The Subtleties and Practicalities of Irrigation in the US as It Applies to Assisting Developing Countries Like Iraq Improve Their Irrigation

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Introduction

This brief analysis is intended to expand upon the strategy that Guy Fipps put together and review some of the practical concerns in implementing it. My perspective comes more from the end users of irrigation water then the researcher, designer, and promoters. It thus tends to emphasis some of the compromises the end users have to make in applying the principles of irrigation. My approach might best be expressed in the List Server Exchange on Irrigation-L I participated in several years ago when on the faculty of AIT. One individual inquired of the group for detailed crop coefficient values needed to compute estimated ET with the Penman equation. I replied to the inquiry to ask if he or anyone knew of an irrigation system, particularly a surface system that could effectively respond to the accuracy he was requesting. The following reply came back:

"Measure it with a micrometer, mark it with a grease pencil, and cut it with a chainsaw."

I thought this an eloquent expression of the extent the science of irrigation has exceed the end user ability to effectively make use of the available knowledge. It also leads me to the rather provocative contention that:

> ***"More money, time and effort has been invested by engineers, agronomists, economists, sociologist, and their respective extension personnel in irrigation technology for less acceptance by the farmer and other end users, than any other crop management activity, worldwide, smallholder or large farmer alike, developed or developing economy".***

The reason for this has nothing to do with knowledge or lack of knowledge or desire to deliberately misuse water and irrigation systems. It has a lot to do with water, or more accurately the water supply, usually not being the major determinant of irrigation management, and the operation of irrigation systems not fully consistent with the users' needs. To the farmers or other end users water and irrigation are just one of several crop management factors they have to optimize. It also has economic value and the most intangible concern of all convenience. Certainly the irrigators in the US have all the knowledge or access to the knowledge to maximize their water management efficiency, and thus what appears to be sub-

[1] The ideas contained in this paper are strictly the author who is solely responsible for the content. Some of these ideas may and probably are in contradiction to other Inma and USAID opinions. In such cases it hope they rational behind the opinions will be appreciated and lead to more comprehensive discussions and better overall programs.

optimal water management to the irrigation specialist is most likely the highly rationalized optimal management by the end user after factoring in all other concerns.

Similarly irrigators in developing countries may not have all the knowledge or access to knowledge as their US colleagues, but they are equally constrained in their effort for highly efficient irrigation management. This is mostly due to delivery systems that are shared with other users, operated on rotation, have limited flows, requiring excessive applications just to push the wetting front across the field, etc. In this case each operator is optimizing their management as the individual entrepreneurs they are, with little concern for their neighbor's irrigation interests. Such farmers are very much members of their community, but by no means communal farmers, even when sharing a common irrigation water supply.

While many of my irrigation colleagues might be a little uncomfortable with this analysis as it contradicts many of the irrigation promotions, most will accept it represents some of the uncomfortable truths of irrigation that should not be overlooked.

Irrigation in the US

In initiating this analysis it might be good to start with a brief review of the US irrigation system particularly in the Western US such as Colorado. The US prides itself on its privately owned, demand irrigation system based on the principle of "Prior Appropriation". This is actually a very legal system in which everyone is entitled to a given amount of water as determined by the flow in the river and when your ditch company's water right was initially decreed. Such water rights now go back 150 years. In Colorado the first ditch company was organized in 1859 in the San Luis Valley. They claim that if your water right was decreed after 1900, in most years you will not receive any direct water, and have to rely on return flows.

The problem with the US system of "Prior Appropriations" is that it is an expensive system to routinely operate as it requires constantly measuring water. We must measure water when it is divert from the stream to assure the diversion is consistent with decreed water rights and are in priority. Again water has to be measured when it is delivered to the end user, to assure they are receiving what they are entitled to, no more – no less. Measuring this much water this frequently is operationally costly and this cost is directly related more to the number of people involved, than the area of land involved. Thus as you deal with more and more people and less and less land per person the operating cost increase logarithmically. This could become a major concern when attempting to measure water to smallholders, such as in Iraq and other developing countries. Also, the concept of decreed water rights is foreign to most irrigation systems outside the US who find the concept just too complex to comprehend in all the details.

The other expense with the US system is that when there are any disputes they end up with complex litigation that is heard in the "water court", a court fully dedicated to hearing only water manners. Like any litigation the legal fees can become excessive. While measuring water is reoccurring operational costs, litigation is expected to be a onetime cost, but an expensive one.

