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ANNUAL TECHNICAL REPORT

OPTIMUM UTILIZATION OF WATER FOR AGRICULTURE WITH EMPHASIS ON "ON-FARM WATER MANAGEMENT"

Report Number V
Grant No. AID/csd-2459

Utah State University
Logan, Utah
November 1974

CUSUSWASH

211(d)

ANNUAL TECHNICAL REPORT 211 (d) PROJECT

AID/csd-2459

Title: Optimum Utilization of Water for Agriculture with Emphasis on "On-Farm Water Management."

Grantee: Utah State University

Director: H. B. Peterson

AID SPONSORING OFFICE: TAB/AGR

Statistical Summary:

Period of Grant: May 23, 1969 to May 22, 1976
Amount of Grant: $750,000
Expenditures for Reported Year: $94,379.81
Accumulated: $586,607.26
Anticipated for next year: $163,392.74

Logan, Utah

November, 1974

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NARRATIVE SUMMARY

Emphases during the initial years of the Grant were directed toward increasing the competence. Eleven new staff members were added. During the current year, one senior drainage engineer with six years experience in L.A. joined the Irrigation Department. During the first three years a Water Management Library was established and a bibliography of 13,000 holdings was computerized. This was published in 1973-1974.

Seventy-six staff and graduate students have received special language training in Spanish. Twenty of the staff are capable of lecturing and conversing in Spanish. In the report year, nine U.S. graduate students conducted research and studied under the program. A total of 22 have been directly involved in the program. A Masters degree program for LDC's was developed in cooperation with the College of Agriculture. The engineering courses can be taught in Spanish by USU staff going to the host countries.

There were 20 responses for consulting during the year. The total to date is 97. Through the Grant, there have been special courses offered during the summer. This year "Irrigation Water Requirements and Irrigation Scheduling" was taught by Dr. Marvin Jensen, Director of the Snake River Research Center. This was attended by 16 foreign students and one U.S. woman.

Manuscripts for three manuals were completed. These were: "Irrigation System Evaluation and Improvement;" "Irrigation Fundamentals;" and "Trickle irrigation." A book, "The Role of Water in Regional Development" was published.

In an economic analysis Grant students found that, except for certain labor immobility, Bolivian farmers are combining available resources quite efficiently. To meet 1985 food demands, more land can be developed at a cost competitive with capital intensive technology such as irrigation with large shifts of labor.

The model developed under the Grant to optimize soil and water research programs, to identify research needs and to insure maximum transferability of information was further developed. An example of specific use was developed in a paper, "Predicting Corn Growth as Affected by Water Management," which showed a "best" planting date yield increase of 50 bushels. With "best" date plus 1 inch irrigation the yield increased 83 bushels.

DETAILED REPORT

General Background and Description of the Problem

There was ample evidence that in developing countries there was urgent need for more food and better nutrition. It was a fact that in most LDC's there is a lack of trained people for transfer of the knowledge available in developed countries. It was known that so urgent were the needs that there is not time for these countries to train the required numbers of people nor to go through a tedious trial and error method of developing the required technologies. The lack of technology and information was known to be a deterant to expanded production and restrict the effectiveness of AID and other donors in solving critical food problems common to many LDC's.

It was reasoned that by making highly qualified and experienced professionals available from centers of competence at Universities that AID could develop and disseminate technologies that would be more effective than those being used in many countries. Through utilization of the technologies transferred, the LDC's could accelerate the rate of production expansion. By establishing strong linkages and networks among developed and developing country institutions and agencies, an even greater quantity and quality of capability could be directed toward improving the food supply.

At the time the grant was awarded the Department of Agricultural Engineering and related departments such as Soils and Civil Engineering had many graduate students from foreign countries. The staff and course offerings were not adequate to teach and direct the research of these students.

Utah State University had considerable competence in the areas of irrigation and water management at the time the grant was approved. It was expected that the expanded full-time professional staff, courses of study, library information, and research would enable the University to respond much more adequately than heretofore to requests concerning agricultural related water management problems from such entities as: USAID/ Washington, USAID Missions, other state and federal agencies.

The proposal for a 211(d) Grant to Utah State University to utilize its competence in the general area of on-farm water management was one of three submitted by universities who are members of the Council of

United States Universities for Soil and Water Development in Arid and Sub-Humid Areas. This consortium has coordinated the AID sponsored research and institutional improvement of these universities. Other universities include the University of Arizona emphasizing "watershed management," and Colorado State University specializing in "water delivery and removal systems and relevant institutional development." The Grant Project was expected to have built-in research, training and advisory components. The creation of special capability in a particular area of knowledge should include the relevant technology and the capacity to pass it on to others. The capacity developed by the institution in its field or fields should enable it to do the following:

a. develop capability in research

b. develop capability in training; and

c. put itself in position to provide consulting services.

It was logical to conclude that a Grant would be a natural complement to the research contract AID/csd 2167.

Purpose of the Grant

The Institutional Grant Program had for its purpose the development of the competence and expertise of U.S. research and educational institutions to deal with critical problems of less developed countries. There are certain identifiable shortages of properly trained personnel and gaps in knowledge and skills that restrict AID's efforts to carry out its programs of assistance in these countries. The Institutional Grants Program is designed to overcome these deficiencies. Individual projects are designed to serve the program needs of AID without a requirement for providing specific services. Institutional Grants are thus to be used to strengthen 'centers of competence' within educational and research institutions and to build long-range resources in depth rather than to procure services for AID for specific limited purposes.

The specific purpose of this Grant was to expand the competency of Utah State University as a center for world-wide training and research in irrigation and drainage. As the competence has been increased the purpose has shifted toward sustaining and utilizing this competence in research, teaching, training and consulting.

Objectives of the Grant

Objectives Restated

The major objective of the Grant program was to increase and expand the existing competence of Utah State University in the science and technology concerned with "on-farm water management" with emphasis on moisture environment on the farm as related to the special characteristics and problems of the less developed countries. Increased competence was to be developed in the teaching and research activities as follows:

1. Expand its full-time professional core staff which will focus its teaching and research activities on the technical disciplines which relate to maintenance of a proper moisture environment on the farm under less developed country conditions. These include irrigation and surface and subsurface drainage. Irrigation and drainage are complex arts requiring the application of the best knowledge of water, soil, climate, and crop sciences and engineering. Existing courses in this area will be reconstructed as appropriate new graduate courses, special short courses, and seminars will be developed as required.

2. Expand its research in less developed countries to increase the knowledge and understanding of subjects such as water requirements of crops, moisture-fertilizer-crop response, management of irrigated soils, drainage requirements, salinity water quality, movements of water in soils, methods of water application, management of irrigation water, and water-crop-soil system analysis.

3. Expand its total library holdings in irrigation and drainage and related disciplines, especially foreign and international publications, so as to become a center of information on world irrigation and drainage practices.

This increased interrelated teaching and research competence will include, but not be limited to, the following subjects as they relate to problems of the less developed countries:

1. Irrigation Practices. The theory and practice of maintaining the optimum moisture environment for plant growth by irrigation and drainage within the complex physical and institutional systems involved.

2. Drainage Theory and Practices. The investigation, design, and operation of drainage systems to assure the optimum soil-moisture environment and avoid or reduce flooding.

3. Water Resources Systems Simulation Engineering. Simulation of multi-purpose projects to provide adequate service for irrigation, drainage, flood prevention, and other purposes as related to on-farm water management.

4. Irrigation Science Research. The basics of consumptive use, infiltration, water physics, water quality, water-salt-soil interactions, within the framework of "on-farm water management" for maximum efficiency and economic returns.

5. Irrigation Economics. The economics of changing water management practices, costs, and economic efficiency of water utilization including the incremental value of water application and water application systems.

Review of Objectives

The objectives and areas of activities, as originally identified, were broad in scope and general in nature. There have been some modifications but there appears to be no particular justification for making major revisions. In the plan for implementation of the program it was anticipated that emphasis on activities would shift. Early emphasis was on identification of staff needs, selection of professors and in language training. This was followed by a review of course content, revision and introduction of new courses. Emphasis was also placed on library improvement and expansion. As the goals in these areas have been reached, emphasis has shifted to teaching, conducting research, responding to requests for technical assistance and increasing accessibility of the library holdings. The results from the increase in language competence is becoming evident in the research and consulting accomplishments. There is a constant demand for the services of the staff having the language competence to teach short courses or provide technical assistance in LDC's.

In a proposal to extend the Grant the purpose will be to focus on utilization of the developed competence and there will be more specific objectives with identified outputs, inputs and verifications.

Review of Critical Assumptions

In the original grant proposal most of the critical assumptions were not specified as such but were largely assumed. One assumption was that the University could increase its competence faster than the increase in demand for the assistance. This has not been the experience. It was assumed that the LDC's, AID, and Missions would cooperate with the University and a consortium in identifying problems, establishing priorities and utilizing the capabilities. They have utilized the capabilities but have helped only in a small way in identifying problems

and establishing priorities for the various activities. It is a difficult task to get the specific problems of the RLDC farmer to the U.S.U. scientists for solution and then transfer the information back for utilization.

ACCOMPLISHMENTS

Library Improvement

For the past five years the Agricultural and Irrigation Engineering Department, in cooperation with Merrill Library, has conducted an intensive program to expand the existing competence of Utah State University in the field of On-Farm Water Management and related fields. To date the On-Farm Water project has purchased some 1,841 books and developed a vertical file system comprising some 391 titles. All of these titles are in addition to the already existing holdings of the Merrill Library. The project has searched the holdings of other centers of information located on campus. This search for pertinent titles has yielded: 1,634 titles from the Utah Water Resources Research Laboratory; 450 titles from the Agricultural and Irrigation Engineering Department Microfilm Water Law Library; 1,700 titles taken from the Special Collections Sections of Merrill Library, 193 titles on Business Law from the College of Business, and 152 titles from the Government Document Section, Merrill Library. All of these titles have been combined in a computerized bibliographic printout, totaling some 13,000 titles. These titles represent the best works, old and new, and in the field of on-farm water and related areas. This collection covers the United States and some 60 foreign countries.

As a result of this program many of the Library's documents and archive holdings, which had never been properly indexed or cataloged, have now been correctly cataloged and the holdings are now being used.

The 13,000 titles have been keypunched (91,000 cards) for entry into a computerized bibliography. This bibliographic printout has been printed in book form and is available for distribution. A copy is included as Appendix A under separate cover.

A "flier" has been prepared which describes the library holdings and invites its utilization. Use of the book materials and publications is open to all students, staff and the general public. Students and staff from other schools may obtain materials through interlibrary loans or visiting scholar permit procedures.

