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WATER MANAGEMENT RESEARCH IN ARID AND SUB-HUMID LANDS OF LESS DEVELOPED COUNTRIES

ANNUAL REPORT
Contract AID/ta-c-1103
November 1, 1974-October 31, 1975

Utah State University
December 1975

CID

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PN-AAD-092
Utah State

WATER MANAGEMENT RESEARCH
IN ARID AND SUB-HUMID LANDS
OF LESS DEVELOPED COUNTRIES

Contract AID/ta-c-1103

<u>Annual Progress Report</u>

November 1, 1974 to October 31, 1975

To the United States Agency
for International Development

Prepared by

Utah State University
Logan, Utah 84322
USA

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ANNUAL REPORT SUMMARY SHEET

Research on Agricultural Response to Water Management in Wet/Dry Climatic Zones
Contract Number AID/ta-c-1103

Project Title and Contract Number

A. Alvin Bishop, Utah State University

Principal Investigator and Contractor

Logan, Utah 84322

Contractor's Address

4-1-74 to 6-30-76	11-1-74 to 10-31-75
Contract Period (as amended) From-To	Reporting Period From-To
Total Expenditures and Obligations Through Previous Contract Year	$ 561,665
Total Expenditures and Obligations for Current Contract Year	$ 488,038*

*To Oct. 31, 1975: An additional $155,000 will be expended in accordance with funding authorization to April 15, 1976.

A – SUMMARY

Research work in Brazil, Ecuador, El Salvador, Guatemala, and Peru, complimented by data analysis on the USU campus, resulted in a number of significant findings and accomplishments. The predictive equations for the three-dimensional yield response surface for corn were developed and tested with data from El Salvador and Brazil. The response surface (water-fertilizer-yield) was verified and mapped. Similar research is well advanced for rice, tomatoes, onions, and pangola grass. Proposed irrigation developments in Colombia were shown to be extremely limited in the variety of crops that could be grown due to the high levels of phosphorus and heavy metals in the soil. A comparison of trickle and furrow irrigation indicated a slight yield advantage for furrow irrigation but required more water to be applied to maintain the same soil moisture levels. Methods for estimating potential evapotranspiration with limited data available in developing countries have been developed and are now being used in many locations. The efficiency of mole drainage for leaching and salinity control was verified, and methods for reducing the draft requirements of moling machines by vibration were tested.

Field work was continued and country ties strengthened in El Salvador and Brazil. Program agreements were developed and permanent staff was assigned to Peru, Guatemala, and Ecuador during the year. The water law digest for the Andean pact countries was expanded to include other countries of South America. Collection of data was started in the Andean Pact countries regarding the legal and institutional impact on water management decisions. The survey form was designed and a number of interviews completed.

Research results of direct local application were disseminated in field work regions by indigenous researchers and USU professionals who were intimately involved in the field research. Contract sponsored seminars were attended by over 100 LDC professionals who were trained in on-farm water management techniques. Seminars were conducted in the field as well as on the USU campus and a report thereof was distributed over a wide area. Over 1500 research reports were requested and supplied to people in 34 different countries and 33 states.

INTRODUCTION

This annual report describes activities, accomplishments, and utilization of research under contract AID/ta-c-1103 in on-farm water management.

Research emphasis within the objectives has been significantly influenced during the past two years by subsequent suggestions from AID and recommendations developed at the AID sponsored symposium on research needs for on-farm water management held at Park City, Utah, in October, 1973. The symposium recommendations, together with continuing counsel from the Technical Assistance Bureau of AID have been beneficial. Several USAID missions in Latin America and directors of collaborating LDC agencies have had a positive influence on the composition of the program.

South America continues to be the primary research area. USU staff is currently stationed in Brazil, Ecuador, El Salvador, Guatemala, and Peru. In addition, data for use in the water law and institutions, economics, and climatological components of the research are regularly collected from most of the other Latin American countries.

With the increasing use of a "systems" approach to research in food production, the technology transfer is enhanced for other developing areas.

The Park City Symposium suggested that three sequential steps in decision making need to be considered in defining research purposes. These are: (1) technological systems, (2) delivery systems and (3) incentives. Early contract resources were focused on the first step; however, as technological systems became more clearly defined, attention began to be given to technology delivery. Recently data from the institutional and economic components have added the "incentives" step. This year the proportion of available resources devoted to each system and each objective has been the target of much careful planning. In general, all activities are organized to logically fit within the "System Outline of On-Farm Water Management Research Program," (Appendix I)* with emphasis being a function of available financial and human resources, the research environment in a collaborating country, new breakthroughs in technology, and other factors.

The activities and significant findings during the past year are found in the following pages. Significant findings are listed, followed by a discussion of additional important accomplishments.

B – PROJECT OBJECTIVES

General Objective

The general objective of this research is to increase food production in the arid and sub-humid lands of the less developed countries through the improvement of water management practices and the integration of these with other good management practices in the semi-arid lands of the Latin American region; but, this will be applicable in principle to similar conditions in other regions. This improvement of water management practices is necessary to obtain maximum economic returns from limited water resources and such inputs as improved seeds, increased use of fertilizers and pesticides, and supporting institutional structure.

Specific Objectives

The specific research studies have been selected to meet the high priority needs of the Latin American area but with intended application and adaptation to other developing countries.

1. Development of farming practices including methods, timing, and amounts of water applied to the land which optimize the use of water from rain and irrigation within the constraints of climate, soils, markets, infrastructure, and interaction with other agricultural practices.

2. Development and adaptation of efficient water control and delivery systems especially for on-farm use.

3. Development of strategies for minimizing the deleterious effects on crops of excess surface and subsurface water, poor water quality, and excessive concentrations of soil salinity, exchangeable sodium and other toxic elements.

4. Identification of institutional and policy factors (legal, social, economic, manpower, credit,

*Appendix I is Figure 3, Page 27 of 5th Annual Progress Report.

etc.) that influence the efficient distribution, management, and utilization of water at the farm level, and the development of strategies for replacing inhibiting factors with facilitating factors.

C – ACCOMPLISHMENTS TO DATE FOR CURRENT YEAR

1 – Findings

a – **Water x Nitrogen Interaction and Crop Yield Response Functions.** Many types of field activities are included in the USU on-farm water management research project. The main experimental design is focused on the development of crop yield response functions of soil moisture and soil fertility. Soil moisture is most frequently analyzed with nitrogen fertility because of the profound interaction between these two plant growth factors.

Data developed during the year relate to the soil water x fertility response functions for corn, upland rice, and pangola grass in El Salvador, and corn, onions, and tomatoes in Northeast Brazil. These response functions deal with a variety of soil and climatic conditions.

Examples of results obtained are two response functions from corn experiments: One from El Salvador, and the other from Northeast Brazil.

Figure 1 gives the predicted corn yield results from a regression equation constructed from measured yield results in El Salvador, as related to

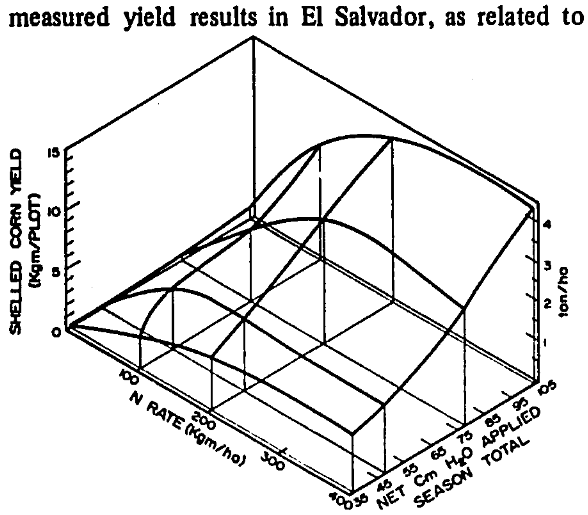


Figure 1. Response surface for corn yield vs. soil moisture and nitrogen fertility, El Salvador. There was some stored water but no stored nitrogen at the beginning of the season. Net water applied is the difference between total input and total output to the furrows. Irrigation frequency varied from 4 at the lowest irrigation level to 19 at the highest irrigation level for the season. These results are from the second year of a 3-year work plan.

applied nitrogen and water. In this figure, the water response is based on total net water applied for the season. Several other kinds of soil water indices are possible. Before the project is concluded, one index will be developed that best describes total seasonal irrigation or soil moisture regime. This index will need to be readily convertible to economic terms so the crop yield can be converted to net economic returns. The soil nitrogen fertility index in Figure 1 is simply a function of actual fertilizer nitrogen applied. Ultimately, this index will be a function of both stored or residual soil nitrogen plus current season applied nitrogen. Soil nitrogen studies that are being conducted simultaneously will provide for a soil fertility nitrogen index.

The goodness of fit term (multiple coefficient of determination) for Figure 1 was $R^2 = .93$. This indicates, among other things, that the field control of the experimental variables was nearly perfect. This project is in its second year of an original three-year work plan.

A comparison study of furrow and drip irrigation carried out simultaneously produced a response surface which was essentially identical to that of Figure 1. There was a difference, however, in overall yield which favored the furrow irrigation method. This will be mentioned later.

Corn response to water and nitrogen individually was highly significant, as was the combined or interaction effects of water and nitrogen.

There are several noteworthy features in Figure 1. First, the response to water was convex upward at all real levels of nitrogen to and including the most frequent irrigation applications. Usually, crop water functions go through a maximum and then decrease at the higher water levels because of over-irrigation effects. The same water response shown in Figure 1 was also obtained the previous year at this site. Special efforts were made this year to stress the upper end of the moisture scale by over-irrigation. The crop yields at the high soil moisture level in Figure 1 indicate that over-watering did not reduce yields. These results tend to support a hypothesis advanced by E. Bresler (Institute of Soils and Water, Volcani Center, Israel, private communication), that there is a

Photo 1 Preparing an experimental plot for an irrigation trial in El Salvador. Local project needs including labor, land, water, seeds, pesticides, etc., are supplied by the El Salvador Ministry of Agriculture.

significant plant growth response to soil moisture between 0 and 1/3 atmosphere total soil moisture potential (i.e., at greater than field capacity moisture content).

Another feature of Figure 1 is that there is no response to water except in the presence of nitrogen. Some response to nitrogen occurred at the lowest level of water availability perhaps because of the added effect of some stored soil moisture. The field plots were deliberately managed to minimize residual nitrogen by growing sorghum during the wet season without fertilization. This was done to facilitate development of the soil fertility nitrogen index referred to above. Figure 1 indicates that 200 kg nitrogen was required for maximum yield of the variety tested. Other data indicate that 150 kg nitrogen or less will be required to attain the same yield potential depending on the intensity of nitrogen fertility management for the preceding crop.

Figure 2, the first set of results from a 3-year planned project, shows a corn yield response function sharply contrasting with that in Figure 1. Figure 2 was derived from the Northeast Brazil data. In Figure 2, the water availability scale is expressed as a function of the percent of available water remaining when the irrigation water was applied. It is apparent from Figure 2 that there was a significant storage or carry-over of both nitrogen and water at the beginning of the season. Responses to applied nitrogen and water were statistically significant as was the water and nitrogen interaction. The agreement between the predicted yields (Figure 2 based on a regression model) and measured yields (not shown) was less precise than in the El Salvador work discussed above.

In Figure 2, the goodness of fit was $R^2 = .50$. This may be attributed to two elements. First, the specific regression equation selected may need to be altered, and second, control of the experimental

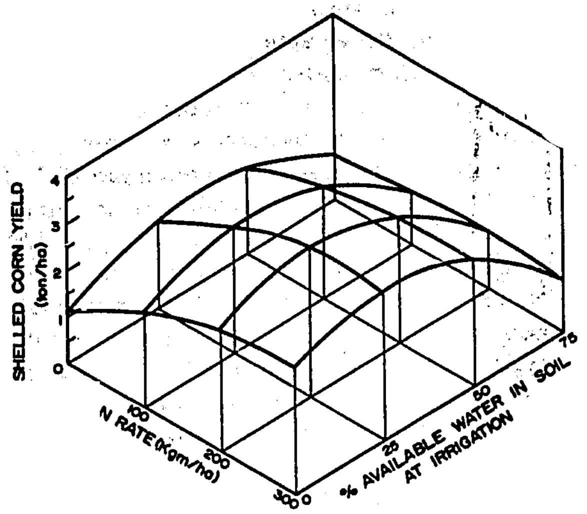


Figure 2. Response surface for corn yield vs. soil moisture and nitrogen fertility, Northeast Brazil. Soil moisture storage and soil nitrogen were both appreciable at the beginning of the season. Irrigation frequency varied from one on the driest plots to 12 on the wettest plots for the season.

variables in the field undoubtedly needs improvement. Experience gained in the initial season will provide guidelines for controlling the soil moisture in the second and third years of the work plan.

In Figure 2, the water response yield functions go through a well-defined maximum. The effect of over-irrigation was more drastic than planned for, as optimum irrigation was apparently at the 25% index level. It is evident that the specific soil depth used to signal moisture stress may need to be reevaluated to give a better distribution along the moisture index scale.

