A REFLECTION ON IRRIGATION CHANGES

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INTRODUCTION

Irrigation has been practiced for many years perhaps first in Egypt several thousand years ago. There is evidence of irrigation in North America that dates back to the year 500 A. D. These systems had evidence of many irrigation ditches moving water from the rivers to the fields in the surrounding valleys. Morgan, 1993 wrote a history of American irrigation titled "Water and the Land." Morgan recognized the irrigation of nearly 200 years ago but wrote that the modern era of irrigation in the United States began in the mid-19th Century as American pioneers moved West. He attributed the teaching of the first college irrigation course in 1883 to Elwood Mead at the Agricultural College of Colorado in Fort Collins. After leaving the college Mead continued his irrigation work for the U. S. Department of Agriculture and as a commissioner of the Bureau of Reclamation. The lake formed by Hoover Dam is named Lake Mead after this agricultural engineer. As a scientist with the Water Management Unit of the USDA in Fort Collins we can trace our roots back to Elwood Mead.

The objective of this paper is to review the evolution of modern irrigation technology in the United States and the Central Great Plains. The major focus will be the last century.

IRRIGATION TECHNOLOGY IN THE EARLY 20TH CENTURY

Irrigation development prior to 1900 in the United States was primarily by local irrigators. They were close to the streams and diverted water to the adjacent land. The United States Bureau of Reclamation (USBR) was established in 1902 to encourage development of the West and migration to the unpopulated area. Without the government policy and goal to populate the West, we would have less area irrigated in the West. Today, approximately 29% of the total irrigated area in the United States is supplied water from USBR projects. Surface irrigation was the dominant method for practically all irrigation systems older than a century. This would be true for all irrigation systems around the world. It is only during the last 70 years with the advent of deep well turbine pumps, combustion engines, rural electrification, sprinkler and drip irrigation systems that we have seen a significant

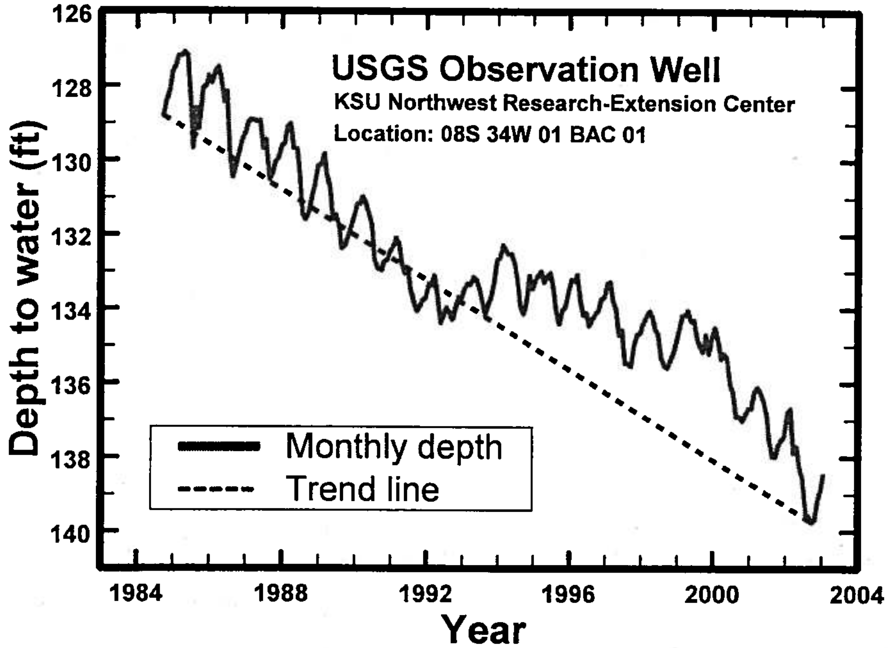

Figure 11. Long term decline in aquifer water levels and partial overwinter recovery of observation well at KSU Northwest Research-Extension Center, Colby, Kansas. Note: Seasonal declines are caused by drawdown.

CONCLUDING STATEMENTS

In summary, the effects on crop production and on the Ogallala are to a great extent temporary. The direct effects on the Ogallala are slow to be realized, so when the drought ends, the scale of these effects is not large. Hopefully, the greatest effect will be social--the renewed understanding of the value of water and its importance in Central Great Plains.

