Intelligation: Minding the Three S's for the Three F's

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Abstract

Intelligation (intelligent irrigation) is important in managing limited water resources shared by the Fish, the Farms and the Families (the Three F's). Irrigation directly influences the overall yield and quality of the crop produced, environmental quality, and the costs of water, fertilizer, pesticides, labor and power to produce the crop – thus farmers should strive to use irrigation water in the most efficient manner possible. Highly uniform systems, such as micro-irrigation systems, should be employed when possible. Farmers can further maximize profitability and optimize resources by intelligently minding The Three S's (Soil, Slope and Scheduling) when designing and operating irrigation systems. The influence of soil, slope and scheduling on micro-irrigation systems will be explored in detail.

Introduction

Fresh water is an important, non-renewable resource that must be better managed in the future to accommodate the various groups competing for it. In California, these competing needs have often been referred to as The Farms, The Fish and The Families, which figuratively denote agricultural, environmental and human needs. As population and environmental pressures increase, agriculture is increasingly looked upon as a source of water. It is the premise of this paper that with better water management, or "intelligation", agriculture can not only save water, but perhaps more importantly, substantially improve profitability.

The following reviews how efficient water use may be achieved in agriculture to maximize profits and optimize resource use. Eight ways irrigation influences farm profitability, resource use and environmental quality is reviewed, along with the relative uniformity of various types of irrigation systems. To ensure efficient water use, farmers should consider choosing highly uniform irrigation systems such as drip/micro, and then employ "intelligation" (intelligent irrigation) practices in their use. In particular, farmers should closely consider the Three S's (soil, slope and scheduling) when designing and operating drip and micro-irrigation systems. This will likely result in more efficient water use, maximized farm profits and optimized overall farm resource use.

Why do we need Intelligation?

Farmers should irrigate intelligently because irrigation influences eight important aspects of farming. First, water costs and/or use may be reduced, and more "crop per drop" obtained. Runoff and deep percolation may be avoided as well, with obvious economic and environmental benefits. Second, energy costs may be reduced if less water is pumped. If a lower pressure irrigation system is adopted, such as drip instead of sprinkler, then additional energy savings may be realized. Third, the cost of chemicals may be reduced if excess water is contributing to plant disease, or if non-targeted irrigation water is supporting weed growth. Fourth, the cost of fertilizers may be lowered if runoff and deep percolation are avoided. If the irrigation system is used as the fertilizer delivery system as well, then fertilizer application costs may be reduced, too. Fifth, flood or portable sprinkler pipe labor costs may be reduced if drip irrigation is adopted. The cost to apply chemicals and fertilizer may also be reduced if the irrigation system is also used as the chemical delivery system. Sixth, environmental quality may be enhanced if water containing fertilizers, chemicals, salts and/or silt does not run off or reach non-targeted surface and/or groundwater supplies. Seventh, crop yield may be enhanced by improving crop health through proper irrigation/fertigation/chemigation, and by using modern irrigation systems to manipulate crop vigor. Eighth, crop quality may be enhanced for the same reasons as crop yield, and proper irrigation may prevent crop contamination from water borne diseases if irrigation water is kept off the plants.

These examples show that intelligation may lead to both better resource use, lower costs and/or increased revenues, all of which point towards improved farm profitability. In the case of corn at $3.50 per bushel, a yield increase of 50, 100 or 150 bushels per acre is estimated to produce enough additional revenue to upgrade to a state of the art subsurface drip irrigation (SDI) system which would pay for itself in 4.4, 2.2 or 1.5 years respectively. This is assuming an SDI system cost of $1,100 per acre, and assumes an Environmental Quality Incentive Program (EQIP) cost share of $330 per acre. All the other potential cost savings listed above could accelerate the estimated payback time frame. In another case, one farmer saved an estimated $66/acre by simply choosing a higher quality drip tape that delivered better application uniformity to an existing operation. Clearly, an improvement in farm profitability is possible.

The Three F's – The Farms, The Fish and The Families

But farm profitability is not the only reason intelligation is important. Water is a scarce resource and "The Farms, the Fish and The Families" (the three F's) are all competing for it. This figuratively denotes the agricultural, environmental and human needs of water. Agriculture obviously needs water to grow crops profitably. The Environment also needs water to maintain the earth's ecosystems which humans are dependent upon for their survival. And last but not least, Humans need water not only to survive but to maintain a high quality of life. Since only 1% of the earth's water supply is fresh, and human population is exploding, and per capita water use is increasing, and non-renewable water supplies are dwindling, and the cost to develop new water sources is high, it makes sense to use what we have wisely. Since irrigation consumes 40% of the US fresh water supply (31% of the surface water and 68% of the groundwater), it is an obvious target for thirsty urban and environmental concerns.