The nitrogen yield function will be better defined in future trials by covering greater stress at the extremes of nitrogen availability. In Figure 2, the lowest fertilizer treatment (zero N) was not severely low, evidently because residual nitrogen from previous seasons was appreciable. On the other hand, the highest fertilizer treatment (300 kg N/ha) was not

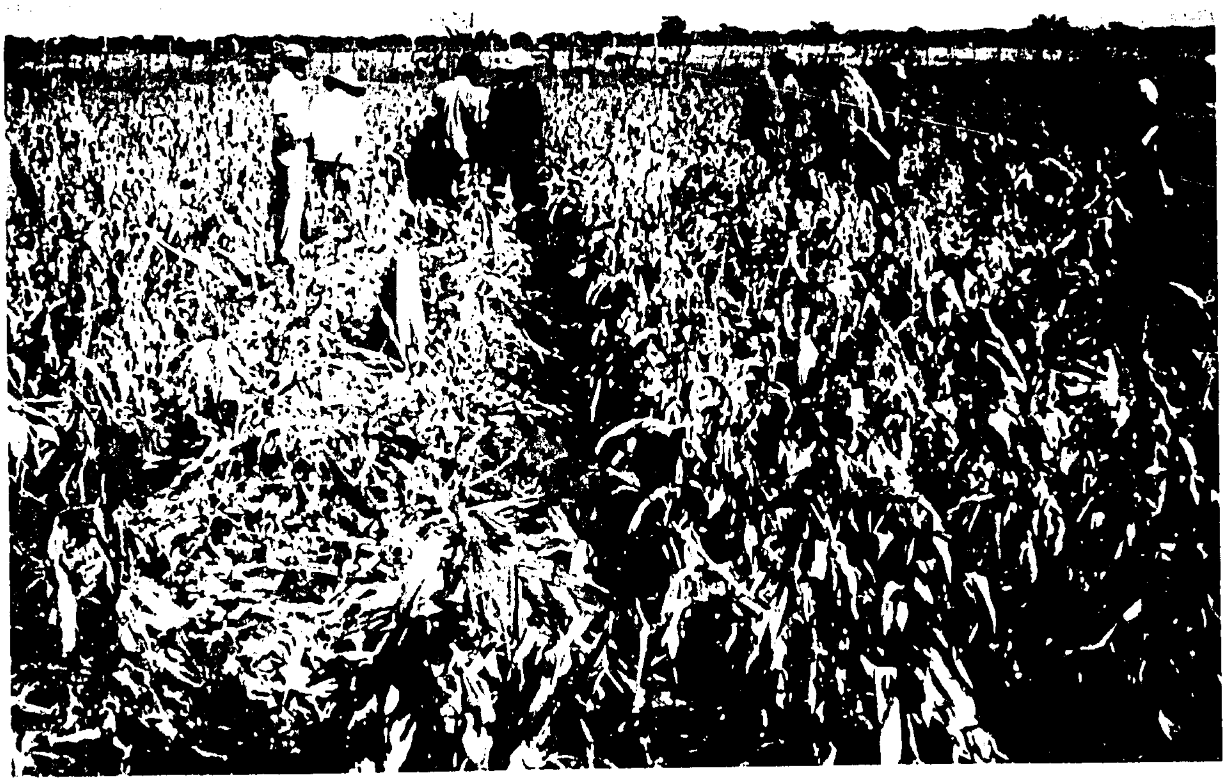


Photo 2 Collecting corn harvest samples in Brazil. USU agronomist Don Kidman concludes a pilot trial on soil water x fertility interaction during the first year of the USU program in this area.

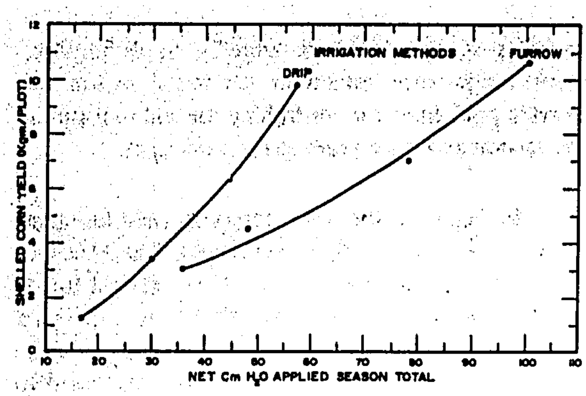


Figure 3. Shelled corn yield as related to method and rate of irrigation, El Salvador. Irrigation frequency under the drip method was 4 on the driest end and 23 on the wettest end. See Figure 1 for frequencies on the furrow plots. Each point is the average of 12 observations (3 replications and 4 nitrogen levels).

excessive since the nitrogen yield response had no apparent maximum. These observations will guide future experimental tactics.

The overall level of yield in this trial is much lower than that given for El Salvador. This is attributed to the use of the only available corn variety at the beginning of the project and does not represent the best corn variety available in the area. This factor, of course, will be evaluated in detail as the project advances. It is believed that the shape of the response surface in Figure 2 is a good approximation of better yielding cultivars.

As previously stated, furrow and drip irrigation methods were compared in a nitrogen and irrigation rate study on corn. The results indicated that there was larger yield under furrow than under drip irrigation. This kind of response was not seen in previous years. This effect is shown in Figure 3 where corn yield is compared with method and amount of water applied. It was concluded that the yield difference between methods was related to the difference in amount of water stored in the soil. Thus, these results do not alter earlier conclusions that crops do not respond to method of water application as long as the amount of water applied is sufficient. In other words, plants respond to water in the soil and not necessarily to the pathway by which it arrives. In terms of yield per cm of applied water, furrow irrigation required about 60% more water than did the drip system.

b – **Effects of Phosphorus and Heavy Metals on Irrigated Crops in Colombia.** It had previously been shown that poor irrigated crop performance mitigated against profitable irrigation agriculture in the heavy soil section of the Atlantico #3 Irrigation District of Colombia. With the exception of rice, all test crops grown were characterized by extremely variable growth. The crops tested, in order of increasing severity of the growth disorders were: cotton, soybean, sesame, sorghum, and corn. Cotton gave 87% of expected yield, based on production in lighter textured soils in the same area, and corn gave 37% expected yield. However, flooded rice gave 118% expected yield amounting to more than 7 metric tons of grain per hectare. Flooded rice culture apparently was not affected by the disorders seen in other crops. Therefore, it was concluded that paddy rice was a reasonable alternative for crops originally intended for production in the area.

The lack of crop response to irrigation culture was previously attributed to salty soil. Field areas with stunted crop growth and decreased overall average production, varied from 5 to 50 meters in diameter. Research showed conclusively that salt was not the limiting factor on these heavy soils, since the pH was between 6.5 and 7.2 and the ECe was less than 2.0. Negative responses were obtained to phosphorus fertilizer as were negative correlations between crop growth and available soil phosphorus. Negative response to foliar applied micro-elements was also observed.

Chemical analysis of several hundred soil samples taken from the problem area gave the following results:

Phosphorus: Total phosphorus ranged from 0.39 to 1.65% in the soil compared to .02 to .08% total phosphorus in normal arable soils. Available soil phosphorus as estimated by the sodium bicarbonate method ranged from 10.4 ppm P, a moderate level, to 77 ppm P, a very high level. The soil test phosphorus by itself would indicate very little or no effect from soil phosphorus, either from the point of view of deficiencies or excesses; but, there was a strong association between total phosphorus and soil test phosphorus (correlation coefficient, $r = .89$), a relationship that has not been observed before and is not known to be reported in any of the world's literature. In addition, there was a notable negative correlation (correlation coefficient, $r = -0.81$) between soil test phosphorus and corn growth. Therefore, the extremely high level of indigenous soil phosphorus is strongly implicated as a factor in poor crop growth.

Heavy Metals: Soil samples were extracted with DTPA, an organic compound that chelates or solubilizes metal ions. A group of samples taken from a transect through a problem soil area was analyzed with DTPA. The results obtained were compared with normal, fertile soils. The comparison follows: See Table 1.

Table 1. Heavy metals extracted from Atlantico Colombia problem soils compared with levels needed for plant nutrient deficiency.

Element	DTPA Extractable-ppm		*Levels needed for nutrient deficiency
	Mean	Range	
Fe	46.3	18–96	2.5
Zn	5.5	2.2–11	0.5
Cu	4.4	2.4–7.1	0.2
Ni	2.1	1.1–3.5	—
Co	.7	.2–1.3	—

*Data from Colorado, U.S.A.

Manganese was also analyzed in this soils, but no conclusions could be drawn from the results for this element because the soils were heat-sterilized when brought into the U.S. Ordinarily, nickel is present in such small quantities that it is not detected by the DTPA procedure. The nickel shown in the Malambito soils is notable because it was present in appreciable amounts. Nickel is not a plant nutrient element but is known to be toxic to plants under certain conditions.

Cobalt is also present in normal soils in very small amounts. The amount shown above for this element would indicate no deficiency, but there is a potential for cobalt toxicity.

The results for iron, zinc, and copper indicate that these elements were high to extremely high in the soils. It was inferred that micro-nutrient imbalances existed because of the large amounts of the heavy elements present. It was also inferred that the strong association found between phosphorus and the heavy metals pointed to an interaction that confounded the total plant nutritional complex. Additional work, especially with plant tissue analyses, would be required to substantiate these inferences. The tentative conclusions made as a result of this work were that several nutrient elements, all of geologic origin, were present in such quantities that normal crop production was impossible to achieve with presently known technology.

c – **Climatological Data and Potential Evapotranspiration.** Data from a number of typical countries show that potential evapotranspiration can be estimated with a high degree of confidence from a small number of common climatic factors. The research has shown that a product of mean temperature and incoming solar radiation will estimate potential evapotranspiration within $\pm 5\%$. These basic equations are:

$$ETP = 0.0075\ RSM \times TMF \quad \ldots\ldots\ldots (1)$$

where ETP = monthly potential evapotranspiration mm

TMF = monthly mean temperature °F

$$RSM = 10\ DM \times RS/L \quad \ldots\ldots\ldots (2)$$

or $$RSM = 0.075\ RMM \times S^{1/2} \quad \ldots\ldots\ldots (3)$$

where DM = number of days in the month

RS = incident solar radiation, Langleys per day

L = Latent heat of vaporization, cal/gm

RMM = extraterrestrial radiation in equivalent monthly mm of evaporation

S = the percentage of possible sunshine

Equation 1 is a significant contribution to the literature on the calculation of potential evapotranspiration.

d – **Mole Drains.** Previous research reports have described economic design of single and double mole plows and their use combined with tile drainage systems. During the year it was found that more salt was leached from the moled area than the unmoled control area per unit volume of water applied. The results are shown in Table 2.

It was also found that significant reduction in draft power requirements could be achieved by vibrating the mole plow. This reduction ranged from 60% at a vibration frequency of 92 cycles per second and soil moisture content of 35% to 22% when the vibration frequency was 43 cycles per second and the soil moisture was 24%. The vibration amplitude was held constant at about 1 mm.

There is an optimum frequency for a given soil moisture both for minimum draft and optimum channel strength and water collecting capability. The relation between draft, moisture content, and vibration frequency was given by

$$Y = 439.57 - 1.3 X_2 - 0.22 X_1^2$$

where Y = draft in pounds
X_1 = vibration frequency in cycles per second
X_2 = soil moisture content, percent.

The utility of mole drains in clayey soils for economically controlling the water table and salt concentration in the upper 18 to 24 inches of soil is thought to have applicability in many developing countries.

Table 2. Initial salt concentrations (X) of the soil samples and total reductions of salt (Y) after irrigation in tons per acre.

Treatment							
1 6 ft spacing		2 12 ft spacing		3 24 ft spacing		4 Control Plot	
X	Y	X	Y	X	Y	X	Y
7.526	5.881	1.010	.233	1.281	.529	1.130	.237
2.168	1.166	1.011	.254	1.462	.485	1.669	.322
3.093	2.004	5.063	.756	1.427	.385	4.875	1.277
6.888	5.794	1.131	.410	.824	.056	1.818	.363
3.979	2.608	1.568	.594	1.399	.526	2.923	.371
3.154	1.614	5.423	1.225	2.625	.476	3.952	.954
7.311	4.098	1.303	.477	.858	.075	6.990	.920
2.946	1.683	2.747	1.314	1.301	.384	5.741	-.521
6.660	4.991	4.873	2.553	6.265	4.343	7.642	.971
Total 43.725	29.839	24.129	7.816	17.442	7.259	36.740	4.894

These data show that there are differences in leaching effectiveness from one treatment to another. The salt removed from the area with 6 ft mole spacing totaled 29 + tons/ac compared to about 5 tons/ac from the control (unmoled plots). There appears to be no great differences between the 12 ft and 24 ft spacings.

e — **Labor-Intensive Water Management.** In previous annual reports, it has been shown that the increase in net economic returns to farmers using supplemental irrigation is very attractive and could easily justify greater adoption of the simple pump or tide techniques. The results reported here show that some modification of this earlier conclusion should be considered. Observation indicates that improved financial results may be associated with some significant inefficiencies.

In the Guayas Basin, Ecuador, summer rice is grown in depressions that retain winter rainfall. Some farmers are able to supplement stored water by utilizing small pumps or river diversions made possible by action of tides. Key findings of a statistical analysis of data from 66 small farmers are presented in Table 3.

Table 3. Division of gross returns per hectare among input factors and efficiency of relative resource levels in summer rice production under campesino cultivation practices – Guayas Basin.

Input Factor	Value of factor marginal products (sucres/ha)	Value of factor share in gross returns* (sucres/ha)
	Supplemental Irrigation (Av. gross returns: sucres/ha = 9433) N=22	
Land	1.65	4862
Capital	0.34	195
Labor	0.26	847
	Collected Rainfall (Av. gross returns: sucres/ha = 4215) N=44	
Land	0.66	2293
Capital	1.45	203
Labor	1.05	1649

*Sums of factor share do not exactly equal average gross returns due to variability of data.

1 – Land obtains the major share of the average gross returns under both cultivation systems, as would be expected in peasant agriculture, but the proportion rises under supplemental irrigation. None of the increase in gross returns goes to capital (rent of pump, etc.) unless farmers own the land. This suggests that benefits of supplemental irrigation can be extracted through land rents.

2 – Both capital and labor seem to be applied too heavily where supplemental irrigation is employed. This is indicated by the values of their marginal products which are only 0.34 and 0.26 sucres per sucre of factor input. No factor VMP should be less than 1.0 sucre. These data are not conclusive, but they suggest that the supplemental irrigation techniques require enough labor to cause farmers to earn (at the margin) less per unit of labor than labor is worth. Labor is utilized very efficiently in the non-irrigation method where land is overcommitted. Therefore both systems of summer rice cultivation indicate a need for adjustments in factor proportions so that the three VMPs (in each case) are closer to being equal (subject to $VMP_i > 1$).

3 – These results are good examples of the dangers of blindly advocating labor-intensive policies that may push the VMP of labor to zero even in situations where labor can be retained in activities providing positive returns.[1]

2 – Accomplishments

Closely related to the significant findings are a number of substantial accomplishments. These are briefly discussed under the following headings:

a – **Reports and Publications.** The publication of significant findings along with pertinent data and discussions is important. During the reporting period eight research publications and manuals have been issued (see Appendix II for listings of titles and authors). One example is "Water Requirements Manual for Irrigated Crops and Rainfed Agriculture." This manual, designed primarily for developing countries in tropical areas brings together the most useful relationships of weather, pan evaporation,

[1] In the Guayas Basin, no particular government policy "pushes" supplemental irrigation.

potential evapotranspiration, crop coefficients, irrigation efficiencies, and leaching requirements. Both hand and computer calculation of these and other relationships are greatly simplified. The manual is useful for irrigation scheduling, estimating dependable precipitation and moisture adequacy, production functions, critical periods of moisture stress, and calculating moisture availability indices. Relevant materials from over 20 different sources are organized in such a way that educated farmers, extension agents, agronomists, economists, and practicing engineers can make many of the needed crop water calculations that previously required a series of textbooks.

