EVALUATION OF THE IRRIGATION COMPONENT OF THE INTEGRATED AGRICULTURAL DEVELOPMENT PROJECT NO. 521-0078

HAITI

USAID

WATER MANAGEMENT SYNTHESIS PROJECT

WMS REPORT 21

PN-AAP-208
ISN-33217
9311007/62

USAID/HAITI

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WATER MANAGEMENT SYNTHESIS - II PROJECT
AGENCY FOR INTERNATIONAL DEVELOPMENT, WASHINGTON, D.C.
and
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT MISSION TO HAITI

September 1983

The views and interpretations expressed herein are those of its authors and should not be attributed to AID/Washington nor USAID/Haiti.

ACKNOWLEDGEMENTS

The evaluation team gratefully acknowledges the cooperation and assistance provided to it by the Department of Agriculture, Natural Resources, and Rural Development. Special appreciation is extended to: Nicot Julien, Montaigu Cantave, Luckner St. Dick, Robert Cassagnol, Jean Theard, Wilner François, Chantal Soukar, Brunet Georges, Robert Bury, Gerald Paul, Smith Jean-Pierre, Jacques Baker, Alex Louis Tanis, Fritz Noel, Roosveldt Compere, Gardy Fleurantin, Roland Myrville, Lucien Badeau, Ernest Louverture, and Charles Maxi.

Valuable insights and assistance were provided by Mohamed Rahman and Jacques Salomon of Sheladia Associates, Inc. Worth Fitzgerald of AID/Washington provided timely and valuable assistance in putting together the evaluation team. USAID/Haiti Director Harlan Hobgood's management concerns and ideas about the PDAI irrigation project were responsible for the initiation and basic directions of the evaluation effort. USAID/Haiti staff provided invaluable logistic support and substantive inputs to the evaluation effort. The evaluation team is especially grateful for the assistance and comments provided by Phyllis Dichter, Shirley Pryor, and John Lewis, the insights and guidance provided by Abdul Wahab, the competent programming of Robert Wilson, the translation services of Jacques Léger, and the efficient clerical support provided by Judith Desmornes and Chantal Woolley.

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I. EXECUTIVE SUMMARY

A. Introduction

Concern about the overall slow progress of the irrigation component of the Integrated Agricultural Development Project (French acronym· PDAI) prompted the USAID Mission to Haiti in June 1983 to seek assistance in deciding whether to continue funding the Project.

Specifically, the Mission sent out a request for an evaluation team to examine the situation and make recommendations. The Mission's concern stemmed from the fact that Phase I of the Dubreuil irrigation system, involving some 225 hectares, was not completed, even though a revised Project Paper had envisioned that work on all 925 hectares of the system would be completed by September 1982. Furthermore, there seemed to be little evidence that the Project's primary goal was being fulfilled -- namely, that the capacity of the Ministry of Agriculture's Irrigation Service to develop and manage existing and potential water systems throughout Haiti was being strengthened.

Though specific problems of Project implementation were bothering the Mission, broader questions also prevailed· Does irrigation make economic sense in a country such as Haiti? What is the feasibility of the Haitian Ministry of Agriculture adequately assisting irrigation projects in the future, and should AID continue to fund irrigation activities in Haiti? Thus, the team realized that although its main focus was on the PDAI irrigation component, the questions posed by this Project and how the team responded to these questions would perhaps have an impact on AID's future involvement in Haiti's irrigation sub-sector.

The evaluation team, which conducted its study August 16 - September 10, 1983, was made up of six persons, including three economists, an irrigation engineer, agronomist, and planner. On their first day, members of the team met with Ministry of Agriculture officials who told them that irrigation, in the Ministry's view, is "une priorité prioritaire" -- a number one priority. Ministry of Agriculture officials conceded that a lot of mistakes had been made -- on the part of the Government of Haiti, as well as that of AID. But, they said, because a great many positive changes had occurred as a result of the Project, it would be wrong to terminate it now.

The scale of the original PDAI project was substantially reduced in 1979. A revised Project Paper called for a $22.6 million package, of which AID was to provide about 54 percent. The money, which would be used for three other Project components besides irrigation -- soil conservation, research and extension, and administration -- would include $9.3 million in AID grant money and $2.8 million in loans. The Government of Haiti would provide counterpart funds totalling $10.5 million.

With regard to irrigation, grant money was to be used for technical assistance, as well as long- and short-term training for Irrigation Service personnel. Loan money would finance construction material costs, and counterpart funds would cover labor costs.

The revised Project was to concentrate on the Dubreuil irrigation system, covering some 900 hectares in southwest Haiti, and the Jean Rabel system in northwest Haiti, covering 400 hectares. However, for reasons that now seem arbitrary, the plan to rehabilitate Jean Rabel was later scuttled. Similarly, some feasibility work was completed on the Thomazeau irrigation system in the Cul-de-Sac, from January to June 1981, but this sub-project was dropped. Plans to rehabilitate the Damien irrigation system likewise were suspended.

Instead, the Marigot irrigation system, in southeast Haiti, was to be rehabilitated. This system, covering 500 hectares, had been considerably damaged in 1966 by Hurricane Ines. USAID later opted to concentrate on five smaller irrigation systems diverting water from the same river, in lieu of rehabilitating the larger single system as originally planned.

Work on the PDAI irrigation component did not really start until July 1981. Presently, topographic work has begun at Marigot and has been completed for one of the Marigot sub-projects (Belle Roche). Actual rehabilitation work has been in progress only at Dubreuil, where about 75 percent of the Phase I work has been completed.

Slow progress has been the result of many Project stoppages, due primarily to interruptions in the availability of construction funds and Title I salary support. Work on the Project stopped almost totally between May and August 1982 and again from December 1982 through June 1983.

The Project is scheduled to terminate June 30, 1985. Remaining funds include about $1.2 million of AID loan money, about $122,000 of grant money for technical assistance, and about $35,000 grant money for training.

In carrying out its study, the Evaluation Team made field trips to the Dubreuil, Marigot, Jean Rabel, Thomazeau and Damien irrigation systems. They reviewed technical documents and met with more than 100 persons, ranging from farmers and district-level workers to Technical Assistance contractors and administrators at the Ministries of Agriculture and Plan, as well as at USAID/Haiti. At the conclusion of their evaluation, team members held meetings with USAID/Haiti personnel and Ministry of Agriculture officials to discuss their findings and to present their recommendations.

The following issues are addressed in this report:

<u>Engineering/Operational Assessment of Dubreuil Project</u>--The technical soundness of the design and construction of the Dubreuil system, and the appropriateness of current provisions for an economically and institutionally sound water user district.

Agricultural Impacts of Dubreuil Irrigation--The expected impact in terms of yields, cropping patterns, animal production levels, agricultural input changes, etc., that will result from the Dubreuil irrigation project. Also, the appropriateness of current complementary inputs in the form of supervised credit, improved seed varieties, fertilizer, chemicals, etc.

Economic Analysis of Dubreuil Irrigation Project--The internal rate of return of the Dubreuil System, including the incremental rate of return of completing Phase II.

Other PDAI Irrigation Systems--A review of the feasibility of rehabilitating other irrigation systems considered by the PDAI project.

Institutional Analysis--The institutional capability of the Ministry of Agriculture to implement a continuing program of irrigation rehabilitation and support services.

Technical Assistance--The need for Technical Assistance to the Ministry of Agriculture and the appropriateness of the current TA contractors.

B. Summary of Findings and Recommendations

Section II - ENGINEERING/OPERATIONAL ASSESSMENT OF DUBREUIL PROJECT

Findings

Rehabilitation of the Dubreuil irrigation system was initiated in July 1981 and was to have been completed in two years. Financial constraints have caused several delays. Construction is now in progress and Phase I, which is approximately one third of the system, is expected to be completed by September 1983.

The project is adequately designed and constructed and the Irrigation Service of DARNDR has a basic competent staff of young engineers who have gained experience on the project and have received some training through the PDAI Project.

Water User groups for the secondary and tertiary canals in Phase I have been formed and delivery schedules prepared by the engineer in charge of operation and maintenance (O&M) and on-farm water application. A Water Users Association capable of managing the system has not been formed. Without DARNDR supervision and financial support, proper O&M probably will not continue after project completion. A legally constituted Water Users Association with authority to levy, collect, and utilize water fees is essential.

Recommendations

1. The second phase of construction should be completed as quickly as possible using construction contracts. This will allow the use of both AID loan funds and GOH counterpart funds for any construction activities and remove the need for the simultaneous availability of both sources of funds. This would also allow for contractors who could bring to the project the needed outside expertise in addition to using local labor.

2. Water measuring devices should be incorporated in the lateral turnout structures in Phase II.

3. Proper water application and O&M are critical areas which need to be strengthened. The Irrigation Service should not focus solely on the construction or rehabilitation of irrigation systems.

   -- Continued and increased recognition and attention should be given by the Irrigation Service and the Agricultural District to the importance and need for educating farmers in water use and application. The O&M/Water Application engineer should continue the regular meetings with the ditch riders and water user groups

for extension in water application methods, with assistance from district animators and extension agents in cultural practices, use of other inputs, cropping patterns, etc.

-- Increased pay should be given to the O&M/Water Application Engineer and other related staff to assure their continuing presence.

-- More technicians need training in water application at the Dubreuil project site to support and complement the current activities of the O&M/Water Application Engineer. Some new people, including extension agents, should be assigned so they can receive training and experience in this very important activity. Funds are available for eight more short term overseas training participants. These funds should focus on strengthening O&M and water application expertise of the field staff.

-- A third ditch rider should be hired by DARNDR as planned to assist in the operation and maintenance of secondary and tertiary canals when both Phase I and II are finished and become operational.

4. Once regular consistent delivery of irrigation water is established in a system such as Dubreuil, the national irrigation tax and Water Users Association fees should be set at a combined rate sufficient to cover all O&M costs. The combined rate should be set by the Irrigation Service for each system rehabilitated. Estimates of the full cost of irrigation O&M range between $60 and $150 per hectare per year. The national irrigation tax should cover all O&M expenses incurred by the Irrigation Service, including an estimated $20/ha to go into a national disaster fund to provide a central pool of money for repair of major disaster caused damage.

5. For systems such as Dubreuil, a bona-fide Water Users Association should be formed with the power to levy, collect and use water fees for maintenance and operation of the system, with technical assistance and supervision provided by the Irrigation Service. The fees collected should be sufficient to pay the salaries of the ditch riders, gate tenders, maintenance personnel, etc., and the cost of labor and materials for normal maintenance and repair.

Section III - AGRICULTURAL IMPACTS OF DUBREUIL IRRIGATION

Findings

Moisture availability indices, based on 75 percent probability of rainfall and potential evapotranspiration indicate that crops in the Dubreuil project area will be subjected to considerable moisture stress. Crop yields could be expected to increase by two times, or more, as water is provided at the proper

time. Reduced risks associated with irrigation will induce farmers to adopt modern technological packages including high-yield seeds, fertilizer and insecticides. Farmers will increase plantings of high value, short growing cycle cash crops such as beans and tobacco. A relatively large reduction in the area planted to sorghum and sugar cane would be expected.

Recommendations

1. Research programs to evaluate crop response to irrigation and the economic influence of irrigation on small farm cropping systems should be developed.

2. The Texas A&M University/Haiti Program should develop complete packages of technological practices through adaptive research on high-yielding varieties, fertilization, pest control and soil and crop management. This research effort should be continued until PACD.

3. Support should be provided for existing seed production and processing facilities and the establishment of additional facilities.

4. The Extension Service must concentrate on priority targets like newly irrigated lands. Work plans should be specific, contain quantifiable objectives and indicate methods to achieve the transition from traditional to modern farming practices within five years. Demonstration plots should be used to show the farmer the benefits of adopting appropriate technologies as well as upgrading the Extension agent's capabilities.

5. Adequate complementary inputs such as credit, fertilizer and pesticides should be provided by the government or the private sector should be encouraged to increase its role.

Section IV - ECONOMIC ANALYSIS OF DUBREUIL IRRIGATION PROJECT

Findings

The costs and benefits of the Dubreuil irrigation project are estimated over a twenty year period. Total project costs are estimated to be $2.2 million and include direct construction costs of $1 million and TA costs of $900,000. Phase II is estimated to cost $1.5 million. The internal rate of return of the total Dubreuil system and the incremental rate of return for completing Phase II are sufficiently high under a variety of assumptions to confirm the project's economic soundness. However, management and financial delays which slow project implementation result in significantly lower estimated rates of return. Completion of Phase II is justified only if these financial and administrative delays are substantially reduced in the future. Furthermore, a lack of attention to operation and maintenance (O&M) and watershed protection activities reduces the expected life of the project and the internal rates of return.

Recommendations

1. Phase II of Dubreuil should be completed if a normal rate of implementation appears probable. If, on the other hand, substantial delays are envisioned to continue, the project becomes uneconomic and should not be completed.

2. Major emphasis at Dubreuil should be placed on O&M activities. Proper maintenance of the system is essential for the economic viability of the system.

3. Reforestation investments in the Acul watershed should receive high priority. This would not only extend the expected life of the project, but would increase the availability of river flow for irrigation in the dry seasons.

Section V - OTHER PDAI IRRIGATION SYSTEMS

Findings

Moisture availability indices based on 75 percent probability of rainfall and potential evapotranspiration, indicate that crops will be subject to considerable moisture stress during four months of the year at Marigot and nine months at Thomazeau if no irrigation water were available. In Jean Rabel, there is moisture stress year around. Significant crop yield increases can be expected by the provision of adequate irrigation water at appropriate times.

Annual net revenue increases attributable to irrigation at Marigot are estimated to be similar to those found at Dubreuil. Revenue increases at Thomazeau and Jean Rabel are expected to be considerably higher. Based on rough cost estimates, the annual net revenue increases per $1,000 invested were estimated for each of the projects. These estimates suggest that all of the projects considered are economically feasible.

Recommendation

Based on the detailed economic analysis of the Dubreuil system and the foregoing comparative analysis of the Marigot, Jean Rabel, Thomazeau, and Damien systems, it appears advisable to proceed with all of them eventually. Because of the availability of topographic and design information, emphasis should be placed on Marigot and Thomazeau, for which the most engineering time has already been spent. Marigot should be pushed to completion as rapidly as possible. Careful and detailed analysis of the comparative costs and benefits of the two alternative Marigot systems should be made before one is selected for construction. The Damien research farm system should also receive priority for early rehabilitation. Jean Rabel will need a reevaluation of the diversion structure location.

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Section VI: INSTITUTIONAL ANALYSIS

Findings

Three main institutional constraints appear to be hampering smooth implementation of the PDAI project. They are:

1. Lack of Proper Administrative and Financial Control - Although the Irrigation Service has a reasonable level of technical competence, serious shortcomings in PDAI management have hampered Project implementation. An absence of clearly defined responsibilities for the Project at DARNDR resulted in Project Implementation Letters (PILs) for release of loan money not being initiated as needed, contributing to later PDAI financial problems. Inadequate control over finances in the past was manifest in the large numbers of employees paid under the Project and in the use of PDAI funds for general DARNDR operations not related to the Project.

2. Lack of Resources - A basic shortage of funds for other DARNDR activities has contributed to unauthorized use of PDAI funds. This, in turn, has caused the Ministry of Plan, which allocates Title I money for the Project, to take corrective action and withhold counterpart funds. Thus, a vicious circle is in place where Project mismanagement, due partly to a general shortage of funds, leads to further constriction of Title I funding for the Project.

3. Lack of Communication - An example of inadequate communication between the Ministries of Agriculture and Plan is the evaluation team's observation that PDAI officials at DARNDR do not seem to have a clear understanding of documentation procedures required by the Ministry of Plan. One source of disagreement on PDAI funding needs could stem from the fact that the Ministry of Plan relies on PDAI bank statements to assess PDAI financial needs, while DARNDR depends on its accrual accounting system.

The future success of the Project will depend on a commitment by the Ministry of Agriculture to adhere to Project budgets and funding regulations. At the same time, AID should support the Irrigation Service to ensure that it can effectively carry out its responsibilities and that improvements in irrigation systems will be longlasting.

Recommendations

1. Loan money for turn-key contracts should be used to a greater extent for field construction work to reduce reliance on the joint availability of AID loan and Title I funds and to help ensure that future work stoppages do not occur due to a lack of GOH counterpart funds for field construction labor costs. Increased use of contracts will not only lead to more effective use of all Project funds, but will also ensure to a greater extent that the loan money is effectively and fully utilized by the Project's completion date.

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2. The Ministry of Agriculture should make a strong commitment, at all levels, to adhere to the PDAI budget and funding regulations so that it may re-establish its credibility. In doing so, DARNDR will reduce the likelihood of future interruption of GOH counterpart funds because of irregularities in the Project's financial management.

The implementation of these two recommendations is considered critical to the smooth functioning of the Project in the future. To facilitate their implementation, the following measures are suggested.

3. A strong, full-time director/coordinator is needed for the PDAI project to provide the necessary leadership and close supervision of day-to-day Project operations. This director/coordinator should not have other responsibilities, and thus should be able to devote his full attention to the PDAI project. In addition, an internal DARNDR proposal that calls for a Coordinating Council for the PDAI appears to have merit and should be pursued further.

4. The Ministry of Agriculture and AID should jointly monitor and manage Project loan funds. The PDAI Director/Coordinator at DARNDR and the AID Project Manager should meet on a monthly basis as part of their joint management functions to review the status of loan disbursements and verify that funds are spent in such a way that reimbursement will be possible. Furthermore, responsibility for the preparation of technical and financial information necessary for initiaion and processing of PILs should be firmly established at the Ministry of Agriculture so there is no question that this function will be carried out as needed.

5. The Ministry of Agriculture and AID should jointly manage Title I funds. Project-related financial and management information reviewed on a monthly basis by DARNDR and AID Project management should include all PDAI financial accounting records, payrolls, job descriptions and fund allocations.

6. AID should consult regularly with the Ministry of Plan regarding the amount and timing of Title I disbursements to the PDAI project. AID should further work to ensure that Ministry of Plan standards and prerequisites for Title I disbursements are applied consistently among AID-financed projects.

7. Title I funds should be used to a greater extent to support salaries of field personnel, and to further efforts already underway by DARNDR to concentrate more Project funds outside Port-au-Prince.

8. AID should encourage representatives from the Ministries of Plan and Agriculture (especially middle-level officials knowledgeable about day-to-day Project operations) to meet to resolve current problems of insufficient documentation provided by DARNDR to the Ministry of Plan.

9. The Ministry of Plan, DARNDR and AID should address the need for Operations & Maintenance (O&M) funds for other irrigation systems in Haiti. The pressure on Irrigation Service Personnel to use PDAI funds for non-authorized expenditures is heightened when other irrigation systems in the country do not have basic O&M funds.

10. Means to simplify the current procedures for checks drawn on the PDAI Master Account (Account No. 799) should be sought. If simplification of this system appears infeasible, then funds allocated to the Revolving Fund (Account No 829-G) should be sufficiently increased to allow for the smooth flow of funds for day-to-day operations. In addition, district-level financial needs should be provided in monthly, or preferably quarterly, disbursements, reducing lengthy delays in approval and disbursement of individual checks drawn on the bank account at Les Cayes. Districts should ideally be given more autonomy in financial management and decision-making.

11. PDAI administrators who adhere to regulations involving the use of PDAI funds and who, in the process, take stances that are unpopular with other DARNDR officials, should receive the full backing and support of AID.

Section VII - TECHNICAL ASSISTANCE

Findings

Technical assistance to the irrigation component of the PDAI has been provided by contract with Sheladia and Associates, beginning in January 1980 and continuing to the present. Approximately 170 person months of expertise have been provided in project management, design, construction, operation and maintenance, hydrology and on-farm water application.

Overall results and accomplishments of the TA have been much less than should be expected. Responsibility for this must be shared by Sheladia, USAID and GOH, since it resulted in large part from untimely arrival of the technicians, lack of support facilities, counterpart personnel, and construction funds. The current TA is provided by two resident engineers, one in design and construction, and one in operations and maintenance.

Recommendations

1. For continuity and to provide assistance to the Irrigation Service staff who are now in a better position to effectively utilize technical assistance than at any other time in the life of the project, the same two experts should be retained until the PACD if funds allow.

2. The TA should locate its offices at Damien and become an integral working part of the Irrigation Service, reporting to its chief.

3. The GOH should provide several qualified counterparts to work with each member of the TA team so as to make more effective use of this costly, but needed resource.

II. ENGINEERING/OPERATIONAL ASSESSMENT OF DUBREUIL PROJECT

A. Introduction

According to various sources about 140,000 ha were irrigated in Haiti during the colonial period. Present estimates are that only about half that amount is being irrigated, and those with a very low efficiency. Much of this loss in irrigated area has been due to lack of maintenance, damage from heavy rains and hurricanes and sedimentation from increased runoff and erosion due to deforestation and increased farming on the steep slopes of the watersheds.

