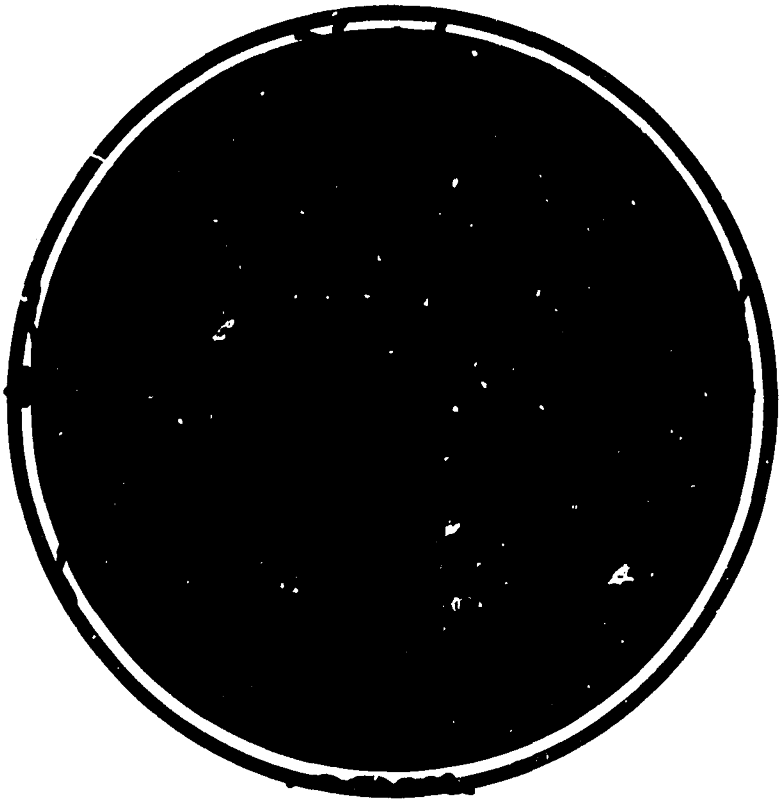

PROJECT REVIEW FOR BAKEL SMALL IRRIGATED PERIMETERS PROJECT NO. 685-0208

SENEGAL
USAID

WATER MANAGEMENT SYNTHESIS PROJECT
WMS REPORT 9

PROJECT REVIEW

FOR

BAKEL SMALL IRRIGATED PERIMETERS

USAID/SENEGAL PROJECT NO. 685-0208

This study is an output of
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PREFACE

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

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

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

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FOREWORD

This study of the Bakel Small Irrigated Perimeters Project was conducted at the request of USAID/Senegal. It is intended to serve as a project review document and includes the teams' conclusions and supporting background statements. It also contains recommendations for the future in anticipation of continuing the Project as a model for the proposed expansion of irrigated agriculture along the Senegal River.

The review team visited Senegal between October 30 and November 24, 1981. The team members were:

Jack Keller, Team Leader and Irrigation Engineer
Raymond E. Meyer, Soil Scientist and Agronomist
Freddie J. Peterson, Rice Agronomist
Thomas F. Weaver, Agricultural Economist
Gerald C. Wheelock, Rural Sociologist

The team did not attempt to evaluate the Project in a traditional manner and concentrate on critiquing the activities and outcomes to date, for it is well known that the Bakel Project has reached a standstill. We realized the more important purpose of our mission was to pinpoint the restraints which had limited the Bakel Project's success to date, and to develop a set of recommendations for overcoming these restraints.

The team approached the task by first studying the Bakel Project and related documents, along with holding discussions with associated personnel (administrators, planners, technicians, advisors, farmer leaders, farmers and critics) and visiting most of the small irrigated perimeters in the Bakel Region. In addition, for comparative purposes we visited the other similar small irrigated perimeter projects and the medium to large perimeter projects along the Senegal River. We then developed a set of conclusions and recommendations for improving project performance. The background for arriving at these recommendations plus other pertinent information for carrying them out was organized and is the body of this report.

The team appreciated the assistance received from a number of the Societe por l'Amerragement et Exploitation du Delta (SAED) employees. (SAED is the principal Government of Senegal (GOS) agency responsible for irrigation development along the Senegal River.) We particularly appreciated the support we received from Mr. Pierre Diouf, Project Director for the SAED Bakel Region, and his Assistant Director, Mr. Amadou Cisse, and the intense interest of and long discussions we had in Saint Louis with Mr. Dia, Director General of SAED.

In addition, the team appreciates the thoughtful and cordial assistance from the many USAID Mission personnel who helped us. We give special thanks to Mr. Joseph Salvo, Project Director, and Dr. Khoi N. Le, Field Team Leader and Agronomist, who accompanied us during parts of our field tour, and to Mr. Moribajan Keita, USAID Agricultural Economist, and Ms. Andrea Hough, Peace Corps Fisheries Technical Advisor, for their assistance during our field tour. We also appreciate the backing and support we received from Mr. John Balis, Agricultural Development Office, and Mr. David Shear, Mission Director.

Following is a brief recap of the teams' itinerary.

Oct. 30 - Arrived Dakar and met by Mr. Joe Salvo at 06:00.

Oct. 30 - Nov. 2 Briefings from USAID offices in Dakar: Mr. John Balis, ADO; Mr. Lance Jepson, Deputy, ADO; Mr. Joe Salvo, Bakel Project Director; and Mr. Ray King, Regional Controller.

Reviewed project papers and related documents assembled by Mr. Joe Salvo.

Nov. 3-4 - Traveled from Dakar to Bakel by car, accompanied by Mr. Joe Salvo.

Nov. 5-10- The team, either collectively or in two groups, visited essentially all of the irrigated perimeters in the Bakel Region. For the first two days we were accompanied by Mr. Joe Salvo, who was then called back to Dakar and afterwards either: Mr. John Peterson, USAID Temporary Assistant Project Director at Bakel; Ms. Andrea Hough, Peace Corp Fisheries Technician; Mr. Moribajan Keita, USAID Ag. Economist; or Dr. Khoi Le, USAID Project Agronomist. Mr. Amadu Cisse, SAED Asst. Project Director also accompanied us on many of the visits.

While visiting the perimeters discussions were held with several of the Presidents of the various perimeters. Of particular interest were discussions with the Presidents of Bakel, Aroundou, Balou, Khourmzani and Yafera Perimeters. We also had the opportunity to have a long discussion with Mr. Diabe

Sow, President of the Khourmzani and founder of the Farmers Federation in the Bakel area, and his wife, Ms. Adrian Adams, who has published scholarly articles dealing with small irrigated perimeters development history and social impact from the perspective of a villager. In addition to visiting the perimeters, the from Mr. Pierre Diouf, SAED Project Director, in assembling irrigated perimeter operational and management data on file at Bakel.

Besides studying the irrigated perimeters, the team also studied the solar thermal powered irrigation pump facility at Bakel, where we were assisted by Mr. Kassimin Milan, the French Technician in charge of the installation. In addition, Meyer reviewed the village fish pond activities with the assistance of Ms. Andrea Hough.

Nov. 11 - Travel to Matan with Dr. Le and visited two of the small irrigated perimeters there before proceeding to Richard Toll. The SAED small irrigated perimeters program in the Matan Region is assisted by the French foreign aid organization, FAC.

Nov. 12 - The team split into two groups with: (1) Meyers, Peterson and Weaver accompanied by Keita visiting the Rice Research Station near Richard Toll, the large SAED mechanized rice production perimeter at Dagana, and the sugar cane plantation Compagnie Sucriea Senegalaise at Richard Toll, where they also have a mechanized rice production pilot farm; and (2) Keller and Wheelock accompanied by Le visiting the medium (250 ha) irrigated perimeter at Guede Chantier, which was assisted by the Red Chinese aid program until recently, the nearly 50 ha Cuma cooperative, which is farmed by a select group of 25 farmers (families) and FAO Rice Station, which is essentially inoperative, and then on to visit a small irrigated perimeter at Cascas, which, along with 20 other nearby perimeters, is assisted under the Dutch aid program.

Nov. 13 - The team visited SAED headquarters at Saint Louis where we had discussions with Mr. Abdul Dia, DPA, and his French advisor, Mr. Lovarn, then traveled to Dakar.

Nov. 14 - Worked in Dakar continuing to study documents and writing report. During this time the team had the following debriefing meetings: (1) November 14 with

John Balis, ADO, Sam Rea, PRM, Lance Jepsen, Asst. ADO, and Joe Salvo, Project Manager of USAID; (2) November 16 with the entire OMVS Project Paper team; (3) November 16 with Vito Staglino, USAID/OMVS Coordinator; (4) November 16, Mr. Mark Ward USAID Energy Advisor for the African Bureau; (5) November 20 in Samil Louis with Mr. Dia, Director General of SAED, where we were accompanied by John Balis; (6) November 21 with David Shear, Mission Director, and several members of the Mission staff; and (7) November 23 with the U.S. Ambassador to Senegal, Mr. Andre Coulibary, accompanied by John Balis.

Nov. 24 - Departed from Dakar, Senegal, 02:00.

CONCLUSIONS AND RECOMMENDATIONS

The USAID Bakel Region Small Irrigated Perimeters Project, as it has evolved to date, has not adhered to either the original project document nor the recommendations of the interim 1980 Joint Assessment review team. It is not an integrated farming system project. It is essentially an irrigated rice project.

Overall, the Bakel Project has been extremely successful at exposing the problems which are encountered in perimeter irrigation development in the Senegal River Valley. From a brief reconnaissance survey of irrigation perimeter shemes operated by the French, Dutch, Chinese and Government of Senegal (GOS), there is ample evidence that these problems are not unique to Bakel.

It would seem eminently wise that solutions to the problems encountered in Bakel be determined before additional funds are spent in expanding perimeter irrigation on some new project in the Senegal River Valley. Perhaps the greatest value from the Bakel Project can be gained if it is seen as a pilot project. It is in this spirit that we present the observations and recommendations which follow.

Overall Design and Development Strategy

The Bakel experience, when viewed as a pilot project, suggests the following general strategies for small perimeter irrigation design and development in the Senegal River Valley. The rationale for these suggestions is developed more fully in the body of the report.

Recommendations

1. Identify the largest indigenous functional decision making unit. By functional it is meant that the capacity for decision-making is such that under normal circumstances the allocative and distribution decisions that need to be made on an irrigation perimeter can be made in a reasonable, timely manner. This will require the best judgments of informed anthropologists and sociologists working with irrigation technicians. The functional unit will vary by location in the valley and possibly through time at a given location (see pages 87 to 89).

2. Irrigation systems should then be designed so that

natural functional units are maintained and do not have to be crossed or combined to efficiently operate the system. For example, a stationary pump site that will irrigate 300 hectares is inappropriate if it requires coordinating the production activities of non-cooperating social units. A series of small pump sets capable of irrigating 200 hectares may be the appropriate system. Or alternatively, rotational units on a larger system might be laid out to accommodate small decision-making units. There are sufficient types of alternatives, irrigation technologies available to permit this type of design selection (a number of these are evaluated in the Bakel context on pages 53 to 62).

3. Local social organizations and farmers have a demonstrated desire and ability to sop-up high production agricultural technology, first to insure subsistent needs and then market surpluses, if cash returns justify the extra investment and labor supplies are adequate. Market prices fixed at a low level are a disincentive to the creation of a market surplus. Furthermore, labor saving technologies must be implemented because with present techniques labor is a serious production constraint (for more detail see pages 65-68 of this report).

4. The initial Bakel project was conceived as an integrated agricultural production project. This view was reemphasized by the interim evaluation team. This evaluation team agrees with this view, i.e., that the integrated farming system and rural development approach be adopted as the central framework of any future irrigation related development projects within the Senegal River Valley (see further discussion pages 1-4 of this report).

Project Management

5. The USAID Mission does not have sufficient internal capacity to manage multiple crop and multiple-cropping/season irrigation projects, nor sufficient in-house expertise necessry to monitor hired consultants and coordinate the activities of internal subject matter specialists.

   Recommendations: For any future perimeter irrigation project in Bakel and the Senegal River Valley, USAID should provide a greater quantity of adequately experienced and trained project managers. The special demands of a pilot project require a greater than normal managerial input. The managerial inputs currently available in Bakel could well be doubled. This is especially true given the very limited pool of indigenous personnel who are adequately trained and available for overall project management.

6. USAID and GOS through SAED have been unable to establish an effective counterpart relationship. On-the-job training potential is thus almost completely lost; SAED has not chosen to post the call for field personnel.

   Recommendation: USAID should consider terminating all capital assistance to the project dependent upon SAED posting the appropriate counterpart system. Viewed as a pilot project it is particularly critical that SAED personnel gain the experience of continual evaluation and adjustment of the project.

7. SAED extension and field personnel, in too many instances, lacks hands-on field experience in the techniques that they are attempting to teach the farmers.

   Recommendation: USAID technicians should conduct a rice, corn and sorghum training program at a demonstration station. The training course conducted at the International Rice Research Station in the Philippines might provide some direction (information on this program can be obtained by writing to Dr. Robert W. Herdt, Director, Economic Research Division, IRRI, Box 933, Manila, Philippines). Similar programs should be developed for maize, sorghum and wheat at the respective International Research Centers and CRSP's. A field experiment training program in irrigated crop production would seem crucial for any future irrigation perimeter development. USAID might consider this as an early project in the development of the Senegal River Valley.

8. The Bakel Perimeter Irrigation Project was jointly funded by USAID and the Government of Senegal. Given this joint financial, and more importantly, operational responsibility, it was unusual that the GOS did not participate in this evaluation. Ordinary procedure would have called for at least one member of the line agency (SAED) to have participated.

   Recommendation: Jointly funded projects, especially, should have joint evaluation.

9. One of the important benefits of an evaluation is the opportunity of USAID and evaluation team members to learn from each other during the evaluation period. Unfortunately, this exchange was severely restricted during this evaluation because project personnel were required to attend to other duties, apparently often at the request of higher authority. This is symptomatic of the need for increased managerial capability. This was an opportunity lost for all concerned. It resulted not only in limiting the learning experience, but also preventing the team from making maximum use of the time available for the evaluation.

    Recommendation: USAID should make certain that the project manager is available at all times to accompany the team. It is important that the individual most responsible for field implementation strategy be intimately associated with the evaluation. This is especially the case for a pilot project of the complexity of Bakel.

Agriculture

10. Estimates made by agricultural scientists that modern high yielding varieties of paddy can be grown at or close to their biological potential in the Senegal River Valley have been confirmed by the Bakel experience. Yields in some rice fields will be as high as 7 metric tons/hectare in this season. With similar HYV's and appropriate inputs high yield levels would be obtained from irrigated corn and sorghum (rather than the present 1 to 2 T/ha yields).

    Recommendation: A continuous program of testing of varieties for suitability to the climate and soil condition of the Bakel area should be continued for rice and begun for maize, sorghum, millet and wheat. This should be standard practice at selected sites up and down the valley as micro-climatic and soil difference can have significant effects of varietical selection. It is important that the plans for developing a demonstration and field testing facility for Bakel proceed immediately. Variety, fertilizer and husbandry demonstrations should be laid out and managed by SAED/USAID personnel. These trials should be in part based on requests and questions raised by farmers (see pages 22 to 39).

11. To date, there seems to have been very few insect and disease problems on paddy rice being grown in Bakel. However, there is no evidence of a capacity to identify and respond to any outbreaks requiring immediate and extensive crop protection practices. For example, red rice is now a problem which could reduce rice yield by over 50 percent within two to five years if not eradicated immediately (see pages 36 and 37 for details on this problem).

    Recommendation: A training program in pest and disease identification should be started for SAED personnel and for selected cultivators or leaders identified by the farmers organization.

    Current practices by GOS of supplying the HCH (25 percent) (a French trade name for chlorinated hydrocarbon), which women are broadcasting by hand to control grasshoppers, is contrary to USAID policy and is possible grounds for immediate withdrawal of all support to the project.

12. The current technique for gathering field data on rice yields is slow and ponderous.

    Recommendation: Project funds should be used to provide a pedal thresher and moisture meter so that yield estimates can be made on-site, reducing sampling and travel costs. The harvested grain could then be handed directly over to the cultivator. The sampling framework and procedure must involve SAED personnel.

13. Farmers are growing flooded rice on some areas not suited because of soil variability. Sand lenses occur which cause major problems in water loss and the farmers are required to learn by experience how to cope with sandy areas and what crops to grow.

    Recommendation: USAID and SAED should provide detailed soil surveys on all new areas before capital investments are made for irrigation. A program should be initiated to also provide such detailed surveys for existing perimeters including ares for expansion.

Engineering

14. Poor pumping plant maintenance and repair services (aggravated by the problems with floats and fueling systems) are causing untimely breakdowns, expensiv major repairs and short (as little as one-sixth of normal) equipment life. This alone is sufficient to destroy the economic viability of the Bakel Project.

    Recommendation: Pumping will be the primary means of obtaining water for irrigation in the Bakel region and throughout the Senegal River Valley. Pumping plant maintenance and repair problems must be solved through training of village/SAED personnel, supplying parts and standardizing equipment. More detailed recommendations on training can be found on pages 60-62 and 96 through 102.

    Some sort of incentive program for both SAED and the farmer groups to maximize the life and performance of the pumping plants might be appropriate. Suggestions as to how this might be developed are discussed on pages 74 through 82 of this report.

    There can be no compromises with this objective if irrigation is to be developed throughout the valley. USAID should make all other aid to the development of the Senegal River Valley contingent upon meeting this objective.

15. Many pumping plants and the penstocks which deliver water to the canals are poorly designed. We observed (as numerous reports have already mentioned) inadequate floats, poorly selected pumps, inadequate fueling systems and improperly used and designed penstocks and canal inlet works. These improper features cause unnecessary malfunctions and shutdowns, excessive wear and higher diesel maintenance costs, high replacement costs and excessive fuel usage.

    Water lifting is essential to any substantial irrigation development in the Bakel Region, and indeed, throughout the Senegal River Valley. Taken as a pilot project, the Bakel experience clearly demonstrates that the inadequacies mentioned above are sufficient to destroy the economic viability of these types of perimeter irrigation schemes.

Recommendation: There is little excuse for allowing design and installation inadequacies to continue. They increase farmer costs and complicate maintenance problems for SAED and the farmers. Existing fiberglass floats should be replaced with reliable and sturdy ones; convenient and clean fuel storage systems should be provided at each pump site. Inadequate and unreliable pumps which are inefficient for the given site conditions and not properly matched to the diesel engine should be replaced. The plastic penstock pipe should be properly buried and provided with necessary elbows or replaced with appropriate metal pipes and fittings. Canal inlets should be redesigned to reduce head requirements (see pages 46 to 49).

16. Although adequate farm watercourses and land leveling are essential project features for adequate and efficient irrigation, these services are not provided. This is because building channels and land leveling, or shaping, is costly beyond comprehension due to poor selection of equipment. Farmers left to their own devices with inadequate hand tools and no tradition of using animal power are hardly up to the task.

Recommendation: Watercourse construction and land leveling and shaping should be done with appropriate technology (equipment). USAID should develop equipment requirements and procedures for the task. This would greatly assist in development of the total valley as well as the Bakel area. Since pumping is already required and the energy costs make water quite expensive, pipe distribution systems should be seriously considered.

17. There seems to be a tendency toward thinking in terms of a fixed size system per motor-pump (20 ha in the Bakel case). In reality, this should not be the case because of the variety of physical and/or social situations.

Recommendation: There is a danger in thinking in terms of a standard optimum size. Flexibility in size and shape should be allowed in the planning and design phase to fully optimize mechanical and physical site conditions while dealing with social realities (see pages 51 and 52).

Economic

18. There is clear evidence that the farmers/cultivators in

the Bakel project area are acting as cost minimizers. They rotate water at high efficiency levels and they are learning to plant short season rice varieties on field situations which tend to have droughty conditions. They ask meaningful questions about fertilizer application rates and some have adopted application strategies whih recognize soil differences. They are also extremely interested in crops other than paddy for irrigation.

Recommendations: The educatable moment is at hand for many of the cultivators in the Bakel project area. There is a clear opportunity for knowledgeable extension workers to transfer information from researchers to cultivators and questions and problems from cultivators to research workers. Any continuation or further development of the river valley must include the planned-for buildup of research capability and, as important, an extension outreach program. USAID should study the feasibility of training members of the production cooperatives selected by the membership to serve as extension para-professionals.

19. Over a five-year period, in spite of continued recommendations, reliable data have still not been assembled on the cost of production of paddy and other crops. Valuable time has been wasted redoing benefit/cost analysis to no effective purpose. The production cost and returns information is necessary for understanding the economic viability of the project.

Using the best information available to date (see pages 64 through 69), it appears that under some circumstances there is very little financial incentive indeed to engage in irrigated paddy cultivation in Bakel. These types of insights, which suggest some corrective measures (see page 70) are critical in a pilot program.

Recommendations: The recommendations on establishing procedures for collecting data on the quantity, quality and cost of crop production in the Bakel Project must be implemented immediately. The agricultural economist must be assigned this as a priority activity and provided with adequate support facilities. Details of this recommendation are given on pages 71 through 74 of this report.

20. A national policy of import substitution for paddy has resulted in a "rice fix" for irrigation development in the Bakel area. Price distortions caused by regulated

pricing can result in resource misallocation at the farm level.[1]

Recommendation: USAID should establish a firm policy of establishing the irrigation potential of all food grains which can be grown in its project areas (including, but not limited to, maize, sorghum, millet, wheat and paddy). It should encourage production decisions based on farmer objectives in response to their environment and market forces. Such a policy of providing low cost food grains can contribute substantially to reducing rice imports.

21. Successful irrigation perimeters appear to be ones in which a strong intrnal leadership has created a management structure and membership/participation which do not cut across traditional lines. Large numbers of the participants share in debt repayment by paying debts with the returns from the collectively farmed fields. These same workers have equal size individual plots which often stretch across non-homogenous land (e.g., plots 5 meters wide/450 meters long). Although the yield from these plots accrues to the individual farm family, work schedules are organized and controlled by the leaders of cooperatives around irrigation rotation schedules. High labor requirements are the primary constraint to expanding the irrigation parameters to greater acreage, thus giving greater returns to participants.

Recommendation: It is anticipated that a formal analysis

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[1] An unfortunate atmosphere has developed regarding the writings of the wife of one of the leading organizers in the region. This controversy is generally over AID and other outside agencies' development policy. The core of the disagreement is who should determine the development path, the farmers themselves or outside forces, be it government or foreign donor. The basic truth, treated by students of development for at least 30 years, is that all successful development programs must be coordinated with and based on the perceived needs and aspirations of the participants. The participants must be included in planning the development process. To proceed otherwise ultimately ends in failure and occasionally, revolution. One very effective means of achieving this is by listening to the participants. This lesson seems very difficult to learn and it bears constant repetition by those who have access to the ears of change agents.

will confirm the existence of a serious labor constraint in irrigated agricuture. It is recommended that USAID begin immediately to investigate an appropriate labor saving technology: better hand tools, animals or small pedestrian tractors. The evaluation team feels that animal power should be considered first and that members of cooperatives should be involved in helping to plan and develop labor-saving strategies. Animal power should be viewed from the perspective of integrating the draft animal into the farming system rather than simply "teaching it to plow." Addressing the labor issue is an imperative for expanding the irrigated acreage in the valley (see pages 39, 69 and 70 for clarification).

22. Only irrigated rice production technology is being delivered to the farmers by the project.

Recommendation: USAID must recognize the great opportunity to increase cereals production by crops other than rice and should commit resources to testing varieties of traditional crops and new crops for both rainfed and irrigated agriculture in the Bakel project area. Priorities should be set by insisting that cultivation needs and interests be determined and included in testing and research activities.

Farmer Federation/Cooperatives

23. There is a missing link between SAED and the individual perimeter groupments. Rather than SAED mediating conficts or promoting cooperation between groupments on the one hand, while instilling competition to produce more on the other, the Federations through traditional processes could perform these functions.

Recommendation: Farmer Federations representing existing organizational networks of perimeters cooperatives should be formally acknowledged and incorporated into project management with SAED and USAID.

24. Farmer Federation cooperatives have accumulated rice surpluses that they consider to be market surpluses at a fair price. Without access to existing markets, it appears that rather than produce rice for SAED prices, the farmers will consume it or grow other crops. Based on previous experiences with government monopoly marketing schemes, farmers correct in being skeptical of

receiving fair treatment. To be convinced that they are getting a fair price, they should be involved in management.

Recommendation: In addition to continued emphasis on production efficiency and higher yields, the farmer federation/cooperative should be incorporated into the marketing structure and its management. Facility loans amortized from the market margin should be structured to make cooperatives owners of their market facilities (see pages 90 through 96 for a more detailed explanation).

25. The cooperatives appear to have very minimal accounting, and the development of an accounting process is felt to be critical to their long term success. It would be essential if an incentive scheme such as suggested for fuel repayment and pumping plant equity were implemented. It is clearly important for financial management and for assuring an equitable distribution of the costs and benefits of irrigation to the members of the cooperatives.

Recommendation: It is extremely important that an internal accounting system be developed for each farmer cooperatives. This is necessary for maintaining the faith in and integrity of the cooperative units. The accounting procedure should be taught to a designated member of the cooperative. The individual(s) should be selected by cooperative members, not by outside authority. The accounting system should be consistent with national laws and should be audited regularly by a reliable authority.

Solar Pump Facility

26. The solar thermal pump system being installed has no hope now or in the future of being anywhere near cost effective because it is too materials intensive. To keep the equipment operating will require the continued participation of a high level (undoubtedly expatriate) technician. Furthermore, the installation will require an expensive maintenance program: to keep the panels free from dust; to repair leaks at the many flexible pipe connections; to service the complicated controls and circulating pumps; and to maintain the thermal heat engine and generating systems. A detailed discussion of the solar pump facility is given on pages 103-107.

Recommendation: As soon as politically feasible, USAID should terminate the solar thermal pump project. The evaluation team realizes such a recommendation may create an awkward situation in many quarters, but feel that if the program is allowed to continue, it will die on its own, causing even further embarrassment and waste. Machinery which has not yet been completely shipped should be diverted to save as much as possible on shipping expenses and disposal procedures should be taken in an effort to salvage as much value as possible. The solar panels (which are alost completely installed) could possibly be used advantageously for solar water heating.

Of course, we recommend that the very excellent buildings and structural facilities be used as planned for the SAED Bakel District Headquarters. Furthermore, we would like to see a demonstration irrigation farm supplied from a diesel engine pumping plant set up for the 32 ha site (which would have been supplied by the solar pump), or at some more advantageous location (such as just upstream from Bakel).

By recommending termination of the solar thermal pump project, we do not mean to condemn solar pumping in general. We sincerely hope that the Bakel experience will not eliminate the desire for appropriate solar technology, but caution that more careful consideration be given to appropriate technology in the future.

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BAKEL SMALL IRRIGATED PERIMETERS

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PROJECT BACKGROUND AND EVALUATION

In the Fleuve Region, which is the extreme eastern part of Senegal, the life supporting systems that have evolved over the years are finely tuned to the seasonal availability of water. Land preparation for rainfed (Dieri) must await the first rain to soften the earth. Traditional plantings of swamp rice begin after the runoff leaves isolated low spots saturated with water. Recessional plantings (Walo) come later after flood tides fall back from high water marks. As the rains end, livestock is grazed on ever decreasing pasture areas, away from the river; and intermittent stream beds are mined for drinking water.

When the rains are below normal for the three to four months rainy season, production from rainfed crops is minimal, river floods leave less surface area replenished with water and silt for recessional plantings, swamps dry up before rice can reach maturity and scarce pasturage increases the number of animals unable to survive the stress of the dry season.

Project History

The small scale irrigated perimeter program of SAED attempts to remove the provision of water from the hands of fate and place it under the control of the producers. It is intended to expand the options open to villagers for agricultural production and reduces considerably the risk of farming. Risk, as measured by losses in production when rains are not sufficient, should be substantially reduced by the project, thus mitigating the shortfalls in traditional production. Irrigated agriculture should also make it possible to introduce new production activities that promise higher income, which would not have been possible without a high degree of control over water.

It has been recognized that the irrigated perimeters program is a structural change in the pattern of agriculture that cannot be captured in isolation, but rather, must be viewed as a force that will change the social and economic parameters of village life.

To date, the irrigated perimeters are being used to supplement income/food being produced under the traditional systems of rainfed agriculture. There is also indication that some of the rainfed fields are being included in the perimeters, as are some of the swampy areas. In any case, the farmers regard this innovation as an insurance measure against a reduced food supply; and a hedge against a reduced demand for the export of labor to France, which is currently the main outlet for excess labor and source of supplemental income to the Bakel Region.

The small irrigated perimeters development program in the Bakel Region was originally started by a farmer from Koughanè Village who formed a farmers' association and made a request to France to supply technical and financial assistance to help them irrigate areas near the river. A Paris based non-governmental private volunteer agency supplied technicians at first. As the small irrigated perimeters concept gained momentum, larger donors were attracted. In August 1977, USAID responded to a request for assistance by authorizing a $5,859,000 grant to help develop a project of about 1800 hectares in at least 23 villages in the Bakel Region. Technical assistance was supplied by SERDA, a Senegalese consulting group and by SAED. Each perimeter is managed by a groupment (group) made up of farmers from a single village. The production technology of pump irrigation is at the core of a series of activities carried out by the perimeter farmers and SAED.

Since the beginning of the project, the roles of both farmers and SAED in the Bakel Region have evolved as a result of pressures for increased management autonomy, production, debt management and marketing by farmers groups. Participating villages first clear nearby land with SAED providing machine time. Villagers provide hand labor to dig the canals and shape the land. They decide how to apportion the land between communal and private plots and then assign the plots to individuals, often by lottery. SAED makes available one or more pump sets and then charges to the group's account the seed, fertilizer, diesel fuel and spare parts. SAED also attempts to provide production assistance, but only for paddy (rice) and for the most part this assistance has not been adequate.

A formal contract specifies the responsibilities and rights of the two parties. This includes SAED, as the sole authorized marketing outlet for rice at a fixed price. Although SAED distributes the necessary inputs, control over their application rests within the group. Harvest and threshing is done by the farmers. Labor, in this case, also becomes management. The groups have complete management responsibilities for their perimeters, deciding among themselves how the land and water will be divided, how the credit will be handled, debts collected, disputes settled and labor allocated.

Under the influence of the farmers' association, the first perimeters formed were collectively farmed with the produce distributed by the group to SAED to pay for the group's debts and to the group members for their own use. The emphasis on collectives has decreased since the inception of the project because SAED has tried to discourage collective farming. However, the three perimeters which were started in 1975 have resented the pressure and still farm about one-fourth of their irrigation land collectively. One small perimeter is totally collective and 15 perimeters have no collective land.

The farmers are able to produce three irrigated crops per year providing they have a sufficient water supply and their credit or cash position is adequate to procure the necessary inputs and labor. In the 1980-81 crop year, the irrigators in the Bakel Region produced 285 ha of paddy and 127 ha of maize and sorghum during the rainy season. They raised 194 ha maize and 10 ha of vegetables in the cool and hot dry seasons combined. While additional hectares could be put into production at much higher levels of productivity, this has not happened for a number of reasons described herein.

Project Plan and Activities

The Bakel Small Irrigated Perimeters Project was identified as an integrated agricultual production project at its inception in 1977. The core activity was the construction and operation of small irrigation systems supplied by diesel pumps floated on the Senegal River. Other necessary conditions for the successful operation of the irrigation perimeter were identified and incorporated into the project. These included an assured supply of other production inputs (fertilizer and seed), the development of indigenous farm level management organizations, an institution for supplying credits for production uses and an extension and research support system.

The vast majority of irrigation projects in the developing world are designed for farming systems in which a tradition of irrigated farming already exists. The Bakel Project introduced irrigation into a culture in which an irrigation tradition was virtually unknown except small plots of vegetables irrigated with water carried by hand. The project planners saw clearly that, given these circumstances, considerable care would be required to successfully integrate irrigated agriculture into the farming system of the area. Furthermore, not only was irrigation virtually unknown, but one of the initial irrigated crops was to be paddy (rice), a crop that had virtually no previous history in the area. (Very small areas of paddy were reportedly grown by women in small low lying fields which often failed.)

As mentioned earlier, the pre-project agriculture of the area was a rainfed/succession agriculture. Crops were taken during the rainy season on some lands, while on areas subject to river flooding and on the inner banks of the Senegal River itself, a succession of crops was grown following the end of the rainy season. The main crop was millet, sorghum and some peanuts and maize were also grown.

The project planners saw clearly that these indigenous crops represented a production potential. However, yields from native varieties under rainfed conditions using traditional cultivation techniques were low. Irrigation of higher yielding varieties of these crops and improved rainfed cropping practices, i.e., a systems approach to agricultural development in the Region, clearly required consideration. Project planners also recognized that one of the pivotal issues associated with the successful introduction of irrigated agriculture, which included paddy, was the total labor stock and the labor flow requirement. This was critical not only for the farmer, but for the economics of the project and a favorable benefit/cost ratio as well. They realized that errors in estimating labor requirements and the opportunity cost of labor would substantially change the benefit/cost ratio and the internal rate of return estimates.

Against this background of a major agricultual development being introduced into a very traditional rainfed farming system was the existence of a very substantial technology. High yielding non-photo period sensitive varieties of paddy had been imported into the country and tested at government research stations. Evaluation by some of the world's leading researchers had identified the climate and some soils of the Senegal River Valley as rather ideally suitable for paddy cultivation. There was considerable optimism that the full power of the "green revolution in paddy" could be unleashed in the area. In addition, the soils and climate hold considerable potential for both rainfed and irrigated maize, sorghum, and possibly, wheat production.

The project planners recommend moving ahead with a simultaneous thrust into investigating all of these production potentials. This evaluation team agrees with the interim evaluation team and with the project planners that this approach was conceptually sound given the ecological and socio/economic characteristics of the region. The evaluation team further recommends that this integrated farming system and rural development approach be adopted as the central framework of any future irrigation related development projects within the Senegal River Valley.

Farmer Responses

From the point of view of the economist, the Bakel Irrigation Project provides a classical validation of ne of its universal assumptions -- that of economic rationality on the part of the farmers. The efforts of the project clearly were directed at the introduction of irrigated paddy. On their own, cultivators resisted this single enterprise approach and began irrigating corn and sorghum. Their stated objective was to investigate the likelihood of higher returns from these cropping alternatives. SAED has recommended the same fertilizer application rate for paddy across all types of soils. Cultivators have questioned these recommendations and some have been using higher application rates on the lighter sandy soils and reduced rates on the heavier soils. Others have suggested that the recommended rate may be too high, and in effect, are asking if the marginal return is not less than the marginal cost at the recommended application rates.