Language Training

During the current year no intensive training courses were supported by the Grant. The students and staff needing training have used the regular university language offerings.

Throughout the life of the Grant training program a total of 76 staff, wives and graduate students received training in Spanish. Most completed the advanced courses. In the area of water management, 20 of the staff are capable of lecturing in the Spanish language. Three of the staff have competence in Portuguese. This competence is especially valuable to the program and the staff assigned to Latin American countries for research consulting, teaching short courses or participating in seminars.

The University has organized a short course in Brazil for July 10 - 26. The lecturing by our staff will be in either Portuguese or Spanish. Four of the staff participated in our AID and FAO sponsored seminar in Costa Rica April 1 - 6. Their presentations were made in Spanish and the written copy was also prepared in Spanish.

Two of the Grant graduate students spent the summer on research in Central America. Both were competent in the use of Spanish.

The staff in Agricultural and Irrigation Engineering are cooperating in offering a Masters degree program to be taught in LDC's. Most all of the courses will be taught in Spanish.

Teaching

Dr. Lyman Willardson was added to the staff of the Department of Agricultural and Irrigation Engineering during the current year. Dr. Willardson is an established leader in drainage and salinity control. He speaks fluent Spanish and has six years experience in Latin America. Those staff members previously engaged were very active in teaching, writing, research and consulting. During the life of the Grant it has supported, in part, the acquisition of 10 new staff members.

In the past years an emphasis has been placed on development of new courses and revisions of the old. A major consideration has been given to meeting the needs of the students from the LDC's.

During the summer quarter 1974 we offered a special course entitled "Irrigation Water Requirements and Irrigation Scheduling." Dr. Marvin Jensen, Director of the Snake River Research Center at Kimberly, Idaho was the guest professor. In attendance there was 1 US woman and 16 foreign students representing 11 countries. For a text the class used a very recent monograph published by the American Society of Civil Engineers entitled "Consumptive Use of Water and Irrigation Water Requirements." This contains the newest information on the subject; in fact, the publication was not available until the class was well into the second week. The course material was a product of a special committee of the American Society of Civil Engineers who had been working on this problem for some four or five years to get together all of the most recent information regarding the various methods of calculating and computing evapotranspiration. Dr. Jensen acted as chairman of this committee for the ASCE and therefore had pre-publication material that could be used until the book became available. We look at this as one of the highlights of the education experiences for our students at the graduate level in Irrigation Engineering. They were complimentary of the material of the course as well as the instructor's enthusiasm and knowledge of the subject.

During the current year emphasis has been placed on the preparation of manuals and texts. John Merriam (of California Polytechnic Institute), Jack Keller and Jose Alfaro have completed the manuscript for a second edition of the handbook on "Irrigation System Evaluation and Improvements." This will be printed during the coming year. A Spanish language edition is being prepared by Dr. Alfaro. Dr. Keller is using in classes the manuscript for a text on Sprinkle and Trickle Irrigation. An attempt will be made to have this published next year. Cris Lewis, Jay C. Andersen, Herbert H. Fullerton, and B. D. Gardner have completed the manuscript for the book, "The Role of Water in Regional Development," under partial support of the 211 (d) grant. A copy of the publication is included in Appendix B. Dr. Stringham completed the manuscript for the manual on "Irrigation Fundamentals." This is for use primarily in instruction in short courses in the LDC's. It is in press and should be available by October.

Drs. Keller and Karmeli completed a manual on trickle irrigation which was published by Rain Bird Sprinkler Manufacturing Corporation. Glendora, California.

Charles Burt, a student supported by the Grant, spent the summer in El Salvador primarily on our research contract. He saw an opportunity to prepare instruction for the use and construction of an automatic siphon. Host country cooperators were invited to contribute. Attached as Appendix C is a draft of the circular they prepared. This will be published during the coming year.

Research

Much of the research was conducted through graduate students supported by the Grant on problems of LDC's and directed by or in cooperation with the staff of the research grant. It has been our objective to have the graduate students do their research on a project in a developing country. However, because of logistic problems this has been somewhat limited, but all have worked on development problems usually using real field information from on-site research efforts.

Results of the student research is reported in the following theses:

AN INTENSIVE EDAPHOLOGICAL CHARACTERIZATION OF THE SOILS OF MALAMBITO EXPERIMENTAL STATION AND ITS IMPLICATIONS IN FUTURE AGRICULTURAL RESEARCH by William L. Rubink

RESOURCE ALLOCATION AND FACTOR SUBSTITUTION IN GUAYAS BASIN RICE PRODUCTION by Gary Scott Glenn

INTRAREGIONAL EFFICIENCY OF PRODUCTION DECISIONS AND INTER-REGIONAL EFFICIENCY OF INPUT USE IN BOLIVIAN AGRICULTURE by Stephen C. Hammond

SOME FEASIBLE LONG-RUN POLICY ALTERNATIVES FOR THE AGRICULTURAL SECTOR IN BOLIVIA by Franklin Bruce Brown

One of the results from the Costa Rica Seminar was recommendation for research on problems of Central America. A specific suggestion was for research on the design of an irrigation system that would function on relatively steep land. The need is for a distribution system that can also provide for surface drainage with minimum erosion during intense rain storms. David Fisher, a graduate student, went to Guatemala to work on this problem during the summer.

Last year J. Keller, H. B. Peterson and D. F. Peterson published a paper proposing the development of a model system to optimize soil and water research programs, to identify research needs and to insure maximum transferability of information. During the year this project has been continued and a paper prepared to illustrate the use of some specific U.S. data. A copy of the paper "Predicting Corn Growth as Affected by Water Management" is included in Appendix D. Preparations for publication have been made. Abstracts or summaries of new publications are included in Appendix E.

Utah State University, organized, conducted, and published the proceedings of a seminar on "Research Needs for On-Farm Water Management" held at Park City, Utah, October 1973. USAID sponsored this seminar through Basic Agreement AID/csd-3703 Task Order No. 3. Members of the staff supported by the Grant participated in the seminar and the recommendations for research are being used to guide future research efforts.

Consulting

As the number of staff members has been increased the demands for their services have also increased. Some responses have been for a few days and in the case of Ken Bach it is for a two year period. Dr. Alfaro will be "on loan" for one year. The number and nature of the responses are indicated in the section of the report on utilization.

Expenditures

Expenditures for the fifth year of the Grant and accumulated expenditures are presented in Tables 1 and 2. Salary and wage support is shown in Table 3. Research support through trainees is summarized in Table 4. The University's monetary contribution is presented in Tables 1 and 5.

Table 1. Distribution of 211(d) grant funds and contributions from other sources of funding* review period July 1, 1973 to June 30, 1974

List all Grant Related Activities	211(d) Expenditures			Non 211(d) Funding Amount, 1973-74
	Period Under Review	Cumulative Total	Projected to End of Grant	
Research	$30,972	$214,074	$67,992	$14,044
Teaching	29,125	166,610	55,350	12,045
Libraries	9,317	47,395	10,000	9,000
Consultation	7,900	24,558	12,000	6,500
Publications	3,335	19,320	5,000	5,000
Other	2,280	81,199	3,051	--
CUSUSWASH	11,451	33,451	10,000	5,000
TOTALS	$94,380	$586,607	$163,393	$51,589

*These figures are our best estimates.

Table 2. Actual and anticipated expenditures under Institutional Grant # AID/csd 2459 review period July 1, 1973 to June 30, 1974

Line Items	Expenditures to Date		Projected Expenditures to End	TOTALS
	Period Under Review	Cumulative Total	Year Six	
Salaries, Wages and Consultants	$43,482.22	$329,393.77	$76,567.74	$405,961.51
Travel				
Foreign	9,697.59	31,995.44	20,375.00	52,370.44
Domestic	3,789.75	17,441.03	8,250.00	25,691.03
Equipment	None	7,492.67	500.00	7,992.67
Stipends, Tuition and Fees	20,345.00	118,516.60	35,200.00	153,716.60
Supplies and Computer Use	2,279.41	30,654.91	7,500.00	38,154.91
Publications	3,334.84	17,661.84	5,000.00	22,661.84
CUSUSWASH	11,451.00	33,451.00	10,000.00	43,451.00
TOTALS	$94,379.81*	$586,607.26	$163,392.74	$750,000.00

*Does not include unpaid obligations.

Table 3. Salary and wage support and effort

Name	Amount Paid	Man Months
Contract Salaries		
Howard B. Peterson	$5,413.34	2.2
Byron C. Palmer	3,167.15	1.7
Jack Keller	10,572.00	6.0
Jose Alfaro	4,175.00	3.0
Ken Bach	1.00	---
Diane Polchow	2,781.61	7.5
Carol Williams	241.67	0.6
Carla Twedt	165.02	0.35
Dorothy McCarty	1,923.00	3.21
Sharon Riddle	84.33	0.16
Salary Payroll		
Robert W. Hill	2,448.61	2.0
Consultants		
Marvin Jensen	1,900.00	.75
Wages	4,705.94	
Staff Benefits	5,903.55	
TOTAL	$43,482.22	

Table 4. Graduate trainee expense (Fiscal Year 1973-74)

Name	Stipend	Authorized Tuition	Total
Ronald David Fischer	$1800	$453	$2253
Charles Burt	1200	151	1351
Bruce Brown	3300	453	3753
Gary Glenn	3300	572	3872
Steve Hammond	3000	453	3453
David Duane Maxwell	3000	533	3533
Dennis Wagner	600	0	600
William Rubink	900	34	934
Richard Conn	450	146	596
TOTAL	$17,550	$2,795	$20,345

Table 5. Summary of 1973-74 expenditures by Utah State University for water management library improvement

Library Materials	
Serials, Abstracts, Indexes, Books	$5,350.00
Personnel	
Orders Processing	
Contractual	257.00
Payroll	100.00
Fund Accounting	
Contractual	280.00
Keypunching and Verifying (11,000 cards)	
Payroll	900.00
Cataloging	
Contractual	230.00
Payroll	230.00
Supplies	
IBM Cards	73.25
Order Forms	8.50
Misc.	228.00
Processing Costs	
Binding	200.00
Computer Time	
Ordering, Processing, and Programming	684.42
Total of Non-211(d) Funds Expended by Library	$8,225.17

IMPACT OF GRANT SUPPORTED ACTIVITIES

The original objectives, simply stated, were to improve the University's competence for teaching, research, and to provide greater resources from which to draw for consulting and technical assistance particularly in LDC's. As a result of the Grant we now have an excellent library for students and faculty and also have a staff with experience and technical competence as well as a capability in the use of the Spanish language for utilization in LDC's.

