

On Farm Irrigation Management - The Shift from Art to Science -

by

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ABSTRACT

Excellent on-farm irrigation management and design have traditionally been promoted for reasons of improved yields and farm input costs. More recently, external pressures require even more detail to on-farm irrigation. These external pressures include competition for water by urban and environmental interests, plus degradation of aquifers and rivers. As irrigation progresses from an art to a science, new concepts must be adopted. Key points made in the paper relate to flexible water deliveries to farms, improved fertigation practices, the importance of on-farm irrigation evaluations, the use of an Irrigation Consumer Bill of Rights by dealers and farmers, and irrigation system hardware improvements.

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THE ART OF IRRIGATION

In spite of several decades of irrigation research and publications, the majority of irrigation still contains large amounts of art. The personality of "Art" is well known to farmers and irrigation district operators. Art takes a long time to get to know, and you can't just learn about Art from reading a book or putting numbers on paper. You need "experience" to artfully manage water.

Art is defined in the dictionary as "the principles or methods governing any craft, skill, or branch of learning". Jack Keller, a distinguished irrigation specialist, has sharpened this definition by the observation that Art is "non-transferable knowledge".

Art conjures nostalgic memories of hand-made shoes and hand woven clothes - technologies and processes which have gone by the wayside in other industries because of the need for efficient operations. Likewise, irrigation is beginning to shift from an ART to a SCIENCE.

An example of irrigation Art is the furrow irrigation of a field with minimal runoff. Farmers know that the correct flow rates and irrigation durations depend upon the soil type, number of previous irrigations, number of tractor passes through a field, slope, weed growth, and other factors. It is virtually impossible for someone to walk up to an unfamiliar furrow irrigated field and know the precise number of furrows to irrigate at once, and for how long. One first needs to know the history of previous irrigations, and then apply some judgment.

Can farmers have very efficient, successful furrow irrigated fields? Yes. But serious questions must be asked, such as:

1. Are there ways to minimize the art with furrow irrigation?
2. Are there other irrigation practices which require less art, yet are still affordable?
3. As the pressures to increase efficiency of all forms (labor, yield, water, energy) increases, how much optimization can realistically be done if there is a large amount of ART in the irrigation process?

We cannot automate ART. It is difficult to methodically optimize ARTFUL processes, because it is difficult to define the processes. The irrigation industry is poised to follow other industrial processes - art will be minimized, and new technologies will replace irrigation techniques for which too much art is required.

There will always be some elements of art in farming and irrigation. The key word in the previous paragraph is "minimize".

Of course, we also need to be careful to not be so ambitious that we blindly adopt new "scientific" technologies which can only be successfully implemented by very artful specialists. All new technologies must be carefully evaluated and appropriately applied. Some technologies fall into the category of "interesting, but I'll go broke if I successfully implement it".

EXTERNAL PRESSURES

In the "good old days" of just 15 years ago, farmers were mainly interested in improving irrigation because of larger yields, better crop quality, or reduced input costs for water, power, or fertilizer. Likewise, the university extension irrigation specialists in California used to be funded to help farmers accomplish those goals. Now, a large part of the budgets for university extension services, the US Bureau of Reclamation, the US Agricultural Research Service, and the US Dept. of Agriculture's Natural Resource Conservation Service (formerly known as the Soil Conservation Service) is dedicated to environmental issues rather than to directly helping farmers increase yields and profits.

In California, about 150 irrigation districts provide all or some of the irrigation water to the majority of irrigated land (about 3.8 million ha, total). Those districts were previously managed by engineers with a construction background. The irrigation districts stopped at the farm turnout - what the farmer did with the water was his/her business. Various governmental agencies which have now received mandates to protect the environment and ensure that water is used wisely, such as the State Water Resources Control Board (in charge of water rights administration and water quality issues in the state) and the US Bureau of Reclamation, have realized that they cannot deal with individual farmers either from a practical or legal standpoint. Therefore, they put restrictions on inflows and outflows of irrigation districts to indirectly stimulate changes on-farm

The irrigation districts must suddenly help/force farmers to implement improved on-farm water management programs. This has sometimes caused considerable local turmoil, since irrigation districts in California are

quasi-public agencies which are typically owned by the farmers themselves, who hire professional managers and staff to run the districts. The traditional irrigation district staff have little or no expertise with on-farm irrigation. ITRC has assisted these districts and various agencies in defining the proper best irrigation management practices for irrigation districts.

