AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION
   A. PRIMARY: Agriculture
   B. SECONDARY: Irrigation

2. TITLE AND SUBTITLE

Trends in Irrigation and Drainage Research

3. AUTHOR(S)

Hill, Robert W. and Hargreaves, George H.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1974	14p	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Utah State University
Department of Agricultural & Irrigation Engineering
Logan, Utah 84322

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

If 18 percent of the crop land in Class 1 to 5 farms in the United States is irrigated and produces 25 percent of the total value of agricultural production it would seem that increased production can easily come from increased area irrigated. However, water supplies are limited. A more extensive use of irrigation or a more intensive development should be based upon a steady improvement of knowledge and techniques. Research should be designed so as to provide know-how to maximize efficiency and production while at the same time minimizing undesirable effects upon the quality of the environment.

Irrigation and drainage research is influenced to a large degree by conflicting goals. Emphasis is given to improving receiving water quality, improving the quality of return flows and to eliminating causes for environmental deterioration. At the same time there is a major effort to increase production of food and fiber crops to meet rapidly growing world demands. Much irrigation research is concerned with the technology and the economics of increasing production on currently irrigated lands and of developing new lands under irrigated agriculture. However, efforts to increase production frequently increase consumptive use for irrigation and generally concentrate soluble solids thus altering the quality of return flows.

This paper describes current emphasis in research programs as indicated by a survey of pertinent journal articles and from limited research funding information.

10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-AAB-254	
12. DESCRIPTORS: Water Supplies, Research, Efficiency, Production, Water Quality, Return Flow, Technology, Economics	13. PROJECT NUMBER: 931-17-128-489
	14. CONTRACT NUMBER: AID/csd-2167
	15. TYPE OF DOCUMENT: Research Paper

AID 590-1 (4-74)

TRENDS IN IRRIGATION AND DRAINAGE RESEARCH[1]

by

Robert W. Hill, Assoc. M. ASCE
and
George H. Hargreaves, F. ASCE[2]

Introduction

If 18 percent of the crop land in Class 1 to 5 farms in the United States is irrigated and produces 25 percent of the total value of agricultural production it would seem that increased production can easily come from increased area irrigated. However, water supplies are limited. A more extensive use of irrigation or a more intensive development should be based upon a steady improvement of knowledge and techniques. Research should be designed so as to provide know-how to maximize efficiency and production while at the same time minimizing undesirable effects upon the quality of the environment.

Irrigation and drainage research is influenced to a large degree by conflicting goals. Emphasis is given to improving receiving water quality, improving the quality of return flows and to eliminating causes for environmental deterioration. At the same time there is a major effort to increase production of food and fiber crops to meet rapidly growing world demands. Much irrigation research is concerned with the technology and the economics of increasing production on currently irrigated lands and of developing new lands under irrigated agriculture. However, efforts to increase production frequently increase consumptive use for irrigation and generally concentrate soluble solids thus altering the quality of return flows.

---

[1]The work presented herein was financed in part by the Agency for International Development through its contract AID/ta-c-1103 and AID/csd-2459 with Utah State University. The views presented herein are those of the authors and do not necessarily represent those of the Agency for International Development or Utah State University.

[2]Assistant Professor and Research Engineer, respectively, Agricultural and Irrigation Engineering, Utah State University, Logan, Utah.

This paper describes current emphasis in research programs as indicated by a survey of pertinent journal articles and from limited research funding information.

Trends as indicated by the literature

Two publications, the Transactions of the American Society of Agricultural Engineers (ASAE) and the Irrigation and Drainage Division Journal of the American Society of Civil Engineers (ASCE) were used for the literature base. A sixteen year period, January 1958 through December 1973 was divided into two separate periods: an eleven year period from January 1958 through December 1968 and a five year period of January 1969 through December 1973. Articles were classified in the following general subject areas:

1. Salinity and drainage.
2. Water quality and reuse.
3. Watershed planning.
4. Surface irrigation systems.
5. Irrigation requirements and scheduling.
6. Improved design methods.
7. Sprinkler systems.
8. Groundwater.
9. Canals and canal structures.
10. Weather modification.
11. Trickle irrigation.
12. Evaporation control.
13. Production function.
14. Water management and planning.