DARNDR officials state that irrigation is their number one priority. However, based on the limited budget allocations to the Irrigation Service, the priority status of irrigation is questionable. A tax of approximately $1.40/ha is collected on the irrigated areas by the GOH, a substantial proportion of which is supposed to go to the Irrigation Service to maintain the various irrigation systems around the country. In fact very little, sometimes none, of this money collected is ever disbursed to the Irrigation Service for maintenance activities.

Given the amounts of annual rainfall in Haiti, it may appear that irrigation is not needed nor economically feasible. A casual observation of the average rainfalls in some areas might lead to this conclusion. However, in terms of agricultural production, average values are not very meaningful because of the extreme annual variations from the means that can occur in tropical climates.

Hargreaves and Samani (2) analyzed rainfall records for several stations in Haiti to determine the 75 percent probability of rainfall occurence and compared it with the potential evapotranspiration to determine rainfall adequacy for crop production. They define the moisture availability index, MAI, as the 75 percent probability of rainfall occurence, PD, divided by the potential evapotranspiration, ETP[$MAI = \frac{PD}{ETP}$. Generally, MAI values of 0.33 or less mean that rainfed agriculture will not be profitable and values of 0.75 or less indicate that without irrigation yields may be limited due to lack of moisture availability. This relationship will be discussed further for the individual systems.

The project paper for the PDAI project identified four irrigation systems to be rehabilitated under the irrigation component of the project. These were selected from those for which feasibility studies were completed (3, 5) and those included in pre-feasibility studies by the J. G. White Engineering Company in 1976 (1). Of these systems, Dubreuil is the only one where actual rehabilitation work has begun under PDAI.

B. Dubreuil System

The Dubreuil irrigation system is located in the Cayes plain on the southern peninsula of Haiti. It diverts water from the Acul River to irrigate

an estimated 1100 ha of land. The Engineering Consultants Inc. (ECI) report (3) states that the water from the Acul River was used for irrigation by the French settlers long before 1745. Since the first diversion dam was constructed in 1761, the project has been restored many times, including a major rehabilitation in 1962. The 1975 ECI report contemplated repairs to the diversion dam, repairs on the main canal of about 10 km long and laterals totalling 35 km, construction of proportional weirs and lining of sixteen km of laterals. The J. G. White Engineering Corporation of New York initiated construction work of the rehabilitation of the Dubreuil system on August 12, 1976 (6) and completed the major rehabilitation activities on the diversion dam and the main canal. The PDAI Dubreuil project activities were not initiated until mid 1981.

Currently the project is divided into two phases consisting of approximately 300 ha in phase 1 and 800 ha in phase 2. Of this total area some 225 ha and 700 ha will be irrigated in the first and second phases, respectively.

The current construction efforts were started January 1982, and consisted of cleaning and maintenance work on the main canal, repair of diversion dam and head works, and construction of a rock wall for downstream river bank protection. Work in the phase 1 area consists of rehabilitation and in some cases construction of secondary laterals and the construction of tertiary canals with required water control structures. Progress to date has been slow due to delays in the release of funds, both AID loan funds for contracts and materials and GOH counterpart funds for construction labor. A target date of September 30, 1983, has been set for completing Phase I. While this may be optimistic, the project has been moving at an acceptable rate since July 1983, after having stopped for 6 to 8 months due to lack of funds.

In general the works appear to be adequately designed and constructed. In many cases the turnout structures to the tertiary canals seem larger than necessary with long lined approach and exit sections of the secondary earth canal. There are no gates in any of these structures but plans call for installation of wooden slide gates. It may be difficult to make these watertight.

Another deficiency observed in the design of the system was the lack of any measuring devices. Much emphasis is placed on water management in the project and an essential part of managing water is to be able to measure it. The main canal and most of the secondary laterals follow land slopes that require drop structures to reduce the canal grade. These drop structures could be effectively utilized for water measurement by incorporating a weir notch into the over-flow section. While the completed structures can be retro fitted with a weir, it would be better to incorporate it as the structure is built, with perhaps some slight modifications of the size and shape of the structure to meet the standard conditions for weir flow measurement. This should be done in Phase II at the head of each lateral as a minimum. Additional measurements at intermediate points on the longer laterals would also be useful.

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According to the Engineering Consultants Report (3) an average flow of 1.7 m^3/sec is available during the period Nov - April. There is some indication that minimum flows may be less than that. A gaging station with water level recorder has been established upstream from the diversion dam to monitor river flows. Some adjustments may have to be made in planting dates to make maximum use of rainfall during the growing season, thus reducing irrigation water requirements in order to stretch the available water supply as the total project area comes into operation.

Hargreaves and Samani (2) give MAI values for the Cayes plain as follows·

Jan.	Feb.	March	Arpil	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
.36	.45	.33	.82	1.36	.76	.63	.90	1.08	1.57	.74	.18

The MAI values of 1.36 and 1.57 for May and October indicate the need for drainage during these months. Drainage is provided for in the project plans and will probably have to be combined with on-farm cultural practices such as planting on raised beds or furrows to assure that yields are not reduced by excess soil moisture in these periods.

MAI values of 0.76 or less for seven months out of the year indicate the need for irrigation to avoid yields limited by lack of availability of soil moisture. Of all the systems under consideration for rehabilitation under the PDAI, Dubreuil has the highest average MAI and thus the least potential for increased yields to irrigation.

Substantial amounts of both AID and GOH funds have been spent on this project and progress to date has been disappointing. Presently construction is progressing satisfactorily towards completion of Phase I. There are trained, experienced personnel on the job and plans and designs are ready for Phase II. Priority should be given to vigorously pursuing and completing Dubreuil as rapidly as possible. This will require that the same experienced personnel be retained, funding is released in a timely manner and that technical assistance is also available.

Another area of concern, of course, is the operation and maintenance of the system once it is completed. Presently there is one engineer who has worked with the water applications TA, has received off-shore training and acquired some experience at Dubreuil. He appears capable, but this expertise is only one man deep in the Irrigation Service. His pay is low and thus it's probable that he will eventually be lost to a better paying job thereby leaving the project with zero in O&M. DARNDR should try to avoid this by increasing the incentive to stay, particularly by a major salary increase. Junior people, agronomists and engineers should be assigned to work with him for training and experience.

C. Water User Associations

The purpose of this section is to assess the appropriateness of current provisions for an economically and institutionally sound water user association, which not only properly allocates water but also technically and financially provides for the maintenance of the Dubreuil irrigation system.

1. Present Status

Control of water for irrigation in the Les Cayes area is the responsibility of the Agricultural District Office. The Water Controller works under the supervision of the Agricultural District Engineer. The Water Controller's duties include·

1) Prepare tax rolls of irrigated areas for the Bureau of Contributions
2) Verify tax payment
3) Supervise water distribution by the ditch riders
4) In case of non payment of tax, see that the ditch rider does not deliver water to that property
5) Prepare notices when canal cleaning is required
6) Report any changes in land areas or ownership
7) Prepare water distribution schedules in collaboration with the District Engineer
8) Inspect systems to see that they remain in good functional condition

Presently, in the Les Cayes area, he is responsible for approximately 13,000 ha covered by some 15 systems. He supervises four ditch riders and three dam and gate tenders - a virtually impossible job since he has no transportation. Therefore much of the responsibility falls to the ditch riders. The water controller, ditch riders and gate tenders all receive a salary from DARNDR.

Maintenance is sorely lacking in most systems due to insufficient funds. A tax on irrigated land is presently collected from land owners at rates of $1.40 to $2.00 per ha. These revenues, which amount to approximately $200,000 per year nationally, go to the national treasury. From there the Ministry of Plan is supposed to distribute approximately 80 percent to the Irrigation Service of DARNDR for maintenance of the irrigation systems in the country. In fact, the funds available to the Irrigation Service in recent years have been much less than this. For example in FY 83 it received no money. It is reportedly budgeted for $60,000 in FY 84. These funds are supposed to cover materials and contract labor for all maintenance of the irrigation systems in the country. Based on the DARNDR estimates of 70,000 ha of irrigated land, this allows less than $1/ha/year for operation and maintenance, which is totally inadequate. Under the present regulations, the irrigation tax payers essentially receive nothing for the taxes paid, partly because the tax is so low and partly due to the manner in which the tax is utilized.

In the Les Cayes area, the District office received $1000 this past year for maintenance. This was used on the Avzac system on which there had been no maintenance for four years. Thus, at the district level, as well as the national level, the O&M funds are far short of what is needed to keep the irrigation systems functioning.

There are some entities in Haiti that have the power to levy water user fees for lands within their boundaries and retain these funds for operation and maintenance. The ODVA collects $11/ha from its users and the ODPG collects

its own fees for fuel used to pump irrigation water. Special legislation and a presidential decree are required to establish this type of organization at present.

2. Dubreuil

Typically, there are no formal water user organizations as such in Haiti. Existing rural organizations are usually community councils which are not specifically organized for irrigation. The earlier work done by J. G. White and ECI stressed the importance of assisting in the formation of a viable, legally constituted, autonomous irrigation District for the Dubreuil area, but there is no evidence of any water user groups in the project area prior to the present rehabilitation.

a. Technical Assistance in Water Application

Technical assistance in the formation of water user groups and water application was provided by an on-farm water management specialist of the technical assistance contractor from March 1980 to March 1983. He began working on the Dubreuil system in July 1981. He provided one and a half years of technical assistance and training to a water applications engineer and a lecturer in the Faculty of Agriculture. Because of the delays in construction, this on-farm specialist arrived too early in the project to effectively carry out his responsibilities in water application. It was difficult to try to train irrigation technicians, and prepare training programs for farmers on land preparation, irrigation practices, irrigation schedules and drainage requirements when no water was being delivered. A Manual of Water Application was prepared by the specialist which includes sections covering on-farm irrigation specialist duties and responsibilities, resource inventory and planning, water users associations, and water management on small farms. The manual is written in English, with a French translation currently being prepared. Since the departure of water management specialist in March 1981, there is one DARNDR engineer responsible for system operation and maintenance, on-farm water application and hydrology.

b. Description of Water User Groups and Supporting District Personnel

One water user group (groupement d'usagers) per secondary canal is planned for the Dubreuil irrigation system. At present, water users groups have been organized for the nine secondary canals in Phase I of the project. When both Phase I and II have been completed there will be nineteen of these water user groups. Each water user group has elected one leader, one assistant and one counselor. There are 20-75 members per water user group.

Plans also call for one users group per each tertiary canal in the Dubreuil project, some of which have been formed and others are now being organized. There will be an estimated 28-30 tertiary groups

for Phase I. Each tertiary group will have an elected leader. The leaders and members of the tertiary groups are all members of the associated secondary water users group. When the Dubreuil system is completed, the water user groups are expected to take over operation and maintenance (O&M) activities on the laterals under the supervision and guidance of the O&M/Water Application Engineer. The leaders of the tertiary groups will be the tertiary gate tenders. These gates will be operated according to the schedule which was prepared by the O&M/Water Application engineer and the on-farm water management specialist. When the Dubreuil system has been completed, the plan is for simultaneous operation of the secondary canals. The water will be rotated among the tertiary canals served by each secondary. During periods of low flow some of the secondary lateral gates will be closed on a rotation basis to ensure adequate flow for the laterals receiving water. Eventually each water user will have a card which indicates the user's name, name of the zone, the secondary canal (lateral) number, the tertiary canal number to which the user belongs, the time schedule for water for the user, and the amount of irrigable land of the user. These cards will help the users and the district personnel allocate and distribute the water more efficiently and equitably.

Because of the small size of land holdings in the Dubreuil project, the water user organizations under each lateral and even under the tertiary canals involve a substantial number of individuals. A block rotational irrigation delivery is proposed where the schedule will be posted, perhaps at each lateral. This will require formal organization and perhaps district personnel intervention. This has not been tried in Haiti before. Problems can be anticipated particularly in the initial phases of project operation.

The O&M/Water Application engineer has responsibility for overseeing, controlling, training and assisting the water user groups. The following observations on a water users meeting held during one of the team's field visits are included as evidence of an effective organization beginning to emerge under the leadership of the engineer. The engineer encouraged the group to elect one leader for each of the tertiary canals in the zone. He described to the users general water application principles emphasizing the need for correct land preparation, including land levelling and furrowing; the water requirements of different crops; the variations in root depth; and the importance of regular irrigation schedules. The meeting also provided the opportunity for a number of sensitive questions to be openly discussed and resolved by the group. For example, during the meeting one of the users asked for a tertiary canal to be located near his land at which point a number of the other users complained that he was asking for special favors. The argument was resolved immediately with the approval of the users. It was pointed out that the special request could not be satisfied due to the topography and alignment of the proposed tertiary canal location.

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A follow-up meeting was scheduled for the water users at a designated demonstration plot so that the engineer could show them some of these principles. The Agricultural Development Society (SAD, a small group of 7-15 farmers with similar economic interests) rents this selected demonstration plot. These plots are used for extension and research purposes as well as for demonstrating water application principles. The SAD purchases all inputs and retains any yield and/or profit from the demonstration plot. After the harvest is sold, the SAD decides whether or not to continue renting the demonstration plot. Each of the other secondary water user groups will have a SAD plot to demonstrate water application practices as well as other general agricultural practices.

The O&M/Water Application engineer also has responsibility over one gate tender, two ditch riders, and four ditch cleaners. The engineer, gate tender and ditch riders are paid by DARNDR[the ditch cleaners are paid by the PDAI project. The gate tender for the main gate at the diversion works also supervises the ditch cleaners who are responsible for cleaning and repairing the main canal, as well as maintaining the access roads adjacent to it. The arangement at Dubreuil is somewhat different from the usual in that the ditch riders and gate tender are under the supervision of the O&M engineer.

The ditch riders are the secondary canal gate tenders. They are responsible for inspecting the secondary and tertiary canals for cleaning needs, signs of water stealing and evidence of illegal canals, vandalism, and animals that are tied too closely to the secondary and the tertiary earth canals where they can damage the canal and/or structures.

There are two control mechanisms for insuring proper water use and minimizing water abuse. If the ditch riders find any of the above-mentioned water abuse problems, they report this to the district water controller who can issue a citation with a fine. The ditch rider delivers the fine citation to the offender. The offender must either go to Torbek and pay the fine to the Bureau of Contributions or face imprisonment. There have been a few cases of citations being issued to offenders and fines being collected.

A second water control mechanism which can be used by the ditch riders for water use abuses is withholding water from an entire tertiary canal. This exerts tremendous peer pressure on the single offender since a water cut off also punishes neighboring water users. The potential negative reaction of these neighboring water users is a big disincentive to water abuse by a single user.

The Bureau of Contributions in Les Cayes levies an annual irrigation tax of $2.40/ha on 980 hectares and an estimated 1098 farms in the Dubreuil project area. There are various estimates of tax collection rates but it seems to be about 75 percent. Other than the imposition of a possible citation and fine, there is little incentive for owners

to pay the irrigation tax since they generally do not receive any direct benefit from it. Tax collecting is further hampered by lack of cadastral surveys and updated ownership information.

Presently water users do not contribute labor for operation and maintenance of the secondary and tertiary canals since the Dubreuil system has not been completed and there is no regular water delivery. The farmers indicated their willingness to maintain the system and the technicians believe that with training and supervision in water application methods and operation and maintenance, the farmers would accept the responsibility for operating and maintaining the secondary and tertiary systems. Since they already pay an irrigation tax, the farmers at the water users meeting said they would contribute labor, but probably not money for main irrigation system repairs.

3. Overall Assessment of Water User Organization Economic and Institutional Soundness

The current and proposed set-up of the secondary and tertiary groups is institutionally appropriate for irrigation system maintenance. However, organization for the overall project is lacking. The ability to operate and maintain the Dubreuil system, as with others, is subject to apparently arbitrary decisions by the Ministry of Plan as to the proportion of the already inadequate tax collection it passes on to the Irrigation Service.

There are so many demands on the capabilities of this service due to the large number of systems in the country in need of maintenance work that the resources are further diluted. What is needed is a legally constituted Water Users Association with an elected Board of Directors with the power to levy, collect and use fees for the operation and maintenance of the irrigation and drainage works within the project boundries. The association would need the continued technical assistance of the O&M/Water Application Engineer for the supervision and training of the ditch riders and the gate tender and support in water application activities, operation and maintenance and scheduling. The engineer would be paid for at the national level within the Irrigation Service but the other personnel would be employees of the Association.

Establishment of this type of organization would require a change in the present law or a Presidential decree and special legislation. In order to finance its operation the fee would have to be raised substantially. This should be acceptable to the farmers if they can see the local benefits and be assured of a dependable water supply. They are willing to invest in irrigation at their level because they realize its benefits as demonstrated by a recent example in the Jacmel Agricultural District. A group of approximately 25 farmers, who have been paying an annual tax of $3.90/ha, collected $300 among themselves, brought it to the Distict office for materials and asked the District Engineer for technical assistance to repair their irrigation system. These farmers, recognizing the value of irrigation and realizing that they

were not going to receive any benefit from the irrigation tax they had been paying, were willing to spend additional money to get their system back in operation.

There are no plans for training additional personnel in water application principles. Only the O&M/Water Application engineer has received technical assistance and training in O&M and general water application principles. It is possible that this engineer could leave the Dubreuil project due to an inadequate salary which is paid irregularly by DARNDR. If this happened, there is no one else at the project site who understands water application methods and how to properly supervise the water master, ditch riders, and ditch cleaners for the main canal, and to organize and supervise the water user groups.

D. Recommendations

1. The second phase of construction should be completed as quickly as possible using construction contracts. This will allow the use of both AID loan funds and GOH counterpart funds for any construction activities and remove the need for the simultaneous availability of both sources of funds. This would also allow for contractors who could bring to the project the needed outside expertise in addition to using local labor.

2. Water measuring devices should be incorporated in the lateral turnout structures in Phase II.

3. Proper water application and O&M are critical areas which need to be strengthened. The Irrigation Service should not focus solely on the construction or rehabilitation of irrigation systems.

   -- Continued and increased recognition and attention should be given by the Irrigation Service and the Agricultural District to the importance and need for educating farmers in water use and application. The O&M/Water Application engineer should continue the regular meetings with the ditch riders and water user groups for extension in water application methods, with assistance from district animators and extension agents in cultural practices, use of other inputs, cropping patterns, etc.

   -- Increased pay should be given to the O&M/Water Application Engineer and other related staff to assure their continuing presence.

   -- More technicians need training in water application at the Dubreuil project site to support and complement the current activities of the O&M/Water Application Engineer. Some new people, including extension agents, should be assigned so they can receive training and experience in this very important

activity. Funds are available for eight more short term overseas training participants. The use of these funds should focus on strengthening O&M and water application expertise of the field staff.

-- A third ditch rider should be hired by DARNDR as planned to assist in the operation and maintenance of secondary and tertiary canals when both Phase I and II are finished and become operational.

4. Once regular consistent delivery of irrigation water is established in a system such as Dubreuil, the national irrigation tax and Water Users Association fees should be set at a combined rate sufficient to cover all O&M costs. The combined rate should be set by the Irrigation Service for each system rehabilitated. Estimates of the full cost of irrigation O&M range between $60 and $150 per hectare per year. The national irrigation tax should cover all O&M expenses incurred by the Irrigation Service, including an estimated $20/ha to go into a national disaster fund to provide a central pool of money for repair of major disaster caused damage.

5. For systems such as Dubreuil, a bona-fide Water Users Association should be formed with the power to levy, collect and use water fees for maintenance and operation of the system, with technical assistance and supervision provided by the Irrigation Service. The fees collected should be sufficient to pay the salaries of the ditch riders, gate tenders, maintenance personnel, etc., and the cost of labor and materials for normal maintenance and repair.

SECTION II REFERENCES

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III. AGRICULTURAL IMPACTS OF DUBREUIL IRRIGATION PROJECT

A. Agronomic Situation

The temperature is strikingly uniform throughout the year with an average of 25°C. This favors year round production of crops. Data from Les Cayes show a mean annual rainfall of 2035mm. During the period from November to March there is the least rainfall with only 492mm in total or 98mm/month. This is extremely low. Rainfall patterns tend to be rather erratic from year to year. Excessive rainfall is likely to occur during May, September and October. Mean annual relative humidity is around 80%. Evaporation varies between 140mm in October to 210mm in March. Mean daily solar radiation is 432 cal cm^{-2} day^{-1}. Estimated potential evapotranspiration is around 113mm/month, with high values of over 130mm in July and August and low values of 98mm in November through February. Potential evapotranspiration is higher than rainfall during part of the year (3,12).

The Moisture Availability Index (MAI), mentioned earlier, ranges from 0.18 in December to 1.57 in October; annual mean value is .77. According to Hargreaves and Samani (12), a MAI value of 0.33 or less for one month during the crop growing season is considered to be a "danger signal". They further indicate that "if the average MAI value for the crop growing season is less than 0.50 then the use of fertilizer may not be economical". In the Les Cayes region, MAI values approach or fall below 0.50 in December, January, February and March, as shown in the MAI index.