Other reports such as the "Irrigation Requirements and Precipitation Deficits," prepared for a number of specific countries, will also be beneficial. A typical computer printout showing data analysis from two stations in Costa Rica is shown in Appendix III. The contract professionals have been requested to conduct studies resulting in reports of special significance with "Irrigation and Drainage Systems and Organization of Rural Cooperatives in the Lower Guayas Basin, Ecuador" being one example.

b – **Establishing New Off-campus Research Bases and Linkages.** The establishment of a significant research activity within the developing country arena is a major achievement requiring continued efforts over long periods. The work of previous years continuing into the reporting period resulted in research activities being established in Brazil, Peru, Guatemala, and Ecuador. Permanent staff was stationed in these four countries during the year resulting in a relationship with USAID's and host country governments. Program agreements have been negotiated and field research initiated, committing support by the host country. In Brazil, for example, the researcher was able to organize, select the site, plant, and harvest the first experimental crops in the first year of residence. In both Peru and Guatemala, program agreements were negotiated, experimental sites selected, cour rparts assigned, and field plots planted.

c – **Continuing a Significant Program.** Closely related to establishing a significant program is the achievement of maintaining a workable program overseas. Work progressed on the water-crop-fertilizer management research in El Salvador. Country ties were strengthened and research activities expanded to include new research designs and tools. The point source continuous water variable tool with its simplifications was used for the first time and reliable results obtained. The water-crop-fertilizer interaction studies were expanded to Peru, Guatemala, and Brazil to test and improve the transferrability and regionality of water management.

The "Water Law Digest for the Andean Pact Countries" was expanded to include the whole of South America. Expansion of this important work began in Argentina, Venezuela, Brazil, and Paraguay.

d – **Andean Irrigation Institutional Research.** Sequels to the water law study are the legal and institutional impacts on on-farm water management decisions. A survey form for the institutional study was designed by on-campus staff and tested in the field (See Appendix IV). Instructions for interviewers were prepared and a number of interviews and data forms completed by the researcher stationed in Ecuador. Supplemental financing was obtained from Resources for the Future for the work in Chile. Preliminary work was done in Bolivia, Colombia, and Peru to conduct interviews and obtain data from these countries. These activities are additional significant accomplishments.

e – **Organizing and Conducting Seminars and Short Courses.** A water management seminar was held in El Salvador in March highlighting the water management research work in El Salvador under CENTA-DGRD-USAID-USU collaboration. This seminar was attended by 22 professionals from the El Salvador Ministry of Agriculture and discussions were organized and led by four USU staff. Utah State personnel were intimately involved in organizing and managing the Global Water Law Seminar held in Spain in September. A special on-campus course was organized for five irrigation engineers from Guatemala. Regular courses were taken with all lectures and discussions given in Spanish. On-campus seminars reporting project research are held several times each year with the graduate students of the Agricultural and Irrigation Engineering Department. Many of these students come from developing countries with fourteen countries being represented at the present time. Project research staff also presented papers at American Society of Agronomy meetings held in August.

f – **Predictive Techniques.** Methods for predicting the effects of climate on crop yields and the response of various crops and varieties to climatological events and influences have been developed. Implementation of computerized systems has resulted in immediate access to large data banks and the handling of large quantities of data. The early emphasis has been directed to corn and soybean crops with encouraging possibilities.

3 – Operational Significance, Side Effects, and Research Design

Water-Crop Response Functions

There is very little water management information available for tropical conditions, especially for the developing countries. With increasing energy and fertilizer costs, the development of crop varieties which show dramatic responses to water and fertilizer, farmers urgently need information concerning the optimal amounts of these manageable resources and the optimal fertilizer application rates under constrained water availability. Under rainfed agriculture, the response surface data may be even more important and used to recommend fertilizer applications for various rainfall amounts. The water-fertilizer-crop interaction is the pivotal point of on-farm water management and only by a continuing field research program can this data be generated.

Indigenous researchers are only now beginning to realize the need for combining both water and fertilizer variables in one experimental design. Their training has in general prepared them for one variable type research.

Considerable effort has gone into the investigation of alternative procedures for increasing the efficiency of irrigation field investigations. This work has been pioneered at the Utah State University campus and has been tested on a pilot scale in various field sites. The collaboration with local and foreign projects has facilitated the research being done in both areas. The evaluation of alternative research procedures has followed two lines:

(a) method of establishing and maintaining soil moisture variables

(b) field plot design

a – Continuous Water Variable

To simplify maintenance of field moisture regimes, the concept of a continuous water variable was introduced and has been under investigation in Utah and El Salvador. Continuous variable means that irrigation water is applied so that it decreases continuously from some high rate at the point of origin to zero at some point at a given distance from the origin. Thus, there is an infinite array of discrete levels that differ regularly or in a nonrandom way. The continuous water variable is established and maintained using a sprinkler nozzle with a cone-shaped distribution pattern. In other words, the rate of water application decreases linearly with distance.

A single sprinkler nozzle may be a point source. An example of this method is given in a study with irrigated upland rice in El Salvador. Here, six nitrogen fertilizer treatments were randomized in 60° arc sections around the circle. Replication was achieved using three non-overlapping sprinklers with a fixed random nitrogen treatment rotated 120° from one circle to another (see frontpiece).

Another continuous water variable, called the line source, was obtained by arranging risers along a sprinkler line at such close spacing that water distribution was essentially constant along any line parallel to the sprinkler line. The line source was obtained by spacing sprinklers at 6 m, making the overlap 240%. Other controlled variables, such as fertilizer rate, plant density, or crop variety were arranged at right angles to the line source. These variables were randomized and then replicated in separate blocks along the line. A control plot was selected at some distance from the point or line source which was used as a reference for irrigation scheduling. This reference may be a predetermined soil moisture stress or some function based on evapotranspiration. When this point received the reference amount of water, all points close to the source received progressively larger amounts of water (over-irrigation), and all points further from the line source were progressively under-irrigated.

The outstanding advantage of the continuous water variable is that an array of application rates is obtained by use of a single valve. Thus, stresses at the extremes of soil water availability are easily achieved and crop water response functions obtained at a minimum of cost.

Photo 3 shows a line source on a companion experiment on corn at Logan, Utah, beside a conventional soil fertility experimental plot. The infrared film used shows both fertilizer and water stress in the line source experiment.

The yield axes of figures 1, 2, and 3 can be replaced by net economic return as mentioned elsewhere in this report. Data to effect this refinement have been collected from several Latin American countries.

b – Field Plot Design

Field experiments with irrigation have been reduced in size and cost by adapting certain kinds of

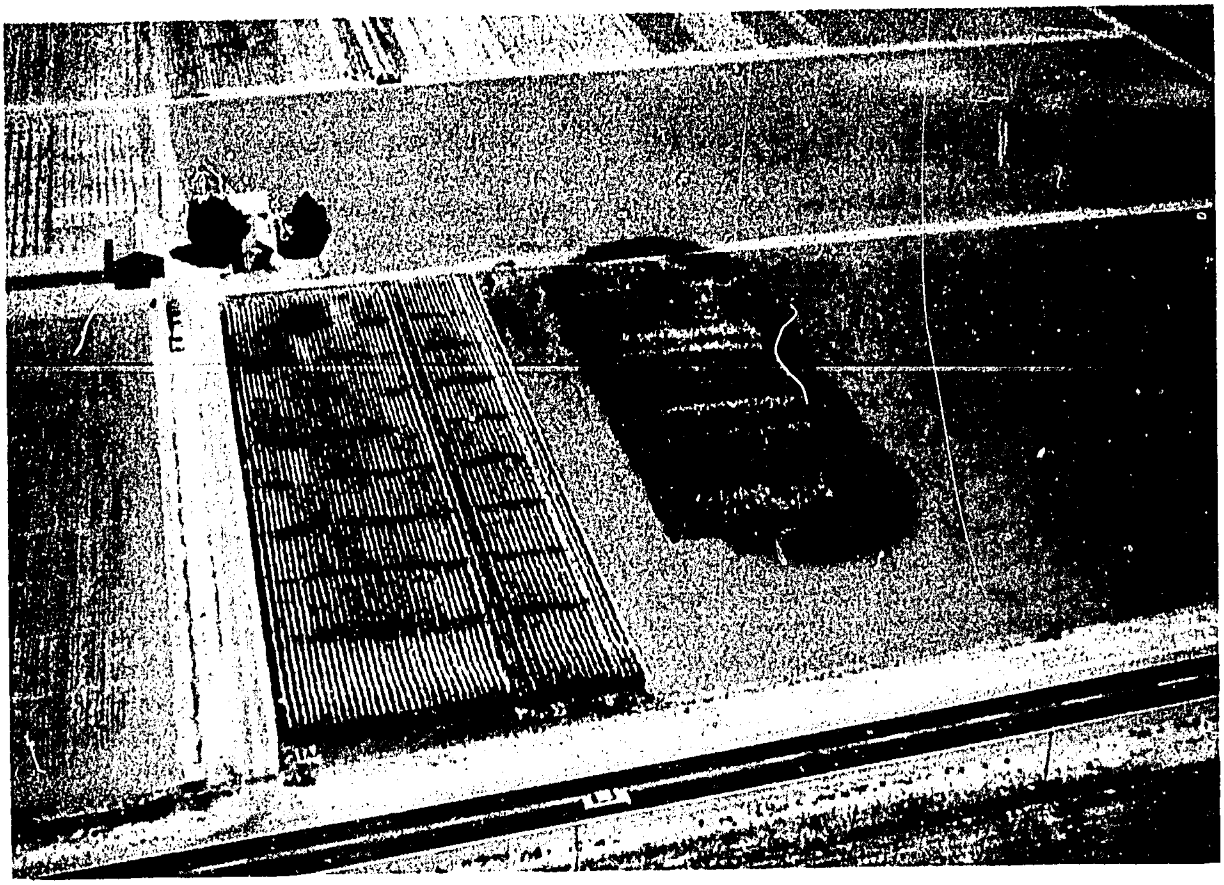


Photo 3. Infrared aerial shot of line source water x fertilizer corn experiments beside conventional wheat plots at the USU experimental farm. Water and nutrient stress in the corn plots show up as different color hues.

experimental design utilizing incomplete factorial or partial replication.

Examples of the kinds of designs deployed in the field follow:

(a) Incomplete replication. One field project had three irrigation regimes and eight nitrogen fertilizer treatments in four replications. For a complete design this would require a total of 12 whole plots and 96 split plots. The experiment was reduced by fixing the second irrigation level at a reference or "optimum level" in four replications and establishing water treatment 1 in reps 1 and 3 and water treatment 3 in reps 2 and 4. Thus, there were 8 whole plots and 64 split plots, a saving of 1/4 in time and space.

(b) Another design involved four water levels, five nitrogen levels, and eight varieties in three replications giving a total of 12 whole plots and 60 nitrogen plots. This experiment was reduced (through an incomplete water x nitrogen factorial) by fixing the number of split plots to 3 nitrogen levels in each whole plot. This gave a saving of about 2/5 in time and space with essentially no loss in information in regard to the building of the nitrogen x water interaction response surface.

The problem with such split-plot designs is that the experimental error term for the whole plot is different than the error term for the smaller or split plots. Special computer techniques have been developed to estimate experimental errors in the non-orthogonal split-plot designs.

The purpose of carrying out these field experiments is threefold: to supply specific recommendations to farmers in the region of the plots, to provide inputs to the crop modeling studies so the data can be made transferrable to other areas, and to assist indigenous collaborating researchers to become proficient in the design, operation, analysis, and interpretation of the research. Each purpose is well served by running these experiments under a variety of soils and climates.

c – Irrigation Method

Irrigation methods experiments are designed to adapt the findings of U.S. research to developing country conditions where labor costs are much lower, power costs higher, equipment is of variable quality, water is of variable quality and quantity, and legal and social constraints differ from those in the U.S.

Photo 4. Dr. Tom Fullerton, USU Agronomist, discusses an irrigated corn trial with El Salvador extension personnel. The demonstrational values of field plots are utilized in educational activities on irrigated crop production management. (Below)

The rapid progress in the technology of water spreading on cropland requires a continuing comparative evaluation of alternatives.

Until recently there has been little interest in low-pressure sprinklers. Few have been designed. Out of forty companies invited to submit sprinkler nozzles for evaluation at low pressures, only three had equipment they felt might be applicable.

These will be evaluated and several new nozzle configurations proposed by USU researchers will be tested. If acceptable operating pressures of about 15 psi can be introduced, this will open new opportunities for farming under sprinkler irrigation.

d – Climatological Data Analysis and Utilization

Considerable staff experience in the field has verified that the simple equations of Blaney and Criddle and Thorthwaite have been extensively used without proper regard to their limitations under local conditions. Equations developed by this research should meet this problem. The equations have the advantage, as compared to other methods, of being applicable over a wide variety of climates and in spite of their simplicity are at least as accurate and often more so than the Penman-type equations. Accurate evapotranspiration estimates are essential in the design of irrigation systems and the apportionment of water to individual farmers.

e – Drainage Method

This year's progress on mole drains has put USU in an position to respond to demands for mole drain installation specifications. Mole drains have a specific utility in helping tropical area farmers quickly drain lands at the end of (or even during) the rainy season in order to get an extra crop on the land. Slow draining clay soils often cost farmers a crop in a continuous cropping potential situation.

f – Predictive Techniques

Predictive techniques provide a technology for transferring crop-environment interaction data from areas where the data have been collected to regions where the field research has been inadequate. Methods for simulating crop responses are now being developed. With them, computer simulation of crop growth is feasible. The objective is to be able to take local available information in a developing area, apply the predictive techniques, simulate the growth of the crop, and determine its performance before resources are committed and management strategies developed.

g – Water Law Digest

Although the published digest has proved to be a useful tool for those drafting and enforcing water legislation, its Andean Pact country base limits its utility. Expansion to include other countries will broaden the base.

h – Irrigation Institutional Research

This program is designed to determine both the subtle and profound ways irrigation institutions control and facilitate or inhibit good management of water.