The total number of articles according to the foregoing classification, was 867 for the sixteen year period. The ASAE publication had a total of 509 articles and the ASCE publication had 358. A summary of the number of articles in the various classifications is given in Table 1.

In Figure 1 the various subjects, as reported in the ASAE Transactions, have been ranked according to frequency of occurrence during the five-year period 1969-1973. The changes in emphasis from the previous 11 years as reflected by percentage of published work are quite apparent. Salinity and drainage studies still remained high in emphasis. However, irrigation requirements and scheduling, surface systems, and canals and canal structures studies lost their previous relative emphasis to water quality and reuse, watershed planning, and surface systems; in that order. Reported emphasis in improved design methods and sprinkler systems remained about the same. Large increases are noted in water quality and reuse, watershed planning, weather modification and trickle irrigation. Two areas, production function and water management and planning, had no articles classified in them by title in the ASAE Transactions.

The relative ranking by subject matter in the ASCE Irrigation and Drainage Division Journal is shown in Figure 2. Here again,

Table 1. Number of articles from a sixteen year period in various categories from the ASAE Transactions and the ASCE I & D Journal

Category	Number of Articles Appearing In: ASAE Journal 1958-1968 (11 years)	ASAE Journal 1969-1973 (5 years)	ASCE I & D Journal 1958-1968 (11 years)	ASCE I & D Journal 1969-1973 (5 years)
Salinity and Drainage	93	33	57	27
Water Quality and Reuse	9	33	11	10
Watershed Planning	13	27	9	10
Surface Irrigation Systems	37	27	9	4
Irr. Req. and Scheduling	46	22	34	19
Improved Design Methods	26	19	28	8
Sprinkler Systems	28	19	8	1
Groundwater	13	7	19	6
Canals and Canal Systems	37	7	25	13
Weather Modification	1	5	7	10
Trickle Irrigation	1	4	5	4
Evaporation Control	1	1	4	3
Production Function	0	0	0	4
Water Man. and Plan.	0	0	12	15
Total	305	204	228	130

