MANAGEMENT STRATEGIES FOR SUSTAINABLE IRRIGATED AGRICULTURE WITH ORGANIZATIONAL CHANGE TO MEET URGENT NEEDS

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INTRODUCTION

Irrigated agriculture faces a crisis because of the urgent needs for increasing productivity, current and increasing severe water shortages, and the increasingly serious impacts of irrigation on the environment (FAO, 1996). Changing individual professionals and the bureaucracies involved in irrigated agriculture to meet these urgent challenges also is daunting. Observations at a general level suggest the changes needed by international consultants, international donor, and research and development organizations, and national and local organizations including farmer organizations also are not achievable. Accomplishing changes in conceptual understanding and specific operational procedures for individuals and organizations is the current urgent need.

This paper identifies some urgent changes needed and defines the conceptual and operational strategies that can address the needs and accomplish the changes. The results provide for improved performance in productivity, for making more effective use of water supplies while making available additional water supplies for irrigation and other uses, and for approaching environmental sustainability in irrigated agriculture. Urgent needs relate to productivity, water scarcity, and managing the environment. Conceptual understanding and operational procedures applicable to improving system management and performance, and management changes in individuals and organizations are the changes necessary to meet the urgent needs in irrigated agriculture. The basis for these observations is more than 35 years of involvement in irrigated agricultural research and development with many organizations and individuals in many countries.

BACKGROUND

Appropriate concepts and operational procedures for the management of irrigated valley systems are basic to accomplishing change in irrigated agriculture. Understanding the performance of

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irrigated agriculture in these valley systems is critical to an effective conceptual understanding. Both understandings are required to define appropriate operational procedures for sustainable irrigated agriculture. Waterlogging and salinity are continuing to reduce the productive area for growing crops while reducing yields on an increasingly larger area. Severe environmental impacts from irrigation development continue to increase and expand. These two factors, yields and environmental impacts, make urgent the changes needed to improve the performance of irrigated valleys and achieve sustainable irrigated agriculture.

Studies in many irrigation projects on various continents and in many countries suggest that professionals in irrigation do not understand the levels of performance that exist in the field. They also do not understand the magnitude of the levels of performance (Clyma, 2000). Interdisciplinary field studies in the U. S. A., Africa, Asia and South America suggest that professionals do not understand that low irrigation efficiencies exist or that productivity is a fraction of potential (Clyma and Lowdermilk, 1988). They believe that water is distributed in irrigation projects as planned instead of the inequitable, inadequate, and undependable performance that actually exists (Clyma, 2000). Farmers are wild flooding their fields and are frequently applying several magnitudes more than the amount of water required. Productivity is a fraction of potential because undependable water supplies make appropriate investments unprofitable. Farmers also do not have access to the knowledge, information and inputs necessary for achieving appropriate levels of productivity (Clyma and Clemmens, 2000). Professionals understand some of these inadequacies, but miss by magnitudes the actual levels of irrigation and productivity performance. The causes of these low levels of performance in irrigation and productivity from the source - water, information, services, or inputs - to the final point of use are not understood. Understanding the performance and causes of performance is critical to effecting improved management and performance (Clyma and Lowdermilk, 1988).

Changing the understanding of individuals and organizations requires the application of current knowledge and operational procedures from management science for accomplishing change (Jones and Clyma, 1988; Dedrick et al 2000; Levine, 1989). Experience has shown that outside consultants can accomplish change in a restricted project or area with continuing consultant support. Changing the understanding of individual professionals and accomplishing organizational change is extremely difficult. Causing an organization to change its mandate while creating knowledgeable and skilled individuals to carry out the new mandate is difficult and has only occasionally been successful. This is the type of change needed in irrigated agriculture if water management and productivity potentials are to be achieved. How do we accomplish such changes? Changing management strategies for irrigated valleys, changing understanding of the performance of irrigated agriculture, and changing individuals and organizations are the focus of the following sections.