The Ford Foundation has agreed to finance the data collection for the Chilean component of this program. Copies of the institutional and farmer questionnaire are included as Appendices IVa and IVb.

D – DISSEMINATION AND UTILIZATION RESEARCH RESULTS

1 – Project Output

Eight reports and theses prepared during this reporting period are listed in Appendix II. Last year's progress report listed all technical reports prepared to date, October 31, 1974.

2 – Dissemination

Requests for 1175 copies of the Water Law Digest have come from 20 countries and 11 states. Toward the end of the reporting year, 250 Spanish and 1000 English brochures advertising the digest were sent to libraries in North and South America and Spain. Requests generated by this mailing are beginning to come in.

The climatological studies have produced requests from 21 countries, FAO, and 22 states. Every continent is represented in the list.

Approximately 350 requests for all other project generated reports were received. The rate of requests has increased significantly since AID began publishing its Research Abstracts. Appendix V lists countries and states requesting reports.

Research professionals presented a paper at the annual meeting of the American Society of Agronomy, August 1975, entitled "Irrigated Yield Potentials for Corn, Beans, Soybeans, and Upland Rice in the Atiocoyo Irrigation District of El Salvador" by T. M. Fullerton, R. K. Stutler, E. R. Shipe, and D. W. James.

The paper "Moisture Availability and Crop Production" by George H. Hargreaves was prepared and submitted for release during 1976 in Transactions of the American Society of Agricultural Engineers. USU staff participated in the AID sponsored Arid Lands Symposium held in March in Saltillo, Mexico, where papers were presented to about 30 professionals.

A water management seminar held in El Salvador in March was attended by 22 professionals from the Research and Extension Departments of the Ministry of Agriculture (DGRD and CENTA). Four USU professors were discussion leaders. Attention was focused on research work being done through CENTA-DGRD-USAID-USU collaboration. Illustrated pamphlets describing farm irrigation techniques to assist extension agents in farmer education were prepared.

Several seminars dealing with project research were presented to USU graduate students from about 20 LDCs.

A group of 5 Guatemalan engineers spent summer quarter at USU working on special programs in the Department of Agricultural and Irrigation Engineering. All course work was carried out in Spanish by five of the department's professors, all of whom made significant use of the research findings and activities.

Contract research activities are being carried out in close collaboration with indigenous research agencies. It is an integral part of the plan of work. This results in a direct dissemination among the LDC staff and a more diffuse but substantial dissemination with extension agents and hence to farmers. An example of typical relationships between USU field staff and indigenous researchers and administrators is included in Appendix V.

Considerable contract-generated data have been transmitted in accordance with the needs of specific users. For example, at the request of the University of California at Riverside and the Consortium for International Development (CID), computer printouts of climatological data for 10 African countries were provided. These included precipitation, moisture deficits, and a moisture availability index for use in connection with AID financed studies in these countries. Peruvian climatological data analyses including irrigation requirements, precipitation, and moisture availability indices were provided to the Peruvian government and to Dr. William E. Hart of Colorado State University in connection with a USAID sponsored study. Updated computer printouts of climatological data analysis were prepared on request for collaborating agencies' specialists in Colombia, Ecuador, Guatemala, Brazil, and El Salvador. The Colorado State University team in Pakistan (AID Contract) requested and received assistance from USU in preparing recommendations to the Pakistan Agricultural Research Council for trickle and sprinkle irrigation. USU professors visited Pakistan and presented a report on the subject in April 1975. Under an AID Basic Ordering Agreement, USU staff prepared a report "Irrigation and Drainage Systems and Organization of Rural Cooperatives in the Lower Guayas Basin, Ecuador" and presented a seminar on design and planning of irrigation systems.

Colorado State University research data on corn production were made available for use in the USU crop simulation system. Considerable crop production data are also being collected from researchers in other areas, especially the midwest. USU's 211-d grant has had a major role in bringing together major researchers in crop production to provide guidelines in simulated cropping. This has generated important linkages and multiple information flow channels among American and some foreign researchers in this field.

Seminars have also been held in Brazil where the project research findings were prominently featured. Researchers and extension agents were the

Photo 5. Pre-irrigating a field in Guatemala. Note the check dams being installed in the furrows during irrigation. Water distribution was very poor – the amount of water applied was too low, even at the upper end of the furrows where contact time was longest. The USU program will evaluate and demonstrate the most effective water application methods in obtaining a desirable soil moisture condition for establishing and maintaining vigorous crop growth.

participants. Counterparts gave several of the presentations.

3 – Utilization

There is normally a significant lag between research findings and application. There are also problems in identification of the utilization of research results. However, a number of subtle changes in water use in several Latin American countries indicate the research is having an impact. The following examples are noted:

a – In Chile's Aconcagúa Valley, a doubling of corn yield resulted from changing to furrow irrigation, providing better water-fertilizer management in the same area and better land preparation for soil moisture conservation.

b – The Colombian government now recognizes the limitations of the soils in their northwest for irrigation development.

c – Ecuadorian water law has been modified during their hydraulic institute's involvement in the preparation of the water law digest.

d – In Colombia the yield of corn increased by using mole plows to control the water table on a farm near Bogota.

e – Viable water management research activities are now taking place on six stations in Northeast Brazil.

The Agricultural Research Agency of Brazil's Ministry of Agriculture has used many of the recommendations made by USU staff in establishing a major water management research facility at Petrolina, Pernambuco. They are currently recruiting 50 professionals and 200 technicians to man this station. Satellite stations are planned throughout the Northeast. A new agreement between EMBRAPA USU and USAID will provide for 2 USU professionals. They will be funded by this contract. Most of their in-country costs and travel for short term USU consultants will be funded by EMBRAPA.

f – Climatological analyses techniques developed by USU are being used for making agricultural decisions in North Africa's Sahel, Brazil, Colombia, Ecuador, Peru, Bolivia, and Central America.

It is expected, by virtue of the publications requested and the counterpart and seminar contact made, that these examples form a minor part of the utilization of the research results to date.

4 – Feedback

Reference has already been made to document requests. See Appendix V for a listing of countries and states requesting reports during the year. Peru has requested permission to translate one of the publications into Spanish. Feedback from LDCs and USAIDs has resulted in changes in program emphasis.

5 – LDC Involvement

In each country where USU staff is working, the program reflects the desires of the collaborating agencies as well as USU's contract obligations. One of the difficulties is that frequently, counterparts assigned to work with USU researchers are moved into administrative positions at some other location after a few month's work on the program. This is largely due to the shortage of experienced administrators and rapidly expanding research programs and will not be resolved utnil sufficient trained people are available. This turnover has both positive and negative effects; negative because it means slowing down research work while new relationships are established and positive because of an increased diffusion or transfer effect. In spite of these obstacles which are part of the landscape in a developing country, USU-indigenous worker relationships are currently satisfactory to excellent.

E – PLAN OF WORK

Figure 4 summarizes the program planned for 1976. These activities will meet the needs of the current agreements with USAID missions, host agencies, and the AID program objectives.

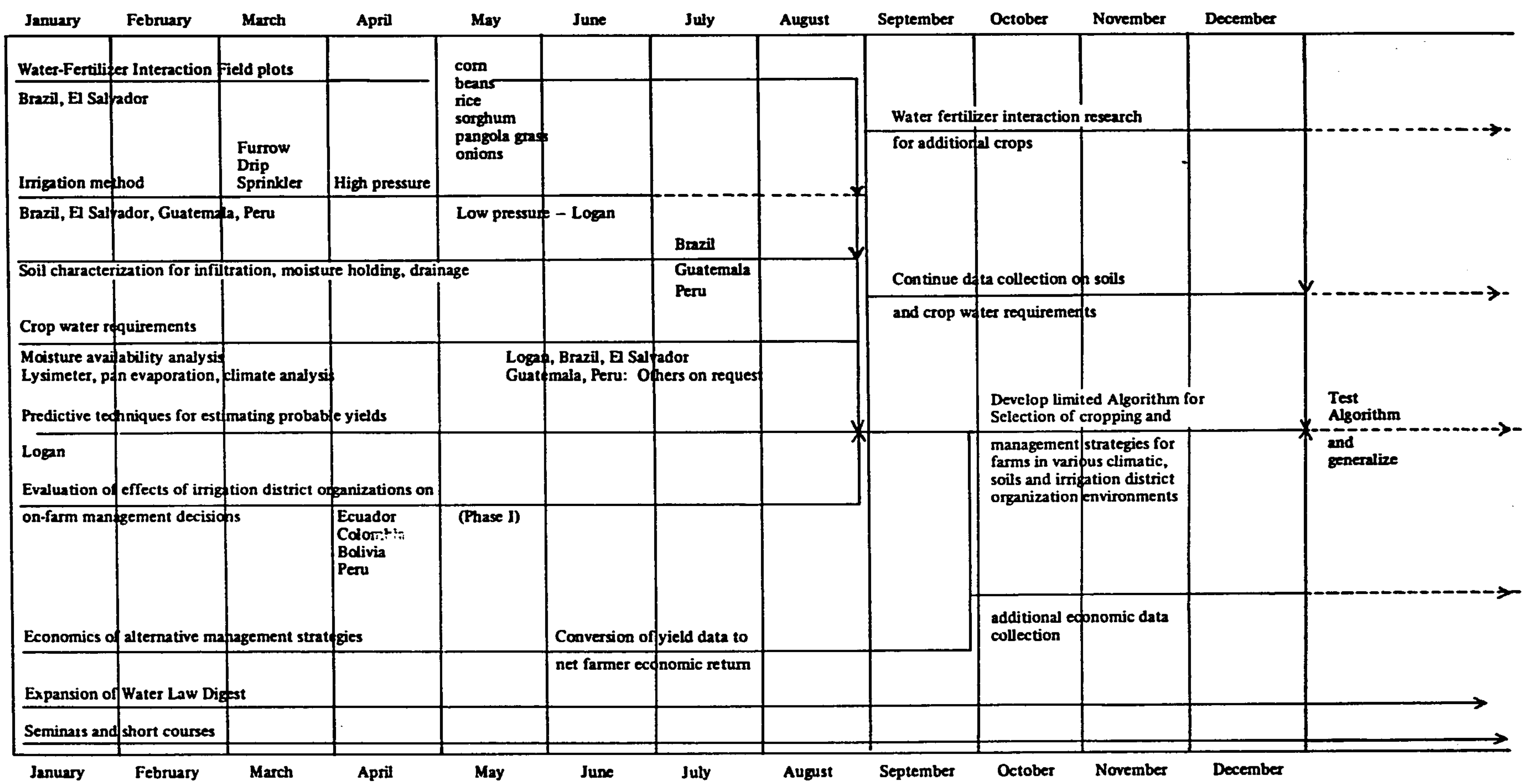
Beginning in September the field generated data will be pulled together into a preliminary systems analysis. The purpose of this analysis is to provide a comprehensive set of useful criteria for making farm management decisions where water is a constraining resource, especially on small LDC farms.

Ongoing seminar and short course activities are included. Implicit in the scheduling are a series of reports and publications which this work will produce.

Appendix VII shows the interrelationships between program objectives, sub-objectives, and activities. In general, activities with five digit or more coding numbers represent action levels in the field.

Figure 4

PLAN OF WORK 1976



F – INVOLVEMENT OF MINORITY PERSONNEL AND WOMEN

Utah State University is an equal opportunity employer. The Department of Agricultural and Irrigation Engineering, which has administrative responsibility for the contract, is one of the leading departments at USU in employment of minority personnel and women. Of the 22 full-time professionals in the department, two professors are from minority groups (Asian and Spanish American). The department also has Dr. Bertis Embry, who holds tenure in the Electrical Engineering Department, working on the contract as a full-time staff member in Guatemala. Dr. Embry has declared his American Indian ancestry. The department assistant editor is a woman and the six secretarial personnel are all women. Professor Unhanand (Asian) was employed half time (6 months) on contract work and Dr. Embry (American Indian) full time after joining the contract staff in January. The contract used seven women for an equivalent of 25.5 months during the year. See Appendix VIII for details.

FORM APPROVED
BOB NO. 105 R0062
EXPIRES 11/76

SMITHSONIAN
SCIENCE INFORMATION EXCHANGE, INC.
1730 M STREET, N.W. PHONE 202-381-5511
WASHINGTON, D.C. 20036

SIE NO.

NOTICE OF RESEARCH PROJECT

SUPPORTING AGENCY:

Agency for International Development
SER/CM/COD/TAB

AGENCY'S NUMBER(S):
Contract No: AID/ta-c-1103
and/or
Control No:

TITLE OF PROJECT:

Research on Agricultural Responses to Water Management in Wet/Dry Climatic Zones

PRINCIPAL INVESTIGATOR, ASSOCIATES — School or Division — Department

Principal Investigator: A. Alvin Bishop — College of Engineering
Associates: B. C. Palmer — Dept. of Agricultural and Irrigation Engineering
David W. James

RECIPIENT INSTITUTION:

