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POTENTIAL IMPROVEMENTS IN IRRIGATION MANAGEMENT PRACTICES: WATER SAVINGS AND COSTS

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I. SUMMARY

A. Improving the efficiency of water use on the farm is presently faced with both obstacles and promising developments. Many current irrigation management practices could be substantially improved by system modification or better operation of the existing irrigation system, but not without cost. Poor practices must be first identified, a difficult task with the evaluation techniques and services currently available and the economics of any proposed changes must be considered. Precise irrigation scheduling information already available in many locations may not be used effectively because of rigid water delivery schedules at the project level. Nevertheless, recent developments in innovative irrigation system design and increased understanding of crop responses to water supply are encouraging steps towards improving the efficiency of water use in irrigated agriculture.

B. Primary References

1. Water Related Technologies for Sustainable Agriculture in U.S. Arid/Semi-Arid Lands. OTA, U.S. Congress, 1983.

2. Jensen, M.E. "Water Resource Technology and Management," _Future Agricultural Technology and Resource Conservation_, pp. 142-166, Iowa State University Press. 1984.

3. Gilley, J.R. and M.E. Jensen. "Irrigation Management Contributions to Agricultural Productivity," _Water Resources Research, Problems and Potentials for Agriculture and Rural Communities_, pp. 22-34. Soil Conservation Society of America. 1983.

4. Section 4, _Future Agricultural Technology and Resource Conservation_, pp. 141-212, Iowa State University Press. 1984.

5. _Water Use Efficiency Report_, Nebraska Natural Resources Commission, 117p. 1985.

6. _Design and Operation of Farm Irrigation Systems_, Edited by M.E. Jensen, ASAE, St. Joseph, MI. 1980.

II. INTRODUCTION

A. Purpose of Irrigation

1. Water is the most limiting natural resource affecting agricultural production. Inadequate water limits plant growth and crop yields nearly every year in semi-arid areas and short periods of drought in humid areas limit crop yields, especially on sandy or shallow soils.

2. The inefficient use of irrigation water results from both the physical conditions of the off-farm conveyance system and the on-farm irrigation system as well as the improper management of these systems. In addition, the efficient use and management of irrigation water may also be influenced by existing institutional and social factors.

B. Water Use in Irrigation

(Solley et al., 1983, "Estimated use of water in the United States in 1980," Geological Survey Circular 1001, U.S. Department of Interior.

1. The primary requirement of a successful irrigation operation is a dependable

water supply of suitable quantity and quality.

2. Irrigation requires large quantities of water.

   a. In 1980, 40% of the total U.S. fresh water withdrawals and 82% of the withdrawals in the 17 western states were for irrigation.

   b. In the more humid east, 82% of the fresh water withdrawals was for industrial uses.

3. Irrigation is the largest consumptive user of water in the U.S.

   a. In 1980, irrigation accounted for 81% of the total consumptive use in the U.S.

   b. This value reached 90% in the 17 western states.

4. During 1980, 40% of water withdrawn for irrigation was from groundwater. In 1950, only 20% was from groundwater.

5. Agriculture is the only industry with the capability to capture and utilize without great expense random occurring, widely

scattered rainfall. This precipitation is too often written off in national water budgets as water lost to evapotranspiration. But this evapotranspiration (2/3 of the total precipitation on a national basis) is responsible for perhaps 3/4 of the crop production and most of the forest production across the U.S.

III. BACKGROUND CONCEPTS

Before beginning a discussion on the potential water saving practices available to irrigators, it is important to understand some background concepts and define some terms relating irrigation practices to basin hydrology. (Water-Related Technologies for Sustainable Agriculture in U.S. Arid/Semi-Arid Lands, OTA, Chapters VI-XI.)