Managing Irrigated Valleys

Managing water in an irrigated valley to minimize the water required to irrigate a field accomplishes water conservation. Water normally supplied for irrigating the field but not required because of improved management is water saved. Water not released from a reservoir or not diverted from a river is water conserved. When the reduction in water used for irrigation results in less water from return flows, then a volume of the saved water is made available at the downstream diversion to replace the lower volume of return flow. Water used to replace the return flow has a greater value than an equal volume of return flow because it was not used initially for irrigation. Conserved water remaining after the replacement of return flows is water available for reallocation. Conserved water that is available for reallocation can be used for municipal, industrial, environmental, or other uses such as additional irrigation (Clyma and Shafique, 2001a, 2001b).

Reduction in nonbeneficial evapotranspiration provides the water available for reallocation. Evaporation from waterlogged areas, increased evaporation or evapotranspiration from high water tables, and other conditions create nonbeneficial use, which is conserved by improved management. Water supplies can be increased by 80% through water conservation in some irrigated valleys (Clyma and Shafique, 2000a). Conserved water can be stored in reservoirs, groundwater systems, or as water not diverted from the river. Conserving water and increasing productivity are both important results of good water management.

Traditional views of irrigated valley management have assumed that improving water management in an irrigated valley does not save water or make additional water supplies available for other uses in the valley. Seckler (1996) and Keller et al (1996) have in the past decade been advocates of such a concept. Clyma and Shafique (2001a, 2001b) have explained the erroneous assumptions in such a concept. They also have identified the serious impacts on productivity, water conservation, and the environment that the continuing implementation of such a concept has in irrigated agriculture.

The key erroneous assumptions, often unstated and perhaps not understood by the advocates of the concept, is that 100% of the excess water from irrigation enters the river as return flow. Clyma and Shafique (2001a, 2001b) have shown that nonbeneficial use, such as occurs from waterlogged areas and poorly defined or nonexistent drainage systems, reduces the return flow to the river. This nonbeneficial use can be conserved as additional water supplies by improving water management. Clyma and Shafique also showed that such an improved water management strategy reduces the impacts of irrigation on the environment. The result is that improved management of irrigated agriculture can approach achieving sustainability. Sustainable irrigated agriculture is limited to a few valleys where management of sufficient rainfall with well-defined drainage systems has accomplished such a condition.

Figures 1 and 2 illustrate the water conservation potential of improving water management in an irrigated valley. Figure 1 illustrates the traditional, but erroneous, concept that improving water management in an irrigated valley does not save water. The concept is that an irrigation efficiency of 50% results in a total water supply of 200 units because of the additional water supply from return flows. Furthermore, an irrigation efficiency of 25% effectively increases the total water supply to 400 units because of the increased return flows (Figure 1). When irrigation efficiency is increased to 75%, the water saved must be reallocated to supply the volume of return flow that would normally have occurred at the lower efficiency of 50% (Figure 1). Thus, the common conclusion is that no water is saved. Actually, the reallocation of the water saved by improving efficiency to replace the return flows is required because of the assumption that 100% of the excess water from irrigation is captured as return flows. The increased water supply at the lower efficiencies is accomplished by recycling 10 to 20 times the irrigation water. The salinity of the return flows is increased to a level of serious yield reduction and in many irrigated valleys would be not be useful for irrigation.

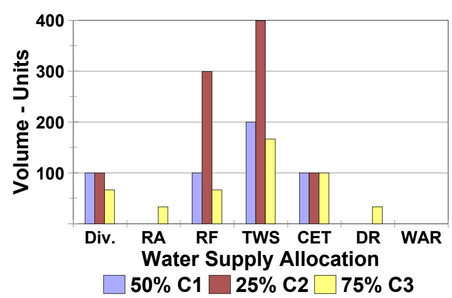

Figure 1. Traditional views of water allocation in an irrigated valley assuming 100% of all excess irrigation water is recovered as return flows.