Name and Address Including Zip Code: Utah State University, Logan, Utah 84322

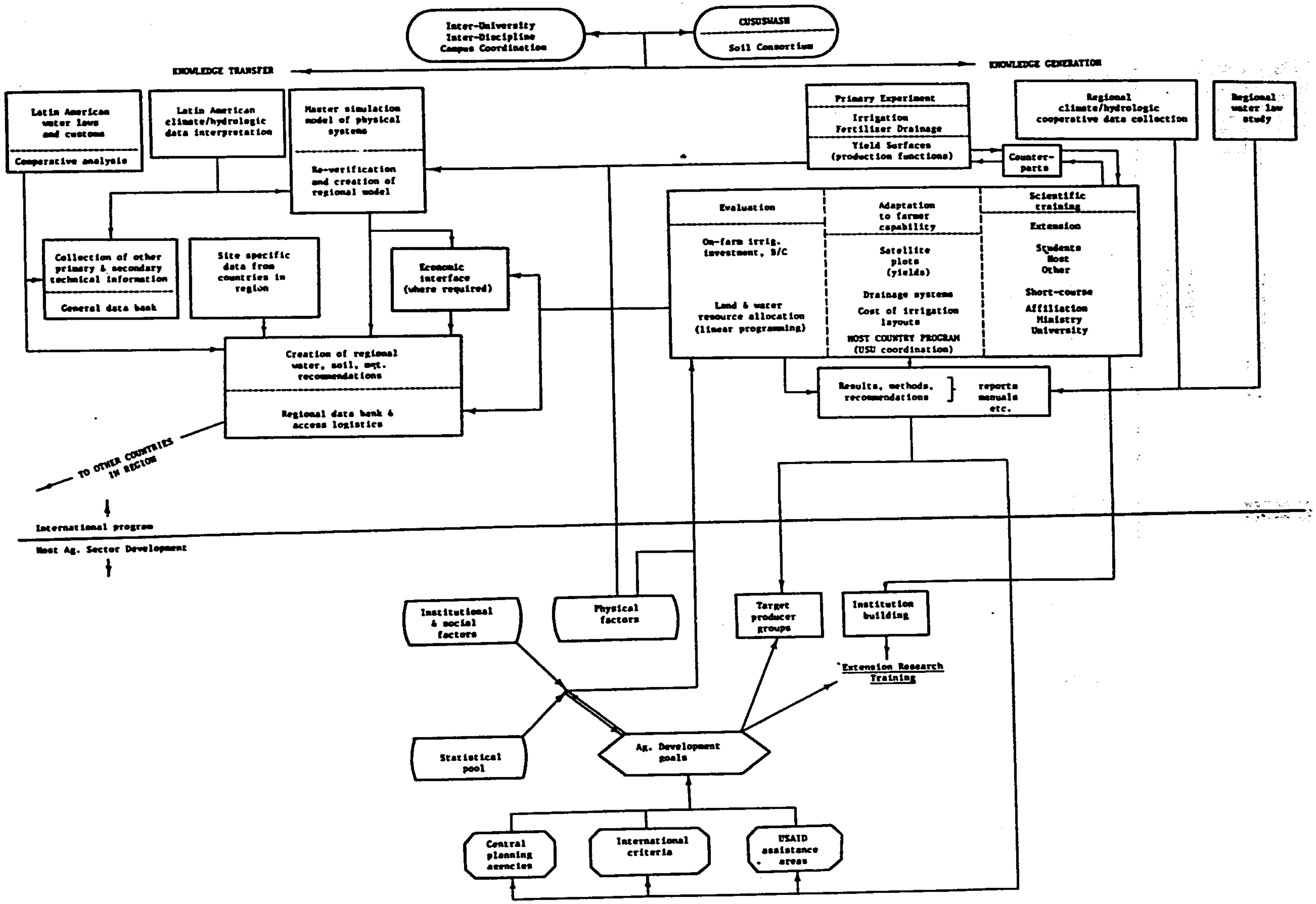
PERIOD FOR THIS NRP:
Start Date: April 1, 1974
End Date: June 30, 1976
Annual Funding: $605,000

SUMMARY OF PROJECT: Be brief-200 word maximum: (Include Objective, Approach, Current Plans and/or Progress)

Purpose - To adapt agricultural water management practices to developing country environments. Research is being carried out in Latin America under four primary objectives:

1. Development of farming practices which optimize the use of water from rain and irrigation within the constraints of climate, soils, markets, infrastructure, and interaction with other agricultural practices.
2. Development and adaptation of efficient water control and delivery systems especially for on-farm use.
3. Development of strategies for minimizing the deleterious effects on crops of excess surface and subsurface water, poor water quality and excessive concentrations of soil salinity, exchangeable sodium, and other toxic elements.
4. Identification of institutional and policy factors that influence water distribution, management, and utilization.

Current emphasis is on crop response functions where water is a major constraining factor, methods for estimating crop water requirements under conditions of limited climatological data, comparing irrigation methods in tropical environments, evaluating legal and institutional impacts on water management decisions, and predictive techniques to estimate environmental influences on crop production in areas where the crop has never been grown. Research teams are currently located in Brazil, Ecuador, El Salvador, Guatemala, Peru, and on the USU campus.



System Outline of On-Farm Water Management Research Program.

APPENDIX II

ABSTRACTS AND AUTHORS

EXPLANATION OF NUMBERING SYSTEM

Example: 75-B211

75 is the year of publication
B is the type of publication according to:

A – Project Reports
B – Theses
C – Papers and Professional Journal Articles
D – Project Reports of Other Agencies
E – Working Papers
F – Proposals and Annual Reports

2 is the objective series and 11 is the 11th report in the "2" series

Objectives are numbered as follows:

1. Development of farming practices including methods, timing, and amounts of water applied to the land which optimize the use of water from rain and irrigation within the constraints of climate, soils, markets, infrastructure and interaction with other agricultural practices.
2. Development and adaptation of efficient water control and delivery systems especially for on-farm use.
3. Development of strategies for minimizing the deleterious effects on crops of excess surface and subsurface water, poor water quality, excessive concentrations of soil salinity, exchangeable sodium and other toxic elements.
4. Identification of institutional and policy factors (legal, social economic, manpower, credit, etc.) that influence the efficient distribution, management and utilization of water at the farm level and the development of strategies for replacing inhibiting factors with facilitating factors.

IRRIGATION REQUIREMENTS AND PRECIPITATION DEFICITS FOR GUATEMALA

By G. H. Hargreaves

Methods are presented for estimating potential evapotranspiration, crop evapotranspiration, dependable precipitation, and a moisture availability index. A general relationship of crop production to moisture adequacy is shown, and leaching requirements, irrigation efficiencies, and irrigation scheduling are discussed. A procedure is proposed for climatic zoning. Mean monthly and annual values are given at 59 locations for temperature, solar radiation, precipitation, an estimated 75 percent probability of precipitation occurrence, potential evapotranspiration, the precipitation deficit, and a moisture availability index.

[75-D157a (52 pages)]

MOISTURE ADEQUACIES FOR AGRICULTURE IN THE SOUTHEAST

By G. H. Hargreaves

Methods are given for estimating potential evapotranspiration, dependable precipitation, and a moisture availability index. A tabulation is presented for 110 locations and/or climatic divisions in the Southeastern States giving mean monthly and annual values of temperature, relative humidity, precipitation, the 75 percent probability of precipitation occurrence, potential evapotranspiration, the evapotranspiration deficit, and the moisture availability index. Computer programs are presented for printing out the above values and for estimating daily potential evapotranspiration.

[75-D157b (34 pages)]

IRRIGATION REQUIREMENTS AND PRECIPITATION DEFICITS FOR BRAZIL

By G. H. Hargreaves

Methods for estimating potential evapotranspiration and crop evapotranspiration are shown. Dependable precipitation is defined and a relationship given between mean and dependable precipitation. General relationships are presented evaluating the effects of moisture adequacy on crop production. Leaching requirements, irrigation efficiencies, and irrigation scheduling are briefly discussed. Tabular values of monthly and annual temperature, relative humidity, precipitation, potential evapotranspiration, and evapotranspiration deficits are presented for 155 locations having the best climatic data coverage in Brazil. Computer programs are presented for calculating potential evapotranspiration and probabilities of precipitation occurrence.

[75-D156 (50 pages)]

CLIMATIC ZONING FOR AGRICULTURAL PRODUCTION IN NORTHEAST BRAZIL

By G. H. Hargreaves

A moisture availability index estimated for 723 locations in Northeast Brazil is used to classify the climate into zones using the classifications very arid, arid, semi-arid, and wet-dry. Each classification is described with respect to agricultural suitability. A map is included showing the climatic zones.

[74-A148 (6 pages plus map)]

WATER REQUIREMENTS MANUAL FOR IRRIGATED CROPS AND RAINFED AGRICULTURE

By G. H. Hargreaves

Methods are given for estimating potential evapotranspiration, ETP, from climatic data and from Class A pan evaporation. Crop evapotranspiration, ET (Crop), is estimated from ETP and crop coefficients, KC. Desirable irrigation efficiencies are suggested, leaching requirements are defined, and soil conditions and other factors influencing the amount of water to be applied are described. A procedure is presented for scheduling irrigation using principally mean monthly climatic data.

A concept of dependable precipitation is developed and used to relate to moisture adequacy and crop production or in the development of moisture adequacy production functions. Critical periods for moisture stress are given for a large number of crops. A classification of moisture deficits and climate is proposed to be used principally for evaluating precipitation potential for rainfed agriculture.

Computer equations are shown for calculating potential evapotranspiration, dependable precipitation, evapotranspiration deficits, and a moisture availability index.

[75-D158 (49 pages)]

EFFECT OF VIBRATION ON DRAFT IN CONSTRUCTION OF MOLE DRAINS

by Abdolhossien Nassehzadeh-Tabrizi

The effect of vibration of mole plows on the draft in the construction of mole drains was investigated by means of a model. The mole plow, consisted of a steel torpedo 19/32-inch in diameter attached to a steel blade 3/16-inch thick, and was pushed through the silty clay soil at a constant depth of 5-inches. The soil was contained in a Plexiglas box 10 x 11 x 18 inches long. The vibration, produced by means of an eccentric shaft, resulted in the actual dynamic amplitude of the torpedo of approximately 1 mm. Four frequencies of approximately 0, 43, 66, and 92 cycles per second and five levels of soil moisture contents of about 24, 25, 27, 30, and 35 percent by weight were used in the tests.

Visual inspection of the mole channel indicated that larger and more extensive cracks appeared on the surface of the soil, silt surfaces, and mole channel in the non-vibrated portion than in the vibrated portion, especially at low moisture content.

The reduction in draft was obtained when either the soil moisture content or the frequency of vibration was increased. The maximum percent reduction in draft of about 60 percent was obtained at a soil moisture content of 35 percent and vibration frequency of about 92 cycles per second. The minimum reduction in draft of about 22 percent was produced at a soil moisture content of 24 percent and a frequency of 43 cycles per second.

By statistical analysis of the experimental results, an equation for prediction of draft requirement expressed as a function of soil moisture content and vibration frequency was derived.

[75-B (120 pages)]

EFFECTIVENESS OF MOLE DRAINS IN LEACHING HEAVY SOILS

Jose Antonio Forero

A field experiment was conducted to determine the effects of leaching by mole drains, 3 inches in diameter, installed 18 inches deep at the spacings of 6, 12, and 24 feet. The water was applied periodically by sprinklers at a rate slightly less than the basic intake rate to avoid ponding. Soil samples, taken before and after leaching from the same location in the experimental area, were analyzed to determine the EC of the saturation extract and the reduction in salt concentration of the soil after leaching. Results of the experiment indicate that, within the limits of the three spacings tested, the combination of mole drains and low application rate of irrigation water leaches the salts more effectively than using the low application rate alone. However, because the initial salt concentration was different from plot to plot, no conclusive result could be drawn as to which mole spacing is most effective in leaching.

[75-B (103 pages)]

IRRIGATION WATER QUALITY EVALUATION

by J. E. Christiansen, E. C. Olsen and Lyman S. Willardson

This report depicts a brief history of soil scientists' thinking over a period of 40 years concerning the effect of salinity and various constituents on physical properties of soils and on-crop yields. The various classification schemes that have been used by various scientists are presented. Factors are shown that degrade waters for irrigation. The evaluation scheme first proposed by Christiansen and Olsen is presented.

The computer program for evaluating the quality of the water for irrigation is given and evaluations for 144 analyses of water samples is presented. Water analyses were selected from 600 evaluated analyses, showing various kinds of water encountered in the Western states and some foreign countries.

[75-D159 (46 pages)]

APPENDIX III

Climatological Data Analysis For Two Stations in Costa Rica

STATION NAME SAN JOAQUIN DE FLORES , LAT. 10 1, LONG. 84 8, ELEV. 1051 10 YEARS DATA

PROBABILITY		95.	90.	80.	75.	70.	60.	50.	40.	30.	25.	20.	10.	5.		90.	80.	75.	70.	60.
MONTH	MEAN	PRECIPITATION													ETP	IRRIGATION REQUIREMENT **				
JAN	16.	0.	0.	0.	0.	0.	1.	3.	6.	12.	17.	23.	47.	76.	124.	124.	124.	124.	124.	123.
FEB	21.	0.	0.	0.	1.	1.	3.	6.	11.	19.	25.	33.	61.	92.	124.	124.	124.	124.	123.	121.
MAR	18.	0.	0.	1.	1.	2.	4.	7.	12.	19.	23.	30.	51.	73.	149.	149.	149.	148.	147.	145.
APR	87.	12.	18.	30.	36.	42.	54.	67.	83.	102.	113.	127.	169.	209.	149.	130.	118.	112.	107.	94.
MAY	279.	90.	117.	156.	173.	189.	221.	255.	291.	334.	359.	389.	474.	553.	145.	28.	-11.	-28.	-45.	-77.
JUN	296.	179.	199.	227.	233.	249.	269.	289.	309.	332.	345.	360.	402.	438.	137.	-62.	-91.	-102.	-112.	-132.
JUL	219.	106.	125.	150.	161.	171.	190.	209.	229.	252.	265.	280.	323.	362.	143.	18.	-8.	-18.	-28.	-47.
AUG	253.	124.	146.	175.	187.	199.	220.	242.	265.	292.	307.	325.	374.	418.	142.	-4.	-33.	-45.	-57.	-78.
SEP	434.	283.	311.	349.	362.	376.	402.	426.	452.	481.	497.	516.	567.	612.	136.	-175.	-212.	-227.	-240.	-266.
OCT	403.	253.	281.	317.	332.	345.	370.	395.	421.	450.	466.	485.	536.	582.	131.	-150.	-186.	-201.	-214.	-239.
NOV	183.	54.	72.	94.	109.	120.	142.	165.	190.	219.	237.	258.	317.	373.	121.	49.	23.	12.	1.	-21.
DEC	39.	5.	8.	13.	16.	18.	24.	31.	38.	47.	53.	60.	80.	101.	120.	113.	107.	105.	102.	96.
ANN.	2244.	1895.	1972.	2065.	2161.	2130.	2190.	2244.	2297.	2357.	2387.	2422.	2516.	2593.	1621.	-351.	-444.	-480.	-509.	-569.