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change from the surface diversions and surface irrigation systems. It was the later changes that dramatically changed the irrigation in the Central Great Plains.

Surface irrigation was the primary method of irrigation. Furrow irrigation typically used earthen ditches and the irrigator would cut the ditch bank or siphon tubes were beginning to divert the water into individual furrows. Tractors became available to level the land, a significant change from the use of horses prior to 1900. The irrigation technology was limited to the existing materials and technology of the time. Sprinkler irrigation systems were being developed in the early 1900's but were quite limited until after World War II. Aluminum was used extensively for the development of airplanes and other equipment used during the war. When it became available to agriculture and industry was looking for a market; gated pipe and hand move sprinkler systems were brought to the market. It was then that all of agriculture became much more mechanized.

IRRIGATION TECHNOLOGY IN THE LATER PART OF THE 20TH CENTURY

It is this time period that we have seen major changes. We were in the Industrial Age and mechanization advanced rapidly in agriculture. The light weight pipe decreased the work for hand move sprinkler systems and contributed to their large increase in popularity. A significant increase in aluminum gated pipe and siphon tubes reduced the labor for furrow irrigation compared with cutting ditch banks. Without this technology and available material, we may have not seen this change take place. The advent of deep well turbines and right angle drives allowed ground water to be developed for irrigation. Without these technologies, much of the Central Great Plains would not have been developed for irrigation. Figure 1 shows the trend of irrigation systems in the last 30 years.

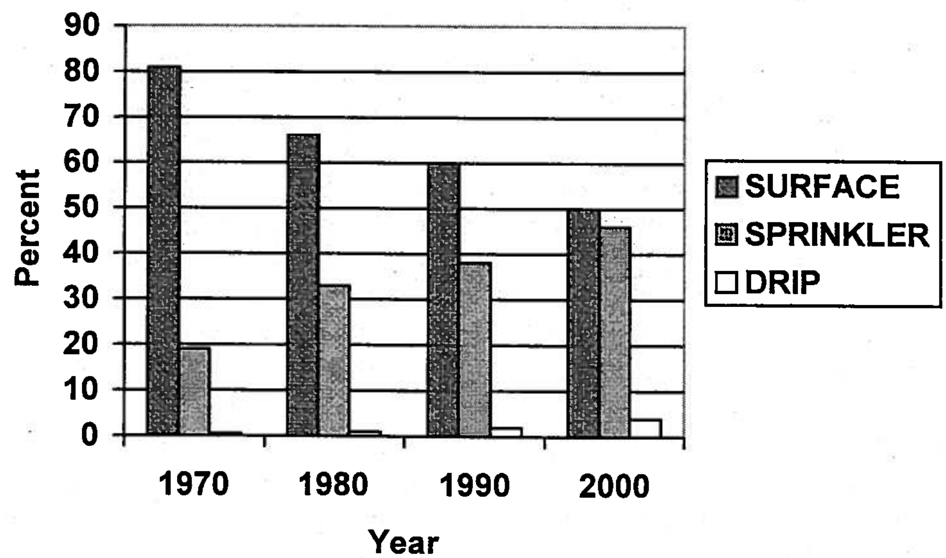

Figure 1. United States Irrigation Statistics.

The center pivot sprinkler irrigation system was invented in 1952. It was in the 1960's when the large scale adoption began and Daugherty (1970) reported that there were approximately 8000 systems in operation by 1970. He was concerned about the lack of governmental support for center pivots in contrast to their efforts to promote and improve furrow irrigation. However, today there are 17.3 million acres irrigated with center pivots in the United States (1998 Farm and Ranch Irrigation Survey, http://www.nass.usda.gov/census/census97/fris/fris.htm) or about 33% of the total irrigated acreage. This is in contrast to the reduction from 81% to 50% of the area irrigated with surface irrigation systems. In the Central Great Plains 62% of the irrigated area is under sprinkler irrigation. Forty percent of the area irrigated with center pivots are in the three Central Great Plains States. Why this rather rapid change? I believe the factor causing the change is the greatly reduced labor for irrigation with the center pivot. Since the 1950's, farm equipment has been increasing in size and the only way producers can be profitable is to increase the size of farms. This trend has made it imperative that the irrigation systems also be able to irrigate larger areas with reduced labor.