A comparison was then made for an irrigated valley where some water diverted for irrigation is consumed by nonbeneficial use. These results are shown in Figure 2. Conditions for C1, Figure 2, are the same as for C1 in Figure 1. For condition C4 in Figure 2, the irrigation efficiency remains at 50%, and 50% of the return flow is consumed by nonbeneficial use. Notice that the nonbeneficial use reduces the return flow, total water supply and crop ET as shown in Figure 2. Condition C5 in Figure 2 represents the condition of improving water management in an irrigated valley to an irrigation efficiency of 75%, where nonbeneficial use is consuming water used for irrigation. Less water is diverted because of the improved efficiency. The less water diverted represents the reduced demand, DR, in Figure 2. Return flow is reduced with the improved water management. Total water supply required for irrigating the area is reduced with the improvements in water management. Crop ET is the same as the condition with nonbeneficial use, but at a lower irrigation efficiency. The demand reduction, measured as reduced diversions, allows water to remain in storage in the reservoir for other uses. Water is available for reallocation, WAR in Figure 2, for additional irrigation or other uses. WAR in Figure 2 may be reduced to replace the return flow if legally required. For example, if the WAR is used for additional irrigation, WAR would irrigate an additional 48 units of crop ET almost doubling the amount of crop ET from the unimproved condition in C4.

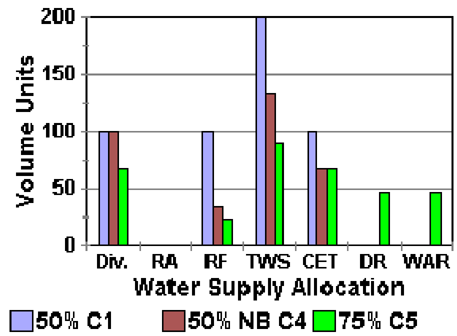

Figure 2. Water conservation in an irrigated valley when nonbeneficial use consumes irrigation water.

An assessment of the volume of water that can be saved in an irrigated valley involves the amount of water diverted for irrigation, the amount of rainfall, the annual potential ET, and the amount of nonbeneficial use. Such an assessment depends upon the specific conditions of a valley. When waterlogged areas are as much as 30% of the irrigated area, an average condition based upon some assessments, and total duty from irrigation and rainfall is low compared with potential ET, improving water management can save 80% of the water diverted for irrigation. Nonbeneficial use from standing water in waterlogged areas, excess evaporation and evapotranspiration from water tables near the soil surface, poor drainage systems, and unlevel fields all cause nonbeneficial water use. Water conservation can be substantial in irrigated valleys under these conditions.

Reducing waterlogging, lowering the salinity and the total volume of return flows from irrigation, all lower salinity loads in an irrigated valley. Releasing water available for reallocation from a reservoir increases the flow of rivers and reduces the salinity of the rivers also. When salinity of the return flows becomes sufficient to limit crop productivity, then disposal in salt sinks or direct diversions to the sea may support a sustainable irrigated agriculture for a valley. This would be a substantial management achievement for irrigated agriculture and the future of food production. The key need is to change the concepts and operational procedures for managing irrigated valleys such that the growing problems of environmental degradation from irrigation are controlled and managed effectively. Sustainable irrigated agriculture, increases in water supplies for additional uses, and improved productivity are the achievable outcomes from such a change.

Irrigated Agricultural Issues

Productivity is a key issue for irrigated agriculture. Waterlogging and salinity continues to eliminate agricultural production or substantially reduce production on millions of hectares. The affected area increases an average of 1 or 2% per year (Postel, 1992). Field assessments of irrigation projects show that water is inequitably distributed from head to tail in the project area (Clyma, 2000). As a result, downstream command areas may receive little water while the heads of the command use several times the planned allocation. Undependable water supplies cause farmers to use traditional seeds, almost no fertilizer, and inadequate management of the growing crops (poor weed and pest control). The result is low levels of productivity compared with the potential for irrigated agriculture. Availability of credit, inadequate seed and fertilizer supplies, inadequate support from irrigation and agricultural personnel, and inadequate farmer organizations also seriously limit productivity in irrigated agriculture (Shafique and Clyma, 2001). Ineffective farm water management practices limit productivity because of lower yields and reduced area irrigated (Clyma and Clemmens, 2000) Good water management combined with effective support of farmers would increase productivity in irrigated agriculture by several magnitudes.