In the early development of the program, emphasis was placed on the preparation of irrigation texts and manuals. These writings have universal use. Spanish versions of the manuals are being prepared for special use in Latin America.

As portions of the objectives were realized the emphasis has shifted more to utilization. The library, manuals, language competence, etc., are being utilized in the numerous responses by the staff and in the teaching and training of students from the LDC's.

The Grant has had a direct beneficial effect on the program to recruit and hold highly qualified scientists supported by other funds. They appreciate the value of association with a viable center. Although these persons are not receiving grant money they are available for teaching, directing the research of LDC graduate students and responding to requests for short-term assistance in LDC's.

The idea to use sprinklers for evaporative cooling to retard early tree development as a means of avoiding frost damage to fruit trees came from staff members in the Department of Agricultural and Irrigation Engineering supported by the Grant. This idea has many beneficial ramifications in relation to tree and shrub management. It is of particular value to Utah and much of the U.S. It is a bonus or spinoff that cost the Grant or the State very little or nothing.

OTHER RESOURCES FOR GRANT-RELATED ACTIVITIES

The program is carried out in cooperation with the Utah Water Research Laboratory, the Departments of Agricultural and Irrigation Engineering, Civil and Environmental Engineers, Soils and Biometereorology and Economics. Other units of the University such as the Agricultural Experiment Station and the Merrill Library make their facilities available. The experimental drainage farm is utilized by the staff and students supported by the Grant. A dollar value for such resources was not included in the contributions recorded in Table 1. Direct expenditures by the library are shown in Table 5.

The program made it possible to employ the new faculty members but cooperating units have provided funds for portions of the salaries so that at present the percentage of salary from the Grant varies from about 10 to 50 percent. During the life of the project a major contribution by the University has been the laboratory facilities and administrative supervisors. Dr. D. F. Peterson, Vice President for Research, has not only given administrative assistance but has been active in developing the ideas for the model being used.

All of the research conducted in Latin America by the graduate students is done in cooperation with AID and the host countries. Private companies in host countries and in the U.S. provide such assistance as equipment, office space and some travel.

UTILIZATION OF INSTITUTIONAL RESPONSE CAPABILITIES IN DEVELOPMENT PROGRAMS

Responses to requests of assistance are met whenever possible. Records are not maintained of all requests received. Some of the requests are received via telephone, word of mouth, etc. And often requests we are not able to fill are referred to other consortium member institutions.

The information recorded in Tables 6 and 7, represent the best we can recall. The information indicates considerable activity and a major effort to make the capability of the university available for a variety of activities and often for extended periods of time.

During the report year 26 students were enrolled in graduate programs in the Department of Agricultural and Irrigation Engineering. Of these students, 3 are U.S. citizens and the remainder are from the following areas: Brazil - 1, Colombia - 2, Guatemala - 1, Venezuela - 2, Chile - 1, Turkey - 1, Thailand - 3, Libya - 1, Iran - 3, Iraq - 3, Israel - 1, Afghanistan - 1, Viet Nam - 1, Taiwan - 1. The details are not available for students in other portions of the University.

Foreign graduates of programs in the Departments of Civil and of Agricultural and Irrigation Engineering have played significant roles in the development of their native countries. In almost all cases students have returned to fill responsible positions in developing countries.

In addition graduates of our programs with U.S. citizenship have accepted employment with consulting firms and, in some cases, governmental organizations whose working scope is international and have been stationed in various LDC countries.

In Table 8 is listed, where known, graduate students indicating positions presently occupied and areas of service.

We have not maintained a record of visitors to our center. Few weeks pass that we are without someone seeking our assistance or wanting to learn about our activities. There has been an exchange of visits with the East West Center in an attempt to better coordinate our activities and to take advantages of the materials each have provided. The Utah

Table 6. Requests for assistance received during reporting period July 1, 1973 to June 30, 1974

A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance	Who Funded Assistance	Size of Effort		Results of Assistance
				Dollars	Man Days	
Alfaro, J. F.						
Coordinate program to assist Guatemala to implement plan of work for irrigated agric.	IBD Guat. Govt.	IBD	IBD		3 mo.	Project is being continued.
Seminar on Irrigation and Drainage at Farm Level for Central Am. countries and Panama.	AID/FAO Costa Rica	AID/FAO	AID		10	Seminar successful and recommendations being followed.
Bach, Ken						
Project identification & development for West Africa Rice Development Assoc., Monrovia, Liberia.	WARDA	WARDA	WARDA		2 yrs.	Continuing.
Bagley, Jay						
To serve on technical team considering programs to alleviate drought effects in Sahel region of Africa.	AID	TAB/AID	AID		22	Inputs served as guide to developing assistance programs.
Bishop, A. A.						
Seminar on Irrigation and Drainage at the Farm Level for Central Amer. countries and Panama.	AID/FAO Costa Rica	AID/FAO	AID		10	Seminar successful, some recommendations research being followed by Utah State University.

Table 6. Continued

A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance	Who Funded Assistance	Size of Effort		Results of Assistance
				Dollars	Man Days	
Christiansen, J. E.						
Assistance to Agricultural Sector Mission to Honduras	IBRD, IBD, AID, Mission	AID	AID		3.5 mo.	Completed Annex II of Mission Report
Consultant for flood control and drainage project for the city of Chimbote, Peru	Eng. Science Inc.	E.C., Inc.	Peru Govt. thru E.C., Inc.		6.5	Prepared report of recommendations as per request
Hanks, R. J.						
Instruct USU team and counterparts in collaboration and utilization of neutron probe and meter research in El Salvador	Mission, USU Host country	USU staff & Mission	AID Research		7	Established use of instrument for moisture distribution & irrigation scheduling
Hansen, Grant						
Assist El Salvador govt. in selecting methods for irrigation	AID Mission	Govt. & Mission	AID		3 mo.	Report on analysis of alternative irrigation methods for El Salvador
Hargreaves, George						
Assistance with Seminar on Irrigation and Drainage at the Farm Level for Central American countries and Panama	AID/FAO Costa Rica	AID/FAO	AID		10	Provided training and orientation in the solution of irrigation development problems

Table 6. Continued

A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance	Who Funded Assistance	Size of Effort		Results of Assistance
				Dollars	Man Days	
Hargreaves, George Assistance with water requirements and water management research for Northeast Brazil	Govt. of Brazil (GOB)	GOB	AID		2 mo.	Rainfall & moisture requirements nearing completion, 3 wk. water management seminar conducted
Keller, Jack Study irrigation project in Hungary	Hungarian govt.	CERES Int.	CERES Int.	3,000	15	Better irrigation system design
LeBaron, Allen Assist in preparing a plan for research data analysis for the host	Min. Agric/ Bolivia	AID/Bolivia	AID		14	Work plan for more Bolivian data analysis completed
Olsen, E. C. Seminar on Irrigation & Drainage at the Farm Level for the Central American countries and Panama	AID/FAO	AID			10	Successful seminar, recommendations being followed
Technical studies related to leaching of salt deposits in soils by sprinkler irrigation in Peru	Min. Agric/ Peru	USAID/Peru	USAID/Peru	12,488	90	Report: "Sprinkler Leaching Program for very Saline Virgin Desert Soils in the LaJoya Irrigation Project, Peru."

Table 6. Continued

A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance	Who Funded Assistance	Size of Effort		Results of Assistance
				Dollars	Man Days	
Peterson, Dean F.						
Work with Brazilian Academy of Science and Ministry of Planning to develop a joint workshop on arid-land management for the northeast	Brazil Acad. of Science Brazil Min. of Planning	Min. of Plan. thru US Natl. Acad. of Sci.	Min. of Plan. thru US NAS		7	Program was developed and a contract signed with NAS. The workshop to be held in Brazil in Sept. 1974
Riley, Paul						
Evaluation of the proposed plan for multiple development of the Senegal River basin in West Africa	The Organization for the Development of the Senegal River Basin	Boeing Services International	USAID	20,000	90	A comprehensive report which was translated into French and used to assist in the evaluation of proposed development plans and policies for Senegal River basin
To assist in the preparation of a team to attend a donors' conference regarding the proposed Senegal River basin project.	AID	AID	AID	1,600	5	Recommendations were developed for the team which will attend the donors' conference in Mauritania, July 74

Table 6. Continued

A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance	Who Funded Assistance	Size of Effort		Results of Assistance
				Dollars	Man Days	
Stutler, Kern Seminar on Irrig. & Drainage at the Farm Level for Central American countries and Panama	AID/FAO Costa Rica	AID/FAO	AID		10	Presented a paper on irrigation
Wennegren, Boyd To assist in agricultural sector analysis	Min. Agric/ Bolivia	AID/Bolivia	AID		3 mo.	Finished preparation of Ag. Sector study

Table 7. Requests for Assistance received during Reporting Period July 1, 1973 to June 30, 1974.

B. Requests not Fulfilled

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance	Who Funded Assistance	Size of Effort		Why not met?
				Dollars	Man Days	
Bagley, Jay To assist in identifying and planning short to medium range programs of US assistance to Sahelian region of Africa		African Bureau, AID	AID			Too many other commitments.
Keller, Jack To review the Kufra Project in Libya		Libyan Govt.	same	2,000	10	Not adequate arrangements with the Government.
To review small project for Brazil		CERES Int.	client in Brazil	2,000	10	Involved with teaching at the time.
Sprinkler irrigation study in Peru		Peruvian business firm				Funds were never made available.

Table 8. Graduate Students from the U.S. and Foreign Countries who were supported by or received benefits from the Grant Program.

STUDENT	COUNTRY	PRESENT STATUS AND/OR LOCATION
Craig Anderson	U.S.	Presently negotiating employment with USAID Contract, Ecuador.
Jose Aquize-Carpio	Colombia	Director, CIDIAT, Bogota, Colombia.
Russ Backus	U.S.	Engineer, CH_2M Hill, Consulting Engineers, California.
Lee Bailey	U.S.	Land Bank, California.
Bruce Brown	U.S.	Bureau of Reclamation, Lakewood, Colorado.
Richard Chase	U.S.	Coordinator, International Programs, Oregon State Univ., Research in El Salvador.
Allen Dedrick	U.S.	Agricultural Research Service, Arizona.
Melke Denekew	Ethiopia	Dept. of Water Resources, Ethiopia.
Yehia El-Shafei	United Arab Republic	College of Agriculture, Soil Dept, Alexandria.
Morgan Ely	U.S.	Private Consulting.
Massood Ghavami	Iran	Private Consulting in Iran.
Gary Glenn	U.S.	Purdue University, Lafayette, Indiana.
Omar Guitierrez	Venezuela	Head, Agric. Eng. Dept., Shell Foundation, Cagua, Venezuela.
Steve Hammond	U.S.	
Grant Hansen	U.S.	Engineer, Rain Bird Sprinkler Co.
James Hardee	U.S.	Engineer, Harza Consulting Engineers, 2 yr. assign. in Iran, presently in Colombia.
Somnuk Indratanee	Thailand	
Abdollah S. Jenab	Iran	Private Engineering in Tehran.