These types of farmers' reactions to a broad spectrum of recommendations are not different from what would be expected from the farmers of a highly developed agriculture. In a very impressive way the farmers of the Bakel Region very quickly moved beyond the ability of the project to supply advisory information in some areas. This is not to say that the farmers know all that is available on the husbandry of paddy. It does say that they have all the characteristics of cost minimizers and they are seeking the most profitable level of enterprise combinations.

Farmers have also been quick to recognize that crop water requirements are a function of soil type and that the marginal value of water is likely to be higher on the heavier than on the lighter soil types. In some areas, land originally prepared for paddy production by the project planners has been put to maize by the cultivators because of high soil permeability. Farmers have also realized that the shorter season though lower yielding rice varieties are less risky on the more droughty (sandy) soils. They appear to be incorporating the probability of a reliable water supply into their planting decisions and understand the need for pump maintenance and replacement.

Now it appears that the GOS is very wisely allowing the cultivators to choose those crops and cropping combinations which maximize returns under local conditions. This is far superior to the earlier strategy which had a rice fixation. Certainly, consumers in the urban centers of Senegal will respond to relative foodgrain prices and rice imports can be reduced to some degree by substituting other foodgrains if available at lower prices. Suitable processing of such foodgrains to render them easier to prepare can greatly assist in their market acceptance.

In the same way the food deficit in the Senegal River Valley can be filled to a large degree by foodgrains other than rice. USAID will do well to recognize the great opportunity to increase cereals production by crops other than rice and to commit resources to their introduction and varietal improvement for both rainfed and irrigated agriculture in the Bakel Project area. Priority should be set by insisting that cultivators' needs and interests be determined and included in testing and reseach activities.

Project Evaluation

The evaluation of the Bakel Project should be based on whether the benefits to the farmers and/or country during the life of the project outweigh the costs and any detrimental effects during the same time period. However, this requires some sort of subjective decision of what would have happened without the project, which is impossible considering the existing data base and lack of experience in similar situations.

The intended number of developing 23 irrigated perimeters has been achieved, but the project target of putting 1800 ha of land into production has not been reached. However, while production at existing perimeters has been improving, it is not yet optimal because of insufficient technical studies and consequent errors in perimeter design and construction. Moreover, technical packages for the various crops have not been well developed and extension work is insufficient to disseminate what is already available. Farm-level record keeping systems to monitor production and inputs are not in place to provide management data to enable decision-making by either farmers or technical personnel.

In view of the above, when evaluated against the original Project Paper, the project failed and it is apparent that the project emphasis and direction has changed considerably. The reasons and/or basis for these changes are not clear, as they have not been articulated. Furthermore, the project has failed in significantly contributing to the achievement of USAID's general goals for Senegal which include:

1. Increasing food output and raising peasant incomes.

2. Providing a multicrop irrigated agriculture.

3. Allowing the farmer to take over production and marketing factors from SAED.

4. Overcoming the national food deficit.

5. Arresting rural-urban migration by improving conditions in the valley -- socially, culturally and economically.

6. Protecting agricultural production from irregular climatic conditions.

On the broad question of food production, the Bakel Project has failed to benefit the local populace, as their preferred diet is principally sorghum and millet. On the other hand, the project has probably reduced the stability of sorghum and millet production and forced the local populace to consider rice as a subsistence crop. On the national level, where the preferred diet includes more rice, the project has contributed minimally, as the excess production over local consumption is very small as compared to the national short fall.

Socially, the project has not followed USAID's directive of minimizing the shock effect of interventions which may substantially affect or change the lifestyle of the indigenous culture. Realizing the political pressures involved and the emphasis on rice culture by the GOS, USAID should have exerted more control and pressure on SAED and invested more wisely in minimizing the disruptive effects of the project on the indigenous people. The fact that in some cases yields of rice are quite high is a tribute to the ability of Senegalese farmers to adjust to and incorporate new technology. It is also a tribute to the willingness and ability of USAID technicians to work with the farmers in the field and at the basic level. The number of areas not planted, however, and the immediate abandoning of irrigated culture for rainfed farming when the rains come is an indication that the project is probably very marginal and has taken insufficient cognizance of the social-anthropological factors involved.

The desirability of introducing the existing culture into a more "modern" society may be debated, but it is apparent that changes will occur because of overwhelming political pressures. However, USAID, with its long and extensive development experience, should have ensured that the questions of labor tradeoffs and returns, needed infrastructure, nutrition and health were sufficiently considered.

It is apparent that the following assumptions as given in the Project Paper were not valid:

1. Animal traction would decrease labor requirements on traditional fields so labor would be utilizable for paddy rice.

2. Farmers would make their own management decisions.

3. Small irrigated areas would be supplemental to the

traditional rainfed culture and would not be restricted by labor availability.

In large part, this was due to the fact that the inputs of technical assistance in rainfed agriculture and animal traction equipment were not provided by the project. This seems to reflect seriously on USAID's program and/or project management. The problem of French speaking expertise availability in rainfed agriculture is recognized. However, this problem should not be allowed to eliminate access to the technical expertise in appropriate rainfed cropping available in the Great and Southern Plains areas of the United States.

Interim Evaluation Team Findings

A three member team comprised of Dr. Ronald Curtis, an agronomist, Mr. John Wetson, an agricultural engineer, and Mr. Richard Miller, a sociologist, evaluated the Bakel Irrigation Project in the Spring of 1980. This evaluation was done as part of the "Joint Assessment of U.S. Assistance Programs in Senegal" by USAID and the Ministry of Planning and Cooperation, GOS, dated March 1980. Their findings, as summarized in the Joint Assessment Report (pages 6-9) are presented below. We generally agree with these findings, although our emphasis differs considerably, especially in the areas of labor shortages and social conflicts:

> "The (Joint Assessment) evaluation team concurred with the basin water-control and self-management themes of the project. It found that the project was strongly supported by the farmers. This was substantiated with precision by the beneficiary study which found a strong desire on the part of the local population to continue with the project.
>
> Despite variations between the two dominant ethnic groups in the area, the survey found that between 40 percent and 68 percent of those surveyed had registered a subsistence consumption surplus and between 7 percent and 23 percent a marketable surplus. This marks a significant achievement in the two years in which the project has been active.
>
> Along with general support for the project, however, the beneficiary survey revealed strong criticism of various elements of project support. A large number of farmers, including a higher proportion of women than men, criticized the high price of inputs, the difficulty of

procuring inputs when needed, as well as the failure of their pump units and irrigation systems to reliably and completely serve their fields.

The evaluation team generally concurred in these criticisms. The team noted serious implementation problems and below optimum production. The team concluded that shortfalls in productivity and hectarage were primarily the result of failures of the implementing agencies to deliver technical assistance and materials in sufficient quantities and at appropriate times. The team therefore recommended that no further expansion of the perimeters should be attempted until these essentially institutional problems could be rectified. Otherwise, more sub-optimal perimeters would be created, to the loss of potential high productivity.

Among the serious deficiencies the team noted was the poor quality of SAED's topographic and pedological studies, a key part of laying out the perimeters. This initial problem was compounded by construction activities proceeding without reference to the studies and without consistent technical control and supervision. The team further found that technical packages (including improved seed, insecticides, fertilizer, herbicides and recommended cultivation techniques) have not been developed and disseminated. This is a joint function of SAED and of ISRA, the government's agricultural research agency.

Training was found to be another serious project shortcoming -- both the training of SAED project staff and of the farmers themselves. Existing project funds for training have been underutilized and are, in any case, insufficient. The evaluation team found that there is not sufficient trained SAED staff to do basic engineering work before the construction of a perimeter. In addition, there are inadequate numbers of SAED personnel to train farmers in water control techniques, pump maintenance and horticultural practices. This training could have an immediate effect on higher production, as the farmers are the first to acknowledge. As a consequence of the lack of training, farmers are dependent upon SAED to help with pump repair. Since this help is unreliable, farmers complain about their inability to consistently increase production to meet the high cost of inputs.

The evaluators found it difficult to make any definite quantified statements about the cost effectiveness of the project. They also found that lack of data made it difficult to assess what increases in productivity may have occurred, whether of food or cash incomes. Farm level records do not exist; therefore, the computation of charges in net income for representative farm budgets are not possible. Nor was SAED able to provide current figures on perimeter indebtedness. Even given this data, however, the team considered that the constant unrecorded flux in such critical economic indicators as fertilizer and seed costs, fuel consumption, labor and productivity would make conclusions based on the data open to question.

This lack of adequate data has three important consequences. First, at the project level, one cannot be sure that the project's rate of return is competitive with other alternatives, such as dryland farming or animal husbandry. Second, because farm-level data is of primary importance in identifying factors which unnecessarily increase costs or restrain production increases, it is difficult to develop and recommend technical packages with any assurance.

Finally, at the perimeter level, the lack of simple farm records renders farmers extremely vulnerable, since they cannot be sure of their indebtedness nor of the wisdom of individual crop choices. Their ability to manage their own plots is thus limited.

Management problems affected the project as a whole. The Evaluation found that there is serious confusion over the respective roles of the expatriate advisors, the AID Project Manager, the SAED Project Director, and, in the health sub-project, the health program staff. Lines of authority are mixed. It is not always clear who is in charge and who should be carrying out which tasks. USAID has served as a source of funds, but not as an active participant in the continuing development of the project. Expatriate staff, supplied by AID, work with SAED and are thus viewed as representatives of SAED's policies and practices. This perception has too often compromised their value as technical experts, lacking the independence in some situations to make direct technical recommendations, based on their own training and experience.

Progress in implementing the perimeters program has been considerably retarded by the inability of both USAID and GOS to speed up equipment procurement processes and the placement of field technicians. Commodity procurement on both sides is laborious, complicated, and slow. Likewise, AID staff recruitment process, which failed to provide experts at a crucial point to assist SAED personnel in perimeter layout. As a partial result, the farmers went ahead on their own with perimeter construction, causing substantial engineering problems.

In summary, the evaluators emphasized the prototypic nature of the Bakel small perimeter activity. 'The benefits from the project will come, not from the few hectares brought under irrigation during the life of the project, but rather from replication of a refined system of irrigated agriculture in later years. The present state of the art, as currently practiced in Bakel, with high costs and low yields allows insufficient margin for error and runs the risk of being rejected by the producers unless efficiencies are produced.'"

General Project Needs

In the Bakel Region farmers individually and/or through their cooperative organizations have demonstrated ability to take up new agricultural technology. They are depending on SAED to either provide (or be the catalyst for the private sector to provide) a stronger service role in terms of pump maintenance, irrigation system design and procurement and land development.

In order for integrated agricultural development to take off, SAED must also provide a more innovative and progressive role in assisting with: labor saving strategies (such as animal or machine mechinization); improved and more finely tuned crop production practices; new crops for better utilization of land, water and labor resources; better seed production and dissemination; and training farmers in farming techniques, machinery and equipment maintenance and accounting practices. In addition, SAED should be cognizant of credit, marketing, transportation and communication needs.

The role of USAID is to assist SAED in the above endeavors. The Conclusions and Recommendations section presented at the beginning of this report gives some of the ways which we as advisors are suggesting that USAID assist SAED with these tasks. We realize that USAID's direct help may be required to achieve necessary short term impact; but we also know that AID will not be able to handle the expanding program immediately and that AID will eventually pull out. Therefore, for the long range success of agricultural development in the Bakel Region, USAID must insist on training SAED counterparts to not only expand direct help efforts, but also be able to carry on in the future.

GENERAL SOIL-CROP-WATER MANAGEMENT

An overview of how the technical support and extension of the Bakel Project area is supposed to operate was not obtained beforehand; therefore, it was difficult to evaluate benefits, detriments or constraints in the agronomic and soil systems. The subject area is thus discussed simply on the basis of what was available to or accepted by the farmer. Whether the lack of needed inputs is due to system constraints as a result of USAID, ISRA or SAED policy is not clear because the design of the overall system is not clear. For example, we were unable to obtain a clear picture of how the SAED system was supposed to operate, let alone what other constraints might be operating.

The general description of agronomy and soils as given in the original Project Paper is reasonably complete and very little can be added based on a short visit to the area. However, project planning and management processes are restricted by lack of data on crop moisture availability based on rainfall probabilities and moisture budgets of different soils, crops and seasons. The major limiting physical factor for increasing production in the Bakel area is water, but definite information on soil-crop-water interrelationships is seriously deficient in the project area. USAID should provide more guidance and support to analyze existing weather, crop and soils data and obtain better and more complete data to develop production surfaces for a number of crops. Increases in production must be substantial and essentially risk-free in order to provide sufficient incentive to be adopted by farmers who must see immediate benefits and be convinced of continued progress.

Soils

Most of the soils we sampled in the perimeters were very similar and quite uniform and conformed to the descriptions given in the Project Paper. Surface textures of the soils planted to rice were generally sandy clay loams with generally heavier sandy clay loam to clay loam, and occasionally, silty clay loam subsoils. Clay contents in general ranged from 25-45 percent and did not appear to be the expanding types. In some of the areas closest to the river they were much sandier and variable, which makes them more suitable for sprinkle than surface irrigation. In order to properly design an irrigation system, detailed soil surveys should be conducted with necessary soil characterization of each perimeter.

Canal leakage appeared excessive in many cases and in several cases subsurface seepage to the river bluff appeared to be "irrigating" recession crops along the river bank. In general, the soils are excellent for irrigation, except that canal and deep percolation losses are probbly greater than expected. Thus, their suitability for different crops would be more limited by the cost of pumping water than by inherent soil characteristics. The soils tend to crust, which reduces the infiltration of rainfall unless corrective measures are taken.

Overall, a more complete physical and chemical characterization of the soil is necessary before necessary levels of inputs and probable water losses can be estimated for a more valid economic analysis.

Climate

Good, extensive and reliable historical and current meteorological data is essential for technology transfer needed for agricultural development in semi-arid regions. We visited three meteorological stations in the Senegal Valley, and none were being operated well enough to instill confidence in any data collected.

In other areas of Africa, indications are that the severity of drought has quite likely been worsened because of poor agronomic and range management. That this may also be true in the Bakel area is apparent from Table 1. If a dryland crop of sorghum, millet or peanut were planted in July, the most critical month of moisture stress would probably be August for maintenance of the crop and September for drastic yield reductions, particularly for short season varieties. Anything above 90 mm in August should be sufficient to maintain the crop unless it comes in one or two rains. From Table 1 it can be seen that there was less than 90 mm of rain during August in only one out of 14 years of record. In only 3 out of the 14 years would the short fall have been sufficient in September to drastically reduce yields. Table 2 shows that in at least 6 of 10 years rainfall in July, August and September should be sufficient to provide reasonable to good yields of traditional rainfed crops. However, if we look at the data for October we immediately see the problem of late plantings or long season varieties. Obtaining short season varieties with acceptable quality and yields should be the highest priority for rainfed crops.

The evapotranspiration of any crop, ETP (crop), can be estimated by:

$$ETP\ (crop) = Kc \times ETP\ (gross)$$

Table 1. Monthly Rainfall in mm at Bakel (1966-1979).

Year	Jan-May	Jun	Jul	Aug	Sep	Oct	Nov-Dec	Total
1966	-	111.8	120.5	153.1	220.7	92.6	3.6	702.3
1967	6.9	92.0	168.7	384.8	227.7	19.9	2.6	902.6
1968	13.5	36.7	287.3	96.0	79.6	5.3	-	518.4
1969	0.8	41.4	156.9	166.9	84.8	131.6	-	582.4
1970	0.4	82.8	96.1	188.0	88.9	.5	-	456.7
1971	-	47.4	133.4	196.7	151.4	5.7	6.0	540.6
1972	36.2	43.7	45.4	130.0	123.7	15.1	-	394.1
1973	1.2	37.0	147.9	146.2	56.0	7.5	-	395.8
1974	-	49.0	182.9	273.4	114.0	62.2	-	681.5
1975	0.3	21.3	349.7	138.8	100.7	56.3	-	666.1
1976	2.7	21.3	85.5	128.6	49.3	32.2	1.1	320.7
1977	17.0	40.7	73.7	33.3	234.3	1.0	-	391.0
1978	4.5	39.0	122.1	139.4	195.1	29.4	34.7	564.2
1979	11.9	33.9	151.4	139.5	54.6	13.8	4.0	409.3
Avg.	6.2	49.9	151.5	165.3	127.2	33.9	3.7	537.7

Table 3 gives seasonal average and peak month, kc, values for various crops of possible interest for the Bakel area. Based on computations of ETP (crop), it is apparent that rainfall comes close to meeting crop requirements from July through September. Under good on-farm water management and low system losses (sprinklers would provide the lowest practical losses), pumping requirements should also be minimal during the normal season of July-September in 6 out of 10 years even for a well irrigated corn crop.

The substantial savings in water use and resultant pumping costs made possible by short season varieties is evident by the drastic increase in pumped water supply needed for October and November for long season varieties or late plantings. Assuming that the severity of hot winds in April and May is as bad as we were told (no solid meteorological evidence was supplied), March through May should probably be restricted to crops with drought tolerance that can be irrigated at levels which will give less than full production, but probably greater than rainfed. The system should be designed to provide irrigations for corn at sufficient levels for full production during the November to February period. This would require a maximum of 166 mm/month of pumped water plus enough additional water to offset system losses.

Table 2. Climatic Data and Potential Evapotranspiration, ETP, for Bakel, Senegal.

Month	Average Precipitation (mm)[1]	60% Probability of Precip. (mm)[2]	Average Temperature °C[3]	Est. ETP (Grass) (mm)[4]
Jan	0.3	0	24.4	141
Feb	0.7	0	26.4	145
Mar	0	0	28.8	189
Apr	0.8	0	30.8	198
May	4.4	0	31.9	203
June	49.9	39	30.4	179
July	151.5	122	28.2	160
Aug	165.3	139	27.2	144
Sept	127.2	89	27.4	131
Oct	33.9	14	28.1	140
Nov	2.7	0	27.6	137
Dec	1.0	0	24.2	132
TOTALS	537.7	518		1900

[1]From Table 1. Bakel is located at Lat. 14° 53' N., Long. 12° 24' W.

[2]The 60 percent probability of occurrence or exceedence (that amount equaled or exceeded 60 percent of the time) calculated from Table 1 by mean of the ranking probability distribution.

[3]The average of 30 year World Meteorological Organization data for Linguere, located at 15° 23' N., 15° 09' W., where the average rainfall is 535 mm per year, and for Tabacunda, located 13° 46' N., 13° 41' W., where the average rainfall is 942 mm/yr.

[4]Average of estimates for Linguere and Tabacunda.

Table 3. Some Selected Average Seasonal and Peak (Full Cover) kc Values for Various Crops.

Crop	Seasonal	Peak
Corn	0.90	1.15
Cotton	0.90	1.20
Peanuts	0.90	1.05
Rice	0.95	1.20
Soybeans	0.90	1.15
Sorghum	0.90	1.10
Tomatoes	0.90	1.20
Vegetables (summer)	0.85	1.15
Sugar Cane	1.00	1.25
Wheat	0.90	1.15
Citrus Fruits	0.75	0.75
Decidious Fruit	0.70	0.90
Decidious Fruit (with cover)	1.00	1.25
Alfalfa	1.00	1.20

Agronomic Systems

Irrigated Crops

Irrigated. Existing irrigation production systems must be improved or serious questions about the economic viability of irrigated agriculture and efforts to develop new projects must be asked. Farmers cannot be expected to make investments in inputs and adopt appropriate irrigation crop production practices if they do not believe that irrigation water will be available on a reliable and timely basis. If existing irrigation does not perform as designed and cannot be improved, it is not realistic to extend the project or design new projects on the same unrealistic criteria. Thus, existing irrigation must not only be improved for the sake of current investments, but also to ensure the economic viability of new projects.

Rice. Rice was the dominant crop seen. Most of the rice looked very good, and in general, good production practices were being followed. Very little of the rice we saw appeared deficient in water or fertilizer, although we suspect that some input cost could be saved by decreasing water application or fertilizer rates or mix.

Flooded rice did not seem to be the most appropriate crop for much of the area because of the amount of water required. There appears to be considerable pressure on the farmers to grow rice and there is a certain resentment on their part that equivalent service and inputs were not provided for other crops.

It should be noted that this emphasis on rice is contrary to the dictates of the Project Paper and is the type of drastic intervention in an existing system that is normally opposed by people involved in agricultural development. It is unbelievable that USAID would condone such an intervention. The high yields achieved are a tribute to the ability of the Senegalese farmers to accept and use new technology. It is also a result of the AID Technical Assistance being heavily involved at the farmer level under adverse conditions of supply and maintenance problems. It is unfortunate that similar assistance wasn't given for other crops, as specified in the Project Paper.

The principal problems we noted seemed to be: unreliability of water supply; lack of a viable seed supply program tied to an effective variety testing program; and poor weed control. Information is also needed on possible tradeoffs between water usage and costs in non-flooded rice production. The amount of area that was not planted to rice because of labor involvement in the rainfed farming would seem to indicate that rice under the existing conditions is quite marginal. Flooded rice should probably be completely limited to the heavier Hollandaise-type soils. Disease and pest problems appeared to be minimal, as would be expected for a new rice area. However, it is quite likely that problems will increase with time.

Corn. Corn was being grown on several of the perimeters and we were informed that several others planned to make major corn plantings during this winter's season. While some of the corn appeared to be an improved open-pollinated variety, it certainly did not receive the types of inputs needed for high yields. It should be practical to double present corn yields of 1.5 to 2.0 T/ha by using improved open-pollinated varieties, adequate levels of fertilizer and irrigation. Under the conditions and soils of the area, with the right inputs corn should yield equal to or 10 percent more than rice under similar levels of management and have lower input costs.

High corn yields in the neighborhood of 6-8 T/ha can only be obtained from hybrid varieties. In order to have hybrid seed available to farmers, a good hybrid seed program is essential. Such a program may be a possibility for the private sector, depending on hectarage projections. A hybrid seed program should not be started, however, unless there is sufficient technical capability projected and the irrigated corn area in Senegal approached the 70,000 ha planned.

The planned reorganization and expansion of research and extension should help greatly in bringing improved hybrid seed corn growing technology to the farmers. Even as an imported input its cost would probably not be greater than the true cost of fertilizer and yield increases would be comparable. The corn marketing base of the grain, green ears or crop residue would seem to be broader than for rice because of possible livestock use. It should also be remembered that if irrigation costs are 35-60 percent of farm costs in rice, the same investment will irrigate a much larger area in corn. We do caution, however, that nutgrass may become a serious problem in much of the area under irrigated corn production.

Grain Sorghum. Grain sorghum was being grown under irrigation to a very limited extent. The few examples we saw were not improved varieties. While the estimated yields of 1.0-2.0 T/ha would certainly exceed those of rainfed, they were far from what would be possible if better inputs and management were made available. Although improved varieties were being tested at Fanaye, they were not available to the farmers in the Bakel region.

Sorghum under good management and irrigation should yield similar to corn with slightly lower input costs, particularly water. It would have the added advantage of being a familiar crop and having a possible future market as livestock feed. Sorghum particularly lends itself as a second or third season crop to make use of residual moisture and fertility from a previous high input crop. It requires minimal supplemental irrigation, resulting in a very high water use efficiency. A seed industry would be important, but hybrid sorghum seed could be produced more easily than hybrid corn seed because of the availability of male sterile lines. (Consumer acceptance would be important for new varieties.)

Other Crops. Millet is not a good candidate for full irrigation. However, it would make excellent use of residual moisture and fertility and with minimal supplemental water, improved varieties would produce considerable grain and/or forage efficiently.

We were informed that wheat was being studied at various locations along the Senegal River, but it was not mentioned at any of the perimeters visited. It certainly merits additional study.

It could substitute for rice at a somewhat lower input cost and could be used as a follow-up second season crop. According to one study, yields greater than 4.5 T/ha after bird and rat damage have been obtained locally.

Vegetables were being grown to a limited extent, but not in an optimal manner. The variety and quantity of vegetables available in the local market was limited, but the local markets could undoubtedly be easily saturated.

Peanuts would do well under irrigation and could be an important rotation crop, as would other legumes, oilseeds and pulses.

Rainfed Crops

Support to the rainfed production in order to improve the probability of farmer acceptance of irrigation was the first priority indicated in the Project Paper. Unfortunately, no serious attempt was made to provide this support. In our opinion, that was a major contributing factor to the lack of success of irrigated perimeters.

Worldwide, the donor community for Africa, Asia and Latin America is coming to the realization that much greater emphasis needs to be placed on rainfed agricultural management. Rainfed agriculture involves more people, greater area and has a greater potential without tremendous capital or technological inputs. It lends itself generally to minimal mechanization, and frequently family labor may improve timeliness of operations without greatly increasing costs. Capital intensive irrigation projects have, more often than not, failed to live up to their projected returns.

An average annual rainfall of 400-500 mm, such as at Bakel, is sufficient to obtain high yields of many crops, including cereals, oilseeds and forages. In areas such as the Senegal River Basin where the rainfall patterns seems to be consistently compressed within the growing season, a rainfall of 90-120 mm/month should be sufficient to obtain reasonable yields. In areas or seasons where rainfall is less, harvesting the rainfall from 25 percent of the area increases effective precipitation on the remaining area by 30 percent, with resulting yield increases of up to 100 percent. Rainfall utilization in the Bakel is probably only 30 to 40 percent, with runoff being greater than 50 percent.

Rainfed cropping systems need to be fairly specific for different areas and based on identification of farmer constraints.

There is a considerable amount of on-shelf technology available that is very pertinent to production systems in arid and semi-arid regions. Use of this available technology require creative and knowledgeable people and close working relationships between the researcher, extensionist and producer. By adopting existing technology, an impact can be achieved much more rapidly. Also, given the constraints of limited qualified personnel, facilities and infrastructure, an emphasis on technical assistance to develop Integrated Production Systems for the area should have rapid payoff.

Studies conducted 10 years ago in eastern Senegal by IRAT demonstrate that good fertilization and tillage practices could increase rainfed sorghum yields by two and one-half times and maize yields by three times. As shown in Table 4, when considering all sites studied, possible yield improvement with improved management is striking. These results have not been extended to the farmer

Table 4. Comparison of Systems of Cropping in Senegal Over All Sites (IRAT, Senegal, 1972).

Crops	Yields Kg/ha		
Pearl Millet	695[1]	1088[2]	1517[3]
Sorghum	975	1642	2166
Maize	436	1308	2573
Rainfed Rice	443	1711	2630
Cotton	1019	1531	2061
Groundnut	1311	1669	1821
Cowpea	653	727	875

[1]Traditional shifting cultivation

[2]Improved shifting cultivation

[3]Semi-intensive cultivation

level, however, and this points out that agricultural research is not complete until carried to the farm. Variety testing must also be carried out to the seed multiplication farms, demonstration farms and on-farm trials.

We inspected sorghum, millet and peanuts under rainfed conditions. The sorghum and millet did not appear to be improved varieties and inputs seemed very low. Yields are generally 0.5-1.0 T/ha at present. Management practices, with improved open pollinated varieties, could improve yields to a considerable extent, probably to 2.0-2.5 T/ha. With short season hybrids and good management, sorghum yields should reach 3-4 T/ha, depending on rainfall.

Demonstration Training Farm

A demonstration farm which could be used for variety trials, new agronomic practices, other management practices and as a source of local data for these items should be initiated in the area, as suggested in the original Project Paper. This would allow the presentation of various practices and production systems without imposing them upon the farmer until shown to be viable. It would also offer a place for training SAED technicians and perimeter leaders, allowing for actual hands-on experience. The farmer organizations should have input in the management of the demonstration farm. The past history of the area would suggest that such a farm, coupled with training and field days, could be a very effective means of presenting new technology and management pracitces and having it accepted by the farmers.

The demonstration farm could present actual examples and/or provide data on some or all of the following for both irrigated and/or rainfed farming:

1. Equipment.

    a. Selection and improvement of hand tools.

    b. Draft animals - training, nutrition, health, types of yokes, harnesses and equipment.

2. On-farm water management.

    a. Farm irrigation system design and management including: control structures and leveling; effect of application rates; timeliness of applications; and methods of application.

b. Water harvesting, micro-catchments.

3. Soil management, including: soil-water relationships; tillage practices for seeding and weed control; residue management for infiltration; and fertility management.

4. Weather data collection and analysis.

5. Agronomic management.

   a. Plant-water relationships, including: water-yield relationships; production per unit of water; and cost per unit of water.

   b. Crop systems and variety selection-testing for season length, yield, drought-tolerance and pest resistant of the following crops: rice, corn, grain sorghum, dual-purpose sorghum, vegetables, oilseeds, pulses and forages.

   c. Planting patterns, including: population, row spacing, seed distribution and seedling emergence.

   d. Mixed cropping such as sorghum/millet with cowpeas/peanut.

   e. Economics of rotations such as legumes as a source of nitrogen, high inputs for cash crops and use of residual inputs by succeeding food crop.

   f. Labor availability, efficiency and input requirements.

   g. Weed control through rotations, mechanical and chemical practices.

   h. Control of diseases, insects and birds by using different rotations, planting times and chemicals.

6. Grain and seed storage, including: drying techniques, structures and insect control.

7. Marketing for profit maximization and risk minimization.

8. Integrated crop-forage-livestock systems using cereals, legumes, tame and native grasses; plus harvesting, grazing and storage.

Illustrative Examples of Management Practices

Irrigated Farming

For flooded rice the pumping capacity must be based on water needs without rainfall because rice can not tolerate water deficits very well. To expand the area flooded rice requires increasing the pumping capacity proportionally. If a crop mix is planted which includes a crop that can tolerate water deficits, much greater flexibility is available regarding pumping capacity and area expansion.

Flooded Rice		Corn		Corn		Sorghum
20 ha	=	30 ha	=	20 ha	+	20 ha

In a good rainfall year, both would be under full irrigation In a poor rainfall year corn would have priority.

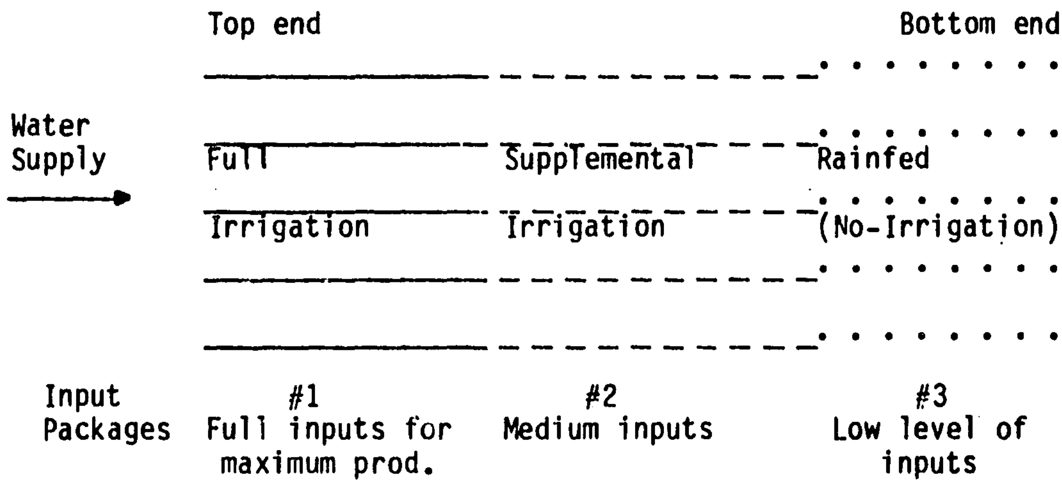
In every season there should be a crop mix involving some crops that can tolerate water deficits without severe yield losses, such as sorghum, wheat and cowpeas, along with the less tolerant but potentially more lucrative crops, such as rice, corn and vegetables.

Possible Crop Mix. One possible irrigated crop mix might be:

	Full Irrigation	Supplemental Irrigation
July-October	Upland rice, corn, vegetables	Sorghum, cowpeas, sesame, sunflower, safflower, forage
Nov.-February	Upland rice, corn wheat	Wheat, cowpeas, sesame, sunflower, safflower, forage
March-June	Sorghum	Sorghum, millet, forage

Combined Irrigated and Rainfed Farming

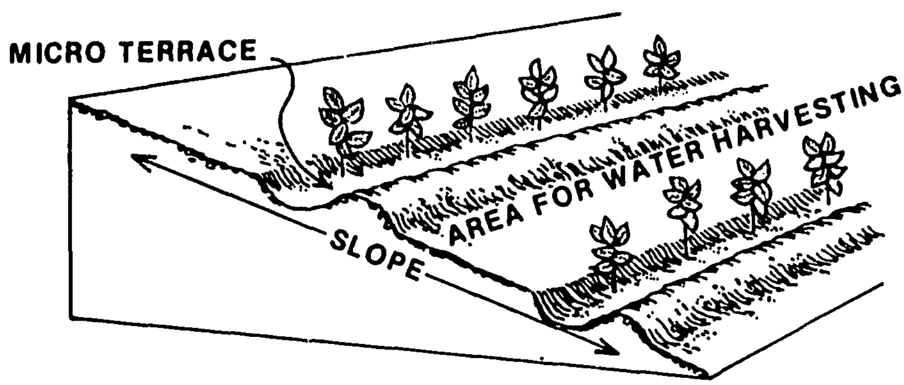
In order to prevent runoff and obtain better utilization of unexpected rainfall, a system can be designed to make full use of pumping capacity and obtain very high efficiencies of water use. To achieve this, the crop must be planted in rows across the slope with very little drop and irrigated from one end. Irrigation is supplied so tht the top ends of the rows receive full irrigation, but the irrigtion water does not reach the bottom ends as shown below:



The location of and the amount of water supplied to the supplemental irrigated area depends on the rainfall for that season.

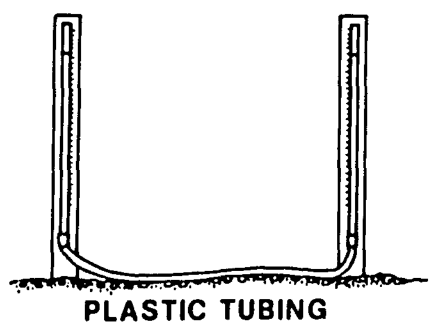
Rainfed Farming

For successful rainfed farming it is important that rainfall percolates into the soil close to where it falls and be stored for future crop use. Rainfall in the Bakel area is intensive and the soils tend to seal, so the water must be retained in order to have time to soak in or it will run off. Large level furrows constructed across the slope (on the contour) are a convenient and simple means of preventing runoff. The spacing between furrows can be adjusted to allow for optimum water harvesting as determined from field demonstration studies. The crop should be planted along the bottom and sides of the furrows, as depicted in the sketch below:



The furrows must be started at the top of the slope to prevent erosion of the lower rows. The furrows which act as micro terraces do not have to be remade every year, but simply maintained. Thus, each year a new area can be added to the total.