Farmers often think that their situation is unique and they are being unfairly targeted by agencies to improve on-farm irrigation management. While each situation truly is unique, such external pressures are widespread and increasing. This is due to the scarcity of water and our improved understanding of its complex influences. ITRC has often been called on to inform farmers about events in other parts of the state, so that they understand that the water picture in the whole state is becoming very complicated very fast.

Four examples of external forces on irrigation districts which have required changes in irrigation district and/or on-farm irrigation management are given below.

1. Grand Junction, Colorado
 - a. Deep percolation of on-farm water picks up salt from the soil. Return flows to the Colorado River are very salty, which impacts downstream users in California.
 - b. The irrigation districts divert large flows and have a very simple control system which allows a high degree of water delivery flexibility to farms but which requires that there is a lot of canal spill. The canal spill is not degraded in quality and returns to the river downstream of the project. A 24-km stretch of the Colorado River below the diversion dam for the local irrigation districts has been found to have an endangered fish species. The canal control (and possibly the farm irrigation practices) must be changed so that there is less canal spill, and therefore less diversion from the river.
2. Central Valley Project, California
The Central Valley Improvement Act was passed by Congress in 1992. It dedicated 800,000 acre-feet (986 million cubic meters) of water for improvement of the fish, wildlife, and habitat. This water was formerly dedicated to agriculture and M&I.
3. Imperial Irrigation District (IID)
IID has been sued by its neighbors, the State, and others because its return flows enter the Salton Sea, causing its quality to degrade and its water level to rise. A major component of the return flows is uncollected tailwater from surface irrigated fields. Numerous solutions have been attempted.
4. West side, San Joaquin Valley
Irrigated land of several irrigation districts overlies soil with high selenium levels. Deep percolation picks up the selenium, boron, and other salts. The high water tables require the usage of on-farm tile drains, which depend upon irrigation district drains to convey the water to discharge points on the San Joaquin River. Acceptable selenium, salt, and boron limits in the river are grossly exceeded, causing the State Water Resources Control Board to place severe restrictions on the drainage from the irrigation districts. Farmers are scrambling for ways to irrigate more efficiently and with saltier, recirculated water.

BOTTOM LINE

It doesn't really make any difference what the incentive is for improving on-farm irrigation management. Powerful incentives exist from perspectives of (i) profit, (ii) environmental needs, and (iii) urban competition for water. The particular mix of incentives will vary, but they are becoming stronger rather than weaker.

The bottom line is that good on-farm irrigation management is no longer just some nice goal. It is a requirement in most areas. And one of the important elements of modernization is the substitution of Science for ART.

The remainder of this paper contains insights from California on various actions which have been, or will be, used to minimize the ART in irrigation.

IRRIGATION EVALUATIONS

How can you improve any process until you clearly understand how it is performing? ITRC has developed widely-used on-farm irrigation evaluation procedures. For quick, farmer-oriented service we favor an evaluation of the distribution uniformity (DU) over a more detailed irrigation efficiency evaluation. This is because it is relatively simple to improve the uniformity of irrigations, and the evaluation does not require nearly as much expertise to perform as one which examines irrigation scheduling.

We have also learned that a cursory examination of seasonal irrigation efficiency can be misleading. Especially with surface irrigation (furrows and border strips), it is necessary to evaluate the performance of irrigation events throughout the season in order to determine seasonal application and irrigation efficiencies.

One problem in discussing efficiencies is the lack of a common understanding and vocabulary by all of the players in a room. ITRC has conducted numerous classes on the topics of efficiency, uniformity, and irrigation evaluation procedures. This has helped to standardize procedures and vocabulary.