The competition in manufacturing center pivots has led to the development of reliable and efficient systems. The number of center pivot manufacturers was in excess of 20 during the 1970's. Only in the past 10 years has the number of manufacturers became more stable with less than 10 companies manufacturing most of the new systems. Clearly, a majority of the center pivot systems are manufactured in the Central Great Plains states. However, the large number of manufacturers did provide many new ideas that has contributed to the success of center pivots. The large number of manufacturers provided a large sales staff to promote this technology. As the systems became more reliable, the continued demand has stayed high. Today, many surface irrigation systems are being converted to center pivot systems throughout the U.S. (1998 Farm and Ranch Irrigation Survey, http://www.nass.usda.gov/census/census97/fris/fris.htm),

The research community also increased the number of studies for the design, evaluation, maintenance and operation of the center pivot systems. This was probably a factor in increasing the adoption rate. The other factor that has had a strong influence on the center pivot design was the sharp increase in energy costs. Irrigators demanded low pressure systems to decrease pumping costs. Two commercial companies began focusing on application devices that would operate at lower pressures and still give the desired uniformity on a center pivot system. The healthy competition promoted a rapid development of effective low pressure application devices for use on center pivots. Higher quality plastics became available and were used in the manufacture of these low pressure application devices. The newer plastic nozzles actually are less subject to wear than the previously used brass nozzles. The ability for these plastics to resist the damage from sunlight (UV) has extended the life of these devices. Again, it is the available new materials that has contributed to new developments.

The quality plastics also provide the manufacturers of drip irrigation pipe and emitters a material that allowed them to develop more economical and reliable components. Drip irrigation was just being developed for the market in 1970, with increased emphasis on both research and development during the 1970's and 80's. By 1980, microirrigation systems irrigated approximately one percent of the total irrigated area. Today that number is approximately four percent. The number of acres in the Central Great Plains is report 832 acres in the 1998 census. The development of the filter requirements and filter systems contributes to the acceptance and reliability of microirrigation systems. Increased water cost and limited availability are factors that stimulate the adoption of microirrigation systems. The high cost of these systems becomes economical with high valued fruits and vegetable crops. The uniformity can be high and the soil surface evaporation can be minimized with subsurface drip irrigation systems and they are an excellent choice where water supplies are limited.

Irrigation scheduling technology has improved and the total amount of water applied per season has been decreasing. This is in part due to the better performance of pressurized systems. The 1998 Census reports that 1.6, 1.3 and 0.8 ac.ft./ac were used yearly with sprinkler irrigation systems, in Colorado, Kansas and Nebraska, respectively. Surface irrigation systems used yearly totals of 1.6, 1.6, and 1.0 ac.ft./ac in Colorado, Kansas, and Nebraska, respectively. This demonstrates that less water was used where the farmer could more easily control his irrigation system. Applying the right amount of water at the right time is also better understood by irrigators. In the late 1960's, computers became more available and water budget programs were developed. Many of these programs were developed for main frame computers and demonstrated by different government agencies. Now there are many versions of the water budget approach to scheduling that have been developed by researchers and consultants. Private consulting firms provide the service of recommending irrigation schedules with weekly visits to each field. The limited availability of evapotranspiration data was a major hurdle when this technology was first developed. Today most western states have some level of weather station networks and climatic data are readily available from different media sources such as newspapers, telephone, television, satellite networks and the internet.

Irrigation scheduling programs are used by a limited number of growers. This is not because the programs don't work, but most irrigators do not have the time nor inclination to run their computers daily during the irrigation season. Time is valuable and they will invest it where they perceive the most benefit. My experience is that farmers will use irrigation schedules if someone is providing them the results or if the system is automated. Consultants have filled this gap but this is not an expanding market or service. What typically happens is that an irrigator, after contracting with a consultant for several seasons, soon knows what his recommendation will be when the report is given to him. It is an educational process and the irrigator soon questions the value of a continuing contract. Irrigation scheduling technology has

been effectively used for the education and I am confident that most farmers are doing a better job of scheduling irrigations than before the water management programs were demonstrated. A check book approach can be done in a simple manner without a computer and with a fair degree of accuracy.
Computers were an important tool for the advancement of irrigation scheduling technology. But, computers are important for the design and evaluation of irrigation systems. Many models are used for the design of surface, sprinkler and drip irrigation systems. Computers are continually decreasing in cost for the amount of computer power available. Electronic technology is also a key element of many of the controllers used with all types of irrigation systems. Precision agriculture is a new technology that uses global positioning systems (GPS) in addition to computer technology. Geographical Information Systems (GIS) are available for manipulating and processing spatial data. GPS and GIS are used in the design and installation of irrigation systems.