Farmers can lay out their own level furrows or micro-terraces using the following simple technique:



Two stakes or poles with scale.
Plastic tubing with water.

Inspection of Fish Pond Site

There is an interest in utilizing the irrigation pumping facilities to supply water for village fish ponds at the various perimeters. Peace Corps Volunteers (Andrea Hough in the Bakel Region) are providing technical fisheries assistance to the villagers. We were asked to evaluate the proposed site for a group of three demonstration fish ponds near Bakel. The site is close to the Senegal River, but there is a slight secondary depression between the site and the river. The site lies between the river and the proposed La Calanga perimeter, and the main canal serving the perimeter can also be used to carry water for the ponds.

Fish Pond Soils

The soil at the site is a sandy clay loam with a clay content of 20-25 percent near the surface grading to 30-35 percent below 0.5 m. It would be preferable to have both a higher clay content and expandable clay; however, percolation rates at the site will not be excessive and water losses should be manageable.

Percolation data should be accumulated and several different procedures for sealing the ponds tried and evaluated. The information obtained will provide data for developing design and construction procedures to use when expanding the program.

Pond Construction

Since the ponds will only be partially excavated, with dikes constructed to provide the required depth, it is very important that the dikes be compacted and sealed as well as possible. The dikes should be constructed in 10-15 cm layers, wetting and compacting between layers. Dike compaction using machinery, animals and hand labor should be evaluated. A heavy pole with a 10 x 10 cm base attached would make a good tool for hand compaction. After a pond is built, clay (from the swamp area) and manure should be incorporated into the surface 5 cm of the bottom and sides up to the expected full water level, then wetted to a depth of 10 cm and compacted. Wetting and compacting should be repeated several times. Different numbers of wetting and compaction cycles and the incorporation of different amounts of clay/manure should be tested for percolation losses to evaluate the effectiveness of the sealing procedures.

Animals (sheep, goats, cattle or donkeys) could be penned in the pond as one means of compacting the sides and bottom. Wetting the surface and penning the animals could be repeated over several days, as needed. The surface could then be packed smooth using hand tools.

Conclusions

Following are conclusions related to soil-crop water management for the Bakel Project Area:

1. The natural resource potential in the area is impressive.

2. The Project would have been more successful if the original Project Paper had been more closely followed.

3. Significant crop production increases are feasible without large capital investment.

4. Actual production growth will be determined by the crop pricing and marketing policies.

5. There is insufficient adaptive research information available for carrying out a viable irrigated and rainfed agricultural development program in the Bakel area.

6. The level of qualified human resources and the governmental institutional structures necessary for a successful project are limiting.

Recommendations

The following recommendations are made relative to the above conclusions:

1. Set up a demonstration farm for the Bakel Region. Advice from local farmer organizations should be sought in the design of the farm and some recommended actions are:

    a. Hire someone (possibly from Sine-Saloum area) with draft animal experience to live at Bakel and work with oxen on the demonstration farm.

    b. Work out (contract) with CRSP (sorghum/millet) to place a graduate student on the farm to conduct variety trials -- both irrigated and rainfed.

    c. Ask for a small team to design demonstrations for the farm under the USAID centrally-funded Dryland Agriculture Management Project.

    d. Ask each village to send an individual to stay and work at the demonstration farm each season.

2. Work out a long term program with USAID/Washington (S&T/AGR/RNR) or a university to provide recurrent technical advice in water management, both irrigated and dryland. Having the same professional technical advisors returning to the area for perhaps 10 days during each growing season would provide continuity of technical

advice and problem solving, plus give help to professionals and sub-professionals, including SAED, USAID technical staff, Peace Corp volunteers and AID Project Managers.

3. Work (contract) with Peace Corps to provide volunteers with sorghum, rice or irrigation experience for several of the villages.

EVALUATION OF RICE PRODUCTION ON THE PROJECT AREA

In the past few years rice production in the area of Bakel, Senegal, has increased from a few tons produced by traditional agriculture to the production of enough rice by the villagers for their own consumption with some left over to use as the farmers think best. The reasons for this expansion are many and complex because they are associated with the social structure of the area. Some of the most important factors which made it possible for the farmers of the Bakel area to increase rice production were:

1. These farmers are a hard-working, clever people who have a strong desire to improve opportunities for their sons to remain in the area when they become adults. Presently, many of the young men must emigrate in order to earn a living. Most send money home to help support their families and their villages.

2. Irrigation water has recently been made available to farmers living in villages near the Senegal river and its marigots. Rice has a high water requirement. In this area it is doubtful that rice, even the upland varieties, could be produced economically without irrigation. Irrigation was not introduced into the Bakel area by SAED. It was brought to the area through the initiative of local farmers before the present project was started. However, the farmers were not particularly interested in using irrigation to produce only rice.

3. The farmers were quick to learn how to use irrigation water wisely. For example, in many rice-producing areas where water is abundant it is customary to keep a substantial flood on the crop to control weeds. Many of the Bakel area farmers will not keep their rice flooded, but will only flood the field often enough to prevent moisture stress and depend on hand-weeding to control the weeds. A number of rice fields were observed in which the soil was approximately at field capacity, but there was no evidence of yield reduction due to moisture stress as a result of the farmers not knowing when to flood the fields. Apparently, SAED technicians did not recognize this problem and left the farmers to work out a solution for themselves, which they did very effectively.

4. The farmers were quick to learn which fields used more

water. Rice was moved to the heavier soils, and the light soils with higher infiltration rates were used for irrigated upland crops which have a lower water requirement than rice. A good agricultural technician with a knowledge of the soils of the Bakel area and a general soil map showing infiltration rates could have saved the farmers the expense of going through the laborious task of locating the soils best suited to rice production by trial and error. However, neither technician nor soil map was made available and the farmers were again forced to depend on their own resourcefulness.

5. Technical assistance and some advise was made available to most farmers. A program of providing assistance in obtaining pumps, fuels, pump repairs, seed, fertilizer, agricultural chemicals and advice for different production practices was initiated by the joint efforts of SAED, and USAID. Even though the SAED assistance was erratic and often undependable and the technicians were poorly trained, if trained at all, rice production was expanded through the efforts of hard-working, determined farmers.

   During the past two years Dr. Khoi N. Le, a USAID employee, has spent a considerable amount of time training SAED technicians of the Bakel area in current rice production practices which are suitable for local conditions. There was evidence that some of this technology, such as the standard fertilizer recommendation, had reached some of the farmers. Whether this was because of the efforts of SAED technicians, Dr. Le's many visits to the farmers' fields, or both, is difficult to say.

Observations

While traveling for several days by land and one day by boat to visit most of the irrigated perimeters of the Bakel Small Irrigated Perimeters Project, team members made a number of observations regarding rice production. A few general comments are reserved until last.

Rice Production

For the purpose of organizing the information most of these observations are presented in the order that they would occur during the production of a rice crop.

Land Preparation. In the Bakel area almost all land is prepared by hand labor using a short-handled tool called a "daba." Two-wheeled Korean-produced farm tractors were seen, one at the Balou perimeter and one at the SAED headquarters in Bakel. Both were inoperative for want of a spare part. The need to assist these farmers with less labor intensive land preparation methods stands out sharply.

Varieties Planted. The two major rice varieties produced in the Bakel area are Jaya and Ikongpao. Jaya is a long grain high-yielding variety requiring a growing season of about 146 days. It has no disease or insect problems and the grain has an excellent cooking quality. One disadvantage is the long growing season which requires more irrigation water. Ikongpao is a short grain drought-resistant variety which requires a growing season of about 120 days. Because of the drought resistant quality it tillers better and produces more rice on light soils. The short growing season requires less irrigation water. Some disadvantages are that this variety is susceptible to blast, bacterial leaf blight and a smut fungus called dirty panicle. The grain is hard and has a poor cooking quality which local people do not like, according to Dr. Koi N. Le.

Seed Source. Only two varieties are produced because good quality, weed-free, pure seed of other adapted varieties is difficult to obtain. Apparently, other more promising varieties are being tested at the experiment stations, but not in the local area where they must be proved. There is also a considerable waiting time (approximately three years) to receive foundation seed of a released variety from WARDA (West African Rice Development Association). Suggestons for improving this situation are made in the recommendation section.

Of the two major varieties, farmers save some seed from year to year and buy some from SAED. Those sold by SAED are produced under some sort of controlled supervision. It was not possible to locate anyone responsible for maintaining seed purity in order to get a description of the system used. There seems to be a serious shortcoming in the ability of the seed program to provide enough good-quality seed and enough varieties for the farmer's needs.

Planting Methods. Rice planted by four different methods was observed: direct seeded in a row by hand; direct seeded broadcast in the mud by hand; direct seeded in a row with a small two-row mechanical seeder which the farmer pulls; and transplanting. We did not learn the reasons for so many different methods. In some cases it is a matter of personal preference. Transplanting is used as a means of getting the rice ahead of the weeds. Because of the labor-intensive nature of transplanting, a detailed experimental comparison between direct seeding and transplanting is recommended.

Fertilization. Some variation in fertilization practices was reported by perimeter presidents and farmers. Most of the people that we questioned said they were applying approximately 150 Kg of 18-46-0 per hectare just before planting, 100 Kg of urea per hectare at about 30 days and again at 60 to 70 days after planting. This is a standard recommendation for the area. The reported use of potassium fertilizer (KCl or 0-0-60) was not as consistent. Only a few fields in the Bakel area appeared yellow and unhealthy as a probable result of applying too little fertilizer or applying the fertilizer at the wrong time.

Irrigation. Most rice that we observed in the Bakel region was not grown under a continuous flood. Probably due to the high cost of irrigation water, the farmers could not afford to run the pumps long enough to maintain a continuous flood. However, we observed no moisture-stressed rice except where pumping plants had broken down. The farmers are to be commended highly for devising a scheme to irrigate their rice before a yield loss is suffered due to moisture stress.

During our field tour we visited other production areas for comparison. All rice fields observed at the Dagana Large Mechanized perimeter were flooded. The director at Dagana estimated that the farmers maintained a 5 to 10 cm flood from the time the rice was tall enough to take a flood until maturity. The farmers pay a flat rate for water used during each season and thus have little incentive to save water. The rice at the Compagnie Sucriea Senegalaise at Richard Toll also had a continuous flood. The manager said that they had not determined the unit cost of the irrigation water they used.

Weed Control. Most weed control in the Bakel area is done by hand weeding. Very few fields had a serious weed problem. Some areas had a few grassy weeds and some had a few broadleaf weeds. None had a serious problem with both. Red rice is the most serious weed that was observed. The areas of red rice infestation are small now but have a potential for spreading rapidly.

Transplanting is used as a method to get a rice crop ahead of the weeds. The Compagnie Sucriea Senegalaise at Richard Toll was using propanil to kill Cypress weed and a grassy weed which is called Barnyard grass in the United States.

Insect Control. No insect problems were observed or reported in the Bakel area. We did observe a few pruned roots which appeared to be the work of the rice water weevil larvae, however, we were never able to find a larvae or an adult water weevil. The plants did not appear stunted from excessive root pruning. The manager of the Compagnie Sucriea Senegalaise said they had a few stem borers, but the damage was insignificant.

Harvest Method. Harvest of the west season crop was just beginning and it was only possible to observe one field being harvested at the Moundery perimeter. This rice was being cut in the water at a height of about 5 cm. It was being harvested in the water because the surrounding fields were not mature and the farmer could not drain through them. The bundles of rice were laid on the levee to dry. At the Yafara perimeter it was reported that the rice is cut at about 5 cm and the stubble used to feed the animals. After cutting the rice it was left to dry in the sun and threshed by beating.

Drying and Storage. Drying does not seem to be a problem since it is done in the field by the sun. The mud and stick grain bins found in most villages appear to be well constructed with a foundation sufficient to handle a considerable load. The loss from decomposition, insects and rodents is probably high.

Hulling and Milling. Women and young girls of the villages hull and mill the rice by pounding it in a wooden mortar and pestle. This is a very inefficient method which results in a substantial loss and a high percentage of broken grains. A small rice mill could serve each village well and provide employment for a few people.

Marketing. Marketing seems to be the limiting factor for rice as well as all other crops. In order to insure a steady increase in food production, a system must be devised which will allow all farmers to make a reasonable profit from their efforts.

General Observations

These general observations concern rice production at the Bakel perimeters along with observations made during our tour of other areas along the Senegal River.

Yield Estimates. Mr. Amadou Cisse, Assistant Director of SAED at Bakel, estimates that the current crop will yield from 3.5 to 7 MT per hectare. From the fields observed, yields should range from less than 2.5 to 7 MT per hectare with an average for the Bakel project of 4 MT per hectare. Mr. M. Keita, USAID agricultural economist, calculated the yield estimates presented in Table 5

Table 5. Rice Yield Estimates Based on Field Sampling for the 1981 Wet Season Crop.

Perimeter	Type of Field	Variety	Yield Estimate (Mt/Ha)
Yafara	Collective Farm	Diara*	3.15
St. Diali-guel	Farmer	Local (yellow) retained seed	2.23
Moundery	Farmer	Jaya	6.41 average 8.00 good irrigation 4.80 poor irrigation
Seling	Farmer #1	Ikongpao (IKP)	7.20
	Farmer #2		6.00
			6.60 average
Average			4.60

*A new variety from a SAED multiplication field.

based on a 5 square meter sample of rice from several perimeters. These field estimates indicate that a profitable rice crop can be produced.

Demonstrations and Communication. Very little communication was found to exist between research, extension and the farmer. Researchers need to make an occasional visit to a farm. That is where the problems are. Apparently, there exists a considerable amount of research data which is not made available to the farmers.

Colanga de Bakel is a new perimeter which will be developed near Bakel. USAID and SAED should try very hard to recognize the mistakes that were made at other perimeters and take precautions to see that they are not repeated at this new perimeter. This would be a good site for a research-demonstration farm.

A few new varieties are being tested on a large field basis. This practice does not provide a basis for making dependable comparisons and should be replaced by small plot replicated variety trials. The variety KISS which is grown at the Dagana perimeter should be evaluated immediately in the Bakel area. No on-farm general agricultural research was found for either rice or other crops. There is even more need for this type of research-demonstration for rainfed and other irrigated crops than for rice.

At the beginning of the Bakel project it is reported that many farmers felt that the government was using SAED to force them to grow rice. This feeling does not seem to be as strong now as it was reported earlier. SAED does not make an effort to prevent the farmers from growing irrigated other crops; however, their main technical support is for rice production.

Large Mechanized Perimeters. At the large mechanized perimeter visited at Dagana, the rice was well flooded because the farmers paid a flat rate for the irrigation water. A few fields were carrying a heavy crop with a high-yielding potential. The remainder had a very poor appearance. The director at Dagana reported an average yield of 3 T/ha. He thought that SAED should make land preparation a groupment or individual responsibility and limit water use to provide incentive for higher yields and better water use efficiency.

One possible solution to the rice shortage in Senegal under consideration is to allow a private company to develop a large area for rice production. However, a serious effort should be made to evaluate the economic and social effects of this type of development as compared to devising a means to give the small rice farmers a profit incentive to increase their production. Before authorizing a large-scale rice production scheme by a private company, the Senegal government should have a complete understanding of the influence of such a project on its people and be sure that their best interest is being served.

Recommendations

The following relatively detailed set of recommendations is given to provide guidelines for developing the agronomic portion of viable and expanding rice farming along the Senegal River.

Red Rice Identification and Control

An intensive program should be started immediately to teach each SAED and USAID employee working with rice how to recognize and control red rice. Red rice control is very simple. The red rice plant must be pulled up, removed from the field and destroyed immediately because the seed can germinate at a very early stage of development.

Red rice is such a serious weed in rice fields that it is often thought of as a different problem than other weeds. It is very closely related genetically to most domestic rice varieties. For this reason it is very difficult to detect until after heading when there is little time to remove the plant before the loosely attched seeds fall to the ground. Farmers must be taught that red rice is a serious weed. If a field becomes infested with red rice it can be a problem for many years. Some Louisiana rice farmers have cultivated fields deeper than usual (to a depth greater than four inches) and brought red rice seed to the surface which germinated after being buried 30 to 50 years.

In the Bakel area red rice was observed in two fields and reported in others. This serious problem is a direct result of a poor or unenforced inspection policy in the seed rice program. The origin of the red rice must have been from seed produced in another area since rice production is relatively new to the Bakel area. This very serious problem will become unmanageable if left uncontrolled for three to five years. By this time, if no control measures are taken, most fields will become so contaminated that it will be necessary to fallow or divert them to a dryland crop for a few years.

As a specific example, if the red rice in the fields that we observed is not removed and destroyed completely, the next rice crop on those fields will have a sixty to ninety percent infestation. Average yields will be reduced from approximately 4.5 MT per hectare in 1981 to 1 MT per hectare in 1982. It is possible for a field to become so heavily infested that the few remaining heads of domestic rice are not economic to harvest. Red rice reduces yields drastically because the grain shatters and falls to the soil surface before it can be harvested. It makes no contribution to the yield while producing a fifty to one hundred fold increase in seed which will infest the following crop. During the growing season a red rice plant will use approximately the same amount of water and nutrients as any domestic variety.

Rice Seed Production

The seed rice production and distribution program should be improved immediately. Very little evidence was found to indicate that a dependable, controlled source of good-quality, weed-free seed was available to the farmers. Because of problems which were not readily obvious, the present program does not seem to be serving the needs of the farmers. Only two varieties of seed appeared to be readily available to most farmers. Failure to provide farmers with an adequate supply of good-quality, weed-free, pure seed will result in an infestation of weeds, especially red rice, that will become increasingly difficult to control. As farmers are forced to save seed from year to year the purity of each variety will diminish to a point where it will lose its original yield potential.

It should be most useful for the key personnel of the seed production and distribution program in Senegal to visit the United States and observe the seed programs in each of the rice-producing states and to visit the Mississippi State University seed technology laboratory at Starkville. It should also be helpful to obtain consulting help to evaluate and reorganize the rice seed program in Senegal. This consultant should be the person who is responsible for the U.S. program the key personnel feel is best suited for Senegal.

A foundation seed production farm should be established or the present farm should be reorganized. In addition to foundation seed production, the manager of this farm should also be responsible for screening new varieties for adaptation to local environmental conditions by conducting a series of variety trials on the seed farm and in each rice producing area. The manager should have enough background in genetics to understand how a new variety is developed. This is essential if he is to have responsibility for maintaining purity of each variety. He should have had a fair amount of previous experience with a proven record of being a careful manager and a firm supervisor of employees.

One approach to operating the seed program might be:

1. The manager secures a supply of breeder seed and plants them on the seed farm.

2. The foundation seed produced from this planting is sold to farmers who qualify as good seed producers for the production of registered seed which the farmer can sell at a premium to his neighbors.

3. If demand is great enough the program can be carried one step farther and a qualified farmer can plant registered seed and produce certified seed which can also be sold to his neighbors for a premium. Strict control of each seed rice producer is maintained by the manager of the seed farm through inspectors, who inspect each seed rice field for off-type varieties, red rice and other weeds. The inspectors report directly to the seed farm manager, who will either approve or disapprove each field on the basis of each inspector's report. Certified seed should not be produced unless there is a strong demand for it.

A dependable source and varied selection of good-quality, weed-free pure seed of well adapted varieties of all crops is essential if farmers are to improve production. However, we saw no evidence of a dependable source of good-quality seed for any crop varieties. Thus, a similar program should also be initiated for improving the availability of good-quality seeds for a number of other crops.

Labor Reduction

A program should be implemented which will encourage farmers to invest in simple hand or foot operated implements such as threshers, seeders and weeders. The amount of labor which these farmers must do to produce a crop could be reduced considerably with a relatively small investment.

Transplanting Rice. Considering the rather severe labor constraints discussed elsewhere in this report, transplanting rice does not seem practical. A formal experiment should be designed to compare direct seeded to transplanted rice. In addition to comparing yield differences, the results of this experiment should be complete enough to compare the economic and social effects of these two methods of planting rice. All related information should be recorded.

Ratoon Rice Crop. Farmers should be encouraged to produce a ratoon rice crop. Since most farmers find it difficult to produce a second crop of rice, perhaps a ratoon crop would be desirable until conditions are favorable for a second rice crop to be profitable. A ratoon crop can produce from one-third to two-thirds of the original crop with only a minimum input of water and nitrogen fertilizer. Researchers at the Richard Toll experiment station should conduct experiments to determine the most economic method of producing a ratoon rice crop. After a practice is perfected, it should be demonstrated widely on farmers' fields. In the meantime, farmers should leave about 20 cm of stubble, apply 100 Kg of urea per hectare and reflood the fields as soon as the first crop is harvested.

On-Farm Studies

Variety Trials. A series of on-farm variety trials should be organized to provide information for key producing areas. A few of the most promising varieties of rice, corn, grain sorghum and millet should be tested immediately on a number of farms in areas such as Bakel where the information is needed the most. This should be a cooperative effort between experiment station researchers, agricultural technicians and extension people. A good field plot design can serve as an effective demonstration and also provide data which can be statistically analyzed and evaluated for research purposes. The researchers should be strongly encouraged to participate in the field work in order to get some first-hand input and opinions from the farmers. In order to make an effective evaluation it is essential that the researchers at least participate in the planting and harvesting of each on-farm variety trial. This program should begin immediately using variety trial results available from current experiment station data.

Water Use. Since rice farmers have already learned how to produce a good crop of rice by intermittent irrigation instead of maintaining a continuous flood, an experiment should be designed to determine if they are using enough water to produce maximum yields or if it is possible to use less water to produce a maximum yielding rice crop.

Soil Map. Prepare a general soil map of the proposed development areas along the Senegal and Faleme river valleys which will include infiltration rates for the major soil types. This information is needed since there are plans to expand irrigation in these regions. Such a map should have been available to those who planned the Bakel project. It may have prevented a considerable number of mistakes in irrigation design which the farmers have had to correct by trial and error.

Fertilizer Recommendations

Refine the fertilizer recommendations for rice. It is possible that the standard fertilizer recommendation for rice is too high in some cases, and perhaps it is not high enough in others. If the recommendation is too high and if the Senegal government discontinues the policy of subsidizing the price of fertilizer, the economic importance of refining the fertilizer recommendations for rice will be much greater for the farmers.

A series of simple N-P-K experiments should be conducted on the three major soil types of the area. The Fonde soils should be included even though they are too porous for efficient rice irrigation. (Perhaps sprinkler irrigation will be used for rice in the future.) For each experiment site, three separate experiments should be used, one for nitrogen, one for phosphorus and one for potassium. Rates should be: 0, 40, 80, 120, 160 and 200 Kg per hectare for nitrogen and 0, 30, 60, 90 and 120 Kg per hectare for phosphorus and potassium. For each experiment, the plant nutrients that do not vary should remain constant at a slightly more than adequate rate as determined by experience.

A soil test program should be set up as the acreage expands. In the meantime, reference soil samples should be collected from each replication of each experiment. These samples can be identified and stored in a safe place and analyzed when the necessary laboratory equipment and technical support is available.

Two Rice Crops Per Year

If it was desirable, farmers could probably increase rice production in the Bakel area 50 to 90 percent by growing two crops per year. Since no perimeters were producing two crops regularly, it must be assumed that the additional rice is either not profitable or not wanted for some other reason. Some reasons given for not growing two rice crops were:

1. There was not enough water because the river dried up before the second crop was mature.

2. It is possible to make more money growing three crops of corn.

3. Dr. Khoi Le reports that there is a hot dry wind for a period between March and May during some dry seasons which can prevent the rice from flowering.

4. Mr. Moribadjan Keita, an AID agricultural economist, has observed that people do not want to grow a second crop of rice each year because the rainy season crop is enough for them to eat and have a little left over to sell. So why grow a whole crop just for cash? Especially when the dry season crop must depend totally on irrigation and the pumps are not dependable.

It is difficult to recommend this practice as a dependable means of increasing rice production because there are apparently a number of reasons why it hasn't been accepted by rice farmers. It is recommended that research begin immediately to evaluate varieties for efficient dry season rice production. All the problems which restrict dry season rice production in the Bakel area should be described and a means to overcome each problem should be devised and evaluated in the field. For example, windbreaks such as those used at the ISRA Experiment Station at Fanaye may provide some relief from the hot dry wind. The technology necessary to produce a dependable high-yielding dry season dry crop should be available to the farmers when they decide they need it.

Improved Field Sampling Technique

It is important to make numerous yield estimates of field performance for testing and auditing purposes. The following simple equipment would speed up the very time-consuming process considerably:

1. A pedal thresher.

2. A large piece of canvas on which to thresh the rice.

3. A durable and accurate field scale.

4. Plastic moisture sample jars or a field moisture meter. Motomco produces a simple, battery-operated, portable moisture meter with a convenient carrying case which is approved by the USDA Grain Grading Division.

Speeding up the sampling procedure over the present hand threshing method would increase the number of samples possible and improve the accuracy of the estimate. It would also be a good demonstration of a pedal thresher to farmers who are now hand threshing.

Technician Training

Some special training for the technical assistance advsisors to improve rice production is needed in addition to the SAED Training Program discussed later.

SAED-USAID Counterparts. As many SAED leaders as practical should be sent to the United States, IRRI or other suitable institutions for formal training on USAID-funded scholarships. Such a training program will strengthen the USAID-SAED "Counterpart" relationship which is seriously inadequate at present. The "counterpart" relationship should be strengthened at all levels of both organizations. It is the basis for a successful development project of any kind located any place in the world.

USAID Rice Specialist. If Dr. Khoe N. Le is to continue working with rice, he should be sent to the rice research centers in the United States, to IRRI in the Philippines and to IITA in Nigeria in order to get first-hand information regarding current rice production practices. Mr. Le's formal training was in citrus production, which is considerably different from rice production. Considering the excellent job he has done teaching himself and others rice production, both he and the project would benefit greatly from such a training experience.

Improved Grain Storage

Although the farmers do not seem aware of it, large quantities of grain are probably lost each year in the mud and stick grain storage bins due to decomposition, insects and rodents. Some effort should be made to devise a means whereby these bins could be fumigated. Perhaps it would be possible to design a small forced-air dryer that could be attached to each bin for use during the rainy season.

IRRIGATION SYSTEMS AND ENGINEERING

We inspected the irrigation facilities at most of the perimeters which make up the Bakel Small Perimeters Irrigation Project. In addition, we inspected similar facilities at the Dutch and French assisted projects. Even with a quick inspection, it was clearly evident that machine, fuel and water use efficiencies are below 50 percent of potential at most perimeters. Our findings are in agreement with a number of individuals and/or teams who had already studied and commented on the irrigation systems prior to our visit.

Joint Assessment Evaluation

The Joint Assessment evaluation team presented the following comments (early in 1980) concerning water control and engineering recommendations. In general, we concur with their findings and noted that the situation is essentially the same now as then.

Water Control

The Joint Assessment team made the following comments concerning water controls in the Analysis section of their Bakel Project study.

> "The lack of adequate water control is probably the single greatest constraint to high production in the Bakel region. It stems from many different causes:
>
> Lack of leveling in the fields. Most farmers are using a form of basin irrigation and even though the basins are small, sections of each could be seen suffering from a lack or excess of water because of inadequate leveling.
>
> Soil not suitable for rice production or not puddled prior to planting. In some of the perimeters, the farmers estimated that as much as 40 percent of the perimeter was too sandy for good rice production.
>
> Whole perimeter not leveled. In several perimeters, the farmers reported that they had not been able to get water to parts of the perimeter becuse the ditch was too low or they had to cross a low swale in the center of the field. The majority (water channels and swampy areas) do not refill during the rainy season.

The pumps, pump operators, mechanics, pumps and SAED are not reliable. The farmers tend to lump SAED in with all other factors affecting the water supply. Part of this is justified because sometimes the fuel and oil are late, the mechanic does not come when needed, spare parts are not available, or the pipe breaks. However, much of this problem actually is the responsibility of the village. The pump operator does not always stay with the pump so there are frequent breakdowns. Farmers may not want to irrigate at the same time so the pump has to be restarted many times to do the individual small plots. Proper protection is not given to the fuel and oil supply. Training programs have been given for mechanics in the central shops, but apparently little training has been given on field stripping engines and maintaining a high degree of cleanliness.

The farmers do not know how to manage their water nor do they have the tools to do a good job. Most of the farmers who were observed irrigating just let the water "run" rather than guide or conserve it. Ditches and bunds were leaking and most basins had more water than the maize crop could usefully use. Many farmers reported that they did not have shovels to control their water. Many of the ditches were filled with weeds and dry weed pods."

Engineering Recommendations

The specific recommendations made by the Joint Assessment team concerning irrigation engineering aspects of the Bakel Project included the following:

"Assist or support SAED in starting a training program for pump operators, assistant pump operators, mechanics and assistant mechanics on the operation of the pump and engine; fuel and oil handling; daily, weekly, and monthly maintenance procedures; identification of troubles; authorized field repairs; procurement and care of spare parts; and off season storage.

Training of a water master and assistant water master for every perimeter. At present, this job is usually done by the president of the perimeter. Training should include land leveling, ditch and border construction, dike construction, compacting techniques, water control, use of measuring flumes, water guiding and field spreading, water needs of crops, production of irrigated crops, etc. Most of this training should be done at Bakel on-the-job.

Encourage SAED to pull in surplus pumps and pipe and remove pumps from the very small perimeters operated by one man only or where no effort is being made to expand small perimeters after the second or third year.

A small research effort should be mounted to test various pipe materials under Senegalese conditions, determine the most efficient speed for engines on the different models of pumps, develop concrete or other turnouts, gates, ditch blocks or dams, etc. to help the members of the perimeter build, operate and maintain their system. A research system is needed for long term monitoring and decision making.

Work needs to be done on developing a suitable flotation unit. Both the metal and the fiberglass units are breaking up because of the small support area for the pump, the vibration of the engine and collision with floating debris. The use of wide timbers to support the weight, heavier plywood put together with marine glue to frame the fiberglass and rubber mounting pads might help absorb the shock from the running engine."

Pumping Plants

Mr. Ni Van Nguyen, the Bakel Project USAID Irrigation Engineer, has written an internal USAID document, "Technical Report on Pumping Water for Irrigation - Bakel Small Irrigated Perimeters," dated January 10, 1981. This report contains useful data on the pumping plants which are now in place; the area irrigated from each pump; and suggestions for evaluating and improving the irrigation systems.

Pump Efficiencies

Nguyen points out that most of the pump/engine units are poorly matched for the water lifting job at hand. At low river flows, when the lift between the river and canals is about 13 m, pump efficiencies range from 66 to 80 percent for the different pump/engine combinations used. During the rainy season when the river level is high the lift is about 4 mm and the pump efficiencies range from 50 to 77 percent. He recommended that the Marlo pumps be retired from service (and we concur) because they are so inefficient and unreliable; however, this has not yet been done.[1]

Engines

Lister HR2 (2 cylinder) and HR3 (3 cylinder) diesel engines are used exclusively throughout the project. These two engines have many parts which are common to both as well as the larger Lister HR4 and HR6 engines, which may be appropriate for future perimeter expansions. These Lister engines are very appropriate for the task at hand because they are: reliable and durable, relatively easy to service and maintain, simple to operate and efficient (4.7 BHP-hr/li without accessories).

Cost of Pumping

Nguyen suggests evaluating irrigation system performance in terms of the liters of fuel consumed per hectare irrigated. For wet season paddy he suggests the following criteria when pumping from the river:

Excellent	Less than 120 l/ha
Good	Between 120 and 140 l/ha
Average	Between 140 and 170 l/ha
Poor	Between 170 and 200 l/ha
Terrible	More than 200 l/ha

These elements are based on the average of the pump efficiencies and assume 90 l/ha of diesel for applying 560 mm of water with 100 percent overall irrigation efficiency. Our estimates indicate that the consumptive water use of a 120 day wet season rice-crop is in the neighborhood of 600 mm and the average effective precipitation during this same period is bout 400 mm. Thus, the water deficit is only 200 mm and the 560 mm suggested by Nguyen would allow for an average deep percolation loss of 3 mm/day for the entire 120 day growing season.

We found perimeters which had diesel fuel usage levels at both

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[1]The Aroundou perimeter is served by one of the 5 Marlo pumps being used. Just prior to our visit they had their fifth breakdown since obtaining the pump two years ago. This last time the pump shaft broke and was out of commission for three weeks. It was obvious from the appearance of the paddy crop that this last breakdown would severely reduce yield.

extremes: at the Balou perimeter they only used approximately 90 l/ha; and at the Bakel perimeter the pump operator indicated that they used 220 l/ha. We were also informed that the project average is in the range of 140 to 160 l/ha for paddy during the wet season.

According to figures presented by Nguyen, the best pump/engine combination is the Deloule pump (with 260 mm impellor)/Lister HR3. (Unfortunately, only two out of the 50 pumping plants in use are this combination.) The pump has an average efficiency of nearly 80 percent for both high and low river pumping lifts. The estimated the total (fuel, maintenance and capital) cost for pumping (to 20 ha areas in 1981) under average lift and discharge conditions is 3.15 CFA/m^3 for the Deloule/Lister HR3. The pumping cost for other pump/engine combinations range from 10 to 20 percent more. The above figures are based on normal pump/engine life expectancies which are at least three times as long as has been realized to date at Bakel.

Where the water supply is a lake or swamp, which is the case for the Bakel Perimeter, none of the pumps supplied by SAED for the Bakel Project are appropriate. For such situations where the lift is only 2 or 3 mm, appropriate low lift pumps would reduce fuel consumption by 50 to 75 percent.

There is no excuse for poor pump selection. With optimum selections fuel consumption would be reduced by about 15 percent project-wise without further effort. Therefore, all new pumping plants should be fitted with optimally matched pumps and engines for the pumping lifts encountered. Furthermore, a program of refitting the existing pumping plants should be started by immediately replacing the Marlo pumps.

Floats

The existing floats are grossly inadequate. As mentioned earlier, both the fiberglass-foam plastic floats and the metal floats shake apart under operating conditions. Tipping over and literally drowning the engine is an obvious problem and reports indicate that four or five units tip over each year.