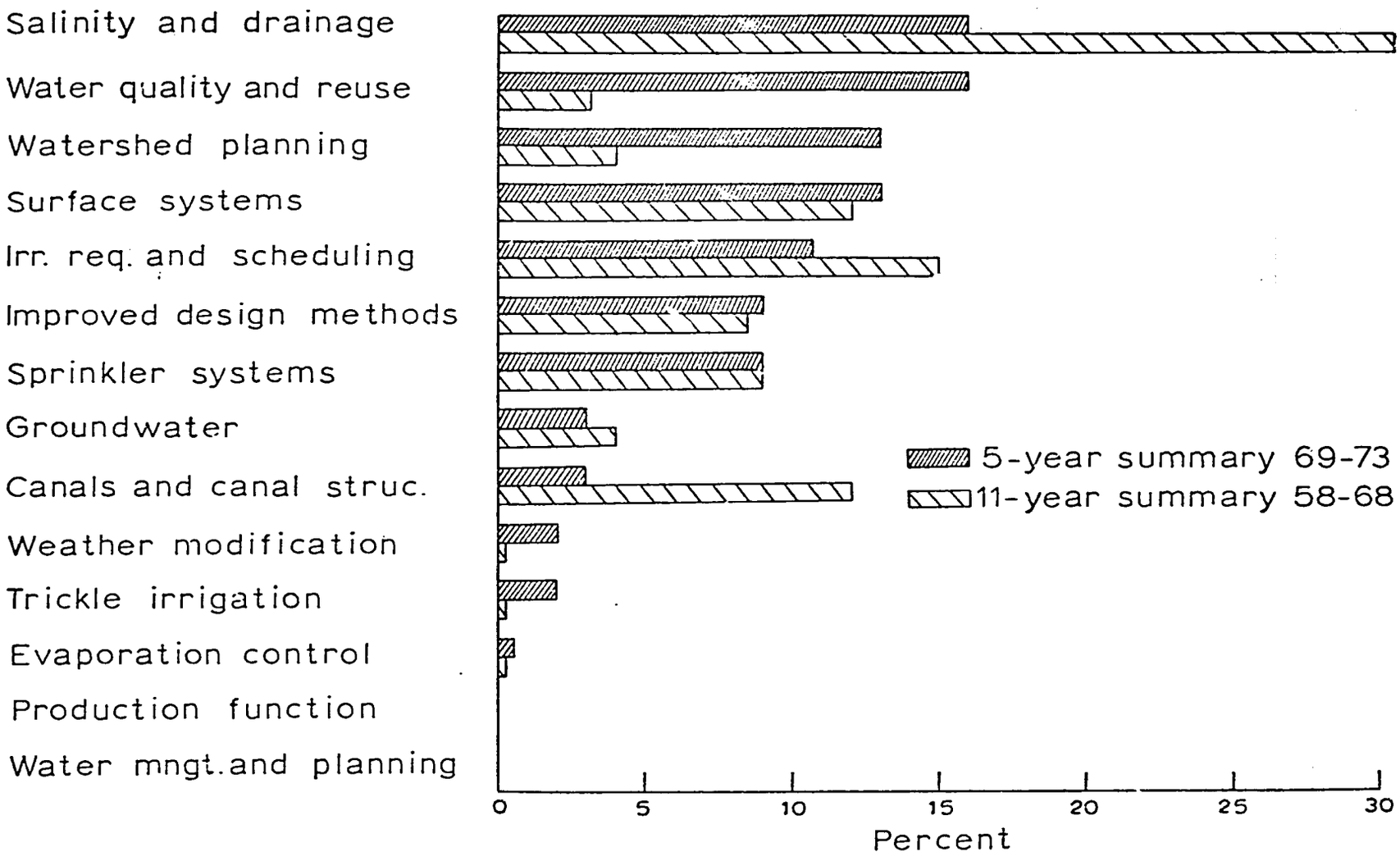

Figure 1. Relative emphasis from number of papers in ASAE Transactions

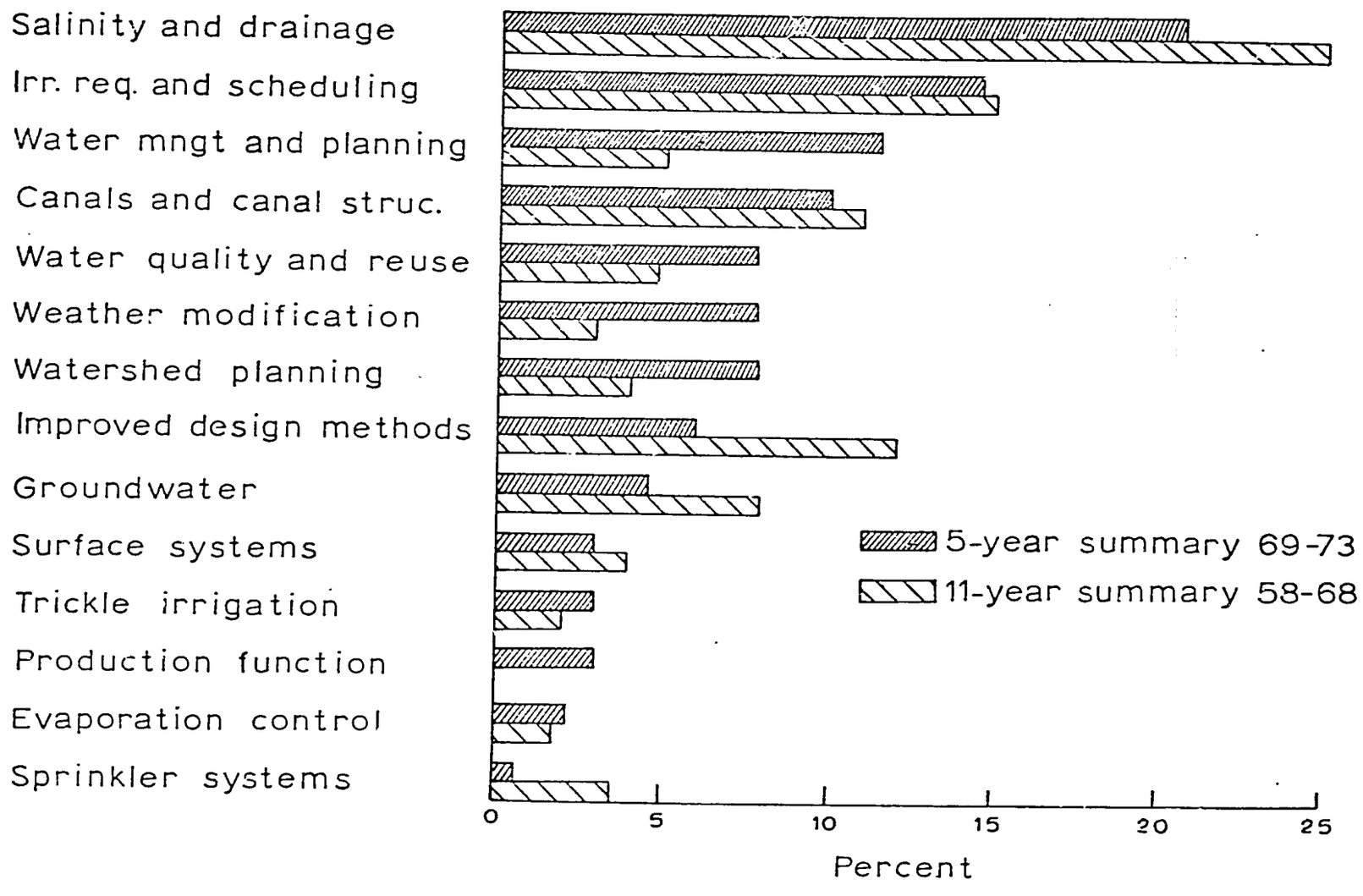

Figure 2. Relative emphasis from number of papers in ASCE I and D Journal

interest in salinity and drainage has remained high. Although the remaining topics are in a different ranked order than in the ASAE Transactions, the changes in emphasis from the earlier 11 year period generally appear to be less drastic. Obviously increased attention has been given in the last five years to water management and planning, weather modification, watershed planning, and production functions. A significant decrease in number of articles occurred in improved design methods, groundwater and sprinkler systems.

Taking Figures 1 and 2 together, and considering articles during the last five years, the topics of salinity and drainage, irrigation requirements and scheduling, and water quality and reuse appear in the top five items of each publication.

It also appears that increased emphasis will be given to production function, trickle irrigation, watershed planning, water quality and reuse, and water management and planning. Not apparent from the selected subject matter categories is the increasing role which some form of computer modeling is playing and will continue to play in research and application studies.

There are, however, some problems with using published articles in the literature as a firm guide to actual current research emphasis. Some of the limitations are:

1. The lag time from work to publication.

2. Repetitive articles from the same project with slightly changed emphasis and title.

3. Lack of articles from some areas of research in the selected publications.

4. The number of published articles may not be proportional to the research effort, funding level or significance of findings.

5. Lack of proper definition in the chosen subject matter classification system.

Trends in research spending

Information was sought from appropriate federal sources of research support to illustrate trends as reflected by funding level. It was impossible to obtain data in the same categories as used for the literature survey. A summary of expenditures in the Soil and Water Conservation Research Division of the Agricultural Research Service (ARS) for the period from fiscal year 1960 through 1975 (estimated) is given in Figure 3, from Barrows (1). The fiscal year 1960 expenditures were $8.2 million with an increase to an estimated $25.7 million for fiscal year 1975. Applying estimated average yearly inflation rates in research costs for the period 1960-1975, inflation appears to account for approximately $11.2 million of the $17.5 million increase. However, since fiscal year 1973 the

