hectares of Niger's developed irrigated area. About 2,400 hectares are in the Konni I and II perimeters. The remaining eight surface storage perimeters range in size from 27 to 750 hectares. Cotton and sorghum are the principal rainy season crops grown on these perimeters which essentially provide only supplemental irrigation. Less than 25 percent of the land is cultivated during the dry season because of insufficient reservoir storage capacity. A major problem with these systems is reservoir siltation, with the reservoir half-lives ranging between 12 and 25 years, and this adds significantly to the water storage shortfall problem. The principal dry season irrigated crops are vegetables (typically onions) and wheat, with millet and other crops being used where water is very limited and/or to use whatever residual moisture may remain.

Niger has developed its first medium-scale jointly managed groundwater pumping system at Djirataoua, on the Goulbi-Maradi. The well field provides water for approximately 500 hectares. Each well serves between 10 and 15 hectares, divided into one-third hectare individual holdings. Such tubewell systems offer promise for developing river valleys with shallow groundwater where surface reservoirs tend to silt up and experience very high rates of evaporation. Because of the more reliable water supply, dry season vegetables are more important on the groundwater pumping systems than on the other non-rice perimeters.

The remaining 3,000 to 4,000 hectares of irrigated land is in individually managed micro and small irrigation systems. The water supply for this area is from 20,000 unlined hand-dug wells and perhaps 2,000 permanent concrete lined hand-dug wells. These are generally small family-sized systems serving from one-quarter to two hectares. A combination of hand and engine powered water lifting devices (referred to as motor-pumps herein) are used to draw water from these wells, with a typical lift ranging from 3 to 6 m.

Small-scale irrigation is found in all four systems. Small-scale systems tend to be 2 to 20 hectares in size, but their crucial identifying characteristics are their management system, not their size. Small-scale systems tend to be initiated and managed by a group of farmers or individual households, with minimal or no assistance from external sources or government agencies.

The cost of developing one hectare of medium-scale irrigation perimeter in Niger is high, even by Sahelian standards, amounting from U.S. $10,000 to over $25,000 per hectare. A key factor acccunting for the relatively high cost includes difficult topography, unnecessarily high design standards and a lack of competition in bidding for construction contracts. Water supply and management appear to be a problem on virtually every perimeter. Reduced rainfall has lowered the flow of the Niger River and reduced the inflow into the inland reservoirs. At the same time, heavy siltation has reduced the storage capacity of the reservoirs, and greatly reduced their ability to provide adequate water for dry season irrigation. Unnecessarily long pumping periods, excessive application of water, poorly cleaned canals and poorly leveled fields all compound problems of water supply.

In general, it has been reported that cultural practices on irrigated perimeters are adequate by West African standards, though there is considerable room for improvement. Farmers generally plan improved varieties and apply close-to-recommended levels of fertilizers. The principal agronomic constraints on increasing yields of irrigated crops include heterogenous soils that prevent plant water needs from being uniformly met; poor seed quality; lack of varieties that are resistent to cold in the case of rice, and disease in the case of vegetables; unpredictable rains and flood levels, leading to untimely planting that depresses rice yields; poor weeding practices and weed control; inappropriate fertilizer recommendations; non-uniform planting dates that lead to inappropriate applications of water on some of the crops; continuous mono cropping on the rice perimeters; and lack of availability and use of insecticides.

In spite of these problems, available evidence suggests and the JSF/W Team found that private returns per day of labor in irrigated farming exceeds those of rainfed agriculture. Onions, improved sorghum and peanuts are consistently among the highest, and cotton and rice among the lowest income producers of the field crops. The principal vegetables grown under irrigation in Niger are onions, tomatoes, peppers, and to a much less extent, carrots, lettuce and cabbage. Onion yields, which average in the neighborhood of 30 to 40 tons/ha, are good by any standards.

## Action Strategy

The action strategy involved the following set of office, organizational and field activities:

- Planning for the JFS/W
- Team Building
- The Field Studies
- Reports

There was nothing out of the ordinary in planning the activity except that it was important to basically field a highly qualified expatriate team with excellent French language capability. This was necessary as French is the professional working language in Niger and all the Nigerien Team members (except one who was from Nigeria and could only handle Hauza and English) were fluent in French but only two others could handle English. Furthermore, to carry out the dual functions of a study and a workshop required considerable expertise.

The Team was fortunate in that most of the expatriate members had been involved with writing the NAAR Project Paper and/or had very recent experience in Niger. In addition, the AID Science and Technology Bureau's Office of Energy in Agriculture provided funding for a Mechanical Engineer with African experience in water lifting energy analysis. This was not originally included in the budget for the JFS/W but it proved to be very worthwhile (as is obvious in the case study reports).

## Team Building

Team building activities were used throughout the in-country study period. The more formal part consisted of two days of lecture during a four-day workshop at the beginning, but the joint Team held periodic discussions (and a few formal training sessions) along with the field activities.

For the formal workshop we used a "Problem Identification Manual" which was prepaid by M.K Lowdermilk, W.T. Franklin, J.J. Layton, G.E. Radosevich, G.V. Skogerboe, E.W. Sparling and W.G Stewart and published as Water Management Technical Report No. 65B of AID's Egypt Water Use and Management Project Contract AID/ta-C-1411 in March 1980 by Colorado State University. Although the WMS II Project has a somewhat similar and updated manual, it is only available in English. We chose the above because it was also available in French. The translation was done by and made available through the International Irrigation Center at Utah State University.

For the lectures each of the expatriate Team members was assigned a presentation on rapid field procedures and data collection techniques in their field of expertise (using the Manual as a text). To provide a "feel" for the comprehensiveness of the manual its Preface is quoted below:

"This manual is designed as a resource for identification of farm system constraints on irrigated agriculture. Information contained in this manual will provide a means for determining what components of the system are not functioning adequately to achieve improved crop production goals. The farm water management system, the focus of this manual, has strong interrelationships with various subsystems. As shown in the idealized description of a farm irrigation system (Figure 1), definite physical boundaries are delineated. The first major boundary is the canal itself which is linked to the total irrigation system including storage, diversion, and drainage facilities. The drainage system is another physical boundary that demarcates the farm irrigation system. Within the farm system there are physical boundaries including conveyance channels, farm fields, irrigation basin, and drainage ditches.

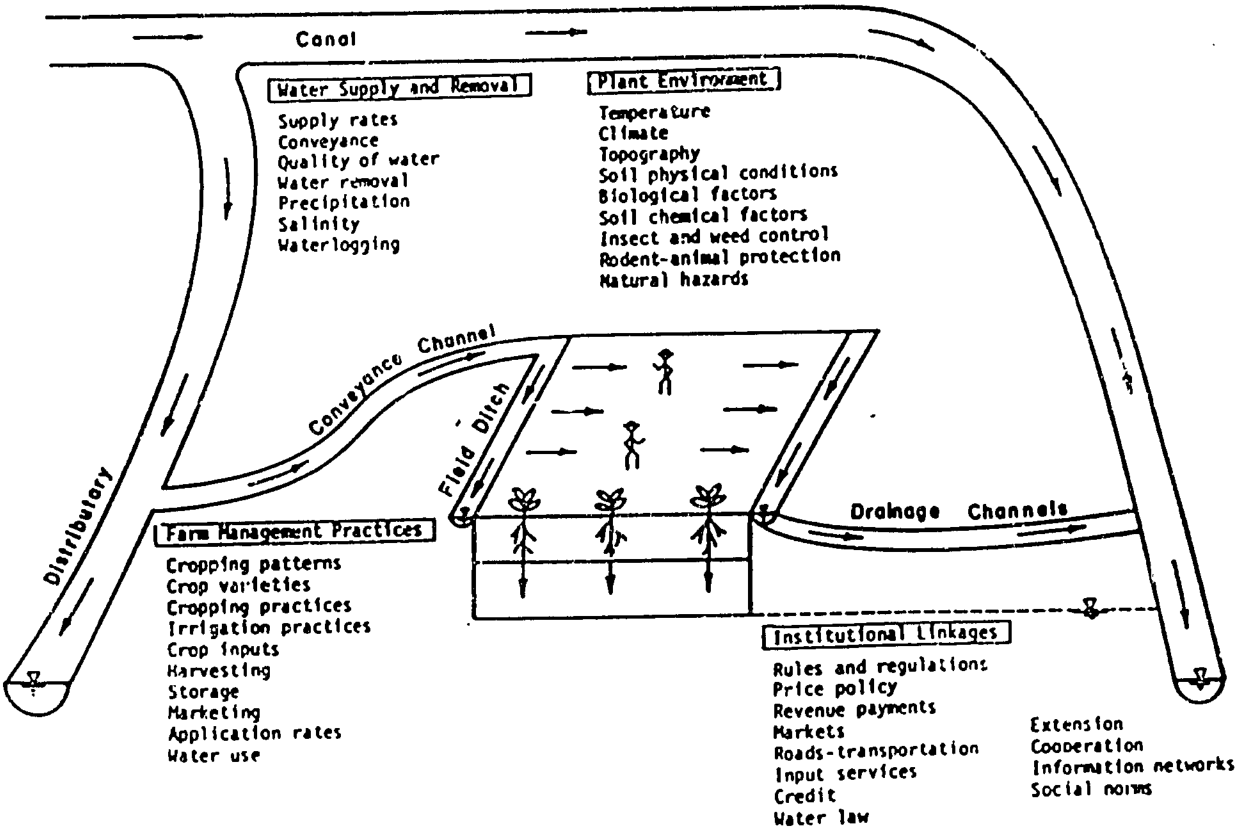

Figure 1. Idealized sketch of a farm irrigation system.

The farm irrigation system is also an open system since it is linked with not only the larger physical irrigation system, but with many organizations that regulate it and supply essential inputs. These organizations include irrigation and agricultural bureaucracies, and private and public organizations that supply essential inputs such as credit, fertilizer, insecticides, seed, and farm equipment. Institutional linkages also include markets and policy-oriented agencies.

The farm irrigation system is man-made. Irrigation is one of the most significant ways man manipulates physical and human resources to increase crop production. The purpose of the farm system is to provide an adequate physical, chemical, and organizational environment for the production of crops to meet basic human needs. In arid and semi-arid climates, irrigation is usually required to grow crops, and on-farm water management is often the greatest constraint to increased agricultural productivity.

The manual provides a systematic set of procedures for describing and analyzing the system in relationship to this purpose. A description of the system and its operation is developed initially from quantitative measurements defining the operational parameters of each of the four major subsystems. These subsystems include the plant environment, farm management practices, water supply and removal, and the institutional linkages as shown in Figure 1.

Several specialists are involved in analyzing the farm system. The engineer measures the efficiency of water distribution, adequacy of volume and rate of water supply, water use, water removal, water dependability, and other aspects. The agronomist is concerned with all the factors that influence the plant environment and measures these factors in relationship to their impact on crop yields. The economist identifies the levels of resource input and output for crop production and farm income. The sociologist identifies the decision-making processes of the farm manager and social factors such as behavior norms, institutional restraints, knowledge status, and information transfer processes that influence farmer decision-making. The perspectives and methods of each discipline are utilized cooperatively to establish a quantitative and qualitative description of each of the four major subsystems and the total operation of the farm water management system.

Information presented in this manual is designed around the four major subsystems: the plant environment, farm management practices, water supply and removal, and institutional linkages. Additionally, Chapter I provides a description of the manual and its use. Chapter II discusses problem identification. Chapters III through VI provide field procedures for describing and identifying problems in each of the four subsystems. Chapter VII discusses the analyses applied to the data collected under the four subsystems and the interpretation of these analyses."

The manual was designed and presented to provide a flexible set of guidelines, concepts, procedures, and methods for identification of factors that may inhibit efficient functioning of farm irrigation systems. Procedures were provided for a systematic approach to objective evaluation of existing farm irrigation systems. The manual provided several aspects that should be considered in evaluating a farm irrigation system. The factors and methods of investigation described served as a checklist to emphasize important variables that may require systematic examination where adequate data does not already exist.

The presentations provided answers to three basic questions about problem identification, namely:

- Why do problem identification studies?
- What is the problem identification process?
- How is problem identification done?

The presentations also provided both reconnaissance procedures and detailed diagnostic methods for the examination of factors related to:

- The Plant Environment
- Farm Management Practices
- Water Supply and Removal
- Institutional Linkages

In each of these four areas, special factors were presented and discussed along with the suggested reconnaissance and detailed diagnostic procedures and methods for use in the rapid appraisal field investigations. The Team members were provided with checklists for each area and encouraged to utilize them as a guide for determining if all essential factors had been covered in the field.

## Field Approach

The JFS/W focused on the jointly managed surface storage and groundwater perimeters as well as the individually managed micro irrigation schemes supplied from small (dug) wells. In addition, the Team conducted very rapid partial reviews of two jointly managed irrigated rice perimeter near Niamey which are supplied with water pumped from the Niger River.

The principal issues which were considered during the JFS/W included:

- Institutional constraints
- Labor constraints
- Micro and macro economics of each scheme
- Agronomic constraints
- Perimeter-wide irrigation scheduling methods and efficiency

- Farmer group activities
- Conveyance system efficiencies
- Field application efficiencies
- Recurring cost repayments

A mixture of standard and rapid field evaluation techniques were employed. Socioeconomic issues were addressed using field interviews with farmers and the various system and community level managers. The ONAHA manager at the jointly managed Galmi Reservoir scheme was part of the JFS/W Team. Engineering and agronomic issues were addressed using standard simplified field techniques for measuring such things as flows, energy use, irrigation application efficiency, crop parameters, etc.

Occasionally the Team members worked in the field as individuals, but generally they worked together in various groupings. Sometimes with a counterpart of the same discipline, sometimes in disciplinary group, sometimes in groups representing two or more disciplines. Discussion and analysis sessions preceding and following each field day were usually carried out either with the entire Team or with the Team split into two sub-groups, one representing the physical and biological sciences and the other representing the social and economic sciences.

The Team studied four major separate and uniquely different cases in the field. Each rapid appraisal involved 3 to 4 days of field work and associated discussions plus time to write a draft report. The Team developed and adopted the systematic outline presented in the Preface which was used for each case study report. For reporting purposes individual team members (or groups) were given specific analytical and writing assignments. However, Section 4 outlining specific restraints and recommendations for each case study was debated and developed by the full Team.

## Case Studies and Major Findings

The four principle cases studied were:

1. Community Managed River Lift Irrigation Scheme near Say, Niger (13 ha).
2. Djirataouna Electrified Multiple Deep Well Irrigation Scheme and the Safo Diesel Powered Ruwana Perimeter near Maradi, Niger (500 ha).
3. Galmi Reservoir Gravity-Fed Irrigation Perimeter at Galmi, Niger (245 ha).
4. Private Irrigation Small Dug Well Perimeters in the Tarka Valley near Madaoua, Niger (300 to 500 ha).

The circles on the map (see Figure 2) show the location of each of the study sites. The full text of each of the case studies is contained in Chapters II, III, IV and V which follow. A brief description of each scheme and a summary of the findings is presented for each case study in the remainder of this chapter.

## Community Managed Lift Irrigation

Along the banks of the Niger River there are a number of small-scale privately operated irrigation schemes which depend on water pumped from the River. The Team visited one such scheme near the village of Say, some 50 km south of Niamey. This scheme is on the west bank of the Niger River and utilizes the medium textured soils on the banks of a marigot (old river oxbow lake). The current scheme utilizes a section of old concrete lined canal which is a remnant of an earlier development which supplied water to a rice field adjacent to the Niger River.

The basic features of the Say scheme are a river motor-pump which supplies water to the marigot through the old canal and a new inlet channel during the season when the River flow is low. During high flow periods the marigot is filled naturally through a flood channel. We estimated the first one-third of the water needed to irrigate a typical onion crop reaches the marigot without being pumped; and the final two-thirds must by pumped from the River with the lift ranging from 3 to 6 m.

From the marigot and/or the channels dug to supply it and extend its length, the water must be transferred through short 10 to 30 m long secondary channels. From these it must be lifted again to irrigate the approximately 84 parcels served from it. We were informed the average parcel size is approximately 0.3 ha and our sample measurements confirmed this. The average lift from the marigot to the parcels is about 1.5 m (+ or - 0.5 m) during most of the winter vegetable growing season. In about 20 percent of the cases the lift was accomplished in two stages by introducing a first stage lift between the supply and secondary channels. Most farmers use calabashes with about a 4 liter capacity and a swing motion (standing at the water level and throwing the water up to the irrigation channels) to lift the water to their plots.

Onions, peppers and tomatoes grown in small 8 to 16 $m^2$ (more or less square) level basins served by small earth channels were the norm. We saw some lettuce grown on the channel banks and the bunds between basins and some corn grown in furrows in larger basins. Only about one-half of each parcel was currently being irrigated.

The Team only concentrated on the winter onion cropping program which is produced from seedlings transplanted in December. The crop requires about four months to mature and is thus harvested during April. The net water required by an onion crop ranges from approximately 5000 $m^3$/ha to 5500 $m^3$/ha depending on planting dates.

The farmers cooperated in digging the necessary main channels and more or less individually dug their own secondary channels. They also built their own field channels and leveled their basins for irrigation.

Operation Overview: When the motor-pump was installed in 1984, it operated for one month prior to the end of the irrigation season. A defect occurred in the starter motor which prevented further use until ONAHA arranged for its repair. There is some indication that the unit may have fallen into the river (or perhaps been submerged during the 1985 flood) which may be the cause of the premature failure of the starter motor. During the 1985 and 1986 irrigation seasons, the only water available to the farmers was the water naturally stored in the marigot following the Niger River's flood season.

All of the naturally stored water in the marigot had been consumed by the time of the Team's visit which was the first week of February 1987 and the pump was scheduled to be operated 13 hours every other night until the end of the winter crop season. The Team measured the discharge with a flowmeter and found it to be 30 lps which converts to an average of 1400 $m^3$/day to serve the estimated 13 ha of land being irrigated.

Theoretically the motor-pump is managed by the cooperative with whatever technical assistance they can get from ONAHA. The cooperative makes some effort to collect a redevances from the farmers to: buy fuel and lubricants; any for repairs and depreciation; and pay the pump operator. But this is done on an as-needed basis apparently without any means of applying sanctions for those who receive water but refuse to pay. The cooperative also must help organize the farmers to dig and clean the main inlet channel and marigot extension channel.

Farmers dig their own secondary intake channels and pits for standing in when lifting water from them. They also provide their own calabash (buckets) and ropes plus erosion control which is needed where the calabashes are emptied. The lifting rate is in the neighborhood of 0.9 to 1.3 lps for each calabash when operating steadily and sometimes two men work side by side producing over 2 lps.

The water is distributed within each parcel through a network of small eastern channels to level rectangular basins ranging from 2 to 4 meters on a side. Flow to each basin is controlled by an irrigator who opens and closes temporary earthen dams constructed and/or removed during each irrigation cycle as needed. The careful leveling of the basins and careful timing of inflows to obtain uniform depths of application within and between basins is essential for efficient irrigation.

Typically, the average depth of the water applied per irrigation cycle is approximately 30 mm which requires 300 $m^3$ per hectare. The total (or gross) depth of water applied per season is 1050 mm. Using an assumed swinging calabash average water lifting rate of 1.1 lps (4 $m^3$/hr) it would take 2,625 hours of steady labor per season to vertically lift enough water 1.5 m to irrigate on hectare of onions. Based on the going wage of 100 FCFA per hour for heavy pumping labor, this would cost 262,500 FCFA per hectare.

(It is interesting to note that even with the inefficient motor-pump, according to the Teams' computations it would only cost 115,000 FCFA per hectare to lift all of water 4.5 m by motor-pump as compared to the 262,500 FCFA to manually lift it another 1.5 m.)

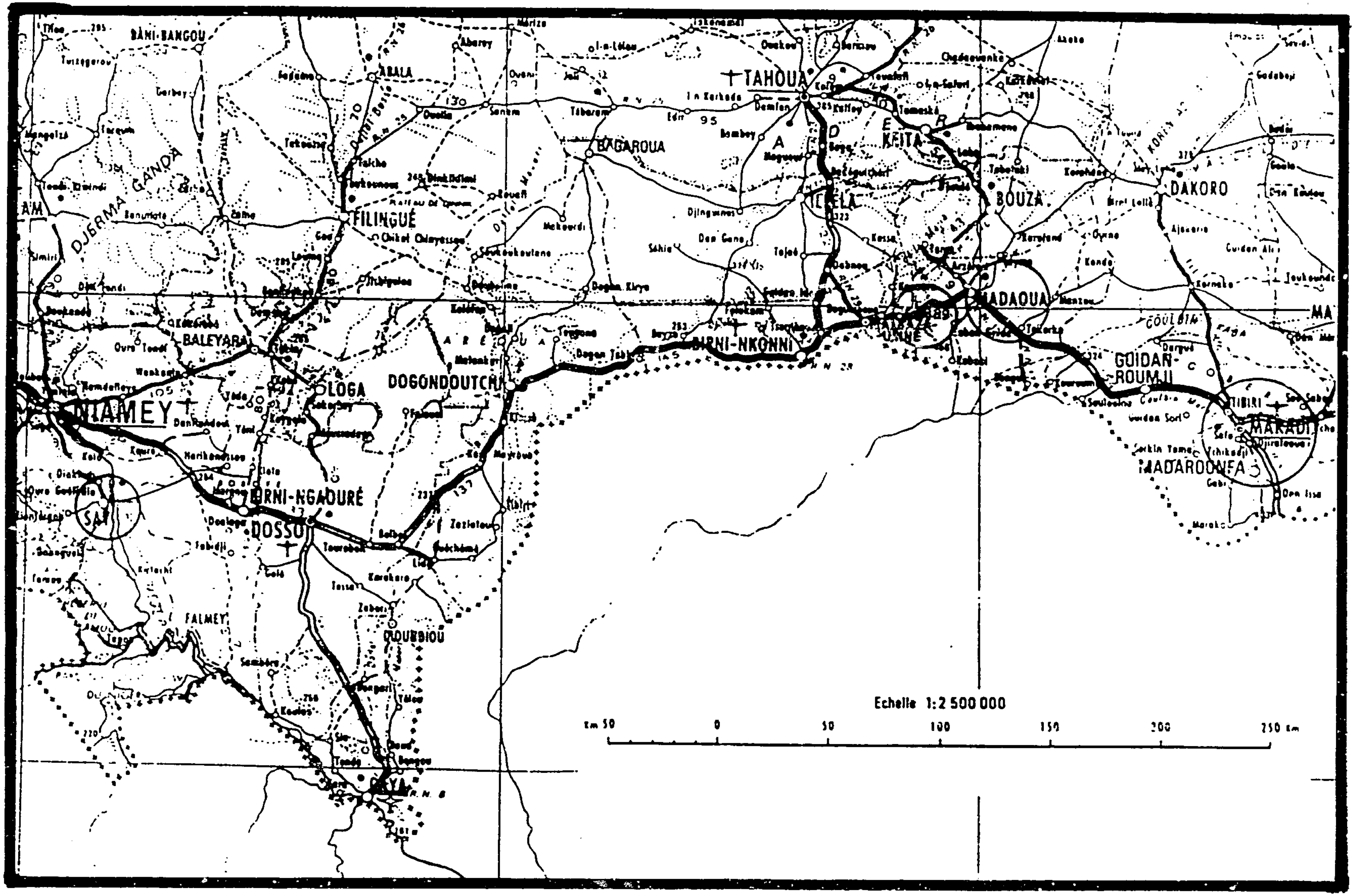

Figure 2. Location of the Four Irrigation Case Study Sites in Niger (see circles).

Land is not a constraint on production, but water is according to farmers. Land on the marigot system can be obtained from the owners of land situated around the inlet and extension channels and the marigot itself. Allocations are annual in principle, but no rents are charged. Irrigators might provide proprietors with a token payments of a bag of onions at harvest. Limited availability of water, which is entirely related to the low rate of payment into the collective fund for diesel fuel, maintenance and repairs, constrains production. But, farmers indicate that there is little competition for labor between dry season irrigation and other components of the farmers system.

Evaluation of Performance: Overall, the performance of the individually controlled lower portions of the marigot system was quite good. However, the Team was not favorably impressed with the installation and operation of the motor-pump. It was not set up level and rested on a rubble stone base. The wheels and tires on the motor-pump trailer were missing so the unit had no cushion to absorb vibrations.

The Team has no reason to assume there is any routine maintenance program for the motor-pump. In fact, we doubted that under the current program of operation it would last through the irrigation season. (It consumed 4 liters of motor oil in 12 hours of operation.) The diesel engine was being operated below rated speed and would have pumped 20 percent more water per liter of diesel fuel if operated at its rated speed. However, the pump was being operated long enough to provide sufficient water to the marigot.

Approximately 5 percent of the water being pumped was lost in the first 50m of the old canal. Furthermore, the old canal was constructed to serve the adjacent land by gravity flow. Thus, the water lift was at least 1.5 m greater than necessary for supplying the marigot. Other aspects of the main system performed adequately except that many of the parcels along the inlet channel only had access to water when it was flowing. Therefore, since the motor-pump was operated for 13 hours every other night, they only had daylight access to the flowing water for a short period every other morning.

The irrigation system management and maintenance at the parcel level seemed impressively good on the few parcels carefully studied. The Team estimated that field channel losses were about 5 percent and on-farm irrigation efficiencies were in the neighborhood of 60 percent because the field channels are short and the basins are small and quite level. These estimates were based on physical flow, time and topographic measurements. Assuming a main system efficiency (below the leaky lined canal) of 90 to 95 percent, the overall irrigation efficiency may be in the neighborhood of 55 percent during the peak water use period and the overall seasonal irrigation efficiency is probably in the order of 50 percent which is quite good.

We did not critique the crop management practices, but the overall appearance of the onion crop was good. The fields were carefully weeded, had good color, were free of insects and the planting density seemed appropriate. Estimates obtained by different Team members place the likely yield of onions at Say at somewhere between 35-42 tons of bulbs per hectare, which is very good.

Irrigation System Economics: With the combination of an efficient low-lift river pumping system and a manual secondary lifting system, total irrigation costs would be approximately 300,000 FCFA/hectare per year at Say. With the current inefficient river pumping system, it is approximately 10 percent higher. While these costs are high, they represent total costs as compared to 230,00 FCFA/ha for operating costs only at Djirataoua. They are not favorable relative to 150,000 FCFA cost per hectare for the motor pumping systems surrounding Galmi and in the Tarka Valley; but Say farmers are still able to compete because of a greater reliance on drying onions. This arises because labor expanded in drying represents a significant portion of total value added and offsets the disadvantage of a high cost pumping systems. Moreover, small motor-pumps would not be able to maintain such low costs given the higher lift and longer run at Say. Thus, the system, as it has evolved, is able to operate economically under current market system/price relationships.

There are manual pumps which would reduce the labor up to 50 percent. But for such pumps to be cost effective, they would need to be available for about 30,000 FCFA, easily and cheaply maintained using indigenous capabilities, and probably financed. Unfortunately, the Team knows of no such pump. Hand pumps (such as the rower type) might reduce labor by 30 percent. Although considerably cheaper than treddle pumps, they would also not be cost effective.

Small 3-hp motor-pumps co-operatively used to irrigate a total of 0.6 to 1.2 hectares each, would be very attractive compared to hand lifting. However, this would require groups of 3 to 6 farmers to organize and would require additional surface channels and construction of irrigation infrastructure. Furthermore, not all of the lands now being irrigated from the marigot system are situated (or have the necessary topographic conditions) for collective pumping. Moreover, some families may not have alternative employment for family labor. Relatively high risk and cash flow inputs associated with motor-pump operations present additional obstacles for many farmers.

In spite of the relatively high yields obtained by onion farmers at Say, their distance from Niamey forces them to adopt value-adding strategies that offset their high transport costs. If all the output were sold at the main harvest time, farmers would earn only 300 FCFA/day. To cope with this situation, farmers shift to drying onions as a means of storing their commodities and reducing transportation costs. Counting the savings in transportation costs and bags, farmers earn an additional 1,100 FCFA per fresh bag equivalent for their labor when selling dried onions during the off season as opposed to selling fresh onions during the flush season. Given the added labor required for drying (roughly one person day per bag of fresh onions), the average return to labor increases from 300 to 540 FCFA per day. This explains why these farmers keep producing onions when high irrigation costs and harvest season prices for onions clearly provide insufficient incentive.

This case study demonstrated that irrigation system economics are intimately connected to the cropping pattern and, in this case, to marketing strategies that influence the total return to farmers. Pumping costs with the hand lift systems at Say are high, but the system is still sufficiently competitive to maintain a market position in the face of competition from Galmi, albeit not in head-to-head competition. Say producers are filling a market niche by drying onions, because of relatively low fresh onion prices, that does not yet interest producers at Galmi. If and when it does, Say producers will probably have to shift away from onions altogether if they are to continue to find irrigated vegetable gardening profitable.

## Deep (Drilled) Well Irrigation Schemes

The Djirataoua Perimeter is the main part of a deep well irrigation scheme near Maradi. It consists of a group of over 40 deep wells. Each well is fitted with a submersible pump which receives its power from an electric grid. Thus, the power grid serves to knit the well/pump units together. However, each unit serves a small (8 to 13 ha) irrigation system. In addition to visiting several electric pumped well systems served from the grid, the Team visited one of three Ruwana (circular) systems served independently. We have included information gathered at the Ruwana Perimeter at the village of Safo for an economic comparison with the Djirataoua Perimeter. The well pump at the Safo Ruwana is diesel powered.

The IBRD funded Djirataoua perimeter (project) lies in the Maradi Goulbi. Average annual precipitation and mean temperature in the area are around 600 mm and 27°C, respectively. The dominant soils within the perimeter are sandy loams and loamy sands underlain by alluvial sands at 45-75 cm, which generally establishes the same effective rooting depth.

The Djirataoua project consists of approximately 500 cultivated hectares supplied by 48 tubewells of which only 44 are now operable. Each well is equipped with a 3.7 kw or 7.5 kw submersible pump. The average dynamic head is about 10 m and the discharges are about 50 $m^3$/hr or 85 $m^3$/hr, respectively. Each tubewell serves an irrigated area ranging in size from 6 to 21 hectares with an average size of approximately 11 hectares. Approximately 1,312 parcel holders are served by the system, with a net cropped area of 0.32 ha per farmer (40 m X 80 m). Water is discharged from the tubewells into prefabricated, concrete rectangular channels (30 cm X 45 cm). At the parcel level water, is removed from the lined channel into field channels with the use of aluminum siphons.

The common characteristic of the Djirataoua parcel holders farm enterprises is possession of at least one 0.32 ha parcel. Since the average farm size is Maradi department is 2.97 ha, the irrigated parcel, with a cropping density of 1.88, actually represents 20 percent of the surface area of an average farmer's holdings. (A year round cropping cycle is suggested for the irrigated field which gives the 1.88 intensity.) Since the majority of the crops grown under irrigation are considered cash crops, the addition of the irrigated parcel to the farm holdings represents a considerable additional commitment of labor and other resources to commercial agriculture.

Each 0.32 ha parcel is divided into two 0.16 ha soles. One sole rotates cotton (rainy season) - peanuts (end of cold to end of hot dry season) in year one with sorghum (rainy season) and varied vegetable production (cold dry season) in year two. The second sole rotates sorghum (rainy season) - wheat (cold dry season) in year two. This cropping calendar and rotation provides a cropping intensity of two (two harvest per year on each unit of land). However, for 1986-87 perimeter management modified the crop rotation in order to extend the cotton season as a measure towards rectifying outstanding debt. Electrical supply to the perimeter was cut off in January 1987 by NIGELEC for non-payment of electricity consumed. The perimeter will not be irrigated and cultivated until the rainfed crop season of 1987 and thus was not being operated during the Team's visit.

The Djirataoua perimeter was originally expected to provide a relatively low cost method for irrigating crops on land located along the Goulbi Maradi, a seasonal river in Maradi Department. By the time the first half of the original system was completed, however, no money remained with which to complete the second half. Overall system cost had risen to 2.3 billion FCFA for 497 hectares of cultivable hand (4.6 million FCFA/ha). In an effort to lower costs still further, the Maradi Project established three experimental single-well pumping systems in nearby villages. Costs for the one operating at Ruwana Safo at the time of our visit amounted to 25 million FCFA for a 9 hectare unit. That comes to 2.8 million FCFA per hectare.

The Ruwana perimeter at Safo supplies irrigation water to 4 ha of land in the dry season and up to 10 ha during the wet season surrounding the well plus domestic water to the village of Safo. The perimeter is unique in that the irrigated area is circular and water is conveyed from a central tank through 115 to 185 m long aluminum pipes (with gated opening over 0.75 m) to small field channels which feed the small basins. The pipe is laid along 9 different radial legs so field ditches are short and seepage losses from them is minimized. The central tank is supplied from a drilled well with a pump powered by a diesel engine. Farm holdings are small with the average size being 0.16 ha.

<u>Operational Overview</u>: The Djirataoua perimeter consists of 4 large units, each one constitutes a co-operative associated with a particular village. Each of the 44 operating irrigation units (GMPs) within these larger units, has its own pump and management committee. Each GMP has some 12-35 parcel holders who are organized into irrigation blocks of about 12 persons each.

Djirataoua is a jointly managed scheme in which three parties, ONAHA, the Maradi Department Rural Development Project (PDRM) and a local cooperative are involved. Under this system, ONAHA is responsible for technical services and cooperative training and monitoring, while the PRDN continues to provide certain major financial supports, notably at the level of infrastructure and infrastructure maintenance. The cooperative has nominal responsibility for all major aspects of production, commercialization and minor systems maintenance. Its executive body is the General Assembly composed of two representatives from each GMP. Each GMP (or pumping and irrigation group) has its own management committee composed of a President, Treasurer and Secretary and democratically elected by the members. Farmers cite the qualities of hard work and reliability as criteria for selection. Managing irrigation scheduling, harmonizing cropping operations, organizing pest detection and treatment and collecting relevances are responsibilities shared by the committee.

During non-peak periods, pumps are usually operated 7-9 hrs/day, completing one irrigation per week in 3-4 days. During peak periods pumps are operated up to 11-12 hrs/day, completing two irrigations per week usually in 6 days, where 7 days would be the exception. Irrigations are ordered in two shifts per day, with each farmer having half a day to irrigate 0.16 ha (one half of their actual holding). Generally, about 6 people in each GMP irrigate at the same time, each using 5 siphon tubes to give a nominal flow rate of about 15 $m^3$/hr (4 lps) per farmer.

Farmers in each GMP designate one among them to turn the pump on and off and oversee irrigations. Generally the local extension agent sets the irrigation schedule. Canal cleaning is generally initialized at the cooperative level and subsequently passed on to the GMP's who then organize and schedule the cleaning within their own sectors. Major canal repairs under 100,000 FCFA are the responsibility of the co-operative. Above this figure the responsibility technically goes to the project.

The power supply to the perimeter is provided by a 20 kv line from the regional generating plant at Maradi. Energy is charged to the cooperatives through a three-tier pricing structure, similar to that in force nationwide. The price per Kilowatt-hour (kwh) in 1985 varied from 56-70 FCFA per kwh, dependent upon utilization patterns. Power is provided to each of the 44 electric submersible pumpsets installed in tubewells distributed throughout the perimeter. The power supply at the Ruwana perimeter at Safo (the adjacent low cost option) is provided by a diesel engine coupled to a vertical axis pump.

Original plans for the Djirataoua perimeter were for 80 m furrows running down slope in the 40 m by 80 m parcels, each to be watered with 1-2 siphons in sequential order. However, farmers dig four 80 m long field ditches to irrigate four field sections of 10 meter furrows set perpendicularly to the slope of their parcel. Farmers irrigate from three to six hours and apply about 30 mm of water per irrigation. Wheat is grown in 10 meter long basins, rather than in a furrow system. The short field furrows permit relatively good application efficiencies, even on the sandy loams and sandy clay loams of the project area. The reduction of furrow length by the farmers allows them to increase evenness of water distribution. Local farmers simply do not have the means by which to develop 80 m length furrows of sufficient size, depth, and linearity to adequately deliver water at acceptable application efficiencies. There are two major sources of water loss. One is the infiltration loss in the field ditches which the Team estimated to be about 25 percent. The second is loss to percolation below the root zone which averages about 30 percent. Actual distribution efficiency in the short furrows is probably very high, in the range of 85-90 percent. However, actual field efficiencies probably are lower than these estimates would indicate (55 percent).

An assessment of the power distribution grid performed in 1982 indicated that grid design was not optimized and that the initial investment for the power supply component could have been reduced by 11 percent. Pumpsets of 7.5 kw rating provide 89.1 cubic meters per hour (average); pumpsets of 3.5 kw provide 53.6 cubic meters per hour when lifting estimated water the average dynamic lift of 13.8 m. However, the stactic level of the water table was monitored and found to be decreasing at the rate of 25 cm/year. Thus, well discharge will be slowly decreasing.

Irrigated parcels within the Djirataoua perimeter seem to be allocated exclusively to household heads and it is likely they provide the bulk of labor to it. Farmers feel that they have a certain amount of say over such irrigation management issues (at the GMP level) as organization of the irrigation schedule, secondary and tertiary canal and drain maintenance, pesticide treatment, and arrangements for labor sharing. GMP level meetings are fairly regular and views are freely aired when it is felt major decisions are imposed upon them. While it was recognized that water stealing and lackadaisical maintenance were occasional problems, most farmers felt sanctions could be successfully applied at the GMP level.

The cooperative management committee sees itself making decisions and passing them down to the GMP leadership and supervising perimeter cropping and marketing cycles in concert with ONAHA technical assistance. The overall technical parameters of perimeter operation have, however, been determined by technicians from ONAHA, CFDT and the Crop Protection Service. To some extent, cooperative and GMP self-management have been sacrificed in the interest of administrative expediency.

<u>Evaluation of Performance</u>: Monthly kilowatt-hour power use for each electrical sector in the perimeter was obtained and converted into hours of pumping. Resultant volumes of water applied were compared to ET crop calculations based on local pan and lysimeter data and divided over respective crop hectarages throughout the course of the year. The data indicate that enough global water is pumped annually to meet crop water demands at an application efficiency of 40 to 45 percent. However, monthly variations are significant indicating management and scheduling inefficiencies, resulting in evident crop losses and significant waste of water.

The irrigation schedule used by the extension agents is largely that prescribed by the early project documents. The irrigation schedule is far too rigid and does not address individual crop water needs, nor the diversity of soil types found in different sectors of the perimeter.

Management is not capable of adequately controlling water stealing, particularly if this occurs at night. Routine maintenance appears to be non-existent. Inspection of the canals, indicated that sealing of cracks or separated seams was not done, and canal sections with removed or broken cross-braces were left unrepaired.

As previously noted, farmers do reasonably well with field application of water. This is largely due to their own adaptations to the system--for example, that of reducing furrow lengths to 10 m. The notable exception, however, is the apparent poor timing/scheduling of water applications, which affects production adversely in some sectors and in different seasons. The project delivers rigid 30 mm or 50 mm net water application per hectare per week. These quantities are very rough approximations of crop water requirements. They do not reflect generally accepted crop coefficients for different stages of plant development. The spread in land preparation and planting dates from two to four or more weeks among parcels is a second major contributor to lower water application efficiencies. However, farmers interviewed said that to minimize energy charges, no pumping is done in a week when rain falls, but unfortunatley no rain gauges are in use at the GMP level to check whether the rainfall is adequate.

Soil heterogeneity is a problem both within and between parcels. Farmers were aware of these differences. But, cropping patterns and water applications have not been adjusted according to soil water holding capacity of specific blocks or parts of a farmer's field.

The overall cropping intensity and yield levels of the project's perimeters are about average for systems of this size and age. Average current and (practical) yields in kg/ha are: cotton 2,100 and (2,500); sorghum 2,000 and (2,800); wheat 2,200 and (3,000); peanuts 1,700 and (2,200); and onions 35,000 and (38,000). The practical potential yields can be achieved on many of the systems and the best farmers already surpass the target potential yields. Average yields are lower than the potential for a variety of reasons. Besides the spread in planting dates and water management, plant protection, and fertilizer application deficiencies already mentioned, there are substantial marketing problems due to a depressed cereal market.

<u>Irrigation System Economics</u>: In a normal year, the net economic value added by the Djirataoua perimeter is on the order of 43,000 FCFA per hectare, exclusive of capital costs and depreciation of heavy investments. The incremental economic value added by irrigated land probably doubles during drought years as rising crop prices reinforce the effect of the lower opportunity cost of land and labor resources. The Team estimates that the economic internal rate of return of the investment in this perimeter, on the basis of the area cultivated, is a negative 7.1 percent per year. In absolute undiscounted terms, the project's net benefit stream, including recapture of the depreciation reserve, amounts to just over 700 million FCFA. This compares with investment costs of 2,300 million.

During the 1986 crop year, farmers at Djirataoua paid 180,000 FCFA per hectare as an irrigation assessment. Of this amount, 91,000 FCFA was payable to NIGELEC for electrical energy consumption. Farmers are complaining about the heavy financial burden, even though it is still about 30 percent below the level required to finance operating expenses and replacement of light equipment. (Government policy is to not charge farmers for heavy investment items such as the wells, electric lines, canals and works, studies, dikes, roads, buildings, and heavy equipment.) Charging farmers less means adequate provision is not being made for equipment amortization and system maintenance. Electricity power costs account for 40 percent of the irrigation assessment. Repairs and maintenance would amount to 23 percent of total costs, if adequately provided for, while depreciation would represent 29 percent.

Because of the relatively high operating costs that characterize a deep well irrigation system, and government policy that the perimeters cover their operating and maintenance costs, farmers at Djirataoua pay the highest irrigation assessment of all farmers in the country--by a factor of two. This places considerable pressure on their ability to earn above average returns for their labor. The average parcel of 0.32 hectares is cropped 1.88 times per year. It yields a gross revenue of 174,700 FCFA/ha when the peanut crop does well and when long-term prices are used to value output. After paying an irrigation assessment at the level required to cover operating expenses, however, the average return per day of labor amounts to only 590 FCFA. This is about the return that farmers obtain on their rainfed fields. Only the greater assurance of a crop during a year of bad rainfall and the provision of dry season employment keep them interested. This is in marked contrast to Galmi where farmers on the perimeter earn 50 percent above the prevailing agricultural wage.

Obviously, irrigation systems economics are not independent of cropping systems. At Galmi, where farmers rely more heavily on onions, gross revenue per hectare amounts to 925,000 FCFA; at Djirataoua, gross revenue per hectare is only 550,000 FCFA. The combination of low revenues and unusually high operating costs at Djirataoua makes it unlikely that such a system could ever be economic with the present cropping program.

Operating costs at the independent diesel powered Ruwana perimeter at Safo amounted to 20,800 FCFA for 0.167 ha or 124,800 FCFA per hectare in 1986. This covers fuel, repairs, salary for the pump operator, fertilizer, minor repairs, service and, presumably, a cooperative assessment.

For the Ruwana at Safo, farmers have considerably greater scope for improvement, since there is not required cropping pattern and they have more control over operation of the system. Coupled with the much lower investment costs per hectare, the Ruwana systems have at least potential of recovering investment costs over the estimated 20 year life of the wells. Much will depend on how effectively farmers take advantage of the flexibility which the Ruwana system offers. It is even conceivable that these systems can earn a competitive return on invested capital once farmers begin obtaining above average yields on a regular basis.

Institutional and Equity Issues: The single biggest institutional constraint cited by farmers to a more satisfactory overall perimeter performance is the weakness of official and private commercial networks.

The Team felt that part of the problem is the individual GMPs are not permitted to take full advantage of the divisible nature of the infrastructure in place. The GMPs have been unable to modify their crop rotation in response to recognized differences in soils type. Technical advice which would enable them to identify irrigation problems or the early stages of infestation are not forthcoming either. Furthermore, economically run pumps are billed no differently than inefficiently run ones.

Evaluation of pump operation and maintenance indicates the low level of technical expertise among parcel holders and co-operative officers. Poor irrigation and pest treatment practice may also be attributed in part to the superficial extension effort mounted by the ONAHA and Crop Protection Service staff. Given the small size of the technical extension staff, this is not surprising and little more could be expected.

Farmers perceive the benefits of cultivation on the perimeter as variable and unpredictable between parcel holders, as well as from season to season. The greater security of irrigated agriculture seems to elude them. In general, and under current conditions, cropping risks costs are high relative to yields. Farmers cite a number of factors in explaining the unequal and unpredictable distribution of benefits from perimeter operation.

In general, our rapid survey of farmers left the impression that imperfections in the management of technological elements of the system is not conducive to the realization of the economic and social potential of the co-operative and the perimeter. As a result, contextual variables, such as the social conflicts within the canton of Djirataoua, for example, are transferred to the arena of the perimeter.

## Surface Reservoir Gravity-Fed Irrigation

The Galmi perimeter is a 245 hectare gravity-fed system served from a reservoir. The main and secondary canals are concrete lined and the farmlands were precision leveled before the land was subdivided for settlement. The perimeter was German funded and constructed and implemented by the French. The system first began operation in the dry season of 1983-84. It is located along the Route Nationale, some 450 km east of Niamey. The system's 7,200,000 $m^3$ capacity reservoir is supplied by a 46.5 $km^2$ watershed. The system serves some 850 parcel owners. In addition to the 245 ha by gravity-fed irrigation from the dam, 20 ha (5 ha within the perimeter and 15 ha adjacent to the perimeter) are irrigated from shallow wells with rope and calabash as well as portable motor-pumps. Annual rainfall is around 450 to 550 mm, with mean annual temperatures on the order of 25-30°C.

The irrigated perimeter itself is laid out in a long-narrow pattern, stretching 6 km from the base of the reservoir to the end of the primary canal and having an average width of approximately one-half km. The principal canal has a maximum design/operational flow rate of 700 lps at the reservoir outlet, and runs virtually the length of the system. Twenty-five secondary canals off-take from the primary canal, with design flows ranging from 15-40 lps. Flows into the secondaries are regulated by fixed orifice gated outlets with check weirs situated in the principal canal immediately downstream of each to control/maintain the necessary heads. Both the principal canal and the secondaries are constructed of concrete poured in place.

The tertiaries are made from compacted silty clay soils brought in from outlying deposits. Simple gated turnouts serve the outlets on the secondaries. Any number of sandbag checks (depending on channel slopes) are placed within the tertiaries to control the water level. Typical parcel dimensions are 25 m by 100 m, and each is served by a set of 5 siphons according to design specifications. Original plans called for furrows 100 m long (during wet season cropping) running downslope the length of each parcel, with 2-3 furrows irrigated at a time.

The soils are mainly alluvial deposits by loams with some areas of sandy clay-loams. During construction the fields were leveled by bulldozers and thus areas can be found where a good deal of stratification exists in the upper soil horizon.

Total investment for the perimeter amounted to 2.5 billion FCFA of which 1.1 billion was for the dam and reservoir. The remainder covered irrigation canals, drains, roads, leveling, studies and other perimeter establishment costs. Over the 245 hectares of irrigable land in the perimeter, the total investment averaged to 10 million FCFA per hectare. In principle, the system allows for double cropping the entire area served.

Operational Overview: The formal institutional set-up at Galmi is similar to that at Djirataoua and the other inland perimeters managed by ONAHA. The perimeter is nominally controlled by an autonomous cooperative and technical norms and extension advice is supplied by ONAHA staff. Galmi is unusual in having a dual cooperative structure. There is a production cooperative, which handles input distribution and other matter related to perimeter management, but there is also a marketing co-operative, an older institution, which as been asked to handle the cotton market by the production cooperative.

The irrigation system was designed for all 25 sectors (secondaries) to receive water at the same time, with an average flow of around 2.5 lps/ha throughout the system. During off-peak periods irrigations run 8-9 hours per day for 3-4 days per week. During peak use periods irrigations can run up to 10 hours per day with irrigation taking place 6 days per week. On the secondary level usually 1 to 4 tertiaries are opened at a time with usually no more than 4 parcels irrigating simultaneously along the same canal. Each sector possesses a set number of siphons (rated at 1 lps each) directly correlated to the design flow of the secondary (sector) turnout. These are then rotated among parcels. Most parcel irrigations are completed in one day, when adequate water is available.

The opening and closing of the reservoir outlet and overseeing the distribution of water is the responsibility of an individual designated by the cooperative officers. Generally, scheduling decisions regarding reservoir opening and closings are made by the ONAHA perimeter director himself, who confers with the cooperative officers. Along the secondaries, it is the sector head elected by the represented farmers, who is charged with overseeing the "tour d'eau." Major maintenance and repairs are addressed by the ONAHA personnel assigned to Galmi, and the cooperative to a lesser extent. Material for repairs and contracted assistance is paid for out of co-operative funds. Since the system is relatively new, few repairs have been necessary thus far. Most of the regular maintenance, however, takes place along the unlined tertiaries several times a year. This generally involves farmers weeding and clearing the canals, and reinforcing eroded sections.

All parcels have been leveled in the system and irrigation is primarily down slope with 10 to 12 m furrows, fed by several field channels running 25 m across the parcel width at regular intervals. (In the dry season the furrows are replaced by 15 to 25 $m^2$ basins for onion and wheat crops.) These cross channels are fed by the main field channel running the 100 m length of the parcel along one side, into which the siphons discharge. The system design prescribes 5 siphons, but generally 4 to 8 are used. All the siphons are placed at the head of the primary field channel. Parcel level flows are usually on the order of 4 to 10 lps. The above mentioned furrow lengths are a reduction from the original design plans of 100 m for parcel layout. As was the case at Djirataoua, local farmers simply don't have the means by which to develop long furrows capable of delivering water at acceptable application efficiencies.

Onions, wheat, maize and some cowpeas were being irrigated during the Team's visit. (There was also some late season cotton still standing.) Onions and wheat are grown in basins. Onion basin dimensions vary from 2 m X 3 m to 4 m X 8 m. Wheat basins are approximately 4 or 5 m X 7 or 8 m. Maize is grown on ridges and often intercropped with cowpeas. Farmers are supposed to receive water once a week. Water theft in the upper parts of the system and system construction errors result in irrigation frequencies ranging from once every four days to once in eleven days. Farmer response has been to put on as much water as possible when it is available.

This year 136 ha were planted in millet and sorghum and 106 were in cotton (which extends into the dry season). For the dry season (during the Teams' visit) 124 ha of onions, 8 ha of wheat, and 2 ha of maize/cowpeas followed the millet and sorghum. While onions were the preferred crop, wheat was planted by those whose food needs were unsatisfied, who could not obtain sufficient onion seed, or who lacked sufficient labor power for onion cultivation. Farmers seemed satisfied with these crops, although not necessarily with their mix.

Evaluation of Performance: Obvious design and/or construction flaws exist in the physical system. It was found that a considerable number of secondaries have flows well above and below their design. Severe inequities still exist in the flows (lps/ha) delivered to each sector. The flow rate per unit area served in the dry season varies from as low as 2.2 lps/ha to as high as 10.2 lps/ha. Measurements taken along the primary canal also indicated severe discrepancies between upper and middle sectors, and the tail-end sectors. While sectors 1 through 18 averaged 5.6 lps/ha, sectors 19 through 26 averaged only 2.8 lps/ha. In turn, this would require nearly 65 hours/ha per week of irrigation in the tail sectors to meet their water requirement needs, while the other sectors would require only half of that on average.

Operational losses are not high and in few places was it noted that any excess water was being wasted. Losses as a result of canal seepage also appeared to be minimal, largely due to the newness of the infrastructure. Most losses are in the field distribution channels and particularly in certain sectors where over-irrigation is significant due to an "excess" availability of water. Overall irrigation system application efficiency in meeting crop water requirements are on the order of 50-60 percent. Global efficiency may be near an acceptable level, but internal variations within the system are high enough to indicate potential crop losses and water wastes.

No apparent prescribed irrigation schedule exists for the perimeter. Decisions as to irrigation scheduling appear to be made primarily by the ONAHA perimeter director, and as was found at Djirataoua, scheduling does not address individual crop water needs nor variances in soil types between sectors. Capability among ONAHA personnel to assess differences in water needs among various crops and soil types seems to be limited. Monitoring of water use among secondaries is evidently poorly done by those charged with the responsibility. However, monitoring of water scheduling by the sector heads within the sectors seems to be done fairly well. In addition, scheduling among farmers along the tertiaries seems to function smoothly.

Farmers appear to do reasonably well with field water applications by adapting to the system in various ways. Farmers at Galmi are expert onion growers and good producers of rainfed cereal crops. System performance is a bigger problem than on-farm water management in onion production. But, on-farm water management can definitely be improved on rainy season crops. However, better supplemental irrigation is closely tied to the amount of water storage behind the dam. The cooperative does not want to release water before or during the rainy season if it will adversely affect the dry season cash crop of onions.

The current average yields of sorghum, wheat, cotton and onions was 10 to 15 percent higher than at Djirataoua. Thus, they were quite close to the practical potential values. However, potential yield figures may be adjusted upwards if better varieties are introduced, and if applied research is done on crop fertilization and plant protection practice to improve yields.

<u>Irrigation System Economics</u>: As a system, the Galmi perimeter is not economic, in spite of the substantial returns earned by farmers. The overall economic internal rate of return is zero using a 23 year time horizon and rises to 3.0 percent using a 40-year time horizon. Because of siltation problems, the 40-year time horizon will not prove realistic unless significant additional investments are made in soil

conservation for erosion control in the watershed. These additional investments will probably offset most, if not all, of the higher return obtained from the longer time horizon.

One benefit of the perimeter that appears to have not been anticipated is a rise in the water table in the area below the dam. This has permitted a significant expansion of off-perimeter dry season cultivation. It represents an increase of 15 hectares over and above the area existing outside of the reservoir/perimeter areas before the project. This benefit accounts for 10-15 percent of total benefits in the far out years when siltation in the reservoir is expected to sharply reduce dry season onion cultivation.

A rotation of cotton, sorghum and millet during the rainy season, and onion, wheat and/or cowpeas during the dry season is evolving. Because operating costs are so low, average economic rents/returns to management are quite high as compared to other irrigation systems in Niger, and that of Djirataoua in particular. The average return to labor employed in agriculture on the perimeter is about 935 FCFA per day, as compared to an average agricultural wage prior to the project of somewhere around 500 FCFA per day plus one or two meals. In contrast, the average return at Djirataoua is about 600 FCFA per day. From the farmers perspective, the Galmi perimeter is profitable indeed.

<u>Institutional and Equity Issues</u>: At the level of the GMP, organizational issues involving canal maintenance and irrigation scheduling seem to have been worked out. Design errors in the water distribution system are penalizing some farmers in GMPs 2, 3, 15, 25 and 26. They are receiving an average of one irrigation every two weeks. Although this reduces yields considerably, no adjustment is made in their cropping fees.

Most overt conflict appears to be related to technical flaws in perimeter design or operation. Disputes over parcel allocation have diminished with time, although some still claim they were unfairly treated. Accommodations with technicians over petty water theft seem to have been worked out. Violations of irrigation schedule occur but seem to have diminished since water is not scarce overall. However, those GMPs which have a water deficit are relatively disadvantaged insofar as the deficit affects crop choice and crop yields and there is considerable latent tension over this situation.

One goal of the perimeter was to diminish social disparities. This is a patent failure, but it was unrealistic to expect that economic development would reduce disparities. The average farmer is certainly no worse off than before, but the possibilities for wealthy farmers and merchants to turn bigger profits at their expense have increased. Sharecropping and purchase of standing onion crops are one mechanism. Monopolization of cooperative structures by this group is another.

There are a couple of groups of unintended beneficiaries of perimeter development. The first, of course, are the off-perimeter onion producers whose available dry season onion hectarage has doubled thanks to dam seepage and irrigation losses. The other group is a number of gardeners near the perimeter who persist in stealing water from the secondaries. The perimeter technicians are unable to sanction these individuals since their limited authority only extends to legitimate parcel holders. Cooperative officers have been unwilling to intervene. One fruit orchard gardener who uses canal water (outside of the official perimeter), and who is part of the cooperative management committee has, however, been prevailed on to pay a relevance to the cooperative.

Development of the canal system and common use of irrigation water for drinking purposes has contributed to the development of an endemic schistosomiasis infection among residents of Galmi. No public health campaign exists to educate the population about this danger or treat their symptoms.

## Private Irrigation Development From Dug Wells

The Tarka Valley case is not a project in a normal sense, for it is merely a place where conditions are favorable for private dug well development. Because of its favorable location, climate, soils and the relatively easy availability of shallow groundwater, hundreds of private entrepreneurs have invested in developing small plots of irrigable land. Typical plots are 0.1 to 0.3 ha irrigated from nearby dug-wells from which water is lifted by hand of by motor-pump. Together, these small irrigated enterprises make an irrigation project that is still rapidly growing in area irrigated.

The area visited by the field Team lies between the Route Nationale and the Nigerien border, due south of Madaoua. Traditionally irrigated onion cultivation in this area is extensive, with surface area estimates on the order of 300-500 hectares. Mean annual rainfall is around 500 mm, with high variations from year to year. Mean annual temperatures are on the order of 25-30°C. The low-lying central portion of the valley is an ancient sandy wash overlain by 2 meters of alluvium, thus, creating near ideal conditions for low-lift irrigation gardening. The soils in the lowest areas are dominated by clay loams, while those soils on slightly higher ground within the same general area are largely sandy-clay loams.

Groundwater is abundant, fluctuating in depth from 1.5 to 3.5 m throughout the length of the dry season. Recharge is fairly rapid in the area. However, it was found that a problem does exist with groundwater quality, particularly with wells penetrating to deeper depths. Only 2 out of 11 of the shallower traditional unlined wells which were sampled had unacceptably high salinity as measured by electrical conductivity (EC) values, while 9 out of 11 of the deeper concrete lined wells sampled indicated high EC values. The indication being a stratification of water quality in the aquifer.