Most of the floating pumping plants we saw were listing at various angles. Listing causes damage to the engine by adversely affecting the lubricating system and loading the shafts and bearings unevenly. The listing and unsteadiness of the floating units makes routine maintenance more difficult and requires expensive procedures for more extensive maintenance. The total adverse effects of the unstable listing floats on engine life is difficult to estimate.

However, we estimate that the inadequate floats are responsible for increasing maintenance and repairs by at least 25 percent project-wise and at the same time reducing engine life by a like amount.

We have considered alternatives to floating pumping plants, but conclude that since most of the potential pumping sites are along the steep erosive aluvial river banks, floating pumping plants offer the best solution. We would only recommend fixed pumping plants (or pumping plants mounted on wheels which could be run up and down on rails) where there are suitable rock outcrops along the river, or for pumping from lakes and swamps. At sites where the aluvial river bank has a gentle slope, pumping plants mounted on rubber tired wheels might be considered. However, at such sites the water may be too shallow near the bank.

The existing floats are inadequate and are probably responsible for increasing engine maintenance costs by 25 percent and decreasing engine lift by 25 percent. Therefore, for the success of the project, existing floats should be strengthened or replaced and properly designed floats should be used on all new installations.

Fueling Systems

The procedures we observed being used for fueling the diesel engines on the river floats were crude beyond comprehension. Drums containng 200 liters of diesel are taken by truck (or boat) to as close as possible to the pump site and stored at the top of the river bank. Diesel is poured from the drums into open buckets and carried down the steep river banks and out (across the water) to fuel the engines which are mounted on floats in the river. Throughout the fueling process there are numerous opportunities to spill or contaminate the fuel with dirt and water.

Undoubtedly, fuel contamination is an important factor leading to short engine life and excessive repair and maintenance problems. We would not be surprised to learn that this factor alone is responsible for a 25 percent reduction in engine life and 25 percent increase in maintenance costs. In addition, the chain of events in the fueling process has several weak links; therefore, the reliability of providing adequate fuel when needed is often inadequate. This is especially true during the rainy season when roads are impassible.

We feel an improved fueling system is a necessity for project success. Depending on the reliability of the road system to be the pumpsets, a storage tank for up to 2,000 liters (this would be a

1 m x 1 m x 2 m tank) should be provided for each pumping unit. The storage tanks should be placed above the high water level on the river banks. Either hoses or closed containers should be used to carry the fuel from the storage tank to the engines. The stored fuel would provide a safety margin against fuel delivery interruptions, and the improved delivery system should eliminate the bulk of the contamination problems.

Maintenance

We found the pumping plant maintenance program was casual at best, especially at the farm level. While the pumpists seemed to have a general idea of routine maintenance needs, we saw little evidence that they followed a systematic program. In addition, they are not equipped with sufficient knowledge or tools to take care of minor repairs. This adds greatly to the work load of the SAED mechanics. With better floats (as discussed earlier), improved fueling systems, recommended routine preventative maintenance and simple repairs taken care of at the farm level, the work load on the SAED mechanics could probably be reduced by 50 to 75 percent.

We were informed that the chief SAED mechanic of Bakel is quite good, but it was obvious that he had insufficient qualified assistants and tools to work with. The SAED mechanical shop facilities at Bakel are grossly inadequate, with both parts and tools in disarray. We saw: deplorable practices such as arc welding without eye protective dark goggles; the deterioration of expensive parts stored outside without protection against the elements; and tools and/or parts being broken because the correct tool (such as an easy-out or proper wrench) for the task apparently was not available.

The above deficiencies suggest that a comprehensive diesel and pump maintenance training program be developed and started for the Bakel Region. This should be a hands-on program and made essential for the pumpist and at least one assistant from each perimeter plus all SAED mechanics assistants. The program should include: routine preventative maintenance practices; minor repairs and service; record keeping; plus principles of diesel engines, centrifugal pumps and water lifting.

With all of the engines and most of the pumps being similar, the training task is simplified. Instruction should be as visual as possible and trainees should be instructed by actually dismantling, repairing, reassembling and servicing the same models of engines and pumps. Full use efficiency, performance, trouble shooting and water lifting demonstrations should also be included in the training program.

Water lifting is essential to any substantial irrigation development in the Bakel Region. Poor pumping plant maintenance and repair services (aggravated by the problems with floats and fueling systems) are causing untimely breakdowns, expensive major repairs and short (as little as one-sixth of normal) equipment life. This alone is sufficient to destroy the economic viability of the Bakel Project. Therefore, it is essential that both the farmer groups and SAED develop the desire to and ability to greatly improve the maintenance program and repair services. This can only be accomplished in conjunction with: sufficient training for farmer operators and SAED mechanics; proper tools and service facilities; and some sort of incentive program for both SAED and the farmer groups to maximize the life and performance of the pumping plants.

Pumping Plant Summary

The potential benefits which can be derived from better design and maintenance of the pumping plants are:

1. Optimum selection of pumps/engines for the lift tasks at hand will reduce pumping costs (based on potential engine and pump life) by about 15 percent project-wise and reduce failures and service problems.

2. Improved floats, fueling systems, maintenance programs and repair services will produce the following potential benefits:

   a. A 10 to 15 percent reduction in fuel use.

   b. A 50 to 75 percent reduction in service and repair costs; however, routine maintenance costs will naturally be higher, perhaps offsetting 10 or 15 percent of the above savings.

   c. Engine life will be extended to between 12,000 and 15,000 operating hours which is three to six times as long as is now being achieved. However, part of this gain will be offset by the added cost of improved floats and fueling facilities.

   d. The added reliability of having pumping plants operable when needed will result in some increases in crop production, perhaps an average of 10 percent or more.

Penstocks

The pipelines which convey water from the pumps floating in the river to the canal head boxes at the tops of the river bank are poorly designed. The plastic pipe we saw being used is misapplied, too small and improperly installed. Instead of lasting 10 or more years, in accordance with project plans, the plastic pipe only lasts two or three years because it is laid on the surface exposed to the sun and under severe mechanical stress.

Extra fitting losses, high pipe function losses and elevated discharge pipe ends (a meter above the canal water level) adds an average of 2 to 3 m of unnecessary lift for most of the installations. This added lift increases fuel usage by 10 to 20 percent.

The existing penstocks should be replaced (or rebuilt) with 10-inch (250 mm) diameter pipe. Plastic pipe should be buried and long radius elbows used at sharp bends. Light weight galvanized steel tubing should be used for exposed portions of the penstock such as between the high river and low river water levels. The penstock discharge should be flared and at or beneath the canal water line. With these improvements the life expectancy of the penstocks should be 10 to 20 years and fuel use should be reduced by 10 to 20 percent.

Water Distribution

We noted some canals which were quite good and others which were very poor. Canal construction appears to be a major labor bottleneck for the groupments. We estimate that the best canals have losses in the neighborhood of 25 percent of the water pumped and many have losses of 50 percent or more. Where canals run along the sandy upper reaches of perimeters (near the river bank) losses are highest. Some groupments have recognized this and used their own ingenuity and capital to line the upper portions of their canals.

In addition to constructing the canals, the farmers must clean them and periodically rebuild needed drop and outlet structures. However, most of the canals we inspected were poorly maintained and had too frew structures.

For a successful project SAED must give more attention to water conveyance. On relatively steep or sandy lands we recommend that either canals be lined or pipe be used. In fact, we recommend considering pipe conveyance throughout the project, or at least in all portions of distribution systems which convey water 40 percent or more of the time. Use of pipe distribution systems would practically eliminate conveyance losses which are expensive since the water must be pumped, reduce labor requirements and simplify irrigation.

Irrigation Application

In terms of topography and soils, the perimeters we visited are well suited for surface irrigation. However, for efficient surface irrigation considerable land shaping and/or leveling is required. However, this is an almost impossible task for the farmers who only have hand tools and requires both technical and physical assistance from SAED.

Existing Irrigation Systems

Typical flooded basin irrigation was being used for rice and basins with furrows or zig-zag furrows were being used for row crops such as vegetables, corn and sorghum. However, we noted that fields had not been leveled or adequately shaped. At best, field water application efficiencies are in the neighborhood of 55 percent for either row crops or paddy unless continuous flooding is practiced. With continuous flooding, application efficiencies may be about 75 percent for paddy, but percolation losses probably range from 2.5 to 4.0 mm/day, which more than offsets the improvement in water application efficiency. Farmers recognized this and we saw many paddy fields which were not continuously flooded, especially on the sandier soils near the river where percolation losses might well exceed 4.0 mm/day.

SAED provides little technical assistance with on-farm design of distribution systems and land preparation. We reviewed the maps and plans which were available for the various perimeters and concluded that:

1. There are essentially no plans for perimeter land development.

2. The detail of the topographic survey and mapping data which has been developed is totally inadequate for: selecting perimeter boundaries; designing efficient canal and field layouts; and determining land shaping requirements. (At present, only rough maps and topographic sketches show a few high and low spots are made.

3. There is no information on soils and recommendations for crop selection and irrigation practices related to soil type are not given.

4. Whatever is done beyond the canal head box represents the ingenuity and work of the farmers, with possibly a little advice from USAID technicians.

SAED provides practically no assistance with land shaping and canal construction. The farmers perform these tasks to the best of their ability with simple hand tools which requires rather staggering labor inputs. For example, we timed young boys building deep zig-zag furrows by hand and calcuated that this practice would require 3000 boy-hrs/ha. The few cases where SAED has assisted with mechanized land shaping costs have been unreasonably high because of inadequate survey data and designs, plus improper use of equipment (using large bulldozers and road graders instead of appropriate sized scrapers and land planes).

Improved Irrigation Systems

From the above comments, it must be obvious that there is substantial room for improving the existing irrigation systems. We believe the success of the Bakel Project, as well as irrigation along the Senegal River in general, depends on substantially improving the irrigation systems and practices we observed.

Surface Irrigation. Substantial improvements in surface irrigation systems can be obtained by better water distribution and land leveling practices. The Balou perimeter happened to have rather ideal physical features and is an example of what might be expected from improved practices. At Balou, four pumps (they have five pumps, but leave one on standby), operating on an average of eight to nine hours per day supplying water for 103 ha of paddy. With 12 hours operation per day they could irrigate over 30 ha per pump set. Diesel fuel use has been between 90 and 100 l/ha for the wet season crop for the last two years and paddy yields are nearly 5 T/ha. Unfortunately, there is no water in the river at Balou for dry season crop.

Near Cascas where SAED is aided by the Dutch assistance program, five perimeters were rehabilitated last year. These perimeters have pumping plants and penstocks similar to those at Bakel. However, the canal systems were completely rebuilt and equipped with appropriate division, drop and turnout structures, and the fields were reorganized and leveled. Farmers are only charged 16,000 CFA/ha for these additional services, which is probably less than 10 percent of actual cost.

The payoff has been impressive. We were informed by the Dutch student technician, who was assisting the project as part of his graduate irrigation engineering studies, that groupments farming the improved perimeters are now double cropping and getting paddy yields of 5 to 7 T/ha from each crop. He also indicated that average fuel use for the wet season paddy crop was less than 150 l/ha and for the dry season crop it was about 200 l/.ha.

For proper design of paddy irrigation schemes, basic information should be collectd on land topography, soil conditions, and especially, on average values of water percolation in a paddy. The following basic data are a must:

A topographic map, scale 1:2500, with 25 cm contour intervals.

A soil map, scale 1:2500.

Percolation rates as found from infiltration tests.

After having the water distribution system and land leveling designed by a competent irrigation technician, SAED should assist in building the canals and installing appropriate structures. SAED should also provide land leveling services (using appropriate technology) either directly or through private contractors.

Pipe Conveyance Systems. Pipe instead of open channels should be considered for distributing water to the fields. Figure 1 shows an ideal (from the standpoint of pipe use efficiency) pipe distribution system for a 30 ha perimeter. Labor for maintaining canals and water losses are practically eliminated by using pipe. Assuming canal delivery efficiencies of 75 percent, by replacing open channels with pipe, 33 percent more area can be irrigated with little increase in fuel or pumping plant costs.

This ideal 30 ha system with pipe distribution and land leveling would cost approximately:

Item	Cost-US $*	Life-Years
Pumping plant, Penstock and Accessories	20,000	7
1600 m PVC 8-inch Pipe @$25/m	40,000	20
Land Leveling 30 ha @$800/ha	24,000	20

*These are rough estimates for comparative purposes only.

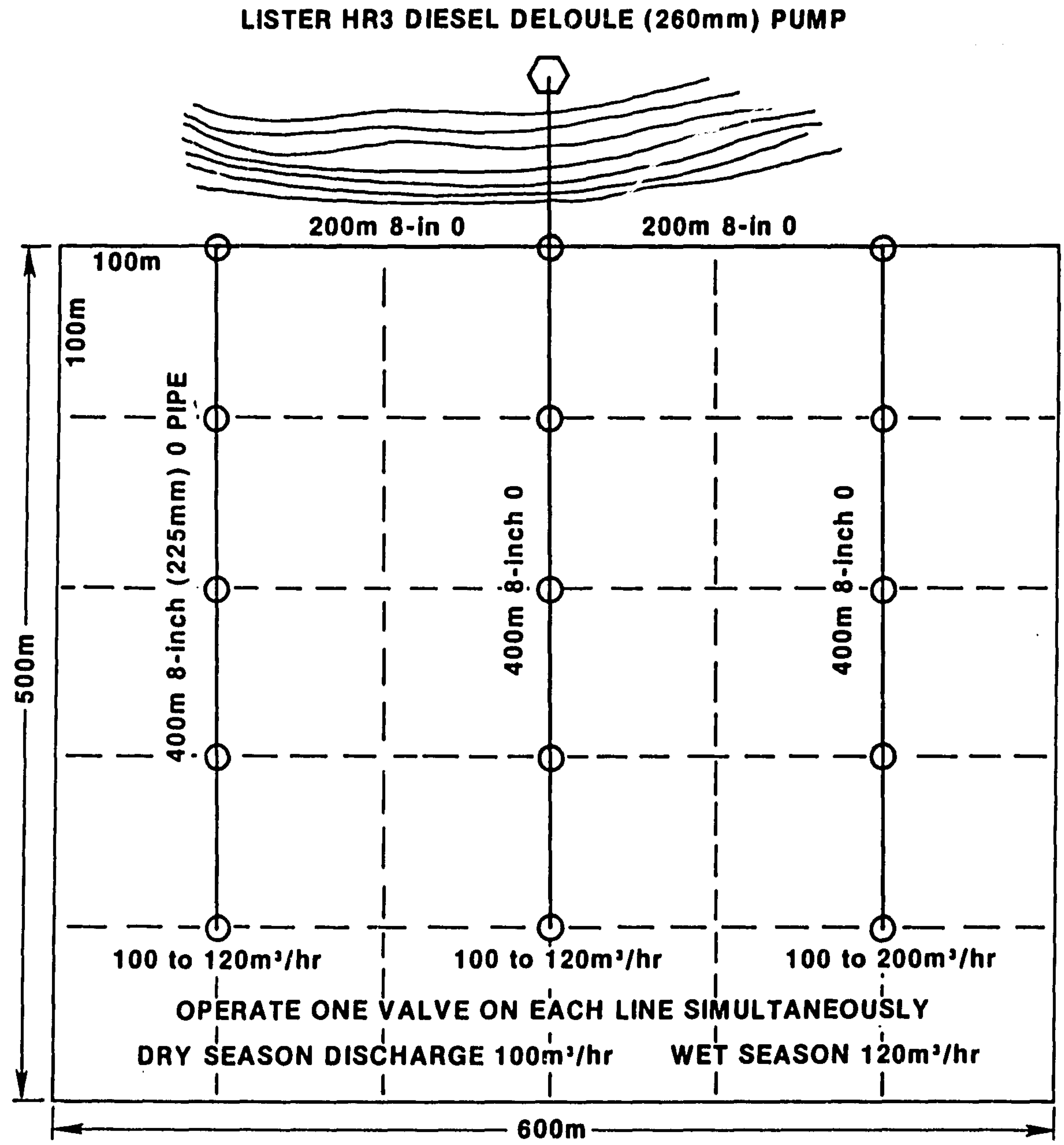

Figure 1. Sample 300 ha Surface Irrigation System with an 8-inch (225 mm) PVC Pipe Distribution System.

An estimate of the diesel fuel requirement in liters for applying 1.0 mm of water to 1.0 ha based on fuel use efficiency of 4.0 BHP/l of diesel and a pump efficiency of 80 percent is:

Season	Av. Discharge (m^3/hr)	Av. Head (m)	Power (BHP)	Fuel Use (l/mm-ha)
Wet	360	15	25	0.174
Dry	300	20	28	0.233

The diesel fuel requirements in liters per hectare for surface irrigation of wet and dry season ponded paddy and corn with different surface irrigation facilities are given in Table 6.

Sprinkle Irrigation. Sprinkle irrigation is an interesting alternative to surface irrigation since water lifting (or pumping) is required in either case. Some interesting potential advantages of sprinkle irrigation as compared to surface irrigation for the Bakel Project are:

1. Perimeter preparation will take less time and technical effort.

2. Farmer labor requirements will be greatly reduced as compared to surface methods, especially for row crops.

3. Overall irrigation costs may actually be less than for the existing surface irrigation systems.

4. Training farmers to manage sprinkle irrigation of new crops is simpler.

5. Sprinkle systems can be used in the steeper sandier soils nearest the river.

6. Sprinkle irrigation is suited for all crops except flooded paddy -- and even upland rice can be grown unde sprinkle irrigation.

7. Sprinkle irrigation is ideally suited to the cooperative efforts of the farmer groupments.

8. Hand move sprinkler lines are simple to operate and even if a few pieces of pipe or sprinklers are inoperative, the rest of the system can still be operated.

Table 6. Fuel Requirements, in Liters of Diesel for Applying 1.0 mm of Water to 1.0 ha, for Different Surface Irrigation Circumstances.

Crop/Season	ET-Rain + Perc .= Total (mm)[1]	Level w/pipe	Level w/canal	Non-Level
		(liters/mm-ha)[2]		
Rice/wet	(600-400) + 400 = 600	104	139	186
Rice/dry	(600-0) + 400 = 1000	233	311	414
Corn/wet	(600-400) + --- = 200	46	62	82
Corn/dry	(600-0) + --- = 600	186	249	331

[1]Deep percolation losses for flooded rice, 120 day crops.

[2]Based on 100 percent pipe conveyance efficiency; 75 percent canal conveyance efficiency; 100 percent application efficiency on level flooded ponded fields; 75 percent application efficiency on unleveled ponded fields; 75 percent application efficiency on leveled fields with furrows; and (.75 x 75) = 56 percent application efficiency on unleveled fields with furrows. Examples: overall furrow irrigation efficiency on level field with canals is (0.75 x 75 percent) = 56 percent; and overall furrow efficiency on unleveled fields with canals is 90.75 x 0.75 x 75 percent) = 42 percent.

Design notes for a sample sprinkle irrigation system are presented as Appendix A. An overall irrigation efficiency of 80 percent can be expected from sprinkle irrigation and the anticipated fuel requirements for wet and dry season corn (or upland rice) are 110 l/ha and 325 l/ha, respectively. These fuel use levels compare favorably with the figures from Table 6 for unimproved surface systems.

The idealized 25 ha sprinkle system presented in Appendix A would cost approximately:

Item	Cost-US $*	Life-Years
Pumping plant, penstock and accessories	20,000	7
420 m PVC 6-inch buried pipe with valves @$20/m	8,400	20
1200 m AL 3-inch portable sprinkler pipe with sprinklers @$15/m	18,000	12
Land Preparation	2,500	20

*These are rough estimates for comparative purpose only.

System Cost Comparisons

A summary of the unit costs per hectare for the different components of the various irrigation systems is presented in Table 7. The water supply system, which includes the pump, engine, float, penstock and accessories, is estimated to cost $20,000 and have a seven year life for all systems. The differences in water supply unit costs for the various systems reflect the various numbers of acres each system could potentially irrigate assuming the surface systems are all operated the same number of hours per year.

Table 8 was developed in order to compare the total annual fixed and operating costs of the various systems discussed above. Annual fixed costs of each item are based on 8 percent simple interest and the life expectancies indicated in Table 7. Annual fixed costs are determined by multiplying the investment cost by the capital recovery factor, ($CRF = i/(1-(1+i)^{-})$), which is: 0.1921, 0.1327, and 0.1019 for n = 7, 12 and 20 years, respectively, for i = 0.08.

Table 8 is presented for general comparative purposes only. The difference between annual total irrigation costs before adding labor inputs are small and the relative positions between systems is insignificant. For example, the sprinkle and piped surface systems are based on ideal layouts and land shape or area restrictions would increase costs considerably; in fact, total irrigation costs of all systems is quite sensitive to the area irrigated. The important point is that alternate systems should be considered for the Bakel Project.

Table 7. Breakdown of System Component Costs in US $ per hectares for Various Irrigation Systems.

System	Water Supply System (7 yrs)	Canals & Structures (7 yrs)	Plastic Pipe (20 yrs)	Sprinkler Pipe (12 yrs)	Land Prep. (20 yrs)
Sprinkle	800 (25 ha)	---	336	720	100
Surface Pipe & Level	667 (30 ha)	---	1333	---	800
Surface Canal & Level	889 (22.5 ha)	200	---	---	1000/ha
Surface Canal & No Leveling	1212 (16 ha)	200	---	---	200/ha

Conclusions

The potential benefits from improved irrigation system design and implementation are impressive. Such benefits are the easiest to achieve. They only require the short term efforts of an expert team (with both physical and social scientists) to set up the design standards and specifications for perimeter development. After this a few well trained technicians can design and supervise the installation of each new perimeter (or rehabilitation of existing perimeters). Improved design and implementation should double the effectiveness of most existing and future perimeters.

Improving maintenance and service capabilities for the pumping plants is an even more critical need for the Bakel Project; because any significant irrigation development along the Senegal River will require efficient operation of water lifting systems. This is a more difficult task than improved design, being an ongoing activity which not only requires training and managing SAED mechanics and service facilities, but also training each farm groupment to take the responsibility to continuously service and maintain their pumpsets more effectively. Furthermore, service requirements will

Table 8. Buildup of Annual Irrigation Costs in US $ per hectare for Various Irrigation Systems for Double Cropping with Rice during the Wet Season and Corn during the Dry Season.

Item	Sprinkle Portable Pipe	Pipe Level	Surface Canal Level	Canal Non-level
Water Supply	154	128	171	233
O&M @5%	40	33	44	60
PVC Pipe	34	136	--	--
Sp. Pipe	96	--	--	--
Canal	--	--	38	38
O&M @2%	21	27	4	4
Land Prep.	10	81	102	20
Main. @2%	2	16	20	4
Fuel[1]				
Wet (rice)[2]	40	38	51	68
Dry (corn)	118	68	91	120
Sub Total	515	527	521	551
Labor[3]				
Wet (rice)	6	16	30	60
Dry (corn)	18	24	44	88
TOTALS:	539	567	595	695

[1]Fuel cost based on 100 CFA/liters and 275 CFA/US $.

[2]Under sprinkle irrigation crop could be upland rice or corn.

[3]Labor cost based on US $2.00/day.

multiply even faster than irrigation development expands because of more and older pumpsets.

The combined effects of improved design and installation with good maintenance and service would double the average area irrigated for a given amount of diesel fuel, practically double the area irrigated from a given pumpset, and triple (or quadruple) engine life. In addition, farmers would be inclined to double crop.

Training

Several simultaneous training programs are needed to accomplish the above. These include training for:

1. SAED survey, design and construction technicians. This could be done as counterpart roles to the USAID advisors at Bakel.

2. SAED diesel and pump mechanics and their assistants.

3. Pumpists and assistant pumpists from each village. Enough pumpists must be trained so that an experienced operator is on hand at each perimeter when any of their pumping plants are in operation.

4. Irrigation system operation and management for farmer managers from each village.

Ideally, farmer and pumpist training programs should be carried out at some sort of demonstration-training facility set up at Bakel.

Future Developments

Since the Senegal River and its tributaries serve as the main water distribution systems in the basin, there is little, if any, economy to be gained from increasing the size of the smallest units beyond 20 to 40 ha per pumping plant. In fact, areas larger than 100 to 200 ha per pumping plant will probably begin showing diseconomies of scale. Therefore, a building-block approach, with farm units that best fit the social units and development progress of the existing villages, is most appropriate. Irrigated perimeters can be expanded in accordance with the capabilities and desires of each groupment.

Flexibility should be maintained and development allowed to progress as the capacity of the farmers increases. The paper presented as Appendix C describes a project in Indonesia which is similar in many aspects to the Bakel Project. Similar development problems were encountered and pumpsets serving 30 ha or more had about the same unit cost for operation as units up to 200 ha. The paper gives some of the inputs and changes needed for improved project performance.

At Bakel, besides the limitations created by ineffectiveness of the physical irrigation system, other and equally important bottlenecks to expanded development are first of all limited labor availability, and secondly, insufficient return to labor which will be discussed in a later section. These two bottlenecks can only be solved by animal or machine mechanization and improved farming practices.

THE PROFITABILITY OF IRRIGATED AGRICULTURE

Cost benefit and internal rates of return were calculated for the original Project Paper. Later this analysis was challenged by an independent investigator whose analysis was in turn largely refuted by yet another in-house analysis. A fourth more recent set of calculations generated investment criteria "amazingly similar to the original Project Paper."

The difference between all of these analyses largely arise from differences in:

1. The value of the paddy output;

2. The opportunity cost of labor;

3. The quantity of labor required to grow the paddy crop; and

4. Mistakes in interpretation of project cost streams.

Today, five years after the original Project Paper was published, it is clear that analytical efforts devoted to establishing the "true" internal rate of return would best have been directed at a careful financial analysis of paddy cultivation. There are current plans to get this activity underway. In addition, a financial analysis of all irrigated crops (paddy, sorghum and maize) and of all rainfed crops is essential for assisting cultivators in farm planning and providing critical data for planning for subsequent perimeter irrigation schemes.

Financial Analysis of Irrigated Paddy

Cultivator decisions to grow any crop are based on the financial return from that particular cropping enterprise. In the Bakel Project, financial returns to the cultivator were counted upon to be high enough to permit establishing a sinking fund for purchasing the next pump and motor. This has only happened at one of the perimeters. A failure to repay loans and to establish sinking funds may well result from low returns to irrigated agriculture.

Given the importance of financial returns to the future conduct of the project and for any subsequent perimeter irrigation in the region, the evaluation team undertook to estimate the returns for paddy. (This analysis should in no way substitute for recommendations that detailed crop budgets must be developed.) The analysis is based on the best available information.

Table 9 shows the variable costs of purchased inputs under three circumstances encountered in the project area. Our judgment is that the budgets describe the situation as it existed in November, 1981. The "worst" circumstances are not the absolute worst, but are within the lowest 15 percentile. The best circumstances are the best encountered in terms of irrigated area and esimtated average yield across the perimeter (although higher yields in individual fields have been recorded). The normal circumstances represent the evaluation team's judgment as to what might be expected under normal operating conditions and good technology and crop husbandry. It is based on field observation and the team's considerable experience. The next to last row of Table 9 shows the monies available to pay for labor and returns to capital investment in pump, engine, float and pipes. In addition, it must also cover the cost of any rainfed crop that was forgone in order to grow paddy; because this is more likely an opportunity cost for labor than for land.

Labor Requirements

The original Project Paper Document estimated labor inputs for paddy as 249 man days. This estimate allows 2 man-days for land preparation and no time for cleaning and repairing irrigation works. The estimates assumed animal power would be available, which so far (November 1981) is non-existent.

Since the original Project Paper several man-days labor input estimates have been used. Franzel estimates 322 days, later D. Brown returned to the original estimates, claiming they were more professional. Next, a Tuskegee Institute report[1] estimated 647 days and about the same time Kaita[2] prepared an analysis base once again on the original Project Paper.

As of this time, it seems certain that the estimates of the Project Paper were wrong inasmuch as: (1) animal power as assumed is not available; (2) a learning curve for labor was not

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[1]"Bakel Small Irrigated Perimeters Production Economics Study," by J. M. O'Sullivan and C. Morgan, a Tuskegee Institute Report for USAID/Senegal, August 30, 1981.

[2]"The Bakel Small-Scale Irrigated Perimeters Project: A Mid-term Evaluation Report," by M. Kaita, an internal USAID document, April 1981.

Table 9. Estimated Input Costs and Returns to Labor and Capital for Irrigated Paddy Production as of November 1981 at the Bakel Irrigation Project.

Cost or Return Item	Inputs and Returns for Different Circumstances		
	Worst (CFA/ha)[1]	Normal (CFA/ha)	Best (CFA/ha)
Variable Costs			
Diesel Fuel[2]	30,800	23,100	15,400
Seed[3]	4,000	4,000	4,000
Fertilizer[4]	4,825	9,500	13,000
Tools[5]	3,850	3,850	3,850
Maintenance[6]	---	---	---
TOTAL	43,475	40,450	36,250
Value of Output @50 CFA/Kg[7]	125,000	175,000	250,000
Returns to Labor and Capital[8]	81,525	134,550	213,750
Capital Costs[9]	132,000	33,000	24,450
Return to Labor[10]	(50,475)	101,550	189,300

[1]280 CFA = $1.00 US as of November 1981.

[2]Diesel fuel costs assuming 200 l/ha, 150 l/ha and 100 l/ha as the quantities of fuel used to irrigate paddy (rice) based on typical field irrigation efficiencies encountered in the project area for the worst, normal and best circumstances, respectively.

The cost of diesel fuel was 150 CFA per litre prior to mid-November 1981 before the import tax was removed for irrigation pumping. Lubricating oil cost is figured at 4 CFA per litre of fuel consumed.

[3]Based on 50 Kg/ha at 80 CFA/Kg for the seed.

[4]Total cost of N-P-K at high recommended and reported actual farm use. The functional form of the production function is not and should not be implied from the figures used here.

[5]Estimated using available information from reports by Kaita, Fenzel and others.

[6]The analysis assumes that maintenance is available free from SAED as has been the practice.

[7]Based on yields of 2.5, 3.5 and 5 metric tons/ha at 50 CFA/Kg. These are yield estimates from field circumstances and 50 CFA/Kg is the November 1981 price paid by SAED. Prior to this the price was 45 CFA/Kg and obviously returns were lower.

[8]Value of output less total variable costs.

[9]Capital costs are based on charging 60 percent of the initial equipment cost against paddy. The total initial capital cost of the pump, engine, floats and pipe is assumed to be approximately 5.5 million CFA. The capital costs are annualized assuming: a 5 year expected life with zero salvage value; zero interest rate; and irrigated areas of 5, 20 and 27 hectares for the worst, normal and best circumstances, respectively.

[10]Returns to labor and capital less capital costs.

postulated; (3) there was no apparent entry for irrigation works maintenance; and (4) threshing is not done, as assumed, with a pedal thresher.

The evaluation team generated their own set of estimates based on: (1) interviews with managers of collective fields and individual farmers; (2) actual field measurements; and (3) estimates suggested by USAID and extension field personnnel.

It became immediately apparent that to measure the labor input it is necessary to distinguish between man/days, woman/days and children/days. Also, since land preparation is done by hand, labor for land preparation is a function of soil type, the higher the clay content, the higher the labor. Furthermore, in fields where transplanting is being undertaken, labor inputs vary and the notion of a learning curve is very appropriate. One field technician estimated 200 person-days/hectare had been used in some cases for transplanting alone.

Given all of the above, the evaluation team estimates that labor requirements for paddy are ranging between 400 and 1000 person-days per hectare. (The distribution is likely scewed toward 1000 person-days since men are reportedly becoming less involved in paddy cultivation because of low returns.) The team did not generate labor estimates for corn, but every indication is that actual labor inputs are considerably higher than those reported in the original project document.

Table 10 gives the return to labor from irrigated paddy for different production circumstances and quantities of labor inputs. The table is separated into three sections with section (a) showing returns before paying either variable or capital costs, (b) showing returns after paying only variable costs, and (c) showing returns after repaying both variable and capital costs. It is useful to look at returns in this way in order to understand the likely reaction of the cultivator when he is asked to repay operating costs and amortize the capital costs.

It is apparent from Table 10 that accumulating a sinking fund for purchase of a new pump and motor drives the labor wage very low. It can be expected that under these circumstances capital accumulation for replacement will be almost non-existent and the variable operating costs may be unpaid.

These large labor inputs and low returns to labor have particular significance when considered in light of the current wage rate and total available labor.

Table 10. Returns to Labor from Irrigated Paddy for Different Production Circumstances and Quantities of Labor Inputs as of November 1981 at the Bakel Irrigation Project.

Labor Inputs Per Hectare of Paddy (Person-Days)	Returns to Labor Per Person-Day for Various Production Circumstances		
	Worst (CFA)[1]	Normal (CFA)	Best (CFA)
	a. With No Repayment of Capital or Variable Costs[3]		
Low - 400	312	438	625
Medium - 750	177	250	357
High - 1000	125	175	250
	b. With No Repayment of Capital[3]		
Low - 400	204	336	534
Medium - 750	109	179	285
High - 1000	82	135	213
	c. With Full Repayment of Capital[4]		
Low - 400	0	254	473
Medium - 750	0	135	252
High - 1000	0	102	189

[1]$1.00 US = 280 CFA in November 1981.

[2]Based on yields of 2.5, 3.5 and 5.0 T/ha of paddy at 50 CFA/Kg.

[3]Based on value of output less variable costs (see Table 1).

[4]Based on value of output less variable and capital costs (see Table 1).

In one perimeter a significant area is being cultivated this season with hired labor. These fields are controlled by government employees who are also members of the local production cooperative. The daily wage rate for men in this perimeter is 500 CFA for the four hours between 8:00 a.m. and 12:00 noon and an additional 400 CFA for the three hours between 3:00 and 5:00 p.m. The presidents of various other cooperatives indicated that to be attractive labor rates should range between 750 and 900 CFA for a six-hour day for men and 375 CFA for women. Thus, the calculated labor returns approach the going wage rate only in the best circumstances (Table 10).

The very large labor inputs required for totally manual farming and high competitive wage rates suggest that it is very unlikely that the opportunity cost of labor is as low as estimated in the many previous economic analyses of the project. While no studies have been carried out, there are a significant number of complaints from and observations by cooperative presidents that paddy cultivation has been carried out as an alternative rather than as an addition to rainfed farming. Clearly, this is a cost to irrigated agriculture.

It is apparent from the preceding analysis that labor is a very real constraint to expanding production. The labor issue becomes even more crucial when we note that in some perimeters 1/20 of a hectare of irrigated paddy is allocated to each family on the basis of one mature male per nuclear family. This amount of acreage across the village appears to exhaust the labor supply given such high labor flow rates. Also, it was noted that contrary to general belief, the bottleneck is more in land preparation than harvesting and weeding.