A. Disposition of Water Applied to an Irrigated Field

1. The water applied to an irrigated field either leaves the field as crop evapotranspiration (ET), evaporation of water during an irrigation event, surface runoff, deep percolation below the crop

root zone, or changes the root soil water content. From an irrigators viewpoint, however, the amount of water applied to the field is only important as it influences his net economic returns. Thus, the relationship between net economic benefit and gross irrigation is a key component in any water management program.

2. Implicit in the on-farm water balance is the concept that some deep percolation is needed to maintain a favorable salt balance in the root zone.

3. Under certain conditions, irrigation water has other beneficial uses on the farm besides contributing to the crop water requirements. At the present time, however, the importance of these uses for the western states is minimal relative to the volumes consumed in the evaporation (E) and transpiration (T) processes

B. Irrigation Efficiencies and Basin Hydrology (M.E. Jensen, Water Resources Technology and Management, Proceedings of the RCA Symposium, Iowa State University Press, 1982.)

1. Significant improvements in the understanding of the interaction between on-farm irrigation practices and basin hydrology have occurred in recent years. A key to this understanding is the recognition that irrigation system losses on the farm and in the delivery system are not necessarily losses to the basin and from a basin point of view, these losses may be beneficial. In general, a portion of water that remains on or below the land surface after it is used for irrigation is recoverable for reuse within the basin. Water transferred to the atmosphere as a result of the evaporation and transpiration processes and the evaporation during the irrigation event are considered irrecoverable and lost from the basin. However, deep percolation and runoff may be partially recovered. Examples of "lost" water include phreatophyte consumption, evaporation and irrecoverable ground water.

2. Irrigation Efficiency Definitions
   a. Overall irrigation efficiency is defined as the ratio of the water

consumed by the crops to the water diverted from the source and includes the terms of application efficiency, farm conveyance efficiency and off-farm conveyance efficiency.

b. A water balance in a basin indicates that the water diverted is either consumptively used or nonconsumptively used. Further, a portion of the water that is not consumptively used may be returned to the basin as return flow and is not lost.

c. The net water depletion from a basin is the volume of water consumptively used and that portion lost from return flow.

d. Effective irrigation efficiency can be defined as the ratio of crop evapotranspiration plus the return flow to the volume of water diverted.

e. A more realistic measure of the effectiveness at which water is used by irrigated agriculture, the net irrigation efficiency, is defined as the ratio of crop evapotranspiration to the net depletion.

f. Several important remarks must be made when considering the reduction of farm irrigation water requirements. 1) For the individual farmer, the nature of the water loss is incidental, and improving the efficiency of water use is an objective only as it results in increased net economic benefits. 2) Irrigation practices are deeply integrated within existing farm practices, thus adoption of new technology depends on its feasibility in relation to the overall farm management practices. 3) Tracing recoverable irrigation water losses within and between basins is extremely difficult. Reliable irrigation information at the project level is required to evaluate benefits of proposed practices.

C. Irrigation Water Management

1. In designing their seasonal water management programs, irrigators are confronted with three essential questions: 1) how often should each field be irrigated; 2) how much water should be applied at each irrigation; and 3) which management technique should be used to uniformly apply the needed amounts of water at the appropriate times.

2. An irrigation is termed adequate when the depth of water applied is neither insufficient nor excessive in replenishing the soil moisture deficit since the last irrigation. The performance of an irrigation system also needs to be evaluated by analyzing how uniformly the water was applied. Engineering design may provide for some systems the means of applying water at very high potential uniformity, which can only be realized if management decisions on irrigation scheduling are correct. On the other hand, systems poorly designed and/or maintained do not allow the irrigator to carry out precise irrigation scheduling recommendations.

Evaluating current farm irrigation practices then becomes the starting point for any recommendations to improve the efficiency of water use on the farm, although other competing uses for water will also influence efficient on-farm water use.