Most individual onion plot sizes tend to be about a tenth of a hectare. Some plots using small motor-pumps (3.5 and 5.0 hp) are larger than this, however. In most plots water is lifted manually in the traditional manner with a calabash (a half-gourd attached to a short rope). Each plot has one or more wells, stabilized with either local wood and straw materials or concrete rings supplied through the Lutheran

World Relief (LWR) Well project or low-cost commercial financing. The plots are divided into small rectangular basins of 3 to 8 $m^2$ with the larger basins usually found in the motor-pump supplied plots. These basins are then fed from the wells by a series of small field channels networked across the plot. Typical elevation differences within the small basins ranged from ± 5 mm and the average depth of irrigation applications is 14 to 25 mm.

Privately owned parcels supplied from several non-lined traditional wells are being replaced by larger parcels equipped with motor-pumps, drawing water from concrete-lined wells. These modernized parcels offer substantially higher returns for labor and are likely to progressively squeeze the traditional growers out of business. The economic balance is delicate, however, and very much dependent upon the proximity of Nigeria, with its trading advantages (in the form of low priced motor-pumps and fuel).

Individual irrigated plot sizes vary from about 0.1 hectares, which is what an individual seems able to comfortably irrigate with calabash lifting methods, to 5 hectares employing motorized pumps and concrete-lined wells. For the small plots the rope and calabash, which require minimal capital investment, can easily be assembled and repaired by indigenous users and is constructed from components readily available at the village markets. The lifting efficiency of the device is low; in consequence, the technology is labor intensive and yields volumes of water which severely limit the area which can be cultivated by a single farmer.

Many farmers dig two or three traditional wells at an annualized cost of around 6100 FCFA each. Their only additional cost is for a cord of rope and calabash to draw water. These do not differ from the irrigation techniques used by off-perimeter farmers at Galmi. On the other extreme, a growing number of more sophisticated and better financed farmers are installing or relying on LWS concrete (pipe) lined wells and rotating 3.5 hp motor pumps between the wells. Some of these farmers are irrigating 0.5 to 1.0 hectares of onions with a single pump rotated among 4 to 5 wells/ha. This design is approaching a technical optimum for the small pump system.

The concrete-lined wells are no more expensive per hectare when installed at a 5 to 12 ratio vis-a-vis traditional wells and when financed at commercial bank interest rates. Their cost doubles, however, if financed at the opportunity cost of private capital which is estimated to be around 50 percent in rural areas. After allowing for the difference in the number of wells required to irrigate one hectare of land, the annualized cost per hectare is approximately 75,000 FCFA for both concrete-lined wells financed with bank credit and for traditional wells. Irrigation from lined wells is actually cheaper than traditional wells where motor-pumps are used for pumping water.

Tarka Valley area farmers manage their onion crop to try to reach markets at favorable price periods. Many farmers transplant their onions in late February, planning to hit the market after the peak production period.

<u>Operational Overview:</u> Dry season onion cultivation in the Tarka Valley is a case of indigenous agricultural intensification largely locally conceived and financed. Most aspects of irrigation in the zone are in private hands. Production is carried out as a household enterprise. Well construction and pump maintenance are likewise in private hands, although the cooperatives intervene to guarantee some loans for well construction. Transport is also in private hands, but is usually not in the hands of the farmers.

Water is lifted from depths of around 1.5 m at the outset of the dry season with water tables usually dropping to about 3 m from the surface at the end of the cycle. Manual lifting is done by one individual in a rhythmic dip-and-lift manner producing flow rates in the order of about 0.5 lps. The small 3.5 horsepower Yamaha or Honda pumps found in the area are usually throttled down to produce an average flow rate of about 1.3 lps. In off-peak periods irrigation of the entire plot is usually done every 2 to 4 days, with the more typical 3 and 4 day cycles taking 2 days to complete one full irrigation of the plot. During peak use periods each plot is irrigated daily. Farmers are at their plots 6 to 10 hours when irrigating the entire onion crop, with about 4 to 6 hours of this as actual pumping time. Numbers on the higher end of these approximations apply to those lifting manually.

During actual irrigation, an adult generally does the lifting while a second person, usually a child, diverts the flow of water into individual basins by hand, or with the use of a small hoe. When a motor-pump is in use only one person is required to manage the system--primarily to divert/distribute water. All repairs are done by the farmer/owner, usually during the course of the day as needs arise. These small maintenance efforts largely consist of fixing small breaks in the channels, reinforcing the cribbing of woven sticks traditionally used to stabilize wells, and removing collapsed sand material from the well bottom to maintain acceptable water storage depths. Routine maintenance is also done on the motor-pumps--with small repairs usually done by the owner. For larger repairs beyond the capability of the owner, there is an enterprising local repairman in the valley area who specialized in small pump repair.

Farmers apply substantial amounts of fertilizer and regularly treat their onion crops with dimethoate for thrip protection. A major problem is the weed challenge to the crop. Many farmers attempt to store onions. Village stores permit some to maintain onions for four to five months, although losses run up to 20 percent.

<u>Evaluation of Performance</u>: On-farm water management practices are good. Relatively careful application of water permits good yields to be maintained over time. However, water application efficiencies may be fine-tuned to better meet crop water requirements once the seasonal progression of soil and water salinity status is better understood. Management and scheduling efficiencies can be expectedly high due to the "micro" nature of the physical system, the low incidence of soil heterogeneity within such a small area, and the single user/manager aspect of the system. Thus, farmers are able to meet crop water demands

at reasonably high overall irrigation efficiencies, on the order of 45 to 60 percent.

Seepage losses in the distribution channels between the wells and the basins were found to be on the order of 18 percent for the manual systems and around 10 percent for the motor-pump systems operating at higher flow rates. Of the existing traditional lifting technologies, that used by the manual lift operators seems the best adapted to the local setting; because water tables are too high to justify shadouf or animal traction units such as the dallou. The motor-pumps used in the area are throttled down well below optimum energy use levels, and the pumps themselves are poorly matched to the head conditions under which they operate in the valley area. But, this latter point is simply a result of what is available on the local market.

Farmers are familiar enough with their systems to be able to adequately meet the necessary leaching requirements--if not overly compensated for them. Farmers have the choice of pumping the added leaching requirement at the cost of added labor (or fuel) or irrigating only to meet ET requirements and taking the loss in yields due to salinity. It appeared that some farmers tend to compromise somewhere between the two. Since farmers are the individual owners/operator of their systems, closer control and monitoring of their plots results in a much better ability to meet the day to day demands of their crop than would be found in the larger developed perimeters.

Routine maintenance and repair in the small systems seem to be carried out well by the farmer. The singular exception would be that of major repairs for motor-pumps. From what was observed in the field, the farmers' sense of ownership and control of their plot results in systems that appear well maintained and managed. Basin leveling, which is done by hand, is quite good which is in part due to the small basins. The uniformity of basin inundation timing is also quite good, even when in the hands of the small children who usually carry this responsibility. Adaptation of basin size and canal capacities to exploitable pumping rates and the associated delivery techniques has evidently been highly refined over a long period of time, and thus results in the high on-farm irrigation efficiencies.

Irrigated farms utilizing handlifting provide an average onion yield of about 32.5 t/ha. The more input intensive motorized pumping yields over 37 t/ha despite having higher salinity irrigation water. Given the high density of planting and the good growing practices usually the farmers, these figures reflect from a 19 percent to about a 10 percent yield reduction respectively compared to a potential yield of about 40t/ha. Thus, additional soil and water management study is needed to determine if current leaching factors are optimal.

Irrigation System Economics: Hand-lifting cannot compete on an equal basis with the motor-pumping systems over the long run. With total costs running two to two and one-half times more than for motor-pumping, survival of the hand-lifting systems is tied directly to the production of high-return crops such as onions. As production expands and prices decline, these cost differences will eventually drive the hand-lifting systems out of business or will reduce their return to labor well below levels obtainable from other pursuits.

Looking at complete systems for pumping from an average depth to water of three meters--typical of much of the Tarka Valley. The total irrigated onion production costs range from 525,000 FCFA/ha for the traditional systems to 210,000 FCFA/ha for a motor pump systems financed with bank credit. At the present time, few farmers are attaining costs this low. Most seem to be running their motor-pumps at 1.25 to 1.5 lps instead of at a more optimum flow rate of 3 lps, because they can not handle larger volumes of water in their irrigation distribution systems. This makes their irrigation costs run around 350,000 FCFA/ha. But with a small amount of extension, and some redesign of field channels, they could easily expand the irrigated area and reach the lower cost levels. As irrigated crop production expands and onion prices decline, competition will force farmers to move in this direction.

The minimum cost of motor-pump system drawing water from shallow wells is not likely to fall much below 200,000 FCFA/ha on a wide-scale for production of one crop per year. This figure, then, represents the ultimate constraint on expansion of this system. But unlike the large irrigated perimeters, it is a full, unsubsidized cost, including amortization of capital as well as operating expenses.

At the present time in the Tarka Valley, irrigation farmers still produce mostly onions. Their input/output relationships appear to be quite similar to farmers at Galmi, with the exception that they time their planting so as to obtain higher prices at harvest time. In addition, some farmers are forced to "over-irrigate" in order to limit the accumulation of salts in the root zone. This increases their operating costs on the order of 20 percent or so. But at present pumping depths and prices for onions suggests that returns to labor are still well in excess of alternative employment opportunities. They average over 1000 FCFA per day for a motor-pump system obtaining 38 tons per hectare and 590 FCFA per day for the hand-lifting/traditional systems obtaining the same yields. In fact, the traditional systems appear to be located in areas where salt accumulation is less of a problem and, consequently, yields and returns to labor may be considerably higher. There is little doubt that Niger would benefit considerably from continued expansion of these small-scale systems.

The economic attractiveness of the calabash system at two meters of lift suggests that research on improved hand and animal pumping systems at increased rates of flow and shallow depths could have a very high social and economic payoff. Such research should have high priority under the NAARP.

<u>Institutional and Equity Issues</u>: Co-operative structures in the valley are relatively weakly developed. While commercial cooperatives exist to market recession agriculture cotton, villages devoted to onion cultivation have benefited little from cooperative credit, input or marketing programs. The "cooperative" in Tarka Valley basically consists of a prominent commercial farmer's private initiatives in the area of input supply.

Extension service activities are limited, but farmers have benefitted from the vigorous concrete-lined well development program initiated by LWR, extended by the sous-prefecture, and now almost entirely in private hands. Farmers recognize the need for help with crop diversification and pump maintenance. However, most inputs, including small pumps, pump parts and private technical help, come from Nigerien sources.

The locally initiated development of the Tarka Valley has resulted in an accentuation in differences in wealth between early innovators and late followers in the movement towards dry season onion production. Early innovators have recently managed to extend control over upstream and downstream market channels and when land resources became limiting they will no doubt also control land development.

Intensive onion production provides a source of local, dry seasons employment and acts to reduce labor out-migration. Competition of a familiar western variety is inspiring farmers to seek improvement in productivity through technical innovations, e.g., differential wage rates for skilled and unskilled labor. Inefficient producers, especially young ones with less access to cash and other inputs, will no doubt be squeezed out of independent commercial production. This will be accelerated by rapid introduction of motor-pumps.

## General Conclusions and Recommendations

The section deals with the global lessons learned, the comparative advantage of the various irrigation development options and general recommendations. A section outlining the "Specific Constraints/ Recommendations" is provided in the respective chapters for each of the four case studies.

### General Lessons Learned

The Team was pleased to find that irrigated agricultural practices at the farm level were generally quite good. This was especially true for onion production and less so for general field crops, but it does indicate a high level of indigenous farmer capability. This irrigation capability apparently results from the fact that irrigated agriculture has been practiced at the micro level in Niger for centuries.

Farmers traditionally prepare the plots for irrigation by constructing small (2 to 25 $m^2$) basins interconnected by a channel network. The basins are quite carefully prepared and leveled (smothered) with elevations differences no greater the + or - 3 to 5 cm. Farmers size their channels and basins according to the flow rate available, the soil texture and the topography. Where flow rates are very small, as with hand-lifting from 3 or 4 m giving flows of less than 0.5 lps, 2 to 4 $m^2$ basins are common. Where flows produced by hand lifting from shallower depths or by motor-pumps was in the neighborhood of 1 to 2 lps, 8 to 12 $m^2$ basin are common, and where flows from siphon tubes were over 4 lps basins up to 32 $m^2$ were being used.

The irrigation perimeters of Djiritaoua and Galmi were leveled and designed for using (80 or 100 m) long furrows fed from 1 or 2 siphon tubes. However, farmers elected to modify the applications system to conform to their traditional small basin or short (10-12 m) furrow approach of applying water. The Team feels the farmers were right in doing this as they simply don't have the means by which to develop long furrows capable of acceptable application efficiencies. This is because they use manual farming techniques and have only limited access to machinery.

We were also impressed by the ability of farmers to organize (with GON assistance) and manage their irrigation systems (water distribution and maintenance) at the tertiary level where this was required (except in cases where cultural, diversity was too extreme). However, we were not favorably impressed by the level of extension expertise, especially in the areas of irrigation scheduling; plant protection; and the operation and maintenance of the public irrigation infrastructure. These shortcomings appear to result from the lack of properly trained personnel and relevant information and not from their lack of interest.

Most of the irrigation potential in Niger does and will continue to require in water lifting. Therefore, minimizing the capital plus operating costs of lifting water is extremely important for the economic development of Niger's irrigation potential. In addition, much of the irrigation potential also must be supplied from wells. Thus, improving the efficiency and cost effectiveness of well development is also of major importance.

After the problems associated with water lifting and well development, the two next most important irrigation system related problem areas are efficiently conveying the water and scheduling the deliveries. While both conveyance and scheduling efficiencies are relatively high, both being in the neighborhood of 75 to 85 percent, there is still room for improvement. Thus, even with application efficiencies as high as 75 percent the overall irrigation efficiencies are between 40 and 50 percent under full irrigation. Even thorugh this is quite good, because of the high cost of lifting water (or storing it), maintaining even higher overall irrigation efficiencies is very important to the economic viability of irrigated agriculture in Niger.

Plant protection is perhaps the most important near and medium term agronomic problem. It affects crop choice (excludes peanuts and cowpeas), yields (cotton, onions), and poses multiple management problems (build-up and transference of pests from cotton). As the irrigated area increases plant protection problems will increase as well. Scheme managers, farmers and researchers need to concentrate their efforts in this area as a first priority. As economic analysis has shown, perimeter production become much more attractive when higher value cowpea and peanut crops can be grown in place of sorghum.

Very limited applied work has been done on the response of existing crop varieties to irrigation. Crop establishment, density, stress management and charges in production inputs, especially fertilizer, have barely been touched by research. The research that has been done in Niger has not been collated and synthesized. Furthermore, the practical experience of perimeter managers and farmers has been only lightly tapped. Experience and research on crop varieties used in Niger and neighboring counties has not been systematically compiled and reviewed. Even the older research results from Niger itself are underutilized.

Most irrigation systems are designed with a specific cropping pattern and rotation in mind. Many irrigation perimeters in Niger seem to attempt major shifts in cropping pattern on a system wide basis with little reference to the individual grower. As Nigerien policy shifts greater operating responsibility to cooperatives, ONAHA and marketing agencies should be careful to spread production and marketing among a broader range of crops. The irrigation requirements of most of the annual crops that can be produced in Niger do not vary so significantly that system operating efficiencies would be much affected by crop diversification. Planting dates on most of the perimeters are spread so largely that truly homogeneous water rotation blocks do not exist anyway.

## Comparative Advantages of Irrigation Development Options

Of the four case studies, three required water lifting. The cost of irrigation to the farmers was considerably higher for all of these as compared to the gravity-fed irrigation perimeter at Galmi. This is because farmers on all schemes, both public as well as private, are responsible for paying the recurring cost for operating and maintaining the irrigation water delivery system. But they are not expected to pay the major capital costs associated with developing the public infrastructures.

Even though the profitability to farmers at Galmi was the highest, from an overall economic (world economic account) point of view, the internal rate of return is zero, even with relatively high value crops. This is considerably better than at the Djirataoua deep well scheme which the Team estimates has an internal rate of return in the neighborhood of a negative 7 percent. But it is much lower than for the less sophisticated developments involving community lift irrigation or dug wells, and possibly individual community operation drilled wells like the Ruwana system at Safo.

Hand lifting water from dug wells, where the lift is less than 3 m, is still profitable for irrigating high value crops such as onions. But it is considerably less (only about half as) profitable as using motor-pumps for lifting the water. For hand-lifting to remain economically viable, new hand pumping technologies are needed. Hand-lifting is important economically because it provides employment, but without improvement in lifting technologies it will eventually be replaced by small motor-pumps.

At the present, small motor-pumps supplied from concrete-lined dug wells (or natural surface supplies such as lakes and rivers) are the most economic water supply systems in Niger. This is especially true where import taxes on fuel and the motor-pump units are avoided (by direct purchases from commercial sources in Nigeria). Such irrigation systems, if optimized, can even be operated profitably for growing relatively low value crops (such as oil seeds, and some grains).

## Recommendations

In the Team's view, the gravity-fed schemes like at Galmi have a viable place in Niger's irrigation development. But, this is only true where donors are willing to subsidize development. This is also true for the more elaborate rice irrigation schemes which require pumping water from the Niger River; and it is possibly true for the individual drilled well perimeters like the Ruwana at Safo. But we were not favorably impressed by the scheme at Djirataoua where an electric power grid supplies a group of wells. Consequently, we do not recommend further investment in this type of development unless a more economic electric mini-grid system were available.

Hand-lifting from shallow wells to irrigate high value crops not only provides a significant source of employment, it is also one means for enterprising farmers with little access to credit to get started with irrigated farming. But, for hand-lifting to be viable, the lift must be small (less than 3 or 4 m) and crop returns to water high. Thus, any development efforts, such as subsidizing large numbers of small motor-pumps for use on dug wells should be pursued with extreme caution. This is because they could easily displace the hand-lifting by lowering the water table and/or greatly increasing commodity supplies causing prices to fall. Therefore, the Team recommends that small motor-pump development be left entirely in the private sector without any subsidies.

In review of the delicate economic balance which keeps water lifting by traditional hand-methods viable, the Team recommends that the NAAR Project concentrate on finding and testing improved hand (and possibly animal) lifting technologies. There is also considerable room for improving motor-pumping. What are needed are pumping units which are better suited for the flow and lift conditions in Niger and improved sales and both private and public service networks.

The hand-dug wells are costly and the depth to which they can be dug is limited. In order to more fully develop the rather extensive groundwater resources in Niger, improved low cost well drilling technologies are needed. The Team recommends concentrating on technologies for constructing very low cost small diameter wells (75 to 100 mm) which can be installed by indigenous means (like in Bangladesh) to tap shallow aquifers; and lower cost larger diameter wells to tap the deeper aquifers like at Djirataoua. The small wells could serve individual farmers using hand or centrifugal-pumps and the larger wells could be used for community operated irrigation perimeters like at Safo using turbine pumps.

It has been suggested that there may be considerable potential for irrigation from groundwater in Niger. To better understand this potential a country wide reconnaissance level groundwater survey would be very useful. But, the Team recommends that instead of conducting costly detailed surveys, groundwater development should be allowed to proceed in incremental steps and carefully monitored. Development should be curtailed wherever either the quantity or quality of the groundwater appears to be unsustainable. While the present irrigation from groundwater in Niger is probably still sustainable, the needed monitoring of both the groundwater levels and water quality is not being done. Therefore, the Team recommends making a country wide reconnaissance level groundwater survey and carefully monitoring important existing developments such as in the Tarka Valley and at Djirataoua area.

The Team also recommends that efforts be made to improve irrigation scheduling, especially for the larger perimeters. While traditional water conveyance channels are satisfactory for the small flows produced by hand-lifting, they are not adequate for the larger flows from motor-pumps. In order to take better advantage of the larger flows, and/or optimize motor-pump effeciency, improved water conveyance techniques are needed. Such techniques might involve the use of lined channels or pipes. Assisting with improved irrigation scheduling and water conveyance technologies are two areas in which the Team recommends the NAAR Project concentrate.

The priority irrigation system and irrigated crop research needs in Niger are very applied ones. Finely tuned variety trials, precise water balance studies, and basic research should not be placed at the head of programming needs. Broad screening of advanced lines and stable crop varieties, simple three to four step fertilization trials and broad screening of herbicides and pesticides is far more important to irrigation in Niger. Much of this work can be done on existing perimeters by a relatively small group of researchers and technicians with skilled and strong central supervision. Currently there is no sustained irrigation research all within INRAN or ONAHA capable of handling on-perimeter trials or demonstrations of new technologies and synthesizing yearly experience on the principal perimeters. As Niger has already expended large sums of money to build and operate irrigation perimeters, a small and agile applied research unit offers substantial promise in improving return to irrigation investment.

Because irrigation is quite costly in Niger, to be financially feasible at the farm and scheme or perimeter level, it must be focused on relatively high return crops. This requires having production packages available which give high yields with low input costs as well as focussing on high value crops. Finding suitable high value crops requires spotting and working with those who have local, regional and/or international "market niches."

Rather than undertaking a new series of trials, an important effort should be make to sift thorough research already documented in Niger and from neighboring Sahelian countries on irrigated crop management as well as water development and application technologies. Such a review would help greatly to focus research programming and to orient on-farm adaptive testing. It may also provide directly usable technology overlooked to date by irrigation schemes growing crops other than rice.

Groups of farmers several farm individual outlets (or wells) do appear to cooperate quite well in operating and maintaining their collective part of the irrigation system. However, they still need managerial, financial and technical assistance in order to improve irrigation performance. This is particularly important in Niger considering the high cost of developing irrigation water supplies.

As with this study Team, a multidisciplinary diagnostic approach should be taken by the NAAR Project to determine the priority problems to be addressed by an applied-adaptive research program. Perimeter-wide studies and research should concentrate on the restraints to irrigated agricultural production. In addition the micro or on-farm irrigation needs of individual farmers (such as how best to lift, convey and apply water to their fields) should also be researched and extended.

# CHAPTER II

# COMMUNITY MANAGED RIVER LIFT IRRIGATION SCHEME, SAY, NIGER

Along the banks of the Niger River there are a number of small-scale privately operated irrigation schemes which depend on water pumped from the River. The Study Team visited one such scheme near the village of Say some 50 km south of Niamey. This was the Team's first case study and while somewhat less complete than the other three, it is nevertheless interesting and unique. Therefore, we have included it as one of the potential development models.

## 1.0 Scheme Setting and Description

The scheme is on the west banks of the Niger River and utilizes the medium textured soils on the banks of a marigot (old river oxbow lake). The current scheme utilizes a section of old concrete lined canal which is a remnant of an earlier development which supplied water to a rice field adjacent to the Niger River.

### 1.1 Physical Features

The basic features of the Say scheme are a river motor-pump which supplies water to the marigot through the old canal and a new inlet channel during the season when the River flow is low. During high flow periods the marigot is filled naturally through a flood channel. We estimated the first one-third of the water needed to irrigate a typical onion crop reaches the marigot without being pumped; and the final two-thirds must be pumped from the River with the lift ranging from 3 to 6 m. Figure S 1.1.1 shows a schematic of the layout.

From the marigot and/or the channels dug to supply it and extend its length, the water must be transferred through short 10 to 30 m long secondary channels. From these it must be lifted again to irrigate the approximately 84 parcels served from it. We were informed the average parcel size is approximately 0.3 ha and our sample measurements confirmed this. The average lift from the marigot to the parcels is about 1.5 m (± 0.5 m) during most of the winter vegetable growing season. In about 20 percent of the cases the lift was accomplished in two stages by introducing a first stage lift between the supply and secondary channels. Most farmers use calabashes with about a 4 liter capacity and a swing motion (standing at the water level and throwing the water up to the irrigation channels) to lift the water to their plots.

The pumping system installed initially in 1964 on the river bank to feed the canal from the river has recently been brought back on line (January 1987), after being out of service throughout 1985 and 1986. When installed new in 1984, the unit operated for one month prior to the

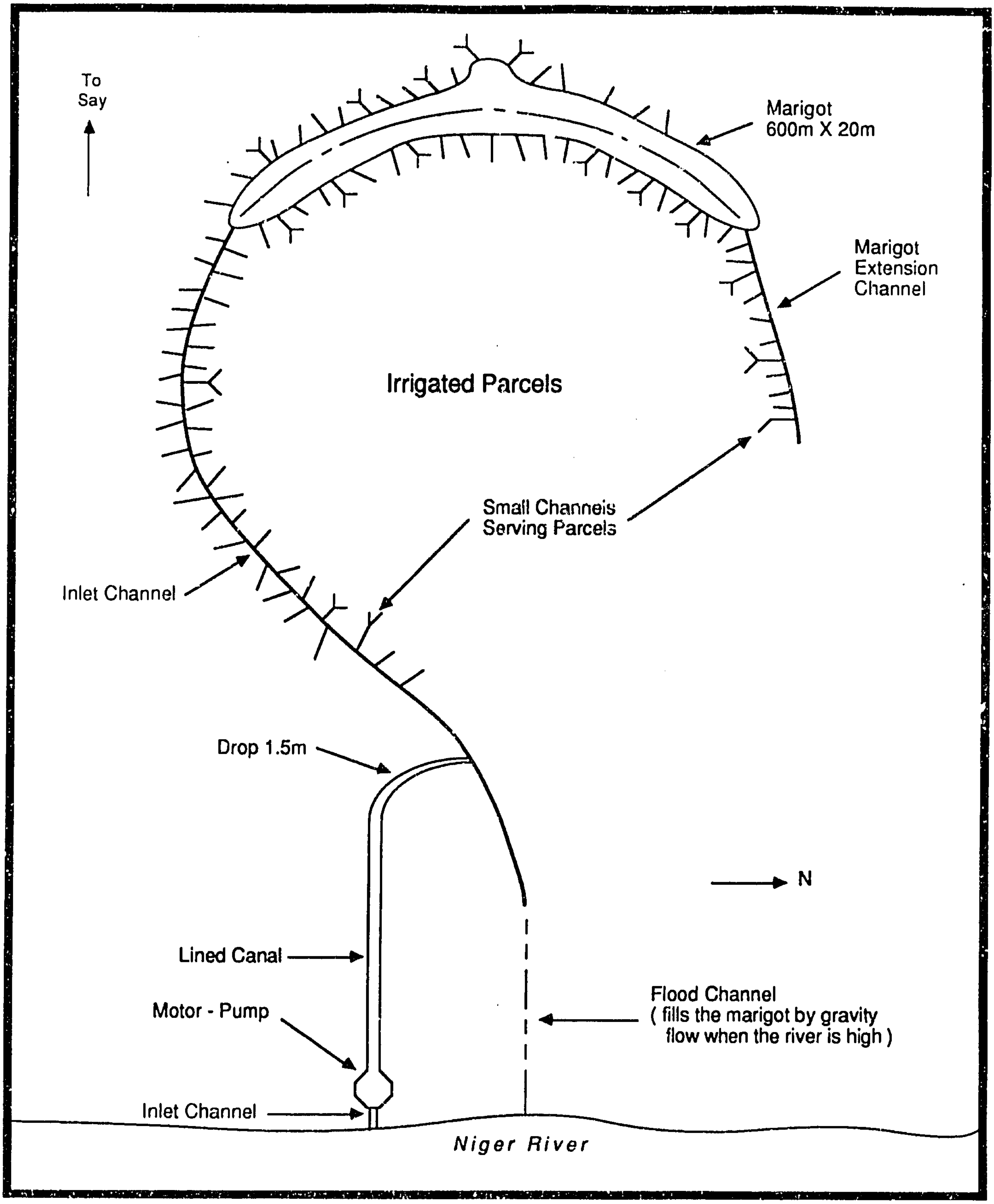

Figure S1.1.1 Descriptive layout of the Say community irrigation scheme.

end of the irrigation season. A defect occurred in the starter motor which prevented further use until ONAHA, the government parastatal organization which had initially provided the pump to the community, arranged for the repair to be performed. There is some indication that the pump may have fallen into the river during the 1984-85 season which may be the cause of the premature failure of the starter motor.

The motor-pump used diesel fuel and at the time of the Team's visit was lifting water 4.2 m to a previously abandoned lined irrigation canal. At the end of the approximately 200 m long lined canal the water cascaded down (dropped) about 1.5 m to the flood channel serving the marigot. The motor-pump lifted water from a short, previously dry, inlet channel connected to the river. A sketch of the general system configuration showing the location of the motor-pump lined canal, and dug channels serving and extending the marigot is presented as Figure S 1.1.1. The total length of the marigot with the inlet and main extension channels was 1500 to 2000 m long.

The pumpset specifications are as follows:

Jeumont - Schneider single stage centrifugal pump
Type: MEN 125-250
Nominal Rating, 200 $m^3$/hr, through 10 m head at 1450 rpm

ADIM - 2-cylinder diesel engine.
Type: 1052LP
Nominal Rating 48 hp

Onions, peppers and tomatoes grown in small 8 to 16 $m^2$ (more or less square) level basins served by small earth channels were the norm. We saw some lettuce grown on the channel banks and the bunds between basins and some corn grown in furrows in larger basins. Only about one-half of each parcel was currently being irrigated.

## 1.2 Farm Characteristic

The Joint Field Study Team did not focus on irrigated rice perimeters. We did take one brief look at on-farm economics at a rice perimeter at Say. In conjunction with data gathered in a similar study of rice perimeters around Tillibery done in 1986, we can make some inferences concerning the economic viability of these systems.

The rice perimeters along the Niger River tend to rely on water pumped from the river via central pumping units serving from 50-500 hectares. Most of the pumps are being converted from diesel to electric. Pumping height varies considerably and so, in turn, do pumping costs. Most of the perimeters produce a double crop of rice.

Investment costs for new irrigated rice perimeters along the Niger have been running at between 5-5.5 million FCFA per hectare, of $16,500-$18,300 per hectare at current exchange rates (300 FCFA/$). These are all inclusive costs, including preparatory studies and roads where necessary. Rehabilitation of existing perimeters is currently being done under a large World Bank project at an estimated cost of $7,000-$10,000 per hectare.

The site of Ganki Bassirou is located five kilometers from Say on the first terrace of the Niger River and consists of two different small-scale irrigation sites. The first site visited utilized a field of dug wells to irrigate a dry season crop primarily by the inhabitants of the village of Ganki. Each of 10 to 15 small plots was fed by a single well and the principle crops were manioc and assorted vegetables. Technical development varies in quality, but a cemented well with a slanted spillway is the highest level of sophistication. Areas served are small (0.1 ha or less).

The second more complicated system is the principle one studied and reviewed herein. It combines river water pumping through an old concrete and simple earthen canal system to a river-fed marigot from which hand thrown (with calabashes) water is used to irrigate basins devoted to onions and to polyculture. The river pump set was donated by ONAHA on the President's orders; the water works are a local initiative. This site is worked by individual farmers from Daweye and Ganki.

The village of Ganki has 1450 inhabitants. Seventy-five farm households work on the irrigation sites. On the canal system, individualized plot are common. Here some individuals have dug separate tertiary canals to their own calabash lifting site; in other cases, several individuals shared a tertiary channel. Extensive tracts of uncultivated ground separated these small gardens.

## 1.3 Crop Calendar

The Team only concentrated on the winter onion cropping program which is produced from seedlings transplanted in December. The crop requires about four months to mature and is thus harvested during April. The net water required by an onion crop ranges from approximately 5000 $m^3$/ha to 5500 $m^3$/ha depending on planting dates.

## 1.4 Irrigation System Costs

The farmers cooperated in digging the necessary main channels and more or less individually dug their own secondary channels. They also built their own field channels and leveled their basins for irrigation.

The pumping system was initially installed in 1984 and was recently brought back on line (January 1987) after being out of service through 1985 and 1986. The motor-pump utilizes a 2 cylinder diesel engine rated at 48 hp which is directly coupled to a centrifugal pump rated at 200 $m^3$/hr through 10 m of head at 1450 rpm. (Specifically, the diesel engine was an ADIM 1052LP and the pump was a Jeaumont-S Schneider MEN 125-250.) The motor-pump was provided by ONAHA on the request of the President of Niger. The cost of such a motor-pump in Niger is approximately 1,500,000 FCFA ($5,000 US).

## 2.0 Operational Overview

Operation of the river system consists of pumping from the Niger River into a feeder channel which empties into a marigot (old river oxbow lake) as shown in Figure S 1.1.1. Water is diverted from this inlet, or extension channels, or the lake proper, through short channels from which it must be lifted (by calabash) to the field channels which serve the small irrigated basins. The pumping lift from the river to the feeder channel is approximately 4 m and the hand lifting from the marigot to the field channels is about 1.5 m.

In addition to studying the river system, the Team economists did review a rice irrigation system near Say. Most of the Niger River Rice Perimeters are managed directly by co-operatives which determine their respective action programs. Generally, the co-operative provides plowing services via contract ox-teams. Usually it provides plant protection products and manages the nurseries. The co-operatives also provide bags and, in some cases, organize transport from the rice field to the co-operative. And, of course, the co-operatives oversee the provision and distribution of water and maintenance of irrigation canals.

For its services, the co-operatives assess farmers a fixed amount per hectare. This assessment is collected in-kind at harvest time, using the official price to value paddy. Co-operative assessments in the Niger Valley vary between 40,000-100,000 FCFA per hectare, depending on the services included and the cost of providing each one.

The on-farm economics of rice production is reported in a special Section 3.6 R.

## 2.1 Institutional/Social Structure

(The Team did not obtain sufficient information during the 1-1/2 day field visit to comment here.)

## 2.2 Irrigation Systems

When the motor-pump was installed in 1984, it operated for one month prior to the end of the irrigation season. A defect occurred in the starter motor which prevented further use until ONAHA arranged for its repair. There is some indication that the unit may have fallen into the river (or perhaps been submerged during the 1985 flood) which may be the cause of the premature failure of the starter motor. During the 1985 and 1986 irrigation seasons, the only water available to the farmers was the water naturally stored in the marigot following the Niger River's flood season.

All of the naturally stored water in the marigot had been consumed by, the time of the Team's visit which was the first week of February 1987, and the pump was scheduled to be operated 13 hours every other night until the end of the winter crop season. The Team measured the discharge with a flow meter and found it to be 60 lps which converts to an average of 1400 $m^3$/day to serve the estimated 13 ha of land being irrigated.

## 2.3 System Management

Theoretically the motor-pump is managed by the co-operative with whatever technical assistance they can get from ONAHA. The co-operative has retained the services of a pump operator whose pay is uncertain. Furthermore, a nearby farmer who has his own small motor-pump drawing water from the Niger River provided some technical help apparently in exchange for fuel. The co-operative makes some effort to collect a redevances from the farmers to: buy fuel and lubricants; pay for repairs and depreciation; and pay the pump operator. But this is done on an as-needed basis apparently without any means of applying sanctions for those who receive water but refuse to pay.

The co-operative also must help organize the farmers to dig and clean the main inlet channel and marigot extension channel.

## 2.4 On-Farm Irrigation and Crop Management

Farmers dig their own secondary intake channels and pits for standing in when lifting water from them. They also provide their own calabash (buckets) and ropes plus erosion control which is needed where the calabashes are emptied. The lifting rate is in the neighborhood of 0.9 to 1.3 lps for each calabash when operating steadily and sometimes two men work side by side producing over 2 lps.

The water is distributed within each parcel through a network of small eastern channels to level rectangular basins ranging from 2 to 4 meters on a side. Flow to each basin is controlled by an irrigator who opens and closes temporary earthen dams constructed and/or removed during each irrigation cycle as needed. The careful leveling of the basins and careful timing of inflows to obtain uniform depths of application within and between basins is essential for efficient irrigation.

Typically, the person lifting water exchanged places with the person irrigating from time to time as a means of sharing the hard work of lifting water. However, in some cases very young (small) children were the irrigators while the adults did the water lifting.

The Team was informed by an extension worker that standard cropping practices were being employed. There was evidence that both chemical and animal fertilizers were being applied. The standard irrigation sequences for onions seemed to be as follows:

| | |
|---|---|
| Pre and transplant irrigations | 2 irrigations |
| 1st month - once per week | 4 irrigations |
| 2nd month - twice per week | 9 irrigations |
| 3rd & 4th months, every 3 days | 20 irrigations |
| Total | 35 Irrigations |

Typically, the average depth of the water applied per irrigation cycle is approximately 30 mm which requires 300 $m^3$ per hectare. The total on gross depth of water applied per season is 1050 mm. This requires 10,500 $m^3$ of water per hectare. Using an assumed swinging calabash average water lifting rate of 1.1 lsp (4 $m^3$/hr) it would take 2,625 hours of steady labor per season to vertically lift enough water 1.5 m to irrigate one hectare of onions.

## 2.5 Training and Extension

(The Team did not obtain sufficient information during the 1-1/2 day field visit to comment here.)

## 2.6 Cost of Operation and Management

The Team estimated that the motor pump would be needed to supply approximately two-thirds of the required water for an onion crop and the primary system delivery efficiency was possibly as high as 95 percent except for the leaks in the first 50 m of the old lined canal. Thus, the river pump should be operated for 34 13-hr cycles (442 hrs) to supply the necessary water to irrigate 13 ha from the marigot. For 13 hours of pumping (one cycle) 40 liters of diesel fuel and 4 liters of motor oil were consumed. (The high oil consumption was due to leaky gaskets.) Assuming the oil leaks are fixed, we estimate the actual seasonal operating costs at:

Diesel fuel 40 liters X 34 cycles X 190 FCFA/liter = 258,000 FCFA
Motor oil 2 liters X 34 liters cycles X 800 FCFA/liter = 54,000 FCFA
Period service - twice per season = 50,000 FCFA
Batteries and miscellaneous = 50,000 FCFA
Salary for pump operator @ 500 FCFA/day = 34,000 FCFA

Total 446,000 FCFA

Assuming the motor pump costs 1,500,000 FCFA and ONAHA charges 375,000 FCFA per year to amortize it in 4 years, the annual redevance to cover the motor-pump operation should be:

$$\frac{(446{,}000 + 375{,}000)\ \text{FCFA}}{84\ \text{parcels}} = 10{,}000\ \text{FCFA per parcel}$$

plus whatever management fees are required (possibly another 1,000 or 2,000 FCFA per parcel).

Assuming a management cost of 1500 FCFA per parcel, the cost of the motor-pump operation would be 77,000 FCFA per hectare of onion for lifting water from the Niger River to supply the marigot. This would be one-third higher if part of the required water did not flow naturally to the marigot through the flood channel (shown in Figure S 1.1.1) during the flood season.

From the computations in section 2.4, 2,625 hrs of steady labor is required per season to lift the water from the marigot to irrigate one hectare of onions. Based on the going wage of 100 FCFA per hour for heavy pumping labor, this would cost 262,500 FCFA per hectare.

It is interesting to note that even with the inefficient motor-pump according to the Team's computations, it would only cost 115,000 FCFA per hectare to lift the all of water 4.5 m by motor-pump as compared to the 262,500 FCFA to manually lift it another 1.5 m.

## 2.7 Systems Functions

The village of Ganki is on the main road to Niamey. It has a cement mosque, a six-classroom school, and a number of concrete and cement-faced buildings. There are several concrete-lined wells. A mill and an as-yet non-functioning manioc flour-making machine are in place. Farming and animal husbandry are the main economic activities, although there is some trade. No fishing occurs. The natural environment is fairly rich by Nigerien standards, with much of the river bank under fairly dense stands of trees. Birdlife is abundant.

The population is ethnically Fulani and settled this area in the late eighteenth century. Intervillage and interhousehold solidarity is not strong. Within households age- and gender-based patterns of control of resources continue to be respected, extending to management of cash crop production. There is little competition for land. By contrast, competition between livestock, the traditional Fulani pre-occupation, and garden crops is strong. While local irrigation systems are adapted to the low resource possibilities of the farmers, knowledge and resources necessary to develop co-operative systems and marketing to improve income generation are limited.

Farming systems in Ganki consist of rainy season dune cultivation of sorghum and millet. Two seasons of rice cultivation are conducted on the Tiaguirire rice perimeter. Rainfed rice is grown in low-lying areas on the river terrace near the village as well. In the dry season, recession cultivation of manioc and polyculture is supplemented with pumped, canal-irrigated onions and polyculture. The villagers of Daweye lack access to perimeters and to rainfed rice and enjoy more limited access to recession manioc cultivation. Both villages are active in livestock production including goats, sheep and cattle.

Land is not a constraint on production, but water is according to farmers. Land on the marigot system can be obtained from the owners of land situated around the inlet and extension channels and the marigot itself (see Figure S 1.1.1). Allocations are annual in principle, but no rents are charged. Irrigators might provide proprietors with a token payments of a bag of onions at harvest. Limited availability of water, which is entirely related to the low rate of payment into the collective fund for diesel fuel, maintenance and repairs constrains production.

Access to plots in the area served by dug wells is limited by the number of wells in place, but data was not gathered on tenure arrangements here. Both individuals and groups, in the case of a women's collective, cultivate plots there. Some plots had gone uncultivated this year.

Farmers indicate that there is little competition for labor between dry season irrigation and other components of the farmers system. Limited bottlenecks occur when rice is harvested in October or when the rains begin in June.

The most notable feature of the systems at the site served by wells is the limited scale of coordinate required by the configuration of the system. Individuals with the help of children or other occasional labor can manage a dug well system, especially as there is but one person per well. In fact there are slightly fewer wells than farmers.

One group of farmers questioned on the pumping and canal site who were sharing a feeder canal consisted of men of similar age. Another group of adjacent parcels seemed to belong to men of adjacent generations. Thus, a number of flexible arrangements exist to facilitate channel maintenance and irrigation. Farmers who do not participate in channel cleaning may have their outlet blocked naturally.

Individual farmers obtain credit from wealthier villages. Standing crops of onions are sold for example. A single basin of onions worth 3500 FCFA at harvest might be pledged against 1500 FCFA when immature. Such loans are used to pay for diesel fuel or other personal necessities.

A co-operative is the formal intermediary between the services and the farmers, but farmers complain of the inactivity of the co-operative management committee. Farmers have received limited technical advice from ONAHA and from the Agricultural service concerning crop choice, pump operation, and transformation techniques. Thus, pump operating fees have gone uncollected for years, in some cases with no sanctions employed. Haphazard pump placement, maintenance and operation indicates that this piece of equipment is under no one's effective control. ONAHA confirms that they play only a limited role in its maintenance. Furthermore, the co-operative plays no role in marketing of produce. Some co-operative leaders sell seeds obtained in Niamey; they also buy pump parts.

## 3.0 Evaluation of Performance

Overall, the performance of the individually controlled lower portions of the marigot system and the dug well system was quite good. However, the community operated pump set for the marigot system is rather poorly maintained and operated.

### 3.1 Irrigation System Operation

The Team was not favorably impressed with the installation and operation of the motor-pump. It was not set up level and rested on a rubble stone base. The wheels and tires on the motor-pump trailer were missing so the unit had no cushion to absorb vibrations.

During the Team's visit, output from the pump was monitored for a range of engine speeds, up to the rated pump speed. Performance at the rated speed and corresponding head complied with the manufacturer's specifications. The pump is normally operated at 1,200-1,305 rpm instead of the intended 1,450 rpm, hence 11-20 percent of the output is lost (Figure S 3.1.1). Actual flow from the pumpset was thus 55-62 l/s instead of 70 l/s. Fuel consumption of the system was monitored throughout 13.5 hours of operation, and determined to be 2.35 l/hr. Oil consumption during this same period was 4 liters. This is due largely to leaks in various engine gaskets. (The engine had been installed by ONAHA technicians one week earlier.) The pump is scheduled to be used for 12-hour shifts on alternate nights. The period monitored was the second cycle of operation since the pump had been put back into service by ONAHA following a 2-year period of non-use.

The pump operator (who was not even certain he would be paid) checked the oil when he added diesel fuel in the middle of the night between our visits. Since he had no light, he guessed at how much motor oil to add and added 2 liters too much. (If the motor oil had been excessively over filled, say by 3 liters, the engine would have been destroyed.)

The Team has no reason to assume there is any routine maintenance program for the motor-pump. In fact, we doubted that under the current program of operation it would last through the irrigation season. (It consumed 4 liters of motor oil in 12 hour operation.)

The diesel engine was being operated below rated speed and would have pumped 20 percent more water per liter of diesel fuel if operated at its rated speed. However, the pump was being operated long enough to provide sufficient water to the marigot.

The flexible discharge pipe supplying the old lined canal leaked excessively as did the canal itself. Approximately 5 percent of the water being pumped was lost in the first 50 m of the old canal. Furthermore, the old canal (see Figure S 1.1.1) was constructed to serve

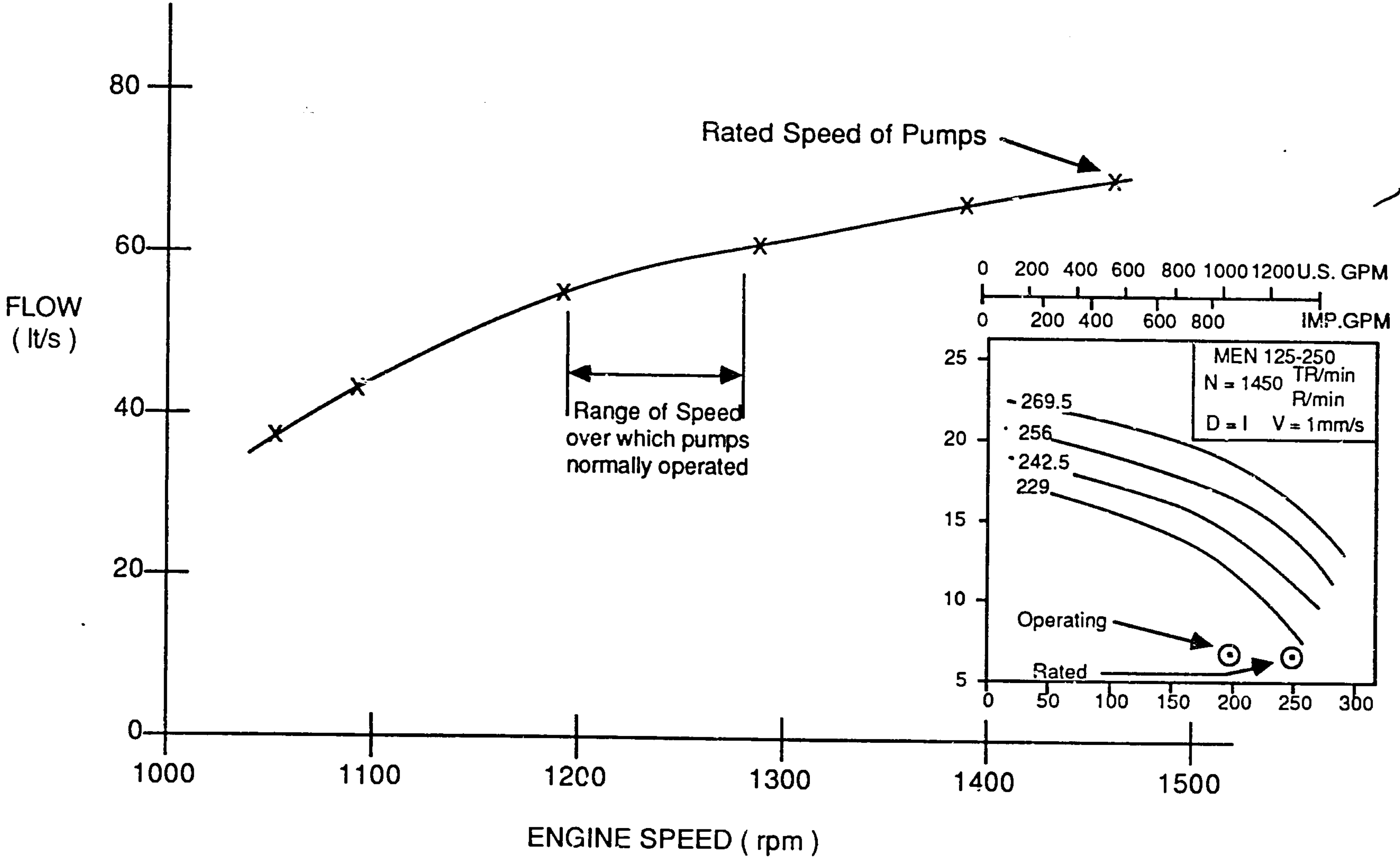

Figure S3.1.1 Field Performance Curve of River Motor-Pump ( with inset showing manufacturer's rating curves ).

the adjacent land by gravity flow. Thus, the water lift was at least 1.5 m greater than necessary for supplying the marigot.

Other aspects of the main system performed adequately except that many of the parcels along the inlet channel (see Figure S 1.1.1) only had access to water when it was flowing. Therefore, since the motor-pump was operated for 13 hrs every other night, they only had daylight access to the flowing water for a short period every other morning.

### 3.2 System Management and Maintenance

Although the motor-pump was supplied by ONAHA, they were not set up to provide much assistance in managing the system. Furthermore, the co-operative seemed to lack the necessary experience and technical knowledge to manage the complex portions of the system like the motor-pump and headworks. However, they did seem able to mobilize the needed manpower to construct and maintain the common portions of the inlet and marigot extension channels and collect fees for fuel and motor oil.

As mentioned earlier, there appeared to be no reliable maintenance program for the motor-pump or perhaps even a plan to move it to high ground during the flood season. However, ONAHA, did repair the starter as mentioned earlier.

### 3.3 On-Farm Irrigation and Crop Management

The irrigation system management and maintenance at the parcel level seemed impressively good on the few parcels carefully studied. The Team estimated that field channel losses were about 5 percent and application efficiencies were in the neighborhood of 60 percent. These estimates were based on physical flow, time and topographic measurements. For example, 16 $m^2$ basins varied in elevation by only ± 15 mm and filling depths by ± 10 percent with an average depth of application of 30 mm every 3 days.

Assuming a main system efficiency (below the leaky lined canal) of 90 to 95 percent, the overall irrigation efficiency may be in the neighborhood of 55 percent during the peak water use period. Based on the general trend to irrigate weekly for the first month, twice per week for the next month, and every three days for the final two months, the irrigation scheduling efficiency may be as high as 90 percent. Thus, the overall seasonal irrigation efficiency is probably in the order of 50 percent which is quite good.

We did not critique the crop management practices, but the overall appearance of the onion crop was good. The fields were carefully weeded, had good color, were free of insects and the planting density seemed appropriate.

## 3.4 Irrigated Agricultural Productivity

Estimates obtained by different Team members place the likely yield of onions at Say at somewhere between 35-42 tons of bulbs per hectare, which is very good. Pepper production appeared to range around 850 bags per hectare, having a wholesale value in Niamey (40 miles away) of 2.5 million FCFA per hectare. Marketing constraints, however, do not permit easy sale of significant quantities of green peppers or tomatoes.

## 3.5 Irrigation System Economics

The only major cash expenses for the irrigation system are the fuel, maintenance, amortization and management of the motor-pump. The breakdown of the costs involved with the present operation is presented in Section 2.6. In those figures, the Team has already assumed the oil leak, which reduced the motor oil consumption by 50,000 FCFA, would be repaired.

Even with these corrections, the motor-pump is not well suited to the actual lift. Furthermore, it is not being operated efficiently because it is lifting water 1.5 meters more than necessary and running well below rated speed. Correcting these two factors would increase the fuel efficiency of the current pump by 20 percent (reduce fuel costs by 50,000 FCFA per season). Eliminating the leaks in the first 50 m of the system would reduce operating costs another 10,000 FCFA. This would reduce the total seasonal operating cost for the current pump to 386,000 FCFA.

If a properly fitted motor-pump were combined with an unlined inlet channel, which can be dug by farmers to replace the existing leaky concrete lined canal, the motor-pump operating and amortization cost for a more optimum motor-pump installation would be:

| | |
|---|---|
| Fuel | 129,000 FCFA |
| Motor Oil | 27,000 FCFA |
| Periodic Service | 60,000 FCFA |
| Miscellaneous | 40,000 FCFA |
| Pump Operator | 34,000 FCFA |
| Total | 290,000 FCFA per year |

This is a 231,000 FCFA reduction over the existing system as it is now being operated and would save each of the 84 parcel holders 2,750 FCFA per year.

The management structure and capacity for operating the motor-pump is very weak and there is very little technical assistance provided by ONAHA (or anyone else). In view of this, the Team feels there is a very high probability the current pump unit will fail in the middle of a season. This would cause an economic disaster for the farmers if the motor-pump is not immediately repaired or replaced. They would not only lose their collective investment in operation of the pump, but would also lose their individual investment (which is several times higher) in the irrigated crops on their parcels.

With the combination of an efficient low-lift river pumping system and a manual secondary lifting system, total irrigation costs would be approximately 300,000 FCFA/hectare per year at Say. With the current inefficient river pumping system it is approximately 10 percent higher. While these costs are high, they represent total costs as compared to 230,000 FCFA/ha for operating costs only at Djirataoua. They are not favorable relative to 150,000 FCFA cost per hectare for the motor pumping systems surrounding Galmi and the Tarka Valley; but Say farmers are still able to compete because of a greater reliance on drying onions. This arises because labor expanded in drying represents a significant portion of total value added and offsets the disadvantage of a higher cost pumping system. Moreover, small motor-pumps would not be able to maintain such low costs given the higher lift and longer run at Say. Thus, the system, as it has evolved, is able to operate economically under current market system/price relationships.

## 3.6 On-Farm Economics

The current labor cost for lifting water from the marigot to the parcels is in the neighborhood of 262,500 FCFA per hectare by the swinging calabash method currently being used by all farmers (see Section 2.6). For fully irrigated 0.3 ha parcels the labor cost is approximately 80,000 FCFA.

There are manual pumps which would reduce the labor by up to 50 percent. But for such pumps to be cost-effective, they would need to be available for about 30,000 FCFA, easily and cheaply maintained using indigenous capabilities, and probably financed. Unfortunately, the Team knows of no such pump. Hand pumps (such as the rower type) might reduce labor by 30 percent. Although considerably cheaper than treddle pumps, they would also not be cost-effective.

Small 3-hp motor-pumps, co-operatively used to irrigate a total of 0.6 to 1.2 hectares each, would be very attractive compared to hand lifting. However, this would require groups of 3 to 6 farmers to organize and would require additional surface channels and construction of irrigation infrastructure. Furthermore, not all of the lands now being irrigated from the marigot system are situated (or have the necessary topographic conditions) for collective pumping.

The average cost of lifting water from the marigot using small motor-pumps would range from 12 to 20 FCFA per $m^3$ of water (assuming all standard fuel and import taxes are paid) depending on how efficiently they are utilized and whether pump acquisition is financed from public or private savings. To achieve the practical minimum cost of 15 FCFA per $m^3$, including all operating and amortization costs and full farmer financing (using motor-pumps similar to those being used in the Tarka Valley), each pump should discharge 4.8 lps. Furthermore, they should be utilized effectively for at least 750 hours per year and be maintained to last four years.

Based on the Team's calculations, 4.8 lps would provide sufficient water for irrigating 0.9 ha of onions when operated 6 hrs per day during the peak water use period. Our calculations are based on applying a 30 mm average depth of application to the onion basins every three days and a field channel distribution efficiency of 90 percent. It would take a total of 575 hrs of operation (and consume approximately 345 liters of gasoline costing 88,000 FCFA) to supply the irrigation water for 0.9 ha of onions. The amortization plus operating cost would be approximately 140,000 FCFA for the 0.9 hectares served (160,000 FCFA per hectare).

From an economic perspective, each motor-pump serving 0.9 ha has the potential of saving the farmers involved the stated labor cost of 0.19 ha X 262,500 FCFA/ha = 236,000 FCFA for hand lifting minus 140,000 FCFA for pumping, which equals 94,000 FCFA per onion season. This would appear to be quite an interesting economic proposition with the cost of a motor-pump on the order of 135,000 FCFA in Niamey. However, from the local socio-economic viewpoint, the economics are not quite as clear. Farmers would have to organize to share the pump in order to reduce costs to these levels. Moreover, some families may not have alternative employment for family labor. Relatively high risk and cash flow inputs associated with motor-pump operations present additional obstacles for many farmers. In spite of the relatively high yields obtained by onion farmers at Say, their distance from Niamey forces them to adopt value-adding strategies that offset their high transport costs. According to farmers, they receive about 2250 FCFA per bag of onions delivered to Niamey at the main harvest time. Transportation costs 150 FCFA per bag to the main road and 700 FCFA to Niamey. The farmer also must supply the bag at a cost of 200 FCFA per bag. He must accompany his produce to market as well.

Putting all this together, Table S 3.6.1 demonstrates that farmers cannot earn a competitive return on their labor by producing fresh onions alone. If all the output were sold at the main harvest time, farmers would earn only 300 FCFA/day. By timing their production, they could obtain higher prices but rice harvesting prevents them from getting an early start on onion production. Returns to green peppers and tomatoes are higher during part of the season; but the pepper and tomato market cannot absorb all they could produce and becomes glutted as well. To cope with this situation, farmers shift to drying vegetables, mostly onions, as a means of storing their commodities and reducing transportation costs.