The majority of the soils of the plains and valleys are probably Mollisols with well developed diagnostic horizons; others are Inceptisols where no genetic horizons can be recognized, that originate from alluvium (1,13,23). They are mostly loams, clay loams and clays. Expanding lattice minerals predominate in the clay fraction. They are generally open, porous, friable, permeable and well-drained except for the compact clays with heavy subsoils (50% clay) of the bottom lands which are imperfectly drained. Data on the physical properties of the soils are meager. The following values were obtained for the uppermost 56 cm of a dark clayey soil in the lower area of Dubreuil (23):

Property	Value
Bulk density, gm/cc	1.1
Water held at 1/3 bar, %	52.0
Water held at 15 bar, %	32.0

Soil-water held at tensions between 1/3 and 15 bar is considered to be available to plants. This soil, therefore, can hold enough moisture in the upper 56 cm where most of the roots develop. In total, down to a 153 cm

depth, it can hold 53 cm of soil-water that is available to plants. Soil pH values are between 7 and 8. Cation exchange capacity values are at around 30 to 40 meq/100g of soil in the upper 45 to 60 cm layers (23). This indicates that the soils have a rather high inherent fertility. The organic matter content of the soils is high, (probably 4% or more) and they appear to be well supplied with phosphorus, potassium and other nutrients. They are rich in calcium (more than 20 meq/100 of soil). They respond to nitrogen fertilization. Their productivity depends largely on rainfall and irrigation. When they receive water and nitrogen fertilizer, they are likely to produce heavy crops.

Field examination of several soil profiles down to 90cm revealed good root penetration. This depth will suffice since most of the roots ---60 to 75%--- of the crops grown are generally confined to the upper 15 to 30cm of soil. The exception is pigeonpeas which could reach lower depths with their vigorous root system. Water and fertilizer requirements for pigeonpeas are low since they can tap lower layers of the soil profile.

In general, soil conditions are suitable, or can be made more favorable through irrigation and adequate management, for food crops production.

Most of the soils in the lowlands have few limitations that restrict their use and can be irrigated by gravity systems. They are suited to a wide range of crops and may be used safely. They are level or nearly level, the erosion hazard is low and they are easy to cultivate. In the lowlands with heavy subsoils, drainage must be provided.

B. Cropping Patterns

In the nearly level land to gently sloping areas of the project area, subsistence farming is the major enterprise. The main crops are corn, grain sorghum, beans, sweetpotatoes, plantains, bananas, pigeonpeas, dasheens, cassava, sugarcane and rice. With the exception of rice and dasheens, which require very wet conditions during most of their growing cycle, many of the crops are grown in associations, i.e., corn and pigeonpeas, bananas and pigeonpeas, and others.

The farming calendar for food crops in the Dubreuil Development Project is strongly influenced by rainfall distribution in the area. Two distinct planting periods are evident: February to March and September to October.

Corn is usually planted in February and March; harvested in June and July. Sorghum is planted in August and September and harvested in January and February. More sloping and steep adjacent areas are used for growing vetiver, fruits and forage; however corn and other clean cultivated crops are also grown on steep slopes. Rugged areas are devoted to poorly managed woodlands and because of rampant deforestation, erosion has become a major problem.

Three of the five zones of the Dubreuil Development Area can be irrigated: Bellabe, Ducis and Dubreuil. The steep relief of the other two - Caiman and Platon - do not permit irrigation.

The predominant crop in Bellabe is sugarcane; in Ducis, corn; and in Dubreuil, sweetpotatoes. In 1982, corn and sorghum occupied 33% of the cropland in Bellabe; 57% in Ducis; and 50% in Dubreuil. Sweetpotato occupied 35% of the cropland in Dubreuil; and 12% in Bellabe. Sweetpotatoes were planted in Ducis in limited amounts. Beans were planted on 15% of the cropland in Bellabe; 28% in Ducis; and 7% in Dubreuil. Sugarcane accounts for 28% of the cropland in Bellabe, but only insignificant amounts were grown in Ducis and Dubreuil. Nearly 5% of the cropland in Ducis was devoted to tobacco (22).

C. Actual Crop Yields

Several studies have observed the agricultural practices of the farmers in the Les Cayes plains. Table III-1 shows differences in yields of major crops grown in the Les Cayes Plain, based on data obtained during a survey in 1975, both under traditional practices without irrigation and under appropriate technology with irrigation (28).

Yield increases attributable to irrigation with the use of appropriate technology are dramatic. There was a fourfold increase in yields of the first crop of sugarcane when appropriate technology together with irrigation was used. This is a sizeable increase that dramatizes the need to replace traditional technology with more appropriate technology and irrigation. Good yields were sustained through the succeeding four sugarcane crops.

Corn yields increased more than threefold through the use of appropriate technology and irrigation. Sweetpotato yields increased more than 160% with appropriate technology and irrigation. In the case of the red beans, less dramatic differences were observed since in both cases the crop received fertilizer and pesticides and the only variable was irrigation. Obviously, there was sufficient soil moisture available (from rainfall) for the bean crop which has a very short growing cycle.

Rice yields were more than doubled by effective water control and appropriate technology.

The 1981-82 results obtained by CIMMYT[1] and Texas A&M/Haiti confirm the impact of technology on crop yields. The replicated experiments and further verification tests done by CIMMYT clearly indicate that applications of 80kg/ha of nitrogen fertilizer are conducive to increased corn yields. A well-defined response to the use of introduced corn varieties of high-yielding potential is also evident (Table III-2).

1/ Dr. Michael Yates, Personal communication, Les Cayes, August 23, 1983.

Table III-1. Crops yields in the Les Cayes Plain with and without irrigation 1/

Crop	Yields, kg/ha	
	With traditional technolology and no irrigation 2/	With appropriate technology and irrigation 3/
Sugarcane (First crop)	30000	120000 4/
Corn	800	3000
Sorghum	750	2000
Red beans	635 5/	1500
Rice 6/	1200	2700
Sweetpotatoes	2250	6000

1/ Enquête et Démonstration Agricole dans la péninsule Sud: Haiti UN, FAO, 1975.

2/ Using local varieties, no fertilizer, no pesticides and no irrigation except if otherwise indicated in footnotes.

3/ Using high-yielding varieties, fertilizer, pesticides and irrigation.

4/ Yields of succeeding ratoon crops: 2nd crop, 110,000; 3rd crop, 90,000; 4th crop, 80,000; 5th crop, 60,000tons/ha.

5/ The red bean crop received fertilizer and pesticides, but no irrigation.

6/ With traditional technology, water application was not controlled; with appropriate technology there was good water control.

The first column of Table III-3 shows actual yields under traditional farming systems. The second column shows average actual yields using appropriate technology and irrigation as found in the Les Cayes area. Irrigation, which reduces the risk of investing in modern inputs, induces farmers to use some of the appropriate inputs. However, they tend to be sub-optimally used. The third column shows potential yields that could be realized provided that high-yielding varieties, irrigation and improved technologies were optimally used. Potential yields are only estimates, although realistic, of what could happen if the Dubreuil Irrigation System were rehabilitated and if farmers adopted better farming techniques.

Using improved technology and irrigation, corn yields can be expected to increase fivefold; beans, sweetpotatoes and sugarcane yields, twofold; sorghum yields, fourfold; rice and pigeonpeas yields, threefold. Based on research station yield levels, potential increases should be as follows: corn, sevenfold; beans and sweetpotatoes, threefold; pigeonpeas and sugarcane, fourfold; rice, fivefold.

As high as the potential yields might seem, they are really conservative estimates in view of achievements already attained by farmers who use high-yielding varieties and improved technologies (28). The results from CIMMYT corn variety and agronomic trials and verification tests at Les Cayes and of the research findings of the Texas A&M/Haiti team (26) further confirm this view.

Yields of 120000 kg/ha of sugarcane, 1500 kg/ha of beans and 6000 kg/ha of sweetpotatoes have been already obtained in Les Cayes, under irrigation and using appropriate technology, as revealed by the 1975 UN-FAO survey (28). Yields of more than 4000 kg/ha of corn have been obtained in farmers' fields in various parts of Haiti planting La Màquina and other improved varieties under irrigation and good management.

Yields as high as 4000 and 5000/ha of grain sorghum have been obtained - using selected varieties, fertilizer, pesticides and irrigation. Rice yields of 5000-6000 kg/ha are also possible with appropriate technology and good water control when improved varieties are grown instead of the local Madame Gougousse which yields only 1500-3000 kg/ha. Cassava yields of more than 20000 kg/ha have been obtained by using irrigation and fertilizer when improved varieties were harvested at 8 to 10 months of age (26).

Cowpeas and soybeans, as well as pigeonpeas, are legume crops that can fix sizeable amounts of nitrogen from the atmosphere to satisfy their own needs and even to provide nitrogen for succeeding crops in a rotation or to other crops grown in association with them. Yields of cowpeas of 2000-3000 kg/ha have been obtained in Haiti (25).

Tobacco is a cash crop that, given adequate conditions, could produce as much as 1700 kg/ha of marketable leaves with irrigation and the use of fertilizers and pesticides (23).

Table III-2. Mean yields of 10 corn varieties at two levels of nitrogen fertilization, Les Cayes, Haiti, 1982 1/

Variety	Mean yields at indicated levels of nitrogen fertilizer 2/		Increase, %
	0	80 kg/ha	
Tocumen 7926	2.18	3.49	60
Chicken Corn	2.18	2.75	26
Poza Rica 7827	2.23	3.53	58
La Maquina 7827	2.24	3.48	55
Poza Rica 7931	1.64	2.87	75
Across 7728	2.05	3.45	68
La Maquina 7928	2.14	3.64	70
Poza Rica 7926	2.57	3.24	26
Sete Lagoas 7728	2.40	3.26	36
Les Anglais	1.98	3.17	60

1/ Magloire, E.; Pierlus, R.; Fleurantin, G.; and Yates, M. 1982. Segundo Fase en la Evaluacion de Variedades de Maiz (Zea mays) en la Region de Les Cayes, Haiti; Unpublished report.

2/ Each value represents the mean of 5 locations

Table III-3. Actual crop yields with traditional practices and expected crop yields with irrigation and appropriate levels of technology at the Dubreuil Project Area.

Crop	Crop cycle, days	Yields, kg/ha 1,2,3/		
		Actual, traditional practices and no irrigation	Actual, appropriate technology and irrigation	Potential, appropriate technology and irrigation
Corn	120-150	800	4000	6000
Beans	80	670	1500	2000
Sorghum	100	750	3000	5000
Rice	90-140	1200	4000	6000
Pigeonpeas	235	600	2000	2500
Cowpeas	60-90	-	2000	3000
Soybeans	80-100	-	1500	3000
Sweetpotatoes	135-150	2250	5300	6000
Cassava	300	4000	6000	10000
Tobacco	90-120	-	1200	1700
Sugarcane	365	30000	70000	120000
Irish potatoes	75	-	-	12000

1/ Actual yields of corn, beans, sorghum, rice, sweetpotatoes and sugarcane taken from UN-FAO, 1975, Enquête et Démonstration Agricole dans la Peninsule Sud, Haiti (28). For other crops, taken from Texas A&M/Haiti 1981 and 1982 Annual Reports (25,26) and from Hargreaves and Samani (12).

2/ Yields of corn, beans, sorghum, rice, sweetpotatoes and sugarcane taken from reference 28; for other crops are taken or adapted from references 12, 25, 26 and 28.

3/ Potential or near maximum yields, are adapted or taken from references 12,25,26 and 28. They are based on the use of irrigation and the adoption of improved technologies

Table III-4. Mean yields of corn varieties under favorable and unfavorable soil moisture 1/

Variety	Yields, kg/ha (ear weights)	
	With favorable soil moisture	With insufficient soil moisture
Tocumen 7926	5658	1941
Chicken Corn	3262	1532
Poza Rica 7927	5306	1911
La Maquina 7827	5647	1542
Poza Rica 7931	4583	1467
Across 7728	5796	1856
La Maquina 7928	5733	1978
Poza Rica 7926	5189	1983
Sete Lagos 7728	6029	1687
Les Anglais	5640	1590

1/ Texas A&M/Haiti, 1982. Annual Report, Integrated Agricultural Development Project, Research and Extention Component, for 1982

The data in table III-4 show that, under favorable soil moisture conditions, eight out of ten corn varieties produced between 5000 and 6000 kg/ha, which is approximately 2000 kg more than the yield of the local Chicken Corn. The other local variety -- Les Anglais -- produced well with favorable soil moisture conditions. Yields of La Maquina 7827 and La Maquina 7928 were more than 60% higher than yields of Chicken Corn (26).

With a reliable irrigation system, the number of crops with a relatively short growing cycle could be increased per year. The following tabulation shows the number of crops that could be grown safely per year and that fit within the normal cropping pattern when irrigation is available:

Crop and growing cycle, days	Number/yr
Corn, 120-150	2
Beans, 80	2-3
Sorghum, 100	2-3
Rice, 90-120	2-3

To obtain more than one crop/yr, improved varieties should be used. The exception is the local rice variety, Madame Gougousse, which can produce 2-3 crops per year, but yields are much lower than those which can be obtained from improved varieties. Local varieties of sorghum differ greatly in length of maturity and probably only one crop per year could be harvested.

D. Expected Changes in Land Use

Table III-5 presents data on non-irrigated land use at Dubreuil, based on studies recently completed by Taylor (22). Corn is planted in 26% of the land; beans, in 16%; sorghum, in 22%; sugarcane, in 8%; tobacco, in 2%; rice, in 2%; and sweetpotato/cassava, in 15%. Other crops are planted in 9% of the land. No major changes in land use patterns have occured in recent years.

It is anticipated that with a reliable irrigation system farmers will gradually switch to high value, short growing cycle cash crops. It is likely that beans will be grown on 25% of the area and tobacco on 10%. A large reduction in the area planted to sorghum and sugarcane, 50% and 75% (on basis of the current land use), respectively, could be expected. These are significant changes.

It is further expected that with the expected switch to high value cash crops there will be a reduction in forage production (less sorghum and less sugarcane). With less available forage for livestock, no increases in the number of animals are likely to occur. This conflicts with the conclusions derived in the 1975 Engineering Consultants, Inc. Report (3). They projected substantial increases in the number of animals as a result of the rehabilitation of the Dubreuil Irrigation System.

Table III-5. Current Non-Irrigated and Expected Irrigated Land Use at Dubreuil 1/

Crop	Land use, ha	
	Current Non-Irrigated	Expected Irrigated
Corn	26%	26%
Beans	16%	25%
Tobacco	2%	10%
Sorghum	22%	10%
Sugarcane	8%	2%
Rice	2%	2%
Sweetpotatoes/Cassava	15%	16%
Others	9%	9%
	100%	100%

1/ Texas A&M/Haiti, 1983. Annual Report, Integrated Agricultural Development Project, Research and Extension Component, for 1982.

E. Availability of Complementary Inputs

In general, it has been demonstrated in many areas, including tropical countries in the Caribbean, that planting high-yielding varieties, at the correct time and spacing, under appropriate soil and crop management techniques, including fertilization and pest control, is essential to fully realize their productive potential. As far as possible, a complete package of technological practices must be used, including irrigation, to maximize production potentials. The omission of a single practice may be disastrous. The best of varieties would not produce near maximum yields if not fertilized and watered as required, if pests are not controlled on time, and if not planted at the appropriate season and at the optimum plant density. Isolated practices, like the use of a good variety but under stress due to constraints in the water regime and/or the nutrient availability, produce sub-optimal yields.

1. Seeds

Farmers of the Dubreuil area use local low-yielding varieties of crops. There is a strong need for good quality seeds of high yielding variety. There are only two seed processing facilities in Haiti: one processed about 200 mt of rice seed for distribution in 1983; the other had processed about 100mt/yr of corn, but is not currently in operation. Additional seed processing facilities are needed in Haiti. The Texas A&M/Haiti team should be encouraged in their efforts to launch a seed multiplication program. The program suffered serious setbacks attributable to inadequate irrigation and other factors. The Texas A&M/Haiti team emphasizes the need to carefully choose cooperators and closely supervise seed multiplication fields, to consider consumers preferences and to carefully plan seed production and distribution operations (26).

2. Fertilizers and Pesticides

The use of fertilizers and pesticides is limited to the more progressive farmers in lands under irrigation. Even these farmers do not use fertilizers at the required rates for adequate crop production. Pesticides are used only when damage is evident and probably irreversible. The GOH provides a limited supply of fertilizer at subsidized prices. The private sector could probably supply all the required fertilizer as well as pesticides.

3. Credit

The "Banque de Credit de l'Agriculture" (BCA) provides limited credit to finance farming operations. Loans are available through bona fide farmers associations and no colateral is required. These associations must meet very strict qualifications in order to be eligible. IDAI also provides production credit.

4. Extension Service

The Extension Services staff in the Dubreuil Area is responsible to the Les Cayes District Agronomist, the Extension Head Agronomist based in Les Cayes and the PDAI Project Director based in the Dubreuil office. At a seminar for project animateurs, extension agents and moniteurs held in Ducis in 1982, there were 26 men who were identified as field technicians for the Dubreuil Project.

There appears to be a difference in the type of work expected from an extension agent (vulgarizator) and an animateur. The vulgarizator plans and conducts field demonstrations where improved technologies are used. The animateurs stimulate farmers through training sessions, seminars and personal assistance. In observing the people at work in the field, they appear to be equally qualified to do either job. They are well known and respected by the farmers, which implies contact and a past history of useful assistance. They are willing to work long hours day after day.

The major problem seems to be a lack of transportation to expand their area of influence. Presently, they travel almost exclusively on foot, but occasionally ride on trucks. Only a few of the men have bicycles. Bicycles could be very useful for transportation in the Project area.

The existing infrastructure should be able to facilitate the quick dissemination of new technologies as they are developed by research and on-farm verification trials. The extension personnel should participate in the on-farm verification trials to increase their knowledge, competence and credibility.

Appropriate technologies, including selected seeds of high-yielding varieties, use of pesticides, plant population density and others are likely to be accepted by the farmers in Les Cayes and elsewhere in Haiti only if:

(1) irrigation is available when needed.

(2) farmers are convinced that it is indeed worthwhile to adopt them. This means that the extension worker should offer the farmer guidance and advice and provide pertinent education. The extension worker must be careful not to dictate to the farmer. Extension cannot hope to succeed without the farmer's complete confidence and trust.

It is necessary to concentrate efforts on clearly selected priority targets so as not to scatter the extremely limited human resources. Work plans must be specific and contain quantifiable objectives to be accomplished together with the specific methods to be used and the activities to be undertaken to achieve these goals. There must be a continuous updating and upgrading process for extension personnel through on-the-job training, reading, familiarity with on-going research or verification trials, collection and analysis of data, teaching and training of farmers.

Technologies must be made relevant to the farmers. One limitation to the adoption of technologies is that farmers do not view them as really pertinent. The method of extending technologies to farmers must make sense, must be adapted and suited to them (culturally, socially, educationally and economically).

Demonstration plots are a valuable tool in the use of improved farming technologies. They allow the farmer to evaluate the technologies in his own community. They also reduce the farmers suspicions as to the influence of external factors not availble to him.

5. Soil conservation

Soil conservation measures in the upper Acul Watershed are essential components of any long-term integrated plan for strengthening agriculture in the area of influence of the Dubreuil Project. Much has been written about the devastating soil erosion and deterioration of watersheds in Haiti due to the increased agricultural activities on the steeper slopes and the use of trees for charcoal production.

This, of course, affects irrigation in that it increases runoff and the sediment load during storms, thus subjecting the systems to flooding and/or siltation. It also decreases the base flow of the streams during dry periods when irrigation water supply is most critical. Soil conservation efforts should continue in the watersheds where irrigation projects are located. Extension activities and subsidies will likely be required to help hillside farmers adopt needed conservation practices and cropping pattern changes until adequate income flows are generated from ecologically sound hillside crops.

Data from Jamaica show soil losses of 179 t/ha per year from yam plantings on steep slopes under traditional cultivation. The losses were reduced to 43 t/ha with continuous contour mounds and a grass buffer strip. Under the gradient, rainfall and cropping pattern conditions obtained during the period, the upper 15 cm soil layer would have been lost in the first case in 12 1/2 years whereas 52 years would be required to sustain a similar loss if the land is prepared in mounds interrupted at appropriate intervals with a grass buffer strip (33).

6. Research

a. Soil Survey

There is hardly any reliable information on the soils within the Dubreuil Project Development Area. A survey should be conducted using the U.S. Soil Taxonomy system as done by Louis et al for the mountainous area of the Acul Watershed (15). Soils should be mapped and data on soil properties collected by field examination of the soils and determined by laboratory tests.