Breakdown in Demand System in US

Even in the US the demand system breaks down when dealing with small users. The primary examples are the Salt River Project in Phoenix, Arizona when they have to provide raw surface water to residential users for irrigating their yards. Here they provide water strictly on a 2 week rotational basis, subject to sign-up sheets. Since the water can be delivered at any time of the day including the middle of the night virtually all residents hire local irrigation companies to manage their water. The latest value for this service I have is from 15 years ago. At that time it was $10 per irrigation. The charge is in addition to the Salt River Project's regular water charges. In total, this could make these residential deliveries some of the most expensive lawn irrigation in the world. The Salt River Project will happily pay the irrigation company on your behalf, and then include the charges in your bill. However, the net effect is the additional cost of delivering water to small residential users is off the Project's books, but most definitely not the homeowners.

The other case, that is becoming increasing a concern along the Front Range of Colorado, is the hobby farm subdivisions with many lots of 35 ac. This is good for raising some wheat or hay or grazing a few cattle and horses. When the subdivision or it members own shares in North Pouder Irrigation Company, Steve Smith, the company general manager, will deal with only one member of the subdivision and will only deliver water if the equivalent of ¾ the subdivision is to be irrigated. This really become a big hassle on all sides. The subdivision representative has a very thankless task of trying to coordinate all his neighbors, and Steve describes them with expletives deleted sufficient to make Richard Nixon's language appear saintly. However, to deal with it any differently the conveyance losses or "shrink" would exceed the water delivered. The idea of block deliveries has been picked up in working with smallholder systems, but usually overlooking the hassle involved in the US application, and thus implying a more comfortable fit then reality. For this reason block delivery of water to smallholders in developing countries usually require continuous external facilitation or they quickly collapse. It also has to be recognized that hobby farmers are far less dependent on the irrigation water for their basic livelihood than their colleagues in developing countries.

The bottom line on this is that while the US system is very effective, it is expensive and breaks down when dealing with the size of farms or other users usually associated with Iraq and developing countries. Thus, for those working with irrigation in developing countries it might be best to consider alternatives that will come as close to the effectiveness of the US system, while remaining cost effective and not financially burdensome to the government or water users.

Single Use Diversions and Return Flows

One of the subtitles' of the US irrigation system is that the water rights and diversion of water to the user is for single use only. This result in measuring the water diverted but not credit the return flows. This forces the concentration and most of the discussion by the engineers and promoters of efficient water use on the initial single purpose for which the water was diverted, with less regard for multiple uses, including the return flows. Under this system the return flows are the physical impossible, but administratively possible manufactured water. And while not a major part of the discussion on water efficiency they are a critical component of the overall system. This is noted by the diversions from the South Platte River each year average more than twice the natural river flow plus all the trans-divide water coming from the Western Slope via Colorado-Big Thompson Project and the older Michigan Ditch with its related tunnels. This can only be done by factoring in the return flows estimated at 4 cusecs per linear mile of river (70 l/sec/km). The South Platte is actually fully diverted to a dry streambed into the irrigation system at least 4 times and perhaps as many as 7 times between Denver and the Nebraska state line.

In this case, it is really necessary to separate the irrigation efficiency of the system as whole from individual field applications. For example historically over most of the last 150 years of irrigated agriculture the surface irrigation systems in the Front Range and Eastern Plains of Colorado operated at about 30% application efficiency, without any detrimental impact on the crops or soils. However, if you do this 4 times the overall efficiency of the system becomes 75%. If it is 7 full diversions the efficiency goes up to 92%. Not bad for surface system with a base efficiency of only 30%, and comparable to the irrigation efficiency of a low pressure center pivot. It is also important to note that the recent shift from surface to Center Pivot along the Front Range has reduced the return flows and caused some severe problems for junior right holders further out on the plains, who historically were dependent on the return flows for their supply.

The importance of return flows can be very critical to the overall system operations. The best example could be the rice production in the Sacramento Valley in California and the operation of the Central Valley Project covering the San Joaquin Valley, one of the richest irrigated agriculture areas in the country. The Sacramento water district charges farmer by the acre irrigated instead of acre foot diverted as is the normal for the rest of the country. This allows rice to be grown without regard to the total amount of water diverted. The massive diversion of much of the early spring runoff into the rice paddies could be critical to buffering the runoff hydrograph and result in more uniform flow into the forebay of the pumping stations that pump water from the Sacramento River into the Central Valley Project. Without this the forebay could be overwhelm during the major spring runoff and substantial water lost to San Francisco Bay.