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
TEMP	21.5	22.2	22.8	23.6	23.2	22.8	22.9	22.8	22.7	22.3	22.4	22.1	22.6
HUM	79.	78.	78.	80.	83.	83.	83.	84.	84.	84.	87.	81.	82.
PMAX	98.	75.	68.	167.	448.	427.	352.	441.	664.	647.	397.	91.	2570.
PMIN	0.	0.	0.	7.	52.	166.	90.	119.	253.	252.	52.	3.	2022.
MAI	.00	.01	.01	.24	1.19	1.75	1.13	1.32	2.67	2.53	.90	.13	1.30

STATION NAME SAN JOSE, COSTA RICA , LAT. 9 56, LONG. 84 5, ELEV. 1172 10 YEARS DATA

PROBABILITY		95.	90.	80.	75.	70.	60.	50.	40.	30.	25.	20.	10.	5.		90.	80.	75.	70.	60.
MONTH	MEAN	PRECIPITATION													ETP	IRRIGATION REQUIREMENT **				
JAN	11.	0.	0.	1.	1.	2.	3.	5.	8.	12.	14.	17.	28.	39.	117.	117.	116.	116.	115.	114.
FEB	15.	0.	0.	0.	0.	0.	1.	2.	5.	11.	15.	22.	46.	76.	115.	115.	115.	115.	115.	114.
MAR	10.	0.	0.	0.	0.	1.	1.	3.	5.	9.	12.	16.	29.	43.	140.	140.	140.	140.	140.	139.
APR	41.	0.	1.	3.	5.	9.	13.	21.	32.	48.	58.	71.	115.	161.	139.	138.	136.	134.	132.	126.
MAY	205.	45.	64.	94.	109.	121.	149.	177.	210.	249.	273.	301.	383.	461.	138.	74.	44.	30.	17.	-10.
JUN	314.	167.	192.	226.	240.	253.	279.	303.	329.	358.	375.	395.	449.	498.	131.	-61.	-95.	-109.	-122.	-147.
JUL	215.	96.	117.	143.	154.	165.	194.	204.	225.	249.	263.	280.	326.	367.	135.	17.	-9.	-20.	-30.	-50.
AUG	265.	146.	167.	195.	206.	217.	237.	257.	277.	301.	314.	330.	373.	412.	135.	-32.	-60.	-71.	-81.	-101.
SEP	364.	201.	230.	269.	285.	300.	324.	350.	385.	419.	438.	460.	521.	576.	130.	-100.	-139.	-155.	-170.	-198.
OCT	332.	236.	255.	279.	289.	297.	313.	329.	344.	362.	372.	383.	414.	441.	126.	-129.	-153.	-162.	-171.	-187.
NOV	162.	58.	73.	95.	105.	114.	131.	150.	169.	192.	206.	222.	267.	308.	114.	41.	19.	10.	1.	-17.
DEC	37.	5.	9.	14.	17.	19.	25.	31.	37.	46.	51.	57.	75.	93.	113.	104.	99.	96.	94.	88.
ANN	1977.	1605.	1681.	1776.	1833.	1847.	1909.	1968.	2028.	2094.	2131.	2172.	2285.	2381.	1534.	-148.	-243.	-280.	-313.	-375.

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
TEMP	19.2	19.4	20.4	21.1	21.4	21.1	20.7	21.0	21.0	20.7	20.1	19.7	20.5
HUM	79.	78.	78.	80.	83.	83.	83.	84.	84.	84.	82.	81.	82.
PMAX	55.	50.	38.	99.	422.	460.	372.	397.	552.	414.	365.	79.	2302.
PMIN	0.	0.	0.	0.	51.	176.	103.	128.	184.	221.	71.	6.	1563.
MAI	.01	.00	.00	.04	.78	1.84	1.15	1.52	2.20	2.29	.92	.15	1.18

APPENDIX IVa

País: Ecuador
Nombre de Organización:

____

£8
Octubre 13

USU/AID

ENCUESTA A LOS USUARIOS DE AGUAS

Cuestionario No.________ ________ ________

Nombre del entrevistador____

Fecha________________________________

Entrevistado

Nombre____

1. Miembro o socio ________1. Si ________2. No. ________

2. Funcionario ________1. Si ________2. No. ________

3. Puesto o cargo anterior____

4. Puesto o cargo actual____

5. ¿Está su organización regida por leyes y estatutos?

   ________1. Si ________2. No ________3. No sabe ________4. No contesta

   ____

6. ¿Está regida por costumbres y tradición?

   ________1. Si ________2. No ________3. No sabe ________4. No contesta

   ____

Actitudes personales

7. ¿Que opina usted de la organización en general?(Proponga)

   ________1. Respuesta positiva (Buena, beneficiosa, productiva, importante)

   ________2. Respuesta negativa (débil, improductiva, mala, etc.)

   ________3. Respuesta intermedia

   ________4. No sabe

________5. No contesta

________6. Otro______________________________ ________

8. ¿Como funciona la organización? (Proponga)

________1. Respuesta positiva (correcta, bien, recta, etc.)

________2. Respuesta negativa (incorrecta, injusta, mal, etc.)

________3. Respuesta intermedia

________4. No sabe

________5. No contesta

________6. Otro______________________________ ________

9. ¿Personalmente, la organización le beneficia?

________1. Respuesta positiva

________2. Respuesta negativa

________3. Respuesta intermedia

________4. No sabe

________5. No contesta

________6. Otro______________________________

____

10. ¿Personalmente, la organización le representa?

________1. Respuesta positiva

________2. Respuesta negativa

________3. Respuesta intermedia

________4. No sabe

________5. No contesta

________6. Otro______________________________

____

11. ¿Personalmente, la organización responde a sus necesidades de agua?

________1. Respuesta positiva

________2. Respuesta negativa

________3. Respuesta intermedia

________4. No sabe

________5. No contesta

________6. Otro______________________________

____

12. ¿Cual es su opinión de los funcionarios de la organización? (Proponga)

________1. Respuesta positiva (justos, vigilan por su bienestar, etc.)

________2. Respuesta negativa (injustos, no vigilan, no trabajan, etc.)

________3. Respuesta intermedia

________ 4. No sabe

________ 5. No contesta

________ 6. Otro ________________________ ________

13. ¿Hay otras organizaciones de riego en la zona que usted conoce?

________ 1. Si ________ 2. No ________ 3. No sabe ________ 4. No contesta

____

14. A. ¿Si funcionan bien, por qúe?

____

____

B. ¿Si no funcionan bien, por qúe?

____

____

15. ¿Están todos los miembros en su organización contentos con ser agricultores?

________ 1. Si ________ 2. No ________ 3. No sabe ________ 4. No contesta

____

16. ¿Sabe usted si alguno planea dejar la agricultura?

________ 1. Si ________ 2. No ________ 3. No sabe ________ 4. No contesta

____

A. ¿Si así, por qúe? ________________________________

____

B. ¿Si así, qué harán? ________________________________

____

Características del Tamaño de Finca

	Total (has)	Cultivadas (has)	Regadas (has)
17. ¿Cuánto terreno tiene usted?	______	______	______

18. ¿Es usted ________ 1. Dueño de la tierra?

________ 2. ¿Arrienda la tierra?

________3. Arrienda parte, dueño en parte

________4. ¿Comparte la cosecha?

________5. Otros (especificar)____

____

19. Es su terreno,

________1. ¿En una sola unidad?

________2. ¿Partida en varios pedazos?

20. ¿Siempre tiene suficiente agua de riego?

________1. Si ________2. No ________3. No sabe ________4. No contesta

____

A. ¿Si no, por qúe?____

____

21. ¿En las condiciones actuales, si usted necesitara más agua, cree que podría obtenerla?

________1. Si ________2. No ________3. No sabe ________4. No contesta

____

A. ¿Si así, como o dé donde la obtendría?

________1. De la organización misma

________2. Arrendar de otro

________3. Pozo o vertiente particular

________4. De otro sin arrendar

________5. No contesta

________6. Otro (especificar)____________________ ________

22. ¿Sus cultivos le alcanzan para la casa nada más o le sobra para el mercado?(proponga)

________1. Subsiste solo

________2. Sobre para mercado

________3. No sabe

________4. No contesta

________5. Otro____

____

23. ¿Trabaja fuera de su terreno para sostenerse? (Proponga)

_______ 1. Si _______ 2. No _______ 3. No sabe _______ 4. No contesta

____

24. ¿A que distancia está su terreno del óvalo o toma?

	Distancia
A. Toma	_______ Km.
B. Ovalo	_______ Km.

25. ¿Cuantos años de los últimos cinco ha perdido cultivos? _______

26. ¿Por qué se perdieron?

1. Falta de agua
2. Esceso de agua
3. Insectos
4. Malezas
5. Exceso de fertilizantes
6. Falta de fertilizantes
7. Falta de obreros
8. Falta de mercado
9. Otros (especificar) _______________

____

____

____

27. ¿Si usted tuviera más dinero, cuáles de los siguientes haría? (Anote los tres primeros)

01. Comprar más tierra
02. Caridad a la Iglesia
03. Compra de ganado
04. Prioste de una fiesta
05. Mejoras del hogar
06. Socializar con sus amigos
07. Comprar fertilizante
08. Educar a la familia
09. Invertir en la agricultura en general
10. Contratar obreros
11. Otros

_______ _______

_______ _______

_______ _______

Participación de Grupo

28. ¿En cuales de los siguientes grupos participa usted regularmente? (Nombre todos los posibles)

_______ 1. Sociedad o cooperativa agrícola, directorio o junta de aguas _______

_______ 2. Grupo local comunitario (ej. mingas, comuna, etc.) _______

_______ 3. Actividades locales de la Iglesia _______

_______ 4. Otros (especificar)_______________________________

_______ 5. Otros (especificar)_______________________________

Notas:____

____

Indice de Cambios

29. Indique con círculo cuáles de los siguientes han cambiado en cuanto a sus métodos de cultivo y describa los cambios.

a. Métodos de riego

b. Mecanización

c. Fertilización

d. Tipos de cultivos

e. Fungicida

f. Uso de crédito

Describa los cambios:_______________________________________

____

____

Leyes de Aguas

30. ¿Existe una ley de aguas para el Ecuador? (Proponga)

_______ 1. Si _______ 2. No _______ 3. No sabe _______ 4. No contesta

____

A. ¿si es sí como supo usted de la ley de aguas?

_______ 1. Agencia de Gobierno

_______ 2. Radio

_______ 3. Periódico

_______ 4. Publicaciones

_______ 5. Abogado

_______ 6. Tradición

_______ 7. Otros_______________________

____

____

31. ¿Conoce usted algún cambio reciente en la ley de aguas del Ecuador?

_______ 1. Si _______ 2. No _______ 3. No sabe _______ 4. No contesta

____

32. ¿Ha pagado usted alguna vez el impuesto al agua, fijado por la ley de Aguas de 1972?

________1. Si ________2. No ________3. No sabe ________4. No contesta

____

A. ¿Si afirmativo, desde cuando?

________1. 1972 ________2. 1973 ________3. 1974 ________4. 1975

____

B. ¿Pagó usted

________1. De acuerdo a la cantidad consumida medida?

________2. De acuerdo a la cantidad fija establecida en el documento de derecho de aguas?

________3. La organización paga todo conjuntamente ________

Notas:____

____

____

33. ¿Cual es su derecho de aguas?______________________________

____

34. ¿Tiene usted derecho del uso del agua?

________1. Si ________2. No ________ 3. No sabe ________4. No contesta

____

35. ¿Ha tenido usted que llenar algún documento relacionado con el derecho de aguas?

________1. Si ________2. No ________3. No sabe ________4. No contesta

____

36. ¿Ha buscado usted informes sobre derechos de usos de aguas?

________1. Si ________2. No ________3. No sabe ________4. No contesta

____

37. ¿Tiene documentos que le dan un derecho de aguas?

________1. Si ________2. No ________3. No sabe ________4. No contesta

____

38. ¿Como obtuvo el uso de aguas?

________1. Herencia

________2. Compró con el terreno

________3. Compró parte y heredó parte

________4. Compró separadamente del terreno

________5. Otro____

39. ¿Hace cuanto tiempo que tiene dicho uso?

________(1) 1 año ________(2) 2 años ________(3) 3 años a 10 años

________(4) 10 años o máa

____

40. ¿Arrienda usted en la actualidad el agua de riego?

________1. Si ________2. No ________3. No sabe ________4. No contesta

____

A. ¿Cuánto cuesta?____

41. ¿Arrendó usted agua antes?

________1. Si ________2. No ________3. No sabe ________4. No contesta

____

A. ¿Hace cuanto tiempo que usted dejó de arrendar?

________(1) 1 año ________(2) 2 años ________(3) 3 años o más

____

42. ¿Donde irían usted y su vecino en caso de una disputa sobre aguas, por ejemplo si se le robara el agua?

________1. Autoridad local de la comunidad

________2. La organización misma

________3. Autoridad de la Iglesia local

________4. Policía

________5. Juez

________6. INERHI

________7. Un abogado

________8. Otro____ ________

43. ¿Ante que autoridad haría un reclamo formal?

________1. Autoridad local de la comunidad

________2. La organización misma

________3. Autoridad de la Iglesia local

________4. Policía

________5. Juez

________6. INERHI

________7. Un abogado

________8. Otro____ ________

APPENDIX IVb

País: Ecuador___

£ 7
Octubre 10

Nombre del entrevistador____

Informantes: ____

____

____

Fecha________________________

ENCUESTA DE INSTITUCIONES Y USUARIOS DE AGUAS

Datos Institucionales

Identificación

Organización

Nombre____

Domicilio o lugar____

____

1. Clase de organización

A. Control Público (del Gobierno)

________ 1.1 Control directo del Gobierno Central o su agencia regional

________ 1.2 Control directo del gobierno central o su dependencia con juntas de usuarios en asesoramiento

________ 1.3 Controlado por una entidad pública regional, municipio o gobierno local

________ 1.4 Otro____

____

B. Control Privado o Particular

1. Formal = (con estatutos aprobados por el gobierno, constitución, reglamentos, etc.)

________2.1 Supervisado por una autoridad pública

________ 2.2 Sin supervisión de una autoridad pública

________ 2.3 Otro ____

2. Informal = (sin estatutos, reglamentos escritos, etc.)

________ 2.4 Supervisado por una autoridad pública

________ 2.5 Sin supervisión de una autoridad pública

________ 2.6 Otro ____

C. Clase de organización privada o particular

1. Directorio o junta de aguas

________ 3.1 Solo distribuye el agua de riego

________ 3.2 Tiene otras funciones o fines además de administrar el agua

2. Cooperativa

________ 3.3 Solo distribuye el agua de riego

________ 3.4 Tiene otras funciones además del riego

3. Otro ____

________ 3.5 Solo distribuye agua de riego

________ 3.6 Tiene otras funciones además del riego

2. Estructura de la Organización

	Si	No
01. Dependencia de Gobierno Central o autoridad pública	____	____
02. Administrador de Distrito (nivel del administrador)	____	____

______ . ______ . ______ . ______ . ______

Título	a Número	b Elejido o Nombrado	c Por quien
03. Miembros o socios	________	________	________
04. Vocales	________	________	________
05. Vocales suplentes	________	________	________

06. Presidente ________ ________ ________

07. Vice-presidente ________ ________ ________

08. Secretario ________ ________ ________

09. Tesorero (controlador) ________ ________ ________

10. Secretario/tesorero ________ ________ ________

11. Gerente; administrador ________ ________ ________

12. Inspector (equivalente) ________ ________ ________

13. Abogado ________ ________ ________

14. Otro____________________________ ________ ________ ________

Función____________________________

15. Otro____________________________ ________ ________ ________

Función____________________________

16. Otro____________________________ ________ ________ ________

Función____________________________

3. Los miembros de la organización tienen reuniones de asamblea general

________1. Anuales

________2. Semianuales

________3. Mensuales

________4. Otro____________________________ ________

4. ¿Cuantos miembros atienden las reuniones?____________________________

5. ¿Cuán frecuentemente debería reunirse la directiva de la organización?