Water scarcity in irrigated agriculture is a growing problem. The Food and Agricultural Organization predicts that by 2020 major shortages in food production will result from inadequate water supplies (FAO, 1996). These impacts are little understood and no strategy other that improving water management appears to have a potential for addressing this critical issue.

Knowledge and Understanding of Irrigated Agriculture

Professionals in irrigated agriculture in previous generations came from a farm background with field experience in irrigated agriculture. Present professionals gain their experience from initial assignments in the field during their early professional years. Thus, knowledge of how irrigation is practiced by the farmer and understanding of the procedures of farm management in the field are limited. Also, recent rapid changes in technology and available technology make unknowledgeable, undirected experience less relevant. A common experience in many countries is to ask professionals about irrigation practices in the field and then go to the field and observe those practices. The differences between knowledge and practice are usually vastly different.

Experience with international, national and local professionals' understanding about performance in irrigated agriculture also shows great gaps between knowledge and actual conditions. One of the greatest differences was documented in Pakistan (Clyma and Corey, 1974) when international donor emphasis, government policy, and professional understanding assumed field application efficiencies of 85%, and watercourse delivery efficiencies of 90%. Waterlogging and salinity were growing serious problems with policy focused on increasing water supplys by building dams and canal delivery systems. Actual application and delivery efficiencies were more nearly 25% and 40%, respectively (Clyma and Corey, 1974). Providing more water supplies created more serious problems because the fundamental problems were not being addressed.

Knowledge and understanding of the performance of irrigated agriculture are necessary to recognize and then accept the urgency of the needs for improvement. For example, in Pakistan in the early 1970s, tradition said watercourse delivery efficiencies were 90%. But actual performance shows that commonly 90% of the water in a watercourse was lost to seepage and spillage from the head to tail of many watercourses. Careful analysis showed that the causes of such low performance were related to unmaintained channels, inability of farmers to organize and accomplish maintenance, inadequate understanding of the magnitude of the losses, and no available technology that resolved the key physical causes of the losses. Thus, a very serious problem was not and could not be resolved because of inadequate understanding of the problem and its solution.

Initial attempts to change the understanding of international, national, and local professionals about the urgency of improving farm water management were met with great resistance. Clyma and Corey (1974) showed that data from a decade earlier had shown that serious problems existed in water management at the farm level. Because of the decade old assumption by professionals that farm water management performance was exceptional, understanding of the need for change was met with great resistance. Data from repeated, extended field studies finally changed the understanding, policies, and priorities of both the country and the international community. Improving farm water management became a priority for Pakistan and international donors and professionals also made farm water management a priority in irrigation projects in many countries. Knowledge and understanding have repeatedly changed the emphasis of irrigation in many countries over the past several decades.

Interdisciplinary Field Studies

Initial emphases in Pakistan were on the physical causes of poor water management. With time this emphasis expanded, by necessity, to include looking at the biological, economic, and social and organizational emphases. Eventually, management principles and procedures were brought together to support, create and accomplish change. Management involved an appropriate process for accomplishing change (Jones and Clyma, 1988; Levine, 1989) and management concepts and procedures for creating understanding in small groups and planning how urgent needs could be met. A key strategy always was that interdisciplinary field studies provided the knowledge and understanding that allowed professionals to understand and then articulate the need for change. Repeatedly, in irrigation projects in a country and in different countries, knowledge and understanding formed the basis for defining the scope for needed changes and then achieving the mandate at the policy level to plan and carry out the needed changes. Common understanding between farmers and professionals, and collaboration between organizations, and between professionals and farmers provided the basis for change that effectively addressed urgent needs.

Physical studies focused on the water soil and other environmental factors. Biological studies looked at crops, yields, management, and key constraints to productivity. Economic issues involved risk, credit, profit, costs, policy, and operational practices. Social and organizational systems were studied to understand farmer to farmer, farmer organizations, farmers to bureaucracy, within bureaucracy, and bureaucracy to bureaucracy interactions (Lowdermilk et al 1983). Integrating these understandings into a comprehensive irrigated agricultural system understanding was a stimulating undertaking never accomplished perfectly, but revealing in the interactions between disciplinary understanding (Clyma and Lowdermilk, 1988). Farmers, as managers of the critical farm system, also provided their understanding of how the system was managed, the levels of performance for critical subsystems, and the critical needs for improving performance. Members of each agency supporting farmers also provided their insights about how the various subsystems were designed for managing, and how they were actually managed. The insights from the data about system performance and the perceptions of the managers of the system about performance were sometimes astounding.