In very rough terms, 2 1/2 bags of fresh onions make one bag of dry onions. During the rainy season, when dried onions are the most expensive, farmers at Say can sell them for 6,000-6,500 per bag, i.e., 600-700 FCFA more gross revenue than they would have received for an equivalent amount of fresh onions at harvest time. Moreover, farmers have only to transport one bag at a cost of 350 FCFA. Counting the savings in transportation costs and bags, farmers earn an additional 1,100 FCFA per fresh bag equivalent for their labor when selling dried onions during the off season, as opposed to selling fresh onions during the flush season. Given the added labor required for drying (roughly one person day per bag of fresh onions), the average return to labor

Table S 3.6.1: Estimated Return to Onion Production on Micro Irrigation Systems at Say, 1987

| Item | Quantity (per ha) | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|
| Production: | | | |
| Onions | 415 bags | 2250 | 933,750 |
| Onion Tops | 80 bags | 500 | 40,000 |
| Sub-total | | | 973,750 |
| Non-Labor Inputs: | | | |
| Seedlings | | | 100,000 |
| Fertilizer | 300 kg | 65 | 19,500 |
| Plant Protection | piece rate | | 18,000 |
| Bags | 495 bags | 200 | 99,000 |
| Transportation: | | | |
| Onions | 415 | 850 | 352,750 |
| Owner | 20 | 500 | 10,000 |
| Irrigation Assessment | | | 77,000 |
| Sub-total | | | 676,250 |
| Net Returns to Labor | | | 297,500 |
| Labor Inputs: | | | |
| Land Preparation | 65 person days | | |
| Preparation of Plant Bds | 50 person days | | |
| Transplanting | 150 person days | | |
| Weeding | 50 person days | | |
| Harvesting | 200 person days | | |
| Pumping & Irrigating | 450 person days | | |
| Transporting | 30 person days | | |
| Sub-total | 995 person days | | |
| Average Return per person-day | | 302 FCFA | |

increases from 300 to 540 FCFA per day. This explains why these farmers keep producing onions when high irrigation costs and harvest season prices for onions clearly provide insufficient incentive.

This case study demonstrates that irrigation system economics are intimately connected to the cropping pattern and, in this case, to marketing strategies that influence the total return to farmers. Pumping costs with the hand lift systems at Say are high, but the system is still sufficiently competitive to maintain a market position in the face of competition from Galmi, albeit not in head-to-head competition. Say producers are filling a market niche by drying onions, because of relatively low fresh onion prices, that does not yet interest producers at Galmi. If and when it does, Say producers will probably have to shift away from onions altogether if they are to continue to find irrigated vegetable gardening profitable.

## 3.6R On-Farm Rice Economics

The Team looked at only on-farm economic performance at one rice perimeter near Say. As mentioned earlier (see Section 2.0), this was not a major Team activity. It is only presented herein to record the rather interesting economic findings for comparative purposes. Table S 3.6R.1 gives a breakdown of the results of interviews with two above-average farmers. By way of comparison, Table S 3.6R.1 provides data based on a larger sample of perimeters around Tillibery done in 1986. These latter data are adjusted to reflect 1987 output prices and the budgeting methodology used in this report.

On the basis of the above-average yields obtained by the two farmers at Say, 5600 kg/ha versus 3300 kg/ha for the Niger River Valley as a whole, rice production looks very attractive from the farmers' point of view. These farmers earn the equivalent of 1160 FCFA per day of labor utilized. This is in spite of paying one of the highest irrigation assessments in the valley.

Table S 3.6R.2 provides a better measure of what is happening to farmers on average. Most farmers use less fertilizer than the two interviewed at Say. They also pay a lower irrigation assessment and pay less per day for piece rate labor. Using the same prices for output prevailing at the time of our visit to Say, it appears that on average Niger River Valley rice farmers earn about half as much per day as do the two farmers at Say, or 567 FCFA per day. Rice production is still attractive relative to dry season alternatives, but it is neck and neck with rainy season alternatives. If one were to take a long run price of 80 FCFA for paddy, rather than current prices between 65-70 FCFA/kg, net revenue would be 45,500 FCFA higher, while return per man-day would be 810 FCFA. Rice production during the rainy season would then be more attractive, provided millet and sorghum prices do not also rise. In all cases, it would certainly be quite attractive during the dry season.

The Team of economists did not address agronomic and irrigation system issues on irrigated rice perimeters that, if resolved, could increase yields or reduce costs over present levels. The economic analysis has shown that, on the basis of current practices and results, rice production using existing approaches is not sufficiently economic to justify new investments.

Although there are certainly several improvements, both agronomic and engineering, that could improve the performance of riverine irrigation systems in Niger, now is an opportune time to examine closely the feasibility of small perimeters, each covering 20 hectares or so, as

Table S 3.6R.1: Farm Budget during Rainy Season, 1986 for Irrigated Rice Perimeter at Say

| Item | Quantity (per ha) | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|
| Average Parcel Size | 0.5 | | |
| Output: | | | |
| Paddy | 5600 kg | 1400 kg @ 70[1] | 98,000 |
| | | 4200 kg @ 65 | 273,000 |
| Stover | 7000 kg | 9 | 63,000 |
| Sub-Total | | | 434,000 |
| Input Costs: | | | |
| Non-Labor Inputs: | | | |
| Plants | provided by co-op | | -- |
| Plowing | piece rate | | 15,000 |
| Fertilizer | 200 kg Urea | | |
| | 200 kg (15-15-15) | 65 | 26,000 |
| Plant Protection | | | 4,000 |
| Rental of Thrasher | two bags of paddy | 4,500 | 9,000 |
| Bags | provided by coop | | -- |
| Transport | 80 bags | 100 | 8,000 |
| | 7 tons stover | 2,000 | 14,000 |
| Sub-Total | | | 76,000 |
| Labor Inputs: | | | |
| Puddling and Leveling | piece rate | | 17,000 |
| Transplanting | piece rate | | 20,000 |
| Replanting | 20 days | 500 | 10,000 |
| Fertilizer Applictn. | 4 days | 500 | 2,000 |
| Irrigations (15) | 30 days | 500 | 15,000 |
| 1st weeding | piece rate | | 30,000 |
| 2nd weeding | piece rate | | 30,000 |
| Harvesting | piece rate | | 20,000 |
| Thrashing | piece rate | | 30,000 |
| Winnowing & Bagging | piece rate | | 16,000 |
| Sub-Total | 217 days[2] | | 190,000 |
| Irrigation/Co-op. Assessment | | | 94,000 |
| Total Costs | | | 346,000 |
| Returns to Capital and Management[3] | | | 88,000 |
| Charge for Invested Capital[4] | | | 25,500 |
| Return to Management/Economic Rents[5] | | | 62,500 |
| Average Return per day of Labor[6] | | | 1,164 |
| Incremental Economic Value Added[7] | | | 186,250 |

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Footnotes to Table S 3.6R.1:

[1] The co-operative requires repayment of the irrigation assessment in kind. The lower price is the free market price and applies to non-co-op sales and household consumption.

[2] Valuing piece rate labor at 1000 FCFA/day.

[3] Total output minus total costs.

[4] Equal to 50 percent of average investment. Average investment equals one third of the sum of non-labor inputs and one half of the value of labor inputs. The one-third value reflects the average crop cycle/investment period of four months. The one-half for labor reflects the progressive application of labor inputs over the four month period, i.e., on average, only one-half of the ultimate cost will have been invested for the entire four months. Both hired labor and family labor are treated as invested capital. No charge is made for the irrigation assessment since that is paid after the harvest.

[5] Returns to Capital and Management, less the charge for invested capital.

[6] Includes returns to management plus labor input costs divided by total days of labor.

[7] Assuming one-half of all inputs other than fertilizer, plant protection materials and the irrigation assessment represents net value added. The remaining half is a real cost to the economy in the form of income or remittances lost from forgone pursuits. Also assumes that one-half of the charge for invested capital is a return to additional savings and investment stimulated by the project. In addition, assumes all returns to management represent net value added for the economy.

Table S 3.6R.2: Farm Budget during Average of Rainy Season and Dry Season, 1985-86 for Irrigated Rice Perimeters at Tillibery

| Item | Quantity (per ha) | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) | |
|---|---|---|---|---|
| | | | Current Prices | Long Run Prices |
| Average Parcel Size | 0.25 | | | |
| Output: | | | | |
| Paddy | 3300 kg | 800 @ 70[1] | 56,000 | 64,000 |
| | | 2500 @ 65 | 162,500 | 200,000 |
| Stover | 7000 kg | 9 | 63,000 | 63,000 |
| Sub-total | | | 281,500 | 327,000 |
| Input Costs: | | | | |
| Non-Labor Inputs: | | | | |
| Plants | Provided by co-op | | -- | |
| Fertilizer | 250 kg | 65 | 16,200 | |
| Plant Protection | | | 4,000 | |
| Rental of Thrasher | | | 12,000 | |
| Bags | 44 | 250 | 11,000 | |
| Transport | 12 bags | 500 | 1,800 | |
| | 32 bags | 500 | 16,000 | |
| | 7 tons stover | 4,000 | 28,000 | |
| Sub-total | | | 89,050 | |
| Labor Inputs: | | | | |
| Plowing | piece rate | | 15,000 | |
| Leveling | piece rate | | 13,000 | |
| Pulling plants | 16 person days | 750 | 12,000 | |
| Transplanting | 20 person days | 500 + meal[2] | 15,000 | |
| 1st weeding | 20 person days | 600 + meal | 17,000 | |
| 2nd weeding | 20 person days | 600 + meal | 17,000 | |
| Harvesting | 24 person days | 1 bun. rice + meal[3] | 18,000 | |
| Threshing | 40 person days | 500 + meal | 30,000 | |
| Winnowing & Bagging | 8 person days | 250 | 2,000 | |
| Sub-total | 188 person days[4] | | 139,000 | |
| Irrigation/Co-op. Assessment | | | 59,400 | |
| Total Costs | | | 287,450 | |
| Returns to Capital and Management[5] | | | -5,950 | 39,550 |
| Charge for Invested Capital[6] | | | 26,425 | |
| Return to Management/Economic Rents[7] | | | -32,375 | 13,125 |
| Average Return per Day of Labor[8] | | | 567 | 809 |
| Incremental Economic Value Added[9] | | | 84,700 | 130,200 |

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Footnotes to Table S 3.6R.2:

[1] The co-operative requires repayment of the irrigation assessment in kind. The lower price is the free market price and applies to non-co-op sales and household consumption.

[2] Meal valued at 250 FCFA.

[3] A bundle of rice approximates the daily wage of 500 FCFA.

[4] Valuing piece rate labor at 750 FCFA/day.

[5] Total output minus total costs.

[6] Equal to 50 percent of average investment. Average investment equals one third of the sum of non-labor inputs and one half of the value of labor inputs. The one-third value reflects the average crop cycle/investment period of four months. The one-half for labor reflects the progressive application of labor inputs over the four month period, i.e., on average, only one-half of the ultimate cost will have been invested for the entire four months. Both hired labor and family labor are treated as invested capital. No charge is made for the irrigation assessment since that is paid after the harvest.

[7] Returns to Capital and Management, less the charge for invested capital.

[8] Includes returns to management plus labor input costs divided by total days of labor.

[9] Assuming one-half of all inputs other than fertilizer, plant protection materials and the irrigation assessment represents net value added. The remaining half is a real cost to the economy in the form of income or remittances lost from forgone pursuits. Also assumes that one-half of the charge for invested capital is a return to additional savings and investment stimulated by the project. In addition, assumes all returns to management represent net value added for the economy.

Source: Niger Applied Agricultural Research Project Paper, Annex Table I-5. Output prices have been changed to reflect 1987 values. Some data items have been rearranged. Others are added by the author.

Table S.3.6R.3: Internal Rates of Return for Irrigated Rice Production in the Niger Valley Under Alternative Investment and Life of Project Assumptions

| | Internal Economic Rates of Return ( % ) | |
|---|---|---|
| Life of Project | Rehabilitated Perimeters | New Perimeters |
| 15 | 5.4 | -3.8 |
| 20 | 7.7 | -0.3 |
| 25 | 8.7 | 1.5 |

an alternative to present methods for developing rice production along the River. Such techniques appear to work reasonably well in Senegal, costing between $3,000-$6,000 per hectare. The smaller systems could probably take better advantage of remaining sites that would be prohibitively costly to develop using larger scale installations. Once a viable prototype has been demonstrated, one could expect that private sector entrepreneurs would begin investing on their own. In all probability, the performance of such system would be better and the life of the investments longer than under current circumstances. To effectively implement such a strategy, ONAHA and/or the private sector would need to expand their capacity to support such private sector initiatives.

On the basis of Table S 3.6R.3, new projects would have to last 25 years just to recover the initial capital investment, not including any interest or return on capital. Rehabilitation projects show modest returns to investment if they last 10 years or more, but they did not yield competitive rates of return even if they last 25 years.

Given that most perimeters now being rehabilitated are less than 20 years old, in some cases less than 15 years old, the wisdom of additional investment in large-scale irrigation is questionable under present circumstances. This is even more true when one considers that most of the better, more suitable land for rice production has already been developed. Costs for future projects will be higher per hectare on an inflation adjusted basis. It would be wise to search for alternative modes for developing irrigation to these areas.

## 3.7 Equity and Social Parameters

Water availability to farmers along the inlet channel (see Fig. S 1.1.1) is limited to when water is flowing during daylight hours. Since the motor-pump at the river is only scheduled for operation from

6:00 p.m. to 7:00 a.m. every other night, farmers along the inlet channel only have access to water for 4 of 5 hours every other day. Whenever the water pumped from the Niger River is insufficient to satisfy all demands, the farmer along the marigot extension channel (the tail-enders) are the first to suffer.

The equity and distribution of benefits picture is mixed. Farmers say, for example, that irrigation activities provide a brake on dry season emigration. There is no question that they provide a food complement. The installation of manioc processing machines in the village may signal the start of a small-scale local processing industry, but it is unclear whether the technical support and market conditions will permit an acceptable rate of return to this operation. Furthermore, the stated local agricultural wage rates, our economic analysis, plus the absence of in-migration suggest that returns to labor from dry season irrigation are marginal.

Certain aspects of the system reflect a certain spirit of initiative and self-help. Thus, the current pump operator is a young fellow who has no guarantee he will ever be paid by the co-operative. He is being helped out by a private entrepreneur who runs an ancient Chinese pump to serve a plot nearby, and who, in return for his technical help, receives some of the water pumped by the farmers. Furthermore, we witnessed collective work on a women's garden plot on both days of our visit. The first day women were clearing the ground. On the second, men were plowing the plot for them. A farmer remarked that women have their own "co-operative" and receive some technical help from their husbands.

But there was ample evidence of the limits of co-operative endeavor. On the well field, for example, the most necessary collective endeavor, a communal fence to protect manioc plantations was in disrepair. This contrasts dramatically with what one sees along the Senegal River where recession sites are bordered with many wooden fences. In Senegal, these are built by collective labor, although each person maintains his/her own section. A distinctive difference between the two systems is the presence of a more solitary lineage structure in Senegal.

The limited commercial potential of the systems is reflected in the low level of development of coordinating institutions and vice versa. Thus, the youth group, or samariya which might be mobilized to carry out maintenance, as in Galmi is limited to cultural activities here. A number of farmers said the co-operative was really a phantom organization.

### 3.8 Training/Extension

(The Team did not obtain sufficient information during the 1-1/2 day field visit to comment here.)

# 4.0 Specific Constraints/Recommendations

## 4.1 Institutional/Social

Constraint: The co-operative structure and related coordinating and sanctioning mechanisms are weak which entails government agents perception of farmer dependence upon the state and perpetuation of unfavorable credit terms with local wealthy peasants.

Recommendation: Develop a program of credit and co-operative development through ONAHA and/or the UNC.

Constraint: A number of problems have to do with the organization or marketing. There is a lack of demand for irrigated produce and a lack of publicity for local produce (on the Tilakaina model) and marketing channel power. High transport costs also constrain profitability of the system.

Recommendation: Conduct a marketing study to determine what crops grown for what markets would best suit the needs of the irrigators at Ganki.

Constraint: Limited technical support from the technical services is clearly a constraint on the system. This includes elements like: the poor training and technical support given the pump operator, the absence of knowledge about and incentives for effective pump operation, persistent problems with termites and ants, and the lack of appropriate storage and transformation technologies.

Recommendation: Retraining of pump operator and institution of effective incentive system monitored by CSRD. Encourage initiatives of the AFN to develop manioc, onion and tomato transformation and storage facilities here.

Constraint: There are also more fundamental issues of socio-cultural orientation such as conflict between herding and gardening components of farming system, which make animal control intractable locally, and inter-generational schisms.

Recommendation: Encourage the local self-help initiative by development of a program of experimental encadrement focused on different interest groups.

## 4.2 Economic (System and On-Farm)

Constraint: With time, market pressures will force Say onion producers to lower production costs in order to maintain their market share. This will almost certainly come in the form of groups of farmers or single larger farmers purchasing a small motor-pump. Once such pumps are readily available in Niamey at competitive prices, one can expect those farmers for whom the pumps make economic sense to adopt them. This will put further pressure on those farmers who lack alternative employment opportunities and will depress their family incomes from onion production. This, in turn, will cause some of them to shift to alternative forms of employment and/or migration during the dry season.

Recommendation: At this time the principle government policies that influence this process are those that relate to the availability of pumps and spares, i.e., trade, import taxing and market regulation policies. The more these policies favor a relatively unrestricted trade, the more easily Say vegetable producers will be able to compete with producers in the eastern part of the country having easy access to low cost material from Nigeria.

At the same time, improved roads would lower transportation costs. In the short run, this would benefit producers in those areas favored by the roads and would harm producers in other areas. Eventually, average costs of production would decline and consumers will be the ultimate winners. The trick from the farmers' perspective is to maintain a steady stream of such innovations so that farmers can reduce average costs of production in conjunction with declining prices.

## 4.3 System Design

Constraint: While the community (main) portions of the system are relatively economic, there is considerable room for cost reductions and improving motor-pump dependability.

Recommendations: 1. Repair the motor-pump oil leaks immediately. If this is not done, we expect the engine will self-destruct before the end of this irrigation season.

2. Provide sufficient blocking with shock absorbing mountings to hold the pump level and reduce vibrations.

3. Increase the engine speed to its rated value of 1450 rpm.

4. Dig a 200 m long unlined channel adjacent to the old lined canal and reduce the pump lift by 1.5 m and leak losses by 5 percent (an alternative might be to locate the pump at the inlet to the flooded channel). The combined effect of the above recommendations will result in a cost savings of 60,000 FCFA or almost 700 FCFA per parcel holder.

Constraint: The existing motor-pump is designed to lift water much higher than the necessary 3 to 5 m encountered. Therefore, its capital cost is about 20 percent higher and its operating cost is about 25 percent higher than necessary even with the system improvements recommendations under constraint 4.3.

Recommendation: When the existing motor-pump is retired, replace it with a smaller lower lift pump designed to discharge 40 to 50 lps for a lift between 3 and 5 m (total dynamic head ranging between 4 and 7 m). This will reduce the amortization plus operating costs by approximately

170,000 FCFA in addition to the 60,000 FCFA discussed earlier for a total of 230,000 FCFA or 2,750 per parcel.

## 4.4 System Management Operation and Maintenance

Constraint: There appears to be no system for a routine motor-pump maintenance program. Without such a program, there is a high probability that costly repairs and down time will result.

Recommendations: 1. ONAHA or some other GON agency should provide technical assistance to the co-operative to help them improve their system design, management, operation and maintenance programs. The co-operative must have the will to improve and properly manage the system in order for the technical assistance to be of value.

2. The operator should be responsible for and capable of performing simple routine maintenance tasks. He should be assigned a basic tool kit, including a grease gun and funnel or syphon to decrease spillage in fueling operations.

Constraint: The operation schedule for the pump is alternate days from 17:00 - 08:00 hours (35 hours/week). The pump is normally used (when in working order) from December/January through until crop harvest in March. The pump is situated outside, with no shelter, no light for night-time operation, and no permanent mounting pad. The operator cannot monitor correct functioning of the unit, cannot verify the oil level except on moonlit nights), and cannot see to add fuel.

Recommendation: That the pumping schedule be modified to a daily schedule. Increase the daytime hours or runtime, thus reducing but not eliminating the risk of operating during hours of darkness. Refueling and oil level checks can, however, occur during daylight hours. Adequate mounting and shelter should also be provided.

Constraint The users along the inlet channel and marigot extension channel (see Figure S 1.1.1) do not have equitable access to water.

Recommendation: Pump water from the Niger to the Marigot from 3:00 to about 10:00 every morning (during the peak use period) so there is sufficient flow during daylight hours for users along the inlet channel. Operate the pump long enough so the end users along the marigot extension channel have sufficient water.

## 4.5 Cropping Program

The cropping program appeared adequate.

## 4.6 On-Farm Management

Farm management appeared adequate.

## 4.7 Research

Constraint: The high cost of manually lifting water by calabash is making the economic viability of the system difficult.

Recommendations: 1. Study (test) and select the most attractive alternative manual and small motor-pump water lifting system for use with surface supplies.

2. Conduct action research using an appropriate new lifting system under actual operating conditions at Say.

## 4.8. Training/Extension

The Team did not gather sufficient information to evaluate the training/extension. There did appear to be significant input from extension. However, needed help for operation and maintenance of the river pump was lacking as indicated in Section 4.4.

# CHAPTER III

# DJIRATAOUA ELECTRIFIED MULTIPLE DEEP WELL IRRIGATION SCHEME AND SAFO DIESEL POWERED RUWANA PERIMETER, MARADI, NIGER

The Djirataoua Perimeter is the main part of a deep well irrigation scheme near Maradi. It consists of a group of over 40 deep wells. Each well is fitted with a submersible pump which receives its power from an electric grid. Thus, the power grid serves to knit the separate well/pump units together. However, each unit serves a small (8 to 13 ha) irrigation system.

In addition to visiting several electric pumped well systems served from the grid, the Team visited one of three Ruwana (circular) systems served independently. We have included information gathered at the Ruwana Perimeter at the village of Safo for an economic comparison with the Djirataoua Perimeter. The well pump at the Safo Ruwana is diesel powered.

## 1.0 Project/System Description

### 1.1 Physical Features

The IBRD-funded Djirataoua perimeter (project) lies in the Maradi Goulbi, the arm of a predominantly Nigerien drainage system which briefly transects a small portion of south-central Niger. Average annual precipitation and mean temperature in the area are around 600 mm and 27°C, respectively. Monthly patterns of precipitation, temperature and evaporation are given in the Table D 1.1.1.

The dominant soils within the perimeter are sandy loams and loamy sands, with some limited areas of sandy-clay loams. All are recent alluvial soils of the goulbi, underlain by alluvial sands at 45-75 cm, which generally establishes the same effective rooting depth.

The Djirataoua project consists of approximately 500 cultivated hectares (1985-86 figure) supplied by 48 tubewells of which only 44 are now operable. Each well is equipped with a 3.7 kw or 7.5 kw submersible pump. The average dynamic head is about 10 m and the discharges are about 50 $m^3$/hr or 85 $m^3$/hr, respectively. Ten of these have adjacent storage tanks of 150 $m^3$, 200 $m^3$, or 250 $m^3$, which were intended for night-time filling during low power demand periods. Each tubewell serves an irrigated area ranging in size from 6 to 21 hectares with an average size of approximately 11 hectares. Approximately, 1,312 parcel holders are served by the system, with a net cropped area of 0.32 ha per farmer (40 m X 80 m). Water is discharged from the tubewells into prefabricated, concrete rectangular channels (30 cm X 45 cm). At the parcel level water, is removed from the lined channel into field channels with the use of aluminum siphons. (See Figure D 1.1.1 for field layout.)

Table D 1.1.1 Monthly Rainfall, in mm, for Different Probabilities, Mean Temperature, in $^{0}C$, and Estimated Monthly Potential Evapotranspiration at Maradi.*
(Samani and Hargreaves, 1986)

Station: Maradi
Location: Lat 13 30 N Long 76 E
Elevation: 369.0 m

| PROB | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | 0 | 0 | 0 | 0 | 0 | 20 | 75 | 103 | 24 | 0 | 0 | 0 | 378 |
| 75 | 0 | 0 | 0 | 0 | 2 | 41 | 114 | 153 | 51 | 0 | 0 | 0 | 475 |
| 50 | 0 | 0 | 0 | 1 | 9 | 63 | 149 | 196 | 79 | 2 | 0 | 0 | 551 |
| 5 | 0 | 0 | 1 | 34 | 104 | 146 | 261 | 332 | 184 | 46 | 0 | 0 | 770 |
| PM | 0 | 0 | 0 | 7 | 25 | 70 | 156 | 204 | 88 | 9 | 0 | 0 | 559 |
| TEMC | 22 | 25 | 29 | 32 | 32 | 30 | 28 | 26 | 27 | 28 | 25 | 22 | 27 |
| EIP | 142 | 155 | 184 | 191 | 197 | 192 | 177 | 172 | 173 | 181 | 150 | 141 | 2055 |

*Analysis based on 25 years of data.

During the wet season, fields are usually prepared for irrigating furrows 10-12 m long, while in the dry season onions and wheat are irrigated in 15 to 25 $m^2$ basins.

The Ruwana Perimeter at Safo supplies irrigation water to 4 ha of land in the dry season and up to 10 ha during the wet season surrounding the well plus domestic water to the village Safo. The Perimeter is unique in that the irrigated area is circular and water is conveyed from a central tank through 115 to 185 m long aluminum pipes (with gated openings at every 0.75 m) to small field channel which feed the small basins. The pipe is laid along 9 different radial legs so that the field ditches are short and the seepage losses from them are minimized. The central tank is supplied from a drilled well with a pump powered by a diesel engine. Farm holdings are small with the average size being 0.16 ha.

## 1.2 Farm Characteristics

The information this section of the report provides is by no means complete from an ethnographic perspective. It presents limited data about household composition, ethnic affiliation, land tenure, labor allocation, organizational development and institutional linkages. Significant variation and cultural particularities are largely ignored.

Most Hausa farm households are (minimally) composed of a man, his wife and unmarried children, but joint farm enterprises composed of a man and his married sons and/or married younger brother are not uncommon.

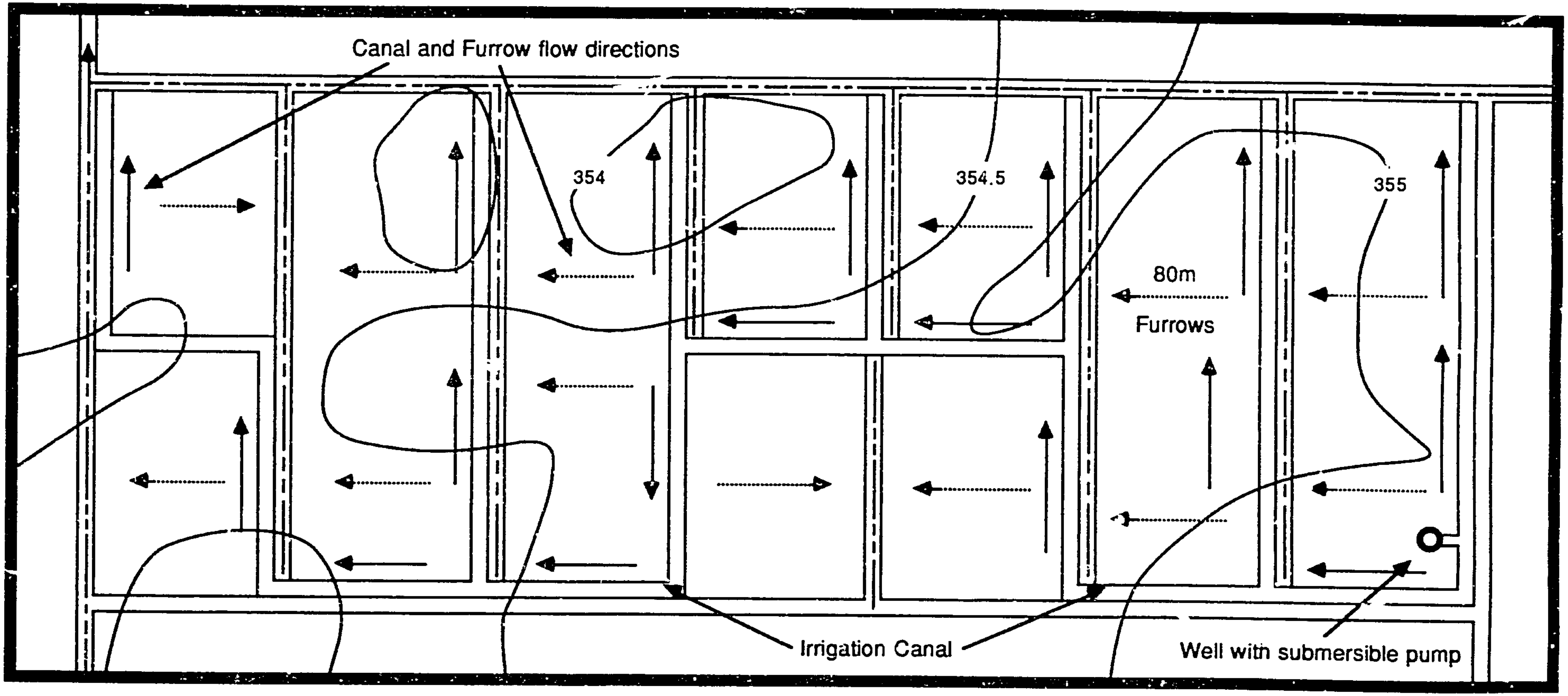

Figure D1.1.1 Typical irrigation system layout.

Amont - Plot 101
scale 1:2500

Some ten percent of households are probably headed by women and may include married sons. Two is the average number of agricultural laborers per farm household in Maradi, but that number commonly reaches 6 or more.

Collectively cultivated dune fields whose product is destined for home consumption are complemented by individually-worked dune fields and dry season gardens. Traditionally, these gardens, such as the Shadouf systems of Soumarana, have served to satisfy individual cash needs.

The common characteristic of the Djirataoua parcel holders farm enterprises is possession of at least one 0.32 ha parcel. Since the average farm size in Maradi department is 2.97 ha, the irrigated parcel, with a cropping density of 1.88, actually represents 20 percent of the surface area of an average farmer's holdings. (A year-round cropping cycle is suggested for the irrigated field which gives the 1.88 intensity.) Since the majority of the crops grown under irrigation are considered cash crops, the addition of the irrigated parcel to the farm holdings represents a considerable additional commitment of labor and other resources to commercial agriculture.

## 1.3 Cropping Calendar and Rotation

The project area's growing season is divided into three seasons:

1. the rainy season (June through October);
2. the cold dry season (November through February);
3. the hot dry season (March through May).

The dryland farming cycle includes millet and sorghum intercropped with peanuts and cowpeas. In the recessional areas of the Goulbi, tobacco, melons, and some vegetables are grown during the cold and hot dry seasons. The cropping calendar and rotation recommended by the project is given in Figure D 1.3.1. Each 0.32 ha parcel is divided into two 0.16 ha soles. One sole rotates cotton (rainy season) - peanuts (end of cold to end of hot dry season) in year one with sorghum (rainy season) and varied vegetable production (cold dry season) in year two. The second sole rotates sorghum (rainy season) - wheat (cold dry season) in year one with cotton (rainy season) - peanuts (hot dry season) in year two. This cropping calendar and rotation provides a cropping intensity of two (two harvest per year on each unit of land).

This cotton - peanut - sorghum - wheat rotation should permit good soil, water and pest management. The deeper rooted cotton is a good crop precedent for peanut. Some nitrogen benefit may be obtained from the peanut crop for the succeeding sorghum crop. A well-managed wheat crop should decrease weed problems for the succeeding cotton crop. The ability to include a vegetable crop each year to replace wheat or peanut should help farmers improve financial returns and adapt to shifting market prices.

For 1986-87 perimeter management modified the crop rotation in order to extend the cotton season as a measure towards rectifying outstanding debt. Electrical supply to the perimeter was cut off in January 1987 by

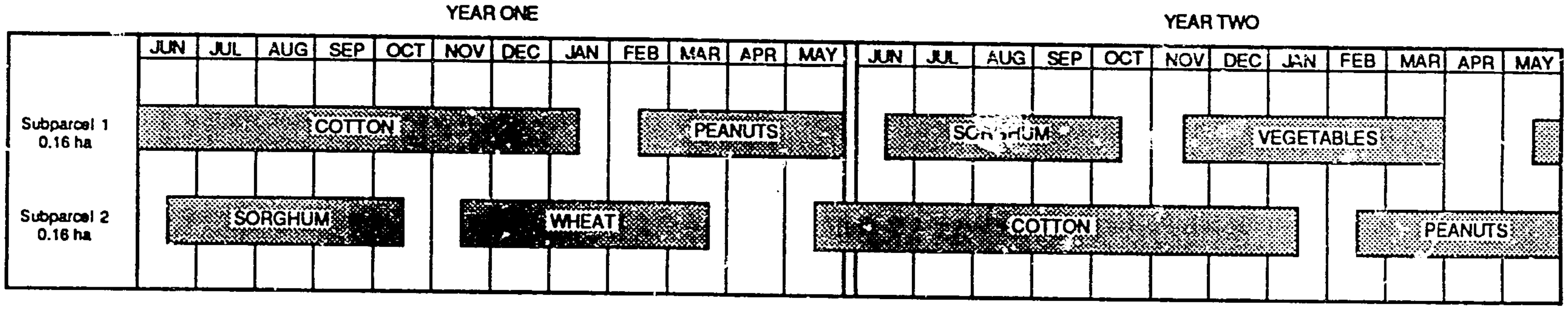

Figure D1.3.1 Djirataoua project planned crop calendar and rotation.

Table D 1.3.1 Estimated Net Irrigation Requirement at Djirataoua for 1984

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REFERENCE CROP Eto. (mm/d)* | 6.7 | 6.0 | 5.8 | 6.1 | 6.7 | 7.9 | 8.1 | 7.8 | 7.1 | 6.1 | 5.5 | 5.8 | |
| COTTON | | | | | | | | | | | | | |
| Stage Duration (days) | | | | | | | | 15 | 30 | 31 | 31 | 15 | |
| Kc | | | | | | | | 0.35 | 0.7 | 1 | 1 | 0.9 | |
| Etc (mm) | | | | | | | | 41 | 149.1 | 189.1 | 170.5 | 78.3 | 628 |
| Effective Rainfall (mm) | | | | | | | | | 47.2 | 92.4 | 46.4 | 18.3 | 204.3 |
| Preirrigation (mm) | | | | | | | 30 | | | | | | 30 |
| NET IRRIGATION REQUIRED (mm) | | | | | | | 30 | 41 | 101.9 | 96.7 | 124.1 | 60 | 423.7 |
| SORGHUM | | | | | | | | | | | | | |
| Stage Duration (days) | | | | | | | | | 15 | 25/5 | 31 | 14/16 | |
| Kc | | | | | | | | | 0.45 | 0.9/1.05 | 1.05 | 1.05/0.65 | |
| Etc (mm) | | | | | | | | | 47.9 | 169.3 | 179 | 145.6 | 541.8 |
| Effective Rainfall (mm) | | | | | | | | | 47.2 | 92.4 | 46.4 | 18.3 | 204.3 |
| Preirrigation (mm) | | | | | | | | | 30 | | | | 30 |
| NET IRRIGATION REQUIRED (mm) | | | | | | | | | 30.7 | 76.9 | 132.6 | 127.3 | 367.5 |
| PEANUTS | | | | | | | | | | | | | |
| Stage Duration (days) | | | | | 25 | 31 | 30 | 15/15 | | | | | |
| Kc | | | | | 0.35 | 0.7 | 1.0 | 1.0/0.8 | | | | | |
| Etc (mm) | | | | | 69.1 | 171.4 | 243 | 210.6 | | | | | 694.1 |
| Preirrigation (mm) | | | | | 30 | | | | | | | | 30 |
| NET IRRIGATION REQUIRED (mm) | | | | | 99.1 | 171.4 | 243 | 210.6 | | | | | 724.1 |
| TOMATO | | | | | | | | | | | | | |
| Stage Duration (days) | | 10 | 20/11 | 29/2 | 28 | 10/15 | | | | | | | |
| Kc | | 0.45 | 0.45/0.8 | 0.8/1 | 1.0 | 1.0/0.9 | | | | | | | |
| Etc (mm) | | 27 | 105 | 153.7 | 187.6 | 185.7 | | | | | | | 659 |
| Preirrigation (mm) | | 30 | | | | | | | | | | | 30 |
| NET IRRIGATION REQUIRED (mm) | | 57 | 105 | 153.7 | 187.6 | 185.7 | | | | | | | 689 |

*From CHAROY (1971)

Table D 1.3.1 (continued ....)

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REFERENCE CROP Eto. (mm/d)* | 6.7 | 6.0 | 5.8 | 6.1 | 6.7 | 7.9 | 8.1 | 7.8 | 7.1 | 6.1 | 5.5 | 5.8 | |
| HOT CHILI PEPPERS | | | | | | | | | | | | | |
| Stage Duration (days) | | 30 | 31 | 4/27 | 13/15 | 5 | | | | | | | |
| Kc | | 0.4 | 0.75 | 0.75/1 | 1/1 | 1 | | | | | | | |
| Etc (mm) | | 72 | 134.9 | 183 | 187.6 | 39.5 | | | | | | | 617 |
| Preirrigation (mm) | 30 | | | | | | | | | | | | |
| NET IRRIGATION REQUIRED (mm) | 30 | 72 | 134.9 | 183 | 187.6 | 39.5 | | | | | | | 647 |

*From CHAROY (1971)

NIGELEC for non-payment of electricity consumed. The perimeter will not be irrigated and cultivated until the rainfed crop season of 1987 and thus was not being operated during the Team's visit.

Table D 1.3.1 gives the estimated net irrigation requirements for the various crops during 1984.

## 1.4 Irrigation System Costs

The Djirataoua perimeter was originally expected to provide a relatively low cost method for irrigating crops on land located along the Goulbi Maradi, a seasonal river in Maradi Department. By the time the first half of the original system was completed, however, no money remained with which to complete the second half. Overall system cost had risen to 2.3 billion FCFA for 497 hectares of cultivable land (4.6 million FCFA/ha). This is just about the same development cost per hectare as for the Niger River rice perimeters. This investment included the cost of bringing in grid electricity (180,000,000 FCFA) from the thermal generating plant in Maradi. Table D 1.4.1 contains a breakdown of investment costs.

In an effort to lower costs still further, the Maradi Project established three experimental single-well pumping systems in nearby villages. Costs for the one operating at Ruwana Safo at the time of our visit amounted to 25 million FCFA for a 9 hectare unit. That comes to 2.8 million FCFA per hectare. At the present time, the Ruwana Safo perimeter is not operating as efficiently as the Djirataoua perimeter. It is newer, however, so one can expect the system to improve in performance with time.

Table D 1.4.1 Investment Costs for Djirataoua and Ruwana Safo Irrigated Perimeters

| Item | | Million FCFA |
|---|---|---|
| Djirataoua: | | |
| Studies | | 31.0 |
| Vehicles, Engines and Construction Materials | | 173.0 |
| Public Works and Equipment: | | |
| Electrification | | 180.0 |
| Canals (66,770 meters of concrete canal) | | 500.0 |
| Pumps (48) | | 100.0 |
| Construction work | | 950.0 |
| Fuel | | 90.0 |
| Repairs and Maintenance of Construction Equipment | | 30.0 |
| Technical Assistance | | 250.0 |
| | | ------- |
| Total Costs | | 2,304.0 |
| Average Cost per hectare (498 ha) | | 4.6 |
| Unit Costs (FCFA) | | |
| Canals, per meter | 7,500 | |
| Pumps | 2,083,000 | |
| Ruwana Safo: | | |
| Motor | | 2.0 |
| Pump | | 1.8 |
| Tubewell | | 8.0 |
| Irrigation Pipe (540 m of 100 mm pipe) | | 3.0 |
| Storage Basin (90 $m^3$) | | 3.5 |
| Site Preparation | | 2.0 |
| Unaccounted | | 4.7 |
| | | ------ |
| Total | | 25.0 |

## 2.0 Operational Overview

### 2.1 Institutional and Social Structure

Conceived originally for some 1500 parcel-holders, the Djirataoua perimeter now numbers some 1312. The perimeter consists of 4 large units, each one constitutes a co-operative associated with a particular village. Each of the 44 operating irrigation units (GMPs) within these larger units, has its own pump and management committee. Each GMP has some 12-35 parcelholders who are organized into irrigation blocks of about 12 persons each. The GMPs are divided into eleven electrical sectors which serve the pumps.

Djirataoua is a jointly managed scheme in which three parties, ONAHA, the Maradi Department Rural Development Project (PDRM) and a local co-operative are involved. Under this system, ONAHA is responsible for technical services and co-operative training and monitoring, while the PRDN continues to provide certain major financial supports, notably at the level of infrastructure and infrastructure maintenance. The co-operative has nominal responsibility for all major aspects of production, commercialization and minor systems maintenance. Its executive body is the General Assembly composed of two representatives from each GMP, while its implementing agency is a co-operative bureau consisting of a President, Secretary and Treasurer with input from the ONAHA perimeter director and accountant.

The institutional relationships between the parties are in fact spelled out in a number of texts and conventions. As for the application of these texts and conventions on the ground, there are a number of apparent accommodations. For example, directives emanating from both ONAHA and the state through a consultive committee on which the prefet sites are sometimes applied unilaterally. To take another example, co-operative training, supposedly under ONAHA's responsibility since 1985, has not been taken on by anyone.

Each GMP (or pumping and irrigation group) has its own management committee composed of a President, Treasurer and Secretary and democratically elected by the members. Farmers cite the qualities of hard work and reliability as criteria for selection. Managing irrigation scheduling, harmonizing cropping operations, organizing pest detection and treatments and collecting redevances are responsibilities shared by the committee. While the president invariably collects the redevances, other functions are portioned out between these officers differently from one GMP to another.

### 2.2 Irrigation Systems

During non-peak periods, pumps are usually operated 7-9 hrs/day, completing one irrigation per week in 3-4 days. During peak periods pumps are operated up to 11-12 hrs/day, completing two irrigations per week usually in 6 days, where 7 days would be the exception. Irrigations are ordered in two shifts per day, with each farmer having half a day to irrigate 0.16 ha (one half of their actual holding).

Generally, about 6 people in each GMP irrigate at the same time, each using 5 siphon tubes to give a nominal flow rate of about 15 $m^3$/hr (4 lps) per farmer. These figures vary, of course, with the pump discharge rate and the associated number of parcels and/or parcel holders.

The schedule and timing of pump operation, parcel irrigation, and exchanging of shared siphons is usually handled by the local extension agent and an individual farmer chosen by the GMP to regulate the prescribed "tour d'eau."

### 2.3 System Management

Farmers in each GMP designate one among them to turn the pump on and off and oversee irrigations. Generally the local extension agent sets the irrigation schedule but the GMP (the farmers) can override this if they are unanimous in their decision--at least in theory. The same farmer chosen to turn the pump on and off is also charged with overseeing irrigation among the parcels. Often he takes care of necessary adjustments such as seeing that farmers with less head have an extra siphon tube or two for compensation.

Canal cleaning is generally initialized at the co-operative level and subsequently passed on to the GMP's who then organize and schedule the cleaning within their own sectors (areas served for a well). Common canals among them are done together, while each section alongside a parcel is cleaned individually by the respective farmer. Major canal repairs under 100,000 CFA are the responsibility of the co-operative. Above this figure the responsibility technically goes to the project. Small repairs are often done by the individual farmer himself, but if any capital costs are encountered for the repair the farmer(s) goes to the co-operative. For slightly more involved repairs the co-operative might hire a local mason to do the job.

The farmer charged with overseeing the pump reports all pump failures and possible repair needs. These are then taken care of by the project maintenance crew. However, there is no routine maintenance program. At present there is one skilled mechanic and two assistants. ONAHA is gradually taking the project over.

2.3.1 Power Supplies and Delivery Mechanisms. The power supply to the perimeter is provided by a 20 kv line from the regional generating plant at Maradi. The system, designed to be installed in four phases, was constructed between 1979-83. An extension (phases 3-4) was not constructed due to the excessive costs incurred in the preparation of the first hectare perimeter (approximately 500 ha).

Energy is charged to the co-operatives through a three-tier pricing structure, similar to that in force nationwide. Electrical supply is separated into 11 sectors, and several pumps are grouped on one sector. Charges to the consumer for actual quantities of water consumed are not possible; thus no incentives for water conservation exist.

Details of the pricing structure are shown in Table D 2.3.1 for 1984 rates and Table D 2.3.2 for 1986 rates. A cost increase of 15 percent occurred in 1985. The price per kilowatt-hour (kwh) in 1985 varied from 56-70 FCFA per kwh, dependent upon utilization patterns.

Power supply is provided to each of the 44 electric submersible pumpsets (7.5 kw and 2.7 kw nominal power ratings) installed in tubewells distributed throughout the perimeter. Each pumpset irrigates on average 11.5 ha and is controlled independently from a command panel at the pumpsite. Each pumpset is equipped with automatic security circuits with visual display for low water level in the tubewell, thermal overload (and storage reservoir shutoff for the ten pumps equipped with storage reservoirs). Voltage surge protection and lightning protection have been added as a retrofit. Energy counters and run-time counters are also fitted to each pumpset.

The total depth of the tubewells is approximately 30 meters, with the upper screen situated at an average of 7.35 meters (3.72 meters minimum) below the dynamic level at the recommended maximum usable flow. The decreasing level of the water table, estimated at 25 cm/year since 1984 (Cf. Figure D 2.3.1) and excessive draw off rates would indicate that the dynamic level is below the top of the upper screen and close to the footvalve of some pumpsets. No dynamic measurements could be performed since electrical power was not available to run the pumps.

Water is discharged from the pumps into prefabricated, concrete rectangular channels (45 cm X 30 cm), then transferred by siphon into earthen canals at the parcel level.

The power supply at the Ruwana perimeter at Safu (the adjacent low-cost option) is provided by a Lister ST2 diesel engine (15 hp at 1,800 rpm) coupled vis-a-vis belt drive to a Caprari (Type P7C4) vertical axis pump. Token measurements made during the case study are included in the comparative performance data.

## 2.4 <u>On-Farm Irrigation and Management</u>

2.4.1 <u>On-Farm Irrigation</u>. Five to six siphons are used per 80 meter field ditch with a discharge rate of 4 to 6 liters/sec. Original plans for the perimeter were for 80 m furrows running down slope in the 40 m by 80 m parcels, each to be watered wtih 1-2 siphons in sequential order. However, farmers dig four 80 m long field ditches to irrigate four field sections of 10-12 meter furrows set perpendicularly to the slope of their parcel.

Table D 2.3.1 Pumping System Energy Consumption Sector Sample 1984 Annual Basis at Djirataoua

| | | | | %Use of Rates | Avg Cost (FCFA/kwh) | Energy Use (kwh/ha) | Energy Cost (FCFA/ha) | Area Cult. (ha) |
|---|---|---|---|---|---|---|---|---|
| Aderawa Est | 1984 Cost | FCFA | 2,610,842 | | | | | |
| | High Tariff | kwh | 153 | 0 | 59 | 1,331 | 79,021 | 33.0 |
| | Med Tariff | kwh | 30,063 | 68 | | | | |
| | Low Tariff | kwh | 13,769 | 31 | | | | |
| | Total | kwh | 43,985 | | | | | |
| Aderawa Ouest | 1984 Cost | FCFA | 2,483,637 | | | | | |
| | High Tariff | kwh | 222 | 1 | 56 | 1,572 | 88,386 | 28.1 |
| | Med Tariff | kwh | 28,514 | 65 | | | | |
| | Low Tariff | kwh | 15,442 | 35 | | | | |
| | Total | kwh | 44,178 | | | | | |
| Koderawa Est | 1984 Cost | FCFA | 2,356,242 | | | | | |
| | High Tariff | kwh | 384 | 1 | 59 | 1,272 | 75,521 | 31.2 |
| | Med Tariff | kwh | 27,274 | 30 | | | | |
| | Low Tariff | kwh | 12,034 | 30 | | | | |
| | Total | kwh | 39,692 | | | | | |
| Koderawa Ouest | 1984 Cost | FCFA | 3,451,295 | | | | | |
| | High Tariff | kwh | 330 | 1 | 58 | 1,117 | 64,534 | 53.5 |
| | Med Tariff | kwh | 41,708 | 70 | | | | |
| | Low Tariff | kwh | 17,688 | 30 | | | | |
| | Total | kwh | 59,726 | | | | | |
| Maradou Ouest | 1984 Cost | FCFA | 1,221,641 | | | | | |
| | High Tariff | kwh | 111 | 1 | 66 | 1,566 | 103,179 | 11.8 |
| | Med Tariff | kwh | 13,159 | 71 | | | | |
| | Low Tariff | kwh | 5,269 | 28 | | | | |
| | Total | kwh | 18,539 | | | | | |
| Djiratao Nord | 1984 Cost | FCFA | 4,410,114 | | | | | |
| | High Tariff | kwh | 1,066 | 1 | 59 | 1,386 | 81,188 | 54.3 |
| | Med Tariff | kwh | 48,875 | 65 | | | | |
| | Low Tariff | kwh | 25,373 | 34 | | | | |
| | Total | kwh | 75,314 | | | | | |
| | | | | | Averages | 1,374 | 81,971 | |

Tariff Rates 1984
High 75.30 FCFA/kwh
Med 47.00 FCFA/kwh
Low 38.00 FCFA/kwh

Table D 2.3.2 Pumping System Energy Consumption

| SECTOR CODE | | Monthly Energy Consumption | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNUAL* TOTALS | %USE OF RATES** | TOTAL ENERGY (kwh/yr) | AVERAGE COST (FCFA/ kwh) | ENERGY (kwh/ ha/yr) | ENERGY COST (FCFA/ ha/yr) | AREA CULTI- VATED (ha) |
| 9 | 1985 Cost FCFA | | 306,758 | 247,969 | 200,676 | 218,614 | 185,004 | 125,922 | 83,680 | 269,482 | 283,445 | 305,112 | 271,755 | 2,725,546 | 6 | 45,939 | 65 | 1,390 | 90,679 | 33.0 |
| Aderawa | 1986 Cost FCFA | 237,584 | 346,785 | 334,427 | 279,546 | 270,366 | 301,911 | 94,342 | 46,370 | 148,123 | 330,220 | 356,682 | | 2,996,025 | 65 | | | | | |
| Est | High Tariff kwh | | 48 | 60 | | 65 | 137 | 23 | | 1,205 | | 77 | | 2,769 | 29 | | | | | |
| | Med Tariff kwh | | 3,718 | 3,421 | | 2,658 | 2,854 | 612 | | 591 | | 3,594 | | 29,911 | | | | | | |
| | Low Tariff kwh | | 1,524 | 1,592 | | 1,204 | 1,435 | 227 | | | | 1,753 | | 13,260 | | | | | | |
| 2 | 1985 Cost FCFA | | 386,292 | 339,176 | 294,195 | 240,755 | 218,808 | 168,219 | 47,118 | 291,624 | 208,233 | 190,770 | 269,590 | 2,896,124 | 41 | 39,694 | 70 | 1,413 | 99,084 | 28.1 |
| Aderawa | 1886 Cost FCFA | 244,528 | 433,649 | 352,713 | 214,123 | 213,772 | 286,599 | 65,375 | 40,878 | 117,041 | 244,277 | 339,290 | | 2,784,267 | 18 | | | | | |
| Ouest | High Tariff kwh | | 3,520 | 2,333 | | 617 | 890 | 154 | 6 | 907 | | 1,111 | | 16,351 | 41 | | | | | |
| | Med Tariff kwh | | 562 | 847 | | 977 | 1,200 | 34 | 2 | 0 | | 598 | | 7,234 | | | | | | |
| | Low Tariff kwh | | 1,151 | 1,249 | | 1,314 | 1,994 | 294 | 0 | 0 | | 3,395 | | 16,109 | | | | | | |
| 4 | 1985 Cost FCFA | | 416,492 | 403,984 | 380,383 | 356,231 | 319,840 | 216,931 | 83,034 | 400,841 | 331,111 | 402,749 | 411,737 | 4,061,818 | 6 | 65,433 | 62 | 1,366 | 83,365 | 49.0 |
| Aderawa | 1986 Cost FCFA | 357,461 | 492,369 | 435,987 | 375,639 | 379,197 | 415,323 | 124,849 | 65,654 | 173,110 | 443,370 | 478,458 | | 4,081,546 | 62 | | | | | |
| Sud | High Tariff kwh | | 705 | 560 | | 446 | 293 | 109 | 8 | 0 | | 58 | | 3,735 | 32 | | | | | |
| | Med Tariff kwh | | 4,858 | 4,303 | | 3,636 | 3,914 | 800 | 238 | 1,474 | | 4,582 | | 40,809 | | | | | | |
| | Low Tariff kwh | | 1,978 | 1,758 | | 1,621 | 2,273 | 480 | 100 | 846 | | 3,129 | | 20,889 | | | | | | |

Average : 1,380   91,043
for 1986

*Includes missing monthly data

**Tariff Rates 1986
High 82.80 FCFA/kwh
Med 56.20 FCFA/kwh
Low 46.50 FCFA/kwh

Tariff Periods
High 19:00 - 22:00 hrs
Med 07:00 - 12:00 hrs & 15:00 - 19:00 hrs
Low 12:00 - 15:00 hrs & 22:00 - 07:00 hrs

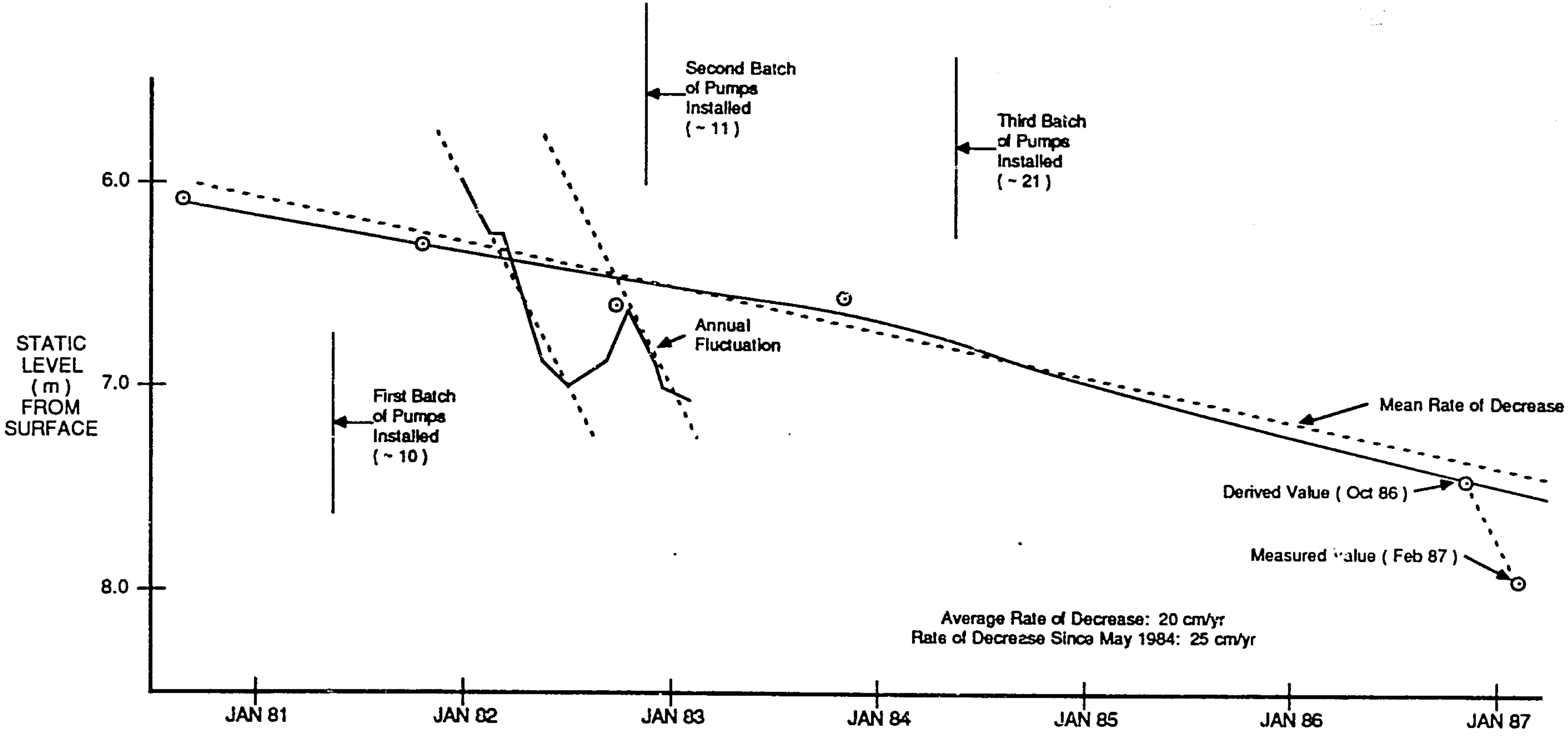

Figure D2.3.1 Static groundwater table levels at various times.

Farmers irrigate from three to six hours and apply about 30 mm of water per irrigation. Pre-irrigation and early crop growth stages receive a single irrigation each week. At flowering or full cover, irrigations are increased to twice weekly. Wheat is grown in 10 meter long basins, rather than in a furrow system. The short field furrows permit relatively good application efficiencies, even on the sandy loams and sandy clay loams of the project area. The reduction of furrow length by the farmers allows them to increase evenness of water distribution. Local farmers simply do not have the means by which to develop 80 m length furrows of sufficient size, depth, and linearity to adequately deliver water at acceptable application efficiencies.

There are two major sources of water loss. One is the infiltration loss in the field ditches which the Team estimated to be about 25 percent. The second is loss to percolation below the root zone which averages about 30 percent. Actual distribution efficiency in the short furrows is probably very high, in the range of 85-90 percent.

Actual field efficiencies probably are lower than these loss estimates would indicate (55 percent). Land preparation and planting dates are often staggered within rotation group, making pre-irrigation water use less efficient and pushing dry season crops into periods of higher potential evapotranspiration.