Current government research programs stress the transfer of new technologies. Cooperative Research and Development Agreements (CRADA's) are encouraged between government researchers and industry to facilitate the transfer of new technology.

Water rights issue is of high importance in the Central Great Plains. There is extreme competition for the water between states as well as from municipal and industrial demands for the water. The current drought is a major problem particularly in Colorado. It is uncertain if many irrigators on the South Platte basin will be allowed to pump water in the 2003 season. The matter is in the hands of the Water Courts and the outcome is highly uncertain.

ASAE NATIONAL IRRIGATION SYMPOSIA

Four National Irrigation Symposia were organized and sponsored by ASAE on 10 year intervals beginning in 1970. The first two were cosponsored by the University of Nebraska and held at Lincoln. The later two were cosponsored by the Irrigation Association (IA) and were held in Phoenix, AZ simultaneous with the IA International Irrigation Exposition. Speakers were predicting the opportunities and potential for automation of surface irrigation. However, this did not take place as predicted. As seen in Figure 1, sprinkler systems became much more prominent. Even though the government was promoting furrow irrigation through research and for newly constructed projects, there was not an industry that provided systems. A major problem confronting surface irrigation automation systems is the unique designs needed for individual fields. The fact that a commercial company did not sell complete systems forced the irrigator to buy components and essentially make his own system. Consultants were not readily available to design the efficient automated surface irrigation system. Center pivots were designed for installation and only needed to be adjusted to the field dimensions. Surge irrigation controllers were provided by industry and had some limited success. Surface irrigation has the inherent problem of the variable soil intake that controls the uniformity. Small depths are difficult to apply economically and uniformly. We will continue to have surface irrigation where water is available in sufficient quantities and labor is available. Even though many areas are limited on available water, many areas have sufficient water at a low cost. Thus, these areas have no incentive to improve their irrigation performance.

The technical program for the First National Irrigation Symposium, 1970 were all invited papers which included a broad coverage of all irrigation technologies. Surface drip, subsurface drip and subsurface irrigation was in its infancy in 1970. A number of authors provided research results and discussed the potential value of these new irrigation systems. Most of the progress had been made only in the ten years prior to1970. The problems identified were related to plugging by roots, blockage of openings by solids and sharp differences in uniformity between emitters.

Surface irrigation and auto-mechanized surface irrigation was the area receiving the most attention. It was still recognized as the dominant method of irrigation with 81% of the irrigated area using surface systems. Swarner, (1970) presented a paper on the potential auto-mechanization on the 17 million ha. irrigated with surface irrigation systems. Looking into his crystal ball he saw the irrigation system of the future to be controlled by moisture-sensing devices installed at selected sites in the field to determine when water is needed and how much to apply. Electronic controls activated the valves controlling the water and delivering it in sequence and shut down the system when the optimum moisture levels were restored. The controls would be extended reaching back progressively through the distribution system to open or close farm headgates or gates at the storage reservoir. He hypothesized that we could use either moisture sensing devices or a computer to calculate the consumptive use from solar radiation or some other criteria. He envisioned that a computer could provide the alternative schedules for irrigation and the water user could select the best option. He did predict that the automation could apply to sprinkler and trickle irrigation as readily as to surface irrigation.

Sprinkler irrigation papers were presented on solid set, center pivot and traveling sprinklers. They also included the application of sprinklers for climate modification, application of chemicals, and liquid waste disposal. Pair, (1970) presented a paper entitled "Mechanized Sprinkler Systems—their Applications and Limitations, What Next? He categorized nine basic types of sprinkler systems as 1) handmove portable lateral, 2) tow-line, 3) giant sprinkler, 4) side roll, 5) side move, 6) center-pivot self-propelled continuously moving, 7) straight lateral self-propelled continuously moving, 8) traveler, and 9) solid set. He predicted that only three of the basic systems will remain as we search for the perfect system; 1) handmove portable lateral, 7) straight lateral self-propelled continuously moving, and 9) solid set. His vision was that the handmove system would be used in irregular areas. The lateral move would have the best water distribution pattern under all wind conditions and the solid set would be buried lines with risers and sprinkler heads that would be retractable below the ground level to not interfere with cultural operations. The system would have automatic adjustable nozzle sizes and could be used for frost control, chemical application, environmental control and irrigation. It is interesting to reflect on the actual changes in sprinkler irrigation systems in the past 30 years. Pair reported that sprinklers irrigated about 20% of the total area in 1970 and predicted an increase to at least 80% as water supplies become more critical. Sprinklers are about half way there today, but not with the systems he predicted.