____

6. ¿Cuántas veces se reune en realidad?

Notas:____

____

7. ¿Es la organización:

A. Una suborganización de una entidad más grande?

________ 1. Si ________ 2. No ________

en caso afirmativo, descríbala____

B. ¿Tiene suborganizaciones que la conforman?

________ 1. Si ________ 2. No ________

En caso afirmativo, descríbalas____

Tomando Decisiones

(Convierta a los números de la pregunta) No. 2

8. Quién hace las decisiones en cuanto a:

a. Presupuesto________________________________ ________ ________

b. Gastos________________________________ ________ ________

c. Horario de regadío________________________________ ________ ________

d. Mantenimiento de canales________________________________ ________ ________

e. Mejoras de capital________________________________ ________ ________

f. Disputas________________________________ ________ ________

Otros (especificar)

g. ________________________________ ________ ________

h. ________________________________ ________ ________

Notas:____

____

Funciones

9. Quién lleva a cabo las siguientes funciones:

a. Pago de Gastos ________________________________ ________ ________

b. Inversión de fondos____________________ ______ ______

c. Tenedurla de
libros____________________ ______ ______

d. Mantenimiento y
operaciones____________________ ______ ______

e. Vigilancia de Distribución
de Agua____________________ ______ ______

f. Relaciones con otras
organizaciones____________________ ______ ______

g. Otros (especificar)____________________ ______ ______
____
____

Notas:____
____

Relación con otras Organizaciones

10. ¿Con que otras organizaciones y agencias tiene relación su organización y sus miembros en cuanto al uso del agua de riego?

______ 1. Ministerio de Agricultura

______ 2. Banco Agrícola Nacional

______ 3. Banco Local

______ 4. Cámara de Agricultura

______ 5. Municipalidad Local

______ 6. Iglesia local

______ 7. Extensión Agrícola (INIAP)

______ 8. INERHI

______ 9. Dirección de Aguas

______ 10. Distrito de riego

______ 11. ____________

______ 12. ____________

11. Cual es la ayuda que recibe su organización o sus miembros y de quién:

Tipos de ayuda	Organización de Asistencia
1. Métodos de riego y construcción	____________
2. Ayuda agrícola en general	____________

3. Administración ____________________

4. Conflictos sobre el uso del agua ____________________

5. Crédito ____________________

6. Consejo legal ____________________

7. Otro (especificar) ____________________

____

Notas: ____

____

12. ¿Tiene la organización en conjunto un derecho del uso de las aguas registrado con el gobierno?

_______ 1. Si _______ 2. No _______ 3. No sabe _______ 4. No contesta

____

13. ¿Ha pagado la organización un impuesto del agua al gobierno?

_______ 1. Si _______ 2. No _______ 3. No sabe _______ 4. No contesta

____

A. ¿Si así, cuánto? ____

B. ¿Si así, sobre qué base? ____

Notas: ____

____

14. Cuántos miembros de su organización tienen fincas en las categorías siguientes:

	Numero	Porcentaje
0 - .4 has	_______	_______
.5 - 1 has	_______	_______
1 - 2 has	_______	_______
3 - 15 has	_______	_______
16 - 50 has	_______	_______
51 o más	_______	_______

Notas:____

____

____

____

15. Total de la tierra cultivable de los miembros en su organización y qué porcentaje es:

	Has.	Porcentaje
Total	________	________
Cultivada (en laboreo)	________	________
Regada	________	________

16. Porcentaje de agricultores en el área circundante que son miembros de una organización que administra el agua de riego ________

Escala: (1) 0-30%, (2) 30-60%, (3) 60-100%

17. ¿Los agricultores en el área que no son miembros de una organización de riego, tienen fincas más grandes que las de miembros de organizaciones?

________ 1. No hay que no son miembros ________ 2. Si ________ 3. No

________ 4. No sabe ________ 5. No contesta

A. ¿Si así, cuál es el tamaño promedio de sus fincas?

Escala: (1) 0-2 has., (2) 3-5 has., (3) 6-15 has., (4) 16-50 has.,

(5) 51-100 has., (6) 100 + has. ________

Notas:____

____

Fuentes de Abastecimiento de Aguas

18. ¿Tienen algunos miembros de la organización agua de otro origen independiente del agua provista por la organización?

________ 1. Si ________ 2. No ________ 3. No sabe ________ 4. No contesta

____

A. Si así cuál es el origen del agua (señale aquéllos que son aplicables)

________ 1. Canal privado (acequia)

________ 2. Pozo o vertiente privado

________ 3. Arrendado de otro

________ 4. Otro (especificar)________________________

________ 5. Ninguna respuesta ________

____

19. ¿Cuál es la principal fuente de origen de agua para los agricultores en la zona que usted conoce que no son miembros de la organización de riego?

________ 1. Canal Privado

________ 2. Pozo o vertiente privado

________ 3. Arrendado de otro

________ 4. No tienen agua de riego

________ 5. Otro (especificar)____________________

________ 6. No hay que no son socios ________

20. En orden, anote los cinco cultivos más comunes de los socios o usuarios, junto con el número de cosechas de cada uno por año.

	Cultivo	No. de Cosechas
1.	________________	________
2.	________________	________
3.	________________	________
4.	________________	________
5.	________________	________

Notas:____

____

____

Indicadores Sociales y Económicos
(Bienestar económico: Observe y conteste en porcentajes)

22. Vivienda:

	No.	%
A. Primitiva	_____	_____
B. Mejorada	_____	_____
1. electricidad	_____	_____
2. agua potable	_____	_____
3. facilidades sanitarias (alcantarillado)	_____	_____
4. radio	_____	_____
C. Agricultor en subsistencia	_____	_____
D. Vehículos particulares	_____	_____
E. Ingresos fuera de la finca	_____	_____
F. Maquinaria mecanizada	_____	_____

(Tipo)____

23. De todos los miembros de la organización cuántos han cambiado en cuanto a:

	No.	%
A. Métodos de riego	_____	_____
B. Uso de crédito	_____	_____
C. Tipos de cultivos	_____	_____
D. Uso de fertilizantes	_____	_____
E. Maquinaria	_____	_____

Notas:____

____

____

Costos de Agua

23. ¿Sobre qué base paga por el uso del agua en su organización?

	Cantidad pagada por cada uno por año
_______ 1. Por hora	_______________

_______2. Volumen consumido ____________________

_______3. De acuerdo al terreno ____________________

_______4. De acuerdo al cultivo ____________________

_______5. No pagan ____________________

_______6. Otros (especificar)____________________ ____________________

____

Notas:____

24. ¿Es este un precio fijo sea cual sea el cultivo?

_______1. Si _______2. No _______3. No sabe _______4. No contesta

____

25. ¿Cuánto paga uno por operación y administración?

____

26. ¿Los miembros de su organización también ayudan al mantenimiento y limpieza del canal?

_______1. Si _______2. No _______3. No sabe _______4. No contesta

____

A. ¿Si es sí, en qué forma?

_______1. La cuota es separada de las tarifas por agua

_______2. Las cuotas incluyen las tarifas por agua

_______3. Mano de obra (jornales)

_______4. Otros (especificar)____________________ ________

27. ¿Sobre qué base paga uno por el mantenimiento?

1. Por hora de agua
2. Volumen consumido
3. De acuerdo al terreno
4. De acuerdo al cultivo
5. Otro____________________ ________

28. ¿Cuánto paga por el mantenimiento?____________________

____

29. ¿Existen dificultades Eu el cobro de las cuotas ó tarifas?

_______1. Si _______2. No _______3. No sabe _______4. No contesta

____

A. ¿Si es sí cuántos usuarios no pagan sus cuentas? _______________

____

30. ¿Las cuotas y tarifas (todas) cobradas a los usuarios cubren los gastos anuales de operación y mantenimiento?

_______.1 Si _______2. No _______3. No sabe _______4. No contesta

____

31. El costo total por mantenimiento y operación de su organización anual es

____

32. ¿Cómo se paga el valor de construcción y mejoras de canales?

_______1. Totalmente por usuarios

_______2. Parcialmente por usuarios; parcialmente por gobierno

_______3. Totalmente por gobierno

_______4. Otros (especificar)_______________ _______

(Obtenga una historia de la amortización de capital de las mejoras y de la forma en que éstas son pagadas, si es posible).

Características Históricas y Sociales

33. Identifique la raza predominante de los miembros de la organización (observe)

_______1. Indígena (tribu_______________)

_______2. Mestizo

_______3. Negro

_______4. Anglo

_______5. Otro (especificar)_______________ _______

34. Identifique el idioma predominante de la mayoría de los miembros de la organización

_______1. Dialecto indígena local (especificar)_______________

_______2. Español

_______3. Otros (especificar)_______________ _______

35. **Describa la educación promedio de los miembros**________________________________

Primaria 0_____, 1_____, 2._____, 3._____, 4._____, 5._____, 6._____,

Secundaria 7._____, 8._____, 9._____, 10._____, 11._____ 12._____, Sobre_______

Notas:____

36. **¿Son los funcionarios del directorio: (a) de la misma raza y, (b) del mismo nivel educacional que los socios?**

A. ________ 1. Si ________ 2. No ________ 3. No sabe ________ 4. No contesta

____

B. ________ 1. Si ________ 2. No ________ 3. No sabe ________ 4. No contesta

____

Características Físicas de la región o zona geográfica

37. **Indique la temporada de riego de la zona (Meses) No.**________________

De____________________ **a** ____________________ **inclusive.**
(mes) (mes)

38. **¿Hay siempre suficiente agua en sus canales para dar riego?**

________ 1. Si ________ 2. No ________ 3. No sabe ________ 4. No contesta

____

A. **¿En caso negativo, cuántos de los ultimos diez años ha faltado agua?**

____

B. **¿Por qué faltó agua durante estos años? (Todo lo aplicable)**

________ 1. Debido a la organización

________ 2. Escasez de agua

________ 3. Derrumbes o defectos de obras

________ 4. Robo

________ 5. Otros (especificar)____________________ ________

____

Notas:____

39. Clima (especificar)

________ 1. Muy árido (ningún mes con MAI arriba de .33)

________ 2. Arido (uno o dos meses con MAI de .34 o más alto)

________ 3. Semiárido (tres o cuatro meses consecutivos con MAI de .34 o más alto)

________ 4. Húmedo-seco (cinco o más meses consecutivos con MAI de .34 o más alto)

____

Notas:____

40. Altura en metros________________________

Descripción de Infraestructura

41. ¿Qué tipo de bocatoma existe en el sistema?

________ 1. Ninguno o rudimentario (describa)________________________

________ 2. Temporales (construídos cada año)

________ 4. Otros (especificar)________________ ________

42. ¿Hace cuánto tiempo que existen los canales?________________________

43. Cuántos kilómetros de canal principal y secundarios pertenecen a la organización. (Obtenga un mapa si es posible)

Principal________________ Km. No.________________

Secundario________________ Km. No.________________

44. El canal principal es:

________ 1. Sin revestimiento Km________________

________ 2. Revestido de piedra Km________________

________ 3. Revestido de concreto Km________________

________ 4. Revestido con plástico Km________________

________ 5. Tubos Km________________

________ 6. Otros________________________ ________

____

____

45. Los canales secundarios son:

________1. Sin revestimiento

________2. Revestidos de piedra

________3. Revestidos de concreto

________4. Revestidos con plástico

________5. No hay canales secundarios

________6. Otro____ ________

46. ¿Qué parte del total de los canales de riego es mantenido por la organización en general?

________1. Sólo el canal principal

________2. Canal principal y secundarios

________3. Canales principal, secundarios y terciarios

________4. Otros (especificar)________________________________

____ ________

47. ¿Que aparatos de control de aquas se encuentran en el sistema?(describa)

Rudimentarios:____

Desarrollados sin medición:________________________________

Altamente desarrollados:________________________________

____

48. ¿Hay algún medidor de volumen de agua para cada usuario?

________1. Si ________2. No ________3. No sabe ________No contesta

____

49. ¿Usan criterios técnicos para determinar el agua necesaria para sus cultivos?

________1. Si ________2. No ________3. No sabe ________No contesta

____

50. ¿Hay otras aguas alimentando el canal (fuera de las tomas principales)?

________1. Si ________2. No ________3. No sabe ________No contesta

____

A. En caso afirmativo, describa________________________________

51. ¿Existen facilidades para almacenamiento de agua?

_______ 1. Si   _______ 2. No   _______ 3. No sabe   _______ 4. No contesta

____

52. ¿Riegan en las noches ustedes?

_______ 1. Si   _______ 2. No   _______

53. Cuánto debería hacer (intervenir) el gobierno en cuanto a los siguientes:

		Más	Menos	Igual
A.	en financiar obras	____	____	____
B.	en prestar asistencia técnica	____	____	____
C.	controlar la administración suya	____	____	____
D.	vigilar el uso del agua	____	____	____
E.	pagar costos de operación y mantenimiento	____	____	____
F.	dar asesoramiento legal	____	____	____
G.	resolver disgustos entre usuarios	____	____	____

54. Preferirían ustedes:

A. más_______

B. menos_______

C. igual_______

¿participación del gobierno en el manejo del abastecimiento de su agua?