This also may be critical in countries like Tajikistan where there are no storage structures for most of the irrigation system, but the system operates on the same type of snow melt runoff that quickly tapers off in the summer. However, they claim to have sufficient water all season. This could only happen if the return flows from the inefficient irrigation in the upper reaches provide the “storage” for the lower reaches in the latter part of the season. Such are the subtitles’ on which irrigation systems depend.

In countries like Iraq with the much weaker water rights concept and thus limited need to measure water at all junctures in the system, the important concern, particularly from the MoWR perspective, is the overall efficiency of the system, rather than individual irrigation applications. This could often mean it is administratively easier and cheaper concentrating on the recovery and utilization of the return flows, than concentrating on individual farm efficiency. This would be a greater concern in the upper reaches of a system with the best opportunity to recover return flows then the lower reaches. If the water is primarily derived from spring snowmelt, the system might actually benefit from inefficiency of the upper reaches. It would also depend on how much the return flows or drain water is contaminated with salts, etc. Most of the time this is not a major problem as much of the return flows represent “flow through” or water that flow through the system and out the tail escape without ever being applied to the fields. The problem is more with the deep percolation water that will contribute to the salt leaching, and increase the salts in the seepage return flows to the drains. However, the mix of the two will normally be of acceptable irrigation quality.

Not to look at the overall system and concentrate on the micro irrigation manage at the farm level could be a major disfavor to the Iraq or other host governments as it would force them to expensive operational costs that would not be justifiable, and encourage farmers to attempt irrigation practices that can be effectively demonstrated in an isolated field or two, but not integrated down a complete farm canal with the normal 8 week spread in crop establishment a major mixture of diverse crops, and other management activities.

Concern for Irrigation Efficiency

In transferring the concern for irrigation efficiency to countries like Iraq it might be interesting to see who among the various individuals involved in irrigation operations in the US are actually concerned with irrigation efficiency and actively promoting it, and who is at best only passively interested.

State Engineer: The Colorado state engineer’s office is comparable to the MoWR in Iraq as the most senior public sector entity involved in overall water management and river diversions. However, he has little concern with how effectively the water is used. His main concern it monitoring the flow in the river using a number of automatic remote sensors continuously reporting to his central data bank, and determining which Ditch Company is “in priority” according to their decreed water right and thus entitled to divert water and how much they can divert. He does stipulate the water be beneficially used, but that can be a very vague term and refer to any of numerous uses for which irrigation is just one. One of the other beneficial uses is diverting into storage reservoirs for later use as irrigation. Most ditch companies will own and operate one or more storage reservoirs. Others beneficial use could include recreational use such as the increasing popular rafting and kayaking industries as well as snow making, or domestic use. In Colorado commercial rafting is a $50,000,000 annual industry. He has no interest in reallocating water from one Ditch Company to another based on differences in crop performance etc. He can, however, cut off water if you have taken too much or your water use is interfering with a more senior right. Recently, the State Engineer’s office cut off water going to City of Golden to the extent they could barely flush the toilets, because during the draught year they had carefreely diverted more water than they were entitled. In this severe drought year the flow became so low a little know and mostly forgotten clause in the decrees said the farmers regardless of how efficiently they were using the water, were entitled to the water, and they got it. It made for some real hardships for the City. The City had to immediately curtail all outdoor watering for lawns and recreational areas, and still had to scramble to “rent” enough water to meet critical domestic needs and even had to truck in water. Also, recently the State Engineer forced some 400 farmers to shut off their irrigation wells claiming the wells were interfering with the return flows to farmers with more senior rights further East on the plains. This caused these farmers some major economic losses that most likely were not compensated for by the production of the farmers that actually received the water.

Northern Colorado Water Conservancy District (NCWCD): The NCWCD manages the water coming from the Colorado – Big Thompson project. This is the major trans-divide water project in the US that brings Colorado River water from the western slope of the Rocky Mountains through a tunnel into the Big Thompson River as well as the Cache La Pouder, both of which are tributaries to the South Platt River. The NCWCD allocates water, according to the shares an organization owns, to the different shareholders that are either Ditch Companies or progressively more municipalities. They have no direct contact with any end users including farmers. However, in addition to the water fees they receive, they are supported by a small tax levy to all property owners in the District, farmers and urban dwellers alike. They use some of their tax income to promote water use efficiency in terms of demonstration, equipment loans for surge-irrigation, xeroscape, etc. However, this is all promotion with no supervisory or enforcement authority. NCWCD does maintain several agro-climatic weather stations and posts the data including ET and crop coefficient computations on their website for anyone interested.