Table 8. Graduate Students from the U.S. and Foreign Countries who were supported by or received benefits from the Grant Program. (cont.)

STUDENT	COUNTRY	PRESENT STATUS AND/OR LOCATION
Rustu Kasap	Turkey	Regional Directorate, Bursa, Turkey.
Abdol Khosravi	Iran	Head, Experiment Station for Soil Institute of Iran.
Henry Kurwahn	Honduras	Director, Dept. Irrig. and Ministry of Natural Resources, Honduras.
Ghazi Mahmoud	Jordan	Amman, Jordan.
Christos Marcoullis	Cyprus	Water Development Dept., Nicosia, Cyprus.
Roberto Michel	El Salvador	Director, Irrig. & Drainage, Ministry of Agriculture, El Salvador.
Hossein Mirnezami	Iran	Dept. of Agriculture, Soil Institute of Iran.
Ken Mitchell	U.S.	
Antonio Moncada	Honduras	Engineer, Consulting Engineer Firm, Dominican Republic.
Michael Moynahan	U.S.	Area Manager, East Division, Rain Bird Sprinkler Co., Australia, Japan, New Zealand.
Benjamin Olsen	U.S.	Engineer, Superior Farms, Consulting Eng., California.
Herbert Paul	U.S.	Engineer, CH_2M Hill, Consulting Engineers, California.
Khalid Pervez	West Pakistan	West Pakistan Agricultural College, Lyallpur, Pakistan.
Kitcha Polparsi	Thailand	Royal Irrigation Dept., Bangkok, Thailand.
Morgan Powell	U.S.	Engineer, CH_2M Hill, Consulting Engineers, California.
Matias Prieto	Peru	Engineer, International Development Bank, Guatemala.
Lanny Ptacek	U.S.	Engineer, Hawaiian Agronomics, Inc. Stationed in Iran.
Luis Ramirez	Venezuela	Engineer, MOP, Caracas, Venezuela.

Table 8. Graduate Students from the U.S. and Foreign Countries who were supported by or received benefits from the Grant Program. (cont.)

STUDENT	COUNTRY	PRESENT STATUS AND/OR LOCATION
Alfonso Ramirez-Lavin	Mexico	Engineer, Sec. de Recoursos Hidraulicos, Mexico City.
Freddy Rondon	Venezuela	Staff, Universidad de Oriente, Managas, Venezuela.
William Rubink	U.S.	Colorado State Univ., working on Ph.D.
Supojana Rujirakul	Thailand	Engineer, Royal Irrigation Dept., Bangkok, Thailand.
Kern Stutler	U.S.	Research Engineer, USAID Contract csd-2459, El Salvador.
Dung-Hai Thai	Vietnam	Taiwan Cheng Kung Univ., Tainan, Taiwan, China.
Kovit Thuamsangiem	Thailand	Dept. of Vocational Educ., Ministry of Educ., Bangkok, Thailand.
Praving Titavunno	Thailand	Electricity Generating Authority of Thailand, Bangkok.
Juan Tosso	Chile	Director of Irrig. Division, Ministry of Agric., Santiago, Chile.
Phil Tscheschke	U.S.	Research Engineer, Okokele Sugar Co., Hawaii.
Duong Van Duc	Vietnam	Saigon 1, So. Vietnam.
Thomas White	U.S.	Alexandria, Virginia.
Shih Chen Yen	Taiwan	Brown and Root, Houston, Texas.
Thomas Young	U.S.	Engineer, Hawaiian Agronomics International, presently in Iran.

Director visited the East West Center and Dr. Allan Phillips from the Center visited the Utah State Campus. At least three scientists from FAO consulted with us during the year. Mr. Juan A. Sagardoy spent time reviewing the FAO program with us and in turn consulted with our staff. We regularly exchange publications with FAO.

During June and July 1974, Dr. Dean F. Peterson further developed our linkages with the University of California and the Rockefeller Foundation. He worked at the Rockefeller Bellogio Study Center near Milan, Italy. His study was supported by the 211(d) Grant and the Foundation.

Many domestic and international linkages have been developed. Those with FAO mentioned above. A by-product of the Park City Symposium on Research Needs for On-farm Water Management was the establishing of connections for linkage development. The Directors of the Grants at Arizona, California, Colorado, and Utah serve as a committee of the Water Consortium to coordinate the activities. The Universities have provided members of teams that have responded to requests from LDC's, cooperated in preparing educational material and participated in seminars in LDC's. Attempts are being made to strengthen the linkages with the various crops centers. The water consortium members also work directly with the soil consortium members. The CUSUSWASH program serves as a strong influence in developing and maintaining linkages and networking programs involving foundations, development banks, host country universities and government agencies.

NEXT YEAR'S PLAN OF WORK AND ANTICIPATED EXPENDITURES

In the early years of the Grant emphasis was placed on increasing the competence. Library improvement and language training were stressed. New courses were offered and curricula revised. The emphasis was then shifted to research and preparation of educational material. The production from these efforts is now becoming more evident with the completion of manuscripts and publications.

During the next year the greatest effort will be directed toward the preparation of manuscripts and publishing of educational material for LDC use. In cooperation with the Consortium universities, two seminars will be organized and conducted in host countries. Research on important problems as identified will be continued.

The anticipated expenditures are presented by activities and line items in Tables 1 and 2. The original designation of activities as shown in Table 1 does not adequately indicate the nature of the activities. These will be changed in the Grant revision.

Publications to be completed:

1. Irrigation Fundamentals. This is an elementary text for use in training technicians in countries where irrigation is not well developed.
2. Energy Inputs to Irrigation. The energy requirements are determined for seven irrigation systems. This will serve as a basis for determining which system to utilize for different energy constraints in LDC's as anywhere else.
3. Small Farm Low Energy Water Management. A series of bulletins will be developed covering the design, operation and management of complete irrigation systems for small farms that may be less than 100 sq. meters. The first in the series will cover drip or trickle design.
4. Predicting Corn Growth as Affected by Water Management. This is an example of use of the model developed for information transfer.

5. Line Sprinkler Plot Irrigator for Continuous Crop Production Surfaces. This system is particularly effective for research and demonstration in LDC's.
6. El Sifon Automatico. A leaflet printed in Spanish describing the construction and use of an automatic siphon. The materials and competence of the countries are considered.
7. Irrigation Handbook. This will be a joint venture with other members of the consortium.
8. Irrigation development as a long-run policy alternative for the agricultural sector in Bolivia.

Seminars:

1. Water and soil management for erosion and sediment control. (Date and place not set).
2. Management of watersheds, ranges and dryland farms. (March 1975).

Research: Two areas will be emphasized. One will be on irrigation system design for water and erosion control during wet season rainfall and for irrigation in dry seasons. The problem was identified as serious at a seminar in Costa Rica, 1974. The second area of emphasis will be on water management information transfer. This is a continuation of the effort to provide transfer and adaptation of technical expertise in on-farm water management from developed countries to the developing countries.

Some flexibility will be maintained in the program in order to be able to respond to any new urgent research problems that are identified during the year.

Consulting

Most requests cannot be anticipated in advance. We have, however, committed Dr. Alfaro to assist in Guatemala until March 1975. Dr. Keller will teach a special course at Colorado State University. The

proceedings from the Park City seminar will be used as a text. Dr. Keller has also agreed to assist Colorado State in preparing a design for a trickle system to be installed in Pakistan. It is likely this will serve a purpose for research and demonstration.

INVOLVEMENT OF MINORITY PERSONNEL AND WOMEN

The Program has supported two minority professional staff members and three technical staff. Included in these are: Dr. Komain Unhanand, Associate Professor of Agricultural and Irrigation Engineering who is actively involved in teaching and developing a State of the Art on water management of heavy soils. Dr. Jose Alfaro, Associate Professor of Agricultural and Irrigation Engineering, has conducted several classes and undertaken numerous consulting assignments including attendance at a Seminar in Costa Rica on irrigation and drainage at the farm level for Central American countries and Panama. He is currently on a long-term consulting activity for the International Development Bank in Guatemala where he is coordinating a program to assist Guatemala in implementing a plan of work for irrigated agriculture. Dr. Alfaro has also authored and co-authored the following publications: "Medias De Aguas En Canales Por Media Del Aforado 'Sin Cuello'," and "Irrigation System Evaluation and Improvement."

Nancy Adams has been employed by the Grant on a part-time basis to conduct research dealing with information transfer. Ms. Adams is a full-time student in the Department of Agricultural and Irrigation Engineering and will enter our graduate program in the near future. Ms. Dorothy McCarty and Ms. Linda Rammell, technicians supported by the grant, have been instrumental in collecting data, assembling reports, and editing publications initiated by staff members. They also cooperate in the distribution of publications.

Past efforts in recruiting minority students and staff have met with limited success. There are almost no women involved in the field of water management research and very few minority males. There is competition for competent minority males as well as females and efforts to locate qualified people have often failed. The Project Director during the current year personally interviewed at Prairie View A & M and the University of Hawaii to recuit minority students and staff. Efforts to attract and encourage minorities are continuing. Nancy Adams has been actively involved in a committee to promote women in Engineering and the Department will enroll a Chinese student. Ms. Hwei-Tzi Chu in a MS program next Fall.