Soils should be described morphologically and information recorded as to depth and boundary of each horizon, color, texture, structure, consistence, and other significant properties. The U.S. Soil Conservation Service, Caribbean Office, has a group of experienced soil scientists that recently completed a detailed soil survey of Puerto Rico. They are now training soil surveyors in the Dominican Republic. Perhaps arrangements could be made to undertake a similar mission in Haiti. Laboratory determinations should include particle size distribution, bulk density, hydraulic conductivity and water retention at various tensions. The most relevant chemical data relates to pH, organic matter content, cation exchange capacity, exchangeable cations, electrical conductivity, and available nitrates, phosphoric acid and potash. Laboratory work could be done at Damien

The mapping and collecting of data on soils of the Dubreuil Irrigation Project Development Area is basic to accurately plan and develop possible alternate new cropping systems and to evaluate soil management practices and crop performance. This is essential to transfer information from one site to another.

b. Adaptive Research

Texas A&M University, through a contract with GOH and AID, has the responsibility for the research and extension component of PDAI. The objective of the work is to increase food crop production levels and improve the economic situation of small farmers. The highly-qualified 5-person team working together with its Haitian counterparts, under the leadership of Mr. Robert L. Cheaney, is making excellent progress. The results of on-going evaluation of improved varieties of cereals, legumes and starchy food crops, under appropriate levels of technology, of the Texas A&M/Haiti team can be far reaching (25,26). One of the members of the Texas A&M staff is stationed on Les Cayes.

The CIMMYT team at Les Cayes is doing an excellent job of determining how to maximize crop yields in the Dubreuil Project Development Area. Their work with high yielding corn varieties, nitrogen and phosphorus fertilization and plant population densities must be commended. This work should be expanded to include other crops of potential value in the area. Since CIMMYT programs are rather restricted in scope, DARNDR should assume more responsibility for the additional work needed, in close cooperation with the University of Haiti College of Agriculture and Veterinary Medicine. The participation of the University of Haiti in the research program should be further encouraged. The recent work of Nader (18), on the performance of corn grown under varying water regimes before and after flowering, exemplifies how faculty and students can become more effectively involved in joint research programs with DARNDR.

The research program must be geared towards devising ways to increase yields and quality of traditional Haitian crops and to introduce, adapt and evaluate new crops of economic potential and high-yielding varieties of crop plants. The development of packages of appropriate technologies to maximize crop potential is essential. The packages must include such components as fertilization; nematode, insect, disease and weed control; population density; time of planting; and crop sequences. Irrigation and drainage are essential components of these packages. Irrigation studies should be concerned with water requirements of crops, amounts of water that should be applied, timing, and frequency of irrigations.

The on-going program of introduction and evaluation of high-yielding varieties and development of appropriate technologies under local conditions must be continued and strengthened. There is a wealth of knowledge on crops and crops management in the Caribbean. A large amount of information can be obtained from various institutions in the Caribbean that could be adapted to the project area. These technologies could be further refined and adjusted to local conditions at a relatively low cost. CIMMYT in Mexico, INRA at the French West Indies, the University of the West Indies and the Caribbean Agricultural Research and Development Institute (with extensive programs throughout the English-speaking Caribbean), CATIE at Costa Rica, CIAT at Colombia, and the University of Puerto Rico (Mayaguez Campus) are some of the research centers that can provide valuable plant material and information applicable to the Dubreuil Area. Under semi tropical conditions in Puerto Rico, packages of technological practices have been developed and are continuously being updated for the production of beans, rice, corn, sugarcane and many other crops. Pubications describing this research are readily available (4,5,6,7,8,10). Linkages with these institutions must be further strengthened.

Major production constraints must be identified as a basis to determine research priorities. The economic impact of irrigation and improved technologies should be addressed.

Research efforts and coordination at the national level in Haiti can be expected to improve under the leadership of Mr. Lionel Richard, Head of CRDA. The research staff must be encouraged to join professional organizations such as the Caribbean Food Crops Society. The results of carefully planned and executed research should be published in Haiti or in outside journals. The policy of the Bulletin Agricole should be changed to provide space for scientific and technical articles. In addition, "Tropical Agriculture", published by the University of the West Indies, and the Journal of Agriculture of the University of Puerto Rico, would accept good quality manuscripts from Haitian scientists if written in English. A policy of encouraging research publication efforts would be encouraging to staff members involved in research.

7. Training

An essential feature of any program geared to improve agriculture in Les Cayes and in Haiti as a whole is the upgrading of human resources. Under the current PDAI/TAMU program not only are young agronomists being trained in research and extension techniques in Haiti, but several have been selected and sent for short-term specialized training at various international centers and universities abroad. Some of the centers where Haitian agronomists and engineers have been sent are CIMMYT and ICRISAT in Mexico, IITA in Nigeria, CIAT in Colombia, Texas A&M University, the International Irrigation Center at Utah State University, and Southwest Louisiana State University. Other centers that should be considered are the University of Puerto Rico (Mayaguez Campus) and the University of the West Indies at Trinidad. The similarity of the tropical environment that prevails at Puerto Rico and Trinidad, mainly as to climate, soils, and crops, would make for a more meaningful training.

In-service training programs for irrigated agriculture should be developed and adapted to the conditions prevailing at Les Cayes.

F. Recommendations

1. Research programs should be developed to evaluate crop response to irrigation and the economic influence of irrigation on small farm cropping systems.

2. The Texas A&M University/Haiti Program should develop complete packages of technological practices through adaptive research on high-yielding varieties, fertilization, pest control and soil and crop management. This research effort should be continued until PACD.

3. Support should be provided for existing seed production and processing facilities and the establishment of additional facilities.

4. The Extension Service should concentrate on priority targets like newly irrigated lands. Work plans should be specific, contain quantifiable objectives and indicate methods to achieve the transition from traditional to modern farming practices within five years. Demonstration plots should be used to show the farmer the benefits of adopting appropriate technologies as well as upgrading the Extension agent's capabilities.

5. Adequate complementary inputs such as credit, fertilizer and pesticides should be provided by the government or the private sector should be encouraged to increase its role.

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IV. ECONOMIC ANALYSIS OF DUBREUIL IRRIGATION PROJECT

A. Introduction

The purpose of this section is to analyze the economic soundness of the PDAI Dubreuil irrigation project. The project's costs and benefits are estimated over a twenty year period. The internal rate of return of the total Dubreuil system and the incremental rate of return for completing Phase II are estimated. These rates are sufficiently high under a variety of assumptions to confirm the economic soundness of the Dubreuil system. However, management and financial delays which slow project implementation significantly lower the estimated rates of return. Completion of Phase II is justified only if these financial and management delays are significantly reduced in the future. Futhermore, O&M and watershed protection activities are essential for the continued operation of the project. If these preventative maintenance activities are not carried forth at the required levels, the expected project life is significantly reduced, as is the project's internal rate of return.

The economic analysis of the Dubreuil irrigation system focuses on the project's goal of improving incomes of farmers at the project site. The institution building aspects of the project are discussed in other sections.

The Dubreuil diversion dam and main canal were largely rehabilitated by J.G. White Engineering in the late 1970's. While some rehabilitation work remained, the bulk of the PDAI Dubreuil project has been directed at increasing the number of hectares irrigated. The project is expected to increase total hectares irrigated from 300 to 925. Phase I will add an estimated 135 hectares, while completion of Phase II would add 490 hectares. Since irrigation of the original 300 hectares could continue without the PDAI project, the relevant costs and benefits are only those associated with the additional 625 hectares to be irrigated.

B. Benefits

The benefits attributable to irrigation are estimated on the basis of observed cultural practices and average yields in the Dubreuil Area during the two 1982 growing seasons. Costs utilized are those cash outlays that the farmers actually paid and include estimates of the value of labor. Selling prices are average prices received by farmers during the harvest periods in 1982.

Table IV-1 provides data on yields, costs, revenue and profits from eight selected crop combinations in the Dubreuil Project Area. The table summarizes the crop budgets presented in Tables A1 to A8 in the Appendix.

As mentioned in the section on yield increases, with improved technology and irrigation, crop responses are expected to be very dramatic. Improved technology includes the use of high-yield seeds, fertilizers, insecticides,

proper weeding, and timely irrigation. Yield increases of approximately 350 to 400 percent are expected in the modern technology irrigated farms as compared to the low technology non-irrigated farms. The increase in profitability of the various crops under improved technology and irrigation is especially dramatic. While the yields and thus the revenues increased 3 1/2 to 4 fold, the costs of production only approximately doubled as the farmers moved from low technology non-irrigated farming to high technology irrigated farming. The increases in profitability of the various crops, considered in table IV-1, with changes from low technology non-irrigated farming to modern technology irrigated farming, ranged from a low of 300 percent to 2300 percent. Red and black beans were the most responsive to high technology management levels.

The increase in net revenue of beans ranged from $31/ha in the case of dry-land low technology to $713/ha with irrigation and modern technology. The combination of sweetpotato, cassava and beans had a net revenue increase smaller than the increase in yields. The net revenue of these crops increased by three times the amount obtained under dry-land conditions from $467/ha to $1428/ha.

Table IV-2 shows the net revenue columns from Table IV-1. These are from eight selected crop combinations under three different conditions; 1) Traditional technology, without irrigation; 2) Traditional technology with irrigation and 3) modern technology with irrigation.

Traditional technology without irrigation refers to traditional agricultural practices observed in the Dubreuil area for farmers that have no irrigation water and do not utilize modern technologies such as improved seed, herbicides, insecticides, fertilizers etc.

Traditional technology with irrigation estimates the yields that would be expected with only the addition of irrigation water to traditional practices. The yields were estimated to increase approximately 25 percent above that produced without irrigation.

Modern technology with irrigation refers to observed practices in the Dubreuil area on farms that have had reliable irrigation water for several years. On these lands the farmers were utilizing improved seed varieties, insecticides, fertilizers, non-random planting schemes and high weeding programs.

This table provides an overview of the net revenues of the eight crop combinations through a complete growing period. It must be noted that the crop combination including cassava occupies the land for a full year, while annual crops such as corn, beans, rice, tobacco and sorghum only occupy the land for half a year or less.

Table IV-1. COSTS AND RETURNS FROM EIGHT CROP COMBINATIONS IN DUBREUIL PROJECT (1982 prices)

Table	Crop	$price per kg	TRADITIONAL PRACTICES								MODERN PRACTICES			
			Without Irrigation				With Irrigation							
			Yields kg/ha	$Revenue per/ha	Cost of Prod.	$Profit per ha	Yields kg/ha	$Revenue per ha	Cost of Prod.	$profit per ha	Yields kg/ha	$Revenue per ha	Cost of Prod.	$profit per ha
Short Season														
A.	Maiz	.20	1100	220	152	68	1375	275	172	103	4000	800	307	493
B.	Beans	.70	340	238	207	31	654	458	230	228	1200	1050	337	713
C.	Rice (paddy)	.38	-	-	-	-	1200	456	401	55	4000	1520	713	807
D.	Sorghum	.28	750	210	100	110	940	263	120	143	3000	840	351	489
E.	Tobacco	2.64	-	-	-	-	-	-	-	-	1200	3168	1830	1338
F.	(Maiz | .20 | 1300 | 260)	400	193	207	1625	325)	500	215	285	4200	840) 1400	403	997
	(Beans | .70 | 200 | 140)				250	175)				800	560)		
Full Year														
G.	(Sweetpotato | .18 | 2200 | 396)	786	319	467	2750	495)	983	340	643	5300	954) 2019	591	1428
	(Cassava | .09 | 2000 | 180)				2500	225)				6000	540)		
	(Beans | .70 | 300 | 210)				375	263)				750	525)		
H.	(Sweetpotato | .18 | 540 | 97)	378	273	105	675	122)	472	300	172	4300	774) 1684	52	1132
	(Maiz | .20 | 485 | 97)				610	122)				1000	200)		
	(Cassava | .09 | 595 | 54)				745	67)				4000	360)		
	(Beans | .70 | 185 | 130)				230	161)				500	350)		

In the case of no irrigation with low technology, the sweetpotato - cassava - beans combination is the best with an annual net revenue of $467 per hectare. The corn and beans association is the most profitable crop combination grown for one cropping season (one half year). The net revenue for this combination was $207/ha. These earnings could reasonably be expected for both the fall and spring cropping periods, given similar selling prices. Sorghum was the next most profitable crop with a net revenue expectation of $110/ha. This return is expected only once a year as the varieties grown under traditional practices are highly photoperiod sensitive, thus maturing late in the year regardless of planting date.

When irrigation is provided and traditional farming practices are used, the roots, tubers and beans combination still provide the maximum net revenue if beans are planted at the beginning of the season. The annual net revenue is $643/ha. The beans and corn association is the next most profitable crop combination with a two-crop net revenue of $570/ha. Rice ranked third with $510/ha expected for two crops.

The most dramatic changes occur when efficient use of irrigation is coupled with more modern high-level technology such as improved seed varieties, proper land preparation, efficient use of insecticides and cultivation and weeding practices, increased usage of fertilizer, proper harvest timing and proper post harvest handling of the crops.

The tobacco crop proved most profitable under these conditions. The growing of tobacco, which is highly technical and probably not recommended for all farmers, provided a two crop profit of $2676/ha. The director of the National Cigaret Company "Comme Il Faut" indicated that the spring crop was much riskier than the fall crop. The potential net revenue was much greater with two crops of tobacco but growing the crop in the fall may fit the Haitian farmer's normal risk aversion. Beans in association with corn was the second most profitable crop, when two cropping seasons were considered. A net revenue of $1994/ha could be obtained over one year. Rice ranked third in profitability with a two crop potential of $1614/ha. Even though quite profitable, the area planted to rice will probably not increase appreciably due to the soil requirements for proper management of irrigation water. Beans, grown in monoculture, was the fourth most profitable crop with a two crop expected net revenue of $1426/ha. These data indicate that the farmer will receive a considerable benefit by having the proper amount of moisture available for plant use at the time it is required.

The yield values for maiz and beans grown in association were aggregated with those yields of the two crops grown in monoculture and placed in Tables IV-3, IV-4 and IV-5, along with six other crop categories. These three tables provide an estimate of the relative contribution of the various agricultural crops to the total net revenue accruing to the farmer under three different farming practices. The practices considered were non-irrigated land with low level technology, irrigated land with low level technology and irrigated land with modern level technology.

Table IV-2. Net Revenues of Eight Crop Combinations under Three Different Technologies (1982 Prices) Dubreuil Area

Table	Crop	NO IRRIGATION Traditional Practice $ profit/ha	IRRIGATION Traditional $ profit/ha	IRRIGATION Modern $ profit/ha
A.	Maiz	68	103	493
B.	Beans	31	228	713
C.	Rice	--	255	807
D.	Sorghum	110	143	489
E.	Tobacco	--	--	1338
F.	(Maiz ((Beans	207	285	997
G.	(Sweetpotato (Cassava (Beans	467	643	1428*
H.	(Sweetpotato (Maiz ((Cassava (Beans	105	172	1132*

* Full year cropping period

Table IV-3 evaluates the relative contribution of the various crops on non-irrigated lands with low level technology. Average net revenue of the various crops were multiplied by the land distribution factor observed with non-irrigated lands in the Dubreuil area. Twenty-six percent of the land would be in corn, sixteen in beans, twenty-two in sorghum and fifteen percent in sweetpotatoes and cassava. The remainder of the land would be in sugarcane and other crops. The average return per hectare was highly influenced by the tuberous crops of sweetpotatoes and cassava with a contribution to total net revenue of $70/ha or 38 percent of the total. Corn and beans combined provided $63/ha or 34 percent of net revenue. Sorghum provided $24/ha or 13 percent. The average net revenue per hectare of land under no irrigation and low technology was $186.

When irrigation is added to otherwise low level technology the average net revenues increased to $374 per hectare. Table IV-4 portrays a slight shift in the relative land areas occupied by the various crops. The major shift occurs in beans whose hectarage increased from 16 percent to 25 percent. There was a two percent fall in sorghum hectarages and a six percent decline in sugar cane hectarages.

The maiz and bean crops provided $216/hectare or 58 percent of the net revenue while sweetpotatoes and cassava were still important with $103/hectare or 28 percent of the net revenue.

As the farmers move to high technology with irrigation, the net revenue attributed to maiz and beans rises to $612 per hectare, which is 50 percent of the total net revenue (Table IV-5). Tobacco provides $268 per hectare, which is 22 percent of the net revenue. The root and tuber crops of sweetpotato and cassava still contribute 19 percent of the net revenue generating $228/ha.

The average returns per hectare were adjusted for land used for fallow or pasture. Fallow and pasture uses are estimated to represent approximately 30%, 20% and 10% under traditional non-irrigated, traditional irrigated, and modern irrigated conditions, respectively. The adjusted average net returns per year per hectare are $130 for traditional non-irrigated conditions, $341 for traditional irrigated conditions, and $1103 under modern irrigated conditions.

To obtain the net benefits per hectare attributable to irrigation, the net revenue under non-irrigated conditions is subtracted from the net revenue with irrigation. The benefits resulting from irrigation are thus estimated to be $211 under traditional conditions and $973 under average modern conditions.

The full transition from traditional dry land farming to irrigated average modern conditions is projected to take five years. Given the prevalence of modern technology irrigated farming and the availability of complementary inputs (seeds, fertilizer, extension, etc) in the Les Cayes and Dubreuil area, this rate of response is reasonable. The resulting irrigation benefits per hectare are as follows:

First Year	$ 440
Second year	630
Third year	783
Fourth year	897
Fifth and following years	973

The total benefits over time attributable to the PDAI Dubreuil project, which will irrigate an additional 135 hectare in Phase I and 490 hectares in Phase II are as follows:

Year	Phase I	Phase II
1st	$ 59,400	$214,600
2nd	85,100	308,700
3rd	105,700	383,700
4th	121,100	439,500
5th and beyond	131,400	476,800

Other benefits that might be attributed to irrigation include increased animal production and health benefits. In the case of Dubreuil, the increased animal forage per hectare that results from irrigation is projected to be offset by a shift to cash crops with less animal feed by-products and a reduction in the land devoted to pastures. Hence, no overall increase is projected for livestock related earnings. Health benefits are expected to result from increased availability of water. However, because the existing main canal and secondary system already provide a rudimentary system of distribution, the benefits at Dubreuil are expected to be minimal compared to the crop related benefit.

C. Costs

Estimates of the direct construction costs of the project were provided by the Sheladia technical assistance team. Engineering, operation and maintenance, administrative and vehicle costs were developed jointly by Sheladia and the evaluation team. The unit costs used are estimates of the inputs' economic cost, or the value to the economy of the inputs in their best alternative use. These economic or shadow prices may vary from observed or administratively determined prices. Timing, quantity, and total costs estimates shown in table IV-6 are based upon project implementation proceeding at a normal rate. Given reasonable performance, Phase I should have taken one year, and Phase II should be completed in two years. These estimates vary considerably from what actually occurred during Phase I. Financial and managerial problems have been largely responsible for Phase I taking approximately two years to complete. The effects of project delays on costs and benefits will be addressed in the cost-benefit analysis.

Table IV-3

Traditional Non-Irrigated Farming in Dubreuil
$ Returns per hectare

Crop	$ Return/ha	$ Return full year or 2 (crop)	% Land Distribution	$ Average return/ha farmed/yr
Maiz	73**	146	26	38
Beans	78**	156	16	25
Rice	--		0	--
Sorghum	110	110	22	24
Tobacco	-		0	
(Sweetpotato ((Cassava	467	467	15	70
*Sugarcane	200	200	8	16
*Others	100	100	13	13
				$186

* estimated

**includes adjustment for yields obtained from maiz and beans grown in association.

Table IV-4

Traditional Irrigated Farming in Dubreuil
$ Returns per hectare

Crop	$ Return/ha	$ Return full year or 2 (crop)	% Land Distribution	$ Average return/ha farmed/yr
Maiz	197**	384	26	102
Beans	228**	456	25	114
Rice	255	510	2	10
Sorghum	143	143	20	29
Tobacco	-		0	
(Sweetpotato ((Cassava	643	643	16	103
*Sugarcane	250	250	2	5
*Others	125	125	9	11
				$374

* estimated

**includes adjustment for yields obtained from maiz and beans grown in association.

Table IV-5

Modern Irrigated Farming in Dubreuil
$ Returns per hectare

Crop	$ Return/ha	$ Profit full year or 2 (crop)	% Land Distribution	$ Average return/ha farmed/yr
Maiz	493**	986	26	256
Beans	713**	1426	25	356
Rice	807	1614	2	32
Sorghum	489	489	10	49
Tobacco	1338	2676	10	268
(Sweetpotato ((Cassava	1428	1428	16	228
*Sugarcane	500	500	2	10
*Others	300	300	9	27
				$1226

* estimated

**includes adjustment for yields obtained from maiz and beans grown in association.

Project Costs, as displayed in Table IV-6, include the following items:

- Topographic survey contracts for 1070 hectares.

- Common works consist of repairs and upgrading of the diversion dam and main canal. The operation and maintenance (O&M) figures are for labor and materials. Normal O&M after project completion is estimated to be $5 per hectare. The "National Disaster Repair Fund" is an allowance for major repairs due to flood damage or other factors. This is estimated to cost $20 per hectare per year. This would allow for major system repairs, ie $200,000 every ten years on average for a system like Dubreuil.