A dilemma arises because in order to reduce the per hectare cost of the capital equipment for irrigation, most perimeters must be expanded to take full advantage of the pumping plant capacities. But increasing the irrigated area is limited by the high labor requirements. Clearly, this constraint must be removed either through: (1) animal power or mechanization; (2) switching to crops requiring lower labor inputs; and (3) teaching the existing labor force better techniques. Undoubtedly, a mixed strategy will be required. It is clear, however, that there can not be a substantial expansion of irrigated land, and thus profitable return to investment in irrigation if the labor issue is not addressed and labor requirements reduced.

The purpose in the above discussion is not to suggest another cost/benefit analysis of the project, but rather to re-emphasize the critical importance of a careful ongoing analysis of labor flows in all cropping activities across the project area. At the same time, however, it should be noted that we have been conservative in our estimates of costs. For example, interest on capital is not charged, there is no opportunity cost for dry season crops not grown, there is no maintenance charges on pumps and motors and we know that floats and pipes have been breaking up in two or three rather the five years used in our analysis. We chose our analysis in order to gain an understanding of farmer behavior. An economic project analysis for future projects must account for the costs not included in our financial appraisal.

Economic Surveys

AID personnel have recognized the need for detailed information on costs and returns from irrigated paddy. Given that many new agricultural activities are being introduced into the area and postulating a downward sloping learning curve, it is more appropriate to organize a continual monitoring system than to rely on cross-sectional studies by outside consultants. The evaluation team recommends the following procedure for obtaining baseline data on labor requirements for a farming system approach to development.

1. The establishment of a cost/accounting project in four or five of the collective paddy fields. This would require enlisting the assistance of the presidents/managers of the cooperative societies which are working the collective fields. These records would not only provide baseline data, but would allow and facilitate the exchange of management practices and techniques between irrigated perimeters. It would also serve as a comparison with individual plot operations. This effort might well evolve into an annual practice carried out by the collective field managers which could be very useful for establishing profitability and managing inputs.

2. A farm survey of dryland farming should be organized for the next cropping season. This would provide baseline data for establishing the cost of reallocating labor and inputs to irrigated agriculture.

3. A farm survey of individual-plot irrigated agriculture by perimeters with alternative organizational forms should be carried out.

4. Case studies of total family enterprises should be undertaken.

The required survey work cannot be accomplished without providing a strong supporting staff for the agricultural economist assigned the tasks. He or she must have the opportunity to train one or two enumerators. It is essential that typing and reproduction services in the field are available. There must be clerical assistance for preparing the data for analysis. Few of these services have been available to date which is one reason why progress has been very slow.

Absolutely no survey work should be carried out without first enlisting the cooperation and agreement of the officers of the production cooperatives. The purpose and utility of the survey should be fully discussed and debated.

The USAID agricultural economist must have a SAED counterpart. This counterpart must gain creditability by occasionally volunteering his labor in the cooperative fields.

Cost/Accounting

The cost/accounts records should provide for an accounting of labor inputs for all the operations from canal maintenance through land preparation to threshing and drying. This should be done on a daily basis across the growing season by type of labor (males and females greater than 14 years old and children). The accounts should also provide data on date of operation and a description of the practices (e.g., quantity, type and method of fertilizer placement or insecticide application). In addition, the account should record quantities of purchased inputs and methods and time of storage and marketing. It is essential that the cooperators in the project be contacted prior to developing the accounting procedures and be allowed to participate in drawing up the forms. This requires that the agricultural economist involved have a clear idea of the type of information needed and usefulness of the effort.

It is also essential that the agricultural economist spend time at the perimeters verifying and assisting with the recording. He should observe all of the field operations, taking occasional measurements for one cropping season to gain complete familiarity with the input allocation and husbandry operations.

Rainfed Farming

In the opinion of the evaluation team, a dryland farm survey should be conducted and organized to study the rainfed farming activities of 30 to 40 cultivators. A purposive sampling technique should be used and differences between men's land, women's land and family land must be recognized. The survey should cover:

1. Type of enterprise.

2. Types of operations.

3. Time of each operation (to produce a cropping calendar.)

4. Labor estimates by type of operation including time spent to and from fields by men, women and children.

5. Purchased inputs (type, quantity, price and source.)

6. Yield (this season) and best estimate of range of yields based on cultivator experience.

7. Rotation and between year practices.

It is quite possible that data already exists which would serve as the baseline information that is being sought here. However, the study team did not have the resources to search the proliferation of study documents which reportedly exist for the Senegal River Valley. Consequently, the team recommends that a thorough search be made of previous studies for production information that can be used to provide a baseline description of agriculture in the project area. This information can then be used to estimate the impact of the introduction of new farming practices and enterprises.

Irrigated Farming

The team also suggests that a cross-sectional survey of approximately 40 individual irrigation cultivators be carried out in both the rainy and dry season. These cultivators should be drawn from across perimeters representing different organizational forms. This will require prior enumeration of organizational patterns. The purpose of this is to identify circumstances in which the organizational survey will enable extension and research workers to place input allocations in a framework which is consistent with cultivators' perceptions.

The small sample size is suggested here on the assumption that the central management of individual plots and the usual layout of individual plots act so as to reduce between plot variation. This needs to be confirmed by careful field analysis.

The survey instruments could be developed with the assistance and cooperation of the technical advisor in the project area. The samples should be drawn from across plots as well as from across perimeters. This should be possible given the existing plot layouts.

A Total Farm Enterprise Approach

Case studies using interview and survey techniques should be carried out to develop an understanding of the total economic system of the production units. This will require close cooperation between an anthropologist or sociologist and the agricultural economist. This work will ultimately be most important for establishing a baseline from which a responsive program for development might be constructed.

General

It is unreasonable to suppose that a single agricultural economist professionally isolated in the Bakel project area could accomplish the suggested tasks. The USAID agricultural economist needs to be given a generous travel budget for establishing a working relationship with other professionals in Africa. Frequent air-travel for consultation with professionals in West Africa and at the leading African Universities wherever they may be, as well as trips to U.S. or European Universities should be provided for. This work should have begun five years ago -- it must be started now!

As a final note, it is difficult for a team of outsiders unfamiliar with the indigenous culture to design the most efficient survey process. The process given here should be used as a starting point and form the basis of developing a study strategy.

Repayment of Capital and Fuel Costs

In some irrigation perimeters credit has been suspended because of a failure of the cooperative to pay fuel and other input costs. The reasons for non-repayment are not totally clear and because of this, there is uncertainty as to the appropriate policy for debt repayment. A failure to repay debt may result because cultivators think they can get away with it or the returns from production have been too low to cover costs. Low net returns may in turn be the result of poor management and husbandry on the part of the cultivators; the enterprise is not profitable at current prices; or a breakdown in input supply networks such as fertilizer and delivered irrigation water. The latter may be a result of pump or engine failure or insufficient fuel at the pumping station and these factors are mostly outside of the control of the cultivators. Given this and the mismatched pumping plant equipment as discussed elsewhere in this report, the repayment policies required of the Bakel project farmers-cooperatives need to be carefully considered.

In the Bakel project, the initial capital items (pump, motor, floats and pipe) were purchased by foreign donors. It was anticipated that after this initial donation, cooperatives would create a sinking fund for purchasing replacement equipment. Financial reasons why this "fund" has not been established are discussed elsewhere in this report.

It is not surprising that engineering and technical difficulties were encountered in the early stages of the Bakel project. This is the nature of the development process. These difficulties need to be understood and dealt with for not only the Bakel project, but future projects as well. Again, these difficulties are discussed elsewhere in this report.

Everything considered, the following points summarize the conclusion of the evaluation team regarding the financing of capital items and repayment of fuel costs for perimeter irrigation of the type undertaken in Bakel.

1. The technical/engineering components of the vast majority of the Bakel project perimeters were generally of a low standard and that necessarily resulted in low financial returns (independent of any inadequacies in the "agricultural package").

2. Based on field experience, sufficient information should now be available to identify the circumstances under which the financial returns to pump irrigation parameters are high enough to make investment in the irrigation capital items attractive.

3. Given a comprehensive identification of item (2) above, an incentive system for fuel payments and establishing equity in the initialk irrigation capital items should be established. The incentive program should be started now with the expected life of the pump engine adjusted to reflect current age and it should be applicable for the following:

a. New project areas with small pump irrigation perimeters where it can be shown that the coefficients determined in (2) above for the Bakel project are applicable.

b. New irrigation perimeters in the Bakel area.

c. Old perimeters in the Bakel area where the pump engines have been in operation for several years.

d. Successful irrigation perimeters in the Bakel area (such as Ballou) which should immediately be granted equity positions in the irrigation capital items on location at their site. This equity position should be based on the post application of the equity formula described in the paragraphs below.

Incentive Repayment Systems

An equity/repayment scheme for irrigation capital items and for fuel should have the following characteristics at the early stage of perimeter development:

1. It should provide a financial incentive for the cooperatives to provide a high level of pumping plant maintenance.

2. It should allow the cooperatives to establish an equity position in the pumping plants;

3. It should provide a financial incentive to the government agency responsible for the supply and introduction of the pump and motor to:

   a. Provide the most efficient match of pump and motor for the pumping situation; and

   b. Provide timely repair services.

4. It should provide a financial incentive to the farmers to utilize the irrigation water efficiently;

5. It should recognize the risk and uncertainty associated with the introduction of a new technology.

As discussed elsewhere in this report, in the Bakel project a poor selection of pumps, floats and pipes; and match of pumps and engines resulted in higher irrigation costs than necessary, independent of any pump or engine repair problems. These types of problems have also significantly contributed to decreased yields and lowered net returns to farmers. In addition, it must be recognized that the farmers of a newly irrigated area such as the Bakel project area are moving along a learning curve as they attempt to minimize labor and purchased input costs. (This type of economic behavior is not in opposition to Government policy.)

The following section outlines an example of a type of an equity/repayment system which meets the objectives as outlined earlier. Other formulations can be developed. (One very important ingredient of any repayment scheme is that it can be presented in a way which is comprehensive to both the administrators and farmers.)

<u>Fuel Repayment Formulation for a Single Cropping Season</u>

Following is a formula for allocating fuel costs to cooperatives:

$$C_c = TF + [K(1-E)TF] - TF \sum_{i=1}^{n} 0.3 \, (B_i - 3.0) \qquad (1)$$

where

C_c is the fuel cost to be paid by the cooperative/pump users.

TF is the cost of the fuel actually used to run the pump-engine during a given crop season.

[K(1-E)TF] is an incentive adjustment to encourage pump maintenance and efficient water use by farmers and efficient pump-engine selection by government where K is an adjustment factor and E equals irrigation equipment capacity use efficiency defined as A/I in which:

A is an equivalent irrigated area.

I is the irrigable area which must be determined as a function of the pump-engine efficiency

$$TF \sum_{i=1}^{n} 0.3\,(B_i - 3.0)$$ is a fuel cost adjustment factor to compensate for crop losses caused by engine breakdowns in which:

B_i is the number of days the pumping plant is down during each breakdown.

n is the number of breakdowns during the season in question.

Allowing (I) to vary by pump-engine type allows for the fact that pumping plants with different efficiency levels have been introduced in the area. The less efficient the pumping plant, the lower irrigable acreage, (I). Making (I) a function of pump-engine type provides an incentive for SAED to be more careful with their pump introductions than in the past. USAID might also be more careful by having manufacturing claims verified by independent laboratories prior to introduction rather than using long field trials on on-site well into the project life as was the case in Bakel.

In practice (I) will be determined by calculating the amount of water pumped at given lifts with the pumping plant operating at the maximum efficiency level during a 10 hour pumping day. By calculation, and most important on the basis of field experience as available in Bakel, the acreage that can be irrigated under average rainfall conditions can be determined. This must be done on the basis of that crop which has the highest water requirement. This is necessary so that all cropping possibilities can be reduced to a common factor. (I) can be calculated by an engineer using evapotranspiration estimates for the particular crop, the efficiency of the distribution systems and measured deep percolation losses. Tables can then be constructed from which (I) can be read directly.

Sample Table A — Determination of I for Paddy

Pump-Engine Combination	I (Project Area A)	I (Project Area B)	etc.
A			
B			
C			
D			
"			
"			
"			
"			
N			

Paddy is used as the basis for determining (I) since it is the crop with the highest water requirement. If initially calculated at the beginning stages of a project, (I) should be verified by actual field measurement as soon as possible. The value of (I) should allow for average water distribution conditions and should not be based on ideal circumstances or else the incentive features of the formulation will be lost. For example, in Bakel for Lister engine and Delovle pump (I) = 20 hectares based on field experience to date.

The equivalent number of irrigated hectares (A) is determined by observing the actual area of all crops which are brought under irrigation and converting it to an equivalent paddy area by the formulation:

Hectares of Paddy x 1.0 = ______ ha

\+ Hectares of Maize x 0.45* = ______ ha

\+ Hectares of Sorghum x 0.45* = ______ ha

Total irrigated area = ______ ha

*Note: Use 0.45 for the rainy season, for the dry season use 0.6)

The reduction numbers such as 0.45 are calculated by dividing (the quantity of water pumped to irrigate a hectare of any crop) by the quantity of water pumped to irrigate a hectare of paddy.

The purpose of adjusting fuel costs on the basis of irrigation capacity use efficiency is to provide an incentive to groupments (i.e., cooperating units) to irrigate the maximum possible acreage. Also, the efficiency factor (E) imposes a penalty for unused irrigation capacity. For example, if E = 0.5, then there would be a 50 percent penalty imposed for failing to fully utilize the irrigation potential: i.e., (1.0-0.5)TF which would be a 50 percent increase in fuel cost to the cultivator. On the other hand, if cultivators through canal maintenance and good water management and pump operation expand the irrigated acreage to twice the standard irrigable area, then (1.0-2.0)TF = -TF and C_n the fuel cost to be paid by the cultivators falls to zero.

The K coefficient is introduced to allow policy makers to adjust the fuel cost incentive dependent upon circumstances. K is a proportion which varies from 0.1 to 1. For example, if K is equal to 0.5, then by irrigating twice the standard specified irrigable acreage as in the above example, cultivators could only reduce their fuel cost by 50 percent. K in practice should be high (at or close to 1.0) at the beginning of a project and then be gradually reduced to, say, 0.5 to reflect a normal learning curve.

In the portion of the equation which adjusts fuel costs to compensate for breakdown days, three (3) days is judged to be a reasonable repair period or time to install a loanable pumpset while repairs are being carried out. Multiplying by 0.3 assumes that each day water is unavailable will on the average result in a 3 percent reduction in crop yields.

For example, suppose that the total fuel used during an irrigation season cost 150,000 CFA but that the pump had gone out of commission twice during the growing season, once for 5 days and a second time for 17 days. Thus, fuel cost reduction which would be allowed to compensate for breakdowns would be calculated as follows:

1st breakdown	0.3(5-3) =	0.6
2nd breakdown	0.3(17-3) =	0.45
		0.51

Therefore, the cost reduction would be:

0.51 x 150,000 CFA = 80,000 CFA

In this case 80,000 CFA would be deducted from the fuel bill to the farmers. In fact, their actual losses would be greater than this (i.e., fertilizer, labor, etc). This fuel breakdown adjustment would provide SAED with financial incentive to be more responsive than in the past in establishing an appropriate maintenance program and repair service. Any actual use of this formulation must involve explaining it to the cultivators. The formula need not be taught; rather, tables could be prepared based on the particular I and K values that have been decided upon by technicians and policy makers.[3]

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[3] A similar process could also be used to reduce the repayment obligation for fertilizer inputs. The amount of fertilizer repayment reduction could be computed by replacing the total fuel cost (TF) by the total fertilizer cost (FZ) in the breakdown component of the incentive equation discussed above. This should remove some of the risks of lost fertilizer response due to irrigation system breakdowns and would give SAED even more incentive to set up a responsible maintenance and repair program.

The above suggested process is far superior to foregoing taxes on fuel as a way of reducing cost. Foregoing taxes will clearly result in a black market and is a disincentive to good water management.

Gaining Equity in Irrigation Capital Items

The initial site of pump, motor, float and pipe which make up the pumping plants are presently being supplied at no cost to the production cooperatives. However, at the present time there is considerable confusion as to ownership. Some of the farming groups appear to take the posture that once the pumping plant is on station they own it, or if they spend money for repair that establishes at least an ownership share. SAED takes the view that the pumping plants belong to SAED.

The cost of the pumping plants can legitimately be figured as social overhead capital which is recoverable as shown by an economic analysis over the length of the project. On the other hand, a financial stake in the pumps and engines should provide an incentive to the farmers to learn and carry out maintenance and minor repairs. Also, the establishment of a sinking fund for replacement seems a wise policy for financial management.

One possible scheme for taking advantage of the incentives of group ownership is as follows. Initially, ownership of the pumping plant is vested in SAED. Then, cultivators gain equity share(s) in the pumping plant for each year of operation, such that:

$$S = TC \sum_{i=1}^{n} \frac{E_i}{L} \qquad (2)$$

where

S is the cooperatives ownership share of TC

TC is the total cost of pumping plant (engine, pump, floats, pipes)

n is the number of years of operation since acquiring the pumping plant

L is the expected life (5 years for Bakel situation) of the engine

E_i is equal to the irrigation equipment capacity use efficiency in that year as $\frac{A_i}{I_i}$ where A_i is the equivalent irrigated area (see pages 78 and 79).

In this way, cultivators are rewarded for good water management by gaining equity shares. It is thus possible that full ownership rights be established in less than L. Under best maintenance the Lister motor might last 10 years or longer. If the cultivators performed excellent maintenance and care there is a benefit to them since it delays the cost of replacement. Any salvage or resale value should, of course, accrue to the cultivators if they have established ownership.

Payment for Maintenance and Repairs

A system of repair responsibility must be established. Costs which would normally fall within a manufacturer's warranty should not be borne by the cultivators even if the manufacturer will not extend the warranty to remote perimeters. This warranty should be extended by government. Minor repairs should be borne by the cooperative, but repairs required because of poor installation such as float breakdown caused engine tilting should be borne by the government. It may be possible to assign an arbitration panel to determine responsibility under questionable circumstances.

With an engine as well known as a Lister a schedule of regular maintenance costs and usual minor repairs should be determined and users charged each season on a flat rate basis. In other words, you pay for filters if you change it or not. (This would discourage, for example, cracking a block under warranty in order to save the cost of filter.)

Farmer Cooperative Accounting

It is extremely important that an internal accounting system be developed for the farmer cooperatives. This is necessary for maintaining the faith in and integrity of the cooperative units. The accounting procedure should be taught to a designated member of the cooperative. The individual(s) should be selected by the members, not by outside authority. The accounting system should be consistent with national laws and should be audited regularly by reliable authority.

This development of an accounting process is felt to be critical to the long term success of the cooperatives. It would be essential if incentive schemes such as suggested earlier were implemented. It is clearly important for financial management and for assuring an equitable distribution of costs and benefits of irrigation.

SOCIOLOGICAL AND INSTITUTIONAL CONSIDERATIONS

A Region's Social Organization as a Reproducible Development Resource

Relative to goals for self-sufficiency in food, the production potential of the Bakel region in particular and the Senegal River Valley in general is immense. This is obvious to the Government of Senegal (GOS) and other governments contributing to its development. What appears to be unrecognized is the potential for economic development through accommodation with the region's social structure. Short of farming the whole river basin by international agricultural corporations, the hypothesis that existing social organization is a vital, if not absolutely necessary resource must be taken seriously. To take this hypothesis seriously requires a plan to systematically integrate and accommodate the region's socioeconomic structure and development objectives with national goals and objectives.

Both sides have much to offer. In exchange for credit and markets, the local social structure can employ its demonstrated capability to expand agricultural production. Capital requirements would include amortization of market facilities (storage, hullers or mills, processing and transportation) and production facilities (land clearing, leveling, canal construction, pumps, sprinkler irrigation facilities, PVC pipes, animal traction, threshers and other implements) as well as annual financing of production inputs. The proposed Caisse Locale de Credit Agricole (CLCA) would initiate the provision of some of these services as close to the farmers, the farmer cooperatives and their market as possible.

As a region's social structure begins to identify and soak up agricultural development strategies, its people must have opportunity to participate in the establishment of their own region-wide development institutions (all weather roads; rural banks and cooperatives; training schools for diesel mechanics, accountants, managers and farmers; and agricultural demonstration farms).

If local communities are to identify with these facilities, they must be involved in decisions regarding the need for and the location of such facilities. The direction of the facilities must also have local social organizational roots, perhaps through lesiglation processes such as the Morrill Act establishing land grant colleges and other acts establishing federal-state-local cooperative programs in the U.S.

While local levels may not have cash inputs or tax bases to generate local contributions, they do posses "in-kind contributions" in the form of social organization that make the public investment in agriculture much more productive. If granting of these facilities could be tied to the local community's demonstrated will and capacity to implement agricutural development strategies, the federal-local cooperative model should be workable. The implication for donor countries and the GOS is that these facilities should not be touted as gifts, but rather as joint investments.

In addition to market surpluses, this type of development creates a rural-based economy that employs and feeds itself while generating an evergrowing market for non-farm goods and services. Both rural and urban economies grow.

The possibility that rural economic power basis will emerge must be viewed by the GOS as an absolutely positive feature. The emerging rural-based economic powers will reproduce themselves. The amount of people and land in any one rural area is not sufficient to sustain infinite or "uncontrollable" growth. Rather, to the extent that rural communities do grow, they provide models for the growth of other rural communities. With a proliferation of competing rural "power bases," central government and urban centers can only benefit by the increased efficiency of rural producers and markets. Income equality issues, e.g., farm size and mechanization, can remain the province of local social organization and the commune rurales, which no doubt will also experience some changes.

Alternately, consider the losses if local social organizations were to be ignored as an asset to the development process. If the urban-based power structure opts for the services of an international agricultural production corporation to develop the river basin, rural social organization will be left a perishable relic occasionally erupting along the country's border. In this way the urban-based government would continue feeding at the mercy of a monopolistic internationally based producer. One current estimate by a commercial firm is that 20,000 hectares of double-cropped rice could be supplied for the price of 12 tons per hectare, clearly a monopolistic price. A monopolistic producer may be more easily taxed by the GOS, but the opportunity to develop a broad based rural consumer economy alongside an equally broad based economy of efficient producers would be lost.

It seems imperative that GOS take a clear look at its development alternatives and choose a plan of action. Most countries have found it imperative to use their indigenous reources (physical and social) to the ultimate.

If the development hypotheses implied in the above discussion hold true, the Bakel region's social organization is one such resource that will grow and reproduce itself several times over.

The original Bakel irrigation schemes were due to the efforts of well traveled and experienced farmers. The schemes were operated as individual village initiatives. The need for technical assistance has always been recognized and sought. The organization of the Federation of Sarakolle villages was largely motivated by leaders who recognized that shared experiences and technical expertise was necessary to address common problems. Organization of the Federation at the initiative of Sarakolle farmer leaders represents a classic case of a peasant movement to gain some control over their own development and to articulate their needs for technological and economic resources possessed by the world outside Bakel. From a social structural perspective, the organizational complexity of Sarakolle civilization and the development orientation of its returned migrants combined with Bakel's physical, political and economic inaccessibility sets the stage for the peasant solidarity movement that takes form in the Federation of Sarakolle villages. If these local organizational resources can be accommodated by national governments, the whole nation may benefit. The nature of this process is extensively researched by Frank Young of Cornell University.

This growth scenario will require continued innovation and resilience on the part of GOS. But, like other governments who have taken the path, they are likely to find it continually stimulating and rewarding in terms of increasingly stable economic development.

Social Organization as a Basis for Co-op Development

A traditional but complex peasant society such as the Sarakolle, endowed with the experience of many man-years of international migration, is generally well situated to pick and choose from the modernizing influences with which it has had contact. The traditional culture provides for individual and collective subsistence needs. Grain and livestock production systems are not only sufficient to carry a village through the long dry season and the growing season until the new crop is available, but reserves are maintained for the drought years as well. To an observer from a market economy the subsistence surpluses appear large, but in fact their necessity has probably been proved over and over again in subsistent economies.

In the case of the Sarakolle, on the Senegal River, Sekou Oumar (Bakel Project Paper, 1976) describes a civilization which has been rhythmed by the river's floods for centuries. All villages use simultaneously rainfed agriculture (DIERI) and flood recession farming (WALO). Their production system provides DIERI lands for each individual family's subsistence plus additional farms for the head families. In turn, they provide for emergencies and family ceremonies. The production system allows everyone to provide for their subsistence; at the same time the distribution system provides security. The head family of family groups or the ruling family of the village have family and individual granaries at their disposal for emergency purposes. Thus, traditionally, individual family hordes or supplies are not indiscriminately marketed. The market surpluses, if any, accumulate in the hands of the family heads and village chiefs for emergency or ceremonial use. Other uses of surpluses would be acted upon by supreme villages councils, extended village councils, or various management committees.

Labor may be the major marketable surplus of the traditional culture. Proceeds from this resource are recaptured by local social organization as well. International migration of young Sarakolle men is apparently influenced by group decisions as well. Young migrants send back regular contribution for the welfare of their families and villages. After several years, with an accumulation of some wealth and experience, they return to their places in the village.

In sum, this traditional society provides an authority structure for the specialization of decision-based activity and rule- or cultural-based activity. Thus regulated, the production and distribution systems have provided for a long sustained and orderly society. It is critical that these social organizational assets be mobilized if cooperative economic development is to be realized.

Social Organization and Irrigation Perimeters

Victor S. Doherthy and Senan M. Maranda, anthropologists and irrigation engineers, respectively, at ICRISAT near Hyderbad, India, are conducting research on social organization and small watershed development. Their research suggests that rule-based activity is suitable for either small or large groups, but that ultimately it is the larger group that must sustain and sanction the rule-based activity. Decision-based activity that sets or changes the rules of cultural activity is most efficiently carried out by individuals, or small or large groups if they are under centralized management. Organization of the village groupments in the Bakel perimeters would appear to fit these conditions. Centralized management in the form of the management committee makes the decisions and sets the rules which are sustained and reinforced by traditional social organization. In turn, small work groups from the perimeters according to the rules laid down by central management.

The irrigation perimeters in Sarakolle region of the Bakel Project are organized in the image of the Sarakolle village. Decision-based activity is handled by the management committees headed by perimeter or groupment presidents. Rules regarding participation in the perimeter are made by the management committees through traditional legitimation processes. The decisions include: the size of an area to be farmed collectively for the purpose of debt payment and accumulation of perimeter surpluses; the amount of labor to be assessed each family for the collective production and maintenance activities; collective individual work schedules; varieties to be grown; inputs to be used; and the fines to be assessed for the breaking of various rules. The sale and utilization of perimeter surpluses is also a management committee decision.

While all able interested males and nuclear families in the village are allocated a prorata share of the perimeter, they do not necessarily work their share as an extended family. For example, in the perimeters at Balou, work groups consisting of five persons within their age group (FEDDI) cultivate a 10 meter by 528 meter strip. Each person from different families takes responsibility for a two meter strip. In this way variation in access to water and land quality is randomly distributed among families; thus, equality is maintained by employing traditional allocation processes.

The individual strips as well as the collective areas are cultivated strictly according to the rules of the management committee. If the rules are broken individually, fines are assessed. If they are broken collectively or the agricultural practice is done wrong, the village's drums are used to recall the participants back to the perimeter the next morning to correct their errors. Among the village perimeters, the average area per cultivator is very small, ranging from 0.1 to 0.2 hectares. While the perimeters are small in area and apparently manageable, they are large in membership. They appear to be too large for effective organization. However, with a clear distinction between decision-based activity on the part of a small perimeter management group and rule-based activity on the part of small work groups, management is currently effective. The apparent fact that this organization of activity parallels the time tested social organization of the village suggests that the culture is more flexible than often expected by development planners. Technical awareness and competence of the management committee represents an innovation in village organization. The oldest members of ruler families are not necessarily the presidents. As Oumar has indicated, the perimeter president is always the one who has traveled a lot, who has met many people in Bakel and Dakar, and who is able to discuss with the political-administrative authorities.

As long as the perimeters are relatively small (20-100 hectares) and they are run as one management unit using scientifically and economically sound practices, traditional social orgnization and process should be relatively efficient. It appears to be more efficient than either a western style consensus model or a centrally managed and operated state farm, as has been tried on other Senegal River perimeters.

However, unless the expected payoffs are realized, the current high levels of organizational focus on irrigation agriculture are not sustainable.

Articulation of Federation Interests with SAED

The Government of Senegal through SAED recognizes potential complementarities in national goals and local cooperative goals. Our observation has been that these complementarities have turned out to be narrowly based. The development attempts of the villages have been broadly based with interests in improving DIERI and WALO farming as well as, among other things, the irrigation perimeters. Farming on the perimeters provides diverse alternatives to intensify agriculture. While rice production offered the potential of a cash crop, so do green and dry corn, vegetables and sorghum. The perimeters could be engineered to mesh with the work rhythm of DIERI and WALO farming. If the cropping systems selected for perimeters prove to enhance or stabilize the productivity of the villages, more labor would be attracted to it.

Groupment organizations and the Federation of groupments are keenly interested in articulating with improved technologies to improve in all of these areas. They expect technical competence in SAED technicians and they expect to learn the technology themselves. Perhaps most important, the Federation and perimeter or groupment leadership expects to be in control of their development. The Federation leadership has expected since the beginning that the Federation should be involved in design and management of the Bakel project; that SAED and donor agencies should be accountable to the Federation as well as the groupments or individuial perimeter. Alternately favoring one perimeter and then another by SAED to place the perimeters in competition with one another may serve SAED's narrowly based goals, but not serve the common broadly based goals of the Bakel region. The principle of local control and accountability is a consistent extension of traditional social organization. The importance of articulation with the national government and international aid is locally recognized, if held accountable, as a potentially vital tool to local development.

However, local leadership believes that if peasant development is to happen, they must be represented in the decision-based activities as well as in implementation of rule-based activities. The Federations should be represented on the design team and management boards for diesel mechanic training schools, demonstration farms, marketing boards, SAED employment and training offices and any other decision making entity that result in new rule-based activity for implementation in the perimeters. The present high degree of local perimeter self-management is offset by a void between groupments/federations and SAED-AID management.

Federation input into decision making has been significant, as recognized by the Joint Assessment (July, 1980), but it is not a routine formal process. Formalization of this process should be done with care not to alienate it from traditional cultural processes. As summarized here and as observed by many scholars and consultants, local social organizations in the Bakel region should be recognizable as a valuable and sophisticated resource.

Rice for Market or Subsistence

Male and Female Opportunity Costs

Based on median estimates of labor requirements for production and harvest (200 adult six hour days per hectare), maximum yields (5 T/ha yields and 3 tons above costs) and average market price in the Bakel area of 75 CFA/Kg of paddy, the returns per day are less than 50 percent more than the opportunity cost of male labor (1120 CFA/day versus 750 CFA/day). In the Tuskegee Institute report, 647 days valued at 200 CFA/day are estimated requirements to cultivate one hectare of rice. This estimate includes unspecified amounts of labor by men, women and children and the day lengths range from 3 to 7 hours. The total value of the labor is estimated to be $129,000 CFA/ha. This estimate is slightly less than the 150,000 CFA/ha minimum that men might be expected to place on 200 six-hour days of their time. In reality, one man could handle about 1/4 hectare on a timely basis equaling 50 days of employment. Little more than two months of work are absorbed by one crop on the perimeter.

Marketing also requires substantial effort on a petty trade basis. In the Koughani collective, the guardian estimated one-half of the collective farm's 13 ton production remains unsold after one year. The Balou collective also has a large year-old reserve and their president and mangement team are seeking marketing alternatives. Because of SAED and GOS restrictions on the trade into Dakar and across national borders, the alternatives to SAED's offer of 50 CFA are exhausted. The SAED market price drops the value of market surplus down to or below the above estimates for men's opportunity costs (750 CFA/day). Rather than sell to SAED, families will likely treat rice as a subsistence food crop.

Women may be expected to work the perimeter as an alternative to less certain food production in their dryland fields (DJERI). Due to competition between DJERI and perimeter subsistent food production, the yield advantage after production cost would be more than 2000 kgs/ha, or a maximum of 50 kgs per family. On a per day basis this represents a value of 500 CFA, less than the opportunity costs for males, but more than that of females (375 CFA).

This rough analysis suggests that SAED price and market structure will do little to encourage surplus production of rice. The economics and labor restraints to production are discussed in greater detail elsewhere in the report.

Male/Female Participation

Examination of SAED records on male and female participation in the Bakel perimeters and their allocation of area to rice, maize or sorghum supports the trend expected. Since 1979 perimeters in the Bakel middle zone, where area expansion and production increases have been most dynamic, women participants increased their numbers by one-third, while men have declined by about 10 percent (Table 11). At the same time, the area under wet-season production has increased 70 percent (Table 12). These increases in the middle zone were encouraged by relatively greater distances to DJERI fields and somewhat more suitable clay soils for irrigation. Also, access to SAED inputs was probably more dependable. The increase in female and decline in male participation (a male to female ratio of 0.78 in 1979 to 0.54 in 1981) is taken as support for the hypothesis that perimeters are being used more for subsistent food consumption than originally expected.

The area of rice in the Northern perimeters has declined slightly. Only one village of eight shows an increase. Four villages have increased maize or sorghum production on lighter soils (Table 12). Two of eight perimeters were inactive in the wet-season of 1979 and 1981. No yield data over time are available at SAED. While yields are expected to have increased, both male and female participants have declined (Table 11, North), suggesting that the

Table 11. Perimeter Membership by Sex (Male and Female Ratio) in Three Bakel Zones.

	Male			Female		
	1979	1980	1981	1979	1980	1981
North - 8 perimeters (G.I.)	601	436	496	1107	947	815
M/F Ratios	(.54)	(.46)	(.58)			
Middle - 10 perimeters (G.S.)	619	635	570	796	1014	1066
M/F Ratios	(.78)	(.63)	(.54)			
South - 8 perimeters (Faleme)	357	362	368	287	425	286
M/F Ratio	(1.24)	(.85)	(1.29)			

low total returns available from such a small area are judged by several as insufficient reward. The preference for maize or sorghum in the Northern perimeters is clear, thus constituting more evidence that the rice market is inadequate.

In the Southern (Faleme) perimeters (Table 12), the area in wet season production is very low suggesting that the DJERI crop in this zone of slightly higher rainfall may be more dependable and/or accessible than in the Middle or Northern zones. One perimeter was inactive during the 1979 wet season and four or more were inactive in 1981. Irrigated maize during the dry season may be more popular than in the wet season.