APPENDICES

APPENDIX A

BIBLIOGRAPHY OF WATER MANAGEMENT

by

Diane Polchow, Mary Jo Lindberg and Lynne Cowles Gabrish

(Included under Separate Cover)

APPENDIX B

REGIONAL GROWTH AND WATER RESOURCE INVESTMENT

by

W. Cris Lewis, Jay C. Anderson,
Herbert H. Fullerton, B. Dellworth Gardner

(Included under Separate Cover)

APPENDIX C

EL SIFON AUTOMATICO

by

Ing. Charles M. Burt, Ing. Gregorio Benjamin Vides Lopez,
and Ing. Jaime Antonio Cea

APPENDIX C

EL SIFON AUTOMATICO

Ing. Charles M. Burt – Utah State University, E.E.U.U.
Ing. Gregorio Benjamin Vides López – Depto. de Ingenería Agricola-CENTA
Ing. Jaime Antonio Cea – DGORD

INTRODUCCION

Un sifón es un tubo que se utiliza para conducir agua desde un canal de riego a un surco o una parcela de tierra. El propósito principal del presente boletín es informar al agricultor acerca de las ventajas y el diseño de un nuevo tipo de sifón. Las ventajas que adelante se mencionan indican que este sifón es muy apropiado donde existen ciertas condiciones que requieren especial control del agua de riego.

FUNCIONAMIENTO

Como todo sifón el Sifón Automático debe cebarse para poder ser puesto en funcionamiento. Sin embargo, a diferencia del sifón corriente, el Sifón Automático se mantiene lleno de agua y listo para funcionar aún cuando este vacío el canal de riego, a menos que ocurra una evaporación excesiva del agua en los depósitos.

VENTAJAS

Las siguientes son las ventajas comunes a todo tipo de sifón:

1. Almacenaje fácil.
2. Liviano y fácil de llevar e instalar.
3. El caudal de agua del sifón puede regularse fácilmente subiendo o bajando uno de los extremos. El aumento en el caudal puede efectuarse utilizando un diámetro mayor o simplemente colocando 2 sifones por surco de acuerdo con los requerimientos de riego.

El Sifón Automático presenta además las siquientes ventajas:

1. No necesita ser cebado antes de cada riego. Esto representa disponibilidad de tiempo para otras labores tales como regulación del caudal en el canal, cierre de escapes en el canal, surcos, etc.
2. En algunas circunstancias tales como falla temporal en el sistema de bombeo, presencia de fugas en el canal principal, etc., el caudal de agua en el canal de riego se disminuye siendo necesario cebar de nuevo los sifones una vez que el caudal se haya restablecido, en el caso de los sifones corrientes. Ante este tipo de circunstancias, el Sifón Automático presenta la gran ventaja de que permanece lleno y listo para ser usado nuevamente.
3. Hay menos erosión debido a que la presión del caudal se amortigua a través del depósito.

CONSTRUCCION

El Sifón Automático se construye con tres tubos de lámina galvanizada N°28, soldadas de tal manera que tomen la forma de un trapecio para acomodarlo a la forma del borde del canal. En cada extremo deberá soldarse un depósito cilíndrico cuyo diámetro esté en relación de 1 1/2 con el diámetro del tubo. El extremo del sifón estará separado del fondo del depósito unos 7 cm, y la superficie libre del agua en el depósito deberá estar por los menos 8 cm arriba de dicho extremo. Esto último para evitar que la evaporación en determinado momento ocasione el vaciado del sifón. El depósito de la entrada llevará una zarada de 1/2 pulgada para evitar la entrada de basura. Este sifón puede ser hecho por cualquier hojalatero. El material necesario para construir un sifón de 1 1/2 a 2 pulgadas de diámetro, es de aproximadamente 3 a 4 piés cuadradros de lámina.

APPENDIX D

PREDICTING CORN GROWN AS AFFECTED BY WATER MANAGEMENT: AN EXAMPLE

by

R. W. Hill, R. J. Hanks
J. Keller, P. V. Rasmussen

APPENDIX D

PREDICTING CORN GROWTH AS AFFECTED BY WATER MANAGEMENT: AN EXAMPLE

By

R. W. Hill
R. J. Hanks
J. Keller
P. V. Rasmussen

Paper developed under partial support from U.S. Agency for International Development under contract AID/csd-2459, and from Utah Agricultural Experiment Station. All reported opinions, conclusions or recommendations are those of the authors and not those of the funding agency or the United States Government.

Department of Agricultural and Irrigation Engineering
Utah State University
Logan, Utah

September, 1974

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PREDICTING CORN GROWTH AS AFFECTED BY WATER MANAGEMENT: AN EXAMPLE[1]

By

R. W. Hill[2] A.M. ASCE, R. J. Hanks[3],

J. Keller[4] M. ASCE, and P. V. Rasmussen[5]

Introduction

Staff members at Utah State University for the past few years have been involved in programs which provide transfer and adaptation of technical expertize in on-farm water management to some of the developing countries (Keller, et. al. 1973). This experience has illuminated the need for an organized means of efficiently transferring our technical capabilities in agriculture production to other areas of the world. This could be accomplished by storing in a retrievable form pertinent crop-water-soils and other agricultural production data. Appropriately designed computer programs could then access this data for supplying recommended agriculture research, farm management, and other programs at any given site. The model described in this article is used to demonstrate the feasibility of this strategy for a particular situation.

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[1]Paper developed under partial support from U.S. Agency for International Development under contract AID/csd-2459, and from Utah Agricultural Experiment Station. All reported opinions, conclusions or recommendations are those of the authors and not those of the funding agency or the United States Government.

[2,4]Assistant Professor and Professor respectively, Agricultural & Irrigation Engineering Department, Utah State University, Logan, Utah.

[3,5]Professor and Research Assistant respectively, Soils and Meterology Department, Utah State University, Logan, Utah.

There are many ways to effect management on the plant-soil-water system. Irrigation and tillage management practices are commonly used to maximize production with a given set of soils, climate, water resources and plant materials. Management may also be improved by selection of different plant materials and by changing planting dates to maximize the effects of naturally occurring rainfall or other favorable climate conditions, or to minimize the effects of detrimental environmental factors.

The objective of this study was to develop a model which combines the influence of climatic conditions on plant growth stage progress with a soil water model which predicts plant growth during each stage. The model depends upon stored information which describes the growth characteristics of a selected plant material (a certain variety of corn, in this example) as affected by site environmental conditions. The model is designed to predict dates at which various phenologic growth stages are reached by the crop and shows changes in yield as affected by climate, planting date, and crop and soil water storage interactions.

The soil water part of the model has been described by Hanks (1974). He demonstrated its usefulness in predicting the influence of soil type and irrigation frequency on amount of yield. Robertson (1973) has described some of the important background literature relative to the climate - crop growth stage, part of the model. Recent work reported by Splinter (1973) and Baker (1974) represent the current emphasis in developing more physiologically based crop models. They use growing degree days as a growth stage timing device for corn as is done by the model described herein.

Environmental Consideration in Plant Growth

During the growth of a plant, as it progresses from seed placement on through harvest, various conditions have greater or lesser influences depending upon the particular growth stage of the plant. Some of these factors are:

1. Climate (temperature, precipitation, radiation, wind, humidity, etc.)
2. Soil (water status, fertility, etc.)
3. Plant (crop, variety, preconditioning, etc.)
4. Pests, disease, etc.
5. Day length and elapsed time.

Information describing crop response to all of these factors must be identified for a model to completely predict crop growth progress. A conceptual basis for handling some of these complex interrelationships is presented by Keller, et. al, (1973). They suggest that the crop response to environmental conditions can be expressed as the interaction of two multi-dimensional vectors: agricultural environment ($\overline{E}$), and production materials ($\overline{M}$). The crop response vector ($\overline{Rc}$) can thus be expressed as $\overline{Rc} = f(\overline{E}, \overline{M})$. For the purposes of the present model, $\overline{E}$ includes daily maximum and minimum temperatures and precipitation, irrigation, soil water properties and potential evapotranspiration data, $\overline{M}$ is a set of plant material properties relating growth stage to accumulated growing degree days.

The calculation of growing degree days utilizes a method suggested by Gilmore and Rogers (1958), now referred to as the Weather Bureau 50-86 method. In equation form this is expressed as:

$$GDD = (TH/2 + TL/2) - 50 \qquad [1]$$

in which

GDD = growing degree days for the given day, ^{o}F;

TH = maximum daily air temperature (TMX), if TMX $\leq 86^{o}$ F; if TMX > 86° F then TH = 86° F;

TL = minimum daily air temperature (TMN), if TMN $\geq 50^{o}$ F; if TMN < 50° F then TL = 50° F.

From a specified planting date the daily growing degree days are accumulated and matched against required accumulated GDD's for the given corn variety to reach growth stage end points, such as tassel or silk. Thus, the accumulated GDD's serve as a timing mechanism for plant growth stage progress.

Estimation of Crop Yield

The purpose of this part of the model was to provide seasonal estimates of plant growth (yield) as influenced by soil water status. Since soil water status is related to evaporation directly from the soil, transpiration from plants, and drainage, it was necessary to devise a procedure which would handle these processes. It was assumed that the only process influencing plant yield directly is the ratio of transpiration (T) to free water evaporation (E_o). Evaporation and drainage have an indirect influence on the amount of water available and thus transpiration, but the model assumes these processes do not directly affect yield. The equation to relate dry matter yield, Y, to transpiration is taken from that of de Wit (1958) which is

$$Y = \frac{mT}{E_o} \qquad [2]$$

in which

Y = yield;

T = transpiration;

E_o = average free water evaporation rate;

m = a crop factor.

For a given crop and year the relation of relative transpiration to relative yield can be obtained from equation [2] as

$$\frac{Y}{Y_p} = \frac{T}{T_p} \qquad [3]$$

in which

T_p = potential transpiration which occurred when soil water is not limiting;

Y_p = potential yield when transpiration is equal to potential transpiration.

In the development of equation [2] de Wit (1958) analyzed a vast amount of earlier data under condition of maximum soil water. Most of the experimental work was done under semi-field conditions where plants were grown in containers, although some straight field data was also analyzed. He concluded that the influence of soil water had a similar effect on both transpiration and yield, therefore, if transpiration could be measured then yield could be estimated.

The validity of equations [2] and [3] is not firmly established. Richards and Wadleigh (1952) cite research indicating that yield and transpiration are highly correlated. They also present conflicting data where yield is reduced before transpiration as soil water decreases as well as the reverse. Rawitz (1970) showed that transpiration is decreased much less than yield at high water levels in a laboratory study.

Experimental work under field conditions by Hanks, et al. (1969) indicated that the model of de Wit (1958) seemed to hold for conditions of differential water status. However, under field conditions, water is returned to the atmosphere by evaporation directly from the soil as well as by transpiration by plants, so estimates of soil evaporation need to be made.