- Construction costs for Phase I and II include materials and labor.

- Engineering costs include four senior engineering positions with a total of 90 person months over the three-year construction period. There are two alternative ways these could be charged to the project. The senior positions are first costed at the rate of $1500 per month, or the rate at which competent senior Haitian engineers could be obtained if the specific skills were available. However, the technical consultants (TA) have in fact been serving as the senior engineers on the project. Using TA instead of Haitian senior engineers costs an additional $8500 per month, or $765,000 over the life of the project. The extra cost of using TA instead of local senior engineers is accounted for with the TA adjustment item (bottom of table IV-6). If the TA is not necessary for project completion and it is producing significant institutional building, the additional cost of TA should not be charged to the Dubreuil project. However, if the TA is required to complete the project and it is not in fact producing any significant institutional building then all TA costs should be fully charged to the project. The true situation in the case of Dubreuil lies between these two extreme alternatives and is probably relatively close to the full TA cost alternative. However, Haitian engineers, through PDAI sponsored education and on-the-job training (institution building) should increasingly be able to assume the senior engineering responsibilities. Hence, the no TA alternative should become more relevant during project implementation. The cost-benefit analysis explores both interpretations.

- O&M personnel costs associated with the added irrigation hectarage are charged to the cost of the project. These represent approximately two-thirds of total O&M personnel costs.

- Total Phase I & II cost, without TA, is estimated to be $1.4 million dollars. Total cost with the TA is $2.2 million.

- Costs which only occur as the field work at Dubreuil is implemented include the topographic surveys, common works, and Phase I and II direct construction costs. These variable costs are over $1 million for the completed project.

- The remaining cost items, including engineering, administration, vehicles, and O&M personnel, generally continue regardless of the pace of field construction. For example, TA costs continue month by month, even if construction temporarily halts. These costs therefore are fixed costs. Total fixed costs for the Dubreuil project, assuming a three year implementation period, are approximately $1.2 million. If the actual construction period were longer, these costs would increase proportionately.

- The long-run operation and maintenance cost associated with the added irrigated land is $36,900 per year, or $59 per hectare per year (last column).

D. Cost-Benefit Analysis

To determine whether the PDAI Dubreuil project is a sound economic investment, project related costs and benefits must be compared over time. Phase I is assumed to be completed in the first year, Phase II costs occur in years two and three, and O&M costs continue thereafter. Phase I agricultural benefits are assumed to begin in the second year. Phase II benefits start the year after completion of Phase II. Benefits increase during a five year transition as farmers shift toward modern irrigated farming methods and continue thereafter at the rate of $973 per hectare.

Project net benefits, or benefits less costs over twenty years are displayed in Table IV-7. The first column (NB) presents net benefits of Phase I & II without charging for TA. The second column (NBTA) shows net benefits of Phase I & II with all TA costs charged to the project. The net present value of the project, after accounting for the cost of capital at the rate of 10 percent, is $2.2 million without TA and $1.5 million with TA. In other words, between $1.5 and $2.2 million in benefits will be generated over the life of the project after all economic costs are accounted for, including the opportunity cost of capital. The internal rate of return is estimated to be 27 percent without charging for TA and 19 percent with the TA.

These high internal rates of return are based upon a twenty year life of the project. If the estimated O&M budget of $59 per hectare per year were actually expended, a twenty year expected life appears reasonable, if not conservative. However, if O&M were to be neglected, a ten year expected life would be more likely. And with the continuing deforestation of the Acul Watershed, a ten year life would be even more probable. A ten year project lowers the internal rate of return to 21 percent without TA and 10 percent with TA. Even though these rates are significantly lower than those obtained when a twenty year life is assumed, they are equal to or greater than the estimated opportunity cost of capital (10 percent). The Dubreuil project becomes a marginal but economically sound investment even if poor O&M and/or flooding destroy the project in ten years. Proper attention to watershed protection and O&M is essential if the project is to be the highly profitable investment it has the potential of being.

Table IV-6: Dubreuil Irrigation Project Costs

Item	Cost/ Month	Phase I Year 1		Phase II Year 2		Phase II Year 3		Construction Period Total		Post Construction Period O &M	
		Unit Months	Cost	Unit Months	Cost	Unit Months	Costs	Unit Months	Cost	Unit Months	Cost
Topographic Surveys			$30,000		$77,000				$107,000		
Common Works											
Wall			70,700						70,700		
Gates			7,000		12,200				19,200		
Drainage			20,000		20,800		20,800		61,600		
O&M			5,000		5,000		4,000		14,000		3,100
National Disaster Repair Fund											12,500
Construction Phase I & II			153,200		200,000		396,200		749,400		
Engineering											
Survey Crew	250	30	7,500	40	10,000			70	17,500		
Design Engineers											
Senior	1500	6	9,000	12	18,000			18	27,000		
Junior	600	12	7,200	24	14,400			36	21,600		
Drafting etc	300	6	1,800	12	3,600			18	5,400		
Construction Eng.											
Senior	1500	12	18,000	12	18,000	12	18,000	36	54,000		
Associate	800	12	9,600	12	9,600	12	9,600	36	28,800		
Junior	600	12	7,200	12	7,200	12	7,200	36	21,600		
O&M/Water Application											
Senior	1500	6	9,000	12	1,800	12	1,800	30	45,000		
Junior	600	6	4,800	12	9,600	12	9,600	30	24,000	12	9,600
Senior Hydrologist	1500	6	18,000					6	18,000		
Administration	800	24	19,200	24	19,200	24	19,200		57,600		2,000
Clerical	300	12	3,600	12	3,600	12	3,600		10,800		
Office, Depot, Supplies etc	500		6,000		6,000		6,000		18,000		2,000
Vehicles											
2 Pick-ups	400	24	9,600	24	9,600	24	9,600	72	28,800	12	4,800
2 CJ-7s	400	24	9,600	24	9,600	24	9,600	72	28,800		
O&M Personnel (2/3)											
Water Master	300	2	600	2	600	2	600	6	1,800	2	600
Gate tender	50	8	400	8	400	8	400	24	1,200	8	400
Ditch Riders	80	16	1,300	16	1,300	24	1,900	56	4,500	24	1,900
TOTAL, No TA			428,300		473,700		534,300		1,436,300		36,900
TA Adjustment	8500	30	255,000	36	206,000	24	204,000	90	765,000		
TOTAL Cost, Full TA			683,000		779,700		738,300		2,201,300		

Table IV-7. Cost-Benefit Analysis of the PDAI Dubreuil Project

Year	(1) NB	(2) NBTA	(3) 1/2NB	(4) 1/2/NBTA	(5) MNB	(6) MNBTA	(7) 1/2MNB	(8) 1/2MNBTA	(9) MNBTAD	(10) 1/2MNBTAD	
1	-428300	-683300	-428300	-683300	-473700	-779700	-473700	-779700	-621500	-621500	-1000000
2	-414300	-720300	-444000	-750000	-534300	-738300	-534300	-738300	-621500	-621500	100000
3	-449200	-653200	-491700	-695700	186700	186700	78900	78900	-527800	-527800	100000
4	284400	284402	123800	123800	279800	279800	125500	125500	-527800	-527800	100000
5	392900	392900	178000	178000	354200	354800	163300	163300	186700	78900	100000
6	478200	478200	220700	178000	410600	410600	190900	190900	279800	125500	100000
7	534000	534000	248600	248600	447900	447900	209500	209500	354800	163300	100000
8	571300	571300	267200	267200	447900	447900	209500	209500	410600	190900	100000
9	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
10	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
11	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
12	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
13	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
14	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
15	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
16	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
17	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
18	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
19	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
20	571300	571300	267200	267200	447900	447900	209500	209500	447900	209500	100000
20 Year Project											
NPV 1%	6863064.	6105115.	2439717.	1641139.	5725187.	5217207.	2127062.	1619082.	3598293.	459889.913	722600.8
NPV 10%	2194926.	1493151.	325035.7	-403254.	1951126.	1459671.	388420.3	-103034.	259071.1	-964769.42	-163508.
NPV 15%	1131006.	455667.3	-140853.	-837423.	1068593.	585201.4	-11599.4	-494991.	-441723.	-1231270.5	-380177.
NPV 20%	506804.7	-144861.	-404718.	-1073545	538644.9	62644.94	-247882.	-723882.	-820594.	-1355383.0	-515650.
NPV 25%	122116.4	-508243.	-559629.	-1203981	202728.9	-266471.	-394427.	-863627.	-1029545	-1406777.1	-605765.
NPV 30%	-124845.	-735939.	-652735.	-1275330	-20163.6	-483087.	-488995.	-951918.	-1144731	-1419926.5	-668947.
IRR *	27.47238	18.79389	13.48834	8.224759	29.89822	20.95172	14.85501	9.461530	11.84841	3.90526242	8.339288
10 Year Project											
NPV 1%	1915611.	1157662.	125767.5	-672811.	1846378.	1338397.	312794.2	-195186.	-280517.	-1354378.2	-143398.
NPV 10%	706177.4	4402.050	-371260.	-1099550	783945.0	292490.4	-157515.	-648970.	-908110.	-1510704.7	-424098.
NPV 15%	315962.6	-359376.	-522053.	-1218623	429597.4	-53793.9	-310482.	-793873.	-1080718	-1530153.1	-522842.
NPV 20%	42606.73	-609059.	-621826.	-1290653	174713.1	-301287.	-418106.	-894106.	-1184516	-1525607.8	-596903.
NPV 25%	-151665.	-782024.	-687678.	-1332030	-11915.9	-481116.	-494825.	-964025.	-1244189	-1507174.7	-653687.
NPV 30%	-291397.	-902490.	-730633.	-1353228	-150740.	-613663.	-550071.	-1012994	-1275308	-1481002.3	-698100.
IRR *	21.09658	10.06050	3.277355	-2.41651	24.68076	14.22327	6.985738	-1.08098	-1.12401	-3.2544681	-1.27417

NB = Net Benefits of Phase I & II, no TA.
NBTA = Net Benefits of Phase I & II, with TA.
1/2NB = 1/2 Net Benefits of Phase I & II, no TA.
1/2NBTA = 1/2 Net Benefits of Phase I & II, with TA.
MNB = Incremental Net Benefits, Phase II, no TA.
MNBTA = Incremental Net Benefits, Phase II, with TA.
1/2MNB = 1/2 Incremental Net Benefits, Phase II, no TA.
1/2MNBTA = 1/2 Incremental Net Benefits, Phase II, with TA.
MNBTAD = Incremental Net Benefits, Phase II delayed, with TA.
1/2MNBTAD = 1/2 Incremental Net Benefits, Phase II delayed, with TA.

* Negative IRRs are not precise estimates due to IRR formula modifications.

The foregoing analysis assumed what is judged to be the most probable benefit stream. However, reduced availabilities of modern irrigation inputs and/or crop price declines could significantly reduce project benefits. Columns 3 and 4 of Table IV-7 test the impact of a 50 percent reduction of benefits of the full Dubreuil project. The twenty year estimated returns are 13 percent without TA and 8 percent with TA. The true rate, of course, lies between these, and is probably in excess of 10 percent. Hence, even if the project benefits were overestimated by 50 percent, the project remains economically viable. This supports the view that the project is economically sound. It also suggests the importance of the availability of complementary inputs such as high yielding seeds, fertilizer, insecticides, extension services, and credit.

The critical importance of proper O&M and watershed protection becomes even more clear when the reduced benefit analysis allows for only a 10 year life-of-project. The internal rate of return falls to 3 percent without TA and is even negative with TA. Proper O&M and watershed protection must be emphasized if an irrigation investment such as Dubreuil is to remain a sound investment.

The preceeding analysis is repeated to determine the incremental rate of return of completing Phase II, assuming all Phase I investments have already been made (Table IV-7, columns 5-8). This analysis basically answers whether it is economically sound to begin implementation of Phase II now that Phase I is nearing completion. As expected, the IRR's are even higher for Phase II and strongly support its completion. The analysis also reveals that proper attention to O&M and watershed protection is essential.

Past project implementation delays have almost doubled the time required to complete Phase I. Fixed costs associated with engineering, administration, vehicles, etc., which amount to approximately $400,000 per year, continue whether construction occurs or not. The impact of continued delays as Phase II is implemented is significant (See Table IV-7, columns 9 and 10). The low internal rates of return that result suggest that Phase II should be implemented only if delays can be substantially reduced in the future. The analysis assumes that Phase II takes four years to complete instead of the two year norm. This increases Phase II costs from $1.5 million to $2.3 million. Benefits from Phase II irrigation are also postponed for two years. With major project delays, administrative and engineering personnel are underemployed and often demoralized. Little or no constructive institution building can take place in this environment. Hence, most or all TA should be charged to the delayed project. The only case where the IRR is above the opportunity cost of capital is when the project lasts twenty years and all benefits are realized. Reduced benefits and/or reduced project life make the delayed project uneconomic.

E. Recommendations

1. Phase II of Dubreuil should be completed if a normal rate of implementation appears probable. If on the other hand, substantial delays are envisioned, the project becomes uneconomic and should not be completed.

2. Major emphasis at Dubreuil should be placed on O&M activities. Proper maintenance of the system will greatly affect the economic viability of the project.

3. Reforestation and other watershed protection investments in the Acul watershed should receive high priority. This would not only extend the expected life of the project, but would increase the availability of river flow for irrigation in the dry seasons.

V. OTHER PDAI IRRIGATION SYSTEMS

In addition to the Dubreuil project, other sites were visited by the team where there are on-going or anticipated PDAI activities. The engineering, agronomic and economic aspects of these are discussed in this section.

A. Marigot

The Marigot project is located on the southern shore of the southern peninsula of Haiti. As originally described by the J.G. White Co. (8), the rehabilitation of the Marigot - Peredo irrigation system would have supplied irigation water from the Plantils river to 500 ha by rehabiliation of structures that were damaged or destroyed by a series of floods and Hurricane Inez. This had been given a top priority rating for further study by White and was considered as one of the areas for the PDAI project. However, USAID decided on grounds which are not clear, that this was not acceptable. It agreed only to a modified proposal to upgrade five smaller systems using water from the same river or its tributaries. This would involve delivering water to about 250 ha for irrigation. Topographic surveys have been completed on the first of these, Belle Roche. Early determination, based on technical considerations, should be made on which of these two schemes, the one larger system or five small ones, is more feasible and proceed on that basis.

Equipment for a gaging station has been purchased to monitor the stream flow in the Plantils River. This will help determine if there is sufficient water to develop additional irrigated areas. The stream appears to have sufficient flow for irrigating a much larger area than that contemplated under either of these two schemes.

The direct construction costs for the larger rehabilitation project of Marigot-Peredo are estimated by the TA to be $1 million. Total costs, including the full cost of TA, would be approximately $2.2 million. This system would irrigate approximately 400 additional hectares. If the five smaller systems were selected, direction construction costs would run approximately $250,000. Total costs would be approximately $550,000. A total of about 250 hectares would be irrigated, of which approximately 50 to 100 are presently irrigated.

There is high community interest in irrigation in Marigot. Some soil conservation and watershed management activities are going on in the area. Agricultural district personnel and community leaders appear to appreciate the inter-relationships between irrigation and watershed protection.

MAI values for Marigot range from 0.01 in January to 1.43 in October with a mean of 0.78 for the year as shown below (4).

Month	MAI value
December	0.02
January	.01
February	.24
March	.43
April	.28
May	.84
June	.38
July	.39
August	.70
September	.77
October	1.43
November	.59

Values below the "danger signal", i.e., 0.33, occur in four months of the year. Values below 0.50 occur in seven months. The December-April and the June-July seasons would be too risky for crop production if irrigation is not provided on a regular schedule. If it were not for irrigation, Marigot would not be an agricultural area of significance.

At Lilancourt, two soil profiles were examined. The soils are Inceptisols or probably Mollisols (Fluventic Hapludolls) derived from relatively recent calcareous alluvium. They are brown to dark brown in color. In texture, the soils are loams and silt loams with good granular structure. They are open, porous, permeable and well-drained. The soils appear to be fertile and suitable for a wide range of crops.

As they are, with irrigation the soils could be tilled and crops produced over most of the area. The possibility that a sizeable amount of water could be lost through infiltration can be ruled out. Among the most important soil properties influencing infiltration are bulk density, pore-size distribution, particle-size distribution and aggregate stability. The soils of the Marigot area probably have moderately slow infiltration. Field observations showed that there is a rather dense layer which limits infiltration immediately below the upper 30 or 45cm of soil and above the uppermost gravel layers characteristic of profiles near the river bank. Soil aggregates appear to be rather stable. The soils can retain sufficient water available for crops. The strong aggregate stability and the large number of macropores would favor rapid water release and availability.

Due to high plant demands and evaporation, the possibility of mulching could be considered. The effect of mulching on available soil-water (water retained at tensions ranging between 1/3 and 15 bar) has been studied elsewhere and can be summarized as follows (5).

Treatment	Available soil water, cm.
Clean cultivation	4.3
Plastic mulch	6.1
Grass mulch	8.1

Corn, cassava, peanuts and sweetpotatoes are the major crops of the Marigot area. Beans, bananas and plantains are also grown. Crops that offer good possibilities are Irish potatoes and vegetables. It appears, however, that plantains may be the best for sale at the Port-au-Prince and Jacmel markets.

It is estimated that agricultural revenue increases attributable to irrigation in the Marigot area would be roughly comparable to that found at Dubreuil, i.e. $973/ha/year (after the initial five year transition period). In the case of the larger Marigot rehabilitation project, this revenue increase could be obtained for a total cost (including TA) of approximately $2,800 per additional hectares irrigated. In other words, for each $1,000 invested in the larger Marigot system, approximately $350 per year would be generated. This compares favorably with the comparable figures for Dubreuil: $3,500 total cost per additional hectare irrigated and $280 annual revenue per $1000 invested.

In comparison, the smaller Marigot system is estimated to cost $3,700 per additional hectare irrigated and yield an annual revenue increase per $1,000 invested of $270. While the larger system appears to be the better investment, detailed engineering costs estimates should be made before deciding on which alternative should actually be constructed.

B. Jean Rabel

The Jean Rabel system, is located on the Jean-Rabel River on the north coast of the northwest peninsula of Haiti. It consists of small diversions with no permanent structures at about 18 different locations along the river to irrigate approximately 250 ha, some of which are scattered small parcels on quite steep slopes. All maintenance is currently done by the farmers. A feasibility report by J. G. White (6) proposed a diversion dam at the uppermost canal (Nan Solon) to serve the upper area and eight smaller diversions farther downstream to serve the lower areas. During a field visit to the project site, a partially constructed diversion dam was observed, which was started about 1979 but never completed. Because of the very limited amount of additional land that can be served from a dam at this location compared to a site farther dowstream and the very steep, unstable hillside which the canal would have to traverse, the site is a poor choice.

It appears much more feasible from the standpoint of both construction and maintenance to build the dam farther dowstream. The proposed system would irrigate approximately 100 ha of additional land for a total of about 350 ha of land and, in addition to the diversion dam, would involve canal lining, grade and water control structures, chutes and drops. The direct construction costs are estimated to be $400,000, while the total cost, including TA, would be approximately $880,000.

The MAI for Jean Rabel as given by Hargreaves and Samani (3) is less than 0.2 for the period January through September and 0.4 or less for the remaining three months of the year. Based on these values, the need for irrigation in this area is obvious; there is essentially no production without irrigation.

The predominate crops grown in the Jean Rabel area are sweetpotatoes, sorghum, corn and plantain. All are planted under dry land conditions. With the low MAI values the probability of a crop failure is quite high and low yields prevail. With adequate, timely irrigation water, plantain is the predominate crop grown.

A study was recently conducted in Puerto Rico comparing a group of plantain growers using more intensively all the modern technologies with another group who followed traditional practices. Results show that the innovators obtained an average yield of 86,000 fruits/ha, produced 5400 "seeds"/ha and had a net profit of more than $5200/ha while traditional farmers produced 58,000 fruits/ha, 1700 "seeds"/ha and obtained a net profit of only $2100/ha (2). With irrigation and improved technology, roughly similar results might be expected in Jean-Rabel.

It is conservatively estimated that agricultural net revenue increases attributable to irrigation at Jean Rabel would be approximately 150 percent of that estimated for Dubreuil, or approximately $1,500/ha/year. With a total cost per hectare estimate of $3,900, annual net revenue per $1,000 invested would be $320. The Jean Rabel project is clearly a sound economic investment.

Other than its remoteness and lack of access during storm periods, it has the potential of a very good irrigation project. The Irrigation Service at Damien, in cooperation with the TA, should update the feasibility report using current costs and changing the diversion site. The system seems to have been properly chosen as one of the sites for rehabilitation under the PDAI project. If the updated study shows it to still be feasible, topographic surveys should be done immediately for design and construction should begun as soon as possible after that.