The main thrust of the papers for environmental considerations were to improve irrigation scheduling. Discussions were given on using soil water indicators and plant water indicators for irrigation scheduling. Several papers discussed using of climatic data to estimate evapotranspiration (ET) and calculate water budgets for irrigation scheduling.

Again all papers for the Second National Irrigation Symposium were invited. The number of papers was limited due to the concurrent publication of the ASAE Monograph "Design and Operation of Farm Irrigation Systems." The themes of the major sessions were 1) Advances in Irrigation System Design, 2) Advances in Irrigation Management and 3) Future Needs and Advances in Irrigation. These were preceded by more general speakers, namely Ronald Robie, Director of Water Resources, CA; Nebraska Lt. Governor Roland Leudtke; Robert Young, Economist; Hester McNulty, League of Women Voters; William W. Wood, Jr., Economist and W. R. Z. Willey, Environmental Defense Fund. These first presentations brought a unique perspective to the symposium and challenged the audience at the National Irrigation Symposium to consider a broader perspective.

It was reported that there has been little incentive for any major innovation to improve efficiency of water use in the last century. Most of the development of irrigated agriculture has focused on the development of water delivery subsystems and the almost complete neglect on other problems. A wide gap exists between "hardware development" and the development of all the other requisites for increased agricultural production. A major obstacle to upgrading systems is institutional constraints including water laws. This was particularly true for the Bureau of Reclamation projects and others where the water was directly diverted from the stream or from on line storage reservoirs.

Most of the sprinkler changes were in the development of low-pressure application devices. Drops were introduced for center pivots that work in conjunction with the newer application devices. Big guns were developed with extended radii. Auto connections were developed for use with sideroll, big guns, and linear move systems. Plastic became widely accepted for application devices and for improved flow control and pressure regulator devices.

Surface irrigation dropped from 81% in 1970 to approximately 2/3 of the total irrigated area in 1980 (Figure 1). The automation projections from 1970 had proceeded slower than anticipated in the 10 years. Microprocessors were beginning to be used in the controls of surface irrigation automation systems, particularly for surge irrigation. New trash screens were developed. As with sprinklers, the use of plastics in gated pipe including a flexible pipe was being adopted. Laser leveling had brought about the ability to rapidly and accurately level land for improved surface irrigation. Low energy precision application (LEPA) systems were developed and adopted particularly for areas with limited water. LEPA was included as both a surface and trickle irrigation advance, even though it uses the center pivot and linear move systems for moving the application devices. Increased computer power had made surface irrigation models a viable technique for surface irrigation system design and evaluation.

Trickle irrigation was approaching one percent of the total irrigated area. Major advances were made in light weight pipe, quick connect fittings, emitters and filters. Computer design procedures and guidelines for operation and maintenance were improved. System automation was greatly improved and the application of chemicals was seen as a valuable contribution to the future of trickle irrigation. Systems include subsurface, above ground and mechanically moved.

Emphasis was given to the value of evaluating a system to identify deficiencies in design and system operation. The goal was to have operational levels equal or exceed the design level of performance. Labor, water, energy and hardware were key ingredients for system selection and one must consider the economics to differentiate between success and failure.

The emphasis on management was seen as an area that had become more prominent in the irrigation research and technology activities. Upgrading water delivery schedules require flexible schedules to allow improvement of irrigation water management on the farm. Close coordination between the water supply agency and the farm operators are needed. Improved schedules made possible the automation of on-farm irrigation and permit increased efficiency of surface systems.

Decreased energy costs are important for sustainable irrigation production. Energy for pumping irrigation water can be reduced by reduction of net water application, improved irrigation efficiency, reduction in total dynamic head and improved pumping plant performance. The 1998 Census for the Central Great Plains states reports approximately 47 % of all center pivots are low pressure (<30 psi). Other possible cost savings are from decreased peak electrical demands, reduced nitrogen leaching through more efficient irrigation and incorporation of conservation tillage practices.