2.4.2 Cropping Practices. Only the cotton crop and scattered plots of tomatoes, hot peppers, and tobacco were seen in mid-February as the irrigation system had not been in operation for some time. Thus, the description of farming practices could only be based mainly on farmer and project staff interviews.

Cotton pre-irrigation and land preparation is done during May to avoid conflict with the labor requirements of dry land cereal crops. Land is plowed with a ridger. Planting is done from late May through June and early July. One hundred kgs of single superphosphate and 100 of urea are applied in split doses. Seeds of the variety ISA/205 are obtained from the CFDT gin. The crop is hand weeded and harvested from November through January. Some harvesting of second grade cotton continues through February. From six to ten pest control sprayings are given per crop. Plants are cut off at ground level and burned before the next crop is planted.

Peanut fields are pre-irrigated and furrows reformed crop with a ridger after the cotton crop. Peanut seed is saved by farmers or purchased from the market or government agencies. The fields are hand weeded. Aphids are a major problem and are not successfully controlled. Peanuts are field cured and threshed.

Sorghum is pre-irrigated and furrows are made with a ridger. The crop is planted in June before the dryland crop is planted. All other operations are done by hand. Stalks are cut in the field and the panicles bunched together for transport and storage. Striga is a major pest of sorghum along with granivorous birds.

Tomatoes, hot peppers and onions are grown throughout the cool and hot dry seasons. Tomatoes and peppers are grown on furrows from the preceding crop that have been reformed. Onions are grown in small basins. Farmers frequently divide a 0.16 ha sole into two 0.08 ha subplots to grow different vegetables or a cereal crop and vegetable crop. Tomatoes and peppers are transplanted from a seed bed after pre-irrigation and land preparation. Tomatoes are of the beefsteak type. Hot peppers are of local and Nigerien varieties. Long red bell peppers are also grown and the onions are almost uniformly of the Galmi type.

2.4.3 Cropping Intensity. As mentioned earlier, the design is to operate at a cropping intensity of 2.0 with two crops per sole per year. In 1984-85 the cropping intensity appeared to be 1.88, the reason being that 0.12 hectare per plot was not cropped during the dry seasons. The cropping intensity in 1983-84 was 1.41, because pump installation lagged behind pilot development in 1983. Farmers had just begun to work the irrigated land and missed planting dates. Data for 1985-86 were not available. Examination of individual GMP records suggests that a good system-wide average cropping intensity is about 1.80.

2.4.4 Yields. Table D 2.4.1 summarizes system yield performances obtained from farmer and project records. The third column gives average yield figures which should be practically attainable with better system-wide water and crop management practice.

Table D 2.4.1 Crop Yields for the Djirataoua Project

| Crop | Dryland/ Recessional (kg/ha) | Average Irrigated (kg/ha) | Potential Yields (kg/ha) |
|---|---|---|---|
| Cotton | 300 | 2,100 | 2,500 |
| Sorghum | 675 (Pure Stand) | - | |
| | 225 (Intercropped) | 2,000 | 2,800 |
| Wheat | - | 2,200 | 3,000 |
| Peanuts | - | 1,700 (+400 kg hay) | 2,200 |
| Tomatoes | - | 22,200 | 28,000 |
| Millet | 400 (Intercropped) | - | - |
| | 600 (Pure Stand) | - | 1,500 |
| Onions | - | 35,000 | 38,000 |
| Niebe | 200 | - | 1,500 |
| Hot peppers | - | - | 7,000 |

## 2.5 Training and Extension

Co-operative training for members has not been offered since 1985. The members of the management committee are trying to learn as they go and rely upon the perimeter director for guidance. The perimeter director and one assistant are responsible for extension of technical information.

Technical information of all kinds is extended through periodic meetings of the General Assembly. The number of meetings called each season is unclear, but probably numbers at last one per month. Topics include: the cropping pattern and calendar; cropping fee amounts and payment schedules; pest treatment arrangements; and co-operative accounts. Attendance of GMP delegates is mandatory but some information seems to be lost in the transfer between delegates and ordinary farmers.

A few farmers have received training in the use of animal traction equipment in the past through the Maradi and other projects. Such farmers plow for others, but no systematic program of training and extension of traction techniques is underway.

The mechanics and electricians trained by the project have been fired for improprieties. However, unfortunately the new group hired by the co-operatives has not received training specific to the pumpsets employed on the perimeter.

## 2.6 Costs of Operation and Maintenance

During the 1986 crop year, farmers at Djirataoua paid 180,000 FCFA per hectare as an irrigation assessment. Of this amount, 91,000 FCFA was payable to NIGELEC for electrical energy consumption. The assessment has grown steadily from around 50,000 FCFA/ha in 1983, the first year of operation, as the project managers have shifted a greater share of system costs to the farmers. At the present level of assessment, farmers are complaining about the heavy financial burden, even though it is still about 30 percent below the level required to finance operating expenses and replacement of light equipment.[1] Much of this increase arises from the loss of 60 hectares, or 12 percent of the total irrigated area, to such factors as unlevel land and waterlogging. This has increased the cost burden to the remaining area.

For the irrigation assessment to completely cover system maintenance and variable operating expenses (as is the stated intention of the Government) it would have been 232,000 FCFA in 1986 for each of the 440 hectares actually producing crops. Even at this level, reduction of certain co-operative operating expenses and elimination of extension agents financed by the co-operative is assumed. Table D 2.6.1 identifies the various components of the full cost assessment. Charging farmers less (than this amount) means adequate provision is not being made for equipment amortization and system maintenance. Without adequate provision for these items, the system probably will not last the full expected 20-25 year life of the wells.

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[1] Government policy is to not charge farmers for heavy investment items such as the wells, electric lines, canals and works, studies, dikes, roads, buildings, and heavy equipment.

Table D 2.6.1 Components of Annual Irrigation Assessment at Djirataoua Assuming Adequate Provision for Maintenance, Repair and Depreciation of Equipment and Light Infrastructure[1], 1987

| | FCFA/ha |
|---|---|
| Electricity | 92,500 |
| General Expenses: | |
| ONAHA Service Charge | 6,000 |
| Cooperative Operating Costs | 1,000 |
| Office Operating Costs | 500 |
| Vehicle Operations (30,000 km @ 60 FCFA ea) | 4,100 |
| Technical Agent Salaries (4 @ 500,000 FCFA ea) | 4,550 |
| Accountant (500,000 FCFA) | 1,150 |
| Extension Agents | - |
| Sub-total General Expenses | 17,300 |
| Plant Protection Products | |
| Repairs Maintenance: | |
| Pumps & Motors (211,200,000 X .06)[2] | 28,800 |
| Electrical Installations | 5,500 |
| Canals (495,000,000 X .01) | 11,250 |
| Principal Drains (80,000,000 X .02) | 3,650 |
| Roads (2,000,000) | 4,550 |
| Sub-total Repairs & Maintenance | 53,750 |
| Depreciation: | |
| Pumps & Motors (158,400,000/7 yrs) | 51,400 |
| Light Vehicles (5,400,000/3 yrs) | 12,300 |
| Siphons and Irrigation Materials | 3,000 |
| Sub-total Depreciation | 66,700 |
| Total Assessment/ha | 230,250 |
| Assessment per 0.32 ha parcel: 74,300 FCFA | |

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[1] Based on 440 hectares of rainfed cultivation on the perimeter as of 1/87. Excludes the cost of the tubewells, electric lines, canals and works, terraces, dikes, drainage canals, roads, buildings and heavy vehicles and engines. These costs are borne by the GON.

[2] Reflects 3 percent of the investment cost for normal maintenance and repairs and 3 percent for extraordinary replacement of pumps and motors due to lightening, electrical surges and other factors not related to normal wear and tear.

Data on pump maintenance and repairs available for the project (for 1982 to 1986) reveal nine major failures due to non-wear and tear causes over a total installed life of 132 years for 43 pumps. Thus, 21 percent of the pumps required replacement during the first 2.07 weighted average years of operation. This amounts to 7 percent per year. The useful life of the pumps is estimated at seven years. However, the 7 percent premature replacement of the pumps means that by the end of year seven 49 percent of the pumps will have already been replaced. This means that half of the pumps will have lost on average, half of their useful lives. This results in an additional 3.5 percent loss due to non-normal wear and tear. Overall repair and maintenance costs, then, appear to amount to about 6.5 percent of the initial cost of the pumps, including the estimated 3.0 percent of initial cost required to cover repairs and maintenance due to normal wear and tear. Since the initial set of equipment included four replacement motors and pumps for the 44 operating pumps, we apply a flat 6.0 percent to the total cost of all pumps and motors to get annual repairs and maintenance costs that should be included in the irrigation assessment.

Electricity power costs account for 40 percent of the irrigation assessment. Repairs and maintenance would amount to 23 percent of total costs, if adequately provided for, while depreciation would represent 29 percent. In fact, it appears that the co-operatives are not setting aside adequate reserves to assure replacement of equipment as it wears out or breaks down. The analysis of the incidence of pump break-downs suggests that extraordinary repairs and replacement require a doubling of the 3 percent acquisition cost currently budgeted to cover repairs and maintenance fully. This line item represents a significant portion of the shortfall in the amount of the current assessment.

Operating costs at the independent diesel powered Ruwana perimeter at Safo amounted to 20,800 FCFA for 0.167 ha or 124,800 FCFA per hectare in 1986. This covers fuel, repairs, salary for the pump operator, fertilizer, minor repairs, service and, presumably, a co-operative assessment. However, the Team was unable to obtain a complete breakdown of the irrigation assessment. But an analysis of 9 out of 10 months of expenditures for 1986 shows fuel accounting for 63 percent of total expenditures, maintenance and repairs 20 percent, while fertilizer and plant protection products were 7 percent of the total. Office expenses, the water guard's salary and miscellaneous expenses accounted for the rest.

2.6.1 Djirataoua Grid-Powered Electric Submersibles. An assessment of the power distribution grid performed in 1982 indicated that grid design was not optimized and that the initial investment for the power supply component could have been reduced by 11 percent.

Pumpsets of 7.5 kw rating provide 89.1 cubic meters per hour (average); pumpsets of 3.5 kw provide 53.6 cubic meters per hour when lifting water through the average dynamic lift of 13.8 m. Total volume per hectare pumped annually is 14,872 cubic meters (see Table D 2.6.2).

Interviews with perimeter management staff indicate that any volumetric assessments of water pumped had been based upon the maximum usable flow specified during the tubewell tests (Ref: Table No. D 2.6.2) and not the actual pump outputs (Table D 2.6.3). No specifications for the installed pumpsets were available at the perimeter or project headquarters. Pump performance for the case study analysis was determined from commissioning test reports conducted by the supplier in 1984 (Figure D 2.6.1) and later verified against manufacturers' specifications.

Most pumpsets were installed between 1981 and 1984. A cumulative total of 132 years of operating experience has been acquired. The average daily run-time since installation is 7.1 hours per day (based upon 6 day working week). Pumping systems are operated 6 days per week for 11 hours per day during peak demand periods and 3 days per week at other times. Systems are normally in operation year round except during the rainy season (August) when levels of utilization are reduced by 75 percent.

The static level of the water table was monitored from the beginning of the project on a regular basis until 1983. The average static depth of the 43 tubewells was 6.02 meters in 1980. This level, based upon depth samplings in 13 tubewells during the case study, indicates that the static depth has increased to 7.26 meters in 1986 when corrected for seasonal fluctuation. This represents a decrease in the level of the water table of 20 cm/year for the period until May 1984, when 21 additional pumpsets were brought on line, and 25 cm/year thereafter (Figure D 2.3.1).

The dynamic level for each tubewell was determined during output capacity tests conducted in 1979-80. During maximum flow tests the average dynamic level was 12.25 meters, decreasing to 10.07 meters at the recommended maximum usable flow of 58.7 cubic meters/hour. The pumpsets installed exceeded the recommended maximum usable flow by 45 percent. (For details on a site-by-site basis see Table D 2.6.2.)

2.6.2 <u>Ruwana Perimeter at Safo</u>. The Ruwana site offers the possibility for direct comparison between the grid-fed perimeter of Djirataoua and a stand-alone diesel (direct-drive) system operating from the same water source and co-operatives.

This site was not examined in detail. However, investment and O & M costs were ascertained, together with some basic performance figures.

Fuel consumption is estimated at 2.80 lph when pumping 47 cubic meters/hour from 11.35 depth. The system is operated 9 hours/day in order to irrigate the 9.5 ha perimeter.

No data was collected on the performance of the distribution system.

Table D 2.6.2 Well Characteristics at Djirataoua

| Sector Code | Old Site Ident. | Site Ident. | Max Outflow New (lps)* | Storage Tank + Yes | Date of Installation | Nominal Pump Rating (kw) | Area Irrigated 1986 (ha) | Static Water Level Ns Oct/Nov80 (m) | Oct81 (m) | Oct82 (m) | Oct83 (m) | Feb87 (m) | Pump Test Dynamic Level (m) | Pump Test Flow (lps) | Dynamic Level at Usable Flow (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 232 | 01RA | 13.00 | + | Dec 82 | 3.70 | 6.82 | 4.73 | 5.03 | 5.31 | 6.21 | 6.70 | 14.31 | 20.05 | 10.80 |
| 2 | 231 | 02RA | 15.00 |  | Dec 82 | 7.50 | 10.56 | 4.62 | 4.96 | 5.26 | 6.21 | 6.60 | 13.28 | 20.00 | 11.11 |
| 2 | 2268 | 03RA | 15.00 |  | Dec 82 | 7.50 | 10.72 | 5.05 | 5.24 | 5.53 | 6.34 |  | 14.62 | 31.20 | 9.65 |
| 9 | 227 | 04RA | 17.00 |  | Jan 83 | 7.50 | 10.36 | 4.04 | 4.19 | 4.44 | 6.21 |  | 8.35 | 25.50 | 6.91 |
| 9 | 228 | 05RA | 17.00 |  | Jan 83 | 7.50 | 13.48 | 4.32 | 4.45 | 4.74 | 5.53 |  | 9.94 | 33.30 | 7.19 |
| 9 | 229 | 06RA | 13.00 |  | Jan 83 | 3.70 | 9.20 | 4.20 | 4.34 | 4.63 | 5.74 |  | 12.00 | 18.90 | 9.68 |
| 4 | 2028 | 07RAA | 15.00 | + | May 84 | 3.70 |  | 4.94 | 4.90 | 5.27 | 5.25 | 6.70 | 14.70 | 17.20 | 10.62 |
| 4 | 201 | 07RAB | 10.00 | + | May 84 | 7.50 | 21.12 | 4.05 | 4.23 |  | 4.92 |  | 15.32 | 21.20 | 12.03 |
| 4 | 200 | 08RAA | 6.00 | + | May 84 | CAPRARI | 5.37 | 5.46 | 5.72 | 5.20 | 7.25 | 14.00 | 9.80 | 9.75 |  |
| 4 | 204 | 08RAB | 18.00 | + | May 84 | 7.50 | 19.52 | 5.37 | 5.46 | 5.84 | 5.23 | 7.30 | 10.50 | 31.20 | 8.33 |
| 4 | 195 | 09RA | 18.00 |  | Jan 85 | 7.50 | 8.32 | 3.84 | 4.12 | 4.35 | 5.22 |  | 13.06 | 14.20 | 10.37 |
| 5 | 168 | 026N | 16.00 |  | Jun 81 | 7.50 | 10.32 | 5.91 |  | 6.22 | 6.82 |  | 9.30 | 20.50 | 8.55 |
| 5 | 169 | 036N | 15.00 | + | Jun 81 | 7.50 | 10.82 | 7.01 |  | 7.29 | 6.73 |  | 13.09 | 20.60 | 11.43 |
| 5 | 170 | 046N | 20.00 |  | Jun 81 | 7.50 | 10.24 | 2.44 | 7.39 | 7.56 | 6.29 |  | 11.01 | 34.00 | 9.54 |
|  | 161 | 016N | 11.00 |  | Jan/Jun85 | 7.50 | 11.52 |  |  |  |  |  |  |  |  |
| 5 | 166 | 056N | 14.00 |  | Jun 81 | 7.50 | 10.24 | 7.97 | 6.94 | 7.56 | 6.32 | 8.20 | 15.60 | 24.00 | 12.00 |
| 5 | 162 | 066N | 18.00 |  | Jun 81 | 7.50 | 11.50 | 7.70 | 7.76 | 7.93 | 6.29 |  | 12.95 | 32.50 | 10.61 |
| 5 | 172 | 00FP | 14.00 | + | Jun 81 | 3.70 |  | 6.70 |  | 4.39 | 7.53 |  | 14.00 | 24.00 | 12.39 |
| 10 | 79 | 016S | 22.00 |  | Mar 82 | 7.50 | 9.88 | 4.41 | 5.87 |  |  |  | 7.42 | 27.70 | 6.80 |
| 10 | 160 | 026S | 18.00 |  | Feb 84 | 7.50 | 12.46 | 5.51 | 6.04 |  |  |  | 11.30 | 30.30 | 8.05 |
| 10 | 151 | 035S | 16.00 |  | Feb 84 | 7.50 | 10.24 |  | 6.21 |  | 6.23 | 7.50 |  |  |  |
| 10 | 157 | 046S | 14.00 | + | Feb 84 | 7.50 | 10.72 |  | 7.08 | 7.18 | 7.02 | 8.65 |  |  |  |
| 10 | 158 | 056S | 18.00 |  | Feb 84 | 7.50 | 8.96 | 6.23 | 6.57 | 6.77 | 6.92 |  | 14.20 | 25.60 | 11.84 |
| 10 | 145B | 066S | 20.00 |  | Feb 84 | 7.50 | 17.60 | 6.38 | 6.65 |  | 6.22 |  | 8.14 | 23.80 | 7.86 |
| 11 | 138 | 076S | 18.00 |  | May 84 | 7.50 | 13.12 |  |  |  |  |  |  |  |  |
| 11 | 141 | 086S | 18.00 | + | May 84 | 7.50 | 11.52 |  |  |  | 6.22 |  |  |  |  |
| 11 | 139 | 096S | 18.00 |  | May 84 | 7.50 | 10.88 |  |  |  | 6.23 |  |  |  |  |
| 11 | 131 | 106S | 17.00 |  | May 84 | 7.50 | 11.24 | 7.30 | 7.40 | 7.65 | 7.46 | 7.65 | 10.46 | 28.60 | 9.47 |
| 11 | 137B | 116S | 19.00 |  | May 84 | 7.50 | 16.48 | 6.80 | 8.86 | 7.13 | 7.02 |  | 10.78 | 30.30 | 9.29 |
|  |  |  |  |  |  |  |  |  |  |  |  | 7.90 |  |  |  |
| 11 | 125B | 6S12 | 19.00 |  | May 84 | 7.50 | 11.52 | 6.89 | 6.89 | 7.16 | 7.14 |  | 13.94 | 31.30 | 11.18 |
| 6 | 121 | 02km | 19.00 |  | May 84 | 7.50 |  | 7.10 | 7.09 | 7.40 | 6.05 | 8.20 | 13.44 | 33.30 | 10.72 |
| 6 | 118 | 03km | 14.00 |  | Aug 84 | 3.70 | 8.00 | 6.75 | 6.72 | 7.02 | 6.25 |  | 16.09 | 19.20 | 13.58 |
| 6 | 118 | 04km | 14.00 |  | May 84 | 7.50 | 10.55 |  |  |  | 6.19 |  |  |  |  |
| 6 | 119 | 05km | 18.00 |  | May 84 | 7.50 | 9.28 |  |  |  | 6.23 |  |  |  |  |
| 1 | 117 | 06km | 18.00 |  | May 84 | 7.50 | 15.68 |  |  |  | 6.21 |  |  |  |  |
| 1 | 109 | 07km | 18.00 |  | Jan 83 | 7.50 | 11.52 | 7.51 | 7.58 | 7.88 | 8.09 |  | 13.86 | 29.40 | 11.40 |
| 1 | 110 | 08km | 18.00 |  | Jan 83 | 7.50 | 13.48 | 6.44 | 6.51 | 6.80 | 6.12 |  | 9.52 | 29.40 | 8.33 |
| 7 | 116 | 09km | 18.00 |  | Jan/Nov84 | 7.50 | 12.00 | 7.68 | 7.68 | 7.68 | 7.05 |  | 12.58 | 31.20 | 10.51 |
| 1 | 101 | 10km | 18.00 |  | Jan 83 | 7.50 | 12.80 | 7.99 |  | 8.43 | 8.29 | 9.45 | 10.50 | 30.30 | 9.48 |
| 7 | 103 | 11km | 18.00 |  | Feb 84 | 7.50 | 13.12 | 7.91 | 7.98 | 8.28 | 8.04 |  | 12.38 | 29.40 | 10.64 |
| 7 | 111 | 12km | 18.00 |  | Jan 83 | 7.50 | 6.08 | 7.45 |  |  | 6.23 |  | 11.34 | 30.30 | 9.76 |
|  |  | 13km | 15.00 | + | Nov 82 | CAPRARI | 5.76 |  |  |  |  |  |  |  |  |
| 8 | E21 | 14km | 19.50 |  | Mar 82 | 7.50 | 11.84 | 8.04 |  |  |  | 8.95 | 12.41 | 24.40 | 11.53 |
|  | Avg Max Outflow |  | 16.45 |  | Averages<br>Total Area |  | 11.53<br>450 | 6.02 | 6.19 | 6.48 | 6.41 | 7.77 | 12.25 | 25.84 | 10.07 |

* Based on well tests
+ New

Table D 2.6.3 Pump-set Performance at Djirataoua

| Distance Top of Screen To Dyn Level | Draw Down Ns-Nd (m) | Q/ Nd-Ns | Accum Run Time (Meter) (hr) | Accum Energy (Meter) (kwh) | Average Power Consumption (w) | Total Operating Head (m) | Flow ($m^3$/hr) | Accu Flow Since Install ($m^3$) | Flow from CNIR ($m^3$/yr) | Flow from CNIR ($m^3$/ha/yr) | Flow From kwh Mtr ($m^3$/ha/yr) | Ratio of Pump Q to Tubewell Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.50 | 6.49 | 2.00 | 7852 | [illegible] | | 14.04 | 52.00 | 41486 | 103646 | 15197 | | 1.13** |
| 6.19 | 4.60 | 3.26 | 11031 | [illegible] | [illegible] | 14.44 | 86.20 | 589202 | 147300 | 13949 | 13949 | 1.60** |
| 7.65 | 2.87 | 5.23 | 8060 | 54828 | 6.80 | 12.55 | 88.50 | 713310 | 178328 | 16635 | 16166 | 1.64** |
| 8.39 | 2.87 | 5.92 | 8376 | 52203 | 5.23 | 8.98 | 94.20 | 789019 | 201280 | 19429 | 17298 | 1.54** |
| 8.11 | 2.87 | 5.92 | 8490 | 60353 | 7.11 | 9.35 | 93.60 | 794664 | 202720 | 15039 | 15272 | 1.53** |
| 5.12 | 5.48 | 2.37 | 8630 | 33208 | 3.85 | 12.58 | 54.80 | 472924 | 120644 | 13113 | 14417 | 1.17** |
| 3.68 | 5.68 | 1.76 | 5634 | 24229 | 4.30 | 13.81 | 53.20 | 299729 | 115280 | | | |
| 4.87 | 7.98 | 1.88 | 9035 | 58833 | 6.51 | 15.64 | 84.20 | 760747 | 292595 | 13854 | 12887 | 2.34** |
| 6.55 | 4.38 | 1.14 | | | | 12.68 | 0.00 | 0 | 0 | | | |
| 5.77 | 2.96 | 6.08 | 7486 | 49922 | 6.67 | 10.83 | 91.50 | 684969 | 263450 | 13496 | 12858 | 1.41** |
| 4.57 | 6.53 | 1.53 | | | | 13.48 | 0.00 | 0 | 0 | | | |
| 7.75 | 2.64 | 6.06 | (3808) | 37438 | | 11.12 | 91.20 | 0 | 0 | | 13504 | 1.58** |
| 7.57 | 4.42 | 3.39 | | | | 14.86 | 0.00 | 578997 | 165428 | 16155 | 13112 | 1.24** |
| 7.86 | 7.10 | 2.82 | 6491 | 36879 | 5.68 | 12.40 | 89.20 | 0 | 0 | | | |
| | | | | | | 0.00 | 0.00 | 0 | 0 | | | |
| 8.80 | 4.03 | 3.47 | | | | 15.60 | 0.00 | 0 | 0 | | | |
| 5.19 | 2.91 | 6.19 | | | | 13.79 | 0.00 | 0 | 0 | | | |
| 4.71 | | | | | | 16.11 | 0.00 | 0 | | | | |
| | | | | | | 0.00 | 0.00 | 0 | 0 | | | |
| 10.50 | 2.39 | 9.21 | | | | 8.84 | 0.00 | 0 | 0 | | | |
| 27.50 | 3.44 | 5.23 | | | | 11.64 | 0.00 | 0 | 0 | | | |
| | | | 5313 | 34653 | 6.52 | 0.00 | 0.00 | 0 | 0 | | | |
| | | | 6107 | 42570 | 6.97 | 0.00 | 0.00 | 0 | 0 | | | |
| 5.26 | 5.61 | 3.21 | | | | 15.39 | 0.00 | 0 | 0 | | | |
| 9.24 | 1.48 | 13.51 | | | | 10.22 | 0.00 | 0 | 0 | | | |
| | | | 4068 | 30402 | 7.47 | 0.00 | 0.00 | | | | | |
| | | | | | | 0.00 | 0.00 | 0 | 0 | | | |
| | | | | | | 0.00 | 0.00 | 0 | 0 | | | |
| 6.42 | 2.17 | 8.76 | 5201 | 38224 | 7.35 | 12.31 | 89.50 | 465490 | 179034 | 15928 | 16723 | 1.46** |
| 6.81 | 2.49 | 7.63 | | | | 12.08 | 0.00 | 0 | 0 | | | |
| | | | 4341 | 31884 | 7.34 | 0.00 | 0.00 | 0 | 0 | | | |
| 6.43 | 4.29 | 4.43 | | | | 14.53 | 0.00 | 0 | 0 | | | |
| 6.58 | 3.62 | 5.25 | 6591 | 20425 | 3.10 | 13.94 | 86.70 | 571440 | 219785 | | | 1.27** |
| 3.72 | 6.83 | 2.05 | | | | 17.65 | 0.00 | 0 | 0 | | | |
| | | | 4117 | 27976 | 6.80 | 0.00 | 0.00 | 0 | 0 | | | |
| | | | | | | 0.00 | 0.00 | 0 | 0 | | | |
| | | | | | | 0.00 | 0.00 | 0 | 0 | | | |
| 9.60 | 3.89 | 4.63 | 7460 | 53197 | 7.13 | 14.82 | 89.50 | 667670 | 166918 | 14489 | 14760 | 1.38** |
| 8.97 | 1.89 | 9.52 | | | | 10.83 | 0.00 | 0 | 0 | | | |
| 7.68 | 2.83 | 6.36 | | | | 13.66 | 0.00 | 0 | 0 | | | |
| 4.85 | 1.49 | 12.08 | 7012 | 49762 | 7.10 | 12.32 | 89.50 | 627574 | 156894 | 12257 | 12427 | 1.38** |
| 6.66 | 2.73 | 6.59 | | | | 13.83 | 0.00 | 0 | 0 | | | |
| 7.54 | | | | | | 12.69 | 0.00 | 0 | 0 | | | |
| | | | | | | 0.00 | 0.00 | 0 | 0 | | | |
| 5.66 | 3.49 | 5.59 | 9205 | 61050 | 6.63 | 14.99 | 85.20 | 784266 | 163389 | 13800 | 13075 | 1.21** |
| Avg.7.35 | 3.95 | 5.26 | 6690 | | | | | AVERAGE ($m^3$/ha/Yr) | | 14872 | | 1.46 |

**Indicates sites selected for detailed analysis.

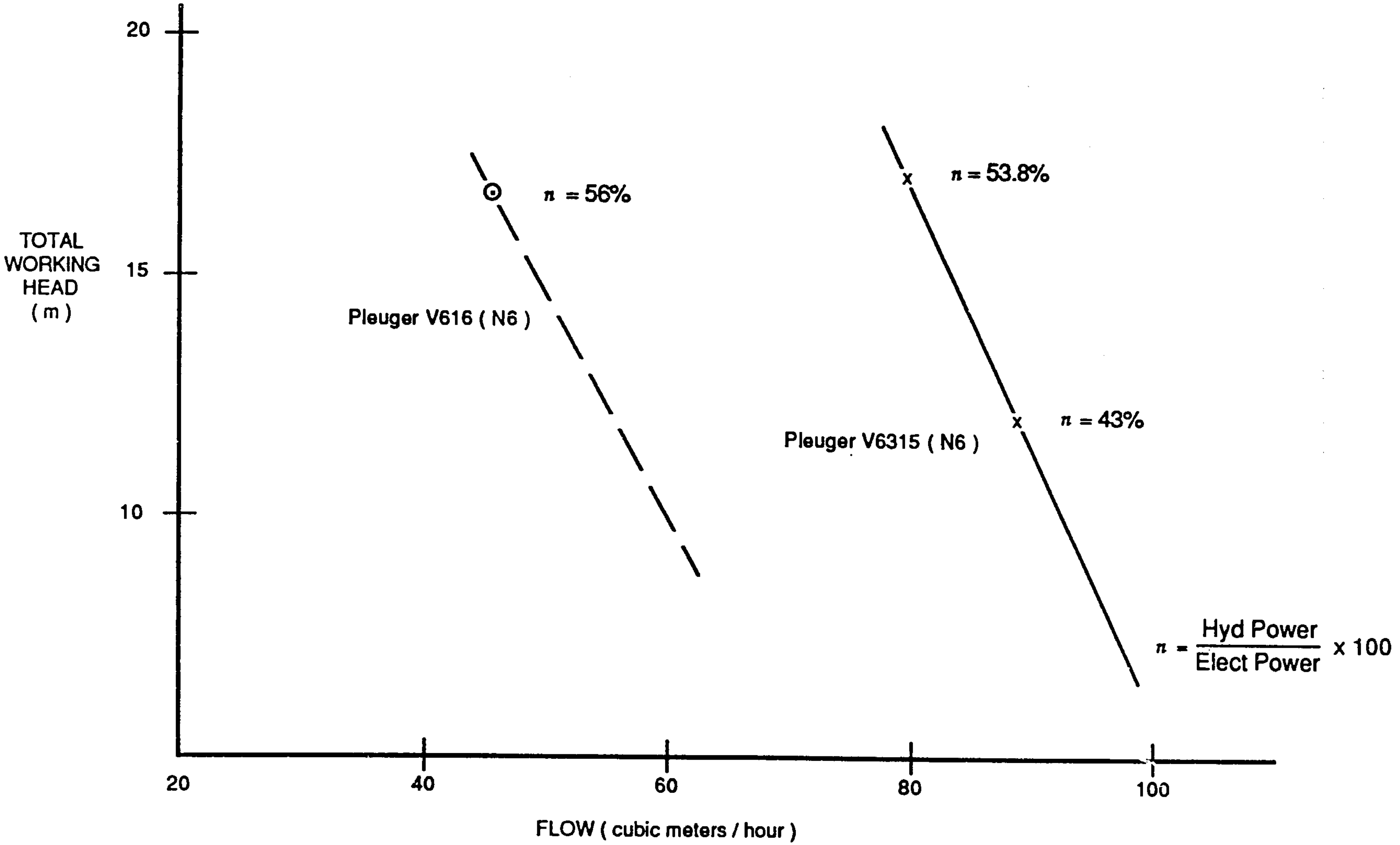

Figure D2.6.1 Performance data from commissioning tests ( May '84 ).

## 2.7 Farm Enterprise and Institutional Functioning

Irrigated parcels within the Djirataoua perimeter seem to be allocated exclusively to household heads and it is likely they provide the bulk of labor to it. The absence of a census of parcel holders makes it impossible to construct a typology of farm types which include perimeter parcels, however. Association of the irrigated parcel with household headship may be an indicator of the importance of irrigated land to the household farm enterprise. However, in the absence of off-farm resources, parcel ownership may also facilitate the break-up of larger household units into nuclear family units.

Our data suggest the following characteristics are relevant to defining the dynamics of farm management:

- variations in the number of perimeter holdings from one to six parcels, though holdings of more than one parcel are still fairly rare;
- the size of off-perimeter holdings, which may vary from none to over three hectares, this being the departmental norm;
- farms may include irrigated holdings, dune fields, and lowland parcels in the Goulbi;
- the household labor supply, which varies from one to more than ten laborers, the norm being less than two fully active laborers per household;
- extent to which households employ extra-household labor, though most do, particularly for weeding and harvesting;
- rate of use of unpaid labor exchange, which varies significantly from one GMP to another;
- degree of competition for labor between rainfed and irrigated cultivation, which depends on relative size of these holdings and labor resources;
- percentage of cash crops grown;
- village of residence, which influences parcel and GMP management, notably in the cases of Djirataoua and Danja;
- parcel soil type and parcel position relative to the pump, which can influence yields; and
- the presence of significant numbers of persons of special social status among parcel holders: women, officials, notables, merchants, lepers, etc., which affects GMP organization.

Putting these factors together, one can detect a number of alternative strategies for successful integration of irrigated agriculture into the farming enterprise. Mobilizing traditional sources of solidarity to cope with individual resource deficits is one strategy. Spreading labor over a range of farm activities is another. Seeking to penetrate upstream and downstream marketing channels from a base in commercial production is yet another. However, the farm enterprise is influenced by broader organizational forces.

At the level of the GMP, irrigation is done in blocks with six persons irrigating in the morning and six in the evening. Water is drawn from tertiary canals with siphons. The order and frequency of GMP level irrigation scheduling is a function of ONAHA's recommendations (based on old IRAT research results), farmers' understanding of crop needs, rainfall patterns (during the rainy season), order in which parcels are prepared for planting and parcel placement in relation to the head of the secondary.

Farmers feel that they have a certain amount of say over such irrigation management issues (at the GMP level) as organization of the irrigation schedule, secondary and tertiary canal and drain maintenance, pesticide treatment, and arrangements for labor sharing. GMP level meetings are fairly regular and views are freely aired when it is felt major decisions are imposed upon them. While it was recognized that water stealing and lackadaisical maintenance were occasional problems, most farmers felt sanctions could be successfully applied at the GMP level.

In the exceptional case of Danja village, a high of 10 GMP meetings in a single season was reported and the performance of their GMP has been praised. In this case, the isolation of lepers as a caste, their diversity of origin, and the intensity of their training at the SIM hospital seems to have facilitated, as theory would suggest, an interest group with a high degree of consensus and potential for effective action. This special case suggests that general improvements in training and extension could lead to improved efficiency of labor allocation at the GMP level.

From the GMP level, cropping fee rate setting continues to be seen as a mysterious and essentially authoritarian process. All farmers seem to welcome cotton as a means of liquidating their debts. While many understand the purpose of the redevance, to others, it is perceived like any other tax whose finality is unknown.

The co-operative management committee sees itself making decisions and passing them down to the GMP leadership and supervising perimeter cropping and marketing cycles in concert with ONAHA technical assistance. The committee which admits its inexperience in a number of areas, especially financial management and management of energy, has begun to assert some control over these areas. A new accountant, an electrician and pumping technicians have recently been hired to replace Maradi Subaltern Project personnel who where found to be diverting co-operative resources to personal ends.

The overall technical parameters of perimeter operation have, however, been determined by technicians from the Maradi Project and more recently by those from ONAHA, CFDT and the Crop Protection Service. The

Prefecture also intervenes in co-operative affairs through an Advisory Committee. Included are such elements as crop choice and rotational sequence, fertilizer dose, irrigation frequency and duration, crop protection products and treatment frequencies and the organization of successful formal marketing circuits for cotton and less successful ones for wheat. To some extent, co-operative and GMP self-management have been sacrificed in the interest of administrative expediency.

The management committee has been given a rolling fund of 8 million francs by the Maradi Project with which to finance its activities and prime the pump of co-operative self-management. In addition, adding cotton to the production system was a decision taken by technical assistance, the management committee and the General Assembly of the co-operative to cope with past arrears. For the management groups then, this decision should have resolved the problem of redevance payments. But the management committee now finds itself in the role formerly played by the Project and ONAHA of policing credit. Non-payers are now seen essentially as bad eggs, the co-operative authorities having essentially adopted the "recalcitrant farmer" position of the administration.

# 3.0 Evaluation of Performance

## 3.1 Irrigation System Operation

Monthly kilowatt-hour power use for each electrical sector in the perimeter was obtained and converted into hours of pumping. Resultant volumes of water applied were compared to ET crop calculations based on local pan and lysimeter data and divided over respective crop hectarages throughout the course of the year. The data, as seen in Table D 3.1.1 of both the Aderaoua and the Maderaoua sectors of the electric grid, indicates that enough global water is pumped annually to meet crop water demands at an application efficiency of 40-45 percent. However, monthly variations are significant--indicating management and scheduling inefficiencies, resulting in evident crop losses and significant waste of water. (To some degree the extremes in some of the monthly variations can be due to the way in which the cropping calendar was reconstructed for crop water requirement calculations and the lack of 1984 weather and pan data; but significant monthly variances in water use exist nevertheless.)

It is interesting to note that periods when labor constraints are at their highest--usually the summer months during rainfed cultivation--are indicated in the table as those periods when water deficits are at their highest in the system (see Table D 3.1.1). Conversely, overuse of water appears to take place in dry season months when labor requirements external to the perimeter are at a minimum. In addition, variances in soils both between and within sectors are not well addressed by the system. Some sectors which even have storage reservoirs are pushed to longer hours of application if their reservoirs are not utilized properly and more frequently, thus, their energy costs are unnecessarily escalated due to day-time filling. (The tubewells, with lower discharge rates per hectare served and which are equipped with storage reservoirs, were designed to fill the reservoirs at night during low power cost periods; however, few appear to be used on this schedule.)

At the parcel level, a number of farmers experience difficulties in obtaining design flows of 4 lps with their siphons due to insufficient head as a result of varying elevation differences between the primary concrete channels and adjacent parcels. This results in farmers having to augment their flows with several extra siphons, and in turn, reduces the total number of farmers who can irrigate at once--since each GMP only has access to a set number of siphons (30-35 usually).

## 3.2 System Management

The irrigation schedule used by the extension agents is largely that prescribed by the early project documents--and which was passed on to extension agents in some of the first (and last!) "training sessions" given in 1980/81. This schedule was apparently based on sparse or, at best, uncertain evaporation data (Charoy, 1971), and pump discharges that

Table D 3.1.1 Djirataoua Water Budget, 1984, and Estimated Irrigation Efficiencies

| Month: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Annual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector: | | | | | | | | | | | | | |
| Aderaoua Est. | | | | | | | | | | | | | |
| CROPS (ha) | | | | | | | | | | | | | |
| Cotton | | | | 7.40 | 14.80 | 14.80 | 14.80 | 14.80 | 14.80 | 7.40 | | | |
| Sorghum | | | | | | 17.28 | 17.28 | 17.28 | 17.28 | | | | |
| Tomato | 8.01 | 8.01 | 8.01 | 8.01 | | | | | | | 8.01 | 8.01 | |
| Vegs. | 5.56 | 5.56 | 5.56 | 2.78 | | | | | | | 2.78 | 5.56 | |
| Arach. | | | | | | | | | | | | | |
| Total | 13.57 | 13.57 | 13.57 | 18.19 | 14.80 | 32.08 | 32.08 | 32.08 | 32.08 | 7.40 | 10.79 | 13.57 | |
| WATER REQ. ($m^3$) | | | | | | | | | | | | | |
| Cotton | | | | 2220 | 5254 | 13793 | 21149 | 21800 | 18670 | 6697 | | | 89583 |
| Sorghum | | | | | | 13461 | 29255 | 30931 | 25160 | 98807 | | | |
| Tomato | 12311 | 15027 | 14875 | 2920 | | | | | | | 4565 | 8411 | 50109 |
| Vegs. | 10175 | 10431 | 2196 | 1098 | | | | | | | 2836 | 8334 | 35070 |
| Arach. | | | | | | | | | | | | | |
| Total | 22486 | 25458 | 17071 | 6238 | 5254 | 27254 | 50404 | 52731 | 43830 | 6697 | 7401 | 16745 | 281569 |
| (mm) | 166 | 188 | 126 | 34 | 36 | 85 | 157 | 164 | 137 | 91 | 69 | 123 | 1374 |
| PRECIPITATION | | | | | | | | | | | | | |
| (1000 $m^3$) | | | | | | 15158 | 29594 | 14917 | 5774 | | | | 65443 |
| (mm) | | | | | | 47 | 92 | 47 | 18 | | | | 204 |
| DELIVERY | | | | | | | | | | | | | |
| Kw-hrs | 3515 | 2138 | 3425 | 4760 | 3097 | 3474 | 1229 | 3829 | 3047 | 1563 | 1697 | 3436 | 35210 |
| hrs | 204 | 124 | 199 | 277 | 180 | 202 | 71 | 223 | 177 | 91 | 99 | 200 | 2048 |
| 1000$m^3$ | 49607 | 30173 | 48337 | 67177 | 43708 | 49028 | 17345 | 54038 | 43002 | 22058 | 23950 | 48492 | 496914 |
| mm | 366 | 222 | 356 | 369 | 295 | 153 | 54 | 168 | 134 | 298 | 222 | 357 | 2996 |
| %EFFICIENCY | 45 | 84 | 35 | 9 | 12 | 25 | 120 | 70 | 88 | 30 | 31 | 35 | 43 |

NOTES: Crops - Hectarages obtained from 1984 recoreds at the perimeter.
Water Requirements - Obtained for each crop from ET-grass (Charoy, 1971) times a crop coefficient.
Precipitation - Values taken from "Djirataoua" station; adjusted for effective precipitation (75%).
Delivery - Kwhr values obtained from monthly Nigelec bills for each sector; hours obtained by dividing by actual power rating of pump.
Efficiency - computed as (water req. - precip)/delivery.

Table D 3.1.1 (continued)

| Month: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Annual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector: |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Maderaoua Ouest |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CROPS (ha) |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cotton |  |  |  | 2.88 | 5.76 | 5.76 | 5.76 | 5.76 | 5.76 | 2.88 |  |  |  |
| Sorghum |  |  |  |  |  | 6.08 | 6.08 | 6.08 | 6.08 |  |  |  |  |
| Tomato | .08 | 0.08 | 0.08 | 0.08 |  |  |  |  |  |  | 0.08 | 0.08 |  |
| Vegs. | .56 | 4.56 | 4.56 | 2.28 |  |  |  |  |  | 2.28 | 2.28 | 4.56 |  |
| Arach. |  | 3.12 | 3.12 | 3.12 | 3.12 |  |  |  |  |  |  |  |  |
| Total | 4.64 | 7.75 | 7.76 | 8.36 | 8.88 | 11.84 | 11.84 | 11.84 | 11.84 | 5.16 | 2.36 | 4.64 |  |
| WATER REQ. ($m^3$) |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cotton |  |  |  | 864 | 2045 | 5368 | 9259 | 9821 | 7266 | 2606 |  |  | 37229 |
| Sorghum |  |  |  |  |  | 4736 | 10293 | 10883 | 8852 |  |  |  | 34764 |
| Tomato | 123 | 150 | 149 | 29 |  |  |  |  |  |  | 46 | 84 | 581 |
| Vegs. | 7410 | 8555 | 6484 | 923 |  |  |  |  |  | 684 | 1642 | 4715 | 30413 |
| Arach. |  | 3092 | 5348 | 7582 | 6571 |  |  |  |  |  |  |  | 22593 |
| Total | 7533 | 11797 | 11981 | 9398 | 8616 | 10104 | 19552 | 20704 | 16118 | 3290 | 1688 | 4799 | 125580 |
| (mm) | 162 | 152 | 154 | 112 | 97 | 85 | 165 | 175 | 136 | 64 | 72 | 103 | 1478 |
| PRECIPITATION |  |  |  |  |  |  |  |  |  |  |  |  |  |
| (1000 $m^3$) |  |  |  |  |  | 5594 | 10922 | 5506 | 2131 |  |  |  | 24154 |
| (mm) |  |  |  |  |  | 47 | 92 | 47 | 18 |  |  |  | 204 |
| DELIVERY |  |  |  |  |  |  |  |  |  |  |  |  |  |
| kw-HRS | 1763 | 2143 | 1748 | 2464 | 1555 | 1406 | 873 | 923 | 1504 | 928 | 900 | 1890 | 18106 |
| hrs | 266 | 323 | 264 | 372 | 235 | 212 | 132 | 139 | 227 | 140 | 137 | 285 | 2731 |
| 1000$m^3$ | 22656 | 27539 | 22463 | 31664 | 19983 | 18068 | 11219 | 11861 | 19327 | 11925 | 11681 | 24288 | 243674 |
| mm | 488 | 355 | 289 | 379 | 225 | 153 | 95 | 100 | 163 | 231 | 495 | 523 | 3497 |
| % EFFICIENCY | 33 | 43 | 53 | 30 | 43 | 25 | 77 | 128 | 72 | 28 | 14 | 20 | 44 |

NOTES:
Crops - Hectarages obtained from 1984 records at the perimeter.
Water Requirement - Obtained for each crop from ET-grass (Charoy, 1971) times a crop coefficient.
Precipitation - Values taken from "Djirataoua" station; adjusted for effective precipitation (75%).
Delivery - Kwhr values obtained from monthly Nigelec bills for each sector; hours obtained by dividing by actual power rating of pump.
Efficiency - computed as (water req. - precip)/delivery.

were underestimated. The irrigation schedule is far too rigid, and that does not address individual crop water needs, nor the diversity of soil types found in different sectors of the perimeter. Management personnel simply need to know better how to handle scheduling given these factors. It also appears that the management is not capable of adequately controlling water stealing, particularly if this occurs at night.

Routine maintenance appears to be non-existent. No regular reconnaissance is made in the perimeter to identify such needs. Inspection of the canals, for example, indicated that sealing of cracks or separated seams was not done, and canal sections with removed or broken cross-braces were left unrepaired.

### 3.3 On-Farm Irrigation and Crop Management

As previously noted, farmers do reasonably well with field application of water. This is largely due to their own adaptations to the system--for example, that of reducing furrow lengths to 10-15 m. The notable exception, however, is the apparent poor timing/scheduling of water applications, which affects production adversely in some sectors and in different seasons. There is evidently some amount of control from above that could be reduced, or at least made more sensitive to local conditions and flexible enough to deal with them.

3.3.1 On-Farm Irrigation. Current water management by the project aims to supply the full ET requirements determined by lysimeter studies at the former IRAT Station Experimentale de l'Hydraulique Agricole (SEHA) at Tarna. The project delivers rigid 30 mm or 50 mm net water application per hectare per week. These quantities are very rough approximations of crop water requirements. They do not reflect generally accepted crop coefficients for different stages of plant development. In the very early stages of each crop cycle some over-irrigation may occur because of deep percolation losses in the sandy and sandy loam soils of the perimeter. During later critical crop growth stages, the 50 mm weekly applications probably do not meet evapotranspiration demand requirements again due to substantial percolation in the lighter textured soils.

The spread in land preparation and planting dates from two to four or more weeks among parcels is a second major contributor to lower water application efficiencies. Within a twelve-parcel rotation group, farmers may plow and plant from two to four or more weeks apart. Some farmers pre-irrigate more than once and others apply greater depths of water than needed to the 8-10 meter strips of land that they may have prepared early.

Late planted crops may not be receiving sufficient water at critical growth stages. For example, the cotton crop is planted from May through early July. The May planted parcels will receive sufficient water if supplemental irrigation is provided during rainfall short periods. However, farmers interviewed said that to minimize energy charges, no pumping is done in a week when rain falls, but unfortunately no rain gauges are in use at the GMP level to provide overall system management with a better idea of whether a given rain provides sufficient water to the crop. Plots plowed and planted later may be over- or under-irrigated depending on the frequency and effectiveness of rainfall. The spread in planting dates decreases overall system efficiency because perimeter subdivisions cannot be managed as single units. Also, the state of the cotton crop observed in February lead the Team to believe that irrigation is continued at least a month beyond the requirements for the planned cotton crop cycle.

Soil erosion does not seem to be a major problem. There is some silt accumulation in the drain areas, but this may be due mainly to field channel dykes or spates. The field channels are being cut deeply. Deeper channels can increase water losses over a two year period by high velocity flows from farmers who double or triple the recommended number of siphons per field ditch.

Soil heterogeneity is a problem both within and between parcels. The great majority of the perimeters are on light to moderate textured sandy to sandy loam soils of alluvial origin with a transition zone to a sandy subsoil at between 45 and 75 cm. The Goulbi has many coarse sand lenses and sand spates in its floodplain which have received finer sandy and silty alluvium overlays with time. Cores taken at 30 meter intervals in some fields showed as much as 20 cm differences in depth to the sand layer over an 80 meter field length. Farmers were aware of these differences. But, cropping patterns and water applications have not been adjusted according to soil water holding capacity of specific blocks or parts of a farmer's field.

3.3.2 <u>Cropping Management</u>. The cropping pattern and rotation planned for the project is generally good. There are technical problems with cropping practices which reduce yields, including:

- the cotton season is extended by an extended planting season and late irrigations into February. Because pre-irrigation for the next cotton crop begins in late April, two major problems result. First, the chances of growing a hot, dry season crop are reduced; and second, the likelihood that pest problems will carry over into the next crop is increased.
- peanuts grown during the hot dry season are severely attacked by aphids. Old stocks of dimethoate were applied without success.
- fertilizer applications are suboptimal in quantity and kind. Triple 15-15-15 and urea is generally used. Single superphosphate is in short supply. Farmers tend to apply too much nitrogen to the cotton and peanut crop in relation to the amounts of phosphate and potassium applied. Fertilizer recommendations are the same as those for dryland crops. They are not sufficient to ensure optimal use of available land and irrigation water.

## 3.4 <u>Irrigated Agricultural Productivity</u>

The overall cropping intensity and yield levels of the project's perimeters are about average for systems of this size and age. However, there is substantial room for improvement in perimeter-wide cropping intensity and yields. The Table D 3.4.1 presents practical potential yield targets for the Djirataoua perimeter:

Table D 3.4.1 Product Yield Targets for the Djirataoua Project

| Crop | Current Yields Average (kg/ha) | Protected Potential Yields (kg/ha) | Current as Percent of Potential Yield (%) |
|---|---|---|---|
| Cotton | 2,100 | 2,500 | 84 |
| Sorghum | 2,000 | 2,800 | 71 |
| Wheat | 2,200 | 3,000 | 73 |
| Peanuts | 1,700 | 2,200 | 77 |
| Tomatoes | 2,200 | 2,800 | 79 |
| Millet | - | 1,500 | - |
| Onions | 35,000 | 38,000 | 92 |
| Niebe | - | 1,500 | - |
| Hot peppers | - | 7,000 | - |

The practical potential yields can be achieved on many of the systems and the best farmers already surpass the target potential yields. Average yields are lower than the potential for a variety of reasons. Besides the spread in planting dates and water management, plant protection, and fertilizer application deficiencies already mentioned, there are substantial marketing problems due to a depressed cereal market. These problems are reflected in the 1985/86 wheat crop.

The wheat crop was planted late due to logistic problems in seed supply. Two varieties were planted. One (Frinqual) was planted at the request of ONAHA for seed. The second variety (Florence Aurora) would have been sold for grain. Late planting delayed flowering and grain filling until the arrival of the hot dry winds of March. Substantial high temperature damage (échaudage) of the crop occurred. The government refused to buy the seed because the two varieties were mixed at harvest and because the seed was of poor quality. Wheat production was unexpectedly high during the cool season throughout Niger, depressing market prices.

## 3.5 Irrigation System Economics

Data in Table D 3.5.1 indicate that, in a normal year, the net economic value added by the Djirataoua perimeter is on the order of 43,000 FCFA per hectare, exclusive of capital costs and depreciation of heavy investments. The presence of the perimeter also prevents crop failures in probably one year in four. During such times the opportunity cost of labor working on non-irrigated land drops sharply since rainfed crops yields and, usually, crop revenue decline as well. The incremental economic value added by irrigated land probably doubles during drought years as rising crop prices reinforce the effect of the lower opportunity cost of land and labor resources.

Table D 3.5.2 summarizes the economic costs and benefits of the Djirataoua perimeter assuming a 23 year life of investment. Only investment costs are considered as a separate cost item since the irrigation assessment as budgeted in Table D 3.5.1 includes provision for replacing pumps and other light equipment and vehicles. The depreciation reserve is then credited as a negative investment at the end of the project. By then the wells will be worn out and there will be no benefit to installing new pumps.

The Team estimates that the economic internal rate of return of the investment in this perimeter, on the basis of the area cultivated, is a negative 7.1 percent per year. In absolute undiscounted terms, the project's net benefit stream, including recapture of the depreciation reserve, amounts to just over 700 million FCFA. This compares with investment costs of 2,300 million. If area cultivated could be restored to 500 hectares per year, the incremental economic value added would increase by approximately 5.5 million FCFA per year or 100 million over the life of the project.[2]

Obviously, irrigation systems economics are not independent of cropping system. At Galmi, where farmers rely more heavily on onions, gross revenue per hectare amounts to 925,000 FCFA; at Djirataoua, gross revenue per hectare is only 550,000 FCFA. The combination of low revenues and unusually high operating costs at Djirataoua makes it unlikely that such a system could ever be economic with the present cropping program.

For the Ruwana at Safo, farmers have considerably greater scope for improvement, since there is no required cropping pattern and they have more control over operation of the system. Coupled with the much lower investment costs per hectare, the Ruwana systems have at least potential of recovering investment costs over the estimated 20 year life of the wells. Much will depend on how effectively farmers take advantage of the flexibility which the Ruwana system offers. It is even conceivable that these systems can earn a competitive return on invested capital once farmers begin obtaining above average yields on a regular basis.

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[2] The fixed component of the irrigation assessment is already being paid by the 440 hectares currently under production and accounts for roughly two-thirds of the total assessment. Thus, the economic value added by restoring the 60 abandoned hectares would amount to 2/3 * 74,300 + 42,900 = 92,681 per hectare in normal years.

Table D 3.5.1 Estimated Farm Budgets Based on an Average Cropping system for 1985 at Djirataoua Irrigated Perimeter

| | Cotton | Sorghum | Wheat | Veget. | Peanuts | Totals |
|---|---|---|---|---|---|---|
| Area (ha)[1] | 0.16 | 0.16 | 0.11 | 0.06 | 0.12 | 0.61 |
| Yield (kg/ha) | 2,100 | 2,000 | 2,200 | 22,000 | 1700/4000[2] | |
| Price (FCFA/kg)[3] | 130 | 75 | 110 | 25 | 15/35[2] | |
| Gross Revenue (FCFA/parcel) | 43,680 | 24,000 | 26,620 | 33,000 | 30,600[4] | 174,700 |
| Input Costs (FCFA/parcel): | | | | | | |
| Non-Labor Inputs | | | | | | 24,435 |
| Soil Preparation | 1,500 | 1,500 | 1,030 | 375 | 1,200 | |
| Seed & Fungicides | 20 | 200 | 950 | 1,620 | 4,500 | |
| Fertilizer | 1,960 | 1,760 | 1,560 | 400 | 1,400 | |
| Transportation | 1,120 | 1,500 | 600 | 440 | 800 | |
| Labor Inputs: | | | | | | 66,600 |
| Hired Labor | - | - | 1,500 | - | - | |
| Family Labor[5] | 24,000 | 9,600 | 7,500 | 12,000 | 12,000 | |
| Irrigation Ass.[6] | 16,650 | 9,610 | 15,930 | 11,260 | 20,850 | 74,300 |
| Sub-Total | 45,250 | 24,170 | 29,070 | 26,095 | 40,750 | 165,335 |
| Charge for Invested Capital[7] | 2,770 | 1,630 | 1,440 | 1,470 | 2,320 | 9,630 |
| Returns to Management/ Economic Rents[8] | -4,340 | -1,800 | -3,890 | 5,435 | 4,330 | -265 |
| Average Person days Labor[9] | 40 | 15 | 18 | 24 | 24 | 121 |
| Average Return per Day[10] | 492 | 488 | 284 | 726 | 580 | 544 |
| Incremental Economic Value added[11] | 10,360 | 5,320 | 2,150 | 12,580 | 12,490 | 42,900 |

Source: Maradi Project Office

Footnotes: See following page

## Footnotes to Table D 3.5.1:

[1] During the rainy season land is planted half to sorghum and half to cotton. Wheat and vegetables are planted during the cool dry season following sorghum in the rotation while peanuts are planted during the hot dry season following cotton. Average area in crop reflects 1985 cropping patterns. Cropping intensity for that year was 1.88.

[2] First figure refers to peanuts in the shell. Second figure refers to peanut hay.

[3] All prices basd on long-run average trends, not current prices.

[4] Top figure is for peanuts, botton is for peanut hay.

[5] Valuing family labor at 600 FCFA per day for rainy season crops (cotton and sorghum) and at 500 FCFA per day for dry season crops (wheat, peanuts, and vegetables).

[6] Allocation of irrigation assessment by crop enterprise is based on the amount of irrigation water used by each crop. Use of irrigation water amounts to 5600 $m^3$/ha for sorghum, 9700 $m^3$/ha for cotton, 13,500 $m^3$/ha for wheat, 17,500 $m^3$/ha for vegetables and 16,200 $m^3$/ha for peanuts. The low figures for sorghum and cotton reflect the contribution rainfall the contribution rainfall makes to meeting crop water needs.

[7] Equal to 50 percent of average investment. Average investment equals on third of the sum of non-labor inputs and one half of the value of labor inputs. The one third value reflects the average crop cycle/investment period of four months. The one-half of labor reflects the progressive application of labor inputs over the four month period, i.e., on average, only one-half of the ultimate cost will have been invested for the entire four months. Both hired labor and family labor are treated as invested capital. No charge is made for the irrigation assessment since that is paid after the harvest.