Changing Individuals to Change Organizations

A key strategy of the field studies is the involvement of national and local professionals in the study of an irrigation project within the country. They provide local history and cultural understanding that are critical for really understanding the irrigated agricultural system. Since they commonly have not studied the irrigated agricultural systems of their country intensively (even in the U. S. A.), they accomplish major changes in their understanding of system performance and the causes of system performance. Creating an interdisciplinary perspective also increases their understanding of the causes of low and high performance. Issues that they were never even vaguely aware become critically meaningful. Understanding the magnitude of particular problems (Farmers at the end of a canal system never receive water.), causes drastic changes in the priority needs for irrigated agriculture. Professionals' knowledge and understanding when expressed to fellow professionals in their organization (especially when the individuals selected for the local team already have a high level of credibility) can change the understanding of most of the professionals in their organization including the policy makers. Thus, changing the understanding of the individuals making up an organization can be effectively accomplished.

New understanding of needs now allows the initial formulation of a strategy for changing how the needs for more effectively supporting irrigated agriculture in a country can be accomplished. Planning brings together key supervisors and operational managers with farmers to create a common understanding of needs and initiate planning for how these needs can be met. All the supporting organizations for irrigated agriculture are brought with farmers together to form this common understanding. Interdisciplinary field studies provide the basic data for resolving conflicts in understanding. The farmers keep the professionals honest in understanding what farmers do, why they do key operational actions, and what the key problems are that farmers' face. Operational managers of the involved organizations also keep the understanding honest, but they also gain new knowledge about how and why their systems perform.

This new common understanding of needs allows the development of key strategies to meet those needs. These key strategies becomes the basis for mandating the changes in the supporting organizations so that needs that are the highest priority can be met. By mandating change at the policy level and planning how the change can be accomplished at the operational level, the result is a changed organization. Because farmers are involved in defining these changes, the new program emphases meet urgent farmer needs. Because the supporting actions require joint decisions of the organizations and the farmers, a coordinated effective support program is the result. Professionals and the involved farmers are amazed at the changes created in the supporting organizations. Farmers also become advocates for farmer changes in management of their farms. Organizational change is accomplished by changing the individual and then having the individual collective change his/her organization and the other involved organizations.

Organizational Change

Experience in agricultural research and development initially suggested that changing individuals and organizations to accomplish significant improvement in productivity was extremely difficult or impossible. Experiences in Pakistan show that careful field studies with farmers to understand the critical needs for change and define a strategy for change that was effective in supporting farmers to accomplish change was possible. Major bureaucracies and influential leaders in both national and international settings could be informed and caused to change their thinking and actions to accomplish major change. Using a technical information strategy for creating change was difficult and slow besides being fraught with misdirections.

Management change processes were introduced on a trial basis for accomplishing change in irrigated agriculture. These initial efforts built upon a long period of experience in using management processes for changing public and private organizations in business, manufacturing, service, and public areas. Applications in development had been made and were continuing. The management change strategy uses small group processes to build teams that define needs, identify successful strategies for change, and the carry out change at the operational level with mandates for the change defined and articulated from the policy level of the relevant organization (Levine, 1989). Among the key components of the strategy for changing irrigated agriculture is the definition of needs from interdisciplinary field studies of the levels of performance and the causes of good and bad performance. These needs are the basis for defining the needs for change and then identifying the changes that will address these urgent needs. This strategy has been applied in Pakistan (Jones and Clyma, 1988), to a limited extent in Egypt (Layton et al 1987), and intensively in Arizona (Dedrick et al 2000).

Key outcomes of these efforts were those individuals and organizations that understood the need for change, created the strategies for accomplishing the needed change, and then carried out the changes in collaborative endeavors that involved multiple organizations and farmers. The results were definitive improvements in productivity and incomes of farmers and in the effectiveness of organizations to support farmer needs. Coordination and collaboration are also improved even in difficult environments where conflict is a frequent condition. Changing individuals and organizations can be accomplished.