Increased accuracy in estimating irrigation water requirements was becoming more important as several western states were experiencing lawsuits or other legal deliberations between water users. It was predicted that future research would include emphasis on refining yield and water consumption relations, refining methods of estimating irrigation water requirements and development of irrigation schemes that minimize energy and water requirements. Significant progress had been made in improving crop coefficients. It was generally understood that an upper bound of yield vs. ET relationship exits. An efficient scheduling process to produce the maximum yield possible with an attainable ET level is usually possible. Since profit frequently maximizes near the maximum yield level; it was suggested that relatively few management regimes are of primary interest. Irrigation in humid areas is particularly important where soils have low water holding capacity and crop rooting depths are limited. Without irrigation, there are extremes in production due to the highly variable distribution of rainfall. Future research was identified as needed to aid in system design, operation, and scheduling technology. The teaching of irrigation scheduling technology through the extension service had increased significantly in the last decade. Commercial irrigation scheduling services were providing improved water management technology to an ever-increasing number of growers.

The last two National Irrigation Symposia were cosponsored by ASAE and the Irrigation Association (IA) and was convened in Phoenix concurrently with the IA International Exposition. The program was significantly different in that the majority of the technical sessions was developed from a call for papers with just a few invited presentations. Many of the typical research results were presented. Water table management using drain lines to both drain and subirrigate were being rapidly accepted in the southeast U.S. Major improvements in drip emitters and the use of slow release herbicides in drip systems were commercially available. A number of papers were presented on the improvements and technology transfer of irrigation scheduling. These included the description of state wide weather networks where data are made readily available to growers for their use in improving their irrigation management of both agricultural crops and turf.

The theme of the fourth keynote session in the Third National Irrigation Symposium was Irrigation and Society. Moore and Downing, (1990) presented two cases demonstrating how cities were buying land for the sole purpose of obtaining water for their urban and municipal use. They saw this type of solution expanding in the southwest. We will probably see more of this approach in the Central Great Plains where water is needed not only for municipal and industrial uses but also for wildlife and environmental needs. Wallace (1990) emphasized the reasons why the development and use of our nation's water resources have become so important and visible a set of policy issues. He indicated that we can find win-win solutions but they will come with significant political battering and strategizing. The answers to the long-run use of this nation's water can be found through conservative political debate and comprise. He concluded that we can find the needed compromises.

The fourth National Irrigation Symposium recognized that future systems will need to put additional emphasis on improved water quality and will come under more scrutiny for preventing non-point pollution. The buzz words of the 70's (water conservation, xeriscape, water reclamation, resource management, water quality and product quality) became serious business in the 80's and became words of wisdom and the price of admission in the 90's.

Lessons from History

We often can learn from history. The preceding review of the history of irrigation and of the four previous decennial National Irrigation Symposia provide us a glimpse of history that we can use to predict the future. A reflection on the history of irrigation shows that much of the new technology has been developed in the last century. If the pace of technology changes continue, we will probably see the same degree of change in the next 50 years that we witnessed in the last 100 years.

Irrigation has been practiced for several thousand years. The cause of most of the systems demise is not clearly known. However, it is postulated that the major problem has been the salinization of the irrigated area. The second probable cause is the lack of available water. It is logical that either could have stopped irrigation. I will limit my scope to the last 100 years and postulate about the causes and forces that have brought us to the current state of irrigation technology. Irrigation systems more than a century old were more than likely surface irrigation with the water diverted directly from the streams. Our current census shows that only 50% of the area is irrigated with surface systems compared to 81% in 1970, (Figure 1).

I should have learned from the predictions made at the earlier ASAE Symposia not to attempt to predict where we are going. However, I will give joy to someone in the future to report how ridiculously wrong I was. First, even though some would stop irrigation completely, I predict irrigation will continue in the future. Current public opinion opposes the policy for expanding irrigation and constructing storage facilities. The federal government has curtailed new projects in the West. Even private or local government is finding it more difficult, if not impossible, to build new irrigation facilities because of environmental impacts and public opinion. Current public sentiment is that we should be dismantling some of the existing structures. The environmental and fish and wildlife groups are strong proponents to leave more water in the stream and to go back to nature. We have seen what can happen in Oregon and California where the water is left in the stream for fish and not made available to the farmers.