[8] Gross revenue minus input costs and the charge for invested capital.

[9] Valuing piece rate labor at 500 FCFA/day.

[10] Includes returns to management plus all labor input costs divided by total days of labor, i.e., [(-265)+66,000] / 121.

[11] Assuming one-half of all inputs other than fertilizer, plant protection materials and the irrigation assessment represents net value added. The remaining half is a real cost to the economy in the form of income or remittances lost from other pursuits. Also assumes that one-half of the charge for invested capital is a return to additional savings and the investment stimulated by the project. In addition, assumes all returns to management represent net value added for the economy.

Table D 3.5.2 Investment Costs and Net Incremental Benefits Associated With Djirataoua Irrigated Perimeter (Million FCFA).

| Year | Investment Costs | Area in Production (ha) | Incremental Economic Value Added | Net Benefits | |
|---|---|---|---|---|---|
| | | | | 440 ha | 500 ha |
| 0 | 1152.0 | 0 | 0 | -1152.0 | -1152.0 |
| 1 | 1152.0 | 250 | 10.8 | -1141.2 | -1141.2 |
| 2 | 0 | 500 | 21.5 | 21.5 | 21.5 |
| 3 | 0 | 470 | 40.4 | 40.4 | 40.4 |
| 4 | 0 | 440 | 18.9 | 18.9 | 18.9 |
| 5 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 6 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 7 | 0 | 440 | 37.8 | 37.8 | 46.0 |
| 8 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 9 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 10 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 11 | 0 | 440 | 37.8 | 37.8 | 46.0 |
| 12 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 13 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 14 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 15 | 0 | 440 | 37.8 | 37.8 | 46.0 |
| 16 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 17 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 18 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 19 | 0 | 440 | 37.8 | 37.8 | 46.0 |
| 20 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 21 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 22 | 0 | 440 | 18.9 | 18.9 | 24.5 |
| 23 | -163.8 | 440 | 37.8 | 201.6 | 209.8 |
| Totals | 2140.2 | | 545.2 | -1595.0 | -1475.6 |

## 3.6 On-Farm Economics

3.6.1 Djirataoua. Because of the relatively high operating costs that characterize a deep well irrigation system, and government policy that the perimeters cover their operating and maintenance costs, farmers at Djirataoua pay the highest irrigation assessment of all farmers in the country--by a factor of two. This places considerable pressure on their ability to earn above average returns for their labor.

Table D 3.5.1 summarizes crop budgets for the typical farmer on the Djirataoua perimeter. The average parcel of 0.32 hectares is cropped 1.88 times per year. It yields a gross revenue of 174,700 FCFA when the peanut crop does well and when long-term prices are used to value output. After paying an irrigation assessment at the level required to cover operating expenses, however, the average return per day of labor amounts to only 545 FCFA, or 590 FCFA after adding back in the charge for invested capital allocated to family labor investments. This is about the return that farmers obtain on their rainfed fields (see Table D 3.6.1). Only the greater assurance of a crop during a year of bad rainfall and the provision of dry season employment keep them interested. This is in marked contrast to Galmi where farmers on the perimeter earn 50 percent above the prevailing agricultural wage. Table D 3.6.2 details the crop budget for irrigated wheat, the only enterprise for which disaggregated labor data were available.

For reference purposes, Table D 3.6.3 gives some selected retail prices at the Maradi market for selected commodities.

3.6.2 Ruwana Perimeter at Safo. Cropping systems were not yet well established at the Ruwana Perimeter at Safo at the time of our visit. The nine hectares served by the central pump are divided into 54 parcels. Most farmers have only one parcel; five have two. Farmers are allowed to acquire a second parcel when no one else from the village wants one.

Farmers planted cotton, onions, peanuts, a smattering of tomatoes and other vegetables. During the previous dry season, they had planted only peanuts on the entire perimeter. During the rainy season, they planted cotton and sorghum. This year they were beginning to produce onions in order to obtain cash for paying the irrigation assessment.

The irrigation assessment for the past year, including both the rainy and dry season, amounted to 1.12 million FCFA, or 124,000 FCFA per hectare. This is about half of the amount paid by farmers on the nearby Djirataoua perimeter. But it does not appear that the full nine hectares are irrigated regularly. Significant sections were not in use at the time of the Team's visit.

Table D 3.6.1 Estimated Returns Per Day from Rainfed Crop Production in Madarounfa Arrondissement 1982-1986 Average

| Crop | Avg. Yield[1] (kg/ha) | Gross[2] Revenue (FCFA/ha) | Costs (FCFA/ha) | Net Revenue (FCFA/ha) | Days of Labor Required[3] (days/ha) | Return to Labor (FCFA/ha) |
|---|---|---|---|---|---|---|
| Millet | 500 | 40,000 | 1,700 | 38,300 | 65 | 589 |
| Sorghum | 225 | 19,125 | 1,700 | 17,425 | 30 | 581 |
| Peanuts | 300 | 71,250 | 2,250 | 69,000 | 110 | 627 |
| Cowpeas | 200 | 41,500 | 2,400 | 39,100 | 55 | 711 |

Source: Ministry of Agriculture, Maradi Department

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[1] The MOA methodology treats intercropped areas as though each crop covers the entire area without adjusting for crop density. Millet is usually the dominant crop with sorghum or cowpeas planted at one-third of their pure cropped intensity.

[2] Millet valued at long-run average price of 80 FCFA/kg, sorghum at 75 FCFA/kg; peanuts at 150 FCFA/kg; peanut hay at 35 FCFA/kg; cowpeas at 120 FCFA/kg and cowpea hay at 35 FCFA/kg. Peanuts and cowpeas are assumed to produce 2.5 kg of hay for each kg of grain.

[3] Average labor inputs are adjusted downward to reflect the lower density that results when intercropped.

Table 3.6.2 Crop Budget for Irrigated Wheat at Djirataoua, 1985-86

| Item | | Value or Cost FCFA/ha |
|---|---|---|
| Average yield[1] | 2,200 (kg/ha) | |
| Long run average price | 110 (FCFA/kg) | |
| Gross Revenue | | 242,000 |
| Operating Expenses: | | |
| Plowing (oxen) | | 9,400 |
| Seed (78 kg @ 110 FCFA/kg) | | 8,600 |
| Fertilizer (100 kg SSP @ 45 FCFA/kg)<br>(150 kg urea @ 65 FCFA/kg) | | 14,250 |
| Transport (22 bags @ 250 FCFA/bag) | | 5,500 |
| Hired labor | | 13,600 |
| Sub-total | | 51,350 |
| Gross margin | | 190,650 |
| Irrigation Assessment[2] | | 144,800 |
| Net Returns | | 45,850 |
| Labor Required (days): | | |
| Preirrigation and fertilizer applications | 3.0 | |
| Planting and irrigation | 21.0 | |
| Weeding | 31.0 | |
| Irrigations (12) | 29.0 | |
| Harvest | 25.0 | |
| Thrashing, Winnowing and Bagging | 19.0 | |
| Transport (manure, grain and straw) | 8.0 | |
| Sub-total | 136.0 | |
| Net Return to labor | 337 FCFA/day | |

[1] A survey of wheat producers in 1985 yielded estimated average yields of 2505 kg/ha based on yield plots and 2113 kg/ha based on reported production. Adjusting the yield plot measure to remove a normal 10% overestimate arising from this methodology and taking the average of both measures gives an estimated average yield of 2184 kg/ha.

[2] Assuming the annual irrigation assessment of 230,000 FCFA/ha is allocated in proportion to irrigation water used by wheat with a cropping intensity of 1.88.

Table D 3.6.3 Retail Prices in FCFA per unit* at Maradi Market for Selected Commodities, By Quarter, 1983-87

| Price for Month Ending | Millet | Sorghum | White Maize | Cowpeas | Onions | Tomatoes |
|---|---|---|---|---|---|---|
| 7/83 | 86 | 92 | 105 | 192 | 166 | 666 |
| 10/83 | 95 | 70 | 96 | 156 | 166 | 427 |
| 1/84 | 78 | 79 | 94 | 201 | 140 | 402 |
| 4/84 | 79 | 79 | 96 | 206 | 143 | 929 |
| 7/84 | 173 | 151 | 151 | 227 | 332 | 1303 |
| 10/84 | 125 | 115 | 114 | 168 | 234 | 548 |
| 1/85 | 151 | 140 | 135 | 212 | 159 | 189 |
| 4/85 | 162 | 156 | 140 | 240 | 96 | 112 |
| 7/85 | 160 | 156 | 136 | 299 | 161 | 500 |
| 10/85 | 66 | 76 | 65 | 126 | 225 | 292 |
| 1/86 | 44 | 46 | 65 | 141 | 94 | 43 |
| 8/86 | 49 | 51 | 71 | 150 | 91 | 197 |
| 11/86 | 37 | 39 | 48 | 81 | 113 | 196 |
| 1/87 | 42 | 42 | 44 | 106 | 111 | 56 |

* Per kg for millet, sorghum, maize and cowpea; per small sack for onion and tomatoes.

Source: Ministry of Plan, Maradi Department

The one farmer from whom we obtained some input output data (one of the better farmers in the system) appeared to have obtained around 1500 kgs/ha for his peanut crop, 1300 kgs/ha for his sorghum and 2000 kgs/ha for his cotton. The yield for his peanuts is good but not spectacular, that for sorghum is poor, and for cotton, average. Assuming the production costs are similar to those at Djirataoua, and that a full utilization irrigation assessment would amount to approximately 175,000 FCFA/ha, farmers at Safo would earn returns to labor about on a par with farmers at Djirataoua. The lower sorghum yields would offset the advantage of the lower irrigation assessment.

## 3.7 Enterprise and Institutional Performance

Failure to pay the assessment or redevance is seen slightly differently at the farm level than at the level of the co-operative committee, and the millions of francs in arrears which had accumulated are evidence of an area of disfunction in perimeter functioning. Redevance rates have, in the past, been set rather uniformly across the perimeter without regard for actual local patterns of use in pumps and water and farmers. Nor were farmers receiving adequate council about lower cost rates periods, nor about billing methods. Thus, incentives for efficient use of resources and facilitating accountability were built out of this system. The co-operative management committee is trying to work out more accurate redevance charges with the current technical assistance from ONAHA while seeking to learn how rates are set.

Farmers add the uncertainty of marketing channels, and the potential economic disruption of major social expenditures continue to influence non-payment of the redevance. Thus, either perimeter parcels are not sufficiently strong performers to provide cash profits to average enterprises and/or accountability is so lax that the sense of obligation for some benefit received is essentially absent.

The single biggest institutional constraint cited by farmers to a more satisfactory overall perimeter performance is the weakness of official and private commercial networks. Public and private buyers are not sufficiently capitalized to purchase agricultural production in bulk at the end of the cropping season. This fact handicaps repayment of cropping fees and constrains farmers from realizing the benefits of cash cropping.

The Team felt that part of the problem is the individual GMPs are not permitted to take full advantage of the divisible nature of the infrastructure in place. GMPs have been unable to modify their crop rotation in response to recognized differences in soils type. Technical advice which would enable them to identify irrigation problems or the early stages of infestation are not forthcoming either. Furthermore, economically run pumps are billed no differently than inefficiently run ones.

Lastly, on the level of the GMP, residence in a single village causes problems while a background of mutual aid and co-operation in some areas enhances the capacity for collective action at this level. Thus, few problems concerning water use or minor maintenance were reported. Freedom to speak at GMP meetings is recognized and changes of GMP leadership personnel occur on the basis of familiar village patterns. However, the frequency and degree of participation in GMP meetings varies considerably with the social distance between parcel holders and leadership. In some cases, GMPs organizational potential is more latent than actual.

There is a clear gap in coordination (and coordinating ability) between the GMP and the co-operative level. Attendance at co-operative wide meetings (General Assembly) for example remains erratic and information generally flows from the top down. Individual farmers feel less free to speak at these meetings partly out of ignorance, but also to perceived insensitivity at higher levels of the GMP organizations. Political subordination and technical dependence of farmers upon Government structures towards which Nigerien farmers have been ambivalent historically, constrains operating efficiency. Association between co-operative leadership and bureaucrats undermines rather than contributes to the authority of the latter. In addition, upstream (input deliveries, including water), and downstream (commercialization), and technical support deficiencies, lead to police action to collect back cropping charges. This reinforces farmer ambivalence towards the technical and coordinating structures which are supposed to serve them.

## 3.8 Training and Extension

Evaluation of pump operation and maintenance indicates the low level of technical expertise among parcel holders and co-operative officers. Poor irrigation and pest treatment practice may also be attributed in part to the superficial extension effort mounted by the ONAHA and Crop Protection Service staff. Given the small size of the technical extension staff, this is not surprising and little more could be expected.

## 3.9 Equity Issues

The Nigerien farmer manages his or her farm as part of a broader strategy of household production and social reproduction. The irrigated perimeter is subject to the same set of goals and operating principles as other parts of the household system. To the extent that management principles applied by exogenous authorities to the irrigated parcel threatens the realization of these household goals, perimeter management suffers.

On the other hand, emphasis on cash crops on the perimeter accentuates a trend towards the monetization of economic relationships in Maradi under way since independence. The rapid intensification and extension of chadouf and motor pump cultivation at Sourmarana provided the Team ample evidence of this. The ability of farmers to control all phases of production, and to move rapidly in and out of production there in response to individual farm enterprise needs and possibilities seems to account for the successfulness of this system relative to the Djirataoua perimeter, in spite of the high costs of production there.

Individual initiatives, which favor increased diversity in commercial crops planted at the parcel level in the most recent year of perimeter operation, perpetuate this trend and are consistent with the initial conception of the system, if not necessarily with the technicians' management schemes.

Farmers perceive the benefits of cultivation on the perimeter as variable and unpredictable between parcel holders, as well as from season to season. The greater security of irrigated agriculture seems to elude them. In general, and under current conditions, cropping risks costs are high relative to yields. Farmers cite a number of factors in explaining the unequal and unpredictable distribution of benefits from perimeter operation:

- insect and animal damage;
- pump breakdowns;

- varietal problems, for example, with maize;
- soils heterogeneity;
- quality of labor applied to the parcel;
- delays in the cropping calendar.

The Team noted other significant factors in the distribution of benefits, for example: the differing abilities of farmers to subsidize his parcel from other farm and off-farm activities and/or to cushion the effects of production problems with these activities; the importance of commerce and gardening among these off-perimeter activities; and some pressure towards concentration of land holdings fueled by expulsions for non-payment of cropping fees. Farmers without strong kinship or social networks are more vulnerable to the effects of variable performance than those with large family or status group networks.

The Team noted a weakness of co-operative structures. The confusion in roles between different institutional participants in perimeter management leads to a reduction in the distribution of both the tangible and non-tangible benefits of co-operative production on the perimeter.

Minor fraud with regard to inputs and use of co-operative property for personal gain have also been reported and have involved both low level cadre and co-operative officers.

The Team's visit coincided with a repressive phase in campaign to wipe out all the co-operative's back debts, of which some 33 million francs ($110,000) remained. Scores of people had been arrested and some jailed. Others had fled. Thus, the burning issue of the day was why are the "redevances" or cropping charges not paid. The interaction of any number of the factors described above can be used to explain why individual farmers may fail to pay their cropping fees. Given the overall fragility of the system technically, individual variables like experience, strength, and luck play a significant role in the distribution of benefits as well.

In general, our rapid survey of farmers left the impression that imperfections in the management of technological elements of the system is not conducive to the realization of the economic and social potential of the co-operative and the perimeter. As a result, contextual variables, such as the social conflicts within the canton of Djirataoua, for example, are transferred to the arena of the perimeter.

## 4.0 Specific Constraints/Recommendations

### 4.1 Institutional and Social Constraints and Recommendations

Constraint: Weak commercial circuits for inputs and outputs.

Recommendation: Clarify extent of co-operative intervention in these circuits. Expand commercial potential of the co-operative to include more crops and/or develop marketing agreements with regional, national, or international consumers. The state might authorize the co-operative to purchase inputs from the private sector.

Constraint: Overly high user fees and user uncertainty about methods of calculation of charges.

Recommendation: Re-evaluate user fees in light of ideal and actual consumption of inputs. Decentralize billing of energy charges. Hold more meetings at the GMP level to explain and debate calculation of user fees.

Constraint: Dependence of farmers upon resource limited government services.

Recommendations: 1. Clarify the extent of involvement and degree of responsibility of technical and management services with the co-operative and the GMP. Develop memoranda of understanding to formalize these relationships. Debate and diffuse this information at the GMP level. Seek greater involvement of the private sector in maintenance and operations of the perimeter.

2. Seek to develop private involvement in input and service delivery.

Constraint: Numerous minor management problems, e.g., irrigation schedule, pesticides application, billing.

Recommendation: Intensify training activities targeted to key actors in phases of perimeter and co-operative management identified as inefficient.

Constraint: Competition for labor between rainfed and irrigated crops.

Recommendation: Decrease uncertainty associated with irrigated farming through improvements in delivery of inputs, reduction of system downtime, and improved agronomic practices.

Constraint: Weakness of co-operative marketing activities, i.e., inability to purchase from farmers at harvest.

Recommendation: See 1 above.

Constraint: Confusion of roles amongst intervening management bodies, including perimeter director, advisory council, co-operative officers, FDRM headquarters, etc.

Recommendation: Seek clarification of roles through a series of bilateral and multilateral meetings. Codify any changes in current formal division of responsibilities adopted.

Constraint: Perception of equivalent risks with irrigated and rainfed agricultural production.

Recommendation: See 5 above. Carry out an intensive applied research program devoted to improving and diversifying crop rotations. More systematic planning of crop calendar in relationship to the overall goals of peasant farming systems and seasonal and commercial variations in cropping environment.

Constraint: Lack of feedback between systems levels.

Recommendation: Intensely informational meetings and co-operative and technical training. Clarify formal responsibilities of intervening parties in perimeter affairs. Consider greater use of written and audio-visual techniques of information dissemination. Consider elaboration of a system to formally adjudicate infractions of co-operative rules. Implement formal contractual agreements between parcel holders and ONAHA and between ONAHA and the co-operative.

Constraint: Low levels of technical and organizational training at all levels. Weakness of technical support in the private sector.

Recommendation: Target key areas where technical and management competence is essential. Target key weaknesses in the current system. Intensify training programs directed at these weaknesses and competencies.

Constraint: Inconsistencies in the extent of transfer of responsibilities of cooperative institutions.

Recommendation: Progressively transfer responsibilities to the co-operative institutions through the collaboration of the CRD and the URC.

Constraint: Widely varying distribution of benefits of the perimeter.

Recommendation: Conduct a survey of the socio-economic impacts of perimeter. Develop a typology of farm enterprises in terms of access to resources and benefits.

Constraint: Technicians are having some difficulty defining the new role assigned to them as technical consultants to, rather than managers of, the co-operatives.

Recommendation: Provide managers with new farming systems diagnostics skills and develop their role in applied research.

## 4.2 Economic

Constraint: With respect to the irrigation system at Djirataoua, the engineering analysis indicates that pump operating costs per hectare could be reduced significantly by standardizing around the smaller pumps currently in use and increasing their intensity of use when the size of the irrigation sector is large. However, even with these and other improvements mentioned in this report, the system will not be economic.

Recommendation: Shifting to higher valued crops such as onions, hot peppers, garlic and perhaps dried vegetables would provided the gross revenue necessary to amortize the system--even that is questionable.

Constraint: Identifying a cropping pattern that can amortize 4.6 million FCFA/ha in investment costs in Maradi will not be easy, especially given the very high operating costs.

Recommendation: At this juncture the best thing to do is to plan maintenance and replacement programs to maximize the life of the current system and help it to evolve toward greater efficiency.

Constraint: The principal economic constraints on the project at the farm level at Djirataoua are the underutilization of land, the absence of a consistent, good yielding crop to follow cotton in the rotation, poor management of, and low prices received for, wheat, and reliance on generally low valued crops to cover the costs of irrigation.

Recommendation: More attention to crop management and irrigation techniques, as well as greater flexibility in the allowed cropping system, would address the first and last of these problems. A well directed research program would address the plant protection and other problems limiting choices for suitable crops to follow cotton.

## 4.3 System Design

Constraint: The water table appears to be falling at an average of approximately 0.20 m/year, and the rate of decline is accelerating. We do not know if this is only cyclic.

Recommendation: The static water table should be monitored at least quarterly. If the decline continues near or above the present rate over the next 3 years, the irrigation of the crops requiring the most water per unit value of crop production should be discontinued in sequences until the water table stabilizes. Furthermore, for new pumps this should be taken into account.

Constraint: The existing reservoirs are not economically viable, nor very useful given the current sizes of pumps and reservoirs.

Recommendations: No new similar reservoirs be constructed as proposed. An interesting alternative which deserves further study is:

1. Replace the existing 7.5 kwh pumps with 3.75 kwh pumps; and
2. Provide a 450 $m^3$ reservoir at these sites.

This would provide the following advantages:

1. All the pumps on the project would be the same size (there are already some 3.75 kwh pumps in smaller GMPs; and
2. These new smaller pumps would be run 20 to 24 hours per day (pumping into storage during off peak power periods) and have lower system losses thus reducing power costs. Note--during the daytime hours, the water flowing from the reservoirs can be doubled the daytime pumped flow into the reservoir.

Constraint: Power service, submersible pumps, protective devices and wiring are not well matched and/or designed. This results in higher unit energy costs (50 percent), higher energy consumption (10 percent), greater premature pump losses (7 rather than 1 or 2 percent per year) and greater service problems than necessary.

Recommendation: Install proper lighting and surge protection devices and revamp safety circuits plus keep pump houses and panels locked. As replacement pumps are needed, new submersible pumps should be bought which have specifications more closely matched to the operating conditions.

Constraint: A brief analysis of the perimeter water table from 1980 to 1987 shows that the water table has been dropping by 20 cm/year with an increase in this rate from 1984 onwards, when the last 22 pumpsets were installed. Figure D 2.3.1 shows the annual trend and seasonal variation.

No data is available for the period 1984-86. The JFS/W mission monitored static levels in 28 percent of the tubewells in use.

Recommendation: The water table should be monitored on a quarterly basis in order to verify this brief analysis. If the analysis is confirmed, measures to reduce water consumption through eliminating crops which yield the least net revenue per cubic meter of water consumed should be introduced.

Constraint: The system design is not optimized, the electrical distribution grid was over-dimensioned, and the cost could have been reduced from 180 million FCFA to 163 million FCFA with the present loads. This could have been reduced further had the design envisaged smaller pumpsets operating 21 hrs/day or any of the other constraints posed under Section 4.4 System Management.

Recommendation: No retrofit action is recommended other than measures to reduce O & M costs discussed in Section 4.4.

Constraint: System design did not include adequate security measures to protect against transients from lightning, grid voltage surges, and electrolytic action of dissimilar metals. Cable lays were not adequately protected and routed, and the electrical control circuitry has not demonstrated high reliability. Contactors, relays, timers, thermal overload switches, reservoir and well level sensors have all suffered from abnormally high levels of premature failure. This deficiency is now aggravated by dust infiltration into the control circuit panel, since doors are frequently left open.

Recommendation: All new pumpsets should be installed complete with updated and upgraded control circuitry designed to withstand local regional environmental conditions. The system electrical design specification should be clearly indicated in the "cahier de charge" and tenders for equipment carefully analyzed to avoid a repetition of pitfalls encountered with the first batch of pumpsets.

## 4.4 System Management and O & M

Constraint: While there is ample water being pumped for the areas, seasons and crop programs being utilized (required only 50 percent global irrigation efficiency in 1984) there appears to be considerable underwatering. This is due to problems with irrigation scheduling which gives excess water in some periods resulting in low water use efficiencies and underwatering in other months resulting in crop production losses.

Recommendation: Water pumping and irrigation cycles be more closely scheduled to meet crop water requirements.

Constraint: High energy tariffs (50 percent of the annual assessment) and pumpset operating schedules contribute to the excessive charges to perimeter farmers.

Recommendations: 1. Pumpsets are now operated 10-12 hours/day for 6 days/week throughout 7 months per year, and 3 days/week during other periods except for August when utilization is minimal. The average daily use is 7.1 hrs/day computed annually for a 6-day working week.

2. Several scenarios of alternative pumpset operating patterns and configurations would influence operating costs. Regional grid electrical energy is charged to the project through a three-tier pricing structure (unit cost) which favors consumption from 12:00-15:00 hrs and from 22:00 - 07:00 hrs and discourages use at the peak load period of 19:00 - 22:00 hrs. The differential energy cost between peak and economy period is 76 percent. Regular tariff is charged at 56.2 FCFA/kwh or 20 percent above the economy tariff.

3. Manipulation of pumping schedules to optimize use of economy tariffs is only possible if water storage reservoirs of 750 cubic meters are constructed for 7.5 kw pumps sites (450 $m^3$ for 3.7 kw). The financial benefits from optimizing use of the economy tariffs are 210,000 FCFA/year/pump and would not justify the investment in enlarged reservoirs.

4. Operating 50 percent of the installed pumpsets 21 hours/day 6 days/week during the peak water demand period and 11 hours/day (economy tariff period) for other needs, and providing storage capacity (750 $m^3$/pump) for the units in operation would reduce the load on the transmission lines and thermal generating plant in Maradi by 50 percent, and pumps not in service could be used as standby or replacement. This would entail distribution system modifications to facilitate supplying 2 GMP from a single pumpset. This scenario would be more applicable to new perimeters laid out on the Djirataoua principle than a retrofit of Djirataoua. Pumping scenarios which do provide significant reductions in O & M costs are as follows:

5. All new pumps installed should be 3.7 kw nominal rating and not 7.5 kw. New pumps would operate 21 hours/day and require 450 $m^3$ storage capacity. This would provide more flexible water management for users and maximize use of economy tariffs, reduce future capital investment costs, improve standardization, and minimize capital invested in replacement parts stock.

6. New submersible pumps should be selected to provide an optimum match between the dynamic head and envelope of maximum efficiency. An increase of 10-15 percent over this figure could be anticipated with correctly matched systems. This would reduce energy costs by 10-15 percent for the same pumped volume.

Constraint: No effective maintenance program is in place. The only skilled electro-mechanical technician who received training from the equipment suppliers was relieved of his duties in 1985. No effort has been made to introduce a preventive maintenance program. The supply of spare pumpsets provided with the initial order has been consumed. Three replacement pumps have been ordered from Grundfos (original equipment was supplied by Pleuger). Electrical compatibility could not be assessed because neither specifications nor performance curves for the installed systems were available at the project level.

Recommendation: An experienced electro-mechanical technician should be recruited and trained within a professional environment immediately. This training should include not only diagnostic and repair procedures, but maintenance program management. A preventive maintenance schedule, spare parts supply and stock control procedures should all be encompassed in the training program.

Constraint: All estimations by project personnel of water flow from the pumpsets have been based upon a supposition that the output from the pumpsets is identical to the rated tubewell discharge, which was determined when the tubewells were drilled and pump-tested in 1979-80.

The only firm data on pump performance was gleaned from a commissioning report conducted on two 7.5 kw units and one 3.7 kw unit in 1984. This data was plotted (Ref. Table 2.6.2) during the case study to estimate flows at 1987 dynamic heads. Pump performance tests were not possible during the case study since the electrical grid to the perimeter was disconnected. Project personnel were not able to produce specifications and rated performance curves for the pumping systems installed. In the 15 systems examined, the average flow from the pumps exceeds the rated tubewell output by 46 percent. Several factors, including cropping requirement calculations, verify that flow rates are those estimated by JFS/W personnel.

Recommendation: The flow rates used by project personnel to determine irrigation schedules are only 68 percent of the actual flow rates. Since the JFS/W Team have ascertained that crops are not overwatered, crop water requirement calculations cannot have been made: otherwise either the pump runtimes would be much longer to compensate for the flow rates which are thought to exist, or crop yields would be severely reduced.

Crop water demands, percolation, distribution efficiency and conveyance efficiencies should be determined through measurement by the project personnel, and the water pumping schedule should be re-programmed accordingly.

## 4.5 Cropping Program

The crop rotation was well-planned in general agronomic terms. Its application has not attained designed cropping intensity and its crop components have performed at about 75 percent of reasonably anticipated results. The following listing suggests improvements which could be made to increase overall agronomic performance of the perimeters:

- the co-operatives should estimate seed and fertilizer demand for each season far enough in advance to obtain sufficient high quality seed and appropriate fertilizers.

- within a GMP, pre-irrigation and land preparation dates should be established by rotation group (of about 12 farmers) and sufficient labor and animal traction units contracted to permit timely planting and avoid overlap of labor requirements with those of dry land crops.

- the co-operatives should establish a cut-off date for cotton harvests, no later than the end at December, with cotton uprooting by the middle of January to reduce pest transfer to succeeding crops and to conserve soil moisture over the hot dry season.

- a pest scouting system should be established by the co-operatives with ONAHA and INRAN assistance to permit early and accurate detection of pest problems. The scouting system should be linked to a pesticide purchase and supply program managed by the co-operative, perhaps piggy-backed onto the pesticide supply system established for cotton.

- the rainy season crop components should be diversified to include maize and millet to permit greater responsiveness to shifting market and weather conditions. Consideration should be given to a rainy season peanut crop, if current aphid problems prove too difficult or costly to control during the hot dry season. Some applied research on planting date and varietal selection will be required.

- on the Madaoua perimeter the crops unsuitable to the shallow soils, e.g., cotton, which probably provide the least return per unit of water applied, should be reduced in surface area or replaced with less drought sensitive crops which provide greater security of production, e.g., millet, niébé.

## 4.6 On-Farm Management

Constraint: Field ditches of 80 meters receive flow rates which cause erosion at the siphon discharge.

Recommendation: If 80 meter field ditches are retained, farmers should protect the discharge point with mats or other splash structures to prevent undercutting of channels.

Constraint: 80 meter field ditch flows of 4 lps or higher are eroding the field ditches. Deeper channels increase water losses in the ditches making irrigation more difficult and time consuming than necessary. Fields are losing their designed grade. Releveling and grading with heavy machinery is costly.

<u>Recommendation</u>: Demonstrate full 80 meter furrow irrigation and 40 meter furrow irrigation to show farmers how to reduce field ditch erosions rates.

<u>Constraint</u>: Water is being wasted in cotton production because no cut out after initial boll set is practiced. ("Cut-out" refers to a short period when water is withheld from cotton to hold tonctinous flowering which increases shattering of the first bolls set. Water is then applied to stimulate a second period of flowering.)

<u>Recommendation</u>: Demonstration of a cut-out regime to farmers should be done following applied research on optimal timing with existing varieties.

<u>Constraint</u>: Farmer fertilization applications are suboptimal.

<u>Recommendation</u>: Fertilizer response demonstrations should be designed after response curves are known. These should be available from INRAN, ICRISAT, other countries with similar soils and climate, and applied research.

<u>Constraint</u>: Aphids are causing severe losses in peanuts and some vegetable yield losses.

<u>Recommendation</u>: Project Maradi/ONAHA should elaborate a program of applied investigations in aphid control with INRAN/TARNA.

<u>Constraint</u>: <u>Striga</u> reduces sorghum yields.

<u>Recommendation</u>: Applied research by Project Maradi with INRAN assistance into the cost effectiveness of glyphosate wiper used to control <u>striga</u>. This control method should be compared with <u>striga</u> control by crop rotation.

### 4.7 <u>Research</u>

1. Water requirements (ET) using modern crop varieties should be researched by INRAN. Varieties of wheat, corn, sorghum, millet, niébé, and peanut have been substantially improved since the late 1960's, including their water use efficiency. The first step should be an extensive literature search on water use studies done with these crops under similar growing conditions.

2. Optimum fertilizer doses for irrigated crops on project area soils should be researched. A review should be first made of research on similar soils in Nigeria, Cameroon and other neighboring countries.

3. Variety tests of potatoes should be run on station and on farmer fields. This crop may be an alternative to wheat in the cold dry season. Diffused light seed potato storage should be investigated as well.

4. A program of field investigations and on station research into integrated pest management especially targeted at the cotton crop and aphid control on dry season crops should be developed by INRAN.

5. Screening of preplant and pre-emergence herbicides for effectiveness, financial feasibility, application methods, and user safety should be done by INRAN.

6. Investigation into the water use, yield, and economic feasibility of forage crops such as berseem, dual purpose barley and wheat, and sorghum. Sudan grass hybrids should be considered by INRAN.

7. Irrigation techniques: a) furrow-long furrow irrigation operations research, b) border irrigation for small grains, to determine water economy, crop response and financial/labor impact? c) cotton crop "cut-out" to decrease water use.

8. Fertilization - simple three step fertilizer tests to establish yield response to N.P.K. sources.

9. Variety yield tests--three or four variety tests for on-farm observations of each major crop every two years following INRAN screening.

10. Plant protection especially for aphid control. Spacing and spraying trials using INRAN recommendations.

11. Weeding using animal traction. The use of ridgers and cultivators to weed cotton, sorghum, and millet crops.

12. Potato crop production potential for the cool, dry season.

13. Late cool or early hot, dry season millet, sorghum and maize production tests to examine a crop rotation alternative to peanut production and perhaps seed production for the rainy season. Bird damage may limit off season small grain potential.

14. Rainy season peanut production tests to determine if plant protection problems can be reduced when the crop is grown during its normal production period.

# CHAPTER IV

# GALMI RESERVOIR GRAVITY-FED IRRIGATION PERIMETER, GALMI, NIGER

The Joint Field Study Team visited the Galmi Perimeter between 19-21 February, 1987. The Galmi perimeter is a 245 hactare gravity-fed system served from a reservoir. The main and secondary canals are concrete lined and the farmlands were precision leveled before the land was subdivided for settlement.

The main body of this report is directed at the Galmi Reservoir gravity-fed irrigation system. Prior to the development of the Galmi project, there was considerable amount of dug well irrigation in the vicinity. Following the development of the project, the dug well irrigation was forced to move to the outer edges of the gravity irrigated lands. Today, there are many small irrigation plots served from these dug wells and a few plots served from water lifted directly from the drains which receive their supply from a combination of reservoir seepage, deep percolation from irrigation applications in the gravity-fed area, and operational spillage.

The Team felt there is an interesting association between the gravity-fed irrigated area and the small parcels, depending upon lift irrigation. Therefore, the Team elected to include discussion covering the pertinent features and comparative economic relationships between the lift irrigation activities and the main gravity-irrigated project area.

## 1.0 Project/System Description

### 1.1 Physical Features

The perimeter was German funded and constructed and implemented by the French. The system first began operation in the dry season of 1983-84. It is located along the Route Nationale some 450 km east of Niamey. The system's 7,200,000 $m^3$ capacity reservoir is supplied by a 46.5 $km^2$ watershed. The system serves some 850 parcel owners. In addition to the 245 ha gravity-fed irrigation from the dam, 20 ha (5 ha within the perimeter and 15 ha adjacent to the perimeter) are irrigated from shallow wells with rope and calabash as well as portable motor-pumps. Annual rainfall is around 450-550 mm, with mean annual temperatures on the order of 25-30$^oC$.

The watershed is sparsely vegetated, surrounded on its periphery by lateritic hills which drain into a broad, sandy valley floor of farmland. Most of the actual storage behind the barrage lies in the remnants of a steep-sided koré (wash) which ran through the central, lower portion of the watershed. For this reason the reservoir has a good storage capacity (per unit area irrigated) and thus, should not have to expect limiting problems due to siltation for at least another 8-10 years; despite the fact that the watershed area is highly erosive. The exception could be during abnormally low rainfall years. Due to the fairly steep, lateritic slopes of a large portion of the inundated area, only limited recession agriculture is practiced behind the barrage at present. Again, not until

8 to 10 years of siltation has occurred should there by any significant exploitation of recessional agriculture. To date, the reservoir has never reached its capacity--in the last two years only coming to within 10 cm of the spillway overflow.

The irrigated perimeter itself is laid out in a long-narrow pattern, stretching 6 km from the base of the reservoir to the end of the primary canal and having an average width of approximately one half km. (see Figure G 1.1.1). The principal canal has a maximum design/operational flow rate of 700 lps at the reservoir outlet, and runs virtually the length of the system. Twenty-five secondary canals off-take from the primary canal, with design flows ranging from 15-40 lps. Flows into the secondaries are regulated by fixed orifice, gated outlets with check weirs situated in the principal canal immediately downstream of each to control/maintain the heads. Both the principal canal and the secondaries are constructed of concrete poured in place.

Table G 1.1.1 Galmi Canal Specifications

| Canal | Material | Length | No. | Average Length (m) | Design Flow (lps) |
|---|---|---|---|---|---|
| Primary | concrete | 6,301 | 1 | 6,301 | 700 |
| Secondaries | concrete | 15,448 | 25 | 618 | 15-40 |
| Tertiaries | earth | 26,857 | 165 | 163 | 5-20 |

To handle overflows and excesses, several secondaries and the primary canal have a number of overflow spillways which discharge into the perimeter drainage system.

The tertiaries are made from compacted silty clay soils brought in from outlying deposits. Each secondary serves an average of seven tertiaries (arroseurs), which in turn serves an average of six parcels of 0.25 ha each. Simple gated turnouts serve the outlets on the secondaries. Any number of sandbag checks (depending on channel slopes) are placed within the tertiaries to control the water level.

Typical parcel dimensions are 25 m by 100 m, and each is served by a set of 5 siphons--according to design specifications. Original plans called for furrows 100 m long (during wet season cropping) running downslope the length of each parcel, with 2-3 furrows irrigated at a time (see Figure G 1.1.2). At present, wet season fields are usually prepared in furrows of 10-12 m for water delivery, while dry season onions and wheat are irrigated in basins of 15-25 $m^2$.

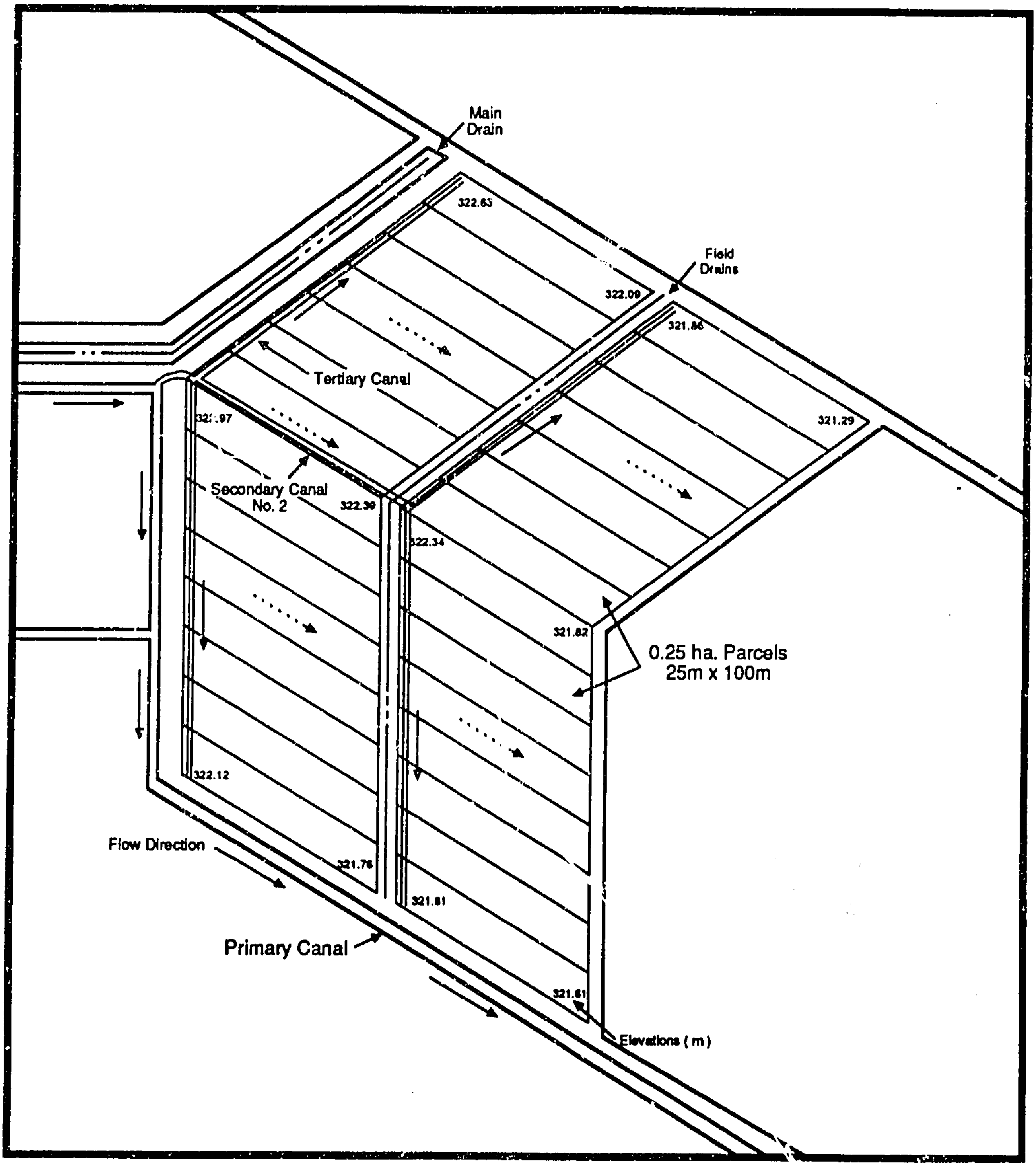

Figure G1.1.1 Example of area served by Galmi secondary canal.

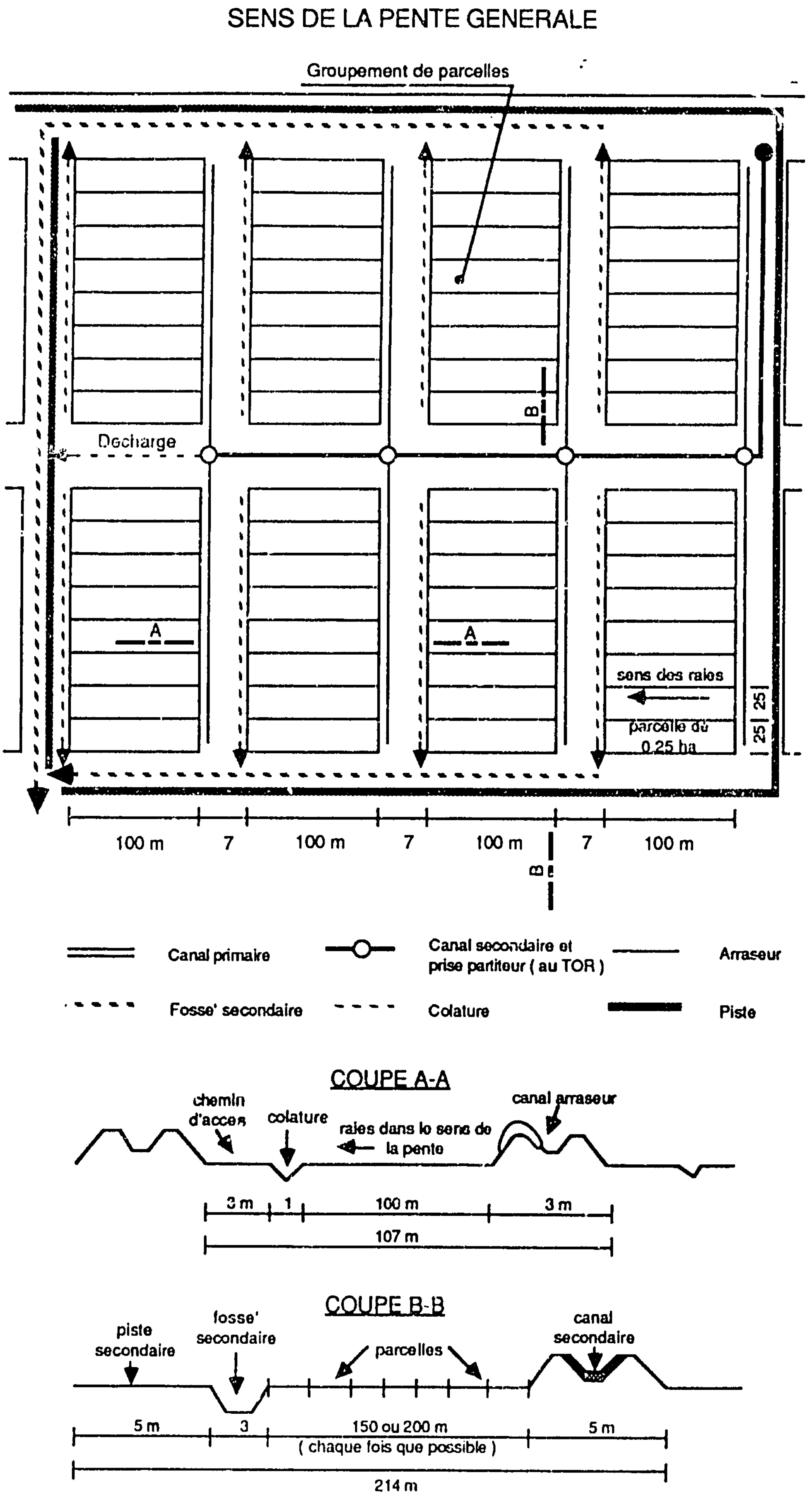

Figure G1.1.2 Typical Layout of Irrigation canal and parcels at Galmi perimeter.

The soils are mainly alluvial deposits by loams with some areas of sandy clay-loams. During construction the fields were leveled by bulldozers and thus areas can be found where a good deal of stratification exists in the upper soil horizon.

## 1.2 Farm Characteristics

The information this section of the report provides is by no means complete from an ethnographic perspective. It presents limited data about household composition, ethnic affiliation, land tenure, labor allocation, organizational development and institutional linkages. Significant variation and cultural particularities are largely ignored. Far more detail can be found in Goldring's March 1986 report for WMS II.

The 854 farmers work on a perimeter of 242 ha divided into 26 GMP with 29 to 44 farmers per GMP. Eight villages or village quarters are involved in the perimeter including two Buzu (low caste Tuareg) villages, and 6 Hausa ones. Four of the latter make up the village of Galmi and one consists of a village resettled from the area currently occupied by the reservoir.

Plot size varies from 0.25 ha to 1.75 ha in one extreme case, but more than two-thirds of parcels are 0.25 ha in size.

In Galmi farming households, the available labor power exceeds the average found in Maradi. Here the number of active males was 2.89 over a sample of 37 households. Goldring also found that 54 percent of Galmi households did not engage in labor migration. Her results are consistent with our own.

Goldring found 37 percent of Galmi farm households had only a single off-perimeter parcel, while 56 percent had 2 or more. Most of the farmers questioned by the survey Team had off-perimeter parcels, and most of them suggested their dune fields were two to four times the size of their perimeter parcels.

## 1.3 Crop Calendar

The Galmi area production year is divided into three seasons:

- the rainy season from June through October;
- the cold season from November through February; and
- the hot season from March through May.

The dryland cropping pattern includes sorghum, millet, cowpeas and squash. In the recessional areas lablab bean (Dolichos lablab) and cotton are grown. Irrigated onion production during the dry season has been a long-standing tradition in the Galmi area.

Figure G 1.3.1 gives the cropping calendars followed in the Galmi perimeter since its first year of operation. Table G 1.3.2 and Table G

1.3.3 show the estimated crop evapotranspiration and estimated net irrigation requirement respectively for various crops at Galmi for 1985-86 dry season. The crop rotation included wheat in 1985-86 because of a national production campaign. Cotton was added during the 1986 rainy season to provide a cash crop of high value and with a controlled market to facilitate repayment of annual charges. Wheat surface area declined greatly from 1985-86 to 1986-87 because of a poor marketing season. The addition of cotton to the rotation has pushed the earliest potential planting date towards March for the hot dry season crops.

### 1.4 Irrigation System Costs

Only a rough breakdown of system investment costs was available at the perimeter level at Galmi. Total investment for the perimeter amounted to 2.5 billion FCFA of which 1.1 billion was for the dam and reservoir. The remainder covered irrigation canals, drains, roads, leveling, studies and other perimeter establishment costs. Over the 245 hectares of irrigable land in the perimeter, the total investment averaged to 10 million FCFA per hectare. In principle, the system allows for double cropping the entire area served.

In contrast to the large investment cost per hectare for the perimeter, large numbers of farmers have established themselves in the surrounding area at a fraction of the cost. Depending on water in the river, water that would probably not be available if the dam were not there, they invest anywhere from 70,000 FCFA/ha for calabash systems to 600,000 FCFA per hectare for motor pump systems. Off-perimeter systems achieve yields that appear to be superior to those obtained by farmers on the perimeter. On those systems using motor pumps, investment costs per hectare average well above what they would be in a more efficient motor pump system. But the large net return that a farmer with a motor pump can earn does not encourage such efficiency. Greater efficiency will occur with time, as the high current returns stimulate increased production and force crop prices and future returns lower. As this unfolds, those farmers using the less expensive hand pumping technologies currently available will find it increasingly difficult to earn a competitive return to labor at pumping depths that exceed 3-4 meters.

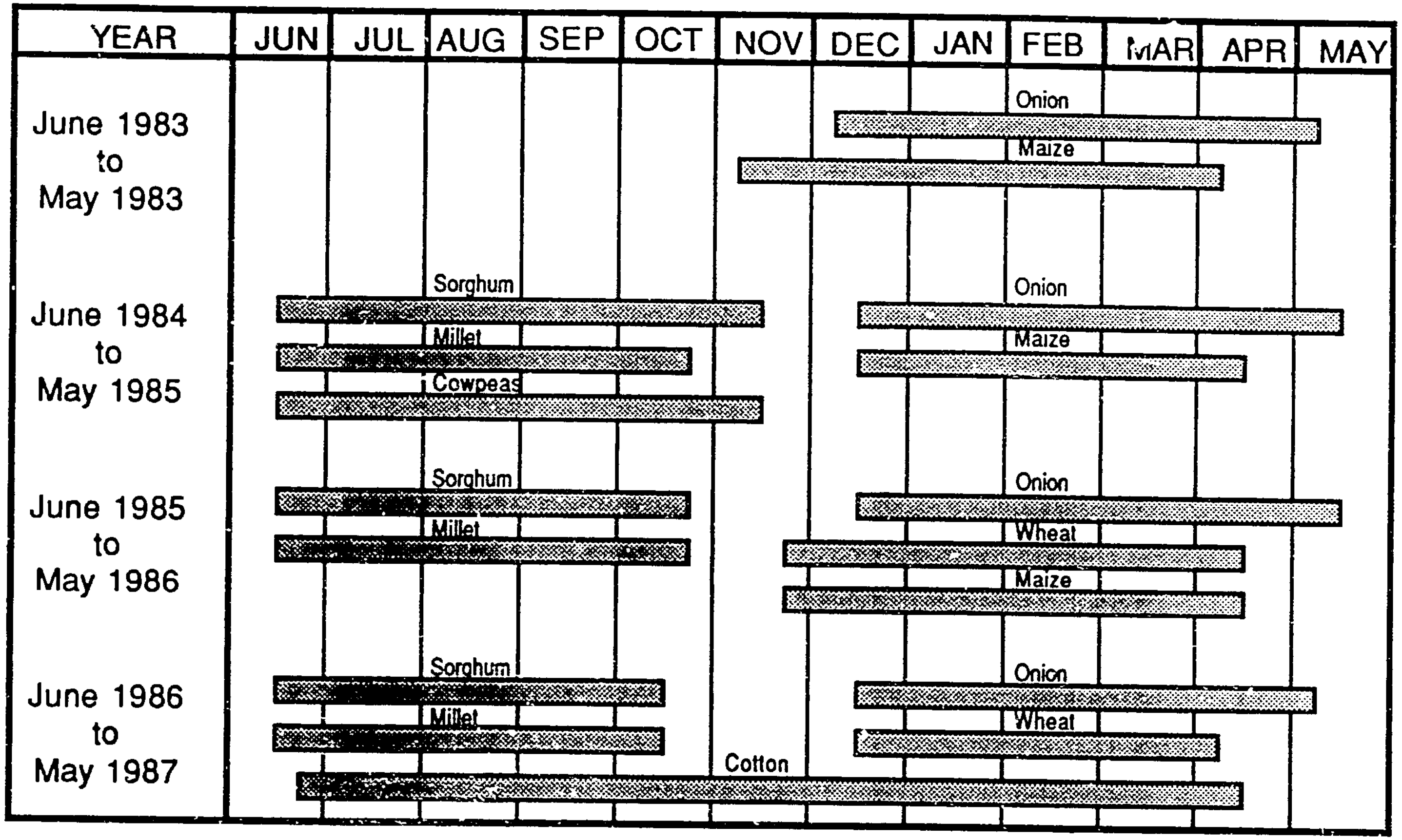

Figure G1.3.1 Galmi cropping calendar since 1983.

Table G 1.3.2 Estimated Crop Water Requirements at Galmi during 1985-1986 Dry Season

| Crop | Planting Date | Area (ha) | Evapotranspiration ($m^3$) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dec. | Jan. | Feb. | Mar. | Apr. | Totals |
| Wheat | 12/9/85 | 38.1 | 35,966 | 55,055 | 63,856 | 61,493 | 5,334 | 221,204 |
| Onions | 12/15-12/20/85 | 32.3 | 21,512 | 34,400 | 39,955 | 63,696 | 27,132 | 186,695 |
| Maize | 12/2/85 | 6.5 | 7,261 | 7,920 | 11,414 | 11,895 | 2,184 | 40,574 |
| <u>GMP Groupings</u> | | | | | | | | |
| GMP 1-8 TOTALS | | | 64,739 | 97,275 | 115,225 | 137,084 | 34,650 | 448,974 |
| Wheat | | 31.1 | 29,358 | 44,940 | 52,124 | 50,195 | 4,354 | 180,971 |
| Onions | | 29.2 | 19,447 | 31,098 | 36,120 | 57,582 | 24,528 | 168,755 |
| Maize | | 0.7 | 782 | 842 | 1,229 | 1,281 | 235 | 4,369 |
| GMP 9-15 TOTALS | | | 49,587 | 76,880 | 89,473 | 109,058 | 29,117 | 354,115 |
| Wheat | | 29.3 | 27,659 | 42,339 | 49,107 | 47,290 | 4,102 | 170,497 |
| Onions | | 27.1 | 18,049 | 28,862 | 33,523 | 53,441 | 22,764 | 156,639 |
| Maize | | 2.4 | 2,681 | 2,887 | 4,214 | 4,392 | 806 | 14,980 |
| Niébé | | 0.37 | 1,135 | 368 | 541 | 701 | 171 | 1,894 |
| GMP 17-23 TOTALS | | | 48,502 | 74,456 | 87,385 | 105,824 | 27,843 | 344,010 |
| Wheat | | 22.4 | 21,146 | 32,368 | 37,524 | 36,153 | 3,136 | 130,345 |
| Onions | | 15.0 | 9,990 | 15,975 | 18,555 | 29,580 | 12,600 | 86,700 |
| Maize | | 3.0 | 3,351 | 3,609 | 5,268 | 5,490 | 1,008 | 18,726 |
| Niebe | | 1.75 | 525 | 1,715 | 2,524 | 3,273 | 796 | 8,883 |
| GMP 24-26 TOTALS | | | 35,012 | 53,667 | 63,889 | 74,496 | 17,540 | 244,604 |

Table G 1.3.3 Estimated Net Irrigation Requirement at Galmi during Dry Season

| Item | Dec. | Jan. | Feb. | Mar. | Apr. | Totals |
|---|---|---|---|---|---|---|
| Reference Crop Eto (mm/day)* | 5.8 | 6.1 | 6.7 | 7.9 | 8.1 | |
| Pan Derived Eto (mm/day)+ | 6.1 | 5.7 | 5.7 | 6.8 | 7.0 | |
| WHEAT | | | | | | |
| Stage Duration (days) | 15/7 | 18/13 | 28 | 9/15/7 | 8 | |
| Kc | .4 /.65 | .65/1.05 | 1.05 | 1.05/.65/ 65 | .25 | |
| Etc - CHAROY (C)* (mm) | | 154.7 | 197.0 | 187.6 | 16.2 | |
| Etc - NORMAN (N)+ (mm) | 64.4 | 144.5 | 167.6 | 161.4 | 14.0 | 551.9 |
| Pre-irrigation (mm) | 30.0 | | | | | 30.0 |
| NET IRRIGATION REQUIRED-C (mm) | 91.2 | 154.7 | 197.0 | 187.6 | 16.2 | 646.7 |
| NET IRRIGATION REQUIRED-N (mm) | 94.4 | 144.5 | 167.6 | 161.4 | 14.0 | 581.9 |
| ONIONS | | | | | | |
| Stage Duration (days) | 15 | 10/21 | 21/7 | 21/10 | 15 | |
| Kc | .4 | .4/.7 | .7/.1 | 1/.8 | .8 | |
| Etc - CHAROY (C) (mm) | 34.8 | 144.1 | 145.4 | 229.1 | 97.2 | 620.6 |
| Etc - NORMAN (N) (mm) | 36.6 | 106.5 | 123.7 | 197.2 | 84.0 | 548.0 |
| Pre-irrigation (mm) | 30.0 | | | | | 30.0 |
| NET IRRIGATION REQUIRED-C (mm) | 64.8 | 114.1 | 145.4 | 229.1 | 97.2 | 650.6 |
| NET IRRIGATION REQUIRED-N (mm) | 66.6 | 106.5 | 123.7 | 197.2 | 84.0 | 578.0 |
| MAIZE | | | | | | |
| Stage Duration (days) | 20/9 | 26/5 | 28 | 7/24 | 6 | |
| Kc | .4/.6 | .6/1.1 | 1.1 | 1.1/.8 | .8 | |
| Etc - CHAROY (C) (mm) | 77.7 | 128.8 | 106.4 | 212.5 | 38.9 | 664.3 |
| Etc - NORMAN (N) (mm) | 111.7 | 120.3 | 175.6 | 183.0 | 33.6 | 594.2 |
| Pre-irrigation (mm) | 30.0 | | | | | 30.0 |
| NET IRRIGATION REQUIRED-C (mm) | 107.7 | 128.8 | 206.4 | 212.5 | 38.9 | 694.3 |
| NET IRRIGATION REQUIRED-N (mm) | 141.7 | 120.3 | 175.6 | 183.0 | 33.6 | 624.2 |
| COWPEAS | | | | | | |
| Stage Duration (days) | | 15/16 | 9/19 | 21/10 | 10 | |
| Kc | | .4/.7 | .7/1 | 1/.65 | .65 | |
| Etc - CHAROY (C) (mm) | | 104.9 | 169.5 | 217.3 | 52.7 | 544.4 |
| Etc - NORMAN (N) (mm) | | 98.0 | 144.2 | 187.0 | 45.5 | 474.7 |
| Pre-irrigation (mm) | 30.0 | | | | | 30.0 |
| NET IRRIGATION REQUIRED-C (mm) | 30.0 | 104.9 | 169.5 | 217.3 | 52.7 | 574.4 |
| NET IRRIGATION REQUIRED-n (mm) | 30.0 | 98.0 | 144.2 | 187.0 | 45.5 | 504.7 |

*From CHAROY Tarna, Niger
+From NORMAN Galmi, Niger

# 2.0 Operational Overview

## 2.1 Institutional/Social Structures

The formal institutional set-up at Galmi is similar to that at Djirataoua and the other inland perimeters managed by ONAHA. The perimeter is nominally controlled by an autonomous co-operative and technical norms and extension advice is supplied by ONAHA staff. Galmi is unusual in that it has a director and two technicians as well as an agent in charge of co-operative development. (More detail on this system can be found in Goldring's 1986 report on Galmi for WMS II.)