C. Thomazeau (Mannville - Duthill)

This project, located in the Cul-de-Sac plain near Port-au-Prince, was not mentioned in the early PDAI documents, but was studied by the Irrigation Service and Sheladia in 1981. It was included in the pre-feasibility studies by J. G. White (6) and given a high priority for rehabilitation. For apparently non-technical reasons on the part of USAID, work was discontinued on this project, even though it appears to offer some real potential.

The principal water sources are the Mannville spring at the lower end of the area, and the Duthill springs at a higher elevation. Pumping is required to deliver the water from Mannville spring to the proposed irrigated area. A diesel powered pumping plant is in place and functional to lift the water through a 24" diameter welded steel pipe line to a masonry lined canal along the hillside. The water from the Duthill springs reaches the irrigated area by gravity through two canals that are lined for a part of their length. Total flow of the springs is estimated to be 320 lps which could likely be increased by cleaning and collecting the surface seeps, especially in the case of the Duthill spring. With some additional canal lining, water control

structures and water management techniques, it may be possible to increase the irrigated area by 120-150 ha. The direct construction cost of this is estimated by Sheladia to be $240,000. Total cost, included TA, would be approximately $528,000.

The Thomazeau area has one of the driest climates in Haiti. MAI values range from 0 in December, January and February to 0.61 in October as shown below (4):

Month	MAI value *
November	0.08
December	.00
January	.00
February	.00
March	.03
April	.24
May	.57
June	.17
July	.09
August	.30
September	.52
October	.61

The mean annual MAI value is 0.41. In nine months of the year, MAI values are below the 0.33 value considered as a danger signal (4). In only three months of the year, mean MAI values are slightly above the 0.50 value where the use of fertilizer may not be economical. Virtually no production is possible without irrigation.

Some of the soils are brownish, loose and loamy, but most are dark, heavy and clayey. The clayey soils are plastic and moderately sticky. Fertility is high and physical conditions appear good for rooting, although at many places imperfect drainage is evident. Soil pH values are betwen 7 and 8. In general, the soils are deep. The main crops currently grown are rice, sugarcane, plantains, sorghum, sweetpotatoes, beans, eggplants, okra, tomatoes and shallot. Corn and cassava are also grown in small areas. Two crops of vegetables are produced/year; the second crop is planted following the harvest of corn, sorghum and rice.

Rice is planted in March and harvested in June. A second crop of rice is usually planted in August and harvested in November. Eggplants are planted in October and November and harvest begins 100 days afterwards and continued at 15-day intervals; usually 5 or 8 pickings are necessary. The crop occupies the land for a period of about 6 months. Under optimum conditions, 20 t/ha may be obtained. During the field visit, some plantings were observed, suffering from restricted soil drainage.

Shallot, botanically related to the onion, is a highly valued cash crop. It is planted in March and in August-September and usually the harvesting period extends from 2 to 3 months. The March plantings command better prices at Port-au-Prince. Returns from one hectare of shallot are reported to be as high as $2000/crop.

The marketing process is competitive, i.e., each farmer sells his/her own produce individually to the middleman. Farmers organizations are strong in Thomazeau and irrigation involves cooperative efforts. Cooperative marketing efforts may be worth exploration.

Thomazeau offers a vast potential for increased vegetable crop production. It is relatively near to the large Port-au-Prince market, irrigation water is available in reasonable quantities and if the soils are tilled properly, large yields can be obtained. The dry climate coupled with irrigation, is ideal for the production of high valued crops.

Vegetable crops often require a systematic protection scheme through the use of pesticides at appropriate intervals. Crop rotation is advisable since planting the same crop on the same plots tend to increase the danger from pests. The more disimilar the botanic relationship between crops in a rotation, the more effective this practice is likely to be.

Aside from climatic and edaphic factors, the frequency of irrigation will depend on several factors such as the depth and distribution of the root system, age of the plant, rate of plant growth, population density and others. The following tabulation shows the typical rooting depth of various vegetable crops when there are no conditions impending root penetration (1).

<u>Shallow rooted</u> (45 - 60 cm)

Onions
Corn
Cabbage

<u>Moderately deep rooted</u> (90 - 120 cm)

Eggplants
Beans
Melons
Cucumbers
Peppers

<u>Deep rooted</u> (more than 120 cm)

Squash
Tomatoes
Watermelon

Wahab et al (7) have shown that on granular, permeable tropical soils, under irrigation, 75% of the total roots of corn, are confined to the upper 50cm depth whereas in heavier soils about 75% of the roots are found in the upper 12 cm. Maximum rooting depth is as follows:

Soil	Rooting depth, cm
Granular, permeable	90 to 95
Heavy	25 to 30

To provide protection to some of the more delicate vegetable crops, wind breaks are advisable. Quick growing plant species such as corn, sorghum, pigeonpea, sunflower and okra could be used as temporary windbreaks. The West Indian cherry (Malphigia punicifolia) would make a suitable permanent, low windbreak. In addition, it will provide abundant cherries which are unusually high in vitamin C content.

Essential elements in vegetable crop production are the removal of weeds and adequate fertilization. Some vegetable crops, like cabbage, remove as much as 100 kg/ha of nitrogen[pepper, only 24.

Yields of the main crops can be increased with adequate irrigation and appropriate technology to the levels indicated below:

Crop and cycle (days)	Expected yield, kg/ha
Rice, 120-140	4000-6000
Sugarcane, 360	60000-80000
Sorghum, 100	3000
Sweetpotatoes, 135-150	6000-8000
Beans, 80	1500
Eggplants, 100	10000
Onions, 120-130	10000
Snap beans, 43	6000-8000
Melons, 65-90	10000
Cabbage, 80-110	10000
Watermelon, 150-165	8000
Tomatoes, 90-100	8000

Okra is grown in Thomazeau and in many other parts of Haiti. It is used as a vegetable, but it offers a vast potential as a source of oil. The Texas A&M/Haiti team reports that okra seeds can produce more oil than many other oil crops. In a replicated trial, with a population density of 20 plants/m^2 and insect control with three sprays of Malathion, without fertilizer, yields of around 1250 Kg/ha of dry seed were obtained (6).

Agricultural net revenue increases attributable to irrigation at Thomazeau are estimated to be roughly 150 percent of that estimated for Dubreuil, or approximately $1,500/ha/year. With a total cost per hectare estimate of

$3,500, annual net revenue per $1,000 invested would be $420. Based on these rough cost and benefit estimates, Thomazeau appears to be one of the more sound projects considered by PDAI. Feasibility studies should be resumed.

D. Damien

This is a small system, fed by springs and pumping from groundwater, passing through the DARNDR compound. It is used by the FAMV for irrigation and livestock water on the research farm. Topographic surveys have been completed and the Irrigation Service is now working on the plans for relocating and improving the canal to serve approximately 80 ha. Some work has been done on cleaning the canal and inverted siphon. This project should receive top priority for completion. Because of its location, it should be relatively easy to complete and can then be used to conduct irrigation experiments. One of the important questions for an evaluation of irrigation in Haiti is, what the is crop response to water? Detailed scientific information on this issue does not exist. Interaction studies of the response of various crops to different levels of irrigation water and fertilizer should be initiated.

The direct construction cost of the needed rehabilitation work is estimated to be $60,000. Including TA, the total cost per hectare is only $1,700. The benefits of a properly functioning irrigation research and demonstration facility clearly merit this low level of expenditure.

E. Recommendation

Based on the detailed economic analysis of the Dubreuil system and the foregoing comparative analysis of the Marigot, Jean Rabel, Thomazeau, and Damien systems, it appears advisable to proceed with all of them eventually. Because of the availability of topographic and design information, emphasis should be placed on Marigot and Thomazeau, for which the most engineering time has already been spent. Marigot should be pushed to completion as rapidly as possible. Careful and detailed analysis of the comparative costs and benefits of the two alternative Marigot systems should be made before one is selected for construction. The Damien research farm system should also receive priority for early rehabilitation. Jean Rabel will need a reevaluation of the diversion structure location.

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VI. INSTITUTIONAL ANALYSIS

A. Introduction

The purpose of this section is to assess the institutional capability of the Ministry of Agriculture to implement a continuing program of irrigation rehabilitation and support services.

A number of observations made in the past about the institutional capacity of the Department of Agriculture, Natural Resources and Rural Development (DARNDR) still hold true today. The original PDAI Project Paper, for instance, described DARNDR as a complex organizational structure with administrative shortcomings in inventory control, recordkeeping, and acquisition and disposal of equipment and supplies. It said that most of the organization's power and authority are vested in the Director General's office, and described salary levels as being far too low to attract and hold qualified personnel on a full-time basis.

The Project Paper also noted that DARNDR has a number of highly dedicated, well-trained and conscientious technical personnel, but that the "system" precludes a high level of functional activity. This is because of organizational "norms" that have evolved, such as employees having a short work day and holding down one or two other jobs. "Salary increments would go a long way toward restructuring the norms of the system, providing the proper control mechanisms, such as insistence on a full 8-hour work day, were designed and enforced."

A study of DARNDR by Multinational Agribusiness Systems, Inc. (MASI) likewise observed that major institutional constraints of the Ministry of Agriculture stem primarily from a grossly inadequate budget.

Although the objective of the PDAI irrigation component is to strengthen the capacity of the Irrigation Service to develop and manage existing and potential water systems throughout Haiti, deep-seated institutional constraints obviously can not be expected to change in a matter of several years. The Project has contributed to a strengthening of the Irrigation Service, primarily through short- and long-term training that has been provided to Irrigation Service personnel and through the interaction of the Technical Assistance team with DARNDR employees. In general, Irrigation Service personnel at Damien and in the field appear to have the technical capability and motivation necessary to carry out their work.

Severe shortcomings do remain, however. Irrigation Service personnel are hampered by their few numbers, by low salaries that can not attract and retain experienced engineers, and by administrative and financial bottlenecks over which they have little control.

The Irrigation Service oversees an estimated 48,000 hectares of irrigated land involving some 70 systems, or an estimated two-thirds of the nation's irrigated land. It is under the direction of a junior engineer, who supervises five design engineers, two statisticians, and 10 surveyors and draftsmen. Overseeing the Irrigation Service is the Rural Engineering Office, which is headed by a senior engineer, assisted by three advisors -- in hydraulics, program and evaluation, and irrigation.

Each district office of irrigation is headed by an engineer who reports to DARNDR's central Irrigation Service on technical matters and to the district director of agriculture (district agronôme) on administrative matters.

This Institutional Analysis focuses on the capability of the Ministry of Agriculture to carry out a program of irrigation rehabilitation and support services. However, it must be recognized from the outset that this capability does not depend on DARNDR alone. It also depends on other institutions interacting with DARNDR, such as USAID and the Ministries of Plan and Finance. Consequently, this Institutional Analysis, while concentrating on the Ministry of Agriculture, will necessarily deal with broader institutional concerns outside DARNDR as well.

B. Analysis of Constraints

Three main institutional factors appear to be hampering smooth project implementation. They are: (1) lack of proper administrative and financial control over the project, (2) lack of Government of Haiti resources, and (3) lack of communication. These problems will be discussed individually, though it must be kept in mind that they are mutually reinforcing and there is great overlap among them.

1. Lack of Proper Administrative and Financial Control

The directorship of the PDAI project has shifted continually since the Project began. The original Project director was later superseded by the Director General. Then various supervisors, coordinators and counterparts were named at Damien, not to mention district-level coordinators and directors. In addition to these changes, frequent replacements at the Minister's level have not contributed to continuity in project administration. The lack of clear authority on important operational matters, combined with the centralized decision-making authority traditionally vested in the Director General, clearly have hurt the project. One Ministry of Plan official lamented to the team, "All kinds of people sign for all kinds of things. The personnel are in perpetual movement. We don't know from one year to another who will be in charge. Who is in charge of that project?"

An example of how lack of proper administratrive control has hampered the Project is illustrated by the lag in processing of Project Implementation Letters (PILs), documents filed to release AID loan money for payment of Project materials. In January 1982, the Government of Haiti started

construction work on the Dubreuil project without waiting for the loan money to be released. It wasn't until November 1982, however, that the first PIL -- PIL No. 20 for $90,000 -- was initiated. The loan money was not released until June 1983. By this time, DARNDR had spent nearly $140,000 on construction materials -- an amount that really should have been advanced by AID as a loan. This created many budgetary problems, given the Haitian government's slim resources, and played a role in subsequent work slowdowns and stoppages. (Project field work was at a virtual standstill on two occasions, from May to August 1982 and from December 1982 through June 1983.)

The delay in release of loan money was apparently due to several factors, including lack of awareness by GOH Project officials that loan money could be used for the purchase of such materials as sand, gravel and cement, in addition to vehicles. Moreover, there was a lack of clear responsibility at DARNDR for developing the technical and financial information necessary for initiation of PILs. This situation appears to prevail today -- a query of DARNDR officials regarding who is responsible for initiating PILs drew varied and uncertain responses.

With regard to AID's role in this matter, more careful supervision of the Project's financial needs and closer contact with Project administrators at DARNDR might have assured more timely initiation of PILs and release of loan funds, and ultimately might have lessened the Project's financial troubles.

(A second PIL for the Dubreuil Project -- PIL No. 22 for about $220,000 -- was approved. The money has not been released, however, pending Government of Haiti submission of proper documentation for the expenditure of AID funds provided for damages caused by Hurricane Allen in August 1980.)

Lack of proper management and financial controls by DARNDR resulted in a ballooning of employees paid under the PDAI Project. In an attempt to rectify this, and to pay off Project debts accumulated from October 1982 to March 1983, drastic slashes were made in April 1983 in the number of PDAI employees. In Port-au-Prince, the number of employees paid under the project plummeted from approximately 100 to about 20. Correspondingly, Port-au-Prince salaries paid under the PDAI Project amounted to $10,372 in February compared to $2,889 in May. Salary supplements totalling $3,520 in March were completely eliminated at Damien (Port-au-Prince).

In Les Cayes, the number of PDAI employees dropped from an estimated 35 to 16. Supplemental salaries were also cut here, though in some cases employees working with the Project were able to receive a contract that effectively replaced the salary supplement. At current levels, PDAI personnel make up about 20 percent of the Irrigation Service staff.

Inadequate supervision also contributed to Project funds being used for other projects. Sometimes money was "borrowed" from the Project, with funds not forthcoming for repayment. In other cases, resources for another activity

were scarce and Project money was used without thought of reimbursing the PDAI account. An example of PDAI funds being used for non-PDAI activities is a payment for personal insurance for 1,226 DARNDR employees that was recently made with Project funds.

The problem of insufficient Project supervision by DARNDR has been compounded by the lack of strong Project monitoring/management by AID in the past. This situation has been rectified with the recent appointment of a capable AID project manager who is eager to provide comprehensive management support to his Haitian counterpart.

2. Lack of Resources

Lack of administrative and financial controls is only a partial explanation for the excess number of employees staffed under PDAI in the past and for the use of PDAI funds for other DARNDR activities. Lack of resources also plays an important role. The Government of Haiti is caught in a serious crunch between a fiscal austerity program mandated by the International Monetary Fund (IMF) and its commitments to cover an agreed share of investment projects and recurrent costs resulting from these projects, as noted in the current Country Development Strategy Statement (CDSS) for Haiti.

Though unauthorized use of PDAI funds can not be condoned, at the same time it must be recognized that DARNDR administrators, faced with other necessary activities starved for money, are tempted to use PDAI funds for these other activities (especially in the absence of the proper administrative controls over the money). Part of the problem in the past also stemmed from the fact that, with the advent of PDAI, agronomists who had never before managed large projects suddenly found themselves responsible for allocating large sums of money, according to DARNDR officials.

Thus, a basic lack of financial resources at DARNDR has led to technically improper use of PDAI money. In turn, such use of PDAI money has prompted AID and the Ministry of Plan to take corrective measures. These measures further constrict DARNDR financial resources and effectively put the PDAI project in a stranglehold.

More specifically, it is the allocation of PL-480 money that is really at issue here. GOH counterpart funds theoretically come from two sources: the National Treasury and PL-480 funds, derived from the sale in Haiti of U.S. commodities purchased by the Haitian Government with Title I loans. In reality, however, the Title I money accounts for nearly all counterpart funds for the PDAI project.

These counterpart funds, which are to cover costs of field construction labor, are the weak link in project funding. The other sources of funds -- AID grant money for technical assistance and training, and AID loan money for materials, equipment and turn-key contracts -- pose relatively no problem. (This, of course, assumes that PILs are initiated in a more timely fashion in

the future to ensure the release of loan money when needed and that problems with AID holding loan checks hostage for accountability on hurricane relief funds will not recur.)

The PDAI project did not receive any counterpart funds from the Ministry of Plan from October 1982 to February 1983. Although the PDAI Project director originally requested a budget of $1 million, the Ministry of Plan rejected this, offering a $300,000 budget instead. Finally, in February 1983, the Project director and Ministry of Plan representatives agreed on a budget of $500,000 for the remainder of FY 82-83. Payments totalling $279,677.60 were made in March, April and May, and then discontinued beginning in June.

On August 9, 1983, the Master Account for the PDAI project, where money allocated by the Minstry of Plan is deposited, had a balance of $40,585.80. Reportedly at AID's insistence, the Ministry of Plan credited the account with an additional $100,000 for a total balance of $140,585.80.

The problem of irregular and insufficient disbursement of Title I monies is not a new one. The 1982 Inspector General's Audit Report noted that from September 30, 1976 to January 31, 1982, DARNDR requested $7.7 million for PDAI operations, of which only $3.5 million was released to the Project. "The lack of adequate GOH financial support to the project coupled with administrative bottlenecks at DARNDR have disrupted field operations," the Audit concluded. (Inspector General Audit Report No. 1-521-82-16, p. 29)

Disruption of field operations continues to be a problem. Whether sporadic and inadequate funding causes these work slowdowns or whether the work slowdowns themselves cause the withholding of Title I funds by the Ministry of Plan becomes something of a chicken-and-egg argument. Ministry of Agriculture officials maintain that progress on the Project has been held up by interruptions in funding flows. Ministry of Plan officials counter that "the Project is not moving in the first place. That's why it's not getting money."

The Ministry of Plan has legitimate reasons for withholding disbursements to DARNDR. They include the following:

- Concentration of operating costs in DARNDR's central office. It is the Ministry of Plan's position that most salary costs should be concentrated in Les Cayes for the field personnel working on the Dubreuil project. Yet, in reality, about 60 percent of these costs were concentrated in Port-au-Prince in FY 82. (In FY 84, this situation is expected to change, with 53 percent of salary costs budgeted for personnel in Les Cayes, 17 percent in Port-au-Prince, and 28 percent in Marigot.).

- Lack of clear authority at DARNDR for the Project. Ministry of Plan officials complain that Project reponsibility is diffused among too many people and that they are not kept informed of changes in Project directorship.

- Use of PDAI project funds for activities not related to the Project and for overall DARNDR operating expenses. These expenditures, though perhaps for legitimate DARNDR operations, are not Project-related and are often incurred under the guise of general "institution-building."

- Non-submittal of quarterly activity reports to the Ministry of Plan, as required by Haitian law. The Ministry of Plan says it must withhold funding unless the reports are filed and it has proof that payments are made according to their stated purpose.

Simply stated, the Ministry of Plan contends that DARNDR has more than enough money for the PDAI Project, while DARNDR maintains that the Project has about $200,000 in debts to pay off. Plan officials counter this argument, however, saying they never see paid bills as required under their documentation system. Moreover, they feel confident the reason they never see the paid bills is because DARNDR is misallocating PDAI money.

DARNDR officials, for their part, have argued in the past that when faced with financial difficulties, the Ministry of Agriculture ultimately has the right to use PDAI funds for general DARNDR operational expenses that are not specifically related to the Project. Since April 1983, however, DARNDR has committed itself to dis-allowing such expenditures.

Regardless of past digressions, it is clear that a no-win situation exists. While the Ministry of Plan is justified in its criticisms of DARNDR's financial management of PDAI, the corrective measures it takes effectively "throw the baby out with the bath water." For want of counterpart funds, the PDAI project suffers and remaining Project funding, namely AID grant and loan money, are wasted in the process.

3. Lack of Communication

Better communication among DARNDR, AID and Ministry of Plan officials involved with the PDAI project might alleviate many of the problems that currently exist. For example, DARNDR officials responsible for Project accounting seem unaware of the need for signed bills to be returned to the Ministry of Plan. It is not clear that the Ministry of Plan has specifically outlined its requirements to DARNDR personnel. A meeting of Plan and DARNDR officials closely involved with the project might lead to DARNDR officials having a better understanding of the requirements. At the same time, Ministry of Plan officials might gain an increased awareness of some of DARNDR's difficulties in complying with the requirements.

Such a meeting could also be a first step in alleviating the complex system now in place for authorization of checks drawn on the PDAI Master Account (Account No. 799). GOH Development Budget funds are deposited in this account on a periodic basis by the Ministry of Finance as authorized by the Ministry of Plan, based on a programming document agreed on by the Ministries of Plan and Agriculture. Checks drawn on the Master Account must not only

have the signature of the PDAI Project Director but also appropriate officials at the Court of Accounts and the Ministry of Finance. A DARNDR employee then personally goes to the Ministry of Finance to retrieve the check. (Also, on receipt of a check, the beneficiary signs for it. These substantiating papers are supposed to be returned to the Ministry of Plan. This, however, apparently either does not occur or occurs sporadically.)