These independent estimates of the returns to labor indicate that perimeter efforts are not as rewarding as originally expected, at least under present SAED market structure. The lack of significant perimeter expansion in 1981 (Table 13), a year following severe drought, is additional evidence that payoffs have topped out.

Table 12. Rainy Season Hectarage for Rice and Maize in 3 Bakel Zones (Number of Perimeters Increasing (+) or decreasing (-) Two or More Hectares Between 1979 and 1981).

Zone	Rice			Maize or Sorghum		
	1979 (ha)	1980 (ha)	1981 (ha)	1979 (ha)	1980 (ha)	1981 (ha)
North (G.I.)	65	56	58 (+1,-2)	11	41	42 (+4)
Middle (G.S.)	134	209	203 (+5,-2)	14	61	59 (+3)
South (Faleme)	20	5	23 (plan) 15 actual (-3,+2)	15	9	28 (plan) 12 (actual) (+2,-2)

Source: Bakel SAED Offices: 1981 data for southern Faleme Zone (plan) conflicted with observation in field (actual). Also found by perimeter in Tuskegee Report (1981). Other 1981 data was roughly consistent with field observation.

Table 13. SAED (Bakel) Estimates of Irrigated Perimeter Production (1979-1981).

Year	Total (ha)	Wet Season		Dry Season (cold and hot)	
		Rice (ha)	Corn & Sorghum (ha)	Maize (ha)	Vegetables (ha)
1979		224	40	211	?
1980	587	269	114	194	10
1981	610*	285	127	?	?

*Estimate based on plan assuming 1981 dry season production equal to that of 1980.

Isolation from the Market

Given the Bakel Farmer-Federation awareness of their market isolation, the evidence supports the hypotheses that production of rice, and other crops as well, is unlikely to generate much more than traditional subsistence surpluses. The groupment attempts to market surpluses have been discouraging. The larger groupments recognize the need to vertically integrate into the market, mill their rice and other grain for bulk marketing and gain a larger share of the retail price in Dakar than presently possible. The Farmer Federations also recognize the monopoly enforced by law that SAED currently has on the DAKAR market. They know how the Regional Development Authority (ONCAD) grew fat on peanut marketing in the peanut basin (Carvin, 1981) and they don't want it to happen in the Senegal River Basin.

USA/DAKAR/FFP records and BCEAO show rice imports of 250,000 MT and 20,000 MT of maize. Another 100,000 MT of wheat is imported. The combined total is more than enough to feed the 1.1 million population of Dakar and most of the total urban population of the country at the rate of 233 Kilos per capita (Magnusson memo, March 11, 1981, p. 16). Only some 30,000 MT of millet of a 450,000 MT crop in Senegal enters the urban market. This estimate alone confirms the almost total monopoly that imports and the GOS has on the Dakar cereals market. The potential for volume marketing by groupments or the Federation without some kind of government sponsorship must be judged at the outset as virtually impossible.

Federation Marketing and Production

While the groupments or the Federation is still hopeful that some accommodation may be made with SAED, efforts have been frustrated. The formal recognition of the Federation has been delayed for several years. The farmers along the Senegal River may be represented by four seats, one from the Bakel Federation, on the 12 man SAED management board in the near future, but outcome of negotiations is still in doubt.

The Farmer Federations are quite aware of these realities and they see little use in additional narrow production based development until a broader market based development is established. This analysis logically concludes that USAID/GOS agricultural devlopment efforts cannot be expected to yield market surpluses without market policy reform. This is the case with or without SAED.

On the other hand, the production potentials of the farmers of the Senegal River Valley, Bakel region in particular, are dramatic. Local social organization and farmers have demonstrated desire and ability to sop-up highly productive agricultural technology, first to insure subsistent needs and then market surpluses, if the cash returns justify the extra investment. With existing technology, labor is a constraint to production of market surpluses.

Increased production capacity could be financed through financial markets, but the farmers' distaste for debt is clear. For the Sarakolle, collective farms have provided a cooperative to share the risk associated with debt. Through the groupments, additional risks may be taken. But rather than strict crop production investments, the Farmers Federation and the groupments (presidents at Balou, Yefara, Koughani) are interested in using their surpluses as collaterals to finance market facilities and to secure alternative markets to the SAED/GOS monopoly. With alternative markets in place, the farmer, groupments and federations are positioned to at least partially control and accelerate their own development of commercial agriculture. The marketing facilities must grow with the market and be self-financed from market margins.

In order to induce farmer commitment to the cash economy, the amortization of market facilities should be structured through joint farmer/GOS/SAED representation. It must provide for ownership by the farmer federations and groupments. With the facilities located in the villages, community development has visibility and broader utility. Both the local consumer market and regional surpluses can be processed in the community. By-products can be processed for food or feed. Decisions on facility loans must be based on financially and economically sound analysis of current market realities and potentials, not future potentials or political considerations.

Through participation as partners with GOS/SAED, the groupment's leadership can learn desired marketing skills that may lead to direct marketing by local cooperatives. The possibility of an alternative market can only come about if farmer federations are in a position to negotiate markets on a continuous basis.

Accountability of leadership to the local level should be maintained through innovation in traditional social organization. Management of marketing facilities should also be selected and paid by the local organizations on the performance basis and not by GOS/SAED, articulation of commercial production potentials of the groupments and GOS objectives will then have a chance to thrive.

The Federation/cooperative should be multi-purpose, utlimately they may secure their own production inputs and their own lines of credit for irrigation equipment and animal traction.

Arrangements should be made to administer these credit lines through standard banking procedures and relationships between the banks and the cooperatives. In the interim, the cooperative will have to have the opportunity to develop standard credit worthiness. All interim GOS/SAED arrangements must use standard accounting procedures, with external audits, bonded warehouses and warehouse men, etc.

Meanwhile, as the mechanisms to interface and articulate local organization and government bureaucracy are accountably fashioned, the general principal of traditional local accountability and intra-government bureaucracy cannot be neglected.

Critical elements of the accountability model are enumerated by E. Walter Coward in the study of "Local organization and bureaucracy in the Lao irrigation project," pp. 329-344 in Coward's edited volume, Irrigation and Agricultural Development in Asia: Perspectives from the Social Science, Cornell University Press, Ithaca, 1980. Adaptation of indigenous leadership role to link bureaucracy and local user organizations can work, it is hypothesized, if accountability for job performance remains largely with the local groups.

SAED Farmer Training

The SAED Training Project (Project Paper, 1977) outlines the structure of the Irrigation Technology Center at Savoigne, five sub-centers on site at major perimeters (Dagna, Guede, Nianga, Matam and Bakel) and a machinery maintenance center at Ross Bethio.

At each of the five sub-centers, the project calls for a classroom facility for 20 trainees with a kitchen, mess-hall and dormitories. Five trainer agents at each sub-station will train 170 farmer trainees-come-farmer-trainers and 30 perimeter office supervisor trainees during the five year life of the project, i.e. 20 trainees per season -- two seasons per year.

The design calls for training to be divided into three distinct phases: sensitization, dissemination of information and apprenticeship. The sensitization phase implies audio-visual introduction to subject matter; dissemination implies demonstration of subject matter and apprenticeship implies hands-on practice and application of subject matter.

The five trainer agents at each sub-center, e.g., Bakel, include two managers and operators of audio-visual training techniques, one active pedagogical methods specialist, one training techniques of rural populations specialist and one teacher. The latter two deal with cooperative training and literacy.

All of these trainers are to be introduced to the content of irrigation farming, animal traction, farm management, cooperatives and rural sociology. The training is to be done within an on-the-job training format. It is acknowledged at the outset of Chapter III in the Project Paper that the SAED personnel do not have prior hands-on or formal training in the subject matter of agriculture.

Although not noted in the Project Paper, a four year agricultural curriculum, B.Sc. level, is now being planned and facilities are under construction at Thies. The World Bank financed campus is designed for 160 up to 500 students with 50 hectares of field space. This curriculum will be planned to incorporate hands-on agricultural training.

In the meantime, this basic mastery of agricultural practices must be accomplished on-the-job with SAED. Without the hands-on competence and the confidence it inspires in working with villagers, the SAED extension personnel are practically non-functional or even detrimental to SAED-farmer relations.

As the Project Paper acknowledges, the personality of the farmer is that of a man who believes only in what he sees, if he sees SAED trainers demonstrating skillful and profitable production techniques, the farmers will learn more rapidly. If the practice is profitable, the farmer may learn anyway, but no credit would be due to a SAED training program. The farmer's pedagogical dialogue with his environment is not likely to enhance the farmer's image of SAED, particularly if his trial and error methods are repeatedly unproductive.

All the process and method outlined in the Project Paper (SAED Training Project) will be void of heart and driving force unless the trainers meet the farmer's prerequisite criteria that the trainer be a hands-on master of that which he tries to teach.

At least it would be advised that one or two sub-center teams have extensive hands-on training with recommended practices and that the differences in their impact as trainers be evaluated.

The next section considers adjustment in the content of the training program that should enhance SAED personnel interest and commitment.

Social Organization and Training Needs

Regional goals and objectives and national goals and objectives should find several points of intersection when critical skills and training needs are identified. To the extent both local social organization and the national government identify with the needs for training, establishment of mutually acceptable mechanisms should be possible and desirable.

The above analysis of the Project Paper for SAED training concludes that the farmer training in sub-centers focuses upon production technologies, but that the SAED trainers will be more nearly masters of teaching method and process than knowledgeable of production technologies and their profitability. Without the latter it is concluded that the sub-center farmer taining program would not command the respect of farmers and will fail.

To succeed, the sub-center farmer training facilities should be established in the context of farmer and farmers federation/cooperative objectives. Curriculum development would involve farmers' input. It would include training to allow farmer control over efficiency of water delivery at the outset and the efficiency of marketing of surpluses at the conclusion of the production process, rather than exclusive focus on the production processes in between. Within the production process, curriculum must be designed to village-level needs including animal traction, multiple cropping and dry-land farming. Literacy and cooperative training are also important. This broad curriculum is more consistent with both farmer/village and national development objectives. If villages can take care of subsistence needs more efficiently, more resources will be available for market production. SAED objectives of increasing surplus production will thus be better served, without compromising other national objectives.

Curriculum Development and Farmer Participation

The curriculum for each training program must take into account the goals and objectives of farmers within their sub-center locality. Even differences within sub-centers must be identified and catered to. Where perimeter soil conditions are not optimum for irrigated rice, other irrigated crops or DIERI crops must be emphasized. Where DIERI farms are distant from the village or relatively more risky than irrigated farming on suited soils, the perimeter techniques must be emphasized. In both cases, sequence and timing of cropping practices to be included in each curriculum should first involve a head-to-head and heart-to-heart dialogue with the farmers in each village prior to selection of their candidates for training. Such a dialogue requires competent and confident trainers who seek to learn from each dialogue rather than to be alienated by dialogue. These trainers will need responsible back-up research which will allow them to modify each training curriculum.

Mutual respect between farmers and trainers will surely grow from this kind of program. Beyond a tailored curriculum for production practices, the key to gaining respect of the farmer is an appreciation and knowledge of his goals and objectives: a more reliable and broader based subsistence and profitable market surpluses.

Diesel Maintenance Curriculum

Key to a reliable food production base is reliable water. All regions along the Senegal River can readily identify with a training institution that provides the skills needed to maintain their irrigation system and insure its reliability.

At current subsistent levels of production, women more than men are critical of pump maintenance. In villages where women have found the perimeter less risky or arduous than DIERI farming in distant fields, the possibility of training women to maintain pumps should be considered. Of course, if perimeter farming is to become reliable and profitable on a commercial scale, there will be no shortage of interested male trainees.

Market Curriculum

The farmer's desire for profitable market surpluses as discussed in the market section cannot be treated strictly in terms of production efficiency. It must be complemented with learning experiences that convince the farmer his markets are efficient and he is getting his fair share. If the farmer cannot earn more by specializing in production and growing two or three crops a year, it is a much more interesting life to spend part of his year producing and part consuming and marketing. The farmer needs to learn, if indeed it is so, that his time is much more profitably spent in the fields than in storage, processing and trading activities. Alternately, if the farmer cooperatives/federations can do both more effectively, they need and want to learn that as well.

Implications for Training

Farmer/farmer federation/cooperative objectives must be serviced in totality by the training program if the national goals of market surpluses are to be served. This perspective has several implications for the training of SAED trainers:

1. Farmer representation should be on the board-of-directors for all SAED training activities, but in particular for training sub-centers.

2. The totality of farmers' federation objectives as well as national objectives should be acknowledged at the outset and constantly referred to in adapting curriculum.

3. Trainer-demonstration farms and trainer-applications farms should be integrated into the curriculum. All agents should have experienced hands-on control of the production process while in training. The training programs of the International Crop Research Institutes are recommended (IRRI and ICRISAT, in particular).

4. The curriculum should focus first on the critical water constraint, efficient and cost effective water supply and a practical appreciation that pump maintenance skills at the village level must be optimum if the system is to be profitable. Engines and pumps must be matched to needs; they must be installed on more reliable floats to minimize maintenance; fuel storage and supply systems must be free of contamination; the farmer should have and know that he has an efficient, durable pump to canal pipe delivery system; and the farmer should be aware that he is amortizing the systems for future ownership. All of this will instill confidence in the trainer and the farmers.

5. With water delivery to the canals standardized, local variation in soil types, water distribution (canals or pipes), cropping systems and social organizations must be brought into consideration.

6. The labor constraint issue is the first production system priority to be addressed by the curriculum. Higher yielding varieties and cultural practices that economize on both labor and water must be sought to relieve the competition for labor between the DIERI and the irrigated perimeter. If the women can produce and process the food crops more efficiently, they will have more time for market crop production. If market crop production costs, namely labor, are minimized, male labor will be attracted back into the farm labor force. Use and maintenance of animal traction, seeders and weeders and peddle threshers

are labor-saving candidates for the curriculum.

7. Land is not a constraint for the Bakel region of some 40,000 population, but converting that land to efficient water and labor use will require more capital investments in water conservation structures and labor conservation practices on both dry and irrigated land. Therefore, use of credit for intermediate term production facility loans must be in the curriculum.

8. All production techniques must be carefully selected for the curriculum. They must be successfully implemented by both trainers and trainees on the demonstration and application farms. Then the information should be shared with local perimeter management committees. Local perimeter managers and other farmers they choose should be invited and transported to demonstration farm field days each year to see the results of adapted practices.

   In collaboration with the newly trained farmers from their perimeters (and SAED agents if invited), local management may decide on a set of rule-based activities to be implemented on perimeter collective farms and ultimately on the individual plots.

9. Once this multi-crop, multi-cropping curriculum is designed for the village, the farmer/farmer cooperatives must have the opportunity to learn that they have open access to efficient market channels that provide them a higher return than they could get by entering the market themselves. The farmer rightfully places a price on giving up the pleasures associated with marketing of his own produce. This price is not insignificant if one takes account of the many strategies that Bakel farmers have employed to market small amounts of collective farm surpluses over the course of one year. A few perimeters still have surpluses of several tons and a bumper crop is at hand. Considering their limited markets and the low-priced SAED alternative, it is likely that less, not more, surplus rice will be produced next year.

Summary of Recommended Training Objectives

In sum, the curriculum must deliver a means for the farmer to produce crops more economically and to market with a greater appreciation of market possibilities and limitations.

The curriculum as designed in the SAED Training Project does not focus on the critical nature of efficient water supply or efficient marketing methods, the two extremes of the production process. Both extremes have implications for the potential of the Bakel region to absorb and retain more labor on a year around basis. Both extremes relate very closely to the social, economic and cultural goals and objectives of the regions' villages. The fact that these needs have been neglected or even constrained by the objective of a low-cost food supply for the urban sector contributes to labor constraints in Bakel and other farm regions.

The effort to communicate basic village objectives is too often misunderstood by national governments and misinterpreted as narrow-based political activity. It is then perceived as a threat, rather than as an asset for development.

If the training programs were to incorporate coverage of broad-based village objectives, e.g., low-risk water supply, labor saving technology and efficient marketing, the social organization capacities of the villages and farmer federations could then serve their own objectives as well as the national objective of increased productivity. SAED and village relations would be improved. SAED employees and farmers could believe they were helping themselves as well as the nation. Theoretical technologies would become working cultural practices. The training program for trainers and farmers would then have content and heart, not just process.

BAKEL SOLAR PUMP PROJECT REVIEW

The evaluation team visited the Bakel Solar Pump Site on November 5, 1981. During our visit to the facility and in discussions with Mr. Kassimen Milan, the French technician in charge of installations (who appears to be doing a very excellent job), we were informed that the net rated electric output (for operating the irrigation pumps) of the facility is 30 KW for 10 hrs/day. This is confirmed in the contract document. Mr. Milan said that the gross output is 32 KW, but it takes 2 KW to operate the circulating pumps, battery charges and control systems. The circulating pumps are operated off the storage batteries when the generator is not in operation. According to Mr. Milan and the contract documents, enough thermal energy to operate for 10 hours can only be collected on absolutely clear days when the sun angle is perpendicular to the fixed collector plates and the glass covering the plates is clean and free of dust.

Value of Power Output

A simple and straightforward way to place a value on the usable energy output is to assume it could be sold at the current domestic electric rate in Bakel. This eliminates the confusion of trying to estimate the potential return based on crops irrigated by using the electricity to pump water. The standard domestic rate charged by the national electric utility, SENELEC, is 34 CFA ($0.12) per KWH. In remote locations like Bakel this is a subsidized rate, but it should be sufficient to cover operating costs for the generating plants.

Since the 2000 m^2 of collector panels are fixed, they are not always at the best (perpendicular) angle to the sun, so the average annual output under full sun will only be about 97 percent of peak potential output. Furthermore, according to climatic data from the World Meteorologic Organization at Linguere, Senegal, the estimated annual percent sunshine is 61 percent and at Tambacounda it is 58 percent. Therefore, it is doubtful that it is greater than 65 percent at Bakel. Using the above figures, the annual electric output of the facility could hardly exceed:

$$30 \text{ KW} \times 10 \times 365 \times 0.97 \times 0.65 = 69{,}000 \text{ KWH/year}$$

At $0.12 per KWH, this much electric power would be valued at:

69,000 KWH @$0.12/KWH = $8,280 per year

This assumes there is a market for all the power, which would not be true if it were only used for irrigation pumping. However, further adjustment of the figures is not warranted because obviously $8,280 is nowhere near sufficient to cover operating costs and technical supervision for the solar facility.

Pumping for Irrigation

Table 14 shows the potential daily power output by month which can be produced by the solar facility. The data in the table was developed using the estimated percent sunshine figures from Linguere and an estimated panel angle of 15 percent to the south. These figures in Table 14 assume an average daily integrated solar radiation level of 6.9 KWH/m^2. These data could be refined from more precise monthly solar radiation data/performance expectations which, according to the contract document, should be available from the contractors (Sofretes and Thermo-Electric).

Pumping Cost

The power output of the Lister HR-2 (2 cylinder) diesel is 21.5 BHP at 1500 RPM. Thus, the solar power installation can be expected to have the same power capacity to pump irrigation water as a $10,000 Lister HR-2 diesel. For example, at 21.5 BHP the HR-2 would only need to be operated for 10 hr/day to pump as much water as the solar facility on an average day in November with an output of 217 BHP-Hr.

From the data in Table 14, the potential annual power output of the solar facility is 77,000 BHP-Hr, i.e., the sum of the products of the average monthly BHP-Hr per day values times the number of days in each corresponding month. In terms of irrigation pumping, the maximum value of this potential energy output from the solar facility can be estimated in terms of current diesel fuel and engine prices. This may be done by assuming that an irrigated crop program could be managed to beneficially use all of the water which could possibly be pumped by the facility at whatever time it happened to be available. The diesel fuel requirements for an engine pumping the same amount of water would be:

$$\frac{77{,}000 \text{ BHP-hr/yr}}{4.0 \text{ BHP-hr/liter}} = 19{,}250 \text{ liter/yr}$$

Table 14. Average Potential Daily Power Output of the Solar Facility for Each Month.

Month	Sun %	Eff %	BHP-Hr* per day	Month	Sun %	Eff %	BHP-Hr per day
June	60	100	216	Dec.	69	92	229
July	52	98	183	Jan.	73	93	245
Aug.	44	97	154	Feb.	70	96	241
Sept.	41	96	142	Mar.	72	97	251
Oct.	51	96	176	Apr.	70	98	247
Nov.	64	94	217	May	66	100	238

*Brake horsepower hours per day assuming 1.2 BHP-Hr/Kw-Hr.

At the current farm gate price of 100 CFA/liter, the diesel fuel would cost:

$$\frac{19{,}250 \text{ liter/yr} \times 100 \text{ CFA/liter}}{275 \text{ CFA/\$1.00 US}} = \$7{,}000 \text{ per year}$$

The number of hours of operation per year required for a Lister HR-2 diesel engine to have the equivalent pumping capacity on the solar facility would be:

$$\frac{77{,}000 \text{ BHP-hr/yr}}{21.5 \text{ BHP}} = 3{,}580 \text{ hr/yr}$$

The current price of a Lister HR-2 diesel engine is $10,000. The engine should have an expected life of at least 7000 hours, or two years, at the above output rate and require no more than $2500/year for service and maintenance. Thus, the annual capital and maintenance cost of the engine should not exceed $8,000/year.

Based on the above figures, we estimate that the entire potential energy outpout from the solar facility can be replaced by a diesel powered pumping plant which would have a current capital plus operating cost of no more than $15,000/year.

Irrigation Capacity

There has been considerable argument concerning the irrigation potential of the solar facility. We feel that the potential has been seriously overestimated which has led to unrealistically high benefit estimates (perhaps 10 times too high). We do not wish to enter this argument further. However, we reason that the irrigation potential of the solar facility is about the same as the area served by a standard 2-cylinder diesel pumping plant floating on the river. Each diesel pumping plant is normally expected to serve 20 ha, but under the most favorable operating conditions we did find some pumping plants serving up to 27 ha.

Summary and Recommendations

In summary, we feel that as soon as it is politically feasible, the Bakel solar pump project should be terminated for the following reasons:

1. It is obvious that the value of the energy which the facility could potentially generate is only a fraction of the inevitable cost of operating it. It will be very expensive to operate the facility in terms of: management inputs on the part of GOS and USAID, which are in short supply; salaries and expenses for expatriot technicians; cleaning, repair and maintenance of the collectors; and maintenance of the machinery.

2. The facility itself is obsolete because it is materials intensive. It requires a large collector area (2000 m^2) fabricated of glass, aluminum and copper to capture the solar heat energy; a complex water circulating system and insulated tank to collect and store heat energy, a heavy, inefficient piston engine to convert the heat energy to work energy; a generator with special controls to convert the work energy to electric energy, and finally, an electric motor to convert the electric energy back to work energy to drive the pump. Being so materials intensive, the cost of such solar pumping plants tends to rise as fast or faster than energy costs. With no hope of ever becoming cost-competitive, similar solar pilot projects are being abandoned elsewhere.

3. We have seen little evidence during our stay in Senegal that there is much hope for properly maintaining sophisticated equipment and machinery, especially in a remote place like Bakel.

Our only hesitatation in making this recommendation is out of fear that it may cause some people to condemn solar power in general, and because we realize that it will create quite an embarrassing situation. On the other hand, reason suggests that the venture will die a slow, painful death, causing even greater disappointment, embarrassment and waste.

We believe the suppliers and consultants would prefer not to carry out the specified five years of: warranty, preventive and semi-annual maintenance, data analysis and training activities required by the contract, because the contract payment schedule for these items will nowhere near cover costs. As compensation for terminating their contract early, USAID should request a payback or at least free assistance with relocating the collectors and machinery.

The buildings at the solar facility should make an appropriate Bakel Region headquarters for SAED and provide much needed space for equipment maintenance and training facilities. However, the adjacent river bank should be stabilized so it does not continue to erode and eventually undermine the buildings.

We inspected the 32 ha irrigation demonstration farm site which is scheduled to be supplied with solar pumped water. The land is good, but it is quite far (1000 m) from the river. Furthermore, we were informed that in the vicinity of the solar pump site the river channel is dry part of the year.

APPENDIX A

THE POTENTIAL FOR RAINFED AGRICULTURAL PRODUCTION IN SENEGAL

by

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THE POTENTIAL FOR RAINFED AGRICULTURAL PRODUCTION IN SENEGAL

by

George H. Hargreaves

Introduction

Senegal is principally between 12°30' and 16°39' North Latitude. The western two-thirds of the country is at elevations less than 200 m. The southeastern portion is mountainous with a maximum elevation of 1368 m. The normal range in mean monthly temperatures is from 20° to 30°C. The rainy season is June through October with most of the rain falling in three months (July, August, September). Mean annual recorded rainfall increases from north to south with extremes of 311 and 1722 mm. During the rainy season the mean monthly relative humidities are usually above 70 percent, and sometimes above 80 percent. The soils present a wide range of conditions.

Considering the climate as the principal factor in crop selection, and assuming that suitable soil conditions can be found, an analysis can be made indicating the crops most appropriate for production in the area. The principal determinant is the duration of the effective rainy season and the amount and distribution of precipitation including depth duration amounts.

Dependable Precipitation, PD

Dependable precipitation, PD, is defined as the 75 percent probability of precipitation occurrence (precipipitation exceedence) or that amount that can be expected to be equaled or exceeded three-fourths of the time. An analyses of the 30 year World Meteorological Organization records indicates that for those months in which PD exceeds one-third of potential evapotranspiration (ETP) values of PD can be reliably estimated for Senegal from mean rainfall, PM. The equation can be written

$$PD = -30 + 0.85 \times PM \qquad (1)$$

in which PD and PM are in mm per month. The coefficient of determination, R^2, was 98 percent, indicating a good degree of reliability in the use of the equation.

Wernstedt[1] gives mean monthly and annual rainfall for 57 locations in Senegal. These data were used together with Equation 1 to estimate the 75 percent probability PD for the 57 locations.

The Moisture Availability Index, MAI

From available climatic data from Senegal and the Gambia, estimates were made of potential evapotranspiration, ETP. Isolines of ETP estimates were drawn on a map of Senegal.

The moisture availability index, MAI, is the 75 percent probability of precipitation occurrence, PD, divided by ETP. The equation can be written

$$MAI = \frac{PD}{ETP} \qquad (2)$$

MAI is a water balance index. Various studies at Utah State University and CIAT (Centro Internacional de Agricultura Tropical) indicate that the number of consecutive months with MAI exceeding 0.33 provides a good index of the length of the economical growing season for many commercial crops.

Table A-1 lists the rainfall stations and presents values of PD and MAI. If MAI exceeds 1.33, rainfall is considered to be excessive for that month. In fairly flat areas (smooth slopes of less than two percent and irregular topography of less than three percent) surface drainage may be needed to remove excess rainfall. Under "symbol" in Table A-1, the notation 3/1 indicates an effective rainy season of three months with one month of excessive rainfall. The climate classification used is that presented in World Water for Agriculture.[2]

Crop Zones

Figure 1 indicates the dependable rainfall for agriculture varying from one or two months in the north to five months in the

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[1]Wernstedt, Frederick L., "World Climatic Data," Climatic Data Press, Lemont, Pennsylvania, 1972, 522 p.

[2]Hargreaves, George H., "World Water for Agriculture," Utah State Univ. and Agency for International Dev., 1977, 177 p.

Table A-1.The Water Balance for Senegal.

THE WATER BALANCE FOR SENEGAL

Station	N.Lat.	W.Long.	Value	June	July	Aug.	Sept.	Oct.	Symbol	Climate Classification
Bakel	14°53'	12°23'	PD	7	70	135	60	0		Semi-arid
			MAI	0.05	0.40	0.85	0.45	0	3/0	
Bambey	14°42'	16°27'	PD	0	74	174	116	12		Semi-arid
			MAI	0	0.55	1.40	0.95	0.10	3/1	
Bigona	12°49'	16°14'	PD	79	199	405	259	93		wet-dry
			MAI	0.60	1.65	3.50	2.15	0.70	5/3	
Boulel	14°08'	15°21'	PD	24	108	146	117	25		Semi-arid
			MAI	0.15	0.70	1.10	0.90	0.20	3/0	
Coki	15°30'	16°00'	PD	0	48	146	83	1		Semi-arid
			MAI	0	0.35	1.15	0.65	0	3/0	
Dagana	16°30'	15°30'	PD	0	14	97	34	0		Arid
			MAI	0	0.10	0.75	0.25	0	1/0	
Dahra	15°21'	15°29'	PD	0	61	134	72	4		Semi-arid
			MAI	0	0.40	0.95	0.55	0.05	3/0	
Dakarville	14°40'	17°26'	PD	0	104	178	78	6		Semi-arid
			MAI	0	0.85	1.40	0.65	0.05	3/1	
Dakar-Yoff	14°44'	17°30'	PD	0	59	157	129	20		Semi-arid
			MAI	0	0.50	1.25	1.10	0.15	3/0	
Dara	15°20'	15°29'	PD	0	48	152	82	0		Arid
			MAI	0	0.30	1.10	0.65	0	2/0	
Daroumousty	13°53'	15°48'	PD	0	57	129	74	11		Semi-arid
			MAI	0	0.40	1.00	0.60	0.10	3/0	
Dialacoto	14°39'	13°09'	PD	98	175	235	204	31		Semi-arid
			MAI	0.60	1.15	1.70	1.65	0.20	4/2	
Didloulou	13°02'	16°35'	PD	32	219	466	213	69		Semi-arid
			MAI	0.25	1.80	4.05	1.80	0.55	4/3	

Table A-1 Continued.

THE WATER BALANCE FOR SENEGAL (Cont.)

Station	N.Lat.	W.Long.	Value	June	July	Aug.	Sept.	Oct.	Symbol	Climate Classification
Dioubel	14°39'	16°09'	PD	5	78	173	116	17		Semi-arid
			MAI	0.05	0.55	1.25	0.95	0.15	3/0	
Fatick	14°20'	16°20'	PD	14	110	230	146	25		Semi-arid
			MAI	0.10	0.80	1.85	1.15	0.20	3/1	
Foundiogne	14°07'	16°28'	PD	7	122	272	169	30		Semi-arid
			MAI	0.05	0.90	2.20	1.35	0.20	3/1	
Gassane	14°49'	15°18'	PD	15	65	138	106	47		Semi-arid
			MAI	0.10	0.40	1.00	0.80	0.35	4/0	
Gossas	14°30'	16°04'	PD	19	102	167	130	73		Semi-arid
			MAI	0.15	0.75	1.30	1.05	0.55	4/0	
Goudyry	14°11'	12°43'	PD	42	117	203	134	31		Semi-arid
			MAI	0.25	0.75	1.35	1.05	0.20	3/0	
Guenoto	13°34'	13°48'	PD	80	129	206	176	13		Semi-arid
			MAI	0.50	0.80	1.50	1.40	0.10	4/2	
INOR	13°00'	15°42'	PD	74	227	344	194	70		Wet-dry
			MAI	0.60	1.75	2.85	1.55	0.50	5/3	
Joal	14°10'	16°51'	PD	2	159	262	186	69		Semi-arid
			MAI	0	1.20	2.10	1.50	0.50	4/2	
Kaffrine	14°06'	15°28'	PD	14	90	205	123	15		Semi-arid
			MAI	0.10	0.65	1.60	0.95	0.10	3/1	
Kadlack	14°08'	16°04'	PD	21	110	229	156	20		Semi-arid
			MAI	0.15	0.80	1.75	1.25	0.15	3/1	
Kebemer	15°22'	16°27'	PD	0	37	164	86	23		Arid
			MAI	0	0.30	1.30	0.70	0.15	2/0	

Table A-1 Continued.

THE WATER BALANCE FOR SENEGAL (Cont.)

Station	N.Lat.	W.Long.	Value	June	July	Aug.	Sept.	Oct.	Symbol	Climate Classification
Kedougou	12°33'	12°10'	PD	136	182	251	255	72		Wet-dry
			MAI	0.95	1.30	2.00	2.10	0.55	5/2	
Khombole	14°46'	16°42'	PD	0	70	196	110	10		Semi-arid
			MAI	0	0.55	1.55	0.90	0.10	3/1	
Kidira	14°28'	12°13'	PD	48	123	186	126	10		Semi-arid
			MAI	0.25	0.70	1.20	0.95	0.05	3/0	
Kolda	12°55'	14°55'	PD	88	180	291	221	73		Wet-dry
			MAI	0.65	1.35	2.35	1.75	0.50	5/2	
Koumpentoum	13°59'	14°33'	PD	49	89	177	122	31		Semi-arid
			MAI	0.30	0.60	1.30	0.95	0.20	3/0	
Koungheul	13°58'	14°49'	PD	69	124	199	129	22		Semi-arid
			MAI	0.40	0.85	1.40	0.90	0.15	4/1	
Linguere	15°23N	15°09'	PD	0	54	156	80	10		Arid
			MAI	0	0.30	1.05	0.60	0.05	2/0	
Louga	15°38'	16°09'	PD	0	43	107	77	0		Arid
			MAI	0	0.30	0.85	0.60	0	2/0	
Maka-Coliben-tan	13°40'	14°17'	PD	56	94	173	139	24		Semi-arid
			MAI	0.35	0.60	1.25	1.05	0.15	4/0	
Matam	15°38'	13°13'	PD	16	68	151	63	0		Semi-arid
			MAI	0.10	0.40	0.95	0.45	0	3/0	
M'Bara Garage	14°59'	16°44'	PD	0	45	172	106	9		Semi-arid
			MAI	0	0.35	1.40	0.85	0.05	3/1	
M'Bake	14°44'	15°55'	PD	0	73	173	100	5		Semi-arid
			MAI	0	0.52	1.35	0.75	0.05	3/0	
M'Bao	14°45'	17°19'	PD	0	32	166	112	3		Arid
			MAI	0	0.25	1.35	0.95	0	2/0	

Table A-1 Continued.

THE WATER BALANCE FOR SENEGAL (Cont.)