City of Fort Collins: The City of Fort Collins actually as more shares of water then they need. Also, their concern is mostly domestic use and municipal use including that for residential and open space irrigation. The latter includes school playground, parks, and golf course. The City also “rents” their excess water to anyone needing it including farmers. While the City has plenty of water entitlement, it does operate a major champagne for water conservation both indoor and outdoor use. The outdoor effort includes use of zeroscape landscaping and use of more native grasses instead of Kentucky Blue Grass, the most common and desired lawn grass, but based on the more humid eastern US.

North Pouder Irrigation Company: The North Pouder Irrigation Company is the consolidation of several ditch companies that, like most ditch companies, date back a100 years or more. The ditch companies are the basis for the Water Users Associations (WUA) promoted for smallholder irrigation in most developing countries including Iraq to maintain and manage farm canals. The North Pouder obtains water from direct diversion of the North Branch of the Cach La Pouder River and on a water swapping bases obtains water from the Colorado – Big Thompson Project. The company owns and operates some 215 miles (346 km) of canals, 15 reservoirs, and commands some 20,000 ac (9090 ha.). This is considerable larger than most WUAs.

In working directly with the water users the company manager has absolutely no interest in what the crops are, the degree of stress they are under, or any other irrigation or crop management parameter. His only concern is how many shares the person owns, how much water that entitles them to, how much they have already received, and how much water they are entitled to. If they do not have sufficient shares to cover their requested water, where will they get the water from and how will they pay for it. He has absolutely no concern for how the water is to be used or the efficiency of that use. That is none of his business.

Colorado State University: In the middle of this is Colorado State University, the Land Grant School for Colorado and one of the more renowned school for irrigation technology in the country. The University currently undertakes research and extension programs in water management for the state, which consistent with the concern for single use diversions, the individual application efficiency and crop production to water. Like most irrigation specialists the assumption is that water is the critical determination of crop management. It also manages a network of agro-climatic stations and posts the data on its website in near real time, including daily computations of potential ET and crop coefficients. Thus the water users of Colorado have all the information they need to manage water to maximum efficiency. No excuses! However, as I review the research studies and talk or receive student reports from the farmers and other end users, I have difficulty determining who as sufficient operational flexibility in their irrigation management to effectively utilize the research results.

Irrigation Compromises

The question is with all this information readily available, why do very few users appear to take advantage of the information in their irrigation practices? Are their reasons rational? And how should that impact on what we should expect of Iraq water users. The first thing would be that the "micrometer" promotions are not as critical to the "chainsaw" operations as the promoters would like, and thus not worth the extra trouble and expense. Also, as farmer and other end users reduce their capital cost of their systems, they usually loss operational flexibility, and thus cannot effectively make use of many of the fine tuning. At this point it might be desirable to separate research results that are statistically significant in identifying relatively small fine tuning of irrigation management from those that are substantial enough to justify the economic cost of adapting them. Some of the compromises are:

Center Pivots in The Eastern Plains: In many areas of the eastern plains the irrigation well yields are declining so that the pumps cannot keep up with the evaporative demand, which for a quarter section CP irrigating 120 ac (48.5 ha) requires 720+ gal/min (45.4 l/sec) to balance a 7 mm ET rate. Thus, these farmers have no choice but to turn their systems on at planting and let them run 24/7, until maturity and the crop is drying down prior to harvest. Even so they are running progressively further behind the accumulative ET and pray to all potential gods for a good thunderstorm to help catch-up with the accumulated ET deficite. All the detailed ET computations are really not very useful. Ultimately, as well yields continue to decline farmers shift to "windshield wiping" their CP instead of doing a full circle depending on the water they have available. The balance remains fallow and a loss in potential income. Perhaps not the most idea irrigation management, but well rationalized out according to what is available to each individual farmer.