The Case for Drip/Micro-Irrigation

Whether the motivation is improved profitability or better resource use, intelligation makes sense. The first step to irrigate intelligently is to use an irrigation system that delivers high application uniformity. In general, flood irrigation systems deliver relatively low application uniformity, sprinklers deliver relatively moderate application uniformity, and drip/micro systems deliver relatively high application uniformity. In the case of drip/micro, it is further convenient that this technology adapts to virtually any crop and terrain. Richard Howitt of UC Davis recently estimated that the probability of adopting drip vs. sprinkler or flood significantly increases as the marginal price of water exceeds $70 per acre foot. However, the irrigation system itself, or its uniformity potential, does not ensure efficient resource use and/or profitability. There is another step beyond choosing a uniform irrigation system.

The Three S's – Soil, Slope and Scheduling

The second step in intelligation is to pay attention to the scientific principles imbedded in the concept of The Three S's - Soil, Slope and Scheduling. If these principles are taken into consideration upon designing AND operating drip/micro-irrigation systems, then farmers may indeed achieve the potential irrigation uniformities made possible by technology. Again, the potential benefit is maximized profits and optimized resource use.

Soil

Soil type influences many aspects of intelligation including the following four. First, soil type influences the maximum irrigation precipitation rate that may be applied without experiencing runoff of farm fluids. Precipitation rate selection should be made at the design/purchase stage. Second, soil type influences the optimum emitter and row spacing to achieve the desired wetting pattern. This decision is also made at the design/purchase stage. Third, soil type influences the maximum irrigation duration to avoid runoff and/or deep percolation beyond the root zone. This is an irrigation scheduling decision, but must be considered at the design stage, too. Finally, soil type influences the frequency at which the system may be operated.

Soil type may be determined by conducting a jar test, a feel test, or a laboratory test. Each of these methods will reveal the relative percentages of sand, silt and clay in the soil sample. The percentages are then plotted on a Soil Texture Triangle to classify the soil as one of twelve possible types including sand, sandy loam, loam, silty loam, silt, clay, etc.

Soil type is important because each soil type behaves differently in its ability to accept, hold and release water. The USDA's Maximum Precipitation Rate Charts may be consulted to ensure that precipitation rates will not result in runoff during irrigation events. The soil type will also determine how much water the soil can hold, and how much of it is available to the plant. This will influence how long the irrigation system may be operated before water runs off or is lost to deep percolation, and to what level the soil moisture may be depleted before the irrigation system should be operated again.

Soil type also influences water movement in the soil and is thus important in choosing the emission device spacing and/or wetting pattern of the various drip/micro irrigation systems available. In general, a wetted corridor of moisture is desired with tape and dripline products, and depending on the soil type, a specific emitter flow rate and spacing will be chosen. It should be noted that in the case of subsurface drip irrigation (SDI), wetting patterns may be larger than with surface drip applications, and soil surface moisture levels may be manipulated as needed. For instance, SDI may be used to avoid soil moisture at the soil surface, thus avoiding evaporative losses and/or possible crop injury/contamination. In contrast, SDI may also be manipulated to achieve soil surface moisture if desired, for instance, in the case of seed germination. Soil type, emitter flow rate, emitter spacing, irrigation duration and irrigation frequency all affect the wetting pattern created.

Slope

Slope influences several aspects of intelligation, but primarily the following two. First, in addition to soil type, slope will also influence the maximum irrigation precipitation rate that may be applied to avoid runoff of farm fluids. The steeper the slope, the lower the precipitation rate should be to avoid the influence of gravity on water movement. USDA charts may be consulted at the design stage to predict precipitation rate compatibility with actual soil type and slope conditions.

Slope also influences the type of irrigation lateral that should be used to optimize the application uniformity of the irrigation system. Irrigation laterals usually consist of emission devices that may be simply categorized as pressure compensating (PC) or non-pressure compensating (Classic). PC devices are designed to be less sensitive to pressure variation than Classic devices, thus provide high application uniformity in situations where pressures vary significantly.

For instance, in hilly terrain or long lengths or run, water pressure may vary substantially from one end of the lateral to the other. In such cases, PC devices will typically achieve a higher application uniformity than Classic devices without the need for additional pipelines or pressure regulation. PC devices are available for virtually all agricultural and horticultural applications and include PC Tape, PC Dripline, PC Emitters, PC Sprays and PC Micro-sprinklers.