Obviously, this process is cumbersome, and with so many signatures involved, long delays in the disbursal of checks are inevitable. Alternatives exist for improving the system, such as eliminating some of the signatures (and accompanying time delays) now required, increasing the Revolving Fund account (Account No. 829-6) so day-to-day operations can be pursued with fewer time delays, or perhaps giving DARNDR more autonomy accompanied by periodic audits.

Another area of misunderstanding between the Ministries of Agriculture and Plan involves the reliance by the Ministry of Plan on DARNDR's bank statement for current information on the Project's financial status, while DARNDR officials base their assessment of PDAI funding needs on figures from their accrual accounting system. On July 31, 1983, for example, the Project balance in the bank was $45,400, a sum Plan officials deemed sufficient for the remainder of the fiscal year. The actual balance, however, was only about $9,000 because of outstanding checks, according to DARNDR Project administrators.

Improved communication between AID, DARNDR and Ministry of Plan officials might lead to some constructive efforts to alleviate Irrigation Service budget pressures so there would be less of a compulsion to use PDAI funds for non-PDAI purposes. A case in point is the dearth of funds available to the Irrigation Service for general Operations and Maintenance of country-wide irrigation systems, as shown in the figures below provided by the Irrigation Service. They also demonstrate the extreme variability of funding levels, rendering planning difficult, at best:

Operations & Maintenance Funds for Irrigation Systems in Haiti

1975-76	$1,100,000
1976-77	$1,200,000
1977-78	$ 875,150
1978-79	$ 120,000
1979-80	$2,207,570
1980-81	-0-
1981-82	$ 164,608
1982-83	-0-

Closer collaboration between DARNDR and AID could perhaps lead to efforts to deal with this problem, such as initiation of a project that would provide overall support for O&M needs of irrigation systems nationwide.

C. Future Funding Considerations

For Fiscal Year 1983-84, it is estimated the PDAI irrigation component will require GOH counterpart funds of $440,000. The Ministry of Plan has allocated $400,000 to the entire PDAI project, of which about one-third or $133,333 is set aside for the irrigation component. Given the Project's budgetary history, however, allocations by the Ministry of Plan do not ensure the disbursal of that amount to DARNDR.

PDAI officials plan to spend this money in the first six months of the fiscal year, demonstrate to the Ministry of Plan that the money has been well-spent, and then request additional funding for the remainder of the Fiscal Year. They are hopeful that some money unutilized for other projects or other PDAI components can be transferred to PDAI, and feel confident that all Phase II work could be completed in one year if sufficient funding is available.

DARNDR officials are optimistic about the financial health of the PDAI project in FY 83-84 for several reasons. One, they say the number of DARNDR projects has been substantially lowered, reducing concomitant financial obligations. Another factor that will contribute to smoother implementation is the intent of PDAI administrators to rely more on contracts for completion of Phase II work, which can legitimately be paid for by loan funds. Additionally, Irrigation Service officials say the imminent release of the PIL No. 22 money will ensure that payrolls are paid even if there is a delay in the availability of government counterpart funds. Thus, work stoppages which occurred in the past due to lack of GOH counterpart funds, will not be likely in future months, according to these officials. Of course, this premise is dependent on AID's issuance of the $212,000 loan check it is holding due to unsatisfactory accounting of 1980 hurricane relief funds.

D. Conclusion

In light of the past problems with GOH counterpart funding, it is difficult for the evaluation team to be optimistic that similar funding problems will not occur in the future. Though DARNDR officials are beginning to understand the PIL process, future timely disbursal of AID loan money is still not assured. Besides loan money, however, the real financial hang-up of the PDAI project is GOH counterpart funds. Even now, for example, at Dubreuil, there is money in the Les Cayes bank account for materials (AID loan money), but none available for labor costs (GOH counterpart money), and district salaries are not fully paid up.

A big factor affecting the future course of the Project will be the motivation and commitment of Ministry of Agriculture officials to support the Project and see that it succeeds. The Ministry of Agriculture appears to have personnel who are technically capable of implementing a continuing program of irrigation rehabilitation and support services. What is required is firm commitment from the top levels of the Ministry of Agriculture on down to adhere to PDAI budgets and to comply with project funding regulations.

At the same time, the evaluation team feels strongly that AID must not abandon pursuit of the objective of the PDAI irrigation component to strengthen the institutional capacity of the Irrigation Service. Granted, the Irrigation Service and DARNDR have serious institutional weaknesses. But any improvement of irrigation systems in Haiti that is to endure requires the involvement of the Ministry of Agriculture's Irrigation Service.

Commitment by the Ministry of Agriculture to the PDAI project and resolve by AID to assist the Ministry's efforts will ultimately determine the success of the PDAI irrigation component from this point to its conclusion.

E. Recommendations

1. Loan money for turn-key contracts should be used to a greater extent for field construction work to reduce reliance on the joint availability of AID loan and Title I funds and to help ensure that future work stoppages do not occur due to a lack of GOH counterpart funds for field construction labor costs. Increased use of contracts will not only lead to more effective use of all Project funds, but will also ensure to a greater extent that the loan money is completely and effectively utilized by the Project's completion date.

2. The Ministry of Agriculture should make a strong commitment, at all levels, to adhere to the PDAI budget and funding regulations so that it may re-establish its credibility. In doing so, DARNDR will reduce the likelihood of future interruption of GOH counterpart funds because of irregularities in the Project's financial management.

The implementation of these two recommendations is considered critical to the smooth functioning of the Project in the future. To facilitate their implementation, the following measures are suggested.

3. A strong, full-time director/coordinator is needed for the PDAI project to provide the necessary leadership and close supervision of day-to-day Project operations. This director/coordinator should not have other responsibilities, and thus should be able to devote his full attention to the PDAI project.

In addition, an internal DARNDR proposal that calls for a Coordinating Council for the PDAI appears to have merit and should be pursued further. As proposed, this PDAI Coordinating Council would meet twice a month and be headed by an Executive Secretary (to be filled by someone other than the director/coordinator). Members of the Council would include the directors of the various offices having responsibilities for the four PDAI components, as well as a delegate from the Secretary of State. Office directors would be assisted by the chiefs of services directly involved with PDAI components. This proposal holds promise for stimulating greater collaboration and communication among those officials working in the four PDAI components, and could serve to ultimately strengthen the individual components, including that of irrigation.

4. The Ministry of Agriculture and AID should jointly monitor and manage Project loan funds. The PDAI Director/Coordinator at DARNDR and the AID Project Manager should meet on a monthly basis as part of their joint management functions to review the status of loan disbursements and verify that funds are spent in such a way that reimbursement will be possible. Furthermore, responsibility for the preparation of technical and financial information necessary for initiaion and processing of PILs should be firmly established at the Ministry of Agriculture so there is no question that this function will be carried out as needed. The future financial stability of the Project depends on the timely initiation of PIL requests by someone knowledgeable about the process. The Project accountant and the Irrigation Service chief would appear to be the logical persons to carry out this responsibility.

5. The Ministry of Agriculture and AID should jointly manage Title I funds. Project-related financial and management information reviewed on a monthly basis by DARNDR and AID Project management should include all PDAI financial accounting records, payrolls, job descriptions and fund allocations. Closer supervision of Title I funds for PDAI will help guide the Project, assure that Title I money can be used effectively to support loan money activities, and avert the drastic cut-off of Title I funds by the Ministry of Plan, as has occurred in the past.

6. AID should consult regularly with the Ministry of Plan regarding the amount and timing of Title I disbursements to the PDAI project. AID should further work to ensure that Ministry of Plan standards and prerequisites for Title I disbursements are applied consistently among AID-financed projects.

7. Title I funds should be used to a greater extent to support salaries of field personnel, and to further efforts already underway by DARNDR to concentrate more Project funds outside Port-au-Prince. Rectifying the current imbalance that favors Damien employees is especially critical in view of the absence of supplemental earning opportunities, such as university teaching, which exist in Port-au-Prince but not in outlying areas. Furthermore, PDAI district personnel should not be overlooked for consideration when training opportunities arise.

8. AID should encourage representatives from the Ministries of Plan and Agriculture (especially middle-level officials knowledgeable about day-to-day Project operations) to meet to resolve current problems of insufficient documentation provided by DARNDR to the Ministry of Plan. It may be that documentation problems cited by the Ministry of Plan are superficial and not fundamental to the problem of recurrent withholding of Title I money. Nonetheless, a meeting between representatives of these ministries might pave the way to resolution of more fundamental issues that are having a detrimental effect on the Project.

9. The Ministry of Plan, DARNDR and AID should address the need for Operations & Maintenance (O&M) funds for other irrigation systems in Haiti. The pressure on Irrigation Service Personnel to use PDAI funds for non-authorized expenditures is heightened when other irrigation systems in the country do not have basic O&M funds. A new project allowing for general support of irrigation systems in Haiti is one alternative that might be considered.

10. Means to simplify the current procedures for checks drawn on the PDAI Master Account (Account No. 799) should be sought. Given the numerous signatures required, long time delays in the actual disbursal of checks are inevitable. If simplification of this system appears infeasible, then funds allocated to the Revolving Fund (Account No 829-G) should be sufficiently increased to allow for the smooth flow of funds for day-to-day operations. In addition, district-level financial needs should be provided in monthly, or preferably quarterly, disbursements, reducing lengthy delays in approval and disbursement of individual checks drawn on the bank account at Les Cayes. Districts should ideally be given more autonomy in financial management and decision-making.

11. PDAI administrators who adhere to regulations involving the use of PDAI funds and who, in the process, take stances that are unpopular with other DARNDR officials, should receive the full backing and support of AID.

VII. TECHNICAL ASSISTANCE

A. Assessment of TA Performance

The required technical assistance for the irrigation component of the project is being provided by Sheladia Associates, Inc. Their contract which became effective January 7, 1980, provided for a total of 198 person months of the following specialists:

Engineering management specialist/Team Leader	45 pm
Irrigation engineer, design and construction	36 pm
Irrigation engineer, operation and maintenance	45 pm
On-farm specialist, irrigation practices	36 pm
Short term consultants as needed	36 pm
Total	198 person months

At the time of the evaluation, approximately 170 person months had been provided, leaving a balance of about 28 person months and $112,000 of the $1.9 million dollars allocated for technical assistance. The present Sheladia team, in residence, consists of an operations and maintenance engineer, who also acts as team leader, and a construction engineer. The technical assistance as provided by Sheladia to date is as follows:

Project management and team leader	Jan 1980 - July 1981
Operation & Maintenance (also team leader since July 1981)	Jan 1980 - Present
Water application	Mar 1980 - Mar 1983
Construction	Jan 1980 - Present
Design Engineer	Mar 1982 - Dec 1982
Hydrologist	Dec 1981 - July 1983

The consultants were to provide expertise in irrigation project management, irrigation systems planning, in-service training, irrigation design and construction, water systems operations and maintenance, on-farm usage of water and irrigation feasibility studies. Through this technical assistance they were to strengthen the capacity of the Irrigation Service of DARNDR to develop and manage the existing and potential irrigation systems in Haiti. This was to be done in part thru field work on two specific systems, Dubreuil and Jean Rabel plus another two systems to be identified.

Overall, very limited results have been accomplished by the TA team. The high TA costs have not yielded significant results. But Sheladia is not solely responsible for the lack of progress. The team members did not arrive

in Haiti in the most logical order to implement their contract, particularly in the case of the on-farm water management specialist who arrived too early in the project (March 1980) to really be effective. He did provide assistance in organizing water user associations in the Dubreuil project and developing irrigation schedules and operation plans. While some lead time prior to delivery of irrigation water is required for these activities, his expertise could have been much more effectively utilized later in the project. Given the status of DARNDR and the numerous Conditions Precedent in the project paper, the advisability of Sheladia mobilizing the full team so early, and AID allowing them to do so, is questionable.

After its arrival in 1980, the team was reportedly instructed by USAID not to work with the Irrigation Service until the Conditions Precedent of the project paper were met. There were also the additional problems of transportation, office space, etc. Thus the team essentially did nothing until July 1981 when some activities were begun. The Integrated Agricultural Development Audit Report (September 1982) suggests that their was only about 25% utilization of the available manpower during this time.

Another reason for the underutilization of the TA is related to the limited absorptive capacity of the DARNDR personnel in the Irrigation Service. There were few senior experienced Haitian engineers to serve as counterparts to the consultants, who were generally over qualified for the relatively straight forward requirements of the irrigation projects. It seemed that in many cases there was too broad a gap to bridge between the consultants and their counterpart, both in terms of age and knowledge and experience. There was also turnover in personnel due to GOH engineers leaving because low salaries and better opportunities available elsewhere within the GOH. Others were sent for both long and short term training. Off-shore training has been essential, but it has stretched the limited manpower in the Irrigation Service.

The TA worked largely on a one-to-one basis with GOH counterpart personnel, largely insulated from broader and more productive interactions with DARNDR engineers. They were not responsible in a general sense to the head of the Irrigation Service. In addition there were language problems and a sense of isolation as a result of Sheladia establishing offices outside of Damien.

Some working papers and manuals have been prepared by various members of the TA team. Manuals of Hydrology, Design and Water Application are available in English and reportedly are being translated into French. A paper was prepared by the first team leader on Irrigation Development on Small Farm Units and is available in both English and French. The present team leader has prepared a paper on the need for reorientation of operation and maintenance procedures. The most recent publication is a bi-lingual report on the Suggested Physical and Financial Program for achieving the targets of the irrigation component of the PDAI project. All of these except the last one appear to be prepared exclusively by the TA team members with little input

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from Haitian personnel. The design manual for example seems incomplete as it does not include any typical design based on conditions at the project sites i.e. Dubreuil.

Many people in the irrigation service at Damien, when asked about these manuals, didn't know about them, and one person who was aware of them questioned their applicability and usefulness. One thing that is obviously missing as called for in the TA scope of work is a procedure for the selection of irrigation systems for rehabiliation to establish their technical and economic feasibility. The TA indicated they have tried to initiate some action in this area but received no support from DARNDR.

There does not appear to be a very close working relationship between the members of the TA team and the Irrigation Service. Part of this may be due to the TA team maintaining a separate office away from Damien. Many Irrigation Service personnel see the team leader primarily as a liason officer with USAID and someone to see that all USAID requirements are met for fund disbursements, rather than as technical person working alongside them on the design and implementation of the irrigation projects. While this role is legitimately part of the team leaders duties, he should involve Damien personnel so that they become familiar with requirements and procedures and can assume this responsibility in the future. It is recommended that the TA work more closely with, and report to the Irrigation Service, as well as have their offices at Damien. Most Damien professionals felt that this would be a better arrangement.

B. Future TA

The present contract with Sheladia for 198 person months at an estimated cost of $1.9 million, ends September 30, 1983. At that time there will be a balance of approximately 27 person months and $141,000. At the current rate of expenditures this would provide for about 12 person months of TA.

The evaluation team feels that continued TA will be required if the Irrigation Service is to carry out its proposed plan of completing 2000 ha of irrigation rehabiliation by October 1985. Achivement of this will, of course, depend on the timely availability of both USAID and GOH funds through the elimination of money constraints addressed elsewhere in this report. There are some indications that future progress will be better than in the past. After being at a standstill for six months, construction activity on the Dubreuil system has been resumed. The Irrigation Service has a reasonably adequate staff who have acquired some experience and training, and three additional training participants will be returning within six months. In other words the, absorptive capacity for technical assistance will be greater during the coming year than any time previously.

In addition to the design and construction help that will be needed, there is some help required in updating or initiating feasibility studies. With the completion of Phase I of the Dubreuil project, scheduled for September 30,

1983, there will be need for some O&M and water application technical assistance. In view of all these needs and assuming that the financial restraints on construction are removed, it is recommended that the present two member team be retained through FY 1984. Under the existing contract with Sheladia this would cost approximately $240,000, and require an additional $100,000 grant funding. If progress in FY 1984 is satisfactory, it is further recommended that additional TA funding be sought in FY 1985 so that the team could remain until June 1985 (PACD). Implementation of this most desirable option allows for continuity in the technical assistance. This is essential for rapid project implementation.

If there are no more funds in the PDAI project that can be made available for TA, then one alternative is to try to maximize the number of person months with the remaining money through personal services contracts. This would allow for approximately 18 person months of TA and could be used for one consultant for a period of one year plus six months of the second team member. This, of course, requires that Sheladia be willing to release its people from the company and allow them to take personal services contracts for the same project. The use of the same professionals is necessary to provide continuity in the technical assistance.

A less desireable alternative is to extend the present contract with Sheladia and keep only one of the team members for an additional twelve months. This would likely require that GOH hire a local senior engineer to work directly with the TA and be in a position to continue the project after the TA left in September 1984.

The least desireable alternative is to lose the continuity of the current TA. While PSC arrangements could be made with other consulting engineers, the loss in time needed to identify and select a qualified candidate and the time required to free up the current grant funds for new TA plus the loss in job specific information would mean a severe discontinuity for the project.

C. Recommendations

1. For continuity and to provide assistance to the Irrigation Service staff who are now in a better position to effectively utilize technical assistnce than at any other time in the life of the project, the same two experts should be retained until the PACD if funds allow.

2. The TA should locate its offices at Damien and become an integral working part of the Irrigation Service, reporting to its chief.

3. The GOH should provide several qualified counterparts to work with each of the TA so as to make more effective use of this costly, but needed resource.

APPENDICES

A. CROPS AND CROP MANAGEMENT UNDER IRRIGATION IN THE DUBREUIL AREA

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Main Cash Crops

Beans: Beans are planted from September to October when the rains are more torrential and also towards the end of February or beginning of March when the rains are "softer", at 50 cm betwen rows (3 rows in 150 cm beds and 7.5 cm between plants. An application of 1000 kg/ha of triple superphosphate should be banded at planting. Irrigation must be as follows: 5 cm weekly from planting until grain filling. At 78 to 83 days some 1500 kg/ha could be harvested (7,15).

Tobacco: Tobacco appears to be a very promising cash crop for the region. Tobacco production is particularly suitable for small farmers. The most widely planted tobacco is of the Virginia type and is used mostly for cigarettes. Tobacco growing requires careful preparation of seedbeds. In the Ducis area the seedlings are transplanted at 1 1/2 month of age. The planting season covers September and October. Harvesting usually begins in December and extends until mid-March. A 12-12-10 fertilizer is used at the rate of 100 pounds/1/16 of a carreaux. Farmers maintain a continuous spraying program at a 6-day interval to control leaf sucking insects. Sevin, Decis and Azodrin are commonly used. Leaves are harvested individually as they reach the appropriate stage. They are then tied and hung in sheds or barns to "cure" for 22 days. Then they are piled until marketed.

Rice: Rice can be grown in the Dubreuil Project Area at any time of the year if irrigation water is available. It should be planted on the most level lands, particularly those with heavier subsoils as observed in some of the lowlands. Fields should be cleared, hoed down to about 15 cm, then levelled if possible or smoothed with a land plane. The best performing varieties should be chosen.

If it does not rain, the field should be irrigated and drained soon after planting and again 8 or 10 days later. Two to three weeks after planting, the field should be weeded and flooded. If the soil can retain water, 10 to 20 cm should be maintained on the surface. If not, it should be flooded at intervals to maintain favorable moisture for rice production. About 1.25 cm of water should be applied daily to permanently flooded fields and 10 cm of water every week to fields irrigated at intervals. Irrigation should be terminated a few days after the panicles bend with the weight of the grain. It has been observed elsewhere that medium and long-grain varieties produce approximately 20% and the short-grain 40% less when not irrigated (17). This highlights the benefits of timely irrigation of rice fields.

About 1200 kg/ha of a 10-5-15 fertilizer should be applied and incorporated into the soil. If necessary, 60 kg of zinc sulfate should be also applied if soil pH is higher than 7. About 125 kg of nitrogen/ha should be applied 30 to 40 days after planting. If cutworms appear, 2 to 4 pints of Diazinon diluted in 18 gal. of water/ha. should be applied.

The short-grained varieties are harvested 90 to 100 days after planting while the long or intermediate grained varieties require 120 to 140 days. It is therefore possible to produce two rice crops/year and even five crops in two years on the same land, each yielding about 4,000 to 5,000 kg of rough rice per ha (15,17).

Corn: Under conditions in Puerto Rico, grain yields of Pioneer variety X-306 have reached 8,724 kg/ha when irrigated; 7274 without irrigation, i.e., a 15% difference (18). During the study period, 583.4 mm of rain fell at the area and evaporation from a class A pan amounted to 692.1 mm. This deficit of 152.4 mm was more than offset by applying 177.8 mm of water to the irrigated plot. The irrigated plot received water as often as necessary to maintain a water tension of less than 1 bar. The high corn yields were obtained with 60 to 120 kg/ha of nitrogen fertilizer. At a second location, maximum non-irrigated grain yields (4.8 t/ha) of a white kernel corn on open, porous soil were well below the 8.3 t/ha obtained on heavier soils with a higher nitrogen supplying power (12). Corn should have enough water during its growing cycle, particularly at flowering and grain filing. From 1.3 to 2.5 cm of water should be applied after planting; repeated every 2-3 days if it does not rain during germination; and then 3.5 cm/week should be applied (5).