We will see a decline in the irrigated area in the West from what it is today. The increased demand for water will reduce the amount for irrigation and more will be used for industrial, domestic and environmental needs. Increased salinity and erosion will remove irrigation in some areas. However, an increase in worldwide demand for food if population doubles by 2050 will require increased irrigated production. In humid areas, I predict more irrigation development. Supplemental water can reduce the risk associated with crop production. Irrigation reduces the drought affects on the year to year variability in production. Water conservation, xeriscape, water reclamation, resource management, water quality and product quality are issues we still face. The recommended strategies to deal with these issues are for increased cooperation, education, technology, planning, implementation, efficiency, and hard work. It is obvious that we must do a better job of educating the public of the issues so that we can solve the problem of ever decreasing water availability.

The types of systems will continue to evolve. My crystal ball is foggy when it comes to predicting a totally new type of system. Subsurface drip irrigation will have the percentage biggest increase in irrigated area. Surface irrigation will continue to decrease and will soon be less than the 50% of the total irrigated area in the U.S. Sprinkler irrigation systems will continue to increase in the near future but I don't believe it will reach the 80% predicted by Pair (1970). As we discussed irrigation technology depends on the current available technologies. Pumping plants, aluminum, plastics, computer technology, laser technology and industry marketing and designing new products and systems are what led to our current technology. The drip industry will continue to develop more effective systems for high value crops and areas with limited water. These systems can be very effective on any size or shape of field.

Moving sprinkler systems (center pivot and linear) have the characteristics to apply variable water and chemicals as precision agriculture becomes adopted. Precision agriculture may offer a similar affect to the adoption of moving systems as did the increase in size of farms, which demanded systems that required less labor. The direction will depend on how the industry meets the challenge to provide a benefit to precision agriculture. The opportunities are here to provide variable applications of water and chemical as an integral part of precision agricultural. Record keeping will be needed for satisfying the regulations controlling the use of chemicals.

There is no doubt the future of irrigation will be integrated into the information age. Precision agriculture is moving in that direction. I see more sophisticated use of computers and controls on new irrigation systems as was predicted in 1970. Sensors will play a big part in this new technology. They will be located in the field and transmit data to control centers. Satellites and aircraft are being promoted for sensor platforms as the way of the future. Being cost competitive and providing immediate access to real time data is a challenge to the remote sensing industry. Irrigation scheduling will become part of a more extensive data collection and processing system. The technology is there but the challenge is to deliver it to the end user in a package that is user friendly and automated with minimum time requirements. Time is a very precious commodity to our farmers.

Environmental concerns will have an increasing impact on the future of irrigation systems. In 1970, environment was used to imply changing the temperature and humidity with irrigation systems. Today environment implies the pollution of our water and soils or reduction of habitat and biological diversity. Runoff from irrigated fields is prohibited in many states and is already changing the management and operation of existing systems. The public is demanding that agriculture not degrade our environment. The challenge is for the industry and producers to preserve or enhance the environment; if not regulations forcing major changes will result. I hope that we have the foresight and willingness to prevent non-point pollution and minimize regulation. Most of us agree that regulations are difficult to write that can be applied universally. Most problems require unique solutions based on local and site specific conditions.

Irrigation is and will be needed to provide the high quality food that we have all learned to enjoy. As the world population continues to grow, we will need to continually increase the production of food and fiber. Irrigation will continue to change not only in the U.S. but in all of the world. The world demand for food is continuing to increase and our productive land is decreasing with the conversion to industry and housing for the increasing populations.

Probably my biggest regret is that I am approaching retirement and will not be an active part of the action in the next 30 years. The challenge is great and I encourage all of you to put your efforts together to solve and be a proactive force and not be reactive and allow major restrictions to unduely limit irrigation in the future. We must form partnerships between industry, researchers and producers to develop tools and technology that are readily acceptable. It isn't always the best technical solutions that are adopted. Reliable products and technology accompanied by the sales network and technical support are important. Research needs to be forward looking but not forget our customer. The forum of the CPIA for discussing research needs and approaches is of extreme value in assuring that our research is solving real problems. Surface irrigation automation was good research but we did not understand the customer needs and partnerships necessary for commercializing the technology. The industry, researchers and producers need to work together to assure that we obtain the best solutions for the future of irrigation. Sustainable and environmentally friendly solutions can be found to assure our customers (the consumer) of high quality and affordable food and fiber.

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