Station	N.Lat.	W.Long.	Value	June	July	Aug.	Sept.	Oct.	Symbol	Climate Classification
M'Bour	14°25'	16°55'	PD	0	67	209	134	13		Semi-arid
			MAI	0	0.50	1.65	1.05	0.10	3/1	
Mont Roland	14°56'	16°59'	PD	0	69	195	133	35		Semi-arid
			MAI	0	0.55	1.20	1.05	0.25	3/0	
Nioro-Rip	13°44'	15°49'	PD	34	131	262	162	28		Semi-arid
			MAI	0.25	1.00	2.00	1.30	0.20	3/1	
Oussouye	12°30'	16°30'	PD	86	347	472	290	103		Wet-dry
			MAI	0.70	3.00	4.10	2.40	0.82	5/3	
Podor	16°38'	14°56'	PD	0	18	82	33	0		Arid
			MAI	0	0.10	0.65	0.25	0	1/0	
Rufisque	14°40'	17°15'	PD	0	40	206	119	0		Arid
			MAI	0	0.30	1.65	1.00	0	2/1	
St. Louis	16°01'	16°30'	PD	0	15	109	71	0		Arid
			MAI	0	0.10	0.85	0.60	0	2/0	
Saraya	12°50'	11°45'	PD	139	199	269	184	107		Wet-dry
			MAI	0.95	1.25	2.05	1.20	0.75	5/1	
Sedhiou	12°43'	15°42'	PD	78	210	355	270	194		Wet-dry
			MAI	0.60	1.60	3.15	2.15	1.45	5/4	
Tabacounda	13°46'	13°41'	PD	78	125	188	160	30		Semi-arid
			MAI	0.45	0.83	1.40	1.30	0.20	4/1	
Thiadiaye	14°25'	16°42'	PD	0	117	200	211	41		Semi-arid
			MAI	0	0.90	1.65	1.75	0.30	3/1	
Thiel	14°56'	15°04'	PD	5	38	130	107	27		Arid
			MAI	0.05	0.25	0.85	0.80	0.20	2/0	
Thies	14°48'	16°56'	PD	0	59	205	138	13		Semi-arid
			MAI	0	0.45	1.65	1.10	0.10	3/1	

Table A-1 Continued.

THE WATER BALANCE FOR SENEGAL (Cont.)

Station	N.Lat.	W.Long.	Value	June	July	Aug.	Sept.	Oct.	Symbol	Climate Classification
Thilmaka	15°02'	16°14'	PD	0	43	152	94	2		Arid
			MAI	0	0.31	1.15	0.75	0	2/0	
Tivaouane	14°57	16°45'	PD	0	46	78	118	1		Semi-arid
			MAI	0	0.35	0.60	0.95	0	3/0	
Tabacouta	12°42'	15°49'	PD	37	96	346	235	50		Semi-arid
			MAI	0.25	0.75	2.90	1.90	0.35	4/2	
Velingara	13°09'	14°09'	PD	98	146	236	204	43		Semi-arid
			MAI	0.65	1.00	1.75	1.55	0.30	4/2	
Yang-Yang	15°40'	15°18	PD	0	48	151	84	3		Arid
			MAI	0	0.30	1.10	0.65	0	2/0	
Ziguinchor	12°35'	16°16'	PD	73	268	423	284	102		Wet-dry
			MAI	0.60	2.25	3.70	2.35	0.80	5/3	

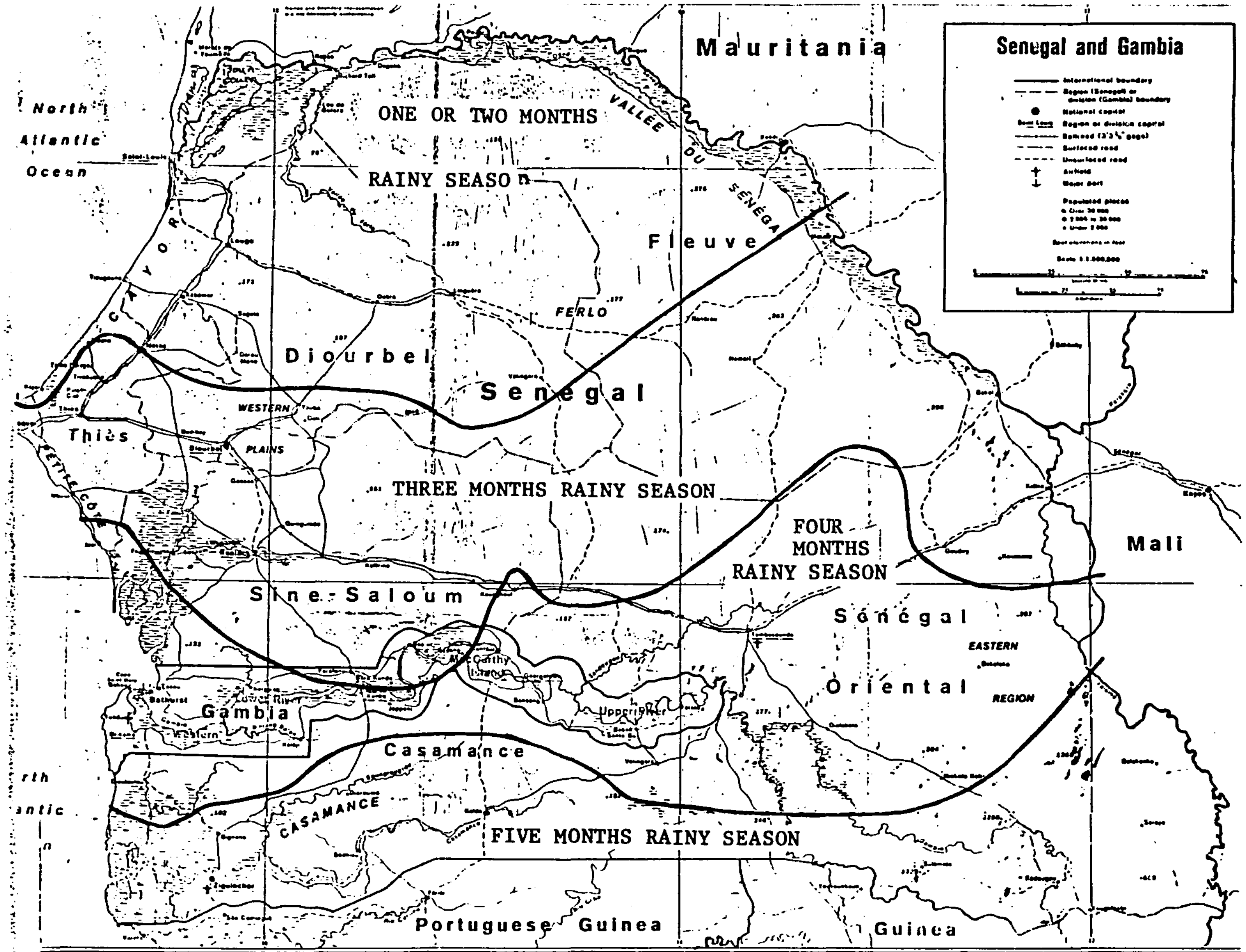

Figure A-1. Length of Dependable Rainy Season.

south. The location of the lines dividing the zones may not be very exact, and therefore some caution is necessary when using Figure A-1 for agricultural production planning.

Crop Selection

Crops considered for subsistance or commercial production should be those having optimum ranges of mean monthly temperatures between 20° and 30°C. The growing season should not exceed the period of dependable rainfall. For some crops more than a hundred established varieties are available with a considerable range of climatic adaption and length of growing season. Much experience or experimentation may be required in order to select the best variety for the local conditions. Some crops that have suitable requirements for temperature and length of growing season are given in Table A-2.

Some leguminous trees already grown extensively in Africa need to be given greater emphasis. These produce useful fodder, firewood, food and fertility for the adjacent soil area. Three that grow well are tamarind, acacia torilis and acacia albida.

In southern Senegal the rainfall season is long enough for cotton production. It is, however, questionable that cotton will be of importance, as this crop is best suited to fairly large commercial operations. Also, intense rains interfere with germination.

Maize will have limited utility as a crop because it is particularly sensitive to drought and to excess water. Sorghum and the millets will yield much better. Sorghum produces well in many areas that have similar climate, but in some cases bird damage to the crop is significant. The millets suggested are pearl, broomcorn and foxtail, as these three have shorter growing seasons than most other millets.

Mung bean is particularly recommended for the areas where the rainfall season is too short for other crops. Some varieties of mung bean mature in as little as 45 days. Sorghums and the millets are essentially energy foods. When combined with mungbeans a source of protein is added.

Surface Drainage

At approximately half of the rainfall stations precipitation is excessive during one to four months. Most of the area has little slope. Over large areas, infiltration rates are low. Studies in

Table A-2. Suggested Crops for Senegal.

Crop	Days to Maturity	Potential yield	ky	kc	Fertilizer kg/ha		
					N	P	K
Cotton	150 - 180	3-4 T/ha	0.85	0.8 - 0.9	100-180	20-60	50-80
Groundnut	90 - 115	3-4 T/ha	0.7	0.75 -0.8	10-20	15-40	25-40
Kenaf	100 - 125	40-50 T/ha	-	-	175	30	85
Maize	100 - 140+	6-8 T/ha	1.25	0.75 -0.9	100-200	50-80	60-100
Millet	60 - 90	2-4 T/ha	-	-	see sorghum		
Mungbean	45 or more	2.5-2.8 T/ha	-	-	see groundnut		
Sesame	85 -150	1-2 T/ha	-	-	50	20	15
Sorghum	90 - 140	3.5-5 T/ha	0.9	0.75-0.85	100-180	20-45	35-80
Soybean	75 -150	2.5-3/5 T/ha	0.85	0.75-0.9	10-20	15-30	25-60
Sunflower	90 - 130	2.5-3.5 T/ha	0.95	0.75 - 0.85	50-100	20-45	60-125

Notes: ky = yield reduction factor to be multiplied times seasonal water deficit to obtain yield reduction.

kc = crop coefficient to be multiplied times seasonal ETP to estimate seasonal crop evapotranspiration

Sources: a) Samuel C. Litzenberger, editor, "Guide for Field Crops in the Tropics and Subtropics," Office of Agriculture AID, 1974, 321 p.

b) FAO, "Yield Response to Water" Irrigation and Drainage Paper 33. 1979, 193 p.

the Gambia made in the groundnut fields indicate infiltration rates of 5 to 20 mm per hour.

At Begampet (Hyderabad), India, soil slopes and climate are very similar to conditions in Senegal. The June through October MAI values are 0.32, 0.75, 0.55, 0.65 and 0.21, respectively. At ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) a system of broad (150 cm) beds and furrows with slopes of 0.3 to 0.8 percent, depending on soil conditions, permitted a change to new cropping systems that consistently increased the value of crops produced by threefold. The broad beds and furrows improved surface drainage while at the same time increasing infiltration into the soils. Figure A-2 shows some of the cropping systems used. It is emphasized that rainfall, temperature, relative humidity and other conditions, except soils, are very similar at many locations in Senegal to those at Hyderabad.

In Central America, with seven successive months of excessive rainfall, a system of broad (20 to 40 m) raised (40 to 80 cm) beds has produced benefits that generally exceed costs by a ratio of five to one.

Soil-Water Relationships

Both the amount of rainfall and the quantity that enters the soil and becomes available in the root zone for use by the crops are important. The United Kingdom, Ministry of Overseas Development,[3] investigated rainfall and soil-water conditions in the Gambia.

Soil-water relationships were studied at 14 locations. The average available water capacity, AWC, is given as 100 to 125 mm/m for the colluvial slopes and 80 to 100 mm/m for plateau soils. It is believed that little water is extracted by groundnuts at soil depths below 75 cm in relatively light sandy soils.

Rooting depth and infiltration rates were evaluated at several locations. Comparisons were made between conditions for gmelina forest and general crops. Rooting depth for gmelina is over 3 m and for general crops, it is given as 50 to 60 cm. Infiltration into the soil under gmelina is given as 60 to 125 mm/hr., and for groundnuts, 5 to 20 mm/hr.

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[3] Technical Bulletin 3, "Soil and Water Investigation in the Gambia," Land Resources Development Center, Ministry of Overseas Development, 1979, 183 p.

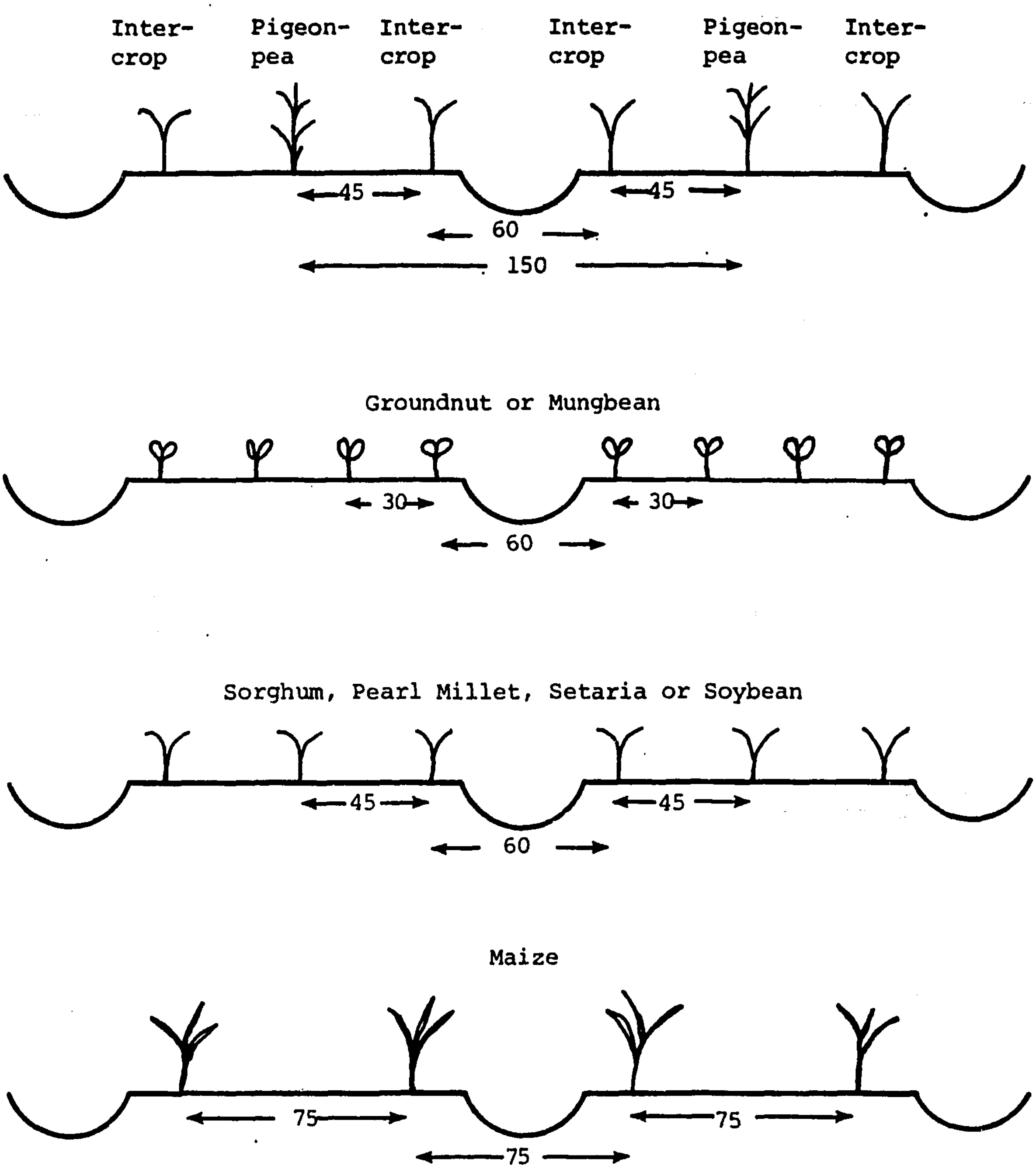

Figure A-2. Alternative Cropping Systems and Row Arrangements on Broad (150 m) Beds. All Dimensions in cm.

Fourteen years of rainfall records are available for Sapu. Daily values are given. Studies of many rainfall records show that 24 hour (1440 minute) rainfall amounts average 1.13 times observation day rainfall. Intensity or amounts vary as the fourth root of the time or duration. One hour rainfalls for many world-wide locations have been found to average 0.51 times observation day rainfall amounts. From this relationship the number of events during each of the 14 years of one hour rainfall exceeding 20 mm (the reported maximum infiltration rate into the soil for groundnuts) was calculated. The number of such events varied from two per year to as many as 10 per year, with an average of 5.2 events per year.

The above analysis indicates that high rates of surface runoff can be anticipated. Thus, it is important to retain as much water as possible in the soil. Soil water reserves need to be kept as large as feasible in order that growth rates will be adversely affected as little as possible during short dry periods.

The rooting depth for groundnuts is generally considered to be about 0.75 m. If an allowable 40 percent extraction of available soil water is desirable and available water is assumed to be 100 mm/m, then with an effective root depth of 75 cm and the extraction of 40 percent, soil water should be replenished when 30 mm of soil moisture has been utilized by the crop. For the climate of most of Senegal, mid-season evapotranspiration by groundnuts should be at least 4 mm per day for near optimum growth and production. This leads to the conclusion that soil moisture needs to be replenished every 7 to 8 days. Most plateau soils are described in Land Resources Study 22[4] as having sandy clay loams and sandy clays in the upper subsoil horizons. From these textures one might assume that the required period between soil water replenishments should be somewhat longer than the 7 to 8 days mentioned above.

In order to analyze water availability for upland agriculture, certain simplifying assumptions were made. It is assumed that all rainfall not exceeding 30 mm in 10 days will enter the soil and that 30 mm in 10 days will maintain a reasonably adequate growth and production rate for groundnuts. From the 14 years of record, the probability of occurrence of 30 mm of rain was calculated for each 10 day period during the rainy season at Sapu in the Gambia. The

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[4]Land Resources Study 22, "The Agricultural Development of The Gambia: An Agricultural, Environmental and Socio-economic Analysis," Land Resources Division, Ministry of Overseas Development, 1976, 450 p.

results are as follows:

Month	June			July			Aug.			Sept.			Oct.		
10 Day Period	I	II	III	I	II	III	I	II	III	I	III	III	I	III	III
% Prob. of 30 mm	51	45	55	61	88	93	75	62	89	100	59	74	31	0	27

The most critical period for water stress for groundnuts is the flowering and seed development stage. Water shortage during this period greatly reduces yields. Since the rainy season is short, varieties with short growing seasons should be preferred. Water is most critical for good crop establishment and during the first 20 days of August, the second 10 days of August having greater probability of water shortage.

Maximum observation day rainfalls for individual years of record during the 14 years of measurements varied from 45 to 139 mm, indicating a range of 23 to 71 mm for one hour amounts, 27 to 84 mm for two hour amounts and 30 to 90 mm for three hour amounts.

Measures to increase water infiltration into the soil and water retention can be designed in several ways. Contour bunds or broad base terraces can be used. Contour ridges and furrows can be constructed or raised beds and furrows can be tried. Whenever possible, crop residue needs to be incorporated into the soil to increase infiltration. Any procedure tried should consider the risks of rainfall exceeding the capacity of the system for retaining the water.

Nitrogen applied early in the season usually increases yields of groundnuts if water is not too limiting. When water is limiting on yields, nitrogen fertilization may actually decrease production. The availability of water for one irrigation during August. would greatly increase the potential for advances to a higher technological level and for better production.

Water, Fertility and Yield

The interaction between water and fertility depends upon the frequency of rain (or irrigation) as well as the amount of water made available. At high levels of fertility, plants can tolerate less moisture stress. At low levels of fertility, increasing water availability may only moderately increase yields. As water availability increases, fertility should also be increased up to the optimum relationship between fertility and yields.

Figure A-3 gives a typical relationship of the interaction between water and nitrogen for a high yielding maize hybrid. The optimum yield is approximated by the relationship between nitrogen, N, in kg/ha and seasonal crop evpotranspiration, ET, in mm, as indicated by the equation

$$N = 0.32 \times ET \quad (3)$$

About 10 percent of the rainfall stations in Senegal have fairly adequate rainfall during four months and roughly 50 percent have reasonably adequate precipitation during three or more months. By selecting the short growing season varieties and applying adequate fertilizer, good yields are possible for groundnut, millet, mungbean, sesame, sorghum, soybean and sunflower. It seems apparent, however, that unless some system is adopted for increasing the opportunity time for water to enter the soil, then yields will be low and response to fertilizer variable.

Figure A-4 shows response to nitrogen for maize in increase in yield as each successive kg of N is applied. This response is for high yielding hybrids with adequate water and other favorable conditions. Presently, one kg of N is worth about four times the value of a kg of maize grain. Figure 4 is thus an economic model. It is suggested that data from Senegal be used to prepare graphs similar to Figures 3 and 4 for the crops recommended above. Most crops will show response that will have a similar shape. The magnitude will, however, vary significantly.

For most non-leguminous crops, if properly selected for the length of rainy season and with water conservation measures, the response to nitrogen should be fairly linear up to about 100 kg/ha.

Some Recommendations

Large multi-million dollar irrigation developments are being considered for West Africa, including Senegal. A fairly limited investment in gaining experience with rainfed agriculture and the practices that can make rainfed production more profitable may provide an alternative means of a more immediate increase in agricultural production. It may also prove to be significantly more cost effective. The following recommendations are provided for

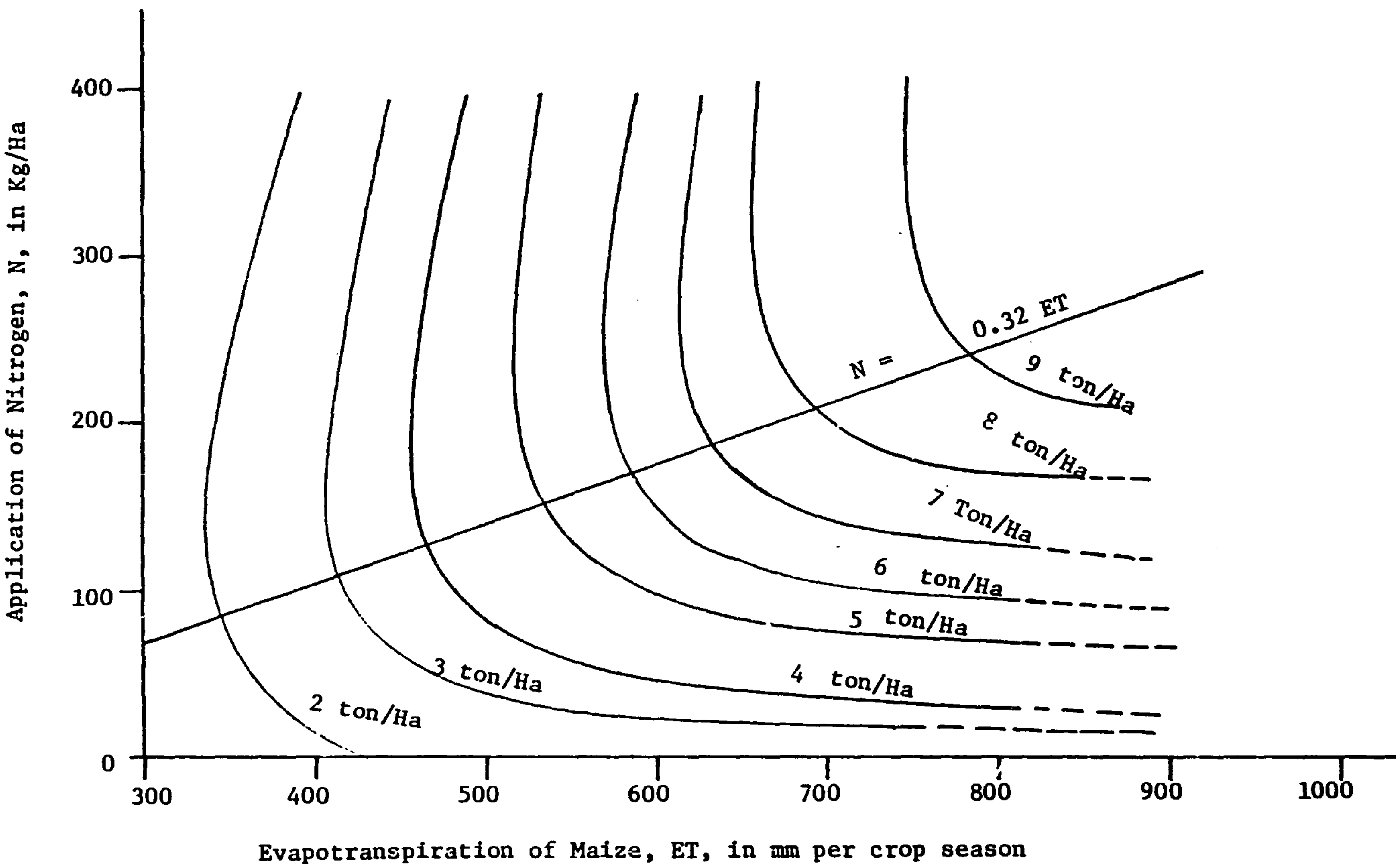

Figure A-3. Isoquants of Maise Production.

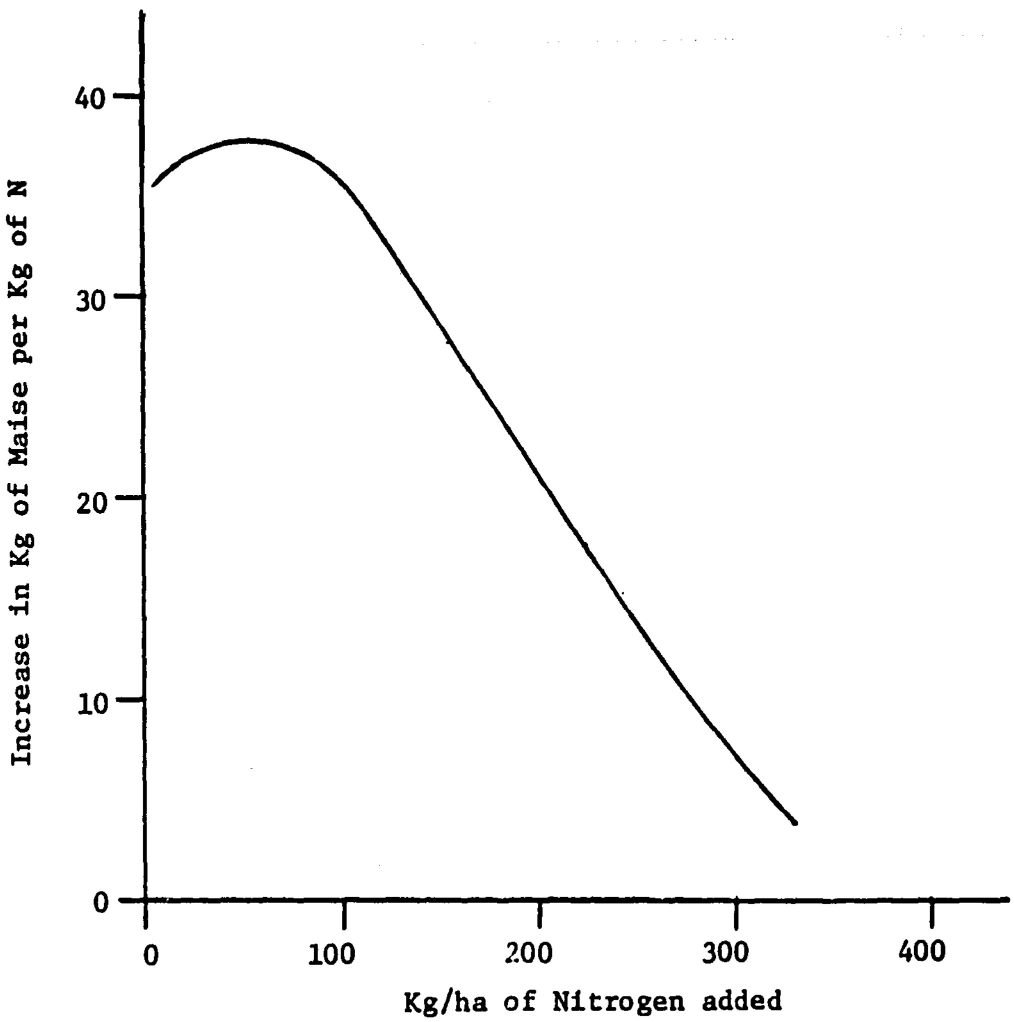

Figure A-4. Increase in Yield of Maise per Kg of Nitrogen Added at Various Rates of Application of N. Water was Adequate at All Levels of N Application.

increasing the productivity of rainfed agriculture:

1. Adopt farming systems and land preparation practices that conserve rainfall.

2. Adjust the crops and cropping season to coincide with the predicted length of the dependable rainy season.

3. Apply adequate fertilizer consistent with the dependable precipitation, its adequacy for the crop grown and previous experience.

4. Select those crops required for the local food supply for import substitution or to meet proven export market demands.

The population of the tropics and sub-tropics is increasing about 2.6 percent per year. Development that will increase agricultural production by 3 percent or more each year is a desirable goal. This cannot be attained by bringing new lands into production. Production must be maintained and yields increased on the lands now under cultivation.

Time required for investigation, planning design, construction and project development of major irrigation facilities may span a generation. In countries where population growth has outrun growth in food production for nearly a generation, it is now appropriate that a major effort be made to maximize benefits from rainfall and the climatic conditions.

APPENDIX B

SPRINKLE IRRIGATION SYSTEM DESIGN NOTES

by

Jack Keller

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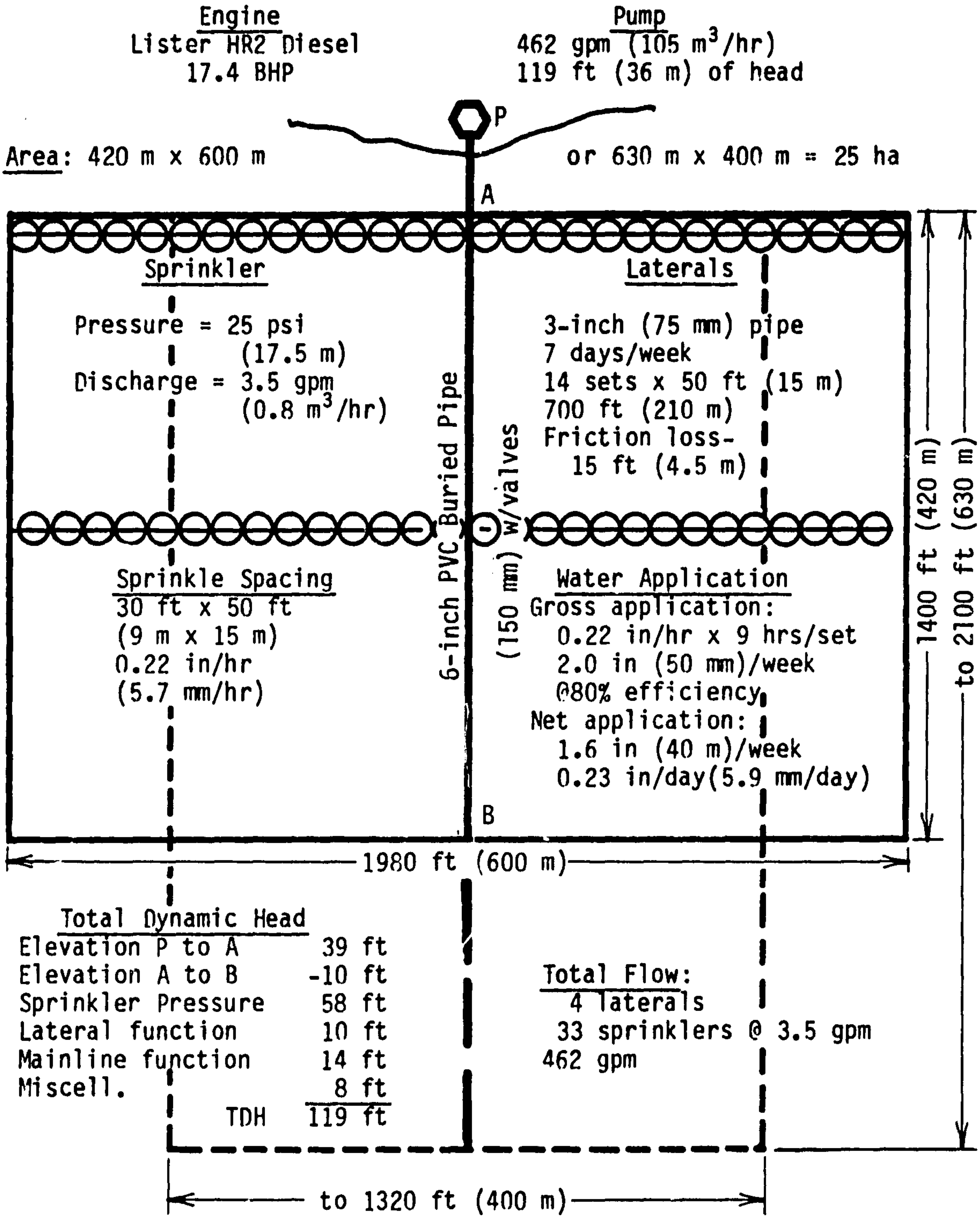
SAMPLE SPRINKLE IRRIGATION DESIGN:



Energy (Diesel Fuel) Requirements:

System operation hours/40 mm net application @80% eff.

7 days x 18 hrs = 126 hrs or 3.15 hrs/mm

Assuming diesel consumption @4.0 BHP-hr/li (15.4/US gallon)

$$\frac{17.4 \text{ BHP} \times 3.15 \text{ hr/mm}}{4.0 \text{ BHP-hr/li} \quad 25 \text{ ha}} = 0.54 \text{ liter/mm per hectare}$$

For upland crops requiring 600 mm net ET

Dry Season: 600 x 0.54 = 325 liter/ha

Wet Season: (600-400) x 0.54 = 110 liter/ha

APPENDIX C

SMALL-SCALE PUMP IRRIGATION IN ACEH UTARA, INDONESIA*

by

R. van Aart and H.L.M. van der Hoff

*From: "Annual Report 1980," International Institute for Land Reclamation and Improvement/ILRI, P.O. Box 45, 6700 AA, Wageningen, The Netherlands, 1981.

Small-scale pump irrigation in Aceh Utara, Indonesia

R. van Aart and H. L. M. van der Hoff

Background

In countries such as Bangladesh and Egypt, low-lift pumps provide water to more than 80 per cent of the irrigated land (Birch and Rydzewski 1980). In Indonesia pump irrigation is not so widespread but its use is expanding. In the district Aceh Utara on the island of Sumatera, 28 pump units are currently in operation. These units supply water to sawahs that are now producing two high-yielding rice crops a year instead of the one local rice crop they formerly produced.