Other information that is relative to the model is the relationship of transpiration to soil water status. Hanks (1974) showed that the model predictions were not very sensitive to the type of relationship between the existing soil water storage, SWS, and the maximum amount of available water storage, AW. The relationship used herein is

$$T = \frac{T_p}{0.5} \cdot \frac{SWS}{AW}, \text{ if } \frac{SWS}{AW} < 0.5 \qquad [4a]$$

or

$$T = T_p, \text{ if } \frac{SWS}{AW} > 0.5 \qquad [4b]$$

and

$$T_p = a\ E_o \qquad [5]$$

in which

SWS = existing soil water storage;

AW = maximum amount of available water storage;

a = a factor which depends on the crop and growth stage.

This computation is adapted to allow for daily estimates and for different layers of soil, and a root growth estimation is used which allows for root extraction to occur at increasingly deeper depth with time. The equations assume there is a unique AW for a given soil condition which may be questionable for some situations.

Soil evaporation is assumed to be related to potential soil evaporation and the time since the last wetting by

$$E = E_p/t^{\frac{1}{2}} \qquad [6]$$

and

$$E_p = b(E_o - T_p) \qquad [7]$$

in which

E = evaporation from the soil;

E_p = potential soil evaporation;

b = a factor which depends on the crop and growth stage;

t = the time in days since the last wetting.

Equation [6] is the same type of relation used by Ritchie (1972). It is subject to the constraint that the soil water storage in the surface 4 in. (100 mm) of soil must be above a lower limit. The approximate value of this lower limit is the air dry soil water storage. The top 4 in. (100 mm) of soil are dried by evaporation and transpiration to the wilting point and then by evaporation only to air dry. The value of T_p and consequently E_p (see equation [7]) are influenced by the kind of crop and stage of growth.

Drainage is assumed to occur if the sum of SWS and the water applied by irrigation or rain is greater than AW for all root depth increments. This simplification does not allow water flow upward into the root zone.

Equation [2] refers to dry matter production only. To estimate grain production where conditions during one stage of growth are more critical than others, the method of Jensen (1968) was used. For corn the season was divided into five stages and relative production computed as

$$\frac{Y\ (\text{grain})}{Y_p} = \left(\frac{T_1}{T_{p1}}\right)^{\lambda 1} \left(\frac{T_2}{T_{p2}}\right)^{\lambda 2} \left(\frac{T_3}{T_{p3}}\right)^{\lambda 3} \cdot \left(\frac{T_4}{T_{p4}}\right)^{\lambda 4} \left(\frac{T_5}{T_{p5}}\right)^{\lambda 5} \qquad [8]$$

in which

λ_i = an exponent to allow for weighting the "ith" stage;

Y (grain) = the potential production for the situation where T_i always equals T_{pi}.

Model Description

The computational procedure for the foregoing mathematical expressions was programmed in FORTRAN IV. A simplified flow chart is given in Figure 1. The following input data are required by the program:

a) Plant descriptor array.

   1. Total heat units planting to maturity.
   2. Accumulated heat units between end points of each growth stage.
   3. Growth stage weighting factors for equation [8].
   4. Coefficients a and b for estimating relative effect of crop growth on potential soil evaporation, E_p, and transpiration, T_p, in equations [5] and [7].
   5. Parameters describing root growth.

b) Soils description, for up to 5 layers.

   1. Initial soil water.
   2. Available soil water per unit depth.
   3. Potential root depth.

c) Daily weather data.

   1. Maximum and minimum temperatures.
   2. Rainfall.
   3. Potential evapotranspiration.

d) Management information.

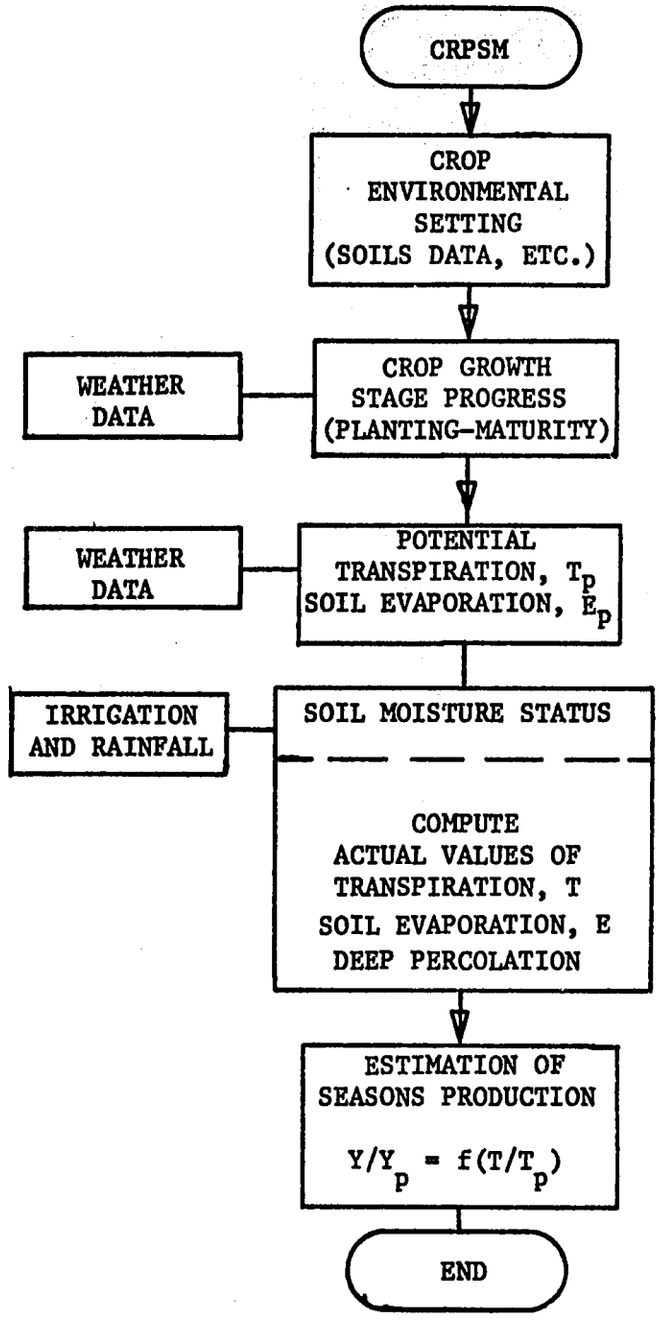

FIGURE 1. FLOW CHART OF WATER AND SOIL MANAGEMENT-CROP GROWTH MODEL (CRPSM).

1. Frequency and amount of irrigation or, date and amount of individual irrigation events.
2. Desired planting date.
3. Control data causing the program to increment irrigation amount at given frequencies for the purpose of generating water production function curves.

The computation then proceeds on a day-to-day basis by using a simple accounting procedure to keep a running account of SWS, cumulative T_p, T, E, drainage, irrigation and rain. The phenologic stage is determined by accumulating daily computed GDD, equation [1], and matching against the required sum for completion of each growth stage. At the end of the season, the cumulative T, E, irrigation, rain, drainage, total water use, T/T_p for each growth stage and relative grain and dry matter yield are printed out. The program allows for a re-initialization of the input data with a different amount of water added at the same or different frequency and, if desired, a new planting date. The computations are then repeated for the same set of daily weather data and soils.

Model Validation

Testing of the soil-water portion of the model is reported by Hanks (1974) for several different sets of research data. An additional check was provided from the management runs using data at Mead, Nebraska (Fishback and Somerholder, 1972) for the 1972 growing season. For a planting data of May 18, 1972, they obtained field grain yields (rainfall only) of 61% of potential yield. The model predicted a grain yield of 63% of potential for the same planting date. The combined growth stage prediction-soil-water model (CRPSM) was also tested with

data received from Stewart (1974) at Davis, California. The model predictions closely matched yields from soil water conditions giving high actual yields. However, for trials in which periods of adequate moisture were followed by drought the model underpredicted the actual yield. Under the latter situation the corn plants may have been "conditioned" such that transpiration was not the main factor in actual yields, thus explaining the poor performance of the model.

Management Results

Figure 2 shows predicted corn yields for different planting dates for the 1972 growing season at Mead, Nebraska under rainfed conditions. There is a definite trend of increased grain yield with later planting dates from April 20 through May 22 after which the grain yield remains around 70% of potential through the June 6 planting. The model predicted that planting after June 6 would have delayed maturity until after the first fall frost. However, the predicted dry matter yield remained more or less constant at about 70% of potential for all planting dates considered. Marley and Ayres (1972) reported similar variations in actual grain yield under rainfed conditions by changing field plot planting dates at Ames, Iowa.

Figure 3 shows the predicted duration of the various growth periods and the rainfall events corresponding to Figure 2. Careful study of Figure 3 suggests that for a planting date of May 18 the silk to milk period was delayed enough to pick up the 1.1 inch rain of July 26. This was sufficient during the critical silk to milk period to cause the predicted yield to jump from 45% to 60%. With later planting dates

