Irrigation Water Management to Sustain Agriculture in the Desert

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Irrigation application requirements of crops and the amount of water used by the crops are important factors in the negotiation of water rights compacts and treaties between states and in the litigation and adjudication of individual water rights (Blaney et al. 1938). Even today litigation is occurring between New Mexico and adjacent states over water rights. Federal, state, and other agencies responsible for the design and operation of multiple-purpose water projects need basic water requirement information. Since irrigated cropland uses about 85% of the water in the state, either irrigation managers will be forced to use water more efficiently so that additional water becomes available for cities or, as the population increases, cities will buy water rights associated with irrigated land. Thus, irrigated agriculture acreage will decline if farmers do not adapt new technology.

The first study of evapotranspiration losses of irrigated crops was conducted in 1903 by the federal government in California. Blaney in 1919 did additional studies at Denver, Colorado, and

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derived a simple, empirical evapotranspiration equation that used air temperature, percent of daytime hours, and a crop scaling factor (Blaney and Criddle 1962). Because evapotranspiration was measured in farmers' fields, the scaling factor used in the Blaney-Criddle method resulted in a seasonal evapotranspiration estimate appropriate for average county yields but did not provide maximum evapotranspiration by the crop under non–moisture stress conditions (Sammis et al. 1982.).

The Blaney-Criddle method of calculating seasonal evapotranspiration has been used in New Mexico to determine water rights based on the amount necessary to grow an average cropping mix (Blaney and Hanson 1965). This method underestimated the amount of water necessary to grow a crop to achieve maximum yield. However, water diversion rights are based on seasonal evapotranspiration divided by irrigation efficiency, which has been estimated to be around 50%. Consequently, farmers still have enough water to achieve maximum yield as long as the irrigation efficiency is 80 to 90%.

Irrigation management means applying the right amount of water at the right time. However, the water requirement of the crop is not a fixed amount. A crop can be grown to maturity under deficit irrigation, but maximum yield is associated with maximum water use. Crop yield decreases as the plants undergo soil moisture stress measured as evapotranspiration (fig. 1).

Traditionally, the timing of flood irrigation is determined by the farmer based on experience, observing the crop and irrigating at the first sign of plant moisture stress, or sampling the soil using either tensiometers or the "feel" method to determine when the soil moisture reservoir has been depleted to the point that irrigation is required. Experience requires that the farmer always attend the fields to irrigate at the required interval. Waiting to irrigate until the crop exhibits moisture stress is too late—yield reductions already have occurred. More direct methods of measuring soil moisture, such as using a neutron probe or a time domain reflectometer, have not been widely

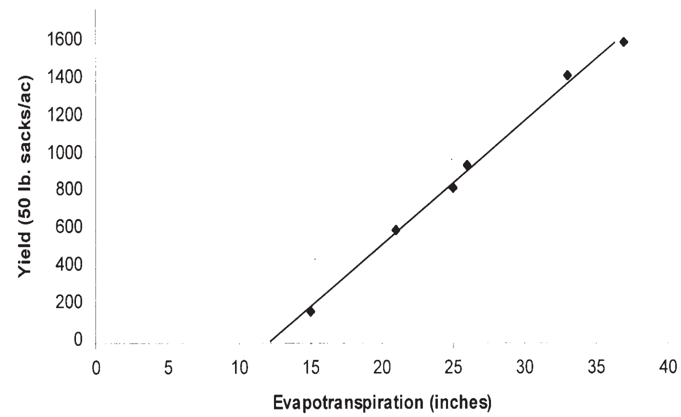

Figure 1. Water production function for onions.

adopted because of their cost and the time required to measure soil moisture daily.

Trade-offs have to be made between conserving water and increasing yields. More frequent flood irrigation prevents plant water stress and increases yield, but decreases irrigation efficiency, which is the amount of water used by the crop divided by the amount of applied water (figs. 2 and 3). Traditionally, farmers who flood irrigate make this trade-off by deficit irrigating, where irrigation is delayed past the optimal time of application, which results in decreased evapotranspiration and yield but higher irrigation efficiency (75 to 82%) (Salameh Al-Jamal et al. 1997). Irrigation efficiencies of 75 to 82% can reduce yield 40 to 50% below maximum (Wierenga 1983; NMASS 1996; Salameh Al-Jamal 1998).

Consistently delaying the optimal irrigation date by 3 or 4 days for onions on a sandy loam soil can increase irrigation efficiency by 13% but decreases yield by 23% (fig. 2). However, when grown on a silty clay loam soil, a 3- to 4-day delay in irrigating decreases yield only 12%, while increasing irrigation efficiency 26% (fig. 2). Deep-rooted chile can be consistently irrigated 3 to 4 days late, resulting in a 2200 kg/ha (2,000 lb/ac)