Surface Irrigation – Internal Rotations: Whenever possible farmers still using surface irrigation will simply turn the water on in the spring and turn it off in the fall, allowing it to flow continuously into their farm throughout the growing season regardless of any climatic variation that would modify the ET, and basic crop water requirements. This would include any thunderstorms that might dump up to 2 inches (5 cm) of rain. The process is to divide the farm into 14 sets, and run each set for 12 hours. The whole process takes the full week to complete then the process is started all over again. To interrupt this to accommodate any rainfall would result in the crop becoming stressed by the time the resumed rotation completed its first weekly rotation. Also, to stop and restart requires the ditch company to send out the ditch rider to cut off and restart the flow, a process that can take a day. Thus they irrigate right through the 5 cm thunderstorm. The key here is convenience which is one of the major intangibles that gets into irrigation practices. In smallholder irrigation such as in much of Iraq this would be analysis to rotational deliveries when users have to take the water when available, or stress the crop before the next opportunity. It has to be recognized and accepted that in most cases the penalties for over irrigating are considerable less than the penalties for under irrigating. The exception would be if there is impeded drainage and a major concern for salt build-up. In Iraq the unreliability of power interrupting the pumps lifting water into the different canals can make the deliveries unreliability for which the natural and proper response by the farmers acting as individual entrepreneurs is to irrigate when water is available with no concern for the limited water deficit or their downstream neighbors irrigation needs.

Recreational Users: The only substantial group of irrigation users that appear to effectively take advantage of some of the more detailed irrigation management tools are the large recreational users managing parks, playground, golf courses and even industrial lands or condominiums. They typically have buried solid set pop-up sprinkler irrigation systems with enough water and pump capacity to irrigate when they want to with whatever amount they wish to apply. They are the group that most frequently hit the climatic sites in either Colorado or Texas for the ET and crop coefficient measurements, and use them in their irrigation planning.

Residential Users: Residential users are those homeowners who irrigate their lawns and gardens. They usually can be divided to those who use hoses and manually move them across the lawn and irrigate for a period of time at each location, and those with automatic systems with timers that automatically come on several times a week. The latter is the most common and includes myself. My operation is based on pure convenience. I turn the system on 1 May and turn it off 1 October each year, set it for operating 2 days a week for 30 minutes a set for 6 sets. That applies about 14 mm of water per irrigation. Between May and October I just let it run on its own making no adjustments for changing ET, such as when temperatures exceed 100 ºF (38 ºC) and the ET goes up to 8 or 9 mm/day even though I know how to easily access CSU's irrigation climatic information. I occasionally will curtail an irrigation for some heavy rains, but usually just irrigate through them, and I have a simple rain gauge mounted on the back fence available to make the adjustments. I also manage a drip system for my flower and vegetable garden using the same causal management except for irrigating 3 days a week for one hour instead of 2 days a week. This very casual highly convenient irrigation management does result in a slight deficit irrigation to the estimated ET rates depending on the amount of summer rains. However, I experience no economic loss to stress my lawn and little aesthetic loss.

Changes in Irrigation In Colorado

Another interesting thing is to take a brief look at some of the changes in irrigation practices in Colorado and what are the motivating factors behind them.

Surface Irrigation to Center Pivot: One of the biggest changes in irrigation in Colorado is the shift away from Surface Irrigation to Center Pivot. This was actually a 2 step shift. The first was from siphon tubes, which defined surface irrigation for nearly a century, to gated pipe. This tended to be relatively short lived as the gated pipe then gave way to the center pivot. Currently, while the total irrigated land in agriculture is declining the area in center pivots is increasing. The driving force behind this shift is actually availability of hired labor to manage the irrigation system. The water savings is a pleasant by-product.

Buried Drip: The other shift in irrigation practices is to buried drip. This is a relatively sensitive irrigation technology as you have to make certain the drip lines are far enough below the surface to avoid equipment passing over it from digging up the lines. This has to be balanced with the need for the capillary rise from the drip line to reach the root zone. In Colorado the depth will be 12 inches (30 cm) for onions and other vegetables, or 18 inches (45 cm) for maize. The latter depth usually requires the initial irrigations to use the old gated pipe to get the crop started enough for capillary rise to reach the young seedlings. Even then it is questionable how much water will be leaching down under gravity while the upper ward capillary movement reaches the roots. The driving force for this technology shift has been mostly the availability of water, not the cost of water. It has been widely used in the Eastern Plains where the declining water tables have made the availability of water scarce.

Conclusions

This brief write-up highlights how what may appear as sub-optimal irrigation practices to irrigation professional in the US, where farmers and other water users are mostly well educated and have access to all the irrigation technology they need, are in most cases well rationalize as the optimal irrigation for their individual needs. For Iraq and similar countries it is important to appreciate that what may appear as sub-optimal irrigation practices could still be optimal irrigation practices when irrigation is integrated into the rest of the crop management activities with the limited water entitlements and canal operations are factored in along with the limited reliability of power to operate the pumping stations.