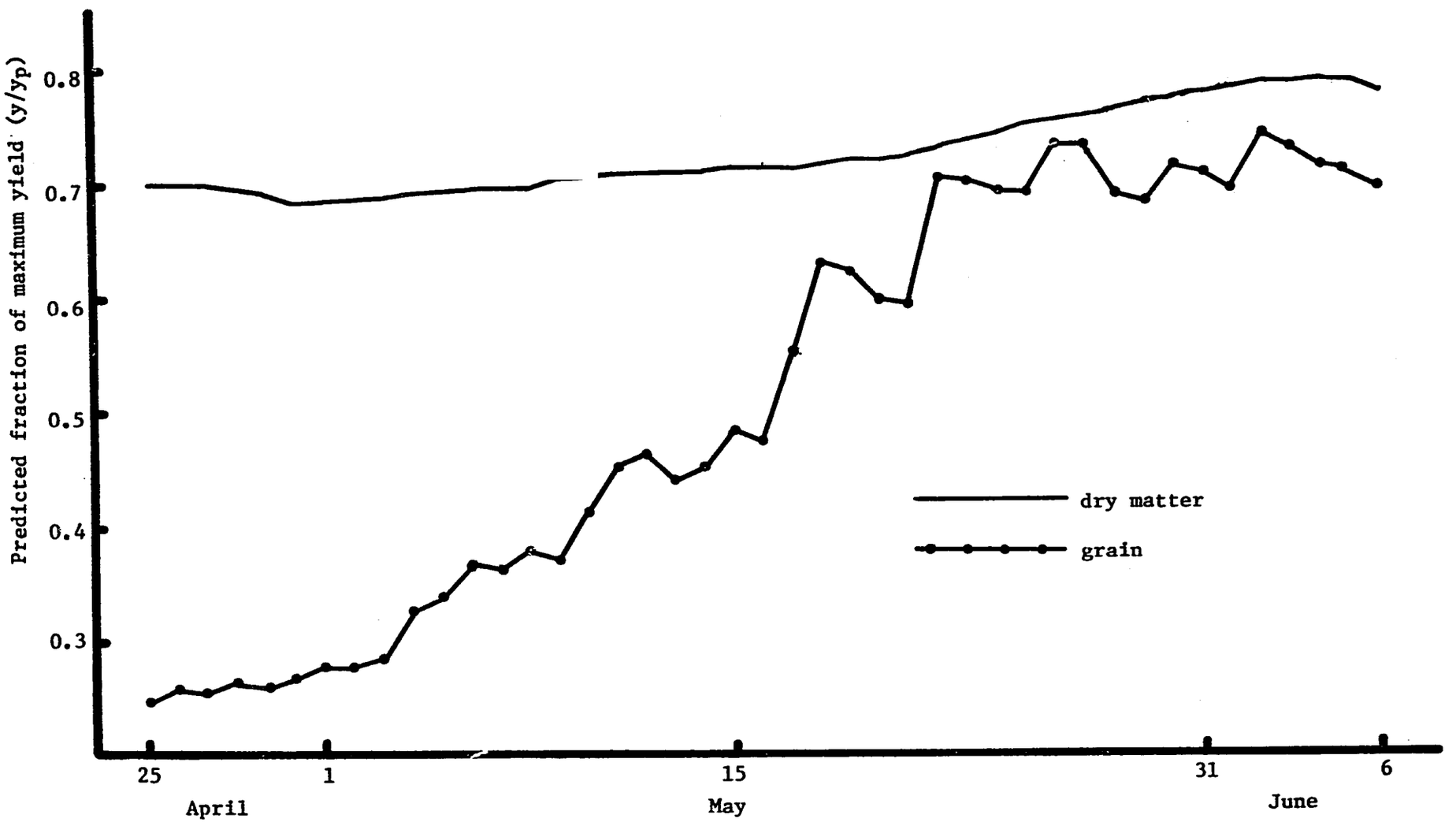

Figure 2. Predicted yield vs. planting date using 1972 Mead, Nebraska data.

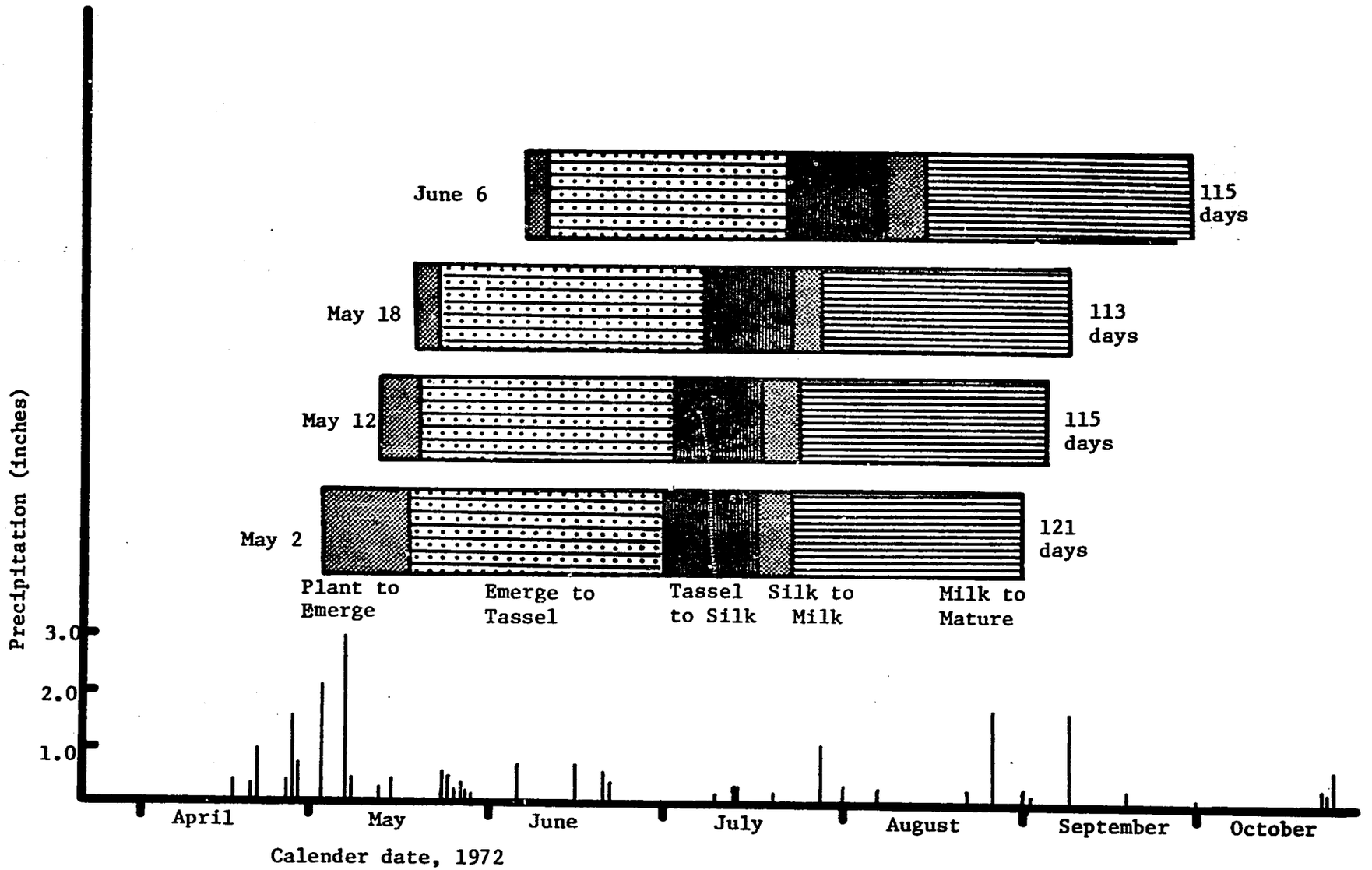

Figure 3. Predicted growth stage progress of corn with four planting dates at Mead, Nebraska, 1972.

this same rainfall is moved further ahead in the critical growth periods increasing the predicted yield up to 70%.

Table 1 gives a summary of predicted corn yields for a few one-inch supplemental applications of irrigation water at Mead, Nebraska, during the 1972 growing season assuming two different planting dates. The same planting date, May 18, as used by Fishback and Somerholder (1972) with a relative yield of 63% was selected as representing good rainfed management conditions. May 4 giving a relative yield of 33% was selected as representing less desirable rainfed management conditions. Irrigation water was added at the "best" time by the model for both planting dates until a relative yield of at least 95% had been reached. As can be seen in Table 1, 2 inches or 66% more water must be applied to corn planted on May 4, in contrast with a May 18 planting, to exceed 95% of potential yield.

Table 1. Predicted corn yields for two planting dates with and without irrigation. (Mead, Neb. 1972 data)

Planting Date	Predicted Relative Yield		Total Water Applied	Required Irrigation Scheduling	
	Rainfed Only	With Irrigation		Date	Amount
May 4	33%	96%	5 inches	May 26	1"
				Jul 3	1"
				Jul 7	1"
				Jul 17	1"
				Jul 19	1"
May 18	63%	96%	3 inches	Jun 15	2"
				Jul 23	1"

Table 2 presents the order in which the various irrigation dates were selected by the model with the attendant relative yields. From Table 2 it is possible to estimate the value of applying supplemental irrigation water for different dates of planting. For example: if the potential yield were 150 bushels of corn per acre, the timely application of 1 inch of water for a May 4 crop could mean an additional yield of 150 (60 - 33)/100 = 40 bushels per acre. However, this would still be a little under the rainfed only yield of a May 18 crop. The first additional inch applied to a May 18 crop could give an increased yield of 33 bushels per acre. At June 1974 average U.S. corn prices an additional 33 bushels of corn would be worth $85. Thus the increased yield from just one inch of irrigation water on May 18 corn may be more than adequate to justify a supplemental irrigation system.

Table 2. Predicted influence of incremental application levels of irrigation water on corn yield (Mead, Neb. 1972 data).

Planting Date	Dates of Application of One Inch of Irrigation (in order of selection)	Resulting Yield (With irrigation on previously selected dates) Per Cent of Potential
May 4	None	33
	Jul 17	60
	Jul 19	74
	Jul 3	85
	Jul 7	93
	May 26	96
May 18	None	63
	Jul 23	85
	June 15	92
	June 15	96

Conclusion

Although many assumptions underlie the model, fairly close agreement with field research data has been demonstrated. The model as currently developed does not correctly predict the effects of "preconditioning" on yield when the plants are subjected to extremely dry conditions late in the reproductive stages. Much information is needed from research efforts to adequately define this and other subtle factors.

Further development and use of models of this type can greatly reduce the amount of field research needed to determine preferred planting dates at various localities. From historical weather records the model could generate probabilities for "best" planting dates and supplemental irrigation requirements to assure desired yield levels. Further development of the model concepts should improve the transferability of field research results by better analysis and utilization of specific site environmental data (weather, soils, etc.). Field research efforts can then be focused to obtain transferable information which should greatly reduce the quantity of site tests required and improve both the efficiency and speed of crop-water-soil management information transfer.

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APPENDIX E

ABSTRACTS

Regional Growth and Water Resource Investment

by

W. C. Lewis, B. D. Gardner, J. C. Andersen and H. H. Fullerton

The objective of the book is to provide an analysis and appraisal of the efficacy of water resources investment as a means of achieving regional economic development. Traditionally the feasibility of a water resource investment has been determined by the one-dimensional benefit-cost criteria. Only if economic benefits, in the present as well in all relevant future time periods, exceed the cost of the investment, is the project then deemed feasible. The Water Resources Council has suggested a broader set of guidelines for use in evaluating proposed water resource investments including consideration of the regional economic development impacts of those investments.

The manuscripts addresses the following questions: (1) Do water resource investments influence regional development? (2) If so, what is the process by which such investment causes economic development? (3) What type of project is most likely to promote development in a particular type of region? (4) What tools are especially useful in predicting and measuring the impacts of public investments? (5) What type of accounting framework should be used at the operational level to provide information to the policy or decision maker?

The book is organized in three major parts. The first is devoted to the development of a framework within which an economic analysis of water investment can be logically evaluated. The important concepts developed include regional delineation, the theory of regional growth and the measurement of economic welfare and growth. The second part considers the role of water resource investment in the regional growth process, and constitutes the heart of the analysis. The discussion ranges from an examination of the characteristics of the water resource to its role in industrial activity. Also considered is the possible development sequence that follows water resource investments. In the last part, an accounting framework for analyzing water investment is outlined, and alternative quantitative techniques for estimating and predicting the development impacts are reviewed and evaluated.