A recent Task Committee report from the Water Resources Division of the American Society of Agricultural Engineers (Burt et al, 1997) provides a valuable reference for concepts and terms related to efficiency and uniformity.

IRRIGATION CONSUMER BILL OF RIGHTS

A properly designed irrigation system is easier to fine tune to a high level of performance than is a poorly designed system. In conjunction with irrigation dealers and manufacturers in California, ITRC developed the Irrigation Consumer Bill of Rights in 1995.

The Irrigation Consumer Bill of Rights is essentially a list of questions for farmers to ask irrigation dealers before purchasing an irrigation system. In addition to the General Bill of Rights, one is also available for Drip/Micro Irrigation Systems. Some irrigation dealers supply the answers in writing. The questions address such topics as warranties, pump efficiencies, chemical injection equipment, the need for pre-filtration of water, stated distribution uniformity, water requirements, etc.

The Irrigation Consumer Bill of Rights was first adopted by the California Irrigation Dealers Association, and later by The Irrigation Association. This program is helping farmers to compare the quality of bids, improve efficiency, and minimize conflicts between the farmer and dealer after the purchase.

IRRIGATION DEALERSHIP TRAINING

In the U.S., most people working for or owning irrigation dealerships have little or no formal training in irrigation. Practical short courses have been made available for these people to sharpen their technical skills. ITRC provides numerous classes every year, including a 2 week Designer/Manager series of classes in July. The Irrigation Association provides a Designer Certification - a program which has been implemented by The Irrigation Association of Australia.

TREATING A FIELD AS A GROUP OF ELEMENTS RATHER THAN AS AN AVERAGE

How many times have we heard the following:

There is no rain in an area, and the crop ET plus leaching requirement is 1 meter. A farmer carefully applies irrigation water with the proper timing, and applies a total of 1 meter.

Evaporation and runoff losses are negligible. Conclusion: The irrigation efficiency is 100%.

Of course, the irrigation efficiency is considerably less than 100%. If 1 meter was applied on the average, that means that half of the field received less than 1 meter and half received more than 1 meter. Half of the field was under-irrigated, and half was over-irrigated. The over-irrigated half had non-beneficial deep percolation.

The conceptual error arose by treating irrigation as an "average" rather than considering the fact that there is non-uniformity in all irrigation applications, regardless of irrigation method. Typical ratios of maximum/minimum applications in a field are 2/1 or even greater.

Once we start treating fields as groups of distinct elements, rather than as an "average", we can make major improvements in the management of irrigation and fertility.

IRRIGATION SCHEDULING

Irrigation scheduling has been the subject of numerous conferences, short courses, books, etc. I have observed that irrigation scheduling is most predominate on (i) continuous move systems, [linear moves and center pivots], and (ii) solid set systems such as drip, microspray, and undertree/overvine sprinklers. These methods are rather simple to schedule - virtually everything is known and controllable. It is easy to apply a specific depth of water uniformly in a given week.

Side roll (wheel line) sprinklers and hand move sprinklers are on a different level. They are simple to schedule, but have much less flexibility than the previously mentioned systems. The basic scheduling decision is whether or not the sprinkler set should start up again, once the 7 day to 12 day rotation has finished. Since both the application rate and duration (due to labor constraints) are usually fixed, the percent soil moisture depletion is a fixed amount.

The tough scheduling job comes with surface irrigation (furrows, border strips, and level basins). In addition to labor constraints, they have a high degree of unpredictability of intake rates. Scheduling can only be done with good knowledge of field history. Even at that, it is typically difficult to apply small depths with a good uniformity unless the soil is quite compacted. For these methods, it is as important to understand the nuances of the irrigation method and field as it is to understand the agronomic aspects of the plant.

In all cases, in California there are probably about 5-6% of the irrigated area which is actually scheduled using a formal crop ET - soil water balance procedure. However, the wide availability of ET information and history of trials with soil moisture sensors, short courses, etc., means that most farmers make informed irrigation scheduling decisions. Conclusion: If you want to adopt irrigation scheduling programs, don't give lectures to farmers on the details of the Modified Penman equation - those lectures will put them to sleep and farmers need to know how to drive the car, not how to build it.