____

APPENDIX V

Countries From Which Requests Have Been Received For Contract Generated Reports

1. Argentina
2. Australia
3. Brazil
4. Canada
5. Czechoslovakia
6. Chile
7. Colombia
8. Costa Rica
9. Ecuador
10. El Salvador
11. England
12. France
13. Germany
14. Guatemala
15. Honduras
16. India
17. Iran
18. Israel
19. Italy
20. Italy (FAO)
21. Kenya
22. Mexico
23. New Zealand
24. Nicaragua
25. Nigeria
26. Panama
27. Paraguay
28. Peru
29. Poland
30. Scotland
31. Spain
32. Taiwan, Republic of China
33. Uruguay
34. USSR
35. Virgin Islands
36. West Germany
37. Yugoslavia

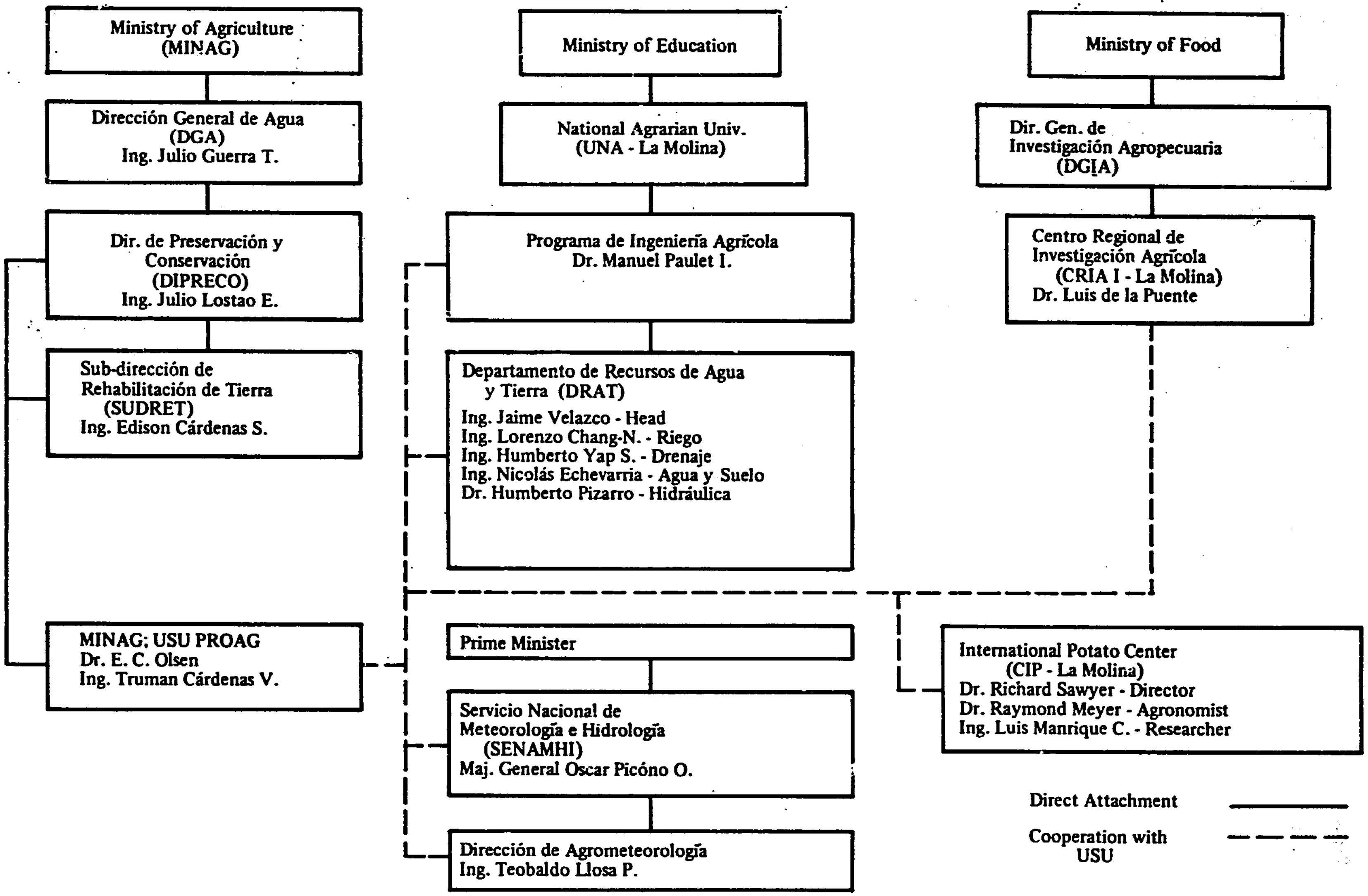
States Requesting Contract Reports

1. Alabama
2. Arizona
3. California
4. Colorado
5. Florida
6. Hawaii
7. Idaho
8. Illinois
9. Indiana
10. Iowa
11. Kansas
12. Kentucky
13. Louisiana
14. Massachusetts
15. Minnesota
16. Missouri
17. Montana
18. Nebraska
19. Nevada
20. New Jersey
21. New Mexico
22. New York
23. North Carolina
24. Ohio
25. Oklahoma
26. Oregon

27. Rhode Island
28. South Carolina
29. Texas
30. Utah
31. Virginia
32. Washington, D. C.
33. Wisconsin

APPENDIX VI

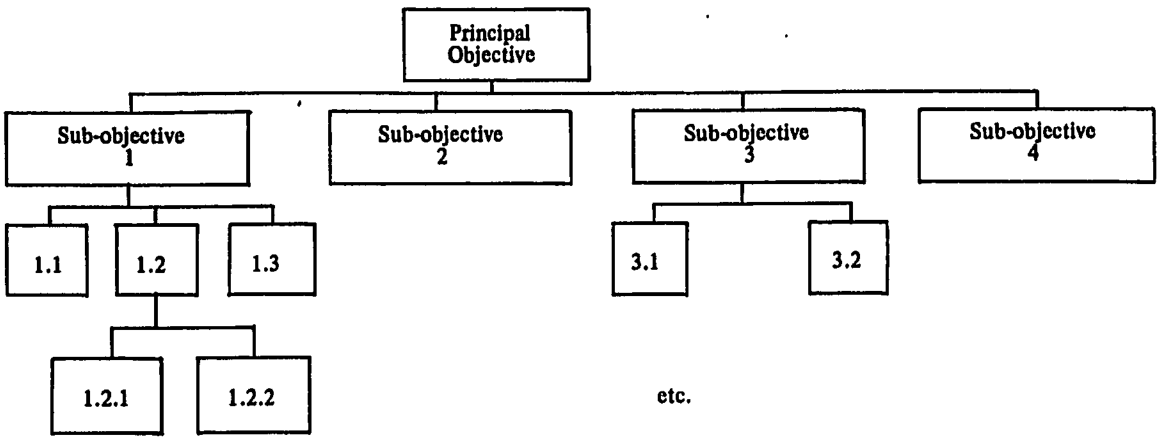
SUMMARY OF COOPERATING ORGANIZATIONS IN PERU



APPENDIX VII

Project Planning Chart

In order to tie program activities into contract objectives, a "Christmas Tree Chart" was prepared beginning with the overall objective and proceeding downward through sub-objectives and activities. The following "relationships" schedule can be conceptualized as follows:



Objectives and activities are coded according to the following scheme.

The first group of numbers (preceding the first semicolon) refer to activities.

The second group of numbers refers to crop.

The third group of numbers refers to location of the activity. The country is first designated, followed by a location code identifier, followed by a semicolon.

Relationships of Objectives, Sub-objectives and Activities

Code	Objective or Activity – Description
	Timing and amounts of water to apply
	Total crop water requirements
	Phenologic stage water requirement
	Water stress-yield relationships
	Interaction of water with non-manageable environmental factors on yield, eg. temperature.
	Interaction of water with manageable environmental factors, eg. fertilizer
02 ;	Corn
03	Brazil

; 08	El Salvador
; 10	Guatemala
1.1.1.3.1; 07 ;	Sorghum
; 08	El Salvador
1.1.1.3.1; 08 ;	Rice
; 08	El Salvador
; 10	Guatemala
1.1.1.3.1; 10 ;	Soybeans
; 08	El Salvador
; 10	Guatemala
1.1.1.3.1; 11 ;	Beans
; 03	Brazil
; 08	El Salvador
; 10	Guatemala
1.1.1.3.1; 16;	Tomatoes
; 03	Brazil
; 08	El Salvador
1.1.1.3.1; 38 ;	Onions
; 03	Brazil
1.1.1.3.1; 54	Grasses
; 08	El Salvador
1.1.2	Leaching Requirements
1.1.2.1	Water quality effects
1.1.2.2	Soil chemistry effects
1.1.3	On-farm losses
1.2	Available water
1.2.1	Available moisture from natural precipitation
1.2.1.1	Frequency

1.2.1.1.1	Probability analysis, moisture deficits, moisture availability indices. Current library will be expanded on request of USAID missions.
1.2.1.2	Amount
1.2.2	Distribution in soil
1.2.2.1	Infiltration
1.2.2.2	Percolation
1.2.2.3	Storage in root zone
1.2.2.4	Soil characterization
1.2.2.4 03;	Brazil
08;	El Salvador
10;	Guatemala
18;	Peru
1.2.3	Available moisture from water table
1.2.3.1	Relationship of soil physical qualities to moisture rise
1.2.3.2	Effect on water table of evapotranspiration
1.2.3.3	Rate of supply
1.2.3.4	Temperature efiects
1.2.4	Available water from irrigation
1.2.4.1	Distribution schedule
1.2.4.2	Amount available for distribution
1.2.4.2.1	Timing of available water
1.2.4.2.2	Physical constraints
1.2.4.2.3	Socio-legal constraints
1.3	Evaporation and transpiration
1.3.1	Lysimeter studies
1.3.2	Pan evaporation studies
1.3.3	Estimates from climate
1.3.3; 03;	Brazil

; 08 El Salvador

; 10 Guatemala

; 18 Peru .

Other countries on request

2. Application methods

2.1 Wild flooding

2.2 Contour ditching

2.3 Border irrigation

2.4 Ponding

2.5 Furrow

2.5.1 Applicability

2.5.2 Effectiveness

2.5.3 Efficiency

2.5.4 Installation costs

2.5.5 Operating costs

2.5.6 Relative yield expectancy

2.5.7 Benefit cost ratio

2.5.8 Social implications

2.5 Furrow
2.6 Drip
2.7 Sprinkler

} Similarly for 2.1 2.2 2.3 2.4 2.6 2.7 2.8 components

03 Brazil

08 El Salvador

18 Peru

2.7.5	Sprinkler irrigation operating costs
2.7.5.1	Design of low pressure sprinkler systems -- Logan
2.8	Other methods
3.	Water removal
3.1	Effects of rain and irrigation on water table
3.2	Requirements to control soil moisture maximum in root zone
3.3	Drainage installations
3.4	Drainage to improve scheduling of other farm activities
3.5	Combined irrigation-drainage systems

Crop Coding for Plan of Work

01 Wheat

02 Maize

03 Barley

04 Oats

05 Rye

06 Millet

07 Sorghum

08 Rice

09 Peas

10 Soyabeans

11 Broad and field beans

12 French or snap beans

13 Runner beans

14 Lima beans

15 Groundnuts

16 Tomatoes

17 Peppers or capsicums

18 Cucumbers and gherkins

19 Watermelons

20 Lettuce

21 Tobacco

22 Cotton

23 Buckwheat

24 Flax and linseed

25 Safflower

26. Sunflowers

27 Opium poppies

28 Snapdragons

29 *Geophila renaris*

30 Sugar and fodder beet

31 Garden or red beet
32 Carrots
33 Turnips
34 Kohl-rabi
35 Cabbage and kale
36 Cauliflower and broccoli
37 Potatoes
38 Onions
39 Tulips
40 Gladioli
41 Avocadoes
42 Citrus
43 Cocoa
44 Coffee
45 Guayule
46 Mangoes
47 Olives
48 Tea
49 Strawberries
50 Cane fruits
51 Hops
52 Legumes
53 Sugar cane
54 Grasses
55 Bananas
56 Pineapples
57 Sisal
58 Oil palms and coconuts
59 Dates
60 Apples
61 Peaches
62 Pears
63 Plums
64 Cherries
65 Apricots
66 Figs

Country Coding for Plan of Work

01 Argentina
02 Bolivia
03 Brazil
04 Colombia
05 Costa Rica
06 Dominican Republic
07 Ecuador
08 El Salvador
09 French Guiana
10 Guatemala
11 Guyana
12 Haiti
13 Honduras
14 Mexico
15 Nicaragua
16 Panama

17 Paraguay

18 Peru

19 Sirinam

20 Trinidad

21 United States of America

22 Uruguay

23 Venezuela

APPENDIX VIII
Man Months of Personnel Working on Project AID/ta-c-1103
From November 1, 1974 to October 31, 1975

Item No.	Name	Specialty	Total Man Months
1.	A. Alvin Bishop	Dept. Head & Professor	0-3/4
2.	Howard B. Peterson	Professor	5-1/2
3.	J. E. Christiansen	Professor Emeritus	5-1/4
4.	Byron C. Palmer	Associate Professor	6-7/8
5.	David Rainey Daines	Associate Professor	9-0
6.	Edwin C. Olsen III	Associate Professor	10-1/2
7.	Komain Unhanand**	Associate Professor	6-0
8.	Dennis Craig Anderson	Research Associate	12-0
9.	George H. Hargreaves	Research Engineer	10-0
10.	Robert Kern Stutler	Research Engineer	12-0
11.	Sharon Jean W. Riddle*	Office Assistant	2-1/2
12.	Bonnie Thompson*	Res. Tech. & Editor	1-1/3
13.	Amy N. Krambule*	Clerk-Steno II	11-1/3
14.	Jeanne Smith*	Research Aid & Office Mgr.	3-3/4
15.	Thomas Mankin Fullerton	Asst. Prof. of Agronomy	12-0
16.	Don Carlos Kidman	Research Agronomist	12-0
17.	David W. James	Associate Professor	6-1/4
18.	Bertis L. Embry**	Professor	9-1/2
19.	Suzanne Roper Lebaron*	Clerk Steno	0-2/3
20.	Carla B. Twedt*	Research Aid	4-0
21.	Linda F. Rammell*	Research Technician	1-7/8
22.	Rex F. Nielson	Associate Professor	0-1/3
23.	Wade Andrews	Professor	0-3/4
24.	Paul Riley	Professor	0-2/3
25.	Allen LeBaron	Professor	1-1/4
26.	Richard Wells	Research Technician	3-0

**Minority

*Women