IV. TECHNOLOGIES FOR MORE EFFICIENT USE OF WATER ON THE FARM

Since agriculture accounts for 80% of all water consumed, a small percentage increase in agricultural water "consumption efficiency" can produce large water savings by other sectors. While some technologies may be widely used, many solutions to irrigation problems on the farm are unique to specific situations. Increased irrigation efficiency is not automatically achieved by installing an improved system because the irrigation efficiency is dependent both on the potential efficiency of the system and the way in which it is managed and operated.

A. Irrigation System Technology

(Design and Operation of Farm Irrigation Systems, Chapters 12-16)

1. Surface irrigation systems, the soil surface serves both as the channel to

distribute water over the field and the control over water entry. Several modifications to existing surface systems can be made to reduce the losses. Many of these will require additional labor or capital inputs.

a. Manipulation of stream size, length of run, set time and irrigation frequency.
b. Land smoothing or leveling (laser controlled).
c. System automation is almost essential to achieve attainable efficiencies.
d. System modification such as surge flow and cablegation.
e. Tail water recovery system.
f. Use of level basins where flow rate and slopes allow.
g. System replacement with another type of system.

2. Trickle irrigation systems, the frequent slow application of water to the soil near the roots of a plant in sufficient amounts to meet its needs.
   a. This system offers several potential advantages, such as reduced evapora-

tion losses under some types of crops and improved water control.

b. Primary disadvantages are cost and emitter clogging.

c. Presently, the greatest potential application for these systems are where water is scarce, soils are difficult to manage and high value crops are grown.

d. System requires a higher level of design, management and maintenance than other irrigation methods.

3. Sprinkler irrigation systems, water is moved dynamically through a pipe network and is distributed through an orifice under pressure where it is broken up into droplets and falls to the soil or crop surface.

   a. There are many different types of sprinkler systems ranging from the hand move system to the large self propelled linear system irrigating large tracts of land.

   b. In general, the operator has more precise control of the water application with sprinkler systems than surface systems.

c. With proper design and management, runoff losses should be minimized. With reduced pressure moving systems, water runoff could be a problem.

d. The center pivot has become a predominate irrigation system in use today. The development of dependable automatic equipment and electronic controls has resulted in a system that enables uniform application of small amounts of water. These systems have enabled farmers to irrigate rolling or sandy soils that were previously considered not suitable for irrigation.

B. Irrigation Water Management (Design and Operation of Farm Irrigation Systems, Chapter 18)

1. The concept of irrigation scheduling has received much attention in recent years. Irrigation scheduling is defined as predicting the time and amount of the next one or more irrigations, taking into account expected precipitation. The most common management technique, where water is not limited and its cost is either low

or not based on volume, is to eliminate water as a production-limiting variable. The negative effects of applying excess water (deep percolation losses) are reduced by delaying irrigations until the soil water depletion is sufficient to permit storage of the next application. Plant water stress is avoided by irrigating before crop yield and/or crop quality are reduced because of inadequate soil water. Irrigation scheduling considers rainfall, evapotranspiration since the last irrigation, allowable soil water depletion at the present growth stage, and expected rainfall before the next irrigation. Irrigation scheduling requires that irrigators make decisions daily or weekly. Use of irrigation scheduling will, in most cases, reduce deep percolation, thereby improving irrigation efficiency. There are some problems and challenges with the adoption of irrigation technologies.

a. Irrigation scheduling programs that supply only current evapotranspiration data on a regional basis without providing specific on-farm services are usually not effective unless they are accompanies by intensive educational efforts.

b. An irrigation scheduling service is adopted when economic benefits can readily be identified by the grower. Potential scarcity alone stimulates significant interest. However, inexpensive, abundant water supply does not preclude interest in an irrigation scheduling service. Some growers with inexpensive, abundant water benefit from an irrigation scheduling service by identifying and better managing problem soils, better organizing farm operations, and ultimately saving money.

c. An irrigation scheduling service can only increase growers' net income to the extent that use of some production inputs (water, energy, fertilizer, etc.) decline or yields increase. There is a general skepticism among farmers that yields can be improved by altering irrigation practices.

d. The role of the private sector in on-farm operations, such as irrigation system design, irrigation water management, timing, and evaluation, cannot be overemphasized. Private as well as agency scheduling service groups must be concerned about the probable acceptance of any new or improved technology. Survival of private service groups in particular depends upon usable, cost-effective technology that provides information that farmers want and need to manage irrigations.