IRRIGATION SYSTEM HARDWARE MODIFICATIONS

In our years of working with farmers to improve irrigation systems, we have realized that for the majority of cases, we only have a limited number of tricks in our bag for each irrigation method. Some insights are given below.

Surface Systems. The items in order of importance are:

- Land grading

- Reasonably short furrow lengths
- Tailwater return systems

In addition, we have done quite a bit of work with furrow shaping, selective compaction of furrows with torpedoes, and chemical water treatment (PAM's and gypsum). In California, which requires full irrigation due to the lack of summer rain, surge irrigation has never really been a big success. Neither has automation, although the use of surge valves for simple automation and tailwater cutback has some promise.

Sprinklers for grid-type systems (hand move sprinklers, side rolls). The number one factor influencing uniformity is the quality of the overlap. New sprinklers have been developed to supplement the tried-and-true impact heads.

California soils typically have very low intake rates, so sprinkler nozzles are typically quite small - making them sensitive to wind. We try to pay attention to the proper spacings and pressures.

Although flow control nozzles have become popular in some installations, improved pressure regulators at sprinkler bases provide better performance in terms of desirable stream breakup and flow rate regulation. There is a large interest in new pipeline materials such as Certalock for portable, solid set sprinklers on crops like carrots. These systems have special non-leak gaskets and check valves within each sprinkler to keep the lines full.

Drip and microspray for trees. The acreage of these systems rises every year - currently servicing between 15 - 20 % of the total irrigated area. Amazingly, the cost is about the same as it was 15 years ago, but the qualities of the filters, fittings, emitters, etc., have improved dramatically. There are three interesting trends at the moment:

- There is an increased usage of pressure compensating emitters, since there are a few excellent products on the market.
- There is a lot of interest in buried drip. Some of these systems have not been successful because of root intrusion or because water rises straight to the soil surface. Reasons for water rising to the surface include (i) excessively high emitter pressures, (ii) high emitter flow rates, (iii) excessive durations of irrigation, and (iv) water quality problems which reduce permeability. In some areas such as Lodi, buried drip on vines is very successful.
- Plugging problems with calcium, iron, and manganese are being successfully addressed with the use of polymers such as phosphonates and polyphosphates.

Challenges include:

- Developing more and better options for inhibiting root intrusion
- Developing better chemicals for keeping emitters clean, especially for organic growers.
- Maintaining good soil health around emitters
- Understanding how much wetted area is really needed for optimum crop growth.

Drip for row crops. This is expanding throughout the U.S. even including on corn in the Midwestern U.S. In California, the emphasis on permanent buried drip has softened in favor (about 85/15) of very shallow buried tape which is either disposed of or is retrieved for re-use.

FERTIGATION

Although Fertigation is widely practiced in California with all methods of irrigation, its implementation is not very sophisticated. Those farmers who pay special attention to fertigation appear to profit from that attention.

A major advance in the past 15 years has been the almost total shift from solid to liquid fertilizers in California. There are some notable exceptions, such as Potassium Sulfate and Gypsum.

Presently, most farmers have some idea of the amounts of N, P, and K to apply. However, there are large advancements to be made in the following:

1. Nutrient ratios. We know that it's not just the amount of N, P, K, etc. you apply and the levels of those nutrients in the plant. The ratios of Ca/Mg, K/P, etc., appear to have an equally important role (Burt et al, 1995).
2. Nitrogen Forms. Farmers prefer different types of nitrogen fertilizer for various crops, seasons, soils, and plant growth stages. However, there is very little hard science between their choices - and fertilizer recommendations virtually never distinguish between applying Urea, Ammonium, and Nitrate forms of nitrogen. We know that young plants have a preference for ammonium, and that there is some optimum ratio between Ammonium and Nitrate applications - this knowledge needs to be expanded and implemented.
3. Timing. The exact timing of fertilizer application types and amounts can be optimized.
4. Interpretation of various nutrient tests, such as (i) plant tissue, (ii) soil, (iii) soil solution, and (iv) plant sap. We have very few tables which clearly give us sufficiency guidelines for all four tests.
5. Proportional fertilizer injection. Most irrigation systems have flow rate changes with time, and there is a need to adjust injection rates when spoonfeeding.