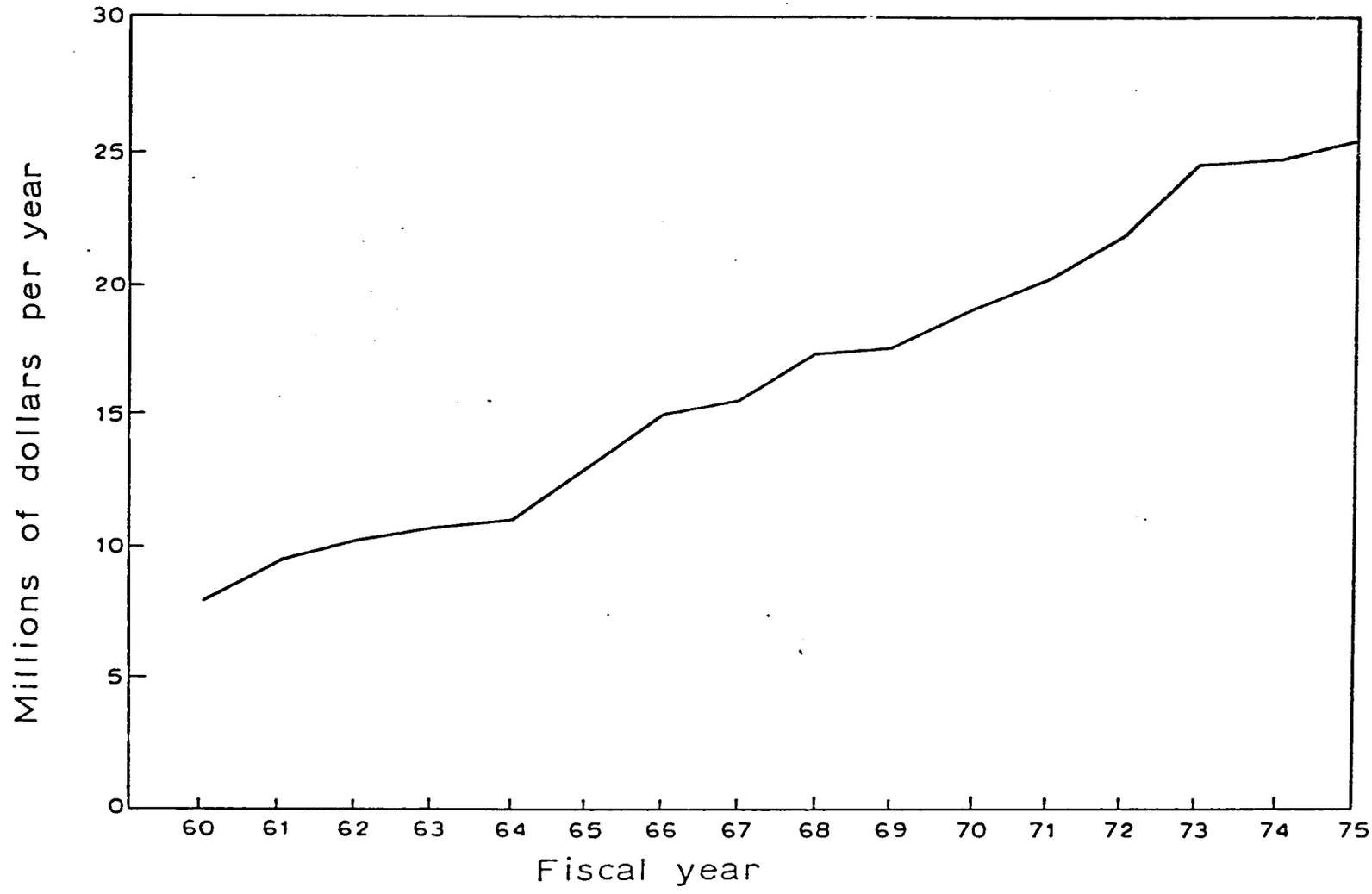

Figure 3. fudning of soil and water conservation research, ARS, USDA

increased expenditures have lagged considerably behind cost increases due to inflation.

The Office of Water Resources Research (OWRR) also finances studies related to irrigation development and other water resources activities. Table 2 contains a ten year (1965-1974) summary of OWRR data available in the Annual Reports (2), also from three classifications reported separately by OWRR, i.e., Section 100, Section 101, and Title II. The types of research financed are categorized as follows in the order of emphasis, based on the past 10 years funding levels:

1. Water Resources Planning

    (a) Techniques of planning
    (b) Evaluation process
    (c) Cost allocation and repayment
    (d) Water demand
    (e) Water law and institutions
    (f) Nonstructural alternatives
    (g) Ecologic impact of water development.