Co-operative structures are fairly well-developed at Galmi given the youth of the co-operative. In fact, Galmi is unusual in having a dual co-operative structure. There is a production co-operative, which handles input distribution and other matter related to perimeter management, but there is also a marketing co-operative, an older institution, which has been asked to handle the cotton market by the production co-operative. Officership in the two co-operatives' bureaus overlaps, but activities of the marketing co-operative are not limited to those involving the perimeter. For example, this year five members of the marketing co-operative received an order from SOJNARA to obtain a substantial tonnage of groundnuts. These groundnuts, imported largely from Tessaous and Nigeria, were stored at the co-operative storehouse during the time of our visit. The marketing co-operative handles cotton transactions with the CFDT and is supposed to turn over the "ristourne," or marginal return on sales, to the production co-operative.

The advantage of this system is that the production co-operative can drawn on the substantial marketing experience of the marketing co-operative in its commercial ventures. The disadvantage is that the presence of wealthy merchants on the two overlapping management committees encourages the emergence of a special interest group whose concerns diverge from those of the average farmer.

## 2.2 Irrigation System

The main system was designed to flow at 700 lps at the head with an anticipated main system water loss of 5 percent. Each secondary then has its respective flow rate as was described in the previous section; theoretically totaling about 630 lps. The irrigation system was designed for all 25 sectors (secondaries) to receive water at the same time, with an average flow of around 2.5 lps/ha throughout the system. A detailed breakdown is given in Table G 2.2.1. During off-peak periods irrigations run 8 to 9 hours per day for 3 to 4 days per week. During peak use periods irrigations can run up to 10 hours per day with irrigation taking place 6 days per week. On the secondary level usually 1 to 4 tertiaries are opened at a time (see Figure G 1.1.1) with usually no more than 4 parcels irrigating simultaneously along the same canal. Each sector possesses a set number of siphons (rated at 1 lps each) directly correlated to the design flow of the secondary (sector) turnout. These

Table G 2.2.1 Design and Actual Water Delivery at Galmi as Measured by Team

| Sector | Design[1] Flow (lps) | Area Served (ha) | Design (lps/ha) | Actual[2] Flow (lps) | AUFR[3] (lps/ha) | 86/87 Dry Season (ha) | AUFR (d.s) (lps/ha) | Comparative[4] [5] Irrig. Time Requirement (hrs) |
|---|---|---|---|---|---|---|---|---|
| 1 | 15 | 6.10 | 2.5 | | | 4.00 | | |
| 2 | 15 | 7.00 | 2.1 | 18.0 | 2.6 | 4.90 | 3.7 | 49.6 |
| 3 | 30 | 14.50 | 2.1 | 35.4 | 2.4 | 9.60 | 3.7 | 49.4 |
| 4 | 15 | 6.33 | 2.4 | | | 3.89 | | |
| 5 | 15 | 6.02 | 2.5 | | | 3.19 | | |
| 6 | 40 | 17.64 | 2.3 | 58.3 | 3.3 | 9.52 | 6.1 | 29.8 |
| 7 | 40 | 16.21 | 2.5 | | | 9.48 | | |
| 8 | 20 | 6.81 | 2.9 | | | 4.37 | | |
| 9 | 20 | 6.62 | 3.0 | | | 6.15 | | |
| 10 | 30 | 10.94 | 2.7 | | | 6.84 | | |
| 11 | 30 | 12.39 | 2.4 | | | 6.83 | | |
| Subtotal | 270 | 110.56 | 2.4 | 370 | 3.4 | 68.77 | 5.4 | 33.9 |
| 12 | 20 | 8.24 | 2.4 | | | 4.70 | | |
| 14 | 20 | 4.79 | 4.2 | 26.7 | 5.6 | 2.63 | 10.2 | 18.0 |
| 15 | 40 | 15.63 | 2.6 | 35.9 | 2.3 | 9.79 | 3.7 | 49.7 |
| 16 | 15 | 5.84 | 2.6 | | | 3.69 | | |
| 17 | 20 | 7.50 | 2.7 | | | 3.75 | | |
| 18 | 20 | 8.10 | 2.5 | | | 4.84 | | |
| Subtotal | 135 | 50.10 | 2.7 | 181 | 3.6 | 29.40 | 6.2 | 29.6 |
| 19 | 20 | 7.5 | 2.7 | | | 3.75 | | |
| 20 | 30 | 12.80 | 2.3 | | | 7.67 | | |
| 21 | 20 | 5.60 | 3.6 | | | 2.80 | | |
| 22 | 30 | 11.50 | 2.6 | | | 6.12 | | |
| 23 | 20 | 8.31 | 2.4 | | | 4.94 | | |
| 24 | 40 | 16.26 | 2.5 | | | 8.41 | | |
| 25 | 20 | 9.10 | 2.2 | 11.3 | 1.2 | 5.07 | 2.2 | 81.8 |
| 26 | 40 | 16.72 | 2.4 | 30.2 | 1.8 | 8.70 | 3.5 | 52.5 |
| Subtotal | 220 | 87.79 | 2.5 | 134 | 1.5 | 47.46 | 2.8 | 64.6 |
| Total | 625 | 248.45 | 2.5 | 685 | 2.8 | 145.63 | 4.7 | 128.1 |

[1] The design flow rates are based on standard outlet modules.

[2] Includes flow rates increased due to sandbags or secondary gates placed in primary canal. Value represents actual running flow measurement in field.

[3] Average Unit Flow Rates (AUFR) determined during the Teams' visit assuming flows delievered to total area served.

[4] Hours of delivery per week based on 7.5 mm ET requirement at 80 percent efficiency during the dry season (d.s.).

[4] Sector 13 is non-existent.

are then rotated among parcels. Most parcel irrigations are completed in one day, when adequate water is available.

## 2.3 System Management

The opening and closing of the reservoir outlet is the responsibility of an individual designated by the co-operative officers. This same individual is charged with overseeing the distribution of water among sectors along the length of the primary canal. He is aided by the ONAHA irrigation technician (one of several personnel assigned to Galmi) who is more familiar with gate flow rates and other technical matters. Generally, scheduling decisions regarding reservoir opening and closings are made by the ONAHA perimeter director himself, who confers with the co-operative officers. Along the secondaries, it is the sector heads (GMP presidents), elected by the represented farmers, who is charged with overseeing the "tour d'eau." These individuals see to it that scheduling among the tertiaries of each sector is regulated in some manner. This also includes overseeing the distribution of available siphons among the tertiaries. Along most tertiaries, the farmers or the sector head have designated one of the parcel holders to oversee irrigation rotation and siphon distribution among the six or so parcels within that subunit.

Major maintenance and repairs are addressed by the ONAHA personnel assigned to Galmi, and the co-operative to a lesser extent. Repairs along the lined primary and secondary canals are usually handled by the irrigation technician--who together with several farmers or by hiring a local mason deals with the necessary repairs. Material for repairs and contracted assistance is paid for out of co-operative funds. Since the system is relatively new, few repairs have been necessary thus far. Most of the regular maintenance, however, takes place along the unlined tertiaries several times a year. This generally involves farmers in weeding and clearing the canals, and reinforcing eroded sections. The perimeter director calls for several of these maintenance exercises a year; one before each cropping season and usually one or two during the wet season cycle. When this is executed, each sector head is responsible for overseeing the activity in his sector. At scheduled irrigation periods, sectors or individual tertiaries can be denied access to water until all weeding and cleaning has been completed.

## 2.4 On-Farm Irrigation and Crop Management

All parcels have been leveled in the system and irrigation is primarily down slope with 10-12 m furrows, fed by several field channels running 25 m across the parcel width at regular intervals. (In the dry season the furrows are replaced by 15-25 $m^2$ basins for onion and wheat crops.) These cross channels are fed by the main field channel running the 100 m length of the parcel along one side, into which the siphons discharge. The system design prescribes 5 siphons, but generally 4 to 8 are used (although sometimes more) by each farmer depending on the availability of water in the tertiary and his time constraints for completing the irrigation. All the siphons are placed at the head of the primary field channel. Parcel level flows are usually on the order of 4-10 lps.

The above-mentioned furrow lengths are a reduction from the original design plans of 100 m for parcel layout. As was the case at Djirataoua, local farmers simply don't have the means by which to develop long furrows capable of delivering water at acceptable application efficiencies. With the flow rates used, the time and labor constraints under which farmers work, and by making adjustments from the original methods prescribed at the inception of the system, they are able to apply water considerably faster and more efficiently than they would be able to do otherwise.

2.4.1 On-Farm Water Management: Onions, wheat, maize and some cowpeas were being irrigated during the Team's visit. (There was also some late season cotton still standing.) Onions and wheat are grown in basins. Onion basin dimensions vary from 2 m X 3 m to 4 m X 8 m. Wheat basins are approximately 4 or 5 m X 7 or 8 m. Maize is grown on ridges and often intercropped with cowpeas. On these dry season crops, on-farm irrigation practice is governed by water availability, a time-based rotation along tertiaries, farmer labor availability and system rules that require all of a farmer's plot to be planted each season. All of these factors lead farmers to try to irrigate as quickly as possible.

Farmers are supposed to receive water once a week. Water theft in the upper parts of the system and system construction errors result in irrigation frequencies ranging from once every four days to once in eleven days. Farmer response has been to put on as much water as possible when it is available. Onions at the two-month stage after transplanting were receiving about 5 cm of water as frequently as water was available. Onions transplanted late showed signs of water stress as did onions planted in the problem sectors of the perimeter. Farmers were applying sufficient water to the onion basins, but they were losing substantial quantities to deep percolation.

Onion basins were leveled within 0.1 percent slope, but were roughly prepared. No observable effects on onion growth were seen. Cotton fields are furrow irrigated. Individual irrigation practice varied widely. Short furrows of 8 to 12 meters are generally formed but height, slope, and water application practices were observably deficient in many cases. Furrows were frequently cut, leading water to accumulate on the downslope side of groups of furrows or in the drains. Sorghum, millet, and cotton are grown as rainfed crops with little pre-irrigation or supplemental irrigation. Consequently, little effort is made to level parcels in the rainy season.

2.4.2 Cropping Practices: Late season cotton and midseason onion, wheat, maize and cowpea crops were observed in the perimeter.

Cotton was grown on the perimeter for the first time in the 1986 rainy season. Cotton spacing was generally at recommended 80 cm X 60 cm. Thinning practice was highly variable with up to seven plants per hill.

The cotton crop was planted between June 25 and July 9 following the onset of the rainy season. Substantial replanting occurred. ONAHA staff indicated that the co-operative would not authorize water release for supplemental irrigation if rain falls during any given ten-day period. CFDT field staff said that the seed of the ISA205 variety had been mixed with other varieties and that seed quality was not high. Both factors contributed to uneven stand development. Plant protection materials are provided by CFDT with farmers supplying only batteries for the ULV sprayers. Even so, spraying schedules within a sector and among sectors are reported not to be well-coordinated. Farmers who don't buy batteries do not spray. Their unsprayed plots become sites for reinfestation of neighboring fields.

Cotton weeding is done by hand. The harvest schedule follows that of the rainfed and recessional cotton outside the perimeter. It begins in December and extends through March or as long as significant quantities of cotton continue to be harvested. The late season cotton was infested with aphids and substantial bollworm damage was seen.

Wheat is grown in flooded basins. It should be planted in late November and early December, but was planted in mid-December through early January this year. The main varieties grown were Hyattam (an awned variety derived from Florence Aurore) and Brinqual (an unawned introduction from the 1984-85 dry season). The crop is planted in poquets to facilitate hand weeding. The early planted stands had good vegetative growth and relatively good panicle formation. However, one-third of the crop will yield little because of late planting and the early onset of hot, windy weather. It also appears that bird damage will be high.

Onions have been cultivated for several decades at Galmi and surrounding areas. Production practice are well perfected. Farmers grow much of their own seed, which is planted to produce bulbs. Bulbs are cut to stimulate shoot initiation from the stem plate. The shoots formed are transplanted to a well-watered bed where they produce flowers and what is called by farmers second generation seed. This seed is used in seedling plant nurseries. Transplanting is done after one to two months of growth. Planting density inside the perimeter is about 512,000 plants per hectare. In the traditional plots the density is higher, about 611,000 plants per hectare.

Weeding is done manually. Fertilization is done with both manure and commercial fertilizer, mainly urea. Farmers indicate that the perimeter onion fields require higher fertilizer applications than traditional plots. They attribute this to the need to offset the "coldness" of the irrigation waters to improve or be forced out of production.

## 2.5 Functioning of Farm Enterprises and Institutions

While ONAHA rules constrain tendencies towards land concentration, the practice of "supari," or buying of immature standing crops of onions, results in flexible seasonal concentrations of land. This arrangement benefits well capitalized merchant farmers. The head of the youth organization had gained effective control of 16 onion plots in this manner.

This year 136 ha were planted in millet and sorghum in function of soils type and 106 ha were placed in cotton (which extends into the dry season). At the level of the parcel, actual area devoted to cotton covaried positively with the amount of back cropping feed owed, and negatively with the perceived risk associated with a new crop, and with farmers' expectations of the amount of water made available to his parcel. The decision to plant cotton was taken jointly by the co-operative management committee and the technicians in order to pay off crop fee arrears in excess of 40 percent.

For the dry season (during Teams' visit) 124 ha of onions, 8 ha of wheat, and 2 ha of maize/cowpeas followed. While onions were the preferred crop, wheat was planted by those whose food needs were unsatisfied, who could not obtain sufficient onion seed, or who lacked sufficient labor power for onion cultivation. Farmers seemed satisfied with these crops, although not necessarily with their mix.

Among those farmers questioned on the perimeter, the available labor per household varied from one active male to over 20 active workers. In the latter case, we were dealing with a wealthy man who made extensive use of hired labor to produce enough food to satisfy social obligations incumbent on his role as an important onion merchant and head of the local youth group (samariya). It is worth noting that this latter group is responsible for maintenance of the 6 kms of primary canal which serve the perimeter.

Competition for labor between the two types of parcels did not appear to pose a problem to most of the farmers we questioned. Perimeter parcels were privileged in relation to off-perimeter parcels; most farmers pointed out that payment of the cropping fee and the small size of the perimeter parcels provided incentives for this. Many added that the supply of wage labor was adequate to their needs and most used hired labor both on and off the perimeter.

Actual labor allocation is highly variable and does not vary linearly with land holding and potential household labor force. The extent of off-perimeter onion holdings, dune fields, and perimeter parcels, availability of onion seed to the household at planting and location of perimeter parcel are among the factors which influence actual labor inputs.

Familiar basis of labor exchange are carried over into the perimeter in some cases. For those farmers who work on irrigation blocks (7 parcel holders on average) with close male relatives, inter-household solidarity among patrilateral relatives ensures timely labor exchange to accomplish labor intensive tasks. On the other hand, both more commercially oriented farmers and more resource poor farmer without much recourse to family labor, may find it respectively more expedient or more necessary to resort to paid labor.

There are two special developments in management of the GMPs. In some cases, all the members of an irrigation block will be close family members, whereas other members of the GMP are less closely related. In this context, one of the family members will be delegated the responsibility of collecting redevance payments and organizing irrigations and crop treatments. He, in turn, will turn redevance payments over to the GMP president. The other special case involves GMPs 1, 2 and 3, which have only a single president. This is partly because of their small size. However, it is also significant that many members of GMPs 1 and 2 are Buzu who must rely on their Hausa president from Galmi to represent their interests. A history of unresolved water supply and input problems suggests all may not be well with this situation.

## 3.0 Evaluation of Performance

### 3. Irrigation System Operation

Obvious design and/or construction flaws exist in the physical system. The original design concept is a sound one, and one that should work well (referring primarily to the use of weirs in the primary canal to regulate pre-set submerged orifice outlets to the secondaries). The principal problem at Galmi is with the secondary offtakes from the primary canal. Table G 2.2.1 shows the design flows for each of the 25 secondaries and the design flow per hectare served. In addition, actual flow rates are given for several secondaries measured during the field reconnaissance. It was found that a considerable number of secondaries have flows well above and below their design. The actual cause for the design/construction fault is unsure, but at least one attempt was made in the first year of operation to correct a number of the submerged orifice offtakes by either increasing or reducing the flow capacity of the orifice. Nevertheless, severe inequities still exist in the flows (lps/ha) delivered to each sector. Upstream attempts by sectors to deal with the problem (e.g., by placing objects in the main canal to raise the head) simply compound the already serious lack of sufficient and timely water delivery to the tail-end sectors. As indicated in Table G 2.2.1, the flow rate per unit area served in the dry season varies from as low as 2.2 lps/ha to as high as 10.2 lps/ha. Measurements taken along the primary canal also indicated severe discrepancies between upper and middle sectors, and the tail-end sectors. While sectors 1 through 18 averaged 5.6 lps/ha, sectors 19 through 26 averaged only 2.8 lps/ha. In turn, this would require nearly 65 hours/ha per week of irrigation in the tail sectors to meet their water requirement needs, while the other sectors would require only half of that on average. (These data were taken from spot checks during 2 days of field work by the Team.)

A second major constraint in the system is the carrying capacity of the main canal, which is insufficient to carry the full flow necessary to serve the system so that all sectors receive equal and sufficient water delivery. This problem exists only during peak use periods in the dry season. When attempts are made to release higher flows from the reservoir, overtopping of a number of overflow spillways along the primary canal occurs and overtopping of the canal itself occurs at one point where the primary canals flows into a siphon running under the Route Nationale. As a result of this, most releases are on the order of 680 lps as opposed to the maximum design flow of 700 lps.

It was noted particularly along a number of secondary canals that either low-grade concrete or a mixture with an excessive sand component was used in construction, resulting in many side sections which tend to flake easily. Some of the drainage infrastructure, particularly culverts and the like, appear to have been rapidly built as an afterthought. These are for the most part constructed of local rock and concrete mortar, but the backfill and soil compaction associated with these was very poorly done, resulting in a good deal of erosion around the structures.

Table 3.1.1 Dry Season 1985-86 Water Budgets and Overall Efficiencies at Galmi

| Sectors (area) | Item | Units | Months | | | | | Season Total |
|---|---|---|---|---|---|---|---|---|
| | | | Dec. | Jan. | Feb. | Mar. | Apr. | |
| Sectors 1 - 8 | ET | (1000 $m^3$) | 65 | 97 | 115 | 137 | 35 | 449 |
| (76.9 ha) | IRRIG | (1000 $m^3$) | 217 | 208 | 281 | 264 | 60 | 1030 |
| | EFF | % | 30 | 47 | 41 | 52 | 58 | 44 |
| Sectors 9 - 16 | ET | (1000 $m^3$) | 50 | 77 | 89 | 109 | 29 | 354 |
| (61.0 ha) | IRRIG | (1000 $m^3$) | 92 | 88 | 121 | 113 | 26 | 440 |
| | EFF | % | 54 | 88 | 74 | 96 | 112 | 80 |
| Sectors 17 - 23 | ET | (1000 $m^3$) | 48 | 74 | 87 | 106 | 28 | 343 |
| (59.2 ha) | IRRIG | (1000 $m^3$) | 114 | 109 | 147 | 138 | 32 | 540 |
| | EFF | % | 42 | 68 | 59 | 77 | 88 | 64 |
| Sectors 24 - 26 | ET | (1000 $m^3$) | 35 | 54 | 64 | 74 | 17 | 244 |
| (42.2 ha) | IRRIG | (1000 $m^3$) | 92 | 90 | 121 | 113 | 26 | 442 |
| | EFF | % | 38 | 60 | 53 | 65 | 65 | 55 |
| System | ET | (1000 $m^3$) | 198 | 302 | 355 | 426 | 109 | 13903 |
| (239.3 ha) | IRRIG | (1000 $m^3$) | 515 | 495 | 670 | 628 | 144 | 2452 |
| | EFF | % | 38 | 61 | 53 | 68 | 76 | 57 |

(Source: Norman, 1987)

On the tertiary level, when water is supplied in sufficient amounts, the system appears to function properly. The exception to this is the gradual disintegration of the sandbag checks used to maintain stable siphon flows. Farmers tend to replace these with rocks, or less desirably, soil dug from around the channel.

Operational losses are not high and in few places was it noted that any excess water was being wasted. Losses as a result of canal seepage also appeared to be minimal, largely due to the newness of the infrastructure. Most losses are in the field distribution channels and particularly in certain sectors where over-irrigation is significant due to an "excess" availability of water.

A water budget for the 1985-86 dry season as seen in Table G 3.1.1 was derived from data collected by Norman (1987). Overall irrigation system application efficiency in meeting crop water requirements was on the order of 50-60 percent. (This value may be on the high side as ET-crop values do not reflect periods when plants may shut-down when high transpiration rates cannot be met, nor are water losses below the root-zone well reflected in the computation.) Month by month values indicate some variance in water use during the cropping cycle. The differences between sector groups from the head to tail of the system are also given, indicating the high differences in ability to meet crop water demands at various points in the system. Thus, global efficiency may be near an acceptable level, but internal variations within the system are high enough to indicate potential crop losses and water wastes.

The 245-ha perimeter is totally gravity-fed and requires no power source to pump water. The drop from the dam to the head gate is approximately 30 meters and could be used for power generation if a retrofit were incorporated. Likewise, the primary canal has approximately 20 drops of 0.5 to 1.0 meters which could technically be used for electrical or mechanical power generation. Power sources for the 20 ha of land which is not gravity irrigated are traditional rope and calabash, and 3.5 to 5.0 hp motor-pumps drawing from 2-7 meters in traditional wells, or surface water from dam seepage.

## 3.2 System Management

No apparent prescribed irrigation schedule exists for the perimeter. Decisions as to irrigation scheduling appear to be made primarily by the ONAHA perimeter director, and as was found at Djirataoua, scheduling does not address individual crop water needs nor variances in soil types between sectors. Capability among ONAHA personnel to assess differences in water needs among various crops and soil types seems to be limited.

Monitoring of water use among secondaries is evidently poorly done by those charged with the responsibility. A deterioration of management control over water use at level of the secondary offtakes is evident in waste distribution data collected by Norman (1987) in the 1985-86 dry season (Table G 3.2.1) as compared to the Team's findings in the 1986-87 season (Table G 2.2.1). Variances of water delivery in lps per hectare served among grouping of sectors ranged from between 2.3 and 2.9 in 1985-86, whereas differences from 2.8 to 6.2 were found in the 1986-87 season. Even though the deficiencies in the physical system were the same during both seasons, the data indicate that it was at least possible (as was done in 1985-86) to manage the system in such a way as to significantly minimize the effects of design/construction flaws in the system infrastructure.

Table G 3.2.1 Water Distribution at Galmi during Dry Season 1985-86

| Sector(s) | Actual Flows (lps) | Areas Served (ha) | Unit Flow Rates (ha) |
|---|---|---|---|
| 3 | 35.1 | 13.5 | 2.6 |
| 14 | 16.8 | 4.8 | 3.5 |
| 26 | 38.4 | 16.7 | 2.3 |
| 1-8 | 234.4 | 80.7 | 2.9 |
| 9-16 | 164.9 | 64.4 | 2.6 |
| 17-23 | 155.6 | 61.3 | 2.5 |
| 24-26 | 96.8 | 42.2 | 2.3 |

(Source: Norman, 1987)

Monitoring of water scheduling by the sector heads within the sectors seems to be done fairly well. In addition, scheduling among farmers along the tertiaries seems to function smoothly.

Routine maintenance in the canal network appears to be fairly well executed. Cracks in lined canals appeared to be sealed, while major cracks of breaks were repaired with cement. These efforts are made largely by ONAHA personnel. Weeding and repairs along the earthen tertiaries appear to be fairly well maintained, although there are places where erosion is significant at the ends of a number of tertiaries. Unchecked erosion also seems to be taking its toll on the drainage system at several points, as well.

Overall system and average field application efficiencies were estimated by Norman (1987) for the 1985-86 as presented in Table G 3.2.2. From this table it is obvious that efficiencies are not uniform throughout.

Table G 3.2.2 System Water Use at Galmi during 1985-86 Dry Season

| Location | | Volumes ($m^3$) | | Efficiencies[1] (%) |
|---|---|---|---|---|
| Release from Dam | | | | Overall System |
| GMP 1-8 | | 1,029,935 | | 43.6 |
| GMP 9-16 | | 441,403 | | 80.2 |
| GMP 17-23 | | 539,488 | | 63.7 |
| GMP 24-26 | | 441,401 | | 55.4 |
| | Total | 2,452,227 | Avg. | 56.8 |
| Water Applied to Fields | | | | Applications |
| GMP 1-8 | | 803,349 | | 55.9 |
| GMP 9-16 | | 344,294 | | 102.9 |
| GMP 17-23 | | 420,801 | | 81.8 |
| GMP 24-26 | | 344,293 | | 71.0 |
| | Total | 1,912,737 | Avg. | 72.8 |
| Water Requirements of Crop | | | | |
| Based on Norman (Pan X 0.98 X Kc X Area X 10) | | | | |
| GMP 1-8 | | 448,971 | | |
| GMP 9-16 | | 354,116 | | |
| GMP 17-23 | | 344,008 | | |
| GMP 24-26 | | 244,604 | | |
| | Total | 1,391,699 | | |

[1] Assuming efficiency equals crop water requirements divided by water released or applied.

(Source: Norman, 1987).

## 3.3 On-Farm Irrigation and Crop Management

Farmers appear to do reasonably well with field water applications by adapting to the system in various ways (e.g., shortening of furrows from the originally prescribed longer lengths). Dry season basin leveling, which is done by hand, is fair, but not as well done as is found in the smaller basins of the traditional systems. With the larger basin size, timing uniformity of basin inundation also tends to drop. Yet, there is evidence that basin size is gradually being reduced from year to year in an effort to adjust the system in such a manner as to increase field level application efficiencies. There is, however, a high degree of variation among parcels as to irrigation rates and applications. Where water is easily accessible, there is often the tendency to over-irrigate. In sectors where water ~~is~~ more limited, underirrigation becomes a real problem. But these two latter issues, though directly affecting field level irrigation, are issues which should largely be addressed upstream of the parcel--primarily at the secondary offtake level.

3.3.1 <u>On-Farm Water Management</u>: Farmers at Galmi are expert onion growers and good producers of rainfed cereal crops. Their on-farm water management of onions would be good if water were delivered at a higher frequency and in quantities needed. The slopes in their small basins appear to have little effect on onion growths. System performance is a bigger problem than on-farm water management in onion production. Basin leveling could be improved for onions and wheat, but the farmers would have to be shown that the added land preparation cost and irrigation time would substantially increase yields. Wheat basins are longer and wider than onion basins. Leveling is done less well than with onions. Low and high spots exist that show some water stress from irrigation. Wheat in higher spots in the basins were attacked by termites. Normal irrigation practice may be better than observed this year, because the wheat crop was planted late to fill a plot when farmers ran out of onion transplants.

On-farm water management can definitely be improved on rainy season crops. However, better supplemental irrigation is closely tied to the amount water storage behind the dam. The co-operative does not want to release water before or during the rainy season if it will adversely affect the dry season cash crop of onions. However, the dam was constructed to serve twice the current irrigated area. Preirrigation before the rainy season and use of effective rainfall calculations would permit earlier planting dates for cotton, cereals, and subsequent dry season crops. Over-dependence on rainfall during cotton crop establishment appears to severely restrict root development. ONAHA field staff indicated that the co-operative will not authorize water release if rain falls during a given week, even if the amount is insufficient for good crop growth. Cotton plants uprooted at the end of their growth showed a foreshortened tap root often in the form of a J with lateral roots well-developed only to a depth of 20 to 30 cm. While a compacted layer exists at 30-40 cm in most fields, the furrow layout, poor field leveling and poor ridging of the cotton crop suggested that shallow irrigations limit rooting depth. However, as 1986 was a good rainfall year, and late season irrigations were adequate, crop yields were generally good.

The perimeter soils are dominated by clay loams and sandy clay loams with some areas of loam and two sections of sandy loams (S-4 and S-5). All appear to be affected by soil compaction, probably due to the superficial plowing done with animal drawn plows and ridgers on moist soils after pre-irrigation and due to continuous foot and hand implement traffic in furrows during weeding. There were no general signs of waterlogging in the perimeter soils. Where land leveling was done in S-

24, S-26, and S-16 soils were mixed in texture. A decrease in soil water holding capacity was found next to the natural drain where sand layers from overflows are found at shallow depth. Other droughty areas were found next to the flood protection dike, where laterite peastone was spread in some fields. While very important to individual farmers, no large areas were adversely affected.

3.3.2 <u>Cropping Practices</u>: The cropping practice observed in February and discussed with farmers are probably conditioned by a series of factors extending back in time to the 1985-86 dry season. The wheat crop produced did not receive a good market price. In addition, Prinqual, the wheat variety introduced, was awnless and subject to important bird damage. It could be anticipated that farmers would to be enthusiastic about a 1986-87 wheat crop. The introduction of a new crop, cotton, was intended to enable farmers to pay their operating cost backlog. However, cotton was grown more like a dryland crop than an irrigated crop until late in its growth cycle, slowing its growth and maturity. As the first harvest didn't begin until late November, the possibility of growing a cool season cereal crop was eliminated. About 15 percent of the planned cotton area was not planted, as some farmers apparently hedged their bets on the likely success of the cotton crop.

The onion crop was transplanted from mid- to late-December, about one month after onions were transplanted outside the perimeter. By this time onion seedlings were in short supply, and farmers were not always able to fill their onion plots. Plant densities were lower than those found in fields outside the perimeter. Some farmers filled the leftover area with wheat. The main wheat crop was planted about the same time as the onion crop. It covered about 7 percent of the wheat area planted in 1985-86. In 1984-85 the wheat crop was planted two weeks before the onion crop, avoiding overlap in labor requirements. The continuing cotton harvest and increasing demands for weeding and harvesting labor makes it unlikely that land for a hot dry season crop can be prepared. In addition, a reservoir of aphids and thrips is building up in the cotton crop. Thrips have already moved to several blocks of onion parcels. Bollworms have already migrated to the cotton root zone.

The cropping alternatives for a hot dry season crop are limited to cowpeas, peanuts, a short-cycle millet, or a short-cycle maize. Both cowpeas and peanuts would require expensive protection from aphids. The millet would be subject to substantial bird damage. The high temperatures and winds of the dry season will result in a high degree of sterility in maize.

Cotton, a relatively profitable crop for farmers and a convenient crop to recover cash debts for ONAHA, has brought about a substantial change in cropping practices. Its productivity will have to be increased if it is to compensate for its substantial reduction of the system cropping intensity and flexibility in dry season land management. Cotton plant protection practices are not adequately mastered by farmers. The problem identified by ONAHA staff is that farmers do not organize themselves to buy batteries for the ULV sprayers to treat an entire block of fields in one GMP. Pests transfer from the untreated fields upon

Table G 3.3.1 Onion Cultivation Inside and Outside Galmi Perimeter

| Practice/characteristic | Inside perimeter | Outside perimeter |
|---|---|---|
| 1. Land preparation | Basins from 3.7 m X 8.70 to 2.5 m X 5.0 m, sloped. | Basins about 1.25 m X 2.0 m, level. |
| 2. Date of Transplanting | Mid- to late-December and early January, competing labor demands. Pushes crop maturity into high ETP period. | November to Mid-December |
| 3. Stand density | 512,700 plants/ha. Because of later planting, seedling shortage, and need (perimeter rule) to cover full plot land area. | 611,400 plants/ha |
| 4. Weeding | Heavier soils with high <u>Cyperus</u> challenge. Not general. | Varies with soil textures, but full cover earlier in cool season reduces problem. |
| 5. Fertilization | Varies. Farmers say use more chemical fertilizer because it is "hot," water "cold," a leaching effect? Manure used too. | Varies. Same as inside, substantially higher, others lower |
| 6. Pest control | Proximity and transfer of thrips and aphids from cotton to onions. HCH cost increasing. | Greater distance better overlap with cotton spraying cycle. May avoid thrips transfer. |
| 7. Water management | Irrigations on field weekly schedule. Some stress locally severe. | Better fit with crop requirements and soil conditions. |
| 8. Harvest | Hits peak availability period of onions on market price decline. Estimate yield at 32t/ha. | Hits early season market when prices high. Estimate yield at 38t/ha. |
| 9. Storage | Good crop dry down may prolong storage of bulbs. Low humidity high temperature effect on dried top quality? | Dry down may be slower? Better cooler conditions for top fermentation and slow drying. |

breakdown of the insecticides. Cotton yields will decline next year if better pest control is not practiced.

Onions are the dominant cash crop in the Galmi perimeter and outside it. Table G 3.3.1 summarizes observations made on both production systems by WMS II and ONAHA agronomists.

### 3.4 Irrigated Agricultural Productivity

The rapid decline in cropping intensity in 1986-87 to 1.55 is cause for concern. The cotton crop will have to be better managed to permit higher cool season cropping intensity, reduction in pest control problems, and maintenance of yields.

The perimeter soils are generally fertile and moderately to well drained. Their production potential has not been fully utilized even though system-wide average yields are in the range of good long-term averages. Niébé is the most profitable crop if its plant protection problems can be solved.

Over the next few years the compaction problem will probably increase in intensity. Subsoiling or rotation with a forage crop may need to be considered if crop yields are adversely affected.

Project management may want to increase the flexibility of the crop rotation by including peanuts and garlic. Also, some consideration should be given to dividing plots into thirds to permit a minimum two-thirds cropping intensity in the cool dry season. Farmers would be able to decide if one or two-thirds of their rainy season field should be planted in cotton.

Practical yield targets are presented in Table G 3.4.1 for Galmi. The potential yield figure may be adjusted upwards if better varieties are introduced, and if applied research is done on crop fertilization and plant protection practice.

### 3.5 Irrigation System Economics

As a system, the Galmi perimeter is not economic, in spite of the substantial returns earned by farmers. The overall economic internal rate of return is zero using a 23-year time horizon and rises to 3.0 percent using a 40-year time horizon. Because of siltation problems, the 40-year time horizon will not prove realistic unless significant additional investments are made in soil conservation for erosion control in the watershed. These additional investments will probably offset most, if not all, of the higher return obtained from the longer time horizon.

One benefit of the perimeter that appears to have not been anticipated is a rise in the water table in the area below the dam. This has permitted a significant expansion of off-perimeter dry season cultivation. Norman (1987) estimated the off-perimeter area at 12 percent. If this is true, it represents an increase of 15 hectares over

Table G 3.4.1 Yield Targets for Various Crops at Galmi

| Crop | Current Average yield (kg/ha) | Practical Potential yield (kg/ha) | Current as Percent Potential Yield (%) |
|---|---|---|---|
| Sorghum | 2,400 | 2,800 | 86 |
| Millet | 2,500 | 2,600 | 96 |
| Cotton | 2,500 | 2,800 | 90 |
| Onions | 38,000 | 38,000 | 100 |
| Wheat | 2,900 | 3,200 | 90 |
| Cowpeas | - | 1,500 | - |
| Corn | 700 | 2,000 | 37 |

and above the area existing outside of the reservoir/perimeter areas before the project. This benefit accounts for 10-15 percent of total benefits in the far out years when siltation in the reservoir is expected to sharply reduce dry season onion cultivation.

Table G 3.5.1 summarizes the incremental economic benefits associated with the perimeter, according to source. By far, the largest portion of benefits arises from production on the perimeter. Recession agriculture in the reservoir never accounts for much because of wider spacing of crops and less water control. It would appear possible, however, to sink wells in the reservoir so as to allow a more intensive utilization of subterranean water. Such activities will necessitate additional investment. The additional output that results is more properly attributed to these additional investments rather than to the perimeter as it is not constituted.

## 3.6 On-Farm Economics

3.6.1 On-Perimeter Crop Budgets: Although the perimeter technical staff is still experimenting with alternative cropping patterns, it seems that a rotation of cotton, sorghum and millet during the rainy season, and onion, wheat and/or cowpeas during the dry season is evolving. Table G 3.6.1 summarizes the average input-output relationships that seem to prevail at the present time, along with the returns to labor and management and/or economic rents that result. Because operating costs are so low, average economic rents/returns to management are quite high as compared to other irrigation systems in Niger, and that of Djirataoua in particular.

Table G 3.5.1: Investment Costs and Net Incremental Benefits Associated with Galmi Irrigated Perimeter (Million FCFA)

| Year | Investment Costs | Incremental Economic Value Added: On Perimeter[1] | Reservoir[2] | Off Perimeter[3] | Total | Additional Value Added with All Onions in dry season |
|---|---|---|---|---|---|---|
| 0 | 1,250 | 0.0 | 0.00 | - | 0.00 | 25.0 |
| 1 | 1,250 | 0.0 | 0.00 | - | 0.00 | 50.0 |
| 2 | 0 | 62.5 | 0.00 | - | 62.5 | 50.0 |
| 3 | 0 | 125.0 | 0.00 | 4.0 | 129.0 | 50.0 |
| 4 | 0 | 125.0 | 0.00 | 8.0 | 133.0 | 50.0 |
| 5 | 0 | 125.0 | 0.00 | 12.0 | 137.0 | 25.0 |
| 6 | 0 | 125.0 | 0.00 | 12.0 | 137.0 | 50.0 |
| 7 | 0 | 62.5 | 0.75 | 12.0 | 72.3 | 50.0 |
| 8 | 0 | 125.0 | 1.00 | 12.0 | 138.0 | 50.0 |
| 9 | 0 | 125.0 | 1.25 | 12.0 | 138.3 | 50.0 |
| 10 | 0 | 125.0 | 1.50 | 12.0 | 138.5 | 46.7 |
| 11 | 0 | 125.0 | 1.75 | 12.0 | 138.8 | 43.3 |
| 12 | 0 | 61.7 | 2.00 | 12.0 | 75.7 | 40.0 |
| 13 | 0 | 122.0 | 2.25 | 12.0 | 136.3 | 36.0 |
| 14 | 0 | 120.4 | 2.50 | 12.0 | 134.9 | 33.3 |
| 15 | 0 | 118.9 | 2.75 | 12.0 | 133.7 | 30.0 |
| 16 | 0 | 117.4 | 3.00 | 12.0 | 132.4 | 26.7 |
| 17 | 0 | 58.0 | 3.25 | 12.0 | 73.3 | 23.3 |
| 18 | 0 | 114.3 | 3.50 | 12.0 | 129.8 | 20.0 |
| 19 | 0 | 112.9 | 3.75 | 12.0 | 128.7 | 16.7 |
| 20 | 0 | 111.3 | 4.00 | 12.0 | 127.3 | 18.3 |
| 21 | 0 | 109.8 | 4.25 | 12.0 | 126.1 | 10.0 |
| 22 | 0 | 54.2 | 4.50 | 12.0 | 70.7 | 6.7 |
| 23 | 0 | 106.8 | 4.75 | 12.0 | 123.6 | 3.3 |
| 24 | 0 | 105.3 | 5.00 | 12.0 | 122.3 | 0.0 |
| 25 | 0 | 103.8 | 5.25 | 12.0 | 121.1 | 0.0 |
| 26 | 0 | 102.9 | 5.50 | 12.0 | 120.4 | 0.0 |
| 27 | 0 | 48.4 | 5.75 | 12.0 | 66.2 | 0.0 |
| 28 | 0 | 90.7 | 6.00 | 12.0 | 108.7 | 0.0 |
| 29 | 0 | 84.6 | 6.00 | 12.0 | 102.6 | 0.0 |
| 30 | 0 | 78.4 | 6.00 | 12.0 | 96.4 | 0.0 |
| 31 | 0 | 72.3 | 6.00 | 12.0 | 90.3 | 0.0 |
| 32 | 0 | 33.1 | 6.00 | 12.0 | 51.1 | 0.0 |
| 33 | 0 | 60.1 | 6.00 | 12.0 | 78.1 | 0.0 |
| 34 | 0 | 60.0 | 6.00 | 12.0 | 78.0 | 0.0 |
| 35 | 0 | 60.0 | 6.00 | 12.0 | 78.0 | 0.0 |
| 36 | 0 | 60.0 | 6.00 | 12.0 | 78.0 | 0.0 |
| 37 | 0 | 30.0 | 6.00 | 12.0 | 48.0 | 0.0 |
| 38-41 | 0 | 60.0 | 6.00 | 12.0 | 78.0 | 0.0 |

(footnotes on next page)

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[1] Assuming net economic value added of 125,000 FCFA per .25 hectares or 500,000 FCFA/ha as per Table G 3.6.1. Incremental production assumes a crop failure in one year out of three that reduces incremental economic value added by 50 percent. From year 12 onward, dry season area cultivated is assumed to decline until it stabilizes in year 34 with only 20 percent of total area under cultivation during the dry season, and all of that in onions. After the dry season area falls to 50 percent of rainy season area, all dry season area is assumed to be in onions.

[2] Assuming a reservoir area of 100 ha, the beginning of significant flood recession agriculture in year 7 on 10 hectares of land, and area in flood recession cultivation growing by 3.33 hectares/yr until 80 hectares are cultivated. The incremental economic value added per hectare equals one half of the average return to labor assuming 130 days/ha and an average return of 1150 FCFA per day, or 75,000 FCFA/ha. Norman (1987) found total returns to all factors of 308,000 per adjusted hectare, i.e., hectares adjusted for an average cropping intensity of 0.6 of normal. Assuming that labor inputs account for 80 percent of revenue gives an average return of labor of 1137.

[3] Assuming off-perimeter cultivation of onions amounts to 30 hectares versus 15 hectares prior to the project. The increase in the water table arising from construction of the dam has permitted a net increase of 15 hectares of onions per year over the without project scenario. Onion production on the perimeter lost to either the dam or the perimeter has already been taken into account in calculating incremental production on the perimeter. The incremental economic value added of a hectare of onions outside the perimeter is assumed to be 800,000 FCFA/ha based on Table G 3.6.7. All additional onion production beyond the 15 hectares due to the rise in the water table is assumed to have occurred in the absence of the project.

Table G 3.6.1: Estimated Farm Budget Based on Average Cropping System for 1986-1987 at Galmi Irrigated Perimeter

| Item | Cotton | Millet | Onions | Cowpeas | Total |
|---|---|---|---|---|---|
| Area (ha)[1] | 0.125 | 0.125 | 0.125 | 0.125 | 0.50 |
| Yield: Grain (kg/ha) | 2,500 | 2,200 | 38,000 | 1,500 | |
| By-Products | - | 150 bnd | 82 bags | 3,500kg | |
| Price: | | | | | |
| Primary Output (FCFA/kg) | 130 | 80 | 26 | 125 | |
| By-Products (FCFA/unit) | - | 100 | 600 | 35 | |
| Gross Revenue (FCFA) | 40,620 | 22,620 | 129,900 | 38,750 | 231,890 |
| Input Costs (FCFA/parcel) | | | | | |
| Non Labor Inputs | 3,540 | 4,220 | 37,490 | 8,820 | 54,070 |
| Labor Inputs | 26,800 | 7,400 | 58,430 | 9,000 | 101,630 |
| Irrigation Assessment | 3,500 | 3,500 | 2,750 | 2,750 | 12,500 |
| Sub-Total | 33,840 | 15,120 | 98,670 | 20,570 | 168,300 |
| Charge for Invested Capit. | 3,120 | 1,320 | 11,120 | 2,220 | 17,780 |
| Returns to Management/ Economic Rents (FCFA) | 3,660 | 6,180 | 20,110 | 15,960 | 45,910 |
| Average labor (Person/days) | 38.5 | 10 | 84 | 12 | 144.5 |
| Average Return per day of labor (FCFA/day)[2] | 791 | 1,375 | 935 | 1,316 | 1,021 |
| Average wage (FCFA/day)[3] | | | | | 703 |
| Incremental Economic Value Added (FCFA) | 19,580 | 12,040 | 71,290 | 22,760 | 125,670 |

Source: Tables G 3.6.2 to G 3.6.5

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[1] Cotton was planted for the first time in 1986. Because of its long growing season, cotton can only be followed by peanuts or cowpeas. Millet is followed in the rotation by onions. This analysis assumes that cotton will be followed by cowpeas because of previous success with cowpeas.

[2] Based on input cost of labor plus return to management divided by average person days of labor.

[3] Based on input cost of labor divided by average person days of labor.

TABLE G 3.6.2: Galmi Perimeter Enterprise Budget for Onions with Adequately Watered Parcels

| Item | Quantity | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|
| Output: | | | |
| Onion Bulbs | 38 tons = 330 Bags | 3,000 | 990,000 |
| Onion tops (dried) | 82 Bags | 600 | 49,200 |
| | | | --------- |
| Sub-Total | | | 1,039,200 |
| Non-labor Inputs: | | | |
| Plowing | oxen team | | 13,000 |
| Seedlings | | | 200,000 |
| Fertilizer | 200 kg urea | | |
| | 100 kg (15:15:15) | 65 | 19,500 |
| Plant Protection Products | | | 18,000 |
| Bag Tops | 330 bags | 25 | 8,250 |
| Transport | 412 bags | 100 | 41,200 |
| | | | --------- |
| Sub-Total | | | 299,950 |
| Labor Inputs: | | | |
| Land Preparation | 16 person days | 640 plus meals | 15,200 |
| Pulverizing Soil | piece rate | - | 36,000 |
| Preparation of Plant Beds | piece rate | - | 41,000 |
| Transplanting | 160 person days | 500 plus meals | 128,000 |
| Weeding | 95 person days | 500 plus meals | 76,000 |
| Harvesting | 220 person days | 400 | 88,000 |
| Irrigation | 96 person days | 500 plus meals | 76,800 |
| Transporting | 8 person days | 800 | 6,400 |
| | --- | | --------- |
| Sub-Total | 672 person days[1] | | 467,400 |
| Irrigation Assessment | | | 22,000 |
| Total Costs | | | 789,350 |
| Returns to Capital and Management | | | 249,850 |
| Charge for Invested Capital[2] | | | 88,950 |
| Returns to Management/Economic Rents | | | 160,900 |
| Average Returns per day of Labor[3] | | | 935 |
| Incremental Economic Value Added[4] | | | 570,300 |

(Footnotes on next page)

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[1] Valuing piece rate labor at 1000 FCFA/day.

[2] Equal to 50 percent of average investment. Average investment equals one third of the sum of non-labor inputs and one-half of the value of labor inputs. The one-third value reflects the average crop cycle/investment period of four months. The one-half for labor reflects the progressive application of labor inputs over the four month period, i.e., on average, only one-half of the ultimate cost will have been invested for the entire four months. Both hired labor and family labor are treated as invested capital. No charge is made for the irrigation assessment since that is paid after the harvest.

[3] Includes returns to management plus labor input costs divided by total days of labor.

[4] Assuming one-half of all inputs other than fertilizer, plant protection materials and the irrigation assessment represents net value added. The remaining half is a real cost to the economy in the form of income or remittances lost from other pursuits. Also assumes that one-half of the charge for invested capital is a return to additional savings and investment stimulated by the project. In addition, assumes all returns to management represent net value added for the economy.

Table G 3.6.3: Galmi Perimeter Enterprise Budget for Cotton

| Item | Quantity | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|
| Output: | | | |
| Seed Cotton | 2,500 kg | 130 | 325,000 |
| Non-labor Inputs: | | | |
| Plowing + preparation rows | oxen team | | 13,000 |
| Fertilizer | 200 kg | | 13,000 |
| Seed | Provided by CFDT | | - |
| Plant Protection Products | " | | - |
| Transport | 100 bags | 100 | 2,300 |
| Sub-Total | | | 28,300 |
| Labor Inputs: | | | |
| Land Preparation | 16 person days | 500 plus meals | 13,600 |
| Planting | 17 person days | 500 plus meals | 36,000 |
| Weeding | 45 person days | 800 plus meals | 49,500 |
| Irrigations | 56 person days | 500 plus meals | 44,800 |
| Spraying | piece rate | - | 13,750 |
| Harvesting | piece rate | - | 80,000 |
| Sub-Total | 308 person days[1] | | 214,450 |
| Irrigation Assessment | | | 28,000 |
| Total Costs | | | 270,750 |
| Returns to Capital and Management | | | 54,250 |
| Charge for Invested Capital[2] | | | 24,950 |
| Returns to Management/Economic Rents | | | 29,300 |
| Average Returns per day of labor[3] | | | 791 |
| Incremental Economic Value Added[4] | | | 156,650 |

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[1] Valuing piece rate spraying labor at 1000 FCFA/day and harvesting labor at 500 FCFA/day.

[2] Same as for Table G 3.6.2.

[3] Same as for Table G 3.6.2.

[4] Same as for Table G 3.6.2.

Table G 3.6.4: Galmi Perimeter Enterprise Budget for Millet

| Item | Quantity | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|
| Output: | | | |
| Grain (kg/ha) | 2,200 kg | 80 | 176,000 |
| Stover | 150 bundles | 100 | 15,000 |
| Sub-Total | | | 181,000 |
| Non-labor Inputs: | | | |
| Fertilizer | 150 kg | 65 | 9,750 |
| Bed Preparation | hectare | 16,000 | 16,000 |
| Seed | 17 kg | 80 | 1,350 |
| Transport | 110 bags | 50 | 5,500 |
| Manure | 40 kg | 30 | 1,200 |
| Sub-Total | | | 33,800 |
| Labor Inputs: | | | |
| Land Preparation | 12 person days | 500 plus meals | 9,600 |
| Planting | piece rate | - | 8,000 |
| Fertilizer Application | 2 person days | 500 plus meals | 1,600 |
| Weeding | 12 person days | 600 | 7,200 |
| Irrigatings | 10 person days | 700 | 7,000 |
| Harvesting | 31 person days | 500 plus meals | 24,800 |
| Transporting | 2 person days | 500 | 1,000 |
| Sub-Total | 79 person days[1] | | 59,200 |
| Irrigation Assessment | | | 28,000 |
| Total Costs | | | 121,000 |
| Returns to Capital and Management | | | 60,000 |
| Charge for Invested Capital[2] | | | 10,550 |
| Returns to Management/Economic Rents | | | 49,450 |
| Average Returns per day of labor[3] | | | 1,375 |
| Incremental Economic Value Added[4] | | | 96,350 |

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[1] Valuing piece rate labor at 800 FCFA/day.
[2] Same as for Table G 3.6.2.
[3] Same as for Table G 3.6.2.
[4] Same as for Table G 3.6.2.

Table G 3.6.5: Galmi Perimeter Enterprise Budget for Cowpeas

| Item | Quantity | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|
| Output: | | | |
| Grain (kg/ha) | 1,500 | 125 | 187,500 |
| Fodder | 3,500 kg | 35 | 122,500 |
| Sub-Total | | | 310,000 |
| Non-labor Inputs: | | | |
| Land Preparation | Plowing | | 11,000 |
| Seed | 30 kg | 125 | 3,750 |
| Fungicides | 4.5 liters | 9,000 | 40,500 |
| Fertilizer | 100 kg 15-15-15 | | |
| | 100 kg SSP | 55 | 11,000 |
| Hired labor | 3 Treatments | 600 | 1,800 |
| Transport | 15 kg | 100 | 1,500 |
| | 4 carts | 250 | 1,000 |
| Sub-Total | | | 70,550 |
| Labor Inputs: | | | |
| Land Preparation | 6 person days | 500 plus meals | 4,800 |
| Planting | 9 person days | 500 plus meals | 7,200 |
| Weeding | 25 person days | 500 plus meals | 20,000 |
| Fertilizer Application | 2 person days | 500 plus meals | 1,000 |
| Irrigating | 13 person days | 500 plus meals | 10,400 |
| arvesting/Thrashing | piece rate | | 26,600 |
| nsporting | 4 person days | 500 | 2,000 |
| Sub-Total | 97 person days[1] | | 72,000 |
| Irrigation Assessment | | | 22,000 |
| Total Costs | | | 164,550 |
| Returns to Capital and Management | | | 145,450 |
| Charge for Invested Capital[2] | | | 17,760 |
| Returns to Management/Economic Rents | | | 127,690 |
| Average Returns per day of labor[3] | | | 1,316 |
| Incremental Economic Value Added[4] | | | 182,100 |

[1] Valuing piece rate labor at 700 FCFA/day.
[2] Same as for Table G 3.6.2.
[3] Same as for Table G 3.6.2.
[4] Same as for Table G 3.6.2.

The average return to labor employed in agriculture on the perimeter is about 935 FCFA per day, as compared to an average agricultural wage prior to the project of somewhere around 500 FCFA per day plus one or two meals. In contrast, the average return at Djirataoua is about 600 FCFA per day. These numbers are indicative only, since data for cowpeas assume farmers can grow a successful cowpea crop following cotton. As yet, the project has not settled on a suitable crop to follow cotton in the rotation, though apart from pest problems, cowpeas appear to be among the more promising. In addition, the average farm budget assumes continuation of a cropping intensity of 2.0 per year at least for a period, even though this will require some alteration to the gates to the secondary canals in order to permit such intensity across the entire system. From the farmers perspective, the Galmi perimeter is profitable indeed.

The large returns to labor that farmers on the perimeter earn has led to a substantial expansion in the use of hired labor. Available evidence indicates that the daily wage has increased significantly from pre-project days, perhaps by as much as 100 FCFA/day. At the same time, out-migration has declined. Moreover, Galmi has experienced net in-migration as farmers from surrounding areas obtain off-season employment on the onion fields.

There is still ample room for improvement, in spite of the high current average returns. Onion production, in particular, appears to be rather marginal on the lower third of the perimeter where inadequate water supply limits the frequency of irrigation. Table G 3.6.6 indicates that the lower average return per day of labor of only 580 FCFA/day, as compared to 935 FCFA on the better situated parcels. Moreover, the entire system obtains lower average prices than onion producers off the perimeter because they all plant later, and at nearly the same. As a result, most sales occur when prices are depressed. Average yields on the perimeter also appear to be lower for reasons explained in the agronomy section.

3.6.2 Off-Perimeter Crop Budgets. Table G 3.6.7 summarizes costs and returns from producing onions using two different off-perimeter pumping systems that do not require wells; a motor pump system and a hand pumping system using a calabash. Pumping costs for the motor pump system include capital, maintenance and labor operating costs. Traditional wells would add another 73,000 FCFA per hectare of investment and maintenance costs annually. Concrete wells would add up to 150,000 FCFA, depending on the depth of the well and the method of financing (see Table T 1.4.1). Obviously farmers' returns will vary enormously depending on well depth, pumping head, number of crops grown and pumping technology, in addition to the cost and returns associated with production and marketing of the specific crop in question. In this case, most farmers grow onions, so crop differences do not arise. The budget is based on two operating efficiencies for both systems in order to demonstrate the range of possible outcomes.

Most farmers in Galmi obtain fuel for motor pumps at black market rates that reflect prices in Nigeria rather than Niger. They usually purchase their pumps in Nigeria where they cost 50-75 percent as much as

Table G 3.6.6: Galmi Perimeter Enterprise Budget for Onions with Inadequately Watered Parcels

| Item | Quantity | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|
| Output: | | | |
| Onion Bulbs | 26 Tons=226 Bags | 3,000 | 678,000 |
| Onion tops (dried) | 56 bags | 600 | 33,600 |
| Sub-Total | | | 711,600 |
| Non-labor Inputs: | | | |
| Planting | Oxen team | | 13,000 |
| Seedlings | | | 200,000 |
| Fertilizer | 100 kg urea | | |
| | 50 kg (15-15-15) | 65 | 13,000 |
| Plant Protection Products | | | 18,000 |
| Bag Tops | 226 bags | 25 | 5,650 |
| Transport | 282 bags | 100 | 28,200 |
| Sub-Total | | | 277,850 |
| Labor Inputs: | | | |
| Land Preparation | 16 person days | 650 plus meals | 15,200 |
| Pulverizing Soil | piece rate | - | 36,000 |
| Preparation of Plant Beds | piece rate | - | 41,000 |
| Transplanting | 160 person days | 500 plus meals | 128,000 |
| Weeding | 95 person days | 500 plus meals | 76,000 |
| Harvesting | 150 person days | 400 | 60,000 |
| Irrigation | 65 person days | 500 plus meals | 52,000 |
| Transporting | 6 person days | 800 | 4,800 |
| Sub-Total | 569 person days[1] | | 413,000 |
| Irrigation Assessment | | | 22,000 |
| Total Costs | | | 712,850 |
| Returns to Capital and Management | | | -1,250 |
| Charge for Invested Capital[2] | | | 80,725 |
| Returns to Management/Economic Rents | | | -80,975 |
| Average Returns per day of Labor[3] | | | 582 |
| Incremental Economic Value Added[4] | | | 247,950 |

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[1] Valuing Piece rate labor at 700 FCFA/day.
[2] Same as for Table G 3.6.2.
[3] Same as for Table G 3.6.2.
[4] Same as for Table G 3.6.2.