DYNAMIC APPLICATIONS

The more intensive change process for improving irrigated agriculture has been applied more extensively in Pakistan, Egypt and Arizona. The processes used for accomplishing change evolved over the several decades of involvement. Initially, physical field studies were the basis for defining the needs for change. Then an interdisciplinary field study approach evolved for understanding system performance and the causes of performance. In the middle 1880s, management specialists were involved in Pakistan and then in Egypt. During the early 1990s, a comprehensive management change process was applied to an irrigation project in Arizona. Each of these locations will now be reviewed for some dynamic changes accomplished.

Pakistan

Changing a country with a long tradition of international consultants and host country professionals that believed farm water management was more effective than any other country in the world was extremely difficult. International consultants, donors, host country professionals, and even professionals from the lead institution criticized and challenged the data and conclusions for several years. Some professionals in Pakistan still challenge the conclusions even after more than 25 years.

Development of technologies for precision land leveling, productivity improvements, and watercourse renovation were a key to the success of continuing change. Farmers articulated to bureaucrats the value of changes better than expatriate and host country professionals. The "Pucca Nucca" (a canal channel outlet), successful farmer support and participation in renovation of earthen channels, and successful lining of channels with indigenous bricks also were a part of the success of watercourse renovation and other water management improvements. Watercourse renovation became, regrettably, the focus of the program because of local values for construction and donor funding of the projects for construction efforts. Value for the improvements was achieved, but the focus on improving productivity was lost until recently.

Water management in Pakistan was initiated by creating a new organization. Creating a new organization is often easier when the mandate for the organization is vastly different from any existing organization. Employee status, permanence, and acceptance by other organizations were and still are major issues. Training also was established to provide the new knowledge and skills the new employees were required to use. The result was a cadre of young professionals with unusual attitudes of determined farmer support. Impacts of farm water management on Pakistan also created almost a hero status for the organization and the personnel involved from the public and farmer perspectives.

The organization, regrettably, did lose the vision of improving productivity and providing precision land leveling services. Construction became the focus and emphasis in part because government loans and donor policy supported such an emphasis. Some productivity emphasis has been restored recently.

Command Water Management was an experiment to created a coordinated set of organizations that supported farmers to accomplish productive irrigated agriculture. Management specialists were brought into the process to help build on the technical knowledge and understanding that was available to create effective programs to support irrigated agriculture with farmer participation. Part of the initial training did provide experiences that brought farmers and agency personnel together and from which effective programs were defined and initiated. USAID selected another contractor to support the ongoing program, and the management strategy and organizational coordination emphases were abandoned. The experiment failed and Command Water Management, an idealistic but appropriate strategy, also failed.

Egypt

The Egypt Water Use and Management Project was funded by USAID and built on the ideas that had created the successful farm water management program in Pakistan. Agriculture and Irrigation as ministries were brought together under the leadership of Irrigation and a process of interdisciplinary field studies, field demonstrations of improvements and a program of irrigation improvements then evolved. The impact on irrigated agriculture in Egypt was significant. Professional personnel established working relationships with farmers and improvements were jointly initiated.

Egypt had a policy of requiring farmers to lift water individually to each field to encourage effective use of water. When the project started, the policy of lifting water could not be written about, could not be a part of a research project, and could not be considered for change. Data on the effects of requiring farmers to lift water changed the policy to initiating a central lift point for each Meskia (community watercourse) from which farmers irrigate by gravity. Farmer organizations were created and made responsible for helping distribute water below the branch canal. Very little interaction with farmers occurred before the project in day-to-day management actions and decisions. Studies showed that excess water was in the canal system during some periods and inequitable water distribution was the result from head to tail of the branch canal offtakes. Water distribution within a branch canal also was inequitable with water shortages often at the tail. A rotation system also caused farmers to irrigate at the beginning and end of a rotation - often when the second irrigation was not needed. Water distribution was changed from rotation to continuous flow. Offtakes at branch canals were regulated such that only when water was needed in the branch canal would water flow into the canal. Within the branch canal, regulators controlled the levels within sections of the canal such that farmers could have more equitable access to water. Productivity of crops was increased substantially even though at already high levels. An irrigation improvement program was defined and is still being implemented. Changes came from the increased understanding of the performance of irrigated agriculture based upon interdisciplinary field studies.