2. Water Quality Management and Protection

    (a) Identification of pollutants
    (b) Sources and fate of pollution
    (c) Effects of pollution
    (d) Waste treatment processes
    (e) Ultimate disposal of wastes
    (f) Water treatment and distribution
    (g) Water quality control

3. Water Cycle (Hydrologic Cycle)

    (a) General
    (b) Precipitation
    (c) Snow, ice and frost
    (d) Evaporation and transpiration
    (e) Streamflow and runoff
    (f) Groundwater
    (g) Water in soils
    (h) Lakes
    (i) Water in plants
    (j) Erosion and sedimentation
    (k) Chemical processes
    (l) Estuaries

4. Water Quality Management and Control

    (a) Control of surface water
    (b) Groundwater management
    (c) Effects on water of man's non-water activities
    (d) Watershed protection

Table 2. Summary of Office of Water Resources Research Projects 1965-1974

Type of Research	Number of Projects by Years						Thousands of Dollars by Years					
	1965-69*	1970	1971	1972	1973	1974	1965-69*	1970	1971	1972	1973	1974
1. Planning	567	167	183	182	167	143	9,340	3,935	4,723	4,419	4,294	3,050
2. Water Quality Protection	891	236	259	306	298	283	8,972	2,457	2,900	3,263	3,421	3,751
3. Water Cycle	452	127	135	131	122	90	5,188	1,581	1,356	1,627	1,816	1,102
4. Water Quality Control	241	21	21	35	29	28	3,526	313	382	899	532	626
5. Resources and Facilities	206	49	47	42	39	33	1,848	411	738	775	492	396
6. Water Supply Augmentation	192	20	23	20	28	24	2,457	303	351	204	465	555

* Average annual values

5. Miscellaneous (Resources and Facilities)

   (a) Nature of water
   (b) Resources data
   (c) Engineering works
   (d) Manpower and facilities
   (e) Scientific and technical information

6. Water Supply Augmentation and Conservation

   (a) Saline water conversion
   (b) Water yield improvement
   (c) Use of water of impaired quality
   (d) Conservation in domestic and municipal use
   (e) Conservation in industrial use
   (f) Conservation in agricultural use

Trends in financing of the above six types of research are given in Figure 4. In general trends do not seem to be very significant. During the 10 year period Water Resources Planning (Type 1) has received the greatest emphasis. However, concern about Water Quality Management and Protection (Type 2) has steadily increased and in 1974 it received a larger amount of funding than any of the other categories.

Based on the authors' personal knowledge of currently funded research projects it appears that both the ARS and OWRR have been liberal in providing funds to obtain a better definition of methods for determining irrigation requirements and for scheduling irrigation applications. Emphasis also is currently being given to the effects of interactions among available moisture level, fertility level, and a variety of practices related to improved agricultural production. The modeling of factors related to economic analysis, to the production function and to interactions is rapidly growing in popularity.

At Utah State University (USU) emphasis has been given to on-farm water management research. Current activity is international in scope. USU is carrying out a project financed by the Agency for International Development which provides for water management research in arid and sub-humid lands of less developed countries. The principal objective is the improvement of on-farm water management and the integration of the results with other good management practices for Latin American countries.

In the Fifth Annual Progress Report (5) objectives have been consolidated and are described under four headings 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.