Table G 3.6.7: Galmi Perimeter Enterprise Budget for Onions Outside Perimeters

| Item | Quantity | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|
| **Output:** | | | |
| Onion Bulbs | 45 tons = 391 Bags | 3,750 | 1,466,250 |
| Onion tops (dried) | 98 bags | 700 | 68,600 |
| Sub-Total | | | 1,534,850 |
| **Non-labor Inputs:** | | | |
| Plowing | Oxen team | | 13,000 |
| Seedlings | | | 200,000 |
| Fertilizer | 200 kg urea | | |
| | 100 kg (15-15-15) | 65 | 19,500 |
| Plant Protection Products | piece rate | | 18,000 |
| Bag Tops | 391 bags | 25 | 9,755 |
| Transport | 489 bags | 100 | 48,900 |
| Sub-Total | | | 309,175 |
| **Labor Inputs:** | | | |
| Land Preparation | 15 person days | 650 plus meals | 15,200 |
| Pulverizing Soil | piece rate | - | 36,000 |
| Preparation of Plant Beds | piece rate | - | 41,000 |
| Transplanting | 160 person days | 500 plus meals | 128,000 |
| Weeding | 95 person days | 500 plus meals | 76,000 |
| Harvesting | 260 person days | 400 | 104,000 |
| Irrigation | 96 person days | 500 plus meals | 76,800 |
| Transporting | 8 person days | 800 | 6,400 |
| Sub-Total | 712 person days[1] | | 483,400 |
| **Pumping Costs (One crop per season):** | | | |
| Motor pump (Normal Op. rate)[2] | 11,500 $m^3$ | | 145,400 |
| " (High Op. rate) | " | | 118,500 |
| Calabash | 10,500 $m^3$ | | |
| (2 meter lift) | 2,900 hrs | 100 | 290,000 |
| (6 meter lift) | 9,700 hrs | 100 | 970,000 |
| **Returns to Capital and Management:[3]** | | | |
| Motor pump: Normal Use | | | 596,775 |
| High Use | | | 623,775 |
| Calabash: 2 meter lift | | | 452,275 |
| 6 meter lift | | | (227,725) |
| **Charge for Invested Capital:[4]** | | | |
| Motor pump:[5] | | | 91,800 |
| Calabash: 2 meter lift | | | 116,000 |
| 6 meter lift | | | 172,600 |

Table G 3.6.7: (Continued..)

| Item | | Quantity | Unit Price or Cost (FCFA) | Total Value or Cost (FCFA/ha) |
|---|---|---|---|---|
| Returns to Management:[6] | | | | |
| Motor pump: | Normal Use | | | 504,975 |
| | High Use | | | 531,975 |
| Calabash: | 2 meter lift | | | 336,275 |
| | 6 meter lift | | | (400,325) |
| Average Returns per day of labor[7] | | | | |
| Motor pump: | Normal Use | | | 1,359 |
| | High Use | | | 1,295 |
| Calabash: | 2 meter lift | | | 928 |
| | 6 meter lift | | | 452 |
| Incremental Economic Value Added[8] | | | | |
| Motor pump: | Normal Use & High Use | | | 928,400 |
| Calabash: | 2 meter lift | | | 917,000 |
| | 6 meter lift | | | 635,000 |

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[1] Valuing piece rate labor at 1,000 FCFA/day.

[2] Taken from Table T 1.4.2.

[3] Output minus input costs and pumping costs.

[4] Equal to 50 percent of average investment. Average investment equals one-third of the sum of all non-labor inputs and one half of labor inputs. The one-third of the sum reflects the average crop cycle investment period of 4 months. The one-half for labor reflects the progressive application of labor inputs over the four month period, i.e., on average, only one-half of the ultimate cost will have been invested for four months. Both hired labor and unpaid family labor are treated as invested capital.

[5] Does not include charge for pump itself. This is included in pumping costs.

[6] Returns to Capital and Management minus charge for invested capital.

[7] Includes returns to management plus the cost of labor inputs divided by total days of labor. Labor inputs for both systems assume 6 hrs of pumping per day. Labor included in motor pump costs is 1.5 hrs per day for 110 days, valued at 100 FCFA per hour.

[8] Assuming one-half of all inputs other than fertilizer, plant protection materials and motor pumping costs represent net value added. The remaining half is a real cost to the economy in the form of income or remittances lost from other pursuits. Also assumes one-half of the charge for invested capital is a return to additional savings and investment stimulated by the project. In addition, assumes all returns to management represent net value added for the economy.

in Niamey. These factors combine to lower pumping costs substantially from what they would otherwise be. The data in Table G 3.6.7 reflected these lower costs. Table T 1.4.2 also shows comparison of costs using Nigerien prices with these costs.

On the basis of Table G 3.6.7, average returns to labor using motor pumps at normal operating speeds amount to 1360 FCFA per man day. This compares with returns of 935 FCFA per man day on the perimeter. The calabash systems pumping from two meters do as well as farmers on the perimeter, even though they must invest an additional 2900 per crop per hectare to obtain their water. At six meters of draw, however, the return to labor drops to 450 FCFA per day. Unless a farmer has very cheap family labor that cannot obtain alternative employment, many of those pumping from those levels will find wage employment for other, better situated farmers more profitable. We can, therefore, expect to see more and more such farmers dropping onion production over the next few years.

Several factors explain the equal to higher returns to labor obtained by farmers off-perimeter in spite of their much higher water costs. Because they have better control over their water, they can plant earlier and obtain higher prices as harvest time. They also get higher yields and require less fertilizer because water applications are more frequent and lighter.

At the farm level, farmers off the perimeter who have motor pumps will probably be better off by not expanding the area irrigated by each pump beyond 0.8 hectares per pump. Above this size channel losses will become quite high. The cost savings per hectare to reduce pumping costs to a minimum will not be sufficient to cover the cost of lining the distribution canals, even with two crops per season, unless costs are less than 1500 FCFA per meter. Farmers are more likely to be able to handle a 3.5 lps rate of flow by building larger field channels and doubling or tripling the labor allocated to distributing water from a single pump.

Where farmers do not have access to a drain or other nearby surface water source, they will have to invest in deeper wells with greater recharge capacity. This added cost will diminish, to same extent, the economic advantage of the motorpump at higher rates of flow. Beyond 0.8 hectares per pump, the savings is not likely to justify the added cost.

The economic attractiveness of the calabash system at two meters of lift suggests that research on improved hand and animal pumping systems at increased rates of flow and shallow depths could have a very high social and economic payoff. Such research should have high priority under the NAARP.

## 3.7 Farm Enterprise and Institutional Performance

The production goal of many farmers on the perimeter continues to be assuring their household food self-sufficiency rather than optimizing commercial revenues. That the margin to be derived from perimeter production is still relatively limited can be seen in the fact that major social expenditures, such as marriages, can compromise payment of cropping fees.

Agro-economic data show that returns to labor from perimeter production and onion production on parcels near the perimeter compare favorably with the average rainfed agriculture wage rate. In addition, employment opportunities spun off from the perimeter, the co-operative, onion trade, and the Galmi SIM hospital have turned Galmi into a net labor importer. Wage labor migration has been slowed. However, the fact that 46 percent of households do export labor suggests that economic inequality in Galmi remains pronounced.

At the level of the GMP, organizational issues involving canal maintenance and irrigation scheduling seem to have been worked out. While the main canal is maintained by the town youth group of "samariya," secondaries are maintained by each GMP as a whole. Tertiary canals are maintained by the 10 to 12 men who have plots along them. Each person usually maintains his own section on days chosen by the GMP president. The GMP committee composed of a president, secretary and treasurer also assure supervision of irrigation schedule and pesticide treatments, the actual distribution of responsibilities varying with the GMP. Collection of redevance payments is entrusted to the GMP president, usually chosen for his personal reliability.

Design errors in the water distribution system are penalizing some farmers in GMPs 2, 3, 15, 25 and 26. They are receiving an average of one irrigation every two weeks. Although this reduced yields considerably, no adjustment is made in their cropping fees.

Farmers now have a fairly clear conception of appropriate technical (i.e., regulating irrigation, overseeing treatments, reporting on problems) and social roles (e.g., transmission of information to and from the management committee) of the GMP heads. There is no real problem of social distance between GMP heads and farmers, although a difference in ethnicity and individual dynamism can play a role in GMP members sense of participation in perimeter affairs.

Most overt conflict appears to be related to technical flaws in perimeter design or operation. Disputes over parcel allocation have diminished with time, although some still claim they were unfairly treated. Accommodations with technicians over petty water theft seem to have been worked out. Violations of irrigation schedule occur but seem to have diminished since water is not scarce overall. However, those GMPs which have a water deficit are relatively disadvantaged insofar as the deficit affects crop choice and crop yields and there is considerable latent tension over this situation.

In contrast to the dry season campaign of 1986, perimeter technicians are far less in evidence on the perimeter. Effects of this relaxation of technical control are evident in modifications to the system undertaken by farmers. For example, sliding gates are jammed into the canal wall to increase the flow into the secondaries. Rocks are thrown into the secondaries to bring up the head. Up to 10 siphons are sometimes employed. Lack of homogenous application of technical norms to perimeter operation not only penalizes some and favors others and contributes to dissension. Requirements that certain persons who benefit from perimeter water in amounts in excess of what they receive on their parcel participate in perimeter performance such as those witnessed at Houllela.

Rigorous performance criteria are not applied to persons in authority by ordinary folk. Replacement of officials is seen as a last resort in case of infirmity or a serious act against the community interest. Social distance between cooperators and the decision-making bodies is increased by the close collaboration between agents of the government, i.e., the ONAHA agents, and the co-operative officers is one. Placing cooperative cotton marketing functions in the hands of the off-perimeter cooperative is another.

## 3.8 Training/Extension

(The Team did not obtain sufficient information
to report in this important area)

## 3.9 Equity Issues

One goal of the perimeter was to diminish social disparities. This is a patent failure, but it was unrealistic to expect that economic development would reduce disparities. The average farmer is certainly no worse off that before, but the possibilities for wealthy farmers and merchants to turn bigger profits at their expense have increased. Sharecropping and purchase of standing onion crops are one mechanism. Monopolization of co-operative structures by this group is another.

There is some evidence the poorer farmers from Guidan Roro and Zengon Anasar, of Buzu ethnicity, suffer from labor and capital constraints. Results include late and uneven planting of onion and wheat crops, parcel rentals and in-field sales of onions. Such practices are prejudicial to their welfare for farmers who engage in them can be caught in a vicious cycle of indebtedness. This was demonstrated in the 1960s by the gradual expulsion of Buzu parcel holders from the Ibohamane system through similar mechanisms.

The Team noted two types of transactions in land occurring on the perimeter with some disturbing consequences. The first is the practice of "sufari" which is a kind of parcel rental after a crop has been established. In this case the farmer works the parcel, pays the redevance, but the renter pays for the inputs and disposes of the product as he wishes. In another arrangement, onion merchants are frequently buying promising standing crops in the field in anticipation of good harvests. The former practice is linked to lack of liquidity with which to furnish agricultural inputs, which may in turn be linked to problems with the previous agricultural season or to pressing cash needs within the family. The latter is linked to the financial needs of the producer.

There are a couple of groups of unintended beneficiaries of perimeter development. The first, of course, are the off-perimeter onion producers whose available dry season onion hectarage has doubled thanks to dam seepage and irrigation losses. The other group is a number of gardeners near the perimeter who persist in stealing water from the secondaries. The perimeter technicians are unable to sanction these individuals since their limited authority only extends to legitimate parcel holders. Co-operative officers have been unwilling to intervene. One fruit orchard gardener who uses canal water (outside of the official perimeter), and who is part of the co-operative management committee has, however, been prevailed on to pay a redevance to the cooperative.

Socially marginal groups, such as those in the two Buzu villages, have not witnessed any positive change in their situation. There is a propensity to associate pre-existent social or economic standing, whether achieved in trade, religion or administration, or ascribed through association with the traditional chieftancies, with rights to authority in general. The peasant tendency both to defer to publicly, while limiting contact with, and acquiescence to, the bearers of authority persists. In interviews most farmers say leaders should not be replaced except for some grave fault.

Development of the canal system and common use of irrigation water for drinking purposes has contributed to the development of an endemic schistosomiasis infection among residents of Galmi. No public health campaign exists to educate the population about this danger or treat their symptoms.

## 4.0 Specific Constraints/Recommendations

### 4.1 Institutional and Social

Constraint: In response to lack of water, seed and labor power, some parcel holders, especially in GMPs 2, 3, 15, 25 and 26 are making technically and economically suboptimal choices about crops and cropping practices.

Recommendation: Resolve infrastructural constraints and improve input management practices through an information campaign and co-operative (inputs) and GMP (labor power) participation in resolution of these problems.

Constraint: Evidence of a certain pattern of accommodation between technicians and the co-operative bureau, supervision of irrigation has declined in quality and upstream repeat or over-irrigation is occurring, which penalize downstream parcel holders. Inter-GMP conflict is a possible outcome.

Recommendation: The technicians need to repeat the reasons for discipline in irrigation to the co-operative managers and develop an agreement to more carefully police water use for the maximum collective benefit.

Constraint: Political controls exercised over the disposition of the co-operative budget make it difficult for the co-operative to develop its potentially broad commercial and social role, and are limiting the distribution of collective social benefits.

Recommendations: 1. Provide additional training to co-operative and GMP leaders in management and insist upon regular financial disclosures.

2. Help to create a public debate about the appropriate uses of co-operative reserve funds, such as improved infrastructure, commercialization of onions or wheat, or public works.

3. Authorize the co-operative management committee to take fuller control of its funds.

Constraint: Neither encadrement nor co-operative management committee has much incentive to optimize perimeter performance. Relative harmony and prompt redevance payments are the major evaluation criteria applied to their performance. Co-operative management committee has limited control over the cropping system.

Recommendations: 1. Introduce a system of agricultural contests among the GMPs with small prizes for best output, best maintenance, quickest paid up redevances, etc.

2. Introduce a system of largely symbolic prizes for performance to be given to perimeter personnel having contributed materially to the performance of the perimeter.

3. Shift greater responsibility to the GMPs for the maintenance of their canals by shifting token budgetary responsibility to their managements committee.

Constraint: There is very little feed-back of technical information from the farm to the technical level via the co-operative structure. Little new technical advice seems to be reaching technicians.

Recommendations: 1. Request co-operative officers to circulate more regularly in the perimeter itself to assess farmers needs and problems.

2. Ask the co-operative officers to synthesize and communicate farmer needs to the technicians.

3. Encourage technicians to ask for advice from competent technical services, i.e., INRAN, GR, Extension, etc.

4. Develop research proposals directly with INRAN services.

5. Encourage more frequent and more detailed technical training sessions and demonstration parcels at the GMP level.

Constraint: Farmers do not have a detailed idea of the role and responsibilities of the comite de gestion in co-operative and perimeter affairs, but at the same time do not see they have any influence over the co-operative bureaus and co-operative funds. GMP level organization seems, however, to function quite well.

Recommendations: 1. Make the co-operative bureau aware of the situation.

2. Intensivity informational campaigns about these issues by GMP.

3. Make co-operative accounts a more frequent subject for co-operative meetings. And be sure GMP presidents understand these accounts.

4. Encourage the technicians to verify that ordinary farmers are aware of the accounts and advise GMP presidents of gaps in information transfer.

Constraint: Most onion producers are virtually excluded from the commercial circuit due to the fact they sell directly at the field level.

Recommendation: Try to develop a co-operative onion marketing plan which will protect the co-operative bureau from charges of corruption, and protect the producers from manipulation and which will ensure a greater share of benefits are passed on to producers.

Constraint: In contradiction to the stated goal of the project, economic activities associated with the perimeter and co-operative seem to be intensifying inequalities in wealth and decision-making authority through a process of actualization of latent interest group awareness.

Recommendations: 1. See recommendation for point 4.1.8.

2. Try to limit sharecropping and parcel rentals.

Constraint: Technicians are having some difficulty defining the new role assigned to them as technical consultants to, rather than managers of the co-operatives.

Recommendation: Provide managers with new farming systems diagnostic skills and develop their role in applied research.

## 4.2 Economic

Background: It is quite clear that a perimeter such as Galmi as currently structured would not be economic if Niger had to repay the investment. Even if water supply and distribution problems were solved so as to allow the entire dry season area to be placed in onions--by far the most profitable cropping enterprise at Galmi from the social point of view--the economic internal rate of return would rise to only 4.6 percent. Moreover, with such a heavy concentration on onions, prices will fall more quickly and reduce economic benefits below even these levels.

By contrast, both the traditional calabash systems and the motor pump systems yield enormous economic benefits, even allowing for well costs. The motor pump system yields returns to management equal to 33 percent of gross receipts, after allowing, for 50 percent return to invested capital and a market wage for all of the labor employed. The two-meter lift calabash system yields returns to management of 22 percent. This system is actually the preferred system, however, since it generates almost five times as much employment per hectare as the motor pumps yet yields a nearly identical incremental economic value added. This is because much of this labor would migrate to Nigeria or would work at low levels of output, except for onions.

Recommendations: It is clearly in Niger's economic interest to divert as many new investment resources as it can away from large perimeters like Galmi and toward improving and diffusing the smaller systems, until potential in areas where they are suitable is saturated. At the same time, research and extension needs to do as much as possible to make the best of what already exists at Galmi. High predictable yields of cowpeas or peanuts, following cotton in the rotation will be necessary to provide sufficient farmer income to meet even the 3 percent rate of return projection. In addition, better water distribution and management are necessary to realize that potential. It would be wise to follow closely the soil conservation efforts at Keita in order to determine whether they offer an economic way of prolonging the life of the reservoir.

### 4.3 System Design

Constraint: Canal capacity is insufficient to carry full input flow of 680 lps at 95 percent efficiency for equitable distribution throughout. Furthermore, the principal canal outlets are not sized to give equitable water supplies throughout. From a spot check outlet flows for the main canal ranged from 5.6/10.1 to 2.1/3.4 lps per hectare served by the associated secondary (and corresponding GMP).

Recommendations: 1. Rehabilitate the principal canal outlets so they deliver 2.5 lps/hectares served for the outlet. This will reduce the main canal flow from the present 680 lps without spilling at the headworks to 640 lps when serving all 25 secondaries with a flow of 2.5 lps/ha and 95 percent operating efficiency.

2. Prior to rehabilitation, the system should be calibrated and operated so that each secondary delivers the same volume of water per hectare served by it.

### 4.4 System Management and O and M

Constraint: In general, the system maintenance was fairly adequate. However, management ordered deliveries were not well done. Part of the problem resulted from inadequacy in system design as was discussed in section 4.3. However, management could have done a better job in assuring reliable and more equitable supplies throughout the system, especially in the tail reaches. During the 1985-86 season, Norman (1987) found the system to be more equitably managed than the Team found during our visit in 1987.

Recommendations: 1. The entire system should be calibrated to determine the best flows and related depths for monitoring purposes such that deliveries to the secondaries are as equitable as possible (as nearly the same number of liters per second per hectare served).

2. The canal should be periodically policed in order to stop users tampering with the main canal to increase water flows into their respective secondary canals. (The Team noted several cases where users had either blocked up the main canal to raise the water depth at their turnout or used a piece of metal in the main canal to divert more water through their outlet.)

3. After the system has been calibrated and assuming farmers do not tamper with the calibration, time allocation should be scheduled such that each turnout receives the same proportionate share of water in accordance with the land area served from it. For example, if the average flow at one turnout serving 10 hectares is 2.5 lps and another 10

hectare plot only received 2 lps then the area receiving 2.5 lps should only be allocated 8 tenths as much operating time as the one receiving 2.0 lps.

## 4.5 Cropping Program

Constraint: The cotton crop occupies too much space, time, and labor to permit planned cropping intensities to be met in the dry season.

Recommendation: Pre-irrigate cotton fields in early May. Plant before the rainy season begins and establish a more deeply rooted crop. If dam storage does not permit early planting, reduce cotton area and increase cereal area to permit a more flexible cool season cropping pattern and a higher cropping intensity.

Constraint: Delayed onion transplanting increases seedling costs, decreases onion density, and pushed the onion crop into the higher evaporative demand period of the year.

Recommendation: Co-operatives and GMP should estimate seeding demand, assist farmers to obtain seed, and program sufficient nursery planting.

Constraint: Onion prices are decreasing as production increases.

Recommendation: Co-operatives and GMPs to launch pilot garlic production.

Constraint: Cowpeas have been dropped from the rotation due to aphid infestation.

Recommendation: Co-operatives and ONAHA should request Protection des Végétaux and INRAN assistance to plan a pest control program for cowpeas.

Constraint: No available crop variety fits in the short, hot, dry season following the cotton harvest. Peanuts and cowpeas attacked by aphids. Millet and sorghum attacked by birds. Maize suffers high sterility under hot, dry, windy weather.

Recommendations: Plant protection research for the legumes. Cool season tolerance selection for sorghum and maize to permit earlier planting.

## 4.6 On-Farm Management

Constraint: Rainy season crops are planted as dryland crops with insufficient planting and supplemental irrigation to permit deeper rooting and better use of later season rain, irrigation, and fertilizer.

Recommendation: Determine end of dry season dam storage which will safely permit irrigated planting and supplementation for late May or early June planting of millet, sorghum and cotton.

Constraint: System water deliveries and frequencies favor over-irrigation of crops. However, they lead to crop stress in sectors 2 and 3, 15, and 25 and water wastage in more well-watered sectors.

Recommendation: Adopt engineering Team recommendations on days of operation and system recalibration. Greater system reliability should improve farmers' ability to improve basin leveling and depth of water application.

Constraint: Cotton plant protection practice is insufficient to prevent pest build up from crop to crop and to avoid pest transfer to the onion crop. ONAHA staff identified a coordination problem at the level of the GMP and a problem in farmer failure to purchase batteries for ULV sprayers. Cotton field cleaning is a problem, but not one easily solved.

Recommendations: 1. ONAHA and the co-operative should help GMP's program cotton praying and determine if the co-operative could prefinance battery purchases for GMP's.

2. Applied research on solar powered sprayers.

3. ONAHA and the co-operatives should negotiate and end point to the cotton crop no later than February 28, and preferably sooner. This recommendation is contingent upon early crop establishment.

Constraint: *Cyperus* weed infestation is a serious problem in the head end of the system (S1-S3) and on heavier soils throughout the perimeter.

Recommendation: ONAHA should work with INRAN to define a testing program for use of glyphosate wipers, EPTC (Eptam) at planting or preplant, and paraquat as a clean-up of sprouted nutsedge, along with trials of suppressing rotation crops.

Constraint: Aphid and other insect pest problems have caused farmers to abandon cowpeas.

Recommendation: ONAHA should solicit INRAN assistance in designing and executing a testing program for aphid and other insect pest control.

### 4.7 Research

1. Onion crop yield response to water deficits at a range of plant densities reflecting common practice.

2. Peanut and cowpea varietal testing and screening for insect pest resistance.

3. Garlic variety trials.

4. Cotton research on critical periods for pest cycle interruption, i.e., aphid host plant transfer, bollworm migration, and late season pest control.

5. Cold tolerance maize and sorghum variety screening.

6. High temperature tolerant wheat variety screening.

7. Date of planting trials for rainy season, cool dry and hot dry season crop.

8. *Cyperus* control research using chemical, crop rotation, and rust spore approaches.

9. Cotton variety testing.

10. Solar backpack ULV sprayer technology testing.

11. Corn, wheat, millet, and sorghum variety testing.

12. Fertilization trials to gauge carryover of nutrients from the onion crop to succeeding rainy season crops.

13. Test of subsoiling on rainy season crop rooting depths and yields.

# CHAPTER V

# PRIVATE IRRIGATION SMALL DUG-WELL PERIMETERS IN THE TARKA VALLEY, MADAOUA, NIGER

The Tarka Valley case is not a project in a normal sense, for it is merely a place where conditions are favorable for private dug-well development. Because of its favorable location, climate, soils and the relatively easy availability of shallow groundwater, hundreds of private entrepreneurs have invested in developing small plots of irrigable land. Typical plots are 0.1 to 0.3 ha irrigated from nearby dug-well from which water is lifted by hand or by motor-pump. Together, these small irrigated enterprises make an irrigation project that is still rapidly growing in area irrigated.

## 1.0 Project/System Description

### 1.1 Physical Features

The Tarka Valley is a wide, alluvial valley in south-central Niger draining in a southwesternly direction for several hundred kilometers before reaching the border of Nigeria. The area visited by the field Team lies between the Route Nationale and the Nigerien border, due south of Madaoua. Traditionally irrigated onion cultivation in this area is extensive, with surface area estimates on the order of 300-500 hectares. Mean annual rainfall is around 500 mm, with high variations from year to year. Mean annual temperatures are on the order of 25-30$^{o}$C.

The low-lying central portion of the valley is an ancient sandy wash overlain by 2 meters of alluvium, thus, creating near ideal conditions for low-lift irrigation gardening. Groundwater is abundant, fluctuating in depth from 1.5 to 3.5 m throughout the length of the dry season. Recharge is fairly rapid in the area.

The soils in the lowest areas are dominated by clay loams, while those soils on slightly higher ground within the same general area are largely sandy-clay loams.

Most individual onion plot sizes tend to be about a tenth of a hectare. Some plots using small motor-pumps (3.5 and 5.0 hp) are larger than this, however. In most plots water is lifted manually in the traditional manner with a calabash (a half-gourd attached to a short rope). Each plot has one or more wells, stabilized with either local wood and straw materials or concrete rings supplied through the Lutheran World Relief (LWR) Well project or low-cost commerical financing. Most traditional wells tend to have a storage depth of only 0.5 to 1.0 meters, while the less common concrete wells are found with storage depths of 1.5 to 3.0 meters. The plots are divided into small rectangular basins of 3 to 8 m$^2$, with the larger basins usually found in the motor-pump supplied plots. These basins are then fed from the wells by a series of small field channels networked across the plot. Typical elevation differences within the small basins ranged from ± 5 mm and the average depth of irrigation applications is 14 to 25 mm.

Privately owned parcels supplied from several non-lined traditional wells are being replaced by larger parcels equipped with motor-pumps, drawing water from concrete-lined wells. These modernized parcels offer substantially higher returns for labor and are likely to progressively squeeze the traditional growers out of business.

The economic balance is delicate, however, and very much dependent upon the proximity of Nigeria, with its trading advantages (on the farm of low priced motor-pump and fuel). Motor pumps procured in Nigeria with FCFA converted at very favorable black market rates and imported illegally into Niger to avoid payment of Nigerien excise duties discourage any growth of a Niger based sales and service network. Fuel purchased from the same source, and readily available at 125 FCFA/liter compared to the official price of 210 FCFA, has generated a unique, but commercially attractive, option for growth of this improved lifting technology.

It was found that a problem does exist with groundwater quality, particularly with wells penetrating to deeper depths (Table T 1.1.1). Only 2 out of 11 of the shallower traditional unlined wells which were sampled had unacceptably high salinity as measured by electricial conductivity (EC) values, while 9 out of 11 of the deeper concrete lined wells sampled indicated high EC values. The indication being a stratification of water quality in the aquifer.

## 1.2 Farm Characteristic

The Tarka Valley south and west of Madaoua lies in a zone occupied by heterogenous groups of Hausa speakers who migrated from the north and east. Peasant farm households are similar in composition to those found in Maradi, however, stronger traces of an older lineage-based form of social organization are present here, especially in the few scattered pagan villages.

Large village communities are composed of patrilineally organized household clusters. Household size tends to be larger than the norm for other Hausa areas. Household labor is nonetheless supplemented by casual wage labor on irrigated plots. The households control and form rainfed dune plots as well as extensive bottom land holdings on several types suitable for rainfed rice, recession-grown sorghum, cotton, cowpeas, and dolek, as well as vegetables. Individual irrigated plot sizes vary from about 0.1 hectares, which is what an individual seems able to comfortably irrigate with calabash lifting methods, to 5 hectares employing motorized pumps and concrete-lined wells. For the small plots the rope and calabash, which require minimal captial investment, can easily be assembled and repaired by indigenous users and is constructed from components readily available at the village markets. The lifting efficiency of the device is low; in consequence, the technology is labor intensive and yields volumes of water which severely limit the area which can be cultivated by a single farmer.

Table T 1.1.1 Well Water Quality (EC) Observations In and Around Tarka Valley (on 2-24-87)

| Sr. No. | Well Location | Type | Depth to | | EC |
|---|---|---|---|---|---|
| | | | Water Table (m) | Bottom (m) | (mmhos/cm) |
| 1 | Haji Buje Farm | Concrete | | | 2.8 |
| 2 | Haji Buje Farm | Concrete | | | 3.3 |
| 3 | Haji Buje Farm | Concrete | | | 3.3 |
| 4 | Haji Buje Farm | Concrete | 3.0 | 4.5 | 3.0 |
| 5 | Haji Buje Farm | Concrete | 3.0 | 4.5 | 3.5 |
| 6 | Adjacent to Haji Buje | Traditional | 2.0 | | 0.6 |
| 7 | Adjacent to Haji Buje | Traditiona | 2.5 | | 1.0 |
| 8 | Adjacent to Haji Buje | Traditional | 1.3 | | 1.3 |
| 9 | Near Haji Buji | Traditional | 2.2 | 3.0 | 1.0 |
| 10 | Near Haji Buje | Concrete | 2.7 | 3.7 | 1.4 |
| 11 | Near Haji Buje | Traditional | 2.5 | 3.0 | 1.0 |
| 12 | Near Haji Buje | Traditional | 3.5 | 4.4 | 0.9 |
| 13 | Near Madaoua | Traditional | 2.0 | 2.5 | 0.7 |
| 14 | Near Madaoua | Concrete | 3.0 | | 1.0 |
| 15 | Near Haji Buje | Traditional | 2.2 | 3.7 | 1.0 |
| 16 | Haji Buje | Concrete | 2.5 | 4.3 | 2.5 |
| 17 | Near Haji Buje | Traditional | 2.3 | 3.0 | 1.85 |
| 18 | Near Haji Buje | Traditional | 2.1 | 2.9 | 2.1 |
| 19 | Near Haji Buje | Traditional | 2.1 | 3.0 | 2.6 |
| 20 | Haji Buje | Concrete | 2.6 | 4.1 | 2.5 |
| 21 | Near Haji Buje | Concrete | 1.8 | 3.1 | 0.85 |
| 22 | Near Haji Buje | Traditional | 2.3 | 2.8 | 1.7 |

## 1.3 Crop Calendar

The Koumassa area of the Tarka Valley has an intricate cropping calendar and crop rotation that relies on rainfall, overland water flow, flood recession, and extracted ground water. Rainy season millet is grown on the sandy dune-derived soils flanking the Tarka Valley. Sorghum and cowpeas are grown on the silty sands and sandy loam soils intermediate to the dunes and valley. These two crops are also grown on heavier soils near the flooded zone. A ratoon crop of sorghum may be grown in these areas drawing on residual soil moisture. This area of loams and sandy clay loams also contains a number of wells used to produce rainy season onions. In the lowest part of the landscape, frequently flooded valley loams and clay loams are cropped to recessional cowpeas and lablab beans. The heavier soils are also the site of intensive dry season cropping of onions. Water is drawn from the shallow groundwater table as mentioned earlier for the irrigation water supply.

## 1.4 Irrigation System Costs

Many farmers dig two or three traditional wells at an annualized cost of around 6100 FCFA each. Their only additional cost is for a cord or rope and calabash to draw water. These do not differ from the irrigation techniques used by off-perimeter farmers at Galmi. On the other extreme, a growing number of more sophisticated and better financed farmers are installing or relying on LWR concrete (pipe) lined wells and rotating 3.5 hp motor pumps between the wells. Some of these farmers are irrigating 0.5 to 1.0 hectares of onions with a single pump rotated among 4 to 5 wells/ha. This design is approaching a technical optimum for the small pump system. The concrete-lined wells are no more expensive per hectare when installed at a 5 to 12 ratio vis-a-vis traditional wells and when financed at commercial bank interest rates. Their cost doubles, however, if financed at the opportunity cost of private capital, estimated to be around 50 percent in rural areas. This explains the tremendous expansion in concrete-lined wells in the Tarka Valley in recent years as government programs have provided low-cost financing and even partially subsidized well installation costs in order to encourage farmers to expand their irrigation activities.

Table T 1.4.1 compares installation costs for concrete-lined wells and traditional wells. Actual costs vary depending on the depth and the source of financing. After allowing for the difference in the number of wells required to irrigate one hectare of land, the annualized cost per hectare is approximately 75,000 FCFA for both concrete-lined wells financed with bank credit and for traditional wells.

Irrigation from lined wells is actually cheaper than with traditional wells where motor-pumps are used for pumping water. The smaller number of wells and much larger reservoir reduces the frequency of moving the pump and increases actual running time for a given day of work. Moreover, the larger reservoir allows farmers to run the motor-pumps at higher speeds, reducing per-hectare pump operating costs considerably. Annual pumping costs for motor-pumps, assuming low, normal and high operating speeds at 3 m head, are presented in Table T 1.4.2[1] using Niger and Nigerien market rates. The table also shows comparison of operating costs when one and two crops are taken per year. Based on the data of this table, we estimate that pump operating costs per hectare for one crop per year would decline by over 100,000 FCFA. This essentially offsets the cost of the concrete-lined wells.

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[1] Assuming that one motor pump on two concrete wells can pump for two hours more per day and at twice the speed and discharge (3.0 l/s versus 1.5 l/s) than it would from five traditional wells.

Table T 1.4.1: Installation Costs (in FCFA) for Wells in the Tarka Valley Area

| | Costs (FCFA) |
|---|---|
| I. Concrete-Lined Wells | |
| Fixed Costs Per Well: | |
| Well Technician | 5,000 to 20,000 |
| Transport of Well Digging Equipment | 500 to 1,000 |
| Depreciation Reserve for Equipment | 7,000 |
| Extra Steel for First Buse (5m @ 125 FCFA) | 625 |
| Sub-Total | 13,025 to 28,625 |
| Variable Costs Per Meter: | |
| Cement (3 sacs @ 2500) (1500 in Nigeria) | 7,500 |
| Gravel (1 cart @ 1500) | 1,500 |
| Reinforcing Rod (18 meters @ 125/m) | 2,250 |
| Digging & Mixing (2 persons @ 750/day) | 1,500 |
| Sub-Total | 12,750 |
| Annualized Costs (FCFA/ha):[1] | |
| Depreciation (10 year life) | 42,250 |
| Repairs (1000 FCFA per well) | 5,000 |
| Interest (@ 50% per year) | 105,600 |
| Sub-Total with 50% Interest | 152,850 |
| Average Cost Per Well | 30,600 |
| Interest @ 15% per year | 31,700 |
| Sub-Total with 15% Interest | 78,950 |
| Average Cost Per Well | 15,800 |
| II. Traditional Wells (3-4 meters) | |
| Labor for Digging (2 persons, one day) | 1,500 |
| Twigs & Wood Reinforcing | 2,200 |
| Filling-In (1/2 Day) | 300 |
| Sub-Total | 4,000 |
| Annualized Costs (FCFA/ha):[2] | |
| Depreciation (one year life) | 48,000 |
| Repairs (250 FCFA/well) | 3,000 |
| Interest (@ 50% per year) | 22,000 |
| Sub-Total | 73,000 |
| Average Cost Per Well | 6,080 |

Footnotes on next page

[1] Assuming 5 wells per hectare, each one 5 meters in depth, including 2 meters under water. Total investment then equals 422,500 FCFA/ha and average investment, on which interest charges are based, are one-half that.

[2] Assuming 12 wells per hectare. Smaller effective reservoir necessitates use of more wells to obtain a given quantity of water. This gives total investment of 48,000 FCFA/ha. Since this investment is entirely consumed in one year, average investment is also 43,000 FCFA/ha. And since public financing for traditional wells would not be possible, only the 50 percent interest rate is used. This 50 percent reflects the estimated opportunity cost of private capital in rural areas.

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Looking at complete systems for pumping from an average depth to water of three meters--typical of much of the Tarka Valley (Table T 1.4.3). The total costs range from 525,000 FCFA/ha for the traditional systems to 210,000 FCFA/ha for a motor-pump lined well system financed with bank credit.

At the present time, few farmers are attaining costs this low. Most seem to be running their motor-pumps at 1.25 to 1.5 lps instead of a more optimum flow rate of 3 lps because they can not handle larger volumes of water in their irrigation distribution systems. This makes their irrigation costs run around 350,000 FCFA/ha. But with a small amount of extension, and some redesign of field channels, they could easily expand the irrigated area and reach the lower cost levels. As irrigated crop production expands and onion prices decline, competition will force farmers to move in this direction.

Table T 1.4.2 Annual Pumping Costs for Motor-Pumps Assuming Low, Normal and High Operating Speeds at 3 m of Lift

| | | Operating Speed | |
|---|---|---|---|
| | Low | Normal | High |
| **Assumptions:** | | | |
| Discharge Rates (lps) | 1.25 | 3.5 | 5.0 |
| Maximum area (ha) irrigable in 9 hrs[1] | 0.40 | 1.1 | 1.6 |
| Average life of pump (hrs) | 6,000 | 4,000 | 2,800 |
| Annual pumping time (hrs) | 750 | 750 | 1,000 |
| Area Cultivated (ha) | 0.30 | 0.80 | 1.54 |
| Fuel Consumption (lph) | 0.19 | 0.42 | 0.68 |
| Pump Cost (FCFA/unit: Nigeria[2] | 90,000 | 90,000 | 90,000 |
| Niger[3] | 135,000 | 135,000 | 135,000 |
| Fuel Cost (FCFA/l): Nigeria | 125 | 125 | 125 |
| Niger | 250 | 250 | 250 |
| **Fixed Costs per Pump per year (FCFA):** | | | |
| Depreciation:[4] | | | |
| Nigeria | 11,250 | 16,875 | 32,140 |
| Niger | 16,875 | 25,310 | 48,215 |
| Interest @ 50%:[5] | | | |
| Nigeria | 22,500 | 22,500 | 22,500 |
| Niger | 33,750 | 33.750 | 33.750 |
| Sub-Total Fixed Costs (FCFA): | | | |
| Nigeria | 33,750 | 39,375 | 54,640 |
| Niger | 50,625 | 59,060 | 81,965 |
| **Variable Costs Per Season (FCFA):** | | | |
| Fuel: | | | |
| Nigeria | 17,810 | 39,375 | 85,000 |
| Niger | 35,625 | 78,750 | 170,000 |
| Oil (0.5 lit/50 hrs @ 750 FCFA/l) | 5,625 | 5,625 | 7,500 |
| Air filters (1000 FCFA/250 hrs) | 3,000 | 3,000 | 4,000 |
| Spark plugs (1000 FCFA/100 hrs) | 7,500 | 7,500 | 10,000 |
| Piston and Rings (6000 FCFA/1500 hrs) | 3,000 | 3,000 | 4,000 |
| Misc. Repairs | 2,000 | 2,000 | 2,000 |
| Labor[6] | 16,500 | 16,500 | 16,500 |
| Sub-Total Variable Cost: | | | |
| Nigeria | 55,425 | 77,000 | 129,000 |
| Niger | 73,250 | 116,375 | 214,000 |
| **Total Costs (FCFA):[7]** | | | |
| Nigeria Prices: | | | |
| One Crop per year: | | | |
| Fixed Costs | 33,750 | 39,375 | 54,640 |
| Variable Costs | 55,435 | 77,000 | 129,000 |
| Total Costs | 89,185 | 116,375 | 183,640 |
| Per Hectare of Onions | 297,300 | 145,500 | 118,500 |

Table T 1.4.2 (continued)

| Total Costs (FCFA):[7] | Operating Speed | | |
|---|---|---|---|
| | Low | Normal | High |
| Niger Prices: | | | |
| Two Crops per year: | | | |
| Fixed Costs | 22,500 | 28,125 | 43,390 |
| Variable Costs | 55,435 | 77,000 | 129,000 |
| Total Costs | 77,935 | 105,125 | 172,390 |
| Per Hectare of Onions | 259,800 | 131,400 | 111,200 |
| Niger Prices: | | | |
| One Crop per year: | | | |
| Fixed Costs | 50,625 | 59,060 | 81,965 |
| Variable Costs | 73,250 | 116,375 | 214,000 |
| Total Costs | 123,875 | 175,435 | 295,865 |
| Per Hectare of Onions | 412,900 | 219,300 | 190,900 |
| Two Crops per year: | | | |
| Fixed Costs[8] | 33,750 | 42,185 | 65,090 |
| Variable Costs | 73,250 | 116,375 | 214,000 |
| Total Costs | 107,000 | 158,560 | 279,090 |
| Per Hectare of Onions | 356,700 | 198,200 | 180,100 |

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[1] Assuming maximum crop demand of 7 mm/day and application efficiency of 70 percent. This gives a pumping requirement of 10 mm of water per day or 100 m3/ha/day.

[2] Assuming Nigerien marketing rates without import taxes.

[3] Assuming Niger marketing rates which include import taxes.

[4] Hrs pumping time/hrs pump life and cost.

[5] Pump cost/2 X 0.50.

[6] Assuming 1.5 hrs/day for 100 days @ 100 FCFA/hr.

[7] Based on 0.3 ha, 0.8 ha and 1.55 ha per motor-pump for low, normal and high operating speeds respectively.

[8] Full depreciation plus one-half of annual interest costs.

Table T 1.4.3: Annual Costs per Hectare of Onions for Traditional Well/Hand Pumping and Concrete-Lined Well/Motor Pumping Irrigation Systems in the Tarka Valley[1]

| | Costs (FCFA/ha) |
|---|---|
| I. Traditional Well/Hand Pumping Systems: | |
| Wells (12 per/ha) | 73,000 |
| Pumping Costs (1500 hrs/meter @ 100 FCFA/hr) | 450,000 |
| | ------- |
| Total | 523,000 |
| II. Concrete-Lined Well/Motor Pumping Systems | |
| A. Private Financing:[2] | |
| Wells (5 per ha) | 152,850 |
| Pumping Costs (1.25 lps, one crop)[3] | 297,300 |
| | ------- |
| Total | 450,150 |
| Pumping Costs (3.5 lps, one crop) | 145,500 |
| | ------- |
| Total | 298,350 |
| B. Bank Financing[4] | |
| Wells (5 per ha) | 78,950 |
| Pumping Costs (1.25 lps, one crop) | 281,550 |
| | ------- |
| Total | 360,500 |
| Pumping Costs (3.5 lps, one crop) | 129,750 |
| | ------- |
| Total | 208,700 |

Source: Table 1.4.1 and Table T 1.4.2 plus adjustments and other Team estimates.

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[1] Assuming only one crop per year and pumping from a depth of three meters. Land is in rice or sorghum during the rainy season.

[2] Assuming opportunity cost of private capital is 50 percent.

[3] Using local prices which are based on Nigeria rather than Niger prices.

[4] Assuming bank financing at 15 percent.

## 2.0 Operational Overview

### 2.1 Institutional and Social Structure

Dry season onion cultivation in the Tarka Valley is a case of indigenous agricultural intensification largely locally conceived and financed. Lutheran World Relief (LWR) has helped to establish five local co-operative organizations in the zone, primarily to manage a credit program for concrete pipe lined well construction. Marketing and input supply functions of these groups are weak. The sous-prefecture has also helped to establish well-fields for dry season irrigation to which individuals have access upon application to the sous-prefecture. CLUSA also has a well development program in the zone. The Agriculture Service supervises these activities and provides some fertilizer and phyto-sanitary services to farmers in the zone.

Most aspects of irrigation in the zone are in private hands. Production is carried out as a household enterprise. Well construction and pump maintenance are likewise in private hands, although the cooperatives intervene to guarantee some loans for well construction. Transport is also in private hands, but is usually not in the hands of the farmers, except in the case of one prominent Elhadji. Due to the lack of a feeder road and limited means of transport, costs of transport to the roadside market in Arewa are high (500 francs/two sacks).

### 2.2 Irrigation System

Water is lifted from depths of around 1.5 m at the outset of the dry season with water tables usually dropping to about 3 m from the surface at the end of the cycle. As well recharge rates drop with the progression of the dry season, many farmers dig an extra well or two, rotating from well to well as each is depleted, leaving time for the other to refill before returning. When motorpumps are used, they are simply carried from one well to another. Thus, the individual can keep up a fairly continuous irrigation without having to wait at intervals for his well to recharge.

Manual lifting is done by one individual in a rhythmic dip-and-lift manner producing flow rates on the order of about 0.5 lps. The small 3.5 horsepower Yamaha or Honda pumps found in the area are usually throttled down to produce an average flow rate of about 1.3 lps. In off-peak periods irrigation of the entire plot is usually done every 2 to 4 days, with the more typical 3 and 4 day cycles taking 2 days to complete one full irrigation of the plot. During peak use periods each plot is irrigated daily. Farmers are at their plots 6 to 10 hours when irrigating the entire onion crop, with about 4-6 hours of this as actual pumping time. Numbers on the higher end of these approximations apply to those lifting manually. Motor-pump types most commonly encountered are Yamaha and Honda. Yanmar also exists, particularly in the east of Niger. All of these pumps are commercially available, fueled with gasoline, kerosene or diesel (the latter two perhaps not in Nigeria), but the gasoline version is most common. Sizes and performance ratings are similar (Ref: Figure T 2.2.1 and Table No. T 2.2.1).

Table T 2.2.1 Portable Motor Pump Performance from Manufacturers Specifications for Honda 3.5 hp

Maximum Power/Total Head

| Total Head | Flow Rate with Suction Head as | | | | Hydraulic Power Developed with suction head of | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 m | 3 m | 5 m | 6 m | 0 m | 3 m | 5 m | 6 m |
| (m) | (lph) | (lph) | (lph) | (lph) | (W) | (W) | (W) | (W) |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28.5 | 6,000 | 6,000 | 6,000 | 6,000 | 466 | 466 | 466 | 466 |
| 26.5 | 12,000 | 10,500 | 10,000 | 9,000 | 867 | 758 | 722 | 650 |
| 25 | 15,500 | 13,000 | 12,500 | 11,100 | 1,056 | 886 | 852 | 756 |
| 20 | 20,000 | 17,300 | 15,900 | 13,300 | 1,090 | 843 | 867 | 725 |
| 15 | 22,700 | 19,700 | 18,000 | 15,800 | 928 | 805 | 736 | 646 |
| 10 | 24,500 | 21,800 | 19,200 | 16,800 | 668 | 594 | 523 | 458 |
| 5 | 25,800 | 23,000 | 20,500 | 17,700 | 352 | 313 | 279 | 241 |
| 0 | 27,000 | 24,000 | 21,000 | 18,000 | 0 | 0 | 0 | 0 |

2.2.1 Portable Gasoline-Powered Centrifugal Pumpsets. Performance measurements were made on four systems during the case study. These measurements consisted of flow tests over a range of engine operating speeds and the corresponding fuel consumption for two systems and flow tests at normal operating and maximum speed for two other systems. These tests are inadequate and do not permit extensive conclusions to be drawn on the performance characteristics of these pumping devices. Several important elements pertaining to performance are, however, apparent.

The pumps in service are designed to provide optimal system efficiency at approximately 22 meters (Ref. Figure T 2.2.1) total head; most are in use at 3-6 meter heads. The pumps in use operate most effectively when the suction head is minimized. Approximately 10 percent of the output is lost at 2.8 m suction, 30 percent is lost at 6 m suction and the flow ceases completely at 7.6-8.4 m depending upon the model (cf. Figure T 2.2.2).

The pumps in service operate most efficiently (at the suction heads observed) when throttled to provide an outflow of 3.5-4.0 lps. Pumps are actually throttled to provide 1.0-1.6 lps, isolated cases were observed at 2.5 lps. One example, drawing from surface water pumped at 3.4 lps,

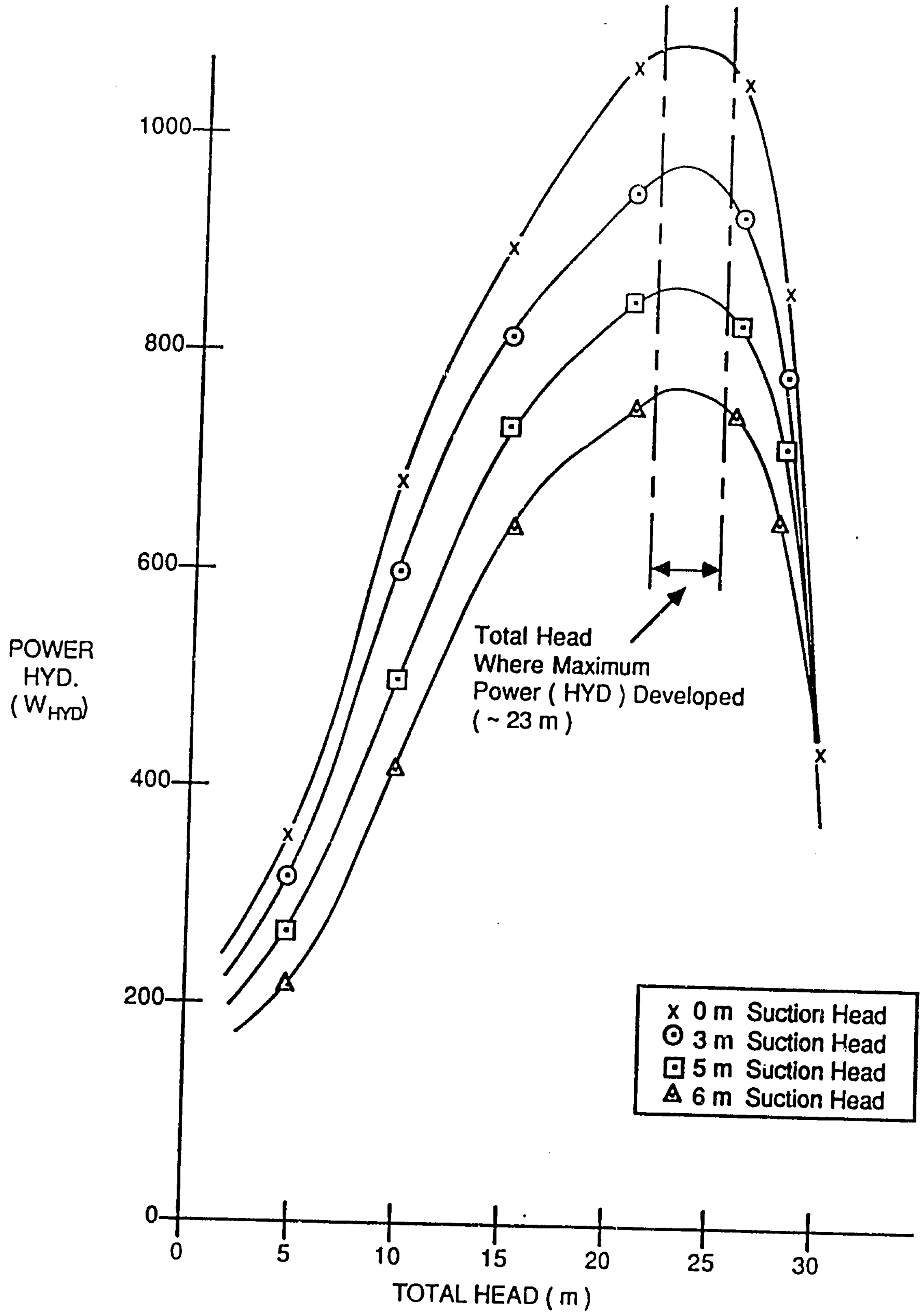

Figure T2.2.1 Maximum Power Curves - Honda 3.5 h.p.
Source: Manufactures Specifications.

the pumping system efficiency is reduced by 25 percent at the lower flow rates (Ref: Figure T 2.2.3 and Table T 2.2.2).

Pumping system efficiency is expressed as:

$$\frac{\text{Energy Output (Hydraulic energy)}}{\text{Energy Input (Energy in fuel consumed)}} \text{ X } 100\%$$

A model developed to examine the sensitivity of parameters which influence the economics of operation shows that the cost of pumping could have been reduced from 23,900 FCFA to 13,900 FCFA and from 20,500 FCFA to 8,500 FCFA per 1000 cubic meters of water pumped for the two systems examined in detail (Ref. Table T 2.2.3). These improvements could be envisioned if the present pumps were operated at optimal (speed) regimes. Further improvement would occur if pumps correctly matched to the lift were introduced.

The cost of water pumped is greater per meter of lift for low-suction based head than for higher suction heads. This phenomena is due to the pump performance profile, which shows a decrease in power output of 20.5 percent as the suction head increases from 0 to 5 m, and an increase in power output of 90 percent as the total head increases by 5 m (Ref: Table T 2.2.1). Tests performed at different suction and total heads were insufficient to quantify this phenomenon.

## 2.3 System Management

All onion cultivation and irrigation activities are done on small, individually managed plots. Thus the individual and/or his immediate family have full jurisdiction over all irrigation activities, with all management decisions made at that level.

During actual irrigation, an adult generally does the lifting with the puissette while a second person, usually a child, diverts the flow of water into individual basins by hand, or with the use of a small hoe. When a motor-pump is in use only one person is required to manage the system--primarily to divert/distribute water.

All repairs are done by the farmer/owner, usually during the course of the day as needs arise. These small maintenance efforts largely consist of fixing small breaks in the channels, reinforcing the cribbing of woven sticks traditionally used to stabilize wells, and removing collapsed sand material from the well bottom to maintain acceptable water storage depths.

Routine maintenance is also done on the motor-pumps--with small repairs usually done by the owner. For larger repairs beyond the capability of the owner, there is an enterprising local repairman in the valley area who specializes in small pump repair.

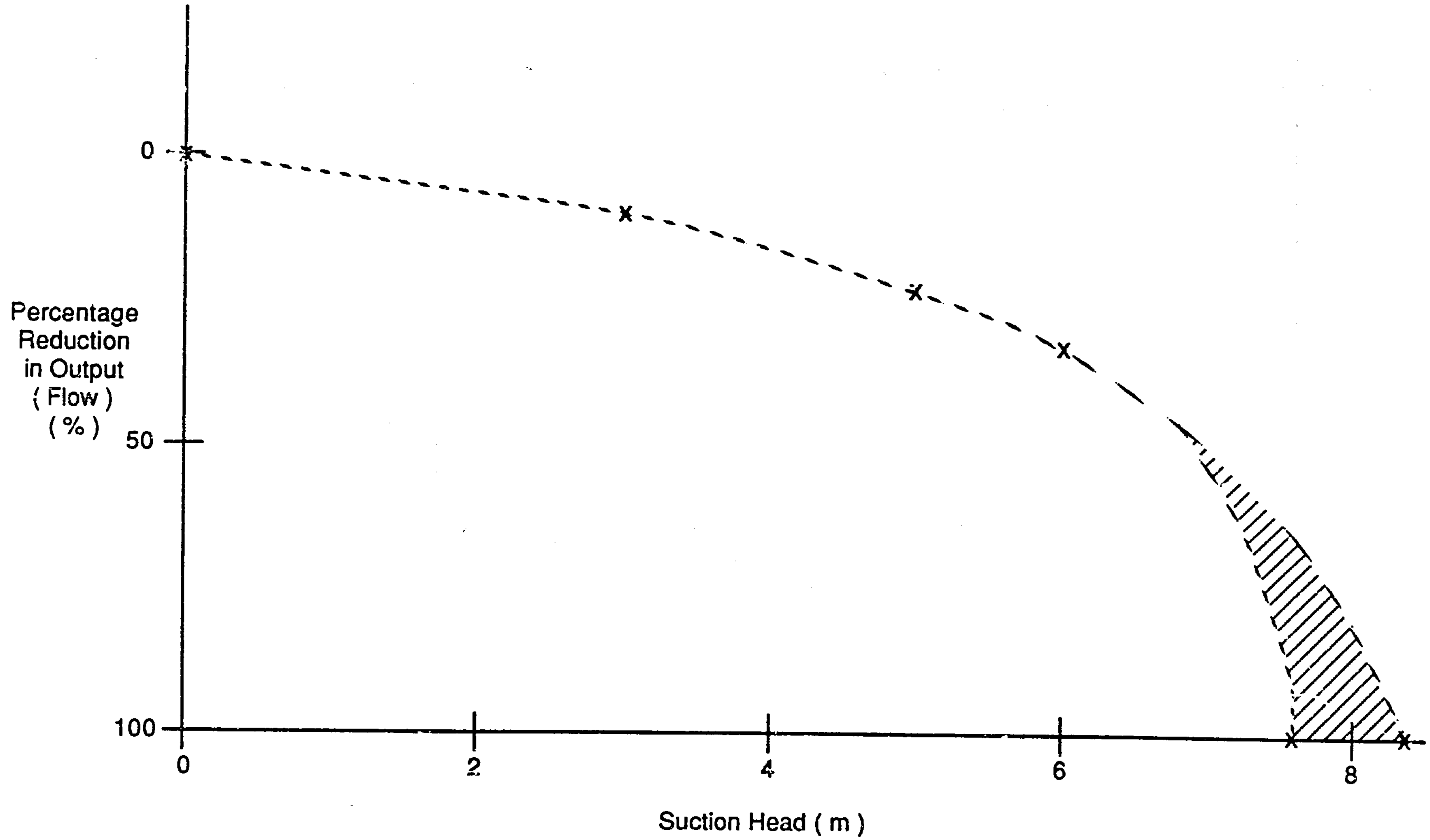

Figure T2.2.2 Typical Curve of Flow Losses as a Function of Suction Head of Portable Motor Pump ( Source: Manufacturer's Specifications).