2. Deficit Irrigation
   (Gilley and Jensen, 1983)

   a. If stored soil moisture, precipitation and irrigation are insufficient to meet the crop water requirements, plant water deficits develop. Through precise irrigation scheduling, limited irrigation could be used, resulting in some yield reduction. The magnitude of the yield reduction will depend upon the timing and degree of stress as well as the irrigation management procedure selected.

b. There are limitations to the application of deficit irrigation programs. These include: 1) Programming moisture stress entails substantial uncertainties unless actual evapotranspiration and the predicted evapotranspiration deficit can be monitored closely and precisely. 2) The relation between applied water (the variable under the control of the grower) and evapotranspiration is affected by so many site-specific variables that it would require designing deficit irrigation programs for each individual farmers and perhaps for each field. 3) The implications of risk for the water production functions have been explored in a preliminary way only. In general, the risks associated with deficit irrigation are much more significant than those associated with applying excess water.

c. The degree of risk varies with the cropping system, and the level of risk tolerable to the farmer will vary with economic factors.

d. Optimal irrigation scheduling thus requires a high level of water management to ensure against overapplication under conditions of adequate water supply, yet careful control to minimize yield reductions resulting from water stress when the supply is limited. In either case, careful water management is required.

3. Irrigation scheduling concepts have tended to focus only on growing season management of irrigation water applications. In many places in the U.S., a more integrated approach to irrigation is needed that focuses on year-round water management concepts, combining conservation tillage, residue management, irrigation scheduling, and other ideas to achieve technologies that minimize annual

irrigation amounts by reducing soil-surface evaporation, deep percolation, and runoff.

C. Alternative Water Supplies

1. Interbasin transfer, use of icebergs, desalination, augmenting precipitation, use of saline water, and water harvesting are all ways to increase the supply of water for irrigation. Augmentation of water supplies for irrigated agriculture by interbasin transfer, desalination, or similar methods, although technically feasible, do not appear practical at the present, either economically or socially. Augmenting supplies with saline water or by water harvesting are feasible for some specific sites, but can not resolve water shortages in most regions. The use of sewage water or industrial waste water can be a locally important source of additional water, or an additional prior use of existing water supplies. However, these amounts are relatively small. Reduced seepage and improved irrigation water management are conservation measures that have proven to be cost effective and are socially viable.

V. POTENTIAL WATER SAVING PRACTICES

Potential technologies for more efficient use of irrigation water on the farm are summarized in Table 1.

Table 1. Potential technologies for more efficient use of irrigation water on the farm.

Technology	Component	Potential for Water Savings
1. Developments in Surface Irrigation	Reuse systems	High
	Automation	Moderate
	Level Basins	Low to Moderate (location)
	Design Renovation	Low to Moderate (site)
	Surge Flow	Low to Moderate (soil & location)
	Cablegation	Low to Moderate
2. Developments in Trickle Irrigation	Clogging and Uniformity	Low
3. Developments in Sprinkler Irrigation	Reduced Pressure	Low
	Reduced Evaporation	Low
4. Irrigation Water Management	Irrigation Scheduling	Moderate to High
	Deficit Irrigation	Low to Moderate
5. Change Irrigation System		Low to High
6. Alternative Water Supplies	Transbasin Diversion	Low
	Others	Low
7. Other Agricultural Management Techniques	Mulches	Low
	Change Crop	Low to Moderate
	Plant Breeding	Low
	Antitranspirants	Low
	Conservation Tillage	Low to Moderate
	Year-Round Water Management	Low to Moderate
	Reduced Leaching Requirement	Low to Moderate