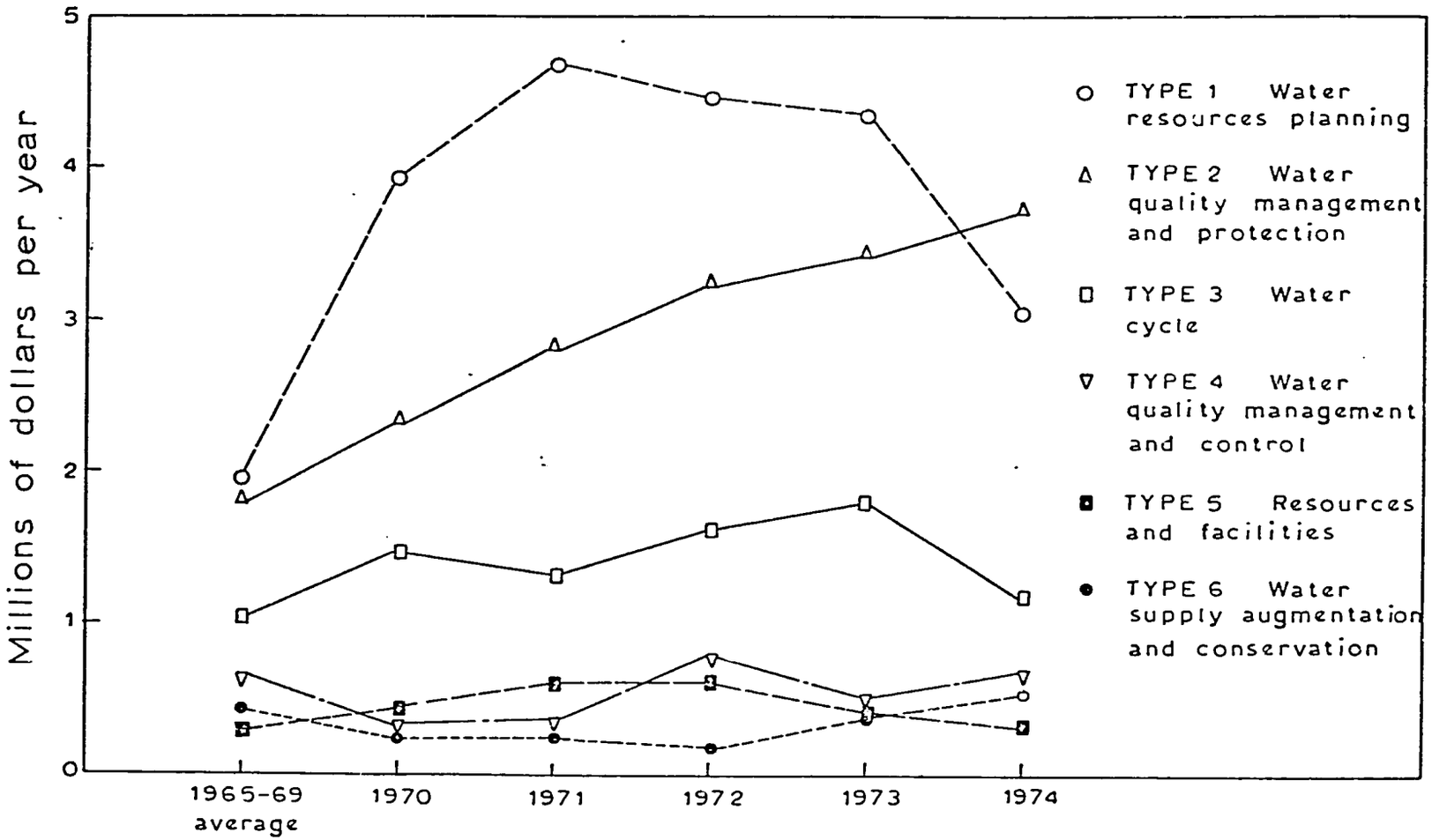

Figure 4. Amounts of and trends in Office of Water Resources Research funding

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, 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."

Although this research is directed toward Latin American conditions many of the results will be applicable to other areas of the world.

Suggested Desirable Trends

As shown by Hargreaves (3) many areas or parts of the United States are characterized by periodic seasonal water deficiencies. Increased U.S. agricultural production in the interests of helping supply world demands and in earning foreign exchange required for maintaining a strong economy should, to an important degree in the future come from increased emphasis on irrigation. Increased consumptive use from irrigation tends to concentrate salts and to alter water quality. Research can help provide a better understanding of these processes, and should make water quality management possible to keep it more nearly within desirable limits. However, considering the limitations of presently developed supplies, major future emphasis needs to be given to large and imaginative projects for improving both quality and quantity available through water importation.