Trends in Irrigation and Drainage Research

by

Robert W. Hill and George H. Hargreaves

A continued rapid rate of increase in agricultural production is required in order for the United States to maintain a strong world economic position. Most non-irrigated agricultural areas suffer from water shortages. Increased emphasis on irrigation is considered essential to major increases in agricultural production. This paper summarizes the irrigation research funding by the Office of Water Resources Research and by the Agricultural Research Service as well as the relative emphasis given to various irrigation related subjects in the publications of ASAE and ASCE.

Research in progress reflects not only the needs within the United States but of the developing countries as well. A history of trends in irrigation research is given for recent years and recommendations are made for desirable future irrigation and drainage research programs and activities. Activities carried out by Utah State University designed to assist the Latin American developing nations are briefly described.

Predicting Corn Growth as Affected by Water Management: An Example

by

R. W. Hill, R. J. Hanks, J. Keller and P. V. Rasmussen

Utah State University has been involved in programs which provide transfer and adaptation of technical expertise in on-farm water management to developing countries. This demonstrated a need for an organized means of efficiently transferring technical capabilities in agriculture production to other areas of the world. This could be accomplished by storing in a retrievable form pertinent crop-water-soils and other agricultural production data. Appropriately designed computer programs could then access this data for supplying recommended agriculture research, farm management, and other programs at any given site. The model described in this article is used to demonstrate the feasibility of this strategy for a particular situation.

A preliminary computer program is presented which illustrates a strategy for relating crop growth and production at specific site locations as influenced by water management. To demonstrate the program, a model based on accumulated heat units as a means of predicting crop growth stage development is used. The effect of soil and climatic characteristics on plant growth at various growth stages is also predicted.

The program requires an evaluation of the soil water in storage at the beginning of the season, available soil water storage in the root zone, and daily values of rainfall, irrigation, and maximum and minimum temperatures. In addition the accumulated heat units required by each given plant material to progress from planting through the various growth stages to maturity must be provided. The example presented utilizes one site, one corn variety, and one year of data. From a series of pre-selected planting dates the program predicts grain and dry matter yield from the relative transpiration during each stage of growth.

Determination of required depth and timing of irrigation water for any planting date is accomplished by application of supplemental water in incremental amounts. The resultant irrigation scheduling is indicated when a pre-selected yield level has been obtained.

For an assumed potential corn yield of 150 bushels per acre the model showed that selection of a planting date which makes good use of natural rainfall was worth 50 bushels per acre over a less advantageous planting date. The appropriate timing of the first inch of effective irrigation water gave a predicted additional yield increase of 33 bushels per acre. For planting date which gave poor yield from rainfall only, the first inch of irrigation water resulted in a 40 bushel per acre increase; however, this was still below the rainfall only yield from the "better" planting date above.

Trickle Irrigation Design

by

Jack Keller and David Karmeli

This is a design text which provides a rather complete review of trickle irrigation with sufficient handbook material and instruction for system design. It is written for students, engineers, researchers, farm advisors and existing or potential users. To enhance its usefulness, dual (metric and English) units of measurements are used throughout the text. It contains design examples for each concept plus complete system design problems.

Trickle irrigation is relatively new to both users and the scientific community. The authors realize the need for more research to refine the design concepts. However, they have made an effort to bridge the many existing gaps in available knowledge in order to present a complete concept for trickle irrigation design.

The book covers the following subject areas: a description of trickle irrigation; characteristics of emitters; soil-water-plant relationships; trickle irrigation efficiency; lateral or hose line design; manifold and mainline design; system operation; filtration, fertilization, and maintenance; and a comprehensive trickle irrigation system design problem.

The editor and publisher of the First Edition (1974) is Rain Bird Manufacturing Corp., Glendora, CA 91740, USA. It contains approximately 150 pages and the hardbound copy is priced at $8.95.

Intraregional Efficiency of Production Decisions
and Interregional Efficiency of Input
Use in Bolivian Agriculture

by

Stephen C. Hammond, Master of Science
Utah State University, 1974

The objectives were to analyze the efficiency with which Bolivian farmers utilize productive resources as they combine them in crop production and to examine the possibility of interregional resource immobility in the production of agricultural products.

Bolivia was divided into seven distinct production regions called departments. A linear program maximizing model was generated for the major crops produced in each department. Land, labor, irrigation, and capital were the input coefficients used in the models. They produced a net return to management, land, and fixed costs associated with land. The linear program using these coefficients generated the profit maximizing hectare combination for each crop by department. These were compared with those reported to have been grown in each department to make an efficiency judgement of production decisions made by Bolivian farmers.

The same department linear programs generated value marginal products for resources in short supply in each model. These were compared interdepartmentally to determine any resource immobility that might be in existence.

Analysis of the linear program maximizing output indicated that in all of the departments considered, with the exception of Santa Cruz, farmers appeared to be efficiently combining their resources in the production of crops considered in this study. It was also noted that a possible labor immobility existed between the Santa Cruz department and the other six considered.

Resource Allocation and Factor Substitution in
Guayas Basin Rice Production

by

Gary Scott Glenn, Master of Science
Utah State University, 1974

The primary objective was to examine changes in resource productivity and factor shares as irrigation was introduced on small rice farms using traditional management techniques.

Average output on irrigated farms was double that of dry farms, because irrigated farms produced two crops as opposed to one crop on farms without irrigation. Examination of marginal products showed that farmers with irrigation could profitably use more land. Dry farmers could profitably use more labor. The low labor input and high MP of labor on dry farms occurs because these farmers are undercapitalized and are obliged to accept off-farm employment at crucial periods of the rice growing season.

On both farm types, irrigated and dry, factor shares of land were high suggesting that a redistribution of land would also redistribute income. This information provides criteria for formation of rice production policy in Ecuador.

Some Feasible Long-Run Policy Alternatives for the Agricultural Sector in Bolivia

by

Franklin Bruce Brown, Master of Science
Utah State University, 1974

The purpose of this paper is to construct a model that will aid in analyzing present agricultural policies along with feasible alternatives. Recently completed studies of production costs, crop prices and yields, and experimental technologies were used as sources of data. A linear programming model was used to project suggested investment for agriculture in land, labor, and capital inputs in order to achieve specific crop production targets. The paper is divided into four major parts: the theory of policy-making, the model description, the application of the model to Bolivia, and the results and conclusions.

An Intensive Edaphological Characterization of
The Soils of Malambito Experimental Station
And Its Implications in Future
Agricultural Research

by

William L. Rubink, Master of Science
Utah State University, 1973

Malambito Experiment Station, in the Atlantico III project area, Department of Atlantico, Colombia, had almost no quantitative edaphological data on which to base agricultural research. Unexplainably low general yields as well as problem areas of deficient plant growth only confounded the results of field plot experiments. Intensive soil sampling and subsequent measurements of pH, EC_e of the saturation extract, and the four major cations disproved the previous suggestions that the crop growth problems were related to saline, sodic, or degraded sodic soil conditions. The Ca/Mg + K + Na ratio, although significant when correlated with plant height, was sufficient explanation for only a small portion of the Malambito problem. The heavy soil texture (50 percent clay) was also shown to be of minor importance in the overall problem. Although no definitive answer was given to explain the variations in plant growth, a basis for further research was provided, including estimates of soluble plus exchangeable cations and their field variability, pH, organic carbon, EC_e and CEC. Future studies in the areas of micronutrient deficiencies and toxicities and possible resistant crops were advocated.

Recent research based on the results of this thesis have now implicated heavy metal toxicity as a probable cause for the growth deficiencies and low yields at Malambito.

Irrigation System Evaluation and Improvement

by

John L. Merriam, Jack Keller and Jose F. Alfaro

This second edition of the manual contains detailed procedures for the field evaluation of sprinkler, surface, and trickle irrigation performance and management practices. It contains details such as: a list of equipment needed; step by step instructions for carrying out the field work; sample forms for recording and organizing the field data; and sample studies demonstrating the entire process. It also includes an analysis and recommendations for the actual case studies used.

The introduction deals with the general uniformity, efficiency, and management concepts employed in the evaluation of each system. The sprinkler section covers both simple and full evaluations of regular fixed grid sprinkler systems as will be under tree orchard, center pivot and traveler sprinkler systems. There is a brief section dealing with trickle (or drip) irrigation and a section on basic irrigation. Both the furrow and border irrigation sections contain a simple (short cut) evaluation procedure as well as complete full evaluations.

Irrigation Fundamentals

by

Glen Stringham

Irrigation Fundamentals has been written to be used as a guide for those involved in teaching the fundamental concepts of irrigation to water users. It discusses the concept of using the soil as a reservoir to store water for plant use, and the principles which must be considered in the reservoir management. Eight laboratory and field demonstrations are presented which help in the visualization of the principles discussed. These demonstrations are presented with complete lists of equipment needed and photographs showing how it is to be assembled and used. Comments are also given on the interpretation of phenomena observed during the demonstration and cautions about some of the pitfalls which may be encountered.

This publication is well adapted for the use of extension personnel and officers of rural development organizations charged with introducing and improving irrigation skills of water users in new or existing irrigation projects.

Bibliography of Water Management

by

Diane Polchow, Mary Jo Lindberg and Lynne Cowles Gabrish

In 1969 Utah State University, in cooperation with USAID (csd/2459) began a five year program to improve and increase the library holdings in on-farm water management and related subjects. This bibliography is the compilation of all of the relevant book titles dealing with on-farm water located at Utah State University. To date, 9,132 titles are housed in the component parts of the Merrill Library which are pertinent to on-farm water. This figures includes: 5,964 books catalogued by dewey decimal call number; 1,593 books housed in the archives and special collections section of the library; 1,152 government documents; 432 vertical file materials; 301 non-book microfilm, microfiche and motion pictures; and 88 maps. Holdings in other centers of information on campus have also been included in the bibliography. There are 1,634 titles in the Utah Water Research Laboratory, 450 titles in the Agricultural and Irrigation Engineering Department, and 193 titles on business law in the College of Business.

The KEY gives the meaning of the various call number symbols and where these books may be located on the Utah State University campus. It also lists the various addresses from which these books may be borrowed if they are not available in your locale. The information is stored on computerized tapes. This book is a photo-reduced computer printout. The bibliography is arranged in alphabetical order by subject.