BASIC RESEARCH

In our rush to operate at a profit and to solve immediate problems, funding for basic research has taken a direct hit in favor of applied research. There is almost no basic irrigation research being conducted. Organizations which traditionally performed basic research, such as universities and the U.S. Agricultural Research Service, have been caught up by the political and financial demands for immediate results.

Basic research is tough to sell if profit margins are low and there are high unemployment rates. However, there is a good argument that it is essential for significant future advancements.

IMPROVED WATER DELIVERY TO FARMS

Many of the new on-farm irrigation technologies require that water be available when needed. A high degree of flexibility in water delivery Frequency, Rate, and Duration is needed. An automated drip system cannot depend upon water from a typical water district which requires about 12-24 hours advance notice before delivering water. Therefore, most automated drip systems are on wells.

In parts of California the rapid shift to drip/micro systems is accompanied by a shift from surface water (supplied by irrigation districts) to groundwater. Farmers pay the high pumping costs because of their need for flexibility and their desire to automate their systems. This is a major problem in some areas, which have critical groundwater supplies.

Cal Poly ITRC typically works with 10-15 irrigation districts at any one time on modernization and training programs to help them respond to the farmers' needs for improved water delivery flexibility. These programs include the design of Supervisory Control and Data Acquisition Systems (SCADA), canal automation, the use of variable frequency drive pumps, implementation of hand held data recorders, new water order software, training of staff and farmers, and on-farm irrigation demonstration projects. In addition, ITRC offers many training

classes to irrigation district personnel on topics such as SCADA, modernization, flow measurement, pumping plant operation, etc.

APPLIED RESEARCH NEEDS

We know most of the important concepts of irrigation management. The devil is in the details. Salt management, for example, is completely different on clay soils as compared to sandy soils. We still don't know what we should about salt management on either type of soil.

New products and management practices need to be evaluated, and the information (good and bad results) must be disseminated so that the learning curves can be shortened. Applied research often involves a systematic appraisal of advancements which private companies or individual farmers have developed - university research does not have to be restricted to ideas which were developed at the university.

The list of applied irrigation research needs is long, but the point is that if it is properly focused and conducted, it does provide quick results for the farming community. It just costs money and requires well trained people - but it certainly is preferable to having each individual reinvent the wheel.

QUALIFIED IRRIGATION SPECIALISTS

The irrigation specialist of today faces a much more complex task than the specialist of 20 years ago did. It is no longer sufficient to just know about a single method of irrigation. An irrigation specialist must understand water law, water quality, the various irrigation system design options, irrigation scheduling for many crops and soils, etc. So where do we get the specialists who understand both the theory and the practical side of irrigation?

It's a tough question. In the United States, university students must take a much larger percentage of General Education classes than a few years ago - meaning that they take a smaller number of technical courses. In most universities, professors are rewarded with promotions and salary increases based on research funding and publications rather than on teaching merit - teaching requires a qualitative assessment but research funding is easily assessed quantitatively. University budgets are decreasing while the cost of technical programs is increasing. Fewer U.S. students now pursue advanced degrees because the starting salaries for B.S. graduates are high, and the students typically have large education loans to repay by the time they graduate.

In short, as irrigation is becoming more complex, it is increasingly difficult to find qualified university graduates. Cal Poly is not immune the pressures mentioned above, but with strong industry support and income from ITRC, it has maintained a high quality irrigation teaching program which emphasizes both the theoretical and pragmatic approaches. Farmers, consultants, government organizations, and irrigation dealerships and manufacturers provide excellent summer-time jobs and internships for students, so they can make their mistakes and learn even more while going to school. It may be possible to apply the Cal Poly formula in Australia, if it is not being done already.

SUMMARY

The past 15 years have seen tremendous shifts in water competition, improved awareness of good water management, and the development of new hardware technologies. We are looking forward to the imminent retirement of ART.

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