Under the conditions prevailing at Damien, corn variety Levy 78-35 appears to need 197 mm of water prior to flowering and 157 mm after flowering (10). These figures represent theoretical calculations that need further refinement.

Overall mean yields of variety La Maquina 7827 on fertilized and unfertilized fields have been 2.94 t/ha while local corn produces 2.61 t/ha. With the application of 80 kg/ha of nitrogen as urea, overall yields, irrespective of varieties, have been 3.20 t/ha vs. 2.35 t/ha without nitrogen fertilizer. Applications of phosphorus fertilizer did not significantly affect yields (zero P = 2.72 t/ha; 50 kg P = 2.82 t/ha). No significant yield differences could be attributed to plant density at levels above 44,000 plants/ha (44,000 plants = 280 t/ha; 58,000 plants = 2.75 t/ha).

Additional tests showed overall yield increases attributable to nitrogen fertilization at the rate of 80 kg/ha of nearly 20% in corn yield. Local varieties with nitrogen produced 2.75 t/ha while La Maquina 7928 produced 3.64 t/ha, an increase of about 33% 2/.

2/ Dr. Michael Yates, Personal communication, Les Cayes, August 23, 1983.

Sorghum: The sorghum root system is fine and fibrous and can go deeper into the soil than other crops such as corn. Under conditions in Puerto Rico on porous soils with or without irrigation, roots can reach a depth of 90 to 100 cm, but about 75% of the roots are generally confined to the upper 15-30 cm of soil (1,19). The greatest demand for water occurs between the boot and grain-filling stage. The total seasonal requirement for a 6,300 kg/ha crop of grain sorghum in the Central Plains of the United States is about 50-70 cm (8). If necessary, one irrigation prior to sowing and maybe one or two during the growing season should suffice. The effect of irrigation on stover yields of grain sorghum on a porous, well-drained clay soil in Puerto Rico is shown in the following tabulation (19):

Moisture Status	Dry stover yields, kg/ha
Irrigated	4831
Nonirrigated	3827

At Paysandu, Uruguay, mean grain sorghum yields from 10 varieties were as follows (9):

Time of Planting	Grain yields, kg/ha
Dry summer	3,000
Moist summer	5,000

These data show that grain shorghum, although tolerant to moisture stress, can indeed use moisture to advantage.

It is possible to produce two crops of grain sorghum under irrigation at Les Cayes. If improved varieties are used, properly fertilized and managed, yields of 4000 to 5000 kg/ha can be obtained per crop (14,15).

The following tabulation shows that under conditions of unlimited moisture, sorghum can consume large amounts of water (8):

Growth stage, emergence to	Cumulative water use, cm
30 cm	10-13
Boot	13-25
Grain dough	45-50
Maturity	50-60

The beneficial effects of irrigation on grain sorghum have been confirmed in the Great Pains of the United States (13) as shown in the following tabulation:

Available water, mm	Yields, Kg/ha
230	0
255	120
305	900
355	2000
405	3750
455	5800

Increasing the water supply produced heavier yields. These results were obtained on soils of moderate to good fertility, using an improved variety and grown without weeds.

Sorghum growth patterns and tillering behavior permit harvesting several crops from a single planting.

Secondary Cash crops

Pigeonpeas: Pigeonpeas are highly drought-tolerant but require moisture at planting and at flowering and fruiting (2.5 cm-ha in each case). The main factor controlling flowering is the length of day. Flowering and fruiting occur during the short days of the year. There are indeterminate and determinate varieties. Yields of 4000 to 5000 kg/ha have been obtained in Puerto Rico using determinate varieties that mature in 115 to 130 days (4). In Haiti, indeterminate varieties are grown. Using improved varieties total yields of 2000 kg/ha have been obtained in three pickings from a 7.5 months crop (15).

No fertilizer is usually needed. Pigeonpeas can fix rather large amounts of atmospheric nitrogen. Furthermore, its deep root system allows for tapping nutrients at lower depths (4).

Sweetpotatoes: Sweetpotato vines could be planted at any time of the year, although for some varieties the best planting season is January (15). The best planting distance is 100 cm between rows. An application of 1760 kg/ha of a 6-6-12 fertilizer, in bands, two weeks after planting is advisable. Irrigation should be gauged to supplement rain up to the equivalent of 3 cm/week probably at 15-day intervals. In Haiti, yields of 3000 to 5000 kg/ha are possible (15). In Puerto Rico, higher yields from the white-fleshed and the yellow-fleshed varieties, under irrigation and high levels of technology have been obtained (2).

Sugarcane: Sugarcane is considered to be the world's best living collector of solar energy. More than any other plant, the sugarcane has perfected the art of converting sunlight to chemical energy and storing it as sugar and fiber. Temperature and light favor sugarcane growth in the Dubreuil Project Area. The ideal climate for sugarcane includes a long, warm growing season and a fairly dry, sunny and somewhat cool ripening-harvesting season.

Some of these conditions prevail at Dubreuil; others, like moisture supply can be modified. The soils of the area can be used advantageously for sugarcane. Water is an essential factor for sugarcane production. Under conditions in Puerto Rico, the mean consumptive use of water by a sugarcane crop is 0.41 cm/day (6). The water requirements for a 12 months cane crop will be some 152 cm. Experiments in Puerto Rico have shown significant differences in sugarcane yields between plots frequently irrigated and less frequently irrigated are shown in the following tabulation (16):

Irrigation	Cane yields, mt/ha
Frequently irrigated (up to 1 month prior to harvest)	165
Irrigations up to 5 months prior to harvest	134

Planting distances should range from 1 to 1.35 m. The direction of the furrows should facilitate drainage and irrigation. Sugar yields can be dramatically affected by weed competition as shown in the following tabulation:

Treatment	Sugar yields t/ha
No weed control	0.6
Weed control during spring	3.0
Weed control since harvesting previous crop	4.1

Other Potential Crops

Plantains: Plantains are a valuable crop in the Caribbean. In Puerto Rico plantains are grown in some 10,000 ha. The value of production per year rose from $17 million in 1978 to $40 million in 1982. Plantains are a useful food crop in the tropics and can be cooked in a variety of ways. They are adaptable to small farms and can be planted throughout the year. This provides for a continuous flow of cash during the year even on small farms. Using appropriate technology, including nematode control, plantains can produce two or more heavy crops without replanting (3).

Plantains require deep, porous, well-drained soils preferably of high fertility. Rainfall should exceed 1800 mm and should be well distributed. Otherwise, irrigation is needed.

Planting material should be selected from specimens producing more than 40 fruits/bunch. With some varieties, 80,000 fruits/ha can be harvested. Deep soils do not require any preparation other than making the planting holes and weeding.

One important item for successful production is the preparation of the corms used as planting material. Necrotic and reddish dotted areas should be cut off the corms. Roots should be eliminated, then the corms should be submerged in a 70% Nemagon or Fumazone solution, at the rate of 5 pints in 100 gal. of water or Furadan 4F at the rate of 1/4 gal. in 50 gal. of water for 5 minutes.

After suberization, the corms should be classified into three sizes (large, medium, small). If they are mixed, the plants emerging from large seeds will grow quicker and compete to advantage with those from smaller corms. The size of the hole should be proportional to the size of the corm. It is not necessary to make wide and deep holes to plant a 1 to 2 kg corm.

After germination, 1/4 kg of a 10-5-20 fertilizer should be applied per plant followed by an equal amount at 4 months intervals, i.e., at 5 or 6 and 10 months of age. It is important to apply all the fertilizer prior to blooming. The first fertilizer application should be distributed evenly around the pseudostem but subsequent ones should be broadcasted covering the peripheric area from the stem to the extent of the leaf canopy. Every two weeks, 7.5 cm of water should be applied.

Harvesting begins around 12 to 14 months after planting. Bunches could be harvested between 90 to 120 days after flowering.

Cassava: Cassava requires light loamy or sandy deep soil. It produces better with abundant, well-distributed rainfall. In semiarid areas, it should be irrigated. In dry places, "seeds" (stem cuttings) should be planted horizontally; in humid places, vertically or inclined. Planting distances should be about 1 m x 1 m for a population density of 10,000 plants/ha. In heavy soils under irrigation "seeds" should be planted in banks. From 300 to 400 kg/ha of a 5-5-10 fertilizer should be applied one month after planting and again, three months later. In heavy soils, irrigation should be used to supplement rainfall up to an equivalent of 2.5 cm/week. Cassava could be harvested beginning at the 8th month. Yields are usually from 10000 to 15000 and even 30000 kg/ha (4,26).

Cowpeas: The cowpea is a versatile legume with a wide range of adaptability to diverse conditions. It is a short cycle crop (60-90 days) that can be grown the year round. Like the soybean and the pigeonpea, it can fix quickly rather large amounts of atmospheric nitrogen and is compatible with many crops in an intercropping system. The Texas A&M/Haiti team have grown cowpeas successfully at Damien with four irrigations (58 mm of water) during the growing cycle and insect control at two-week intervals. No major disease problems occurred. Yields ranging between 2000 to 3000 kg/ha were obtained (14).

Soybeans: Soybeans offer considerable potential for the Les Cayes Plains. They are legumes that if properly inoculated with *Rhizobium japonicum* can fix sizeable amounts of atmospheric nitrogen. Their growth cycle is short

and two crops can be obtained/year. Under conditions in Puerto Rico high-yields have been obtained under irrigation and using appropriate technology. In a recent experiment in Puerto Rico (11), the total number of nodule and nodule dry weight/plants at 32 and 98 days after planting were three times larger under irrigation when compared to dry conditions. This indicates that to obtain effective soybean nodulation in the tropics, a high quality inoculant will not suffice if soil moisture is at critical levels.

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B. COST OF PRODUCTION TABLES

Table A1. Costs and Returns/ha Traditional & Modern Practices
(1982 Prices) Dubreuil Project

Crop - Maiz

One season

Revenue	Yield kg/ha Traditional (Rain Fed)	Yield kg/ha Modern (Irrigated)	$ Value of crop/ha Traditional (Rain Fed)	$ Value of crop/ha Modern (Irrigated)
Maiz at $.20/ha	1100	4000	$220	$800

Expenses	Traditional, without Irrigation	Modern Irrigated
Soil preparation	$ 63 (105 man days)	$80 (133 m/days)
Seed	5	10
Planting	14 (23 man days)	15 (25 m/days)
Cultivation or weeding	53 (88 man days)	70 (117 m/days)
Irrigation	--	15
Insecticide	10	22
Fertilizer	--	70
Harvest	10 (17 man days)	25 (42 m/days)
Total Expenses	$152	$307

Gross profit/ha	Traditional, without Irrigation	Modern Irrigated
Revenue	220	800
Expenses	152	307
Profit	$ 68	$493

Potential $ increase by accepting Modern practices = $425/ha or a twelvefold increase in profits from a 260% increase in yield.

Table A2. Costs and Returns/ha Traditional & Modern Practices
(1982 Prices) Dubreuil Project

Crop - Black Beans

One season

Revenue	Yield kg/ha Traditional (Rain Fed)	Yield kg/ha Modern (Irrigated)	$ Value of Crop/ha Traditional (Rain Fed)	$ Value of Crop/ha Modern (Irrigated)
Black Beans at $.70/kg	340	1200	$238	$1050

Expenses	Traditional, without Irrigation	Modern Irrigated
Soil preparation	$ 53 (88 man days)	$80 (133 m/days)
Seed	22	40
Planting	15 (25 man days)	25 (42 m/days)
Cultivation or weeding	35 (58 man days)	45 (75 m/days)
Irrigation	--	15
Insecticide	16	30
Fertilizer	50	70
Harvest	16 (27 man days)	32 (53 m/days)
	$207	$337

Gross profit/ha	Traditional, without Irrigation	Modern Irrigated
Revenue	238	$1050
Expenses	207	337
Profit	$ 31	$ 713

Potential $ increase by accepting Modern practices = $640/ha.

Table A3. Costs and Returns/ha Traditional & Modern Practices
(1982 Prices) Dubreuil Project (with irrigation)

Crop - Rice

One season

Revenue	Yield kg/ha Traditional (Rain Fed)	Yield kg/ha Modern (Irrigated)	$ Value of crop/ha Traditional (Rain Fed)	$ Value of crop/ha Modern (Irrigated)
Rough Rice at $.38/kg	1200	4000	$456	$1520

Expenses	Traditional, without Irrigation	Modern, Irrigated
Seed bed	$ 35 (58 man days)	$ 69 (115 m/days)
Soil preparation	100 (167 man days)	247 (412 m/days)
Transplanting	50 (83 man days)	58 (97 m/days)
Weeding	40 (67 man days)	60 (100 m/days)
Irrigation	45	78
Insecticide	5	5
Raticide	1	1
Fertilizer	75	115
Harvest and transport	50 (83 man days)	80 (133 m/days)
	$401	$713

Gross profit/ha	Traditional, without Irrigation	Modern, Irrigated
Revenue	$456	$1520
Expenses	401	713
Profit	$ 55	$ 807

Potential $ increase by accepting Modern practices = $752/ha.

100

Table A4. Costs and Returns/ha Traditional & Modern Practices
(1982 Prices) Dubreuil Project

Crop - Sorghum

One season

Revenue	Yield kg/ha		$ Value of crop/ha	
	Traditional (Rain Fed)	Modern (Irrigated)	Traditional (Rain Fed)	Modern (Irrigated)
Sorghum at $.28/kg	750	3000	$210	$ 840

Expenses	Traditional, without Irrigation	Modern, Irrigated
Soil preparation	$ 45 (75 man days)	$ 60 (100 m/days)
Seed	1	4
Planting	14 (23 man days)	15 (25 m/days)
Cultivation or weeding	16 (27 man days)	50 (83 m/days)
Irrigation	--	15
Insecticide	--	22
Fertilizer	--	40
Harvest	15 (25 man days)	25 (42 m/days)
Post harvest	9	20
	$100	$351

Gross profit/ha	Traditional, without Irrigation	Modern, Irrigated
Revenue	$210	$840
Expenses	100	351
Profit	$110	$489

Table A5. Costs and Returns/ha Traditional & Modern Practices
(1982 Prices) Dubreuil Project

Crop - Tobacco

One season

Revenue	Yield kg/ha Modern, without Irrigation	$ Value of crop/ha Modern, without Irrigation
Tobacco at $2.64/kg	$ 1200	$3168

Expenses			Modern
Soil preparation Seed bed and field	200 man days	at	$120
Seed			200
Transplanting	125 man days	at	75
Cultivation or weeding	333 man days	at	200
Irrigation			20
Insecticide			105
Fertilizer			420
Harvest	783 man days	at	470
Post harvest and transport			220
Total Expenses			$1830

Gross profit/ha	Modern, without Irrigation
Revenue	$3168
Expenses	1830
Profit	$1338

Table A6. Costs and Returns/ha Traditional & Modern Practices
(1982 Prices) Dubreuil Project

Crop - Maiz and Beans

One season

Revenue		Yield kg/ha Traditional (Rain Fed)	Yield kg/ha Modern (Irrigated)	$ Value of crop/ha Traditional (Rain Fed)	$ Value of crop/ha Modern (Irrigated)
Maiz	at $.20/kg	1300	4200	$260	$ 840
Red or Black Beans	at $.70/kg	200	800	140	560
				400	1400

Expenses	Traditional, without Irrigation	Modern, Irrigated
Soil preparation	62 (103 man days)	$85 (142 m/days)
Seed	30	57
Planting	15 (25 man days)	17 (28 m/days)
Cultivation or weeding	37 (62 man days)	70 (117 m/days)
Irrigation	--	15
Insecticide	12	35
Fertilizer	--	70
Harvest	26 (43 man days)	37 (62 m/days)
Post harvest	11 (18 man days)	17 (28 m/days)
Total Expenses	$193	$ 403

Gross profit/ha	Traditional, without Irrigation	Modern, Irrigated
Revenue	400	$1400
Expenses	193	403
Profit	$207	$ 997

Potential increase by accepting modern practices = $846/ha.

Table A7. Costs and Returns/ha Traditional & Modern Practices
(1982 Prices) Dubreuil Project

Crop - Black and Red Beans Cassava and Sweetpotato

One Full year

Revenue	Yield kg/ha Traditional (Rain Fed)	Yield kg/ha Modern (Irrigated)	$ Value of crop/ha Traditional (Rain Fed)	$ Value of crop/ha Modern (Irrigated)
Black & Red Beans at $.70/kg	300	750	$210	$ 525
Cassava at $.09/kg	2000	6000	180	540
Sweetpotato at $.18/kg	2200	5300	396	954
Total Revenue			$786	$2019

Expenses	Traditional, without Irrigation	Modern, Irrigated
Soil preparation	$ 80 (133 man days)	$120 (200 m/days)
Seed	100	130
Planting	40 (67 man days)	60 (100 m/days)
Cultivation or weeding	60 (100 man days)	112 (187 m/days)
Irrigation	--	25
Insecticide	--	10
Fertilizer	--	70
Harvest	30 (50 man days)	50 (83 m/days)
Post harvest	9 (15 man days)	14 (23 m/days)
Total Expenses	$319	$591

Gross profit/ha	Traditional, without Irrigation	Modern, Irrigated
Revenue	$786	$2019
Expenses	319	591
Profit	$467	$1428

Potential increase by accepting modern practices = $961/ha or 190% increase in gross profit/ha.

Table A8. Costs and Returns/ha Traditional & Modern Practices
(1982 Prices) Dubreuil Project

Crop - Maiz, Black Beans, Cassava & Sweetpotato

One year

Revenue		Yield kg/ha Traditional (Rain Fed)	Yield kg/ha Modern (Irrigated)	$ Value of crop/ha Traditional (Rain Fed)	$ Value of crop/ha Modern (Irrigated)
Maiz	at $.20/kg	485	1000	97	200
Black Beans	at $.70/kg	185	500	130	350
Cassava	at $.09/kg	595	4000	54	360
Sweetpotato	at $.18/kg	540	4300	97	774
Total Revenue				$378	$1684

Expenses	Traditional, without Irrigation	Modern, Irrigated
Soil preparation	$ 80 (133 man days)	$104 (173 m/days)
Seed	10	25
Planting	40 (67 man days)	60 (100 m/days)
Cultivation or weeding	22 (37 man days)	40 (67 m/days)
Irrigation	--	25
Insecticide	--	20
Fertilizer	--	70
Harvest	51 (85 man days)	73 (122 m/days)
Post harvest	70 (117 man days)	105 (175 m/days)
Total Expenses	$273	$552

Gross profit/ha	Traditional, without Irrigation	Modern, Irrigated
Revenue	$378	$1684
Expenses	273	552
Profit	$105	$1132

Potential increase by accepting modern practices = $1027/ha.

C. SUGGESTED SCOPE OF WORK FOR IRRIGATION SECTOR ASSESSMENT

C. SUGGESTED SCOPE OF WORK FOR IRRIGATION SECTOR ASSESSMENT

The scope of work for the Irrigation Sector Assessment team proposed for the summer of 1984 will generally be an updating and extension of the current evaluation. Assistance in developing the expertise and capability for operation and maintenance of the existing irrigation systems in Haiti appears to be one of the areas that should receive special consideration and perhaps be emphasized during the assessment. Specific activities will include the following:

1) Review of Dubreuil project to determine progress during past year on the construction, evaluate the operation of phase I and the on-farm water aspects of this completed project and the effectiveness of the water user organizations.

2) Collect and analyze all available data on water use and increased yields as a result of the project phase I along with rate of acceptance of high technology by the farmers.

3) To establish a comparative framework for progress in this sector, review status of other projects involving irrigation, financed by GOH or other donors and their plans for the future. This should include, but not necessarily be limited to ODVA, DRIPP, ODN, PVO's, ODGP, ODN, FONEV, PVOS etc.

4) Overall assessment of current irrigation and potential for further development and contribution of irrigation to agricultural sector.

5) Review of current laws and regulations and/or legislation regarding water use and its impact on irrigation development, procedures for forming water users associations, and possible fee schedules necessary to meet the recurring costs of system maintenance.

6) Suggest appropriate institutions, either existing or to be created, to be responsible for irrigation development in Haiti including institutional arrangements for fee collections and maintenance funds, accounting, and budgeting.

7) Develop alternative development options and investment strategies for AID in irrigation.

The team would consist of the following French speaking U.S. professionals:

-- One Irrigation Engineer

-- One Ag Economist experienced in Farm budgets and project cost/benefit analysis

-- One water Institutions and water user Association Specialist.

These could be supplemented by a qualified Haitian Ag Economist and Haitian Agronomist.