Effective organizational coordination was not accomplished between agriculture and irrigation. Some personal relationships between professionals still carry over today in joint decision making. The goal of establishing an institute to continue to define ongoing needs in irrigated agriculture was not accomplished. The institute, jointly staffed from agriculture and irrigation, did not have access to the management support to create an organizational change process. Coordination between agriculture and irrigation, and coordination of programs within irrigation is limit continuing improvements in irrigated agriculture today (2002).

Arizona

After more than 15 years of applying a process for improving irrigated agriculture, the U. S. Water Conservation Laboratory decided to attempt applying the process to an irrigation project in Arizona. The result was that state and federal agencies were brought together and an initial strategy defined. A water district agreed to participate in the effort. Then local agencies were brought into the group.

Many serious questions were asked. Was the process relevant and beneficial for the U. S. A.? The project selected was an irrigation district that only a few years earlier had contracted with the U. S. Bureau of Reclamation and had a modern, automated canal delivery system constructed. The project distributed Central Arizona Project (Colorado River surface water) water and pumped ground water from district managed wells. The cost of water in the project was approximately ten times the cost of irrigation water in other areas of Arizona and the U. S. Some thought the cost of water would add an important dimension to water management improvement. Serious, repeated questions were asked concerning the relevance of an improvement program in one of the most modern irrigation projects in the world.

Comprehensive results from the Management Improvement Program have been prepared and are available to the readers.[1] There were many similarities to the Management Improvement Program in other countries, but impact was vastly different from the technical knowledge and understanding approaches initially used in Pakistan and Egypt. Organizations changed their interactions with farmers and with other organizations. Farmers changed their interactions with other farmers and various organizations. The U. S. Water Conservation Laboratory personnel changed their perceptions of their clients, their understanding of research priorities, and their

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[1] Volume 14, Nos. 1 and 2, 2000 issue of *Irrigation and Drainage Systems* provides the results. The articles also are available at http://www.uswcl.ars.ag.gov/pdf/uswclpubs/WCLPUB

interactions with other organizations and the farmers. While the impact of the effort was great in the project and even within the state, apparently perceptions of the research bureaucracy were that the effort was not appropriate research to be carried out by the Laboratory. No additional projects were funded and carried out with other projects in Arizona or other states. The U. S. Bureau of Reclamation was mandated to become a management-oriented organization, but the management emphases of the project effort did not become an important part of the bureau's program.

The district found many opportunities to improve their management and services to farmers. Their role with other organizations was strengthened greatly, from almost nothing to many coordinated actions. Their relationship with the Arizona Department of Water Resources changed from conflict to continuing collaboration and coordination. Farmers came to perceive their supporting organizations and personnel as helpful instead of a bureaucracy to be avoided. Many personal friendships were established and maintained. The district, farmers and the supporting organizations improved water management.

SUMMARY AND CONCLUSIONS

Improving water management in an irrigated valley can save substantial water. With serious shortages in water supplies growing around the world, water conservation is an urgent priority. Improved water management also increases productivity, and reduces or controls the waterlogging and salinity impacts of irrigation.

Increased knowledge and understanding from interdisciplinary field studies of irrigation systems are an appropriate strategy for identifying needs and defining strategies for improving irrigation systems. Gaining the understanding of farmers, local officials, and key participants as managers of the systems is a key to that understanding. These key participants also are involved in setting priorities and defining strategies for improving the system.

Changing individuals and organizations is difficult. Knowledge and understanding are the basis for changing key individuals, and then mandating change for the involved organizations. Strategies for meeting needs of highest priority become plans for creating change. Management process support created and mandated these changes. Efforts in three different countries and continents have demonstrated that critical changes can be defined and accomplished. The challenge of the third millennium is systematically to accomplish change in all countries while improving the well-being of farmers and the people they feed.

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