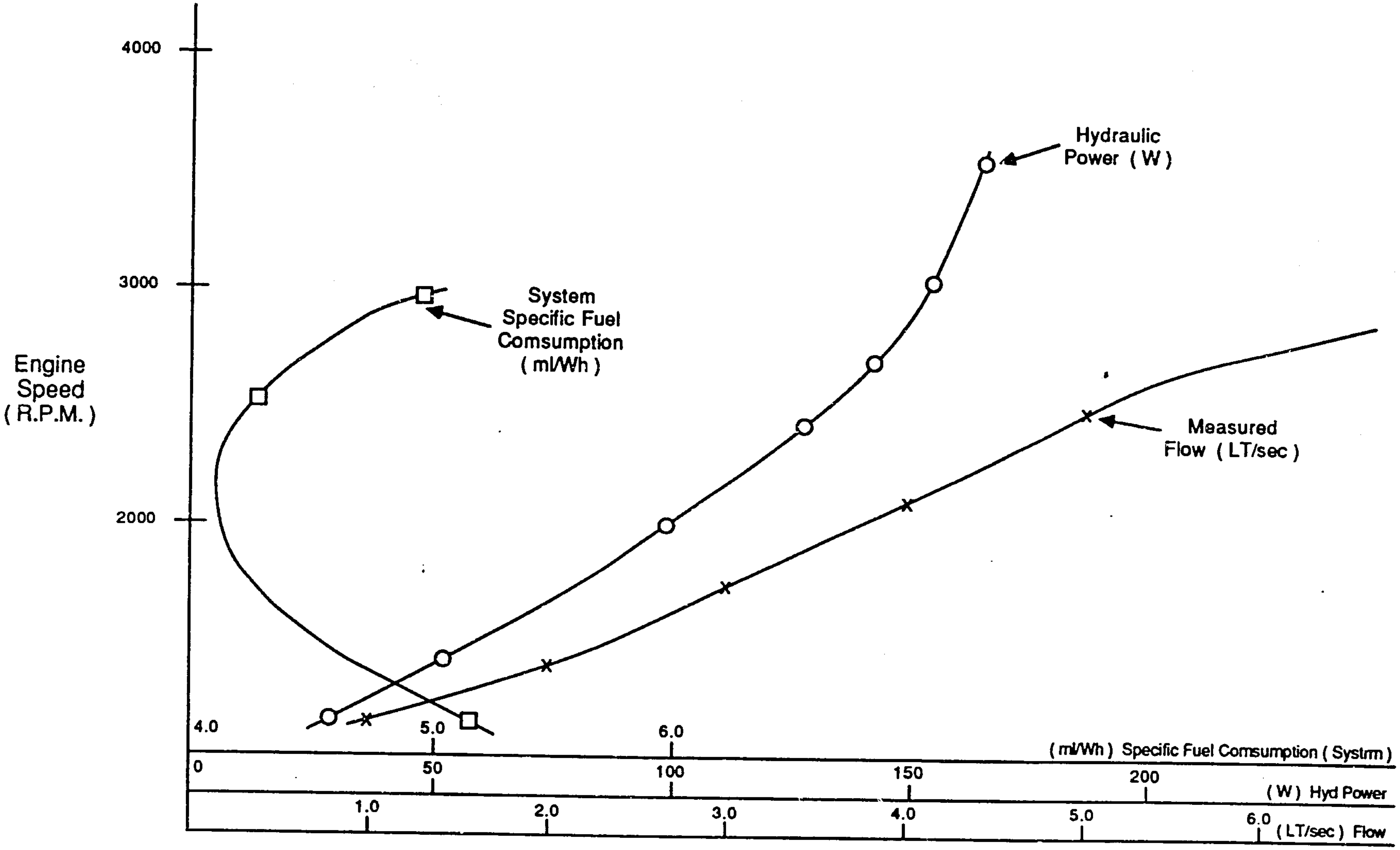

Figure T2.2.3 Performance: Honda GX110, 3.5 HP
Pump Type: ACT W20
( 1 month old ~ 200 hrs. )

Table T 2.2.2 Measured Motor Pump Performance.

System: Honda GX110, 3.5hp
Pump Type ACT W20

| RPM | Flow | Suction Head | | dicharge | Average Total | Hydraulic | Fuel | Specific Fuel |
|---|---|---|---|---|---|---|---|---|
| | (lps) | Head (m) | Factor | Head (m) | Head (m) | Power (w) | consumption (lph) | consumption (ml/w-hr) |
| 1420 | 1.05 | 2.71 | 0.9 | 0 | 3.0 | 30.8 | | |
| | | 2.69 | 0.9 | 0 | | | | |
| 1425 | 1.06 | 2.60 | 0.9 | 0 | 2.89 | 30.1 | 0.16 | 5.32 |
| 1700 | 2.02 | 2.69 | 0.9 | 0 | 3.03 | 60.1 | | |
| | | 2.77 | 0.9 | 0 | | | | |
| 2128 | 3.23 | 2.75 | 0.9 | 0 | 3.12 | 98.6 | | |
| | | 2.86 | 0.9 | 0 | | | | |
| 2400 | 3.92 | 2.82 | 0.9 | 0 | 3.21 | 123.3 | | |
| | | 2.95 | 0.9 | 0 | | | | |
| 2530 | 4.00 | 2.53 | 0.9 | 0 | 2.81 | 110.3 | 0.47 | 4.26 |
| 2950 | 4.88 | 2.55 | 0.9 | 0 | 2.83 | 135.6 | 0.65 | 4.79 |
| 2990 | 5.00 | 2.85 | 0.9 | 0 | 3.20 | 157.0 | | |
| | | 2.91 | 0.9 | 0 | | | | |
| 3580 | 6.25 | 2.5 | 0.9 | 0 | 2.84 | 174.1 | | |
| | | 2.61 | 0.9 | 0 | | | | |

System: Yamaha YP 20G, 3.5hp

| RPM | Flow (lps) | Head (m) | Factor | dicharge Head (m) | Average Total Head (m) | Hydraulic Power (w) | Fuel consumption (lph) | Specific Fuel consumption (ml/w-hr) |
|---|---|---|---|---|---|---|---|---|
| 2130 | 0.90 | 3.03 | 0.89 | 0 | 3.40 | 30.2 | | |
| 2390 | 1.43 | 3.13 | 0.89 | 0 | 3.52 | 49.4 | | |
| 2675 | 1.58 | 4.12 | 0.82 | 0 | 5.02 | 77.9 | 0.55 | 7.06 |
| 2700 | 2.13 | 3.23 | 0.88 | 0 | 3.67 | 78.6 | | |
| 2885 | 2.51 | 3.33 | 0.87 | 0 | 3.83 | 91.3 | | |
| 3080 | 2.98 | 3.48 | 0.87 | 0 | 4.00 | 117.1 | | |
| 3350 | 2.58 | 4.03 | 0.84 | 0 | 4.80 | 121.4 | | |
| 3370 | 3.71 | 3.7 | 0.87 | 0 | 4.25 | 154.9 | 0.86 | 5.55 |
| 3435 | 3.56 | 3.58 | 0.86 | 0 | 4.16 | 145.5 | | |
| 3724 | 3.92 | 3.75 | 0.85 | 0 | 4.41 | 169.4 | | |
| 4400 | 4.47 | 3.97 | 0.84 | 0 | 4.73 | 207.2 | | |

Table T 2.2.3 Cost of Analysis for Different Types of Pumping Systems.

|  | Unit | Honda 5hp 6X140 1100 lps Rt.28 m 8cm dia | Yamaha YP206 Ht.25 m 2" dia | Honda3.5hp GX110 520 lpm Ht.32 m 2" act.w20 | Honda GX110 4000 Ht.25 2in.d |
|---|---|---|---|---|---|
| COSTS PER UNIT |  |  |  |  |  |
| Fuel | FCFA/l | 125.00 | 125.00 | 125.00 | 125.00 |
| Oil | FCFA/l | 750.00 | 750.00 | 750.00 | 750.00 |
| Pump Impellor and Seals | FCFA/unit | 4500.00 | 4500.00 | 4500.00 | 4500.00 |
| Spark Plugs | FCFA/unit | 1000.00 | 1000.00 | 1000.00 | 1000.00 |
| Pistons & Rings | FCFA/set | 5000.00 | 5000.00 | 5000.00 | 5000.00 |
| Interest Rate per Year | %/100 | 0.50 | 0.50 | 0.50 | 0.50 |
| Aquisition Cost | FCFA | 150000 | 7,500.00 | 7500.00 | 150000 |
| Hours Used Per Year | hr/year | 750.00 | 1042.50 | 908.70 | 750.00 |
| FUEL CONSUMPTION |  |  |  |  |  |
| Operating: New Pump Fuel Con. | l/hr | 0.50 | 0.57 | 0.16 | 0.25 |
| Old Pump Fuel Con. (1,25X New) | l/hr | 0.63 | 0.71 | 0.20 | 0.31 |
| Average Fuel Con. | l/hr | 0.56 | 0.64 | 0.18 | 0.28 |
| Optimal Average Fuel Consump. | l/hr | 0.65 | 0.86 | 0.48 | 0.39 |
| (Flow) | lps | 2.43 | 1.58 | 1.06 | 3.40 |
| Ratio Operating/Optimal rpm |  | 0.69 | 1.11 | 0.62 | 0.50 |
| Optimal Flow | lps | 6.16 | 3.26 | 3.80 | 4.16 |
| PUMP LIFE |  |  |  |  |  |
| At Normally Operated Throttle | hrs | 4200.00 | 6405.00 | 8164.80 | 4200.0 |
| At Optimal Throttle | hrs | 3658.54 | 7087.23 | 6657.99 | 3000.0 |
| Total Flow Over Life of Pump |  |  |  |  |  |
| At Normally Opreating Throttle | 1000 $m^3$ | 36.74 | 36.43 | 31.16 | 51.4 |
| At Optimal Throttle | 1000 $m^3$ | 81.13 | 83.06 | 91.08 | 44.9 |
| LIFE OF PUMP INPUTS (OPERATING) |  |  |  |  |  |
| Fuel | l | 2362.50 | 4107.21 | 1469.66 | 1181.2 |
| Oil | l | 63.00 | 96.08 | 122.47 | 63.0 |
| Pump Impellors & Seals |  | 1.40 | 2.14 | 2.72 | 1.4 |
| Spark Plugs |  | 42.00 | 64.05 | 81.65 | 42.0 |
| Pistons & Rings | sets | 2.80 | 4.27 | 5.44 | 2.0 |
| LIFE OF PUMP INPUTS (OPTIMAL) |  |  |  |  |  |
| Fuel | l | 2362.50 | 6095.02 | 3193.84 | 1181.2 |
| Oil | l | 54.68 | 106.31 | 99.87 | 45.0 |
| Pump Impellors & Seals | units | 1.22 | 2.36 | 2.22 | 1.0 |
| Spark Plugs | units | 36.59 | 70.87 | 66.58 | 30.0 |
| Pistons & Rings | sets | 2.44 | 4.72 | 4.44 | 2.0 |
| LIFE OF PUMP COSTS (OPERATING) |  |  |  |  |  |
| Depreciation | FCFA | 150000 | 75000 | 75000 | 150000 |
| Interest | FCFA | 210000 | 115198 | 168471 | 210000 |
| Fuel | FCFA | 295313 | 513401 | 183708 | 147656 |
| Oil | FCFA | 47250 | 72056 | 91854 | 47250 |
| Impellrs/Spark Plugs & Misc. | FCFA | 48300 | 73658 | 93895 | 48300 |
| Piston & Rings | FCFA | 14000 | 21350 | 27215 | 14000 |
| Life of Pump Cost (Operating) Total | FCFA | 764863 | 870662 | 640145 | 617206 |
| LIFE OF PUMP COSTS (OPTIMAL) |  |  |  |  |  |
| Depreciation | FCFA | 150000 | 75000 | 75000 | 150000 |
| Interest | FCFA | 137195 | 132806 | 124837 | 112500 |
| Fuel | FCFA | 295313 | 761877 | 399230 | 147656 |
| Oil | FCFA | 41159 | 79731 | 74902 | 33750 |
| Impellors/Spark Plugs & Misc. | FCFA | 42073 | 81503 | 76767 | 34500 |
| Piston & Rings | FCFA | 12195 | 23624 | 22193 | 10000 |
| Life of Pump Cost (Optimal) Total | FCFA | 677934 | 1154621 | 772730 | 488406 |
| AVERAGE COST PER 1000 $m^3$ DISCHARGE |  |  |  |  |  |
| NormalOperating Condition | FCFA | 20817.34 | 23898.52 | 20545.85 | 12006.04 |
| Optimal Condition | FCFA | 8355.97 | 12901.33 | 8483.95 | 10876.09 |
| AVERAGE COST (1000 $m^3$)/m LIFT |  |  |  |  |  |
| Normal Operating Condition | FCFA/m | 2618.90 | 5637.92 | 6788.12 | 4197.91 |
| Optimal Position | FCFA/m | 1051.21 | 3279.47 | 2803.00 | 3002.83 |

## 2.4 On-Farm Irrigation and Crop Management

The irrigated plots are laid out with small leveled basins measuring 2 to 4 m on a side. A network of small channels is constructed to serve each plot by gravity flow with water lifted from a nearby well. The flowing water is rotated around and allowed to fill each basin to a depth of 50 to 100 mm before being diverted to the next basin. This is the typical system for irrigating onions throughout Niger.

2.4.1 On-Farm Water Management. On manual lift plots typical depths applied in the basins during each irrigation are on the order of 30 to 50 mm, while those with motor-pumps in use usually apply depths on the order of 40 to 80 mm. Timing of basin opening and closing is solely dependent on the judgment of the individual diverting water in the plot.

Table T 2.4.1 shows estimated irrigation requirement for dry season and Figures T 2.4.1 and T 2.4.2 present irrigation water applications to the field and estimated crop evapotranspiration (ETe). ETe is estimated from pan evaporation data collected by Norman in 1984-85 along with application of a pan coefficient which was found to correspond closely with Charoy's longer-term regressions of pan evaporation and lysimeter measurements of reference crop evapotranspiration (ETo) and standard crop coefficients. Conductivity measurements showed water quality ranging from 1.0 mmho/cm to 3.5 mmho/cm. Salinity hazard ranges from medium-high to high. Farmers with the more saline waters must apply a leaching factor to the dry season onion crop to avoid substantial yield losses.

Irrigation data were collected directly in the field by Norman in 1984-85 and verified by the study Team in February 1987. Soil samples are being analyzed by the INRAN soils laboratory to determine soil water conductivity and salt balance but are not available yet.

The onion crop is grown in small basins with groundwater extracted by hand drawn calabashes or small gasoline powered pumpsets. The pumpsets are usually put on the deeper saltier wells. Irrigation practices between the two cases is very different as seen from Figures T 2.4.1 and T 2.4.2. Hand lifting, using higher quality water, moves from moderate leaching to early stressing (after transplanted onions have reestablished) to substantial leaching of salts during the period of maximum bulb growth.

Motorized pumping, using saltier water, requires relatively constant leaching of salts to avoid drastic yield reductions. At peak ET demand, the highest leaching factor is applied.

2.4.2 Crop Management. Onions of the Galmi type are grown in the Tarka Valley area. Local farmers claim that they cultivated onions long before growers in Galmi did. They also claim to have selected subtypes of the Galmi onion for their rainy and dry season production.

Table T 2.4.1 Estimated Net Irrigation Requirement in Tarka Valley.

| | NOV | DEC | JAN | FEB | MAR | TOTAL |
|---|---|---|---|---|---|---|
| Reference Crop Eto (mm/d)+ | 7.9 | 6.1 | 5.7 | 5.7 | 6.8 | |
| ONIONS - CALABASH CASE | | | | | | |
| Stage Duration (days) | | 20/5 | 31 | 28 | 26 | |
| Kc | | .4/.7 | .7 | 1.0 | .8 | |
| Etc (mm) | | 70 | 124 | 160 | 141 | 495 |
| Leaching Requirement (mm) | | 18 | 31 | 40 | 44 | 133 |
| Preirrigation (mm) | | 30 | | | | 30 |
| NET IRRIGATION REQUIRED (mm) | | 88 | 155 | 200 | 185 | 657 |
| ONIONS - MOTOR PUMP CASE | | | | | | |
| Stage Duration (days) | | 20/8 | 31 | 28 | 30 | |
| Kc | | .4/.7 | .7 | 1. | 0 | .8 |
| Etc (mm) | | 83 | 124 | 15 | 163 | 530 |
| Leaching Requirement (mm) | | 66 | 99 | 127 | 131 | 424 |
| Preirrigation (mm) | 30 | | | | | 30 |
| NET IRRIGATION REQUIRED (mm) | 30 | 149 | 222 | 387 | 294 | 983 |

+From Norman (Epan X 0.8)

Seeds are generally produced by each farmer, although seed and seedling exchange are frequent. Selection is for large, vigorous flowers and seeds. Plant density is high, ranging from 621,000 to 775,000 plants per hectare. The higher densities were found on larger scale operations.

Tarka Valley area farmers manage their onion crop to try to reach markets at favorable price periods. Many farmers transplant thier onions in late February, planning to hit the market after the peak production period. Because onions are cultivated year-round, a greater degree of staggering of nursery planting and transplanting takes place than is seen in Galmi.

Farmers apply substantial amounts of fertilizer and regularly treat their onion crops with dimethoate for thrip protection. A major problem is the weed challenge to the crop. Cyperus and Portulaca both require substantial labor inputs. When nutsedge becomes a severe problem farmers will rotate onion land to a recessional lablab (Dolichos) bean crop during the dry season.

Many farmers attempt to store onions. Village stores permit some to maintain onions for four to five months, although losses run up to 20 percent.

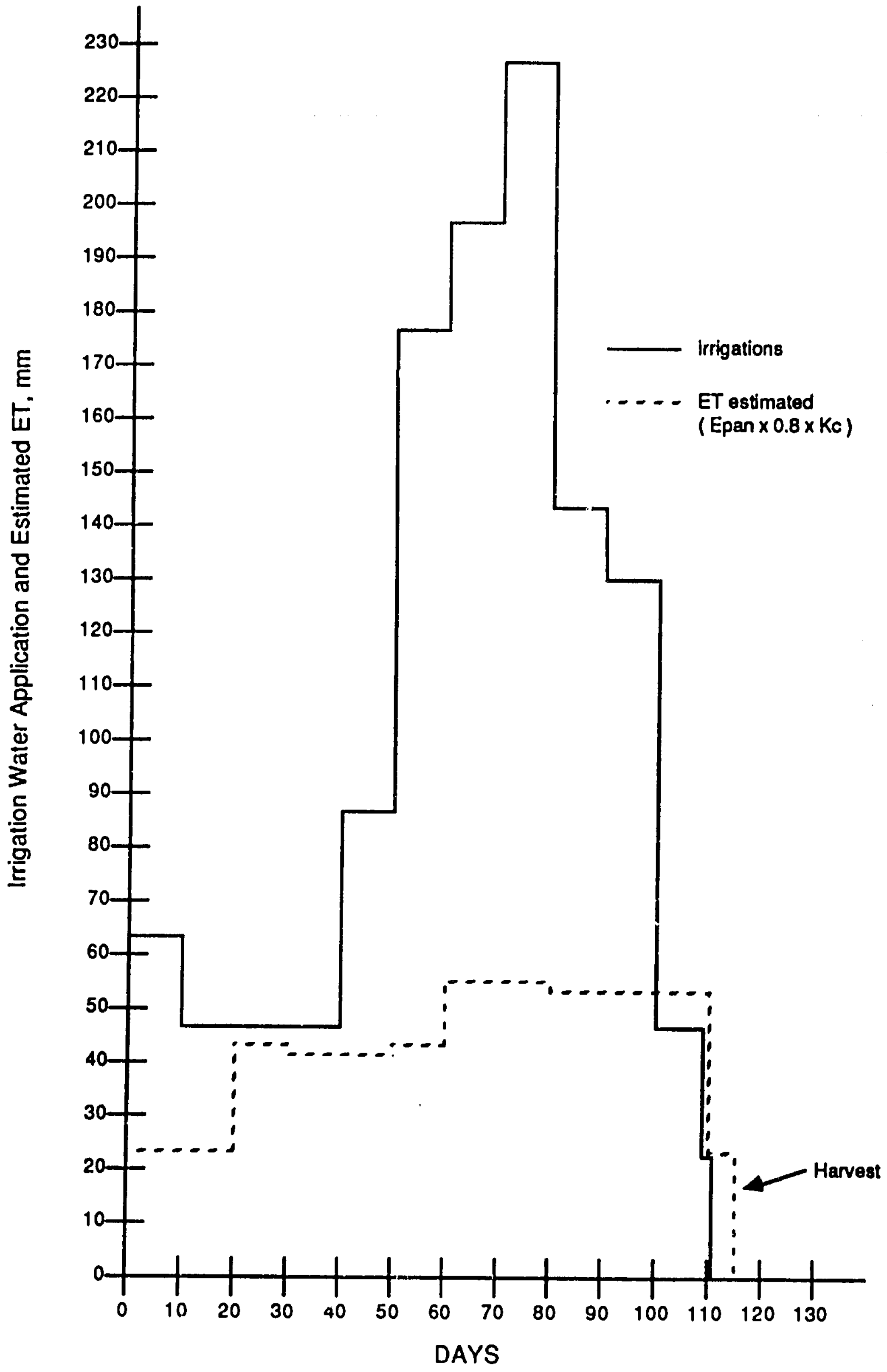

Figure T2.4.1 Koumasa Calabash Onion Production.
( Y = 37.4 T/ha, EC = 3.0 milliohms )

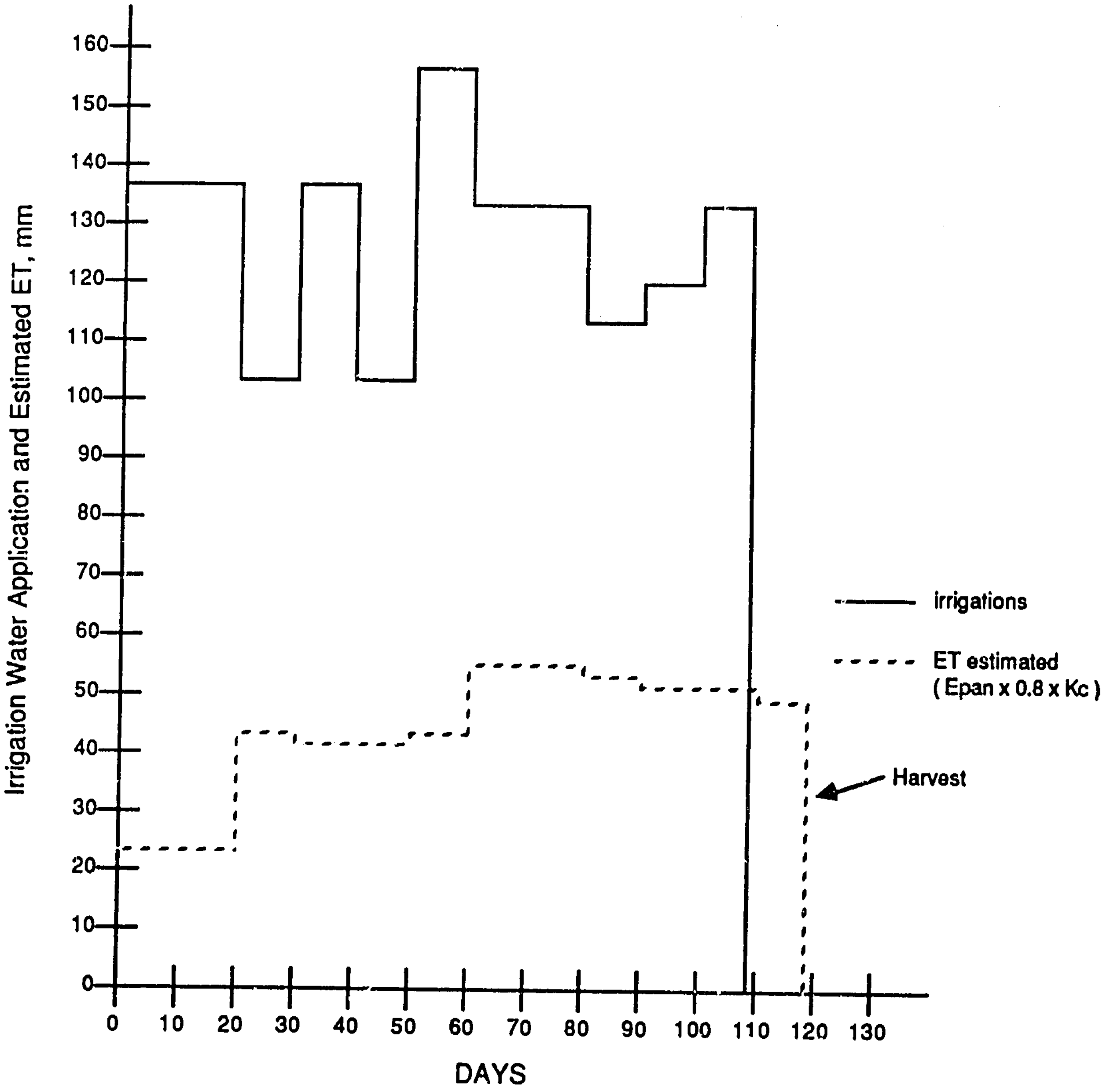

Figure T2.4.2 Koumasa Motor-Pump Onion Production.
( Y = 37.4 T/ha, EC = 3.0 milliohms )

## 2.5 Training and Extension

LWR and the Agriculture Service have provided long-term support to co-operative development and well construction technology transfer. Some rudiments of co-operative marketing of cotton have also been disseminated. In general, the Agriculture Service admits that local farmers know as much about onion cultivation and marketing as they do and that they have nothing much to teach them in this domain. Some tentative steps towards developing improved onion storage have been made by outside agencies, and it is possible that a new FED-sponsored project may provide training and extension services in this and other areas.

## 2.6 Cost of Operation and Maintenance

The cost of operating motor pumps is detailed in Table T 1.4.2. These are essentially the same for Galmi and Madaoua/Tarka Valley farmers since both lie on the Nigerien border. These range from 300,000 FCFA/ha at low operating speeds (and discharges) to 120,000 FCFA/ha for optimum speeds for one crop. Maintenance costs on the wells are minimal and are already included in annualized well costs.

# 3.0 Evaluation of Performance

## 3.1 Irrigation System Operation

On-farm water management practices are good. Relatively careful application of water permits good yields to be maintained over time. However, water application efficiencies may be fine-tuned to better meet crop water requirements once the seasonal progression of soil and water salinity status is better understood.

From data collected by Norman (1987) during his fieldwork in 1985-86, a monthly water use budget was developed for both a manual lift and a motor-pump system for the dry season cycle. The results in Table T 3.1.1 indicate that the farmers are able to meet crop water demands at reasonably high overall irrigation efficiencies on the order of 45-60 percent. Management and scheduling efficiencies can be expectedly high due to the "micro" nature of the physical system, the low incidence of soil heterogeneity within such a small area, and the single user/manager aspect of the system.

Table T 3.1.1 Irrigation Application, 1985-86 for Onions in the Tarka Valley.

| | | Pre-irrig (mm) | Months Dec (mm) | Jan (mm) | Feb (mm) | Mar (mm) | Seasonal Total (mm) | Seepage Loss % | Planting Date | Harvest Date | Yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Manual Lifting | ET & Lch. | 30 | 88 | 155 | 200 | 186 | 658 | | | | |
| | IRRIG | | 158 | 298 | 706 | 298 | 1459 | 18 | 12/7 | 3/21 | 32.5 |
| | % EFF | | 75 | 52 | 28 | 62 | 45 | | | | |
| Motor Pump | ET & Lch. | 30 | 149 | 222 | 287 | 294 | 982 | | | | |
| | IRRIG | | 423 | 423 | 429 | 356 | 1632 | 10 | 12/4 | 3/22 | 37.4 |
| | % EFF | | 42 | 52 | 67 | 82 | 60 | | | | |

(Source: Norman, 1987)

Leaching requirements seem adequately met in both systems, if not overly compensated for. Salinity levels for the manual system were assumed and thus could have been under-estimated, resulting in the comparatively lower application efficiency for that system. Another explanation is that as the water table dropped during the season, water quality might have significantly decreased, as well, requiring the increase in over-irrigation (leaching) indicated in the latter months of the cycle.

Seepage losses in the distribution channels between the wells and the basins were found to be on the order of 18 percent for the manual systems and around 10 percent for the motor-pump systems operating at higher flow rates.

Of the existing traditional lifting technologies, that used by the manual lift operators seems the best adapted to the local setting, because, water tables are too high to justify shadouf or animal traction units such as the dallou. The motor-pumps used in the area are throttled down well below optimum energy use levels, and the pumps themselves are poorly matched to the head conditions under which they operate in the valley area. But, this latter point is simply a result of what is available on the local market. As to the former point, it is probably linked to several interrelated constraints. If the pumps were run at optimum flow rates (so as to obtain maximum returns to fuel consumption), well storage volumes would be depleted rapidly, requiring excessive starting and stoppage--as well as much more frequent moving around from well to well. In addition, increased flow rates would require more labor to manage field water distribution (i.e., the single child in the plot would not be capable of adequately diverting such volumes). Thus, application efficiencies could drop if flow rates were increased.

Wells stabilized in the local manner (with sticks for cribbing) tend to have limitations as to available storage depths and usually have to be reinforced several times during the course of the season as the water table drops and the sides of the well interior collapse. These wells must also be re-dug each season. The concrete lined wells, though a much costlier investment, maintain a better storage volume and are virtually maintenance free. As mentioned, recharge does not appear to be a problem of any significant dimension, although the rate may drop as the season progresses. This is, of course, highly dependent on the amount and timing of the rainfall during the preceding wet season. When rates do drop in the course of the season, the individual farmer is capable of handling up to 3 separate wells to irrigate his plot.

## 3.2 System Management

Very young people can manage the flow rates used in these small systems. Because they are laid out in a systematic way, water distribution can be mastered by 5-7 year-olds, as was evident in the field.

Farmers are familiar enough with their systems to be able to adequately meet the necessary leaching requirements--if not overly compensated for them. Farmers have the choice of pumping the added leaching requirement at the cost of added labor (or fuel) or irrigating only to meet ET requirements and taking the loss in yields due to salinity. It appeared that some farmers tend to compromise somewhere between the two.

Since farmers are the individual owners/operators of their systems, closer control and monitoring of their plots results in a much better ability to meet the day-to-day demands of their crop than would be found in the larger developed perimeters. The ability to more closely follow the crop water demand curve is demonstrated with the traditional systems

(Table T 3.1.1) as compared to Djirataoua (Table D 2.6.1, Djirataoua Section) or Galmi (Table G 2.2.1, Galmi Section).

Routine maintenance and repair in the small systems seems to be carried out well by the farmer. The singular exception would be that of major repairs for motor-pumps. The technical assistance for such is available in the area, but the time lag and costs involved in obtaining parts from Nigeria can cause serious setbacks.

From what was observed in the field, the farmers' sense of ownership and control of their plot results in systems that appear well maintained and managed.

## 3.3 On-Farm Irrigation and Crop Management

As mentioned in Section 3.1, application efficiencies seem reasonably good, while losses are within the limits of what would be expected for small unlined canals on such soils as exist in the area. Basin leveling, which is done by hand, is quite good which is in part due to the small basins. The uniformity of basin inundation timing is also quite good, even in the hands of the small children who usually carry this responsibility. Adaptation of basin size and canal capacities to exploitable pumping rates and the associated delivery techniques has evidently been highly refined over a long period of time, and thus, results in the high on-farm irrigation efficiencies.

Weed control, harvesting and storage are three potential areas where improvements can be made. As elsewhere in Niger, substantial labor is involved in controlling Cyperus. More effective chemical or rotational practice is needed in some areas of the valley.

The practice of cutting leaves close to the bulb at harvest does not favor good dry down of the neck of the onion. The open top favors higher respiration and weight loss and development of molds and rots during rainy season storage.

Village stores are of low capacity. Ventilation and temperature insulation appear to be problems. Studies have been done on storage losses. The key constraint appears to be the cost of improving the structures. Cost will become an increasing constraint to improved storage as surface area grows and prices decline, making individual investment in onion storage less financially attractive.

Crop alternatives are needed to respond to the declining markets for onions. Competition is growing in the Galmi area and in Nigeria. Tarka Valley is relatively isolated and transport to the road expensive. Garlic is one alternative that fits current cropping practice. Farmers also want to try sesame. Expansion of hot pepper production should also be considered.

### 3.4 Irrigated Agricultural Productivity

Irrigated farms utilizing handlifting provides an average onion yield of about 32.5 t/ha. The more input intensive motorized pumping yields over 37 t/ha despite having higher salinity irrigation water. Given the high density of planting and the good growing practices usually the farmers, these figures reflect from a 19 percent to about a 10 percent yield reduction respectively compared to a practical potential yield of about 40 t/ha. Thus, additional soil and water management study is needed to determine if current leaching factors are optimal.

### 3.5 Irrigation System Economics

Table T 1.4.2 clearly demonstrates that the hand-lifting cannot compete on an equal basis with the motor-pumping systems over the long run. With total costs running two to two and one-half times more than for motor-pumping, survival of the hand-lifting systems is tied directly to the production of high-return crops such as onions. As production expands and prices decline, these cost differences will eventually drive the hand-lifting systems out of business or will reduce their return to labor well below levels obtainable from other pursuits. The only event likely to forestall such an outcome would be substantial expansion of the market for onions, possibly by installing an onion processing/drying operation that could turn a profit while paying farmers prices not too far from current levels. Whether this is possible is a question that requires further study.

The minimum cost of a motor-pump system drawing water from shallow wells is not likely to fall much below 200,000 FCFA/ha on a wide-scale for production of one crop per year. This figure, then, represents the ultimate constraint on expansion of this system. But unlike the large irrigated perimeters, it is a full, unsubsidized cost, including amortization of capital as well as operating expenses.

What kinds of crops with what yields can cover these costs, in addition to other production costs? Sorghum probably could if yields could be pushed to three tons per hectare and the price rose to 100,000 FCFA/ton. Neither of these events are out of reach. A reasonably diligent application of existing knowledge would push irrigated sorghum yields to three tons. One year of bad rains would push sorghum prices in rural areas back to 100,000 FCFA. Thus, the system itself has potential for producing traditional crops economically.

### 3.6 On-Farm Economics

With the small-scale irrigation systems, on-farm and system economics converge. It is the on-farm production system that capitalizes the value of the irrigation system.

At the present time in the Tarka Valley, irrigation farmers still produce mostly onions. Their input/output relationships appear to be quite similar to farmers at Galmi, with the exception that they time their planting so as to obtain higher prices at harvest time. In addition, some farmers are forced to "over-irrigate" in order to limit the accumulation of salts in the root zone. This increases their operating costs on the order of 20 percent or so. But at present pumping depths and prices for onions, Table G 3.6.7 suggests that returns to labor are still well in excess of alternative employment opportunities. They average over 1000 FCFA per day for a motor-pump system obtaining 38 tons per hectare and 590 FCFA per day for the hand lifting/traditional systems obtaining the same yields. In fact, the traditional systems appear to be located in areas where salt accumulation is less of a problem and, consequently, yields and returns to labor may be considerably higher. There is little doubt that Niger would benefit considerably from continued expansion of these small-scale systems.

At the farm level, farmers off the perimeter who have motor-pumps will probably be better off by not expanding the area irrigated by each pump beyond 0.8 hectares per pump. Above this size, channel losses will become quite high. The cost savings per hectare to reduce pumping costs to a minimum will not be sufficient to cover the cost of lining the distribution canals, even with two crops per season, unless costs are less than 1500 FCFA per meter. Farmers are more likely to be able to handle a 3.5 lps rate of flow by building larger field channels and doubling or tripling the labor allocated to distributing water from a single pump.

The economic attractiveness of the calabash system at two meters of ift suggests that research on improved hand and animal pumping systems at increased rates of flow and shallow depths could have a very high social and economic payoff. Such research should have high priority under the NAARP.

## 3.7 Farm Enterprise and Institutional Performance

A tendency toward agricultural intensification has been in evidence for twenty-five years. Between 1977 and 1985 the area around Tarka Valley devoted to onions increased by 40 percent, and we estimate the number of irrigated plot holders doubled to around 400. In consequence, a market for labor exists, agricultural mechanization has become established, and a limited local market for land exists, mainly taking the form of rental arrangements.

More than anything else, favorable agricultural conditions have led to the growth of large population concentrations in the valley. There appears, however, to be no shortage of agricultural land. Extended family household organization prevails, but the opportunities offered for profitable cash crop production have led towards several new forms of production organization.

One extreme represented by a well-known Elhadji (Haji Buje) in Koumassa constitutes a commercial farm enterprise, organized through a traditional patron-client relationship. Haji Buje has attracted a number of clients to his household who act as farm managers for him. These men supervise rainfed cereals production, purchase inputs in Nigeria, transport onions to the transhipment point at Arewa, and oversee operations carried out by work gangs of 5 to 10 men in the onion fields.

In this system, workers are paid by the season of which there are three: at least two onion seasons (October/September--December/January; January/February--April/May) and a rainy season. Junior workers entrusted only to water and weed are paid between 25,000 and 30,000 FCFA francs per season. More senior workers who apply fertilizer and oversee motorized pump irrigation receive from 30,000 to 40,000, while the most senior overseers receive up to 50,000 FCFA per season. All are well-fed. Obligations between patron and client nominally are wiped clean at the end of the season. Long-term relationships may be built up through this mechanism leading to extension of the farm. Enterprises are fragile, however, and usually do not extend beyond the life of the original entrepreneur.

A second type of development in farm organization is a tendency towards increasing fragmentation of production units, especially during the dry season onion campaigns. Younger and younger men are working their own small (0.1 ha) onion plots. Sometimes older men are left only with very young children to help them open and close the irrigation basins. Young men may work alone, painstakingly drawing water and opening and closing their own basins, or they may work with a younger sibling. The latter type of farm enterprise is undercapitalized, i.e., fewer and smaller quantities of inputs are applied. Seeds are the minimal input. Even a small plot may require expenditure of 24,000 FCFA for seed. If successful, in later years urea is likely to be applied to the parcel. Finally, farmers may begin to apply pesticides as their enterprise matures.

Most farm enterprises employ some casual wage labor especially in onion production. Wage labor is employed for land preparation and transplanting. Both wage labor and reciprocal labor exchange, called "gayya," are employed in harvesting. During peak demand there can be labor shortages. In fact, "gayya" employed in harvesting is a response to the limited pool of skilled laborers who can quickly harvest onion bulbs without scarring them. Scars must be avoided if onions are to be stored with any degree of success. Less expensive, casual wage labor can be used to cut onion tops, and children are often used for this purpose.

Co-operative structures in the valley are relatively weakly developed. While commercial co-operatives exist to market recession agriculture cotton, villages devoted to onion cultivation have benefited little from cooperative credit, input or marketing programs. The "co-operative" in Tarka Valley basically consists of a prominent commercial farmer's private initiatives in the area of input supply. He buys inputs in Nigeria for resale in the Valley and allows his assistants to make commission purchases in Nigeria. Five co-operatives promoted by LWR in the area remain weakly developed institutionally. Leaders are reticent to commit rolling funds to social enterprises, and loan repayments continue to circulate through the leaderships' hands often detouring through private loans before making it to the bank.

### 3.8 Training and Extension

Extension service activities are limited, but farmers have benefitted from the vigorous concrete-lined well development program initiated by LWR, extended by the sous-prefecture, and now almost entirely in private hands. Farmers recognize the need for help with crop diversification and pump maintenance. However, most inputs, including small pumps, pump parts and private technical help, come from Nigerien sources.

### 3.9 Equity Issues

The locally initiated development of the Tarka Valley has resulted in an accentuation in differences in wealth between early innovators and late followers in the movement towards dry season onion production. Early innovators have recently managed to extend control over upstream and downstream market channels and when land resources become limiting they will no doubt also control land development.

Farmers deny that access to land or water is a problem. Virtually anyone can try their hand at onion cultivation. With increased agricultural intensification, access to good land and less saline water may become more problematic. In this eventuality, the first to suffer will be those outsiders who migrate into the valley in the dry season to cultivate onions on borrowed plots.

Intensive onion production provides a source of local, dry season employment and acts to reduce labor out-migration.

Competition of a familiar western variety is inspiring farmers to seek improvements in productivity through technical innovations, e.g., differential wage rates for skilled and unskilled labor. Inefficient producers, especially young ones with less access to cash and other inputs, will no doubt be squeezed out of independent commercial production. This will be accelerated by rapid introduction of motor-pumps.

The weakness of local Nigerien circuits for input delivery implies that a significant outflow of capital to Nigeria occurs through purchases of inputs of machinery and fertilizers.

Lack of roads and market access allows a number of intermediary market actors to skim profits to the disadvantage of producers.

## 4.0 Specific Constraints/Recommendations

### 4.1. Institutional and Social

Constraint: There is a lack of extension activity in the areas of crop diversification, conservation, transformation, and storage aspects of irrigated crop production, in which farmers have nevertheless expressed an interest.

Recommendations: 1. Develop an extension and technology transfer program through a program of on-farm diagnostic assessments and intensive mechanic retraining programs with NGO support.

2. Conduct market research to determine local, regional and international markets for alternative crops produced in the Valley.

Constraint: There is a weakness of co-operative local involvement in onion marketing in contrast to the Galmi area.

Recommendation: Develop a feeder road system to the sites of production and help organize co-operative local marketing and storage facilities.

Constraint: There is economic and social dependence of farmers upon a few well-connected men for agricultural inputs and technical service from tenuous Nigerien sources.

Recommendation: Develop an extension and technology transfer program through a program of on-farm diagnostic assessments and intensive mechanic retraining programs with NGO support.

### 4.2 Economic

Constraint: Due to expanded irrigated areas, onion production is increasing causing prices to weaken (fall).

Recommendations: 1. Researchers need to begin now examining the economics of producing a multitude of mass consumed crops under small scale irrigation systems. The current high price for onions gives them a few years to build a knowledge base. By the time onion prices fall to unattractive levels, they should have production packages for other high valued crops, or even for sorghum, peanuts, and cowpeas, ready to replace onions.

2. In the meantime, government efforts to encourage expansion of motor-pumps and concrete-lined wells should continue. Credit for well construction is an excellent way of doing this. Concrete-lined wells are durable and cannot be carried to market for sale when a farmer gets strapped for cash. The wells represent about half of total production costs under current practices, so bank financing would make a significant difference in the adoption rate. At the same time, construction of

concrete-lined wells generates mostly local employment and represents an easily assimilated technology. With bank financing for the wells, many farmers would find money elsewhere to finance the pump and its operation during the first season. From then on they could continue on the basis of the cash flow generated by the investment.

Constraint: At the farm level there is a clear need for a stronger extension program aimed at teaching farmers how to operate their irrigation systems at maximum efficiency. We found farmers hungry for assistance.

Recommendation: A few well placed and well done demonstration plots in the Tarka Valley could make a significant improvement in water application efficiency for the motor-pump systems. Apart from that (and with time, even without that) the private sector can and will move these systems to a higher level of efficiency as they adapt cropping patterns to market opportunities. In the short-run, the thrust will continue on onions. But as onion prices fall, attention will shift to alternatives. This is the point at which the Tarka Valley will enter the take-off in an agricultural revolution that will be limited only by ground water supplies.

### 4.3 System Design

Constraint: The systems based on traditional wells and hand lifting have been optimized by the users for generations. However, systems with concrete-lined wells and motor-pumps have not been optimized by indigenous users as they are new. Two basic problems cause higher than necessary irrigation costs from the plots utilizing motor-pumps. First, the distribution channels and basin sizes being used are not well adapted to the higher flow rates from motor-pumping compared to hand lifting. Secondly, the pump discharges tend to be too large as compared to well recharge and storage capacities.

Recommendations: 1. Intermediate techniques and technologies between hand and motor-pump lifting should be studied and tried in the field.

2. Strategies for rotating motor-pumps around several lined wells should be developed in order to utilize more optimally the available motor-pumps. (This is necessary because it is probably not practical to obtain units which are properly sized for one well.)

3. New techniques for conveying and applying water to the plots should be studied and tried in the field. Such things as small lined channels or pipes to convey the water and optimum size basins for spreading it should be investigated.

Constraint: The number of 3.5-5.0 hp portable motor-pumpsets used for onion production is increasing yearly. The growth rate observed in the Tarka Valley and close to Maradi is comparable to the net growth rates of 15-20 percent observed in the Komodougou region in April 1986 (cf. Rapid

Country Review: Niger, June, 1986). This growth rate can be directly attributed to the proximity of activities to the Nigerien border, and the availability of low-cost pumps (75,000 FCFA), spares, and fuel. This trend is not observed along the Niger Valley. The potential for expansion of this pumping technology is limited to zones adjacent to Nigeria and is subject to continuing positive diplomatic relations between Niger and Nigeria.

Recommendation: Honda 3.5 hp pumpsets are available ex-works (FOB factory) in the UK for 75,000 FCFA (5 hp units cost 142,000 FCFA). Similar models are available at pump suppliers in Niamey for 110,000-140,000 FCFA. This price includes excise duties freight costs, etc. (Excise duties represent 43 percent of FOB prices.)

If the source of supply from Nigeria should "dry up," the Niger private commercial sector will become the sole source of supply for most private sector farmers. With increased levels in demand, the supply market is likely to become more competitive, with more entrepreneurs seeking to penetrate a growing market. This has certainly been the trend with other pumping system commodities elsewhere in West Africa. (Tubewell drilling in Mali has decreased from 200,000 FCFA/meter in 1980 to 48,000 FCFA/meter in 1986 for large quantity projects. Manual pumping system costs for village water supplies have also decreased at the retail level.)

The following three measures should be envisaged to render the Niger market option more competitive with imports from Nigeria:

1. Importation tariff reforms for imported pumping systems, particularly those destined for irrigation applications. (Importation duties, although subject to regulations, are rarely paid on pumpsets brought in from Nigeria.)

2. Private sector market stimulation by donor organizations, would educate the local market regarding the best matched pumpset combinations for use in typical situations making well-matched, locally-marketed pumpsets more competitive on a cost/cubic meter basis with Nigerien imports; and

3. Donor-initiated credit programs aimed at encouraging small farmers to depend upon the Niger supply sector for systems and parts supply. It is acknowledged that with the present Nigerien source of supply, market penetration in the border areas will be difficult. Efforts should be made to develop an attractive market and supply situation elsewhere in Niger, which can then be extended to the border areas if the present source option ceases.

Constraint: The motor-pumps which are imported from Nigeria are poorly matched to typical lift and volumetric applications encountered in the Tarka Valley.

Recommendation: Several commercially available motor-pump technology variations would permit a reduction in the cost/cubic meter of water pumped. According to tests performed on several systems during the case study, pumps in use produce maximum hydraulic power at 22 m of total head when operating at full throttle. These pumps, when in good condition also demonstrated a close to linear relationship between flow and engine speed between 1,600 and 2,600 rpm, with a decreasing flow/rpm ratio towards maximum rpm, and a minimum specific fuel consumption for a fixed head at 2,300 rpm. This would imply (although it was not possible to verify in field trials) that optimal pumping system efficiency (expressed as hydrualic energy produced/fuel energy consumed) would occur at 2,300 rpm when lifting through a total working head of 23 meters. The hydraulic power output at this operating regime is estimated to be 740 w as against 116 w measured at a lift of 3 m. Specific fuel consumption would, of course, be increased, but not of the magnitude of the power ratio.

An improvement in pumping system efficiency of 40-300 percent could be envisaged with the same 3.5 or 5.0 hp engines if directly coupled to centrifugal pump units optimized for 3- to 7-meter head instead of a 23-meter head.

Constraint: The direct coupled centrifugal portable pumpsets are not the most appropriate pump technology for needs at Tarka Valley, where traditional and improved well infiltration rates rarely exceed 3 lps and are frequently in the order of 1 lps.

Recommendation: Explore the innovative power systems, in particular, improved manual lifting technologies.

Constraint: Traditional and improved well infiltration rates restrict pump technology options and the size of parcel which can be irrigated from a single well. Multiple wells increase initial investment costs.

Recommendation: Refer to Dan Jenkins, REDSO/WCA, "Well Technology for Micro-Irrigation Systems," prepared as input to the NAAR Project Paper design.

Constraint: The upper limit of hydraulic power which can be generated with efficient manual lifting devices when actuated by a regular experienced operator on an intermittant-with-rest-period basis is 50-85 w. This is equivalent to a flow of 1.5 lps at 6-meter head. (The Jenkins pump shows peak performance of 88 w at the 6-meter head.)

The minimum power generated by a 3.5 hp portable pumpset when operating at optimal regime (but not at optimal head) is 400 w at 6-meter discharge head. This is equivalent to a flow of 4.5 lps with minimal suction head. Motor-pumps of the type commonly used are not well suited to provide flows available from the better quality, deeper, concrete-lined well when used at an optimal regime, and manual lifting devices lack sufficient power.

Recommendation: Explore innovative power system options.

Constraint: Presently the development in the Tarka Valley is dependent on dug wells, but in the prefatory regions the depth of water is too great for their optimum use.

Recommendation: Investigation should be carried out for testing new well and pump technologies to arrive at an optimum mix for developing the Tarka Valley more fully.

Constraint: The existing irrigation systems are not very efficient when employed on the dune areas.

Recommendation: Tests should be conducted on innovative irrigation technologies such as low pressure sprinkle and trickle irrigation for use where water supplies are limited by volume or because of high lifting cost.

## 4.4 System Management

Constraint: Relatively high salinity ground water reduces the yield of onions and would be more significant on other more sensitive crops.

Recommendations: 1. Irrigation water scheduling should be carefully worked out so that farmers could be informed as to the quantities of water required throughout the growing season for the various crops of interest (especially onions).

2. The extension service should provide a salinity monitoring program to inform farmers about the quality of their water at various times during the growing season. The quality information should then be interpreted in terms of the leaching water required to maintain high yields. The leaching water and evapotranspiration requirements should then be combined along with estimated irrigation efficiencies so that farmers would know how much total water to apply and the frequency in which to apply it throughout the crop growing season.

Constraint: There seems to be little known about the Tarka Valley aquifer although it is being rapidly exploited.

Recommendations: A ground water survey should be commissioned in order not only to ascertain the resource available, but also to provide management information so that competition for water does not create economic havoc by lowering the water tables below the economic limits of the existing users. This is especially important where there is a combination of hand-lifting and motor pumping.

Constraint: Motor-pump owners do not operate pumps efficiently, but express interest and concern about maintenance procedures. Maintenance standards in the area appear adequate to maintain pumps in operational condition for 4-6 years depending upon utilization levels. Pump life is estimated at 4,000-8,000 hours. During this period, major components are changed at the following frequency:

| | |
|---|---|
| Piston, rings and cylinder | 1,500 hours |
| Pump impellor and seals | 3,000 hours |
| Spark plugs | 150 hours |
| Misc. components, carburetors, magneto, etc. | 3,000 hours |

Routine maintenance such as oil changes, spark-plug renewal, and air-filter cleaning vary considerably from site to site (30-150 hours for oil changes and weekly to 3-monthly for plugs). Since owners are unaware of manufacturer-recommended maintenance practice and tend to use hear-say as a reference source, this shortens the effective operating life of the motor-pumps.

Recommendation: Users of pumps imported from Nigeria do not normally receive manuals recommending maintenance schedules or optimal operating regimes. In addition, the majority of farmers involved are illiterate. Training in recommended O & M techniques would permit farmers to reduce the cost per cubic meter of pumped water by up to 50 percent. This training could be envisaged either directly through the private sector (i.e., pumping system suppliers in Niger), which would assist in market penetration, or through an extension service.

In either case, reference to the manufacturers or major regional distributors would be essential for training materials, maintenance norms, and training methodologies. The national equipment distributors would be better placed to receive support from manufacturers and would have a vested interest in promoting the market. It is recommended that this issue be presented to pumping equipment suppliers for expressions of interest and proposals for the execution of training programs, initially in zones where this technology is already practiced and growing, and later by extension along the Niger Valley.

Constraint: The use of motor-pumps to irrigated small parcels reduces the need for labor, but is more cost-effective. The seasonal migration of labor from Niger to Nigeria is somewhat reduced as small-scale irrigated agriculture production increases along the Niger/Nigeria border, particularly when manual pumping techniques are used. (The use of motor-pumps, on the other hand, encourages migration.)

Motor-pumps offer farmers the most attractive technology option for irrigation for several important reasons inter-related with other, environmentally dictated elements. These reasons include portability, bearable initial investment costs, increased flow rates, decreased labor needs, and above all higher incomes and profit margins. Presently practiced manual lifting methods are becoming less competitive as production levels increase and profit margins decrease. Even now, manual lifting systems drawing from depths of more than 2 meters barely survive economically unless family (including child) labor is used.

Recommendation: If the capital investment costs are not prohibitive, improvement in the efficiency of manual pumping technologies will help alleviate the labor issue by providing a more competitive technology option to motor-pumps. Since the labor issue is of significant importance to the longer-term national economy, any activities which generate productivity and increase employment should be encouraged.

Efficient manual pumps for irrigation applications are rare in West Africa but commonplace on the Indian sub-continent and China. Jenkins of REDSO/WCA has, however, made substantial progress in the development of a high efficiency locally manufacturable and maintainable unit. Further input is required before this unit would be ready for production in Niger. The USAID project "Project Productivity" executed by Development Alternatives, Inc. is equipped and technically capable of assuming this responsibility. One private sector consulting firm in Mali (I.T. Power, West Africa) is also seeking joint venture partners for continued development and production of the Jenkins pump.

Constraint: While farmers do know quite well how to schedule irrigations for onions based on the experience of others in the valley, they may have considerable difficulty in efficiently irrigating other crops with which they are not familiar.

Recommendation: Irrigation scheduling programs should be developed for the various appropriate crops which might be grown in the Tarka Valley. This will involve estimating the evapotranspiration (ET) throughout the growing season for each crop of importance. (This should be done by utilizing a combination of field research and information available in the literature.) The ET value should then be converted into an irrigation scheduling guide for the different soils and crops in question taking into account the crop period, root and soil depth, expected irrigation efficiencies, and water quality parameters.

## 4.5 Cropping Program

Constraint: While the Koumassa cropping pattern is a diversified one overall, irrigation production is too heavily concentrated on onions.

Recommendation: Applied on-farm testing of garlic, hot pepper, sesame and other crops with good to moderate salt tolerance should be supported.

## 4.6 On-Farm Management

Constraint: Current water management practice is relatively good, but the leaching factor applied still results in 10-25 percent yield reductions.

Recommendation: ONAHA and INRAN should study seasonal progression in soil water and ground water salinity to determine if it is feasible to improve yields through more accurate application of leaching factors throughout onion crop growth.

Constraint: Weeds present a major challenge and cost to onion production.

Recommendation: Trials of chemical, rust, and rotational control of *Cyperus* should be conducted.

Constraint: Losses in storage range up to 20 percent after four to five months in traditional storage structures.

Recommendations: 1. Operations research should be carried out to determine if leaving a neck and field curing will improve storage characteristics. Additional operations research with a sampling of growers should be encouraged to compare storage losses in onions by damage category.

2. Applied research should be carried out on low-cost improvements to storage capacity and thermal insulation of village stores.

## 4.7 Research Agenda in General

1. Groundwater salinity studies to determine depth, stratification, and seasonal progression of salinity levels.

2. Soil salinity studies to determine needed leaching factors and identify leaching water application management.

3. Screening of Galmi onion accessions for salt tolerance and yield potential.

4. Screening of alternative crop varieties for salt tolerance and yield potential.

5. Trials of herbicides, rust spores, and crop rotations for nutsedge control. Improvements to storage capacity and thermal insulation of village stores.

6. Alternative crops and variety testing.

7. Seasonal water management studies to estimate water and salt balance. Use of these studies to determine if the area under dry season irrigation at Tarka Valley can be expanded.

8. Date of planting, density, fertilizer, and water application trails on garlic.

# REFERENCES

Charoy, J.

1971 Les Cultures Irriguees au Niger. Resultats de Septs Annees de Mesures et d'Experimentations (1963-1970). SEHA de Tarna. L'Agronomie Tropicale, 1971, vol. 26, No. 9, pp. 979-1002.

Goldring, L.

1987 "Social and Economic Influence on Perimeter Management and Operation: Findings from Research in the Maggia Valley, Niger." WMS-II Project.

Norman, W. R.

1987 Water Management in Developed and Traditional Irrigation Systems in Niger, West Africa. Ph.D. dissertation, draft. Ithaca, New York: Cornell University.

Samani, Z. A. and Hargreaves, G. H.

1986 "Rainfall probabilities and Agricultural Water Requirements for the Sahel and Other African Countries," International Irrigation Center, Department of Agricultural and Irrigation Engineering, Utah State University, Logan, Utah.

## WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

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WMS 25 Interdisciplinary Diagnostic Analysis of a Work Plan for the Dahod Tank Irrigation Project, Madhya Pradesh, India

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WMS 37 African Irrigation Overview: Summary; Main Report; An Annotated Bibliography (3 volumes)

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