Research interest in hardware improvement and the development of new devices for water distribution, measurement, application, and drainage water removal should continue to receive support from private and public sources.

Recommendations for priority water management research needs were identified as part of a Symposium sponsored by the U.S. Agency for International Development (AID) in late 1973 (4). These needs were stated so well that six are reproduced verbatim as follows:

"1. Improve the understanding of the physiological responses of plants to environmental stresses of water, salinity, temperature, and their interactions under field conditions. Particular emphasis should be given to methods of generalizing research data and to methods of transferring general information to field problems which are site-specific.

2. Obtain improved knowledge of the interrelationships between water and other inputs in order to optimize crop production. This information is needed for both irrigated and rainfed agriculture.

3. Study methods for transferring crop productivity information geographically by systematically organizing or modeling the collection, storage, and retrieval of information and considering physiological theory on crop responses to stress and interrelationships between water and management inputs.

4. Develop improved design for on-farm irrigation systems and means for implementing them which are readily adaptable to countries with limited resources. This need includes improved design of simple and economic irrigation and drainage systems, economic structures for water control, and land forming.

5. Develop improved production systems, including appropriate technology and plant breeding, and a much better understanding of climatic risk and microclimate modification for rainfed agriculture.

6. Improve the predictability of quantity and quality of surface and subsurface water supplies, and evapotranspiration. Develop better engineering procedures for water collection, storage and delivery systems, and general drainage systems that are responsive to optimal on-farm water management needs."

These recommendations are of such immediate concern that irrigation, drainage, and other agricultural related research should be promptly directed to their consideration. Let it be emphasized in particular that a great need exists for research results to be transferable and adaptable to other geographic regions of the world.

Accomplishments

It is exceedingly difficult to identify a dollar value of any contribution which irrigation and drainage research has had on the average citizen. It is a well known fact that irrigated land has a disproportionately greater share of the dollar value of agricultural products than nonirrigated areas. Research which has brought about improved application uniformities and increased productivity through improved drainage techniques must certainly be given proper credit for contributing to the irrigated land advantage.

There have been many accomplishments in terms of hardware improvements in sprinkler, trickle and surface application systems as well as in drainage materials and equipment. Research has brought about improved design and management procedures for difficult situations as well as for average conditions. However, one of the major accomplishments of irrigation and drainage research has been the general success with which its results have been adapted to the benefit of those who are in the everyday business of agricultural production. Many other research areas would do well to follow the example of practical applicability of this work.

Conclusion

The funding by OWRR indicates a greater current emphasis on water quality management and protection than upon water resources planning. This trend probably has reached a peak. Due to the urgent requirements for increasing agricultural production, emphasis will probably soon shift to give first priority to water resources planning and development.

Without the availability of irrigation water, most parts of the United States suffer severe moisture shortages for agricultural production. Due to recent monetary policies and the rapid industrial development of other nations, the maintenance of a position of world leadership by the United States depends increasingly upon a rapid expansion of facilities for agricultural production. Ability to expand these facilities depends to a large degree upon willingness to give greater emphasis and higher priority to imaginative water resources planning activities.

Research alone, however, cannot provide a good solution to the existing problems without resorting to imaginative engineering application of available knowledge.

REFERENCES

1. Barrows, H. L., personal communication, July 2, 1974.

2. Office of Water Resources Research, "Annual Report, Cooperative Water Resources Research and Training," U.S. Dept. of Interior.

3. Hargreaves, G. H. 1974. Moisture Adequacies for Agriculture in the Southeast. Paper presented at I & D Division Specialty Conference, Biloxi, Mississippi.

4. Peterson, D. F. 1974. Editor. Research Needs for On-farm Water Management. Proceedings of an International Symposium Sponsored by USAID, Technical Assistance Bureau Agriculture at Park City, Utah, October, 1973. Published by Utah State University, Logan, Utah, March 1974.

5. Utah State University, "Water Management Research in Arid and Sub-humid Lands of Less Developed Countries" 1973, 62 p.