In one case, a PC tape allowed 12.5 psi pressure variation along the lateral compared to only 3.5 psi allowable variation in a Classic tape. Both systems achieved an Emission Uniformity (EU) of 90%, but the owner of the PC tape system enjoyed the luxury of achieving either long lengths of runs on flat ground, or running up and down slopes in hilly terrain, without the need for additional pipelines or regulation. These benefits can be of significant operational and financial value.

Scheduling

Irrigation scheduling is the art and science of deciding when irrigation events will take place: which days, when during the day, and how long. It can also be simply viewed as irrigation frequency and duration. With advancements in automation, virtually any schedule is possible since the burden of considering availability of labor is eliminated. In the case of drip/micro irrigation systems, irrigations may be scheduled without concern for wind conditions or most field operations as well. Irrigations may be scheduled to spoon feed crops with water and nutrients on an as-needed basis as opposed to an “as convenient basis”. Assuming ready availability of source water, irrigation duration and frequency may be seconds, minutes or hours. The advantage is that the operator has the luxury of manipulating soil moisture status, and likely plant vigor, on a micro or macro level.

The schedule for a drip/micro irrigation system is influenced by many factors including the following four. First, the plant’s water requirement (PWR) must be determined. This is typically expressed in inches or millimeters day and is determined by multiplying the reference evapotranspiration (ET_0) by the crop coefficient (K_c) and microclimate factor (K_{mc}). PWR information is typically available from local government or educational institutions, or may be determined privately with the use of a weather station and crop coefficient and microclimate data. Once crop water use is known, the irrigator may begin to develop a schedule.

Second, the irrigation system application uniformity must be known. This is normally expressed as the Emission Uniformity (EU) or the Distribution Uniformity (DU), and is typically expressed as a decimal or a percentage. To assess field performance, water flow from a number of field emission devices is measured, and the average measurement of the “low quarter measurements” (lowest 25% of the readings) is divided by the overall average. This figure is then used to estimate how much additional water needs to be applied to ensure that the driest part of the field receives an adequate amount of water, i.e. how much over-irrigation will be required to compensate for imperfect uniformity.

For example, if a system has a uniformity of 90% and is scheduled such that the driest part of the field receives adequate water, then 0% of the water will be wasted as over irrigation. Another way of looking at it is the affect on irrigation duration. If a system has a uniformity of 50%, the system will need to be operated twice as long as theoretically necessary to compensate for the lack of uniformity, and to ensure that the driest part of the field receives adequate water. Much of this water may be wasted to deep percolation or runoff since much of the field will be over-irrigated, resulting in crop and/or environmental damage. The tradeoff to wasting water is to under irrigate part of the field and suffer possible crop damage. Obviously, it is best if the system uniformity is high (near perfect) so that neither water waste nor crop damage are necessary.

Third, the system application rate must be known, and it must be compatible with the soil and slope as previously discussed. In addition, proper scheduling ensures that the system duration does not deliver water in quantities that exceeds the soil's water holding capacity. Water holding capacity varies greatly according to soil type, with sands holding a little over an inch of water per foot of depth at field capacity, and clays holding nearly 4" of water per foot of depth at field capacity. Clearly, these two extremes would likely need different irrigation duration and frequency to efficiently manage the irrigation water..

Finally, soil moisture content should be regularly measured to double check, and to provide a "reality check", on the existing schedule. Soil moisture content may be estimated by hand using "the feel" method, or it may be determined with instruments such as tensiometers. Although irrigation scheduling is largely an exercise of replacing daily or weekly crop water use with timely irrigation applications, soil moisture status should always be monitored as well to ensure that desired results are achieved. This is because crop water use calculations, irrigation performance and management decisions are not always perfect - soil moisture monitoring may prevent serious errors from causing harm. Or, in some instances, farmers may choose to intentionally deficit irrigate to manipulate crop vigor, using soil moisture status to decide the level of deficit desired. Whatever the reason or method, farmers should monitor soil moisture. Many have aptly said that in spite of the advances of technology, one of the most important things a farmer can still put in the field is footprints.

Summary

Intelligation is not easy. It requires thorough knowledge of many disciplines including irrigation technology, soils and agronomy. However, with basic knowledge of the Three S's – Soils, Slopes and Scheduling – obvious errors may be corrected. With advanced knowledge, superior results may be achieved. In either case, the end result is better resource management for the Three F's – The Farms, the Fish, and the Families – and the possibility of improved profitability for a very large and important irrigation segment, agriculture.