In Indonesia, rice is the staple food of the population but its yield lags behind the total demand. Between 1976 and 1979 Indonesia imported 35 per cent of the total world trade in rice, a quantity equal to 8.5 per cent of the national rice production or 2.1 million tonnes (Holtzappel 1980). With an estimated GNP of US $ 370 per capita in 1980, it is understandable that the Indonesian Government is making great efforts to alleviate the situation.

Environmental conditions in Aceh Utara

The district Aceh Utara is one of the eight districts of the province Daerah Istimewa Aceh and encompasses a gross area of about 619,000 ha (Figure 1).

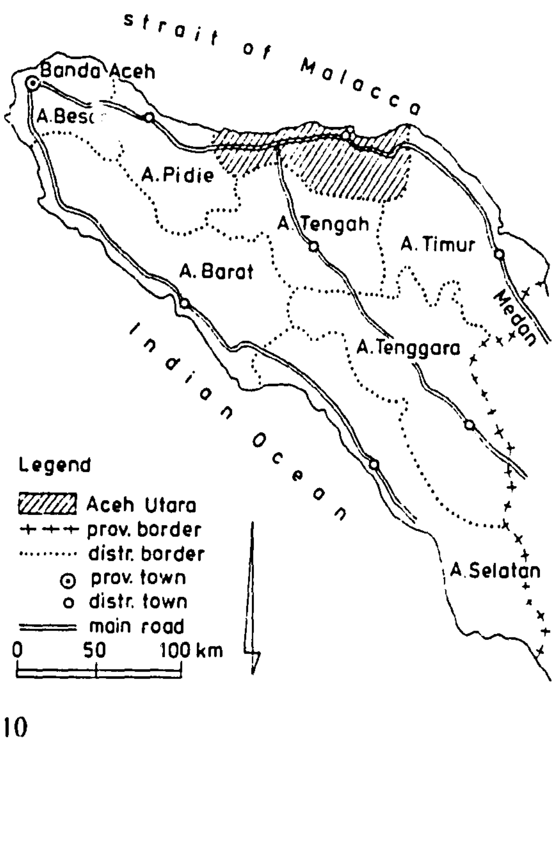


Fig. 1. District Aceh Utara.

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Its length along the coast is 120 km and its breadth land-inwards is 35 to 40 km. The population is concentrated on the coastal plain, which stretches along the entire coastline. The hinterland is forested and very thinly populated.

Climate

The climate is tropical monsoon, which is typified by high annual rainfall, but also by periods of consecutive dry months with less than 100 mm rainfall. The main dry season lasts from February to September and the main wet season from September to February, although from place to place and from month to month, great variations in rainfall occur.

The average annual rainfall is 1520 mm at Lhokseumawe and 1650 at Bireuën, both situated on the coast (Figure 2). Towards the mountains, the average annual rainfall gradually increases and the dry spells become fewer and shorter. Table 1 shows the monthly rainfall data for Lhokseumawe and Bireuën.

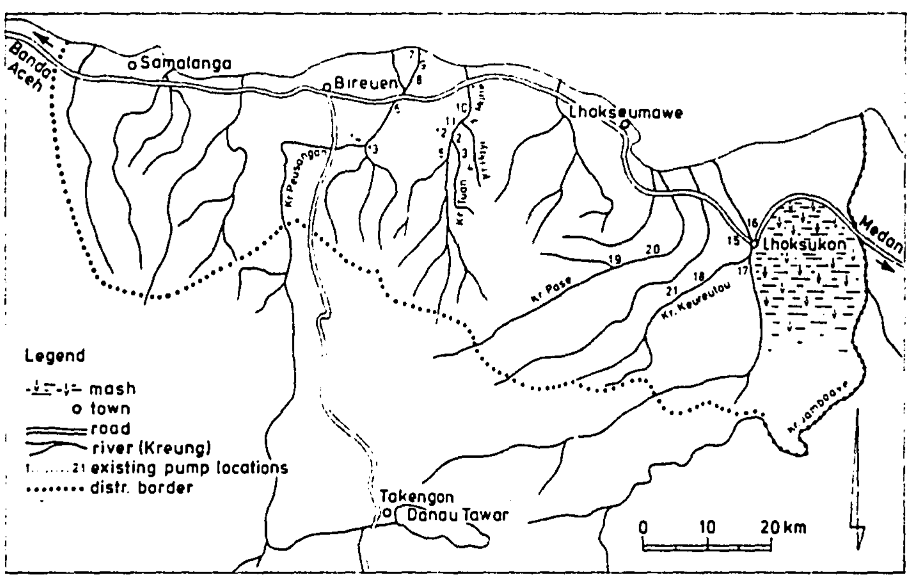

Fig. 2. Detailed map of Aceh Utara district.

Table 1. Monthly and annual rainfall data of two stations in Aceh Utara (mm).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Annual average
Lhokseumawe 30 years	199	61	75	89	108	84	82	93	111	163	193	262	1520
Bireuën > 19 years	170	109	149	104	130	72	80	67	115	185	234	235	1650

Physiography and geomorphology

Physiographically, the district Utara can be divided into a coastal plain and a hilly-to-mountainous hinterland sloping upwards to the central Aceh massive with elevations of over 2000 m.

The coastal plain varies in width from 3 to 4 km near Samalanga in the west to about 30 km near the Krueng Jamboaye in the east. It is composed of a narrow coastal belt or tidal plain, about 2 to 4 km wide, which is under the influence of tidal flooding by seawater, and a river plain with its common geomorphological features of river levees, river basins, oxbows, and backswamp deposits. The elevation of the levees is generally 1 to 2 m higher than those of the basins. Along the greater part of the coast there are beach ridges of low sand dunes, behind which marshes and lagoons have formed. At other locations the beach ridge is absent and the land bordering the sea is directly under the tidal influence of the sea.

The coastal plain gradually slopes from the mountains towards the sea, the average slope near the upstream irrigation headworks being estimated at 2 m/km and near the coast at 0.5 m/km.

Hydrology

The hydrology of Aceh Utara is characterized by high variability of rainfall and river flow, and the important bearing of soil moisture in the run-off process. Many rivers of varying size rise in the Aceh mountains and debouch in the Strait of Malacca. Their lengths vary from 5 to 120 km and their catchment areas from 32 to 1125 km^2. For the Kreung Peusangan, the maximum discharge is 1400 m^3/s, the average discharge 25 to 50 m^3/s, and the minimum discharge 10 m^3 s. Most other rivers have lower discharges.

It is believed that seawater intrudes into the lower reaches only over a short distance (about 1 km), beyond which the river water is suitable for irrigation.

Groundwater occurs at an average depth of 4 to 8 m below surface. Hand-dug wells have been constructed at the levees to make use of this water for domestic purposes.

Soil and land use

The soils are of alluvial origin and have no major limitations that would make them unsuitable for rice cultivation. The river levees are permeable and no standing water remains after heavy rain. The river basins are less permeable and water from rain showers takes one to two weeks to disappear. Certain parts of the river basins, especially those bordering the river levees, are more permeable and water from rain showers disappears within two days.

Agriculture is practised on most of the alluvial coastal plain. In the coastal belt, the major forms of land use are mangrove vegetation, fishponds, and sawahs. Villages and fruit gardens are situated on the sandy beach ridges.

In the river plain, the villages, gardens, and palm groves are located on the river levees. The river basins are invariably used as sawahs.
No detailed statistical data on land use are available, but information from the Agency for Agriculture gives the pattern for the district Aceh Utara as shown in Table 2.

Table 2. Land use pattern in the district Aceh Utara (1977).

Land use classes	Area (hectares)
Sawah	
One crop year	24,260
Two crops year	19,520
Smallholders (perennial crops)	50,950
Estates	15,960
Dry agricultural land (tegalan)	5,110
Grassland	46,950
Critical and eroded land	-
Fishponds	11,970
Forest	350,000
Swamps	42,680
Lake	-
Urban areas	29,720
Other land	22,360
Total	619,480

Irrigation

In the early 20th century, an extensive gravity irrigation system was developed. By means of dams, *brondjongs* (dams constructed of locally available material), and *waduks* (storage reservoirs), irrigation water was brought to the land. Throughout the years, the system worked successfully, but owing to lack of maintenance various major structures like dams and *brondjongs* are now in need of reconstruction or rehabilitation and part of the canal system is in need of repair. District authorities are well aware of the situation and construction and rehabilitation are underway at various locations.
In Aceh Utara about 15,000 ha are under semi-technical irrigation and about 10,000 ha under simple irrigation.

Present state of pump irrigation

In Aceh Utara, certain highly situated basins located near river levees are at present being supplied with irrigation water pumped from the rivers by diesel engines. A total of 28 of these schemes have been established or will shortly be in

operation. They are located along the rivers Peusangan. Mane, Tuan, Pase, and Lhoksukon (Figure 2).
The size of the schemes ranges from 5 to 200 ha, with an average of 55 ha. The total area covers 1,470 ha. The number of farmers per scheme varies from 30 to 630, and the average irrigated rice area per farmer ranges from 0.13 to 2.86, with an average farm size of 0.35 ha. Plot sizes vary from 20 × 20 m to 80 × 80 m. The number of plots per farmer varies from 2 to 6, with an average of 3 to 4. In 26 of the projects, 4035 farmers are working, 1455 of whom are tenants (36 per cent).
A survey of the pumping schemes revealed shortcomings in waterlifting by diesel pumps, in rice cultivation, in water distribution and use, and in organizational aspects.

Diesel pumping
All pump units are driven by diesel engines of various makes, which complicates their maintenance and repair. About two-thirds of all diesel motors have either too little or too much power for the respective irrigation schemes, causing bad running conditions and sometimes no running at all.
One-third of the pump units are located incorrectly and suffer from frequent river flooding. River bank erosion at the pump sites is also a common problem.
Most water pumps are non-self-priming centrifugal pumps, also of various makes. In about half of tnem, the suction-pipe/foot-valve construction is completely filled with mud owing to river bank erosion.
As a result of river flooding and the lack of adequate supplies of spare parts, a number of diesel units are not in proper running condition.
Other, but equally serious, shortcomings are badly aligned and weak pipe constructions and weak foundations of the pump units. There is a general lack of mechanical skill in operating the diesel engines. Of 27 operators, only one is well-trained in maintenance and minor repairs.

Rice cultivation
Before pump irrigation was introduced, only one crop of rain-fed sawah paddy was annually cultivated during the main rainy season from September to February. Long-stemmed local varieties were invariably cultivated with a growing period of 7 to 9 months.
Those local varieties were better adapted to the unfavourable environmental conditions of drought during the dry season and wetness during the wet season. Depending on the rainfall, rice yields varied from 0 to 5 ton/ha with an average of 2 ton/ha. The input package was small: fertilizers and chemicals were seldom used.
The provision of irrigation water made it possible to raise the rice yields substantially, both by the cultivation of two rice crops a year and by an increase in the rice yield per hectare. Two rice crops a year are now grown, one in the wet season

and one in the dry season. The time of planting, however, varies considerably from place to place. Since the introduction of irrigation, annual rice yields have increased more than fourfold from an average yield of 2 ton/ha to an average yield of 8.8 ton/ha. Annual variations in rice yields, however, are big, ranging from 4 to 15 ton/ha/year. This great discrepancy in yield can be ascribed to a complex of factors, the major ones being improper soil and water management and the application of incorrect doses of fertilizers and chemicals.
In most cases high-yielding varieties like IR 28, 32, 36, 38 and 42 are cultivated. These varieties require a whole input package to generate high yields. As fertilizer, urea and triple-superphosphate are regularly provided. Urea doses vary from 75 to 300 kg/ha with an average dose of 200 kg/ha. Triple-superphosphate doses vary from 50 to 250 kg/ha with an average dose of 120 kg/ha. Chemicals are applied in doses varying from 1 to 6 l ha, with an average dose of 3 l ha. The wide range in seed rate and in the quantity of fertilizers and chemicals applied is striking.

Water distribution and water use

In most schemes the water distribution is based on a simultaneous delivery system, although rotational distribution is applied at some locations. Farmers generally prefer the simultaneous delivery system because of its simplicity. A handicap, however, is the low irrigation efficiency obtained and the subsequent reduction in area that could be served by pump irrigation. The average pump capacity under simultaneous delivery is 2.45 l sec ha and under rotational delivery 1.50 l sec/ha. In the dry season the average number of daily pumping hours is 16.5 for simultaneous supply schemes and 13.5 for rotational schemes. Changing from simultaneous to rotational irrigation in the peak irrigation season could mean a water saving of 50 per cent.
The distribution network varies from scheme to scheme. At most locations water is delivered to the fields via a system of tertiary and quaternary field channels which have been designed by the Department of Public Works and constructed by the farmers.
The density of the conveyance channels, too, varies from scheme to scheme and ranges from 6 to 167 m/ha, with a narrow correlation between average farm size and average density of the conveyance channels. The irrigation system as a whole has a minimum of water regulatory devices and lacks control structures.
Although pertinent data regarding water use are lacking, data on pump capacities and information supplied by the farmers indicate that irrigation water is in adequate supply at certain locations and inadequate at others.
Water is not always applied uniformly. The water applications vary from 3 to 15 cm and no fixed schedule has been worked out. In some of the schemes, where the water percolation is high, a maximum water depth of only 5 cm could be maintained on the rice fields.In approximately 50 per cent of the schemes,

drainage is inadequate or entirely lacking. During times of heavy rain, the lack of drainage sometimes causes flooding.

Organization

Prior to the development of the pumping schemes, no particular organization existed in the area, so association with an already existing organization was not possible.

The district head (*bupati*) of Aceh Utara has instructed that each of the villages that falls under a pumping scheme should establish a village water committee (*panitia*) responsible for operating the scheme. This committee would have the authority to distribute and allocate the water, collect the water charges, employ an operator to run and maintain the pump, and organize the repair and maintenance of the water distribution system and its structures. Experience has shown that if a committee is strongly organized, it works well, and a group of farmers is able to operate a scheme. Common problems, however, are shortages of funds for initial investments, an unskilled operator, and a lack of discipline among the farmers, which makes it difficult to collect the water charges.

The structure of the present water organization shows that in most schemes the farmers are organized in blocks (*kelompoks*) whereby each block receives water from a separate distributary. There are 2 to 10 blocks per scheme, with an average size of 18 ha, and the number of farmers per block ranging from 6 to 250, with an average of 37 per block. Only in three pumping schemes has no grouping of farmers in blocks taken place. The head of a minor scheme is called *keujreun blang* (water manager); he is often one of the head men of the village.

Apart from these village water committees, which in fact have no legal status, only two pumping schemes have an official water association.

Agricultural extension

Agricultural extension services are regularly provided by the Department of Agriculture. Their programs aim at providing extension advice and a package of inputs on credit to intensify rice production. The package consists of the introduction of high-yielding varieties, intense fertilizer application, and the use of insecticides and pesticides. Only under the extension programs are rice yields of over 6 ton ha being obtained.

Improvement of pump irrigation

The pump irrigation schemes should be considered supplemental to major irrigation development and rehabilitation. At some locations, future gravity irrigation will replace those pump schemes that fall within the future command area. At other locations, irrigation water will have to be supplied by lifting, either from the irrigation canal system or from another water source.

Pump unit

The lift irrigation schemes should be served by diesel-driven pumps, which have as advantages the flexibility of water supply, the mobility of the pump units, the possibility of gradual introduction, and low energy costs. Against that, their disadvantages are their high maintenance needs, the high risk of breakdowns if not properly maintained, the relatively complicated operation, and the high cost and short life of the diesel motor (Kool 1978).

The diesel engines should be medium-speed, air-cooled, and of local make, for guaranteed spare-parts supply and vendor service.

The pumps should be of the centrifugal type as their speed can be matched to that of the driving engine and they can be directly coupled to it. For long-run operation, ordinary pumps are to be preferred above self-priming ones, although technically the latter are better. Experience has revealed, however, that with muddy river water self-priming pumps generally wear sooner than the normal standard centrifugal types.

Flexible pipe connections at the suction and discharge ends of the pump, together with vibration-absorbers under the rigid steel frame of the diesel motor pump unit, should be included in the construction. They prevent the transmission of vibrations to pump house, foundations, and suction and delivery pipes. For more simple erection and maintenance, flanged standardized pipe connections with rubber gaskets (possibly of old lorry tubes) could be used.

The pump house could be a simple concrete building with a slightly inclined roofing of aluminium sheets. If the soil requires a heavy pump-house foundation, it should be investigated whether the use of reinforced concrete poles are better and/or cheaper than concrete wellrings, dug in and filled with rammed concrete. A cross-section of the pump-house is shown in Figure 3.

Bank protection of the suction pit is generally required.

In cases where frequent and high river flooding causes problems, the pump units could be placed on locally manufactured pontoons of simple design, the pontoon being connected with the fixed discharge pipe ashore by means of flexible hoses. Such pontoons are being used with success in the Sumani Pumping Irrigation Project near Padang in West Sumatera (Directorate of Irrigation 1979).

Pump capacity

As all pumping plants are invariably used for the irrigation of rice, the pumping capacity should be related to this crop. The peak water demand for rice occurs immediately before and after transplantation. The water supply to a rice field during the presaturation period can be conveniently calculated with the formula developed by van de Goor en Zijlstra (1968), which reads:

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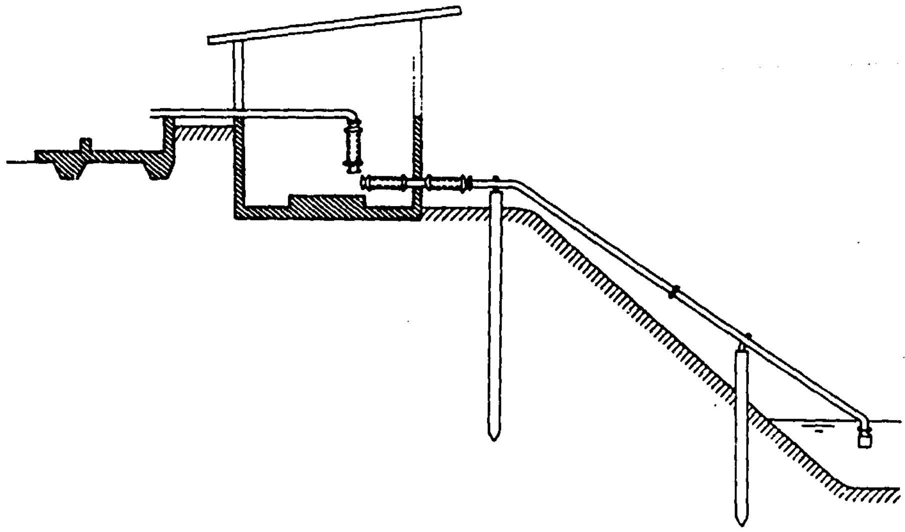

Fig. 3. Cross-section of a pump-house.

$$I = \frac{M e^{\frac{MT}{S}}}{e^{\frac{MT}{S}} - 1}$$

where

I = the water supply required during the presaturation period in mm/day;
M = the water supply required for maintaining the water layer after presaturation is completed in mm/day;
S = the quantity of water required for presaturation in mm;
T = duration of the presaturation period in days.

The calculation is as follows:
M = open water evaporation of a free water surface (Eo) + percolation (P) − effective rainfall (R).

If the summer rice crop is transplanted by the middle of June and the duration of the presaturation period (T) is 21 days, a figure of 4.2 mm/day can be taken for the open water evaporation. For the average percolation rate (P) an average value of 2.5 mm per day can be taken. The effective rainfall (R) can be taken at 70 per cent of the actual rainfall or at 2 mm per day. Owing to the small extent of the minor irrigation schemes, areal rainfall reduction and variability factors need not be taken into account. The quantity of water required for presaturation of the soil (S) can be taken at 100 mm.

If the overall irrigation efficiency is taken at 70 per cent, the irrigation requirement is (10/7)0.87 = 1.24 l/sec/ha. If the maximum number of pumping hours per day is 12, the required pumping capacity works out at 2.50 l/sec/ha.

Consumptive use of rice
The peak water requirement falls in July and amounts to 6.4 mm/day. If 2 mm per day is taken for the effective rainfall, 2.5 mm per day for the percolation losses, and the overall irrigation efficiency is 70 per cent, the peak irrigation requirement for rice during the growing period is 1.15 l/sec/ha.

Agricultural aspects
The introduction of pump irrigation has already caused a remarkable increase in rice production from an average annual yield of 2.0 ton/ha to one of 8.8 ton/ha. It is thought that rice yields can be further increased to an average of 10 tons/ha provided that proper agricultural, soil, and water management practices are applied. It should also be possible in the future to obtain five rice crops in a period of two years.
In improving the agricultural practices and eventually standardizing the technique of rice production, attention should be given to the following:
- the improvement of nursery techniques, time of seeding, and seed rate per hectare;
- a standardized cropping calendar for the cultivation of two rice crops a year, and in the future for five crops in two years;
- the standardization of certain rice practices like spacing of seedlings after transplanting;
- more research and demonstrations on the use of fertilizers;
- better weed control by timely saturation of the fields prior to transplanting of the seedlings;
- a reduction in pest control through the cultivation of pest- and disease-resistant varieties; in addition, the use of chemicals should be standardized.

In how far such agricultural practices as land preparation and puddling should be mechanized needs to be investigated; small fragmented holdings and irregularly shaped fields could make mechanization less practical. At present, the use of tractors and threshers is being introduced by private enterprise.

Soil and water management aspects
For the proper selection of a potential minor irrigation scheme, basic information should be collected on land topography, soil conditions, and especially on the average value of water percolation in a rice field. The following basic data are a must:
- a topographic map, scale 1:2500, with contour intervals of 25 cm;
- a soil map, scale 1:2500;
- percolation rates as found from infiltration tests.

Information on water infiltration is important as farmers sometimes complain about the light texture of the soil and subsequent high percolation losses, particularly during land preparation and saturation of the soil profile. Soil cracking sometimes occurs and this increases percolation in the presaturation period.
To improve soil and water management practices, the following principles should be adopted:

- The size of a minor irrigation scheme should be between 30 and 60 ha, which is a size that can be properly supplied with lift irrigation water;
- The water should be supplied from the pump to the scheme via one main canal. This canal should preferably run perpendicular from the river to the sawah and will thus cross the river levee. The length of the main canal varies from 100 to 1000 m in the existing schemes and should be lined to prevent seepage losses.
- Each minor scheme should be divided into equally sized blocks in the range of 6 to 12 ha.
- The water from the main supply canal should pass a turnout gate at the head of the sawah, and from there it should be distributed to the individual blocks via a system of distribution channels.
- Depending on the slope of the land, field-to-field irrigation can be practised. The upper limit, however, should be a sequence of 6 to 7 plots whereby each field should be situated not more than 300 m from the farm channel.

Further rules underlying any rehabilitation plan of a minor scheme should be based, as far as possible, on the principles for tertiary development as developed by Prosida (1975).

Distribution of water

When irrigation water is supplied to a minor irrigation scheme by pumping, the water supply is controlled, but, as permanent structures within the scheme are lacking, the distribution of flow is uncontrolled.
Either the simultaneous or the rotational delivery system could be considered for the water distribution. The simultaneous system requires a minimum of regulatory structures and its irrigation ditches can be small: this means that its investment costs are low, but so too is its irrigation efficiency. A rotational system can attain a relatively high degree of efficiency, but its structures mean relatively high investment costs.
In Indonesia the basis for water distribution at tertiary level is laid down in the Water Management Plan for Sederhana Irrigation, Reclamation, and Land Development Project, issued by the Directorate General of Water Resources Development in August 1977. In this plan, simultaneous delivery gets first priority for reason of its simplicity, although each project should be considered separately in the light of the available water supply.

Drainage

The improvement or construction of a drainage system should form part of the on-farm activities of improving soil and water management. Each minor scheme should be provided with a drainage system. Wherever possible, the drainage water should be collected and re-used lower down in the scheme.

Organizational aspects

At Governmental level, no single organization exists with sole responsibility for the pumping plants. This is the main reason why problems with the operation and maintenance of the pumps occur so often. Centralization of responsibility is badly needed.

For an adequate long-term policy for the development, operation, and maintenance of pumping schemes, the following organizational rules could be adopted at district level:

- The overall responsibility should lie with the district head;
- Day-to-day affairs should be the responsibility of the head of the Department of Public Works, which has a special sub-department for minor irrigation schemes: this sub-department should be made responsible for engineering, construction, maintenance, administration, training, and extension;
- Engineering and construction involve the development of new locations and the improvement of existing ones;
- Approval for new pump locations has to be given by the district head after consultation with the head of Public Works;
- Public Works should be responsible for training the operators;
- A central workshop should be set up and should include a store for spare parts;
  Public Works should also be responsible for the construction of the main channel to the sawah, the main intake structure for the tertiary network, and the main distribution system up to 50 m inside the minor schemes;
- The irrigation and drainage network within the minor schemes should be constructed by the farmers themselves, with technical guidance from the Department of Rural Development of the Department of Agriculture.

Water association

In each of the pumping schemes a water association should be established and involved in aspects of planning, construction, operation, and maintenance. The task of the association is to make its members a working group (*gotong royong*) for proper irrigation and for community work in the fields. Another of its tasks will be to collect the water charges, which should be done by a finance officer elected by the association.

The head of the water association should be elected by its members. He may be the head of the village or a progressive farmer. His title is *keujreun blang* (or water manager) and he should be paid by the farmers via the water charges. In this way he will not be a burden on the district's budget. The water manager should arrange the distribution of water, the coordination of the planting dates, and the maintenance and cleaning of the canals.

The organizational structure of minor schemes should in first instance be kept simple. This is in line with the rules for the distribution of water, which should also be kept simple. Over the years, as the farming communities acquire greater proficiency, the organizational structure and the water distribution could gradually become more advanced.

The great discrepancies in size of the schemes, in block sizes, and in the number of farmers per block should be reduced. New minor schemes should be between 30 and 60 ha, which is an area that can be conveniently supplied with irrigation water. Each scheme should be divided into blocks ranging from 6 to 12 ha, and each block should be served with water from a separate distributary. Within each block, water could then be supplied to the various fields in rotation. In this way the average number of farmers per scheme could range from about 90 to 180, with each block having about 20 to 40 farmers.

The head of each block will be a farmer, who will assist the water manager to carry out his duties. He will be responsible for the operation and maintenance of the farm channels and the structures in his block.

Agricultural services

The agricultural extension programs currently underway should be expanded to cover all pumping schemes.

Within the framework of the water association, cooperative activities like hiring a tractor for land preparation and puddling could be organized for the members.

Economic and financial aspects

The minor irrigation schemes can be constructed quickly, each generally within a period of six months, and they yield immediate benefits.

An economic analysis of 21 minor schemes is presented in Table 3. The analysis was made under the following assumptions:

- The project costs are the costs of the pump house, the pump, and the annual costs of operation and maintenance;
- The depreciation on the pump house is 10 per cent per annum and on the pump 20 per cent per annum.

Figure 4 shows that the larger the scheme, the less the capital investment per pump unit per hectare will be, whereby a scheme size of between 30 and 60 ha is also very suitable from an investment point of view.

For the project benefits, the initial situation without irrigation and the annual cultivation of one local rice crop is compared with the present situation with pump irrigation and the annual cultivation of two, usually high-yielding, rice

Table 3. Economic analysis of minor irrigation schemes

Loc. No.	Area	Annual rice yield		Scheme costs			Scheme benefits		Net present worth scheme at 12.5%	Net present worth ha at 12.5%
		Without irrigation	With irrigation	Pump house	Pump	Annual operation + maintenance	Without irrigation	With irrigation		
	(ha)	(ton/ha)	(ton/ha)	Rp × 10^6	Rp × 10^6	Rp × 10^6	Rp × 10^6	Rp × 10^6	Rp × 10^6	Rp × 10^6
1	65	2.00	11.00	8.0	4.5	1.60	7.504	71.195	210.888	3.08
2	8	NC	10.00	1.0	2.1	0.83	-	7.002	19.160	2.40
3	15	1.50	10.00	1.5	2.3	1.59	1.062	14.116	37.458	2.50
4	7	1.50	10.00	1.0	2.1	0.79	0.472	6.589	16.159	2.31
5	8	3.00	9.00	2.5	2.8	1.11	1.142	6.523	10.607	1.33
6	50	0.50	9.00	16.0	9.5	4.15	1.626	40.810	103.733	2.07
7	50	2.00	4.00	3.0	3.3	2.89	7.800	15.604	12.038	0.24
8	50	2.50	5.00	16.0	15.1	3.78	8.000	14.658	-16.404	-0.33
9	60	1.50	12.50	2.5	5.0	2.65	6.024	72.135	219.237	3.65
10	30	NC	10.00	3.0	7.5	2.43	-	27.120	78.271	2.61
11	22	1.50	15.00	5.5	8.3	2.33	2.352	30.924	81.203	3.69
12	40	0.75	12.00	7.0	15.1	4.13	2.460	50.201	135.183	3.38
13	50	2.50	5.00	6.0	8.8	2.57	9.126	21.553	21.985	0.44
14	50	1.50	10.00	23.0	33.2	4.32	5.376	49.242	91.041	1.82
15	40	2.00	5.75	5.0	17.0	2.00	6.240	21.546	26.790	0.67
16	40	1.00	10.00	4.4	4.0	1.98	3.710	36.796	103.622	2.59
17	50	5.00	10.00	5.0	12.0	2.28	24.485	47.379	23.730	1.16
18	100	2.25	4.50	4.0	9.6	2.55	23.930	42.048	42.966	0.43
19	200	2.00	8.00	10.0	11.3	2.90	30.500	71.664	117.776	0.59
20	5	3.00	8.00	5.0	8.8	0.36	1.225	3.393	- 5.968	-1.19
21	200	3.60	9.60	12.5	11.3	5.60	70.650	178.740	344.737	1.72

NC = not cultivated.

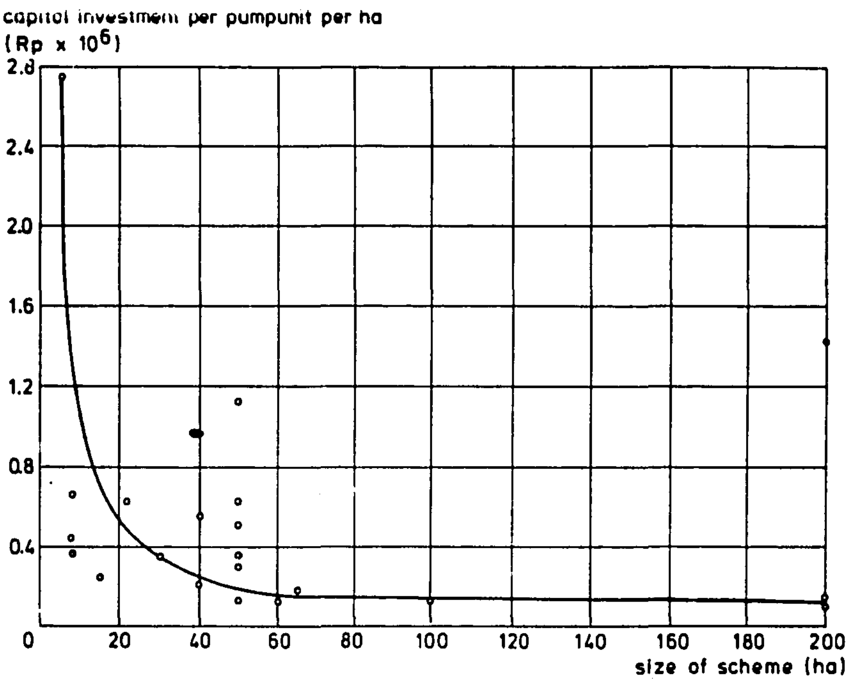

Fig. 4. Capital investment versus size of scheme.

crops. In comparing the benefits with and without irrigation, an important factor to be taken into account is that the average market price of local rice is Rp. 80/kg and that of high-yielding rice Rp. 100 kg.

The net present worth of the various schemes has been calculated against an interest rate of 12.5 per cent and over a project period of 5 years, which is the life expectancy of a diesel pump. It is seen that most schemes are economically feasible against the 12.5 per cent interest rate and that the net present worth varies from Rp. 0.24×10^6 to Rp. 3.69×10^6 per hectare.

Water charges

In all schemes a water charge is paid by the farmer. The present charges vary widely from one scheme to another and range from Rp. 0.90 to $4.50/m^2$/season. The water charges are used to cover the costs of spare parts and maintenance and to guarantee the pump operator a basic income. In addition, 10 per cent of the total charge is paid to the water committee (head, finance officer, and others) for their services. Fuel and oil costs are levied on the rice yield.

The water charge is only paid when water is taken, which is not an appropriate system. If the pumping schemes malfunction, farmers usually refuse to pay the charge. Obvious repercussions are that the operation and maintenance costs cannot be met and that no payment can be made to the operator. The system of charging needs to be adjusted so that an irrigation cess is levied whether water is

taken or not. The present charges have no relation to the real costs of irrigation nor to the benefits due to irrigation. It would therefore be more appropriate to develop a system of water charging that takes into account the repayment capacity of the beneficiaries.
The major problem encountered in all schemes is the shortage of funds to cover the first period after the scheme is launched. A solution has to be found for a first payment to the farmer prior to his first rice harvest, an initial loan for the operator, and credit for the running of the pump. This problem needs to be studied in more detail before pertinent recommendations can be made.

References

Birch, D. R. and J. R. Rydzewski (1980). *Energy options for low-lift irrigation pumps in developing countries: the case of Bangladesh and Egypt*. Institute of Irrigation Studies. University of Southampton, United Kingdom.

Directorate General of Water Resources Development (1977). *Water Management Plan for Subproject Tertiary Basis for Sederhana Irrigation, Reclamation and Land Development Project* (draft). Jakarta. 36 pp.

Directorate of Irrigation (1976). Feasibility study on Krueng Jreue and Krueng Baro Irrigation Projects. Binnie and Partners. Jakarta (various volumes).

Directorate of Irrigation (1979). Sumani Pumping Irrigation Project West Sumatera Province. *Yearly Report 1978 79 Swiss Technical Cooperation*. Jakarta.

Goor, G. A. W. van de and G. Zijlstra (1968). *Irrigation requirements for double cropping of lowland rice in Malaya*. Publ. 14. ILRI. Wageningen.

Holtzappel. A. (1980). De voedselproducerende landbouw in Indonesië. *Intermediair* 16e jaargang 16-18 april 1980: 59-69.

Kool, J. (1978). *The sakia and the motorized pump*. MSc-thesis. State Agricultural University. Wageningen.

PROSIDA (1975). Irrigation Rehabilitation VII. Feasibility Report Vol. 1 *Tertiary Development*. DPUTL. Jakarta.

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