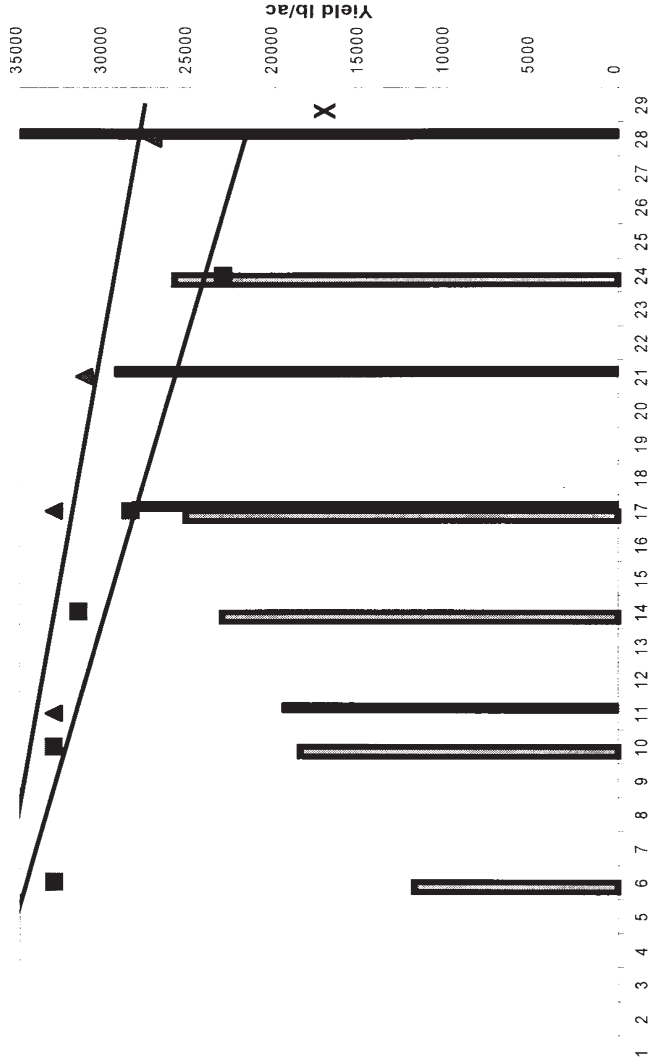

Figure 2. Furrow irrigated onion yield, average county yields (X), and irrigation efficiency as affected by irrigation interval and soil type.

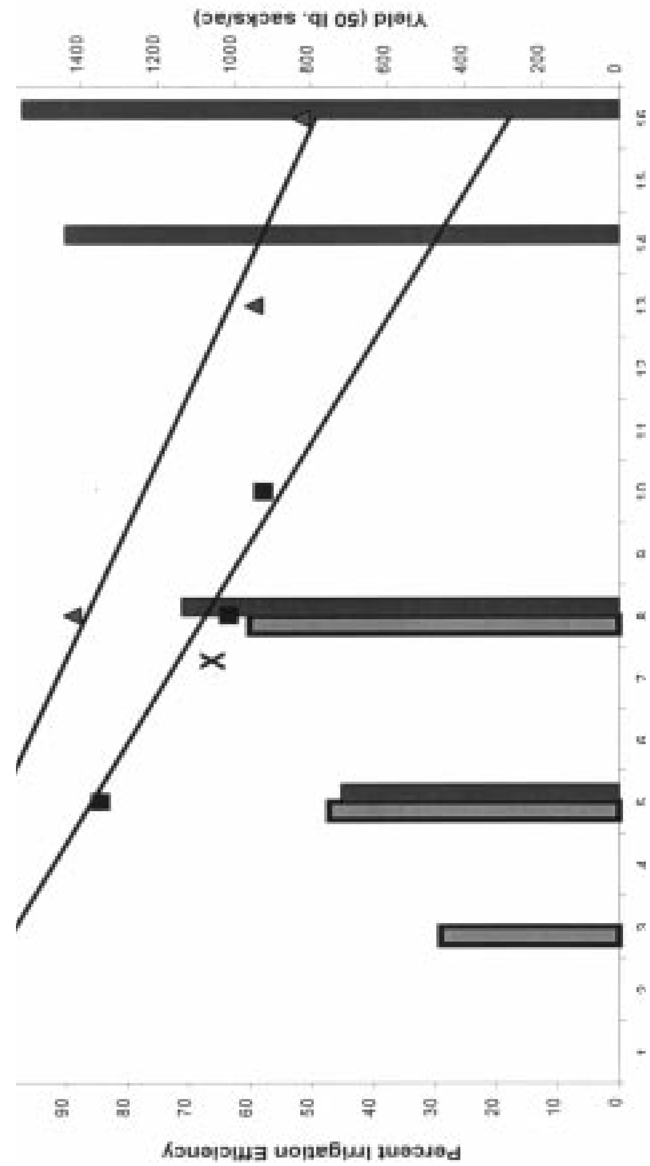

Figure 3. Furrow irrigated chile yield, average county yields (X), and irrigation efficiency as affected by irrigation intervala nd soil type.

reduction in yield but a 13% increase in irrigation efficiency on a sandy loam soil, and a 3% increase in irrigation efficiency on a silty clay loam soil (fig. 3). However, if the farmer irrigates the chile field too early by 4 days, then the yield will be nearly the same but the irrigation efficiency will decrease by 16%. Additionally, nitrogen will be leached from the soil profile. Given that the current cost of water is \$12/1000 m^3 (\$16/ac-ft), deficit irrigation is not economical. However, it is practiced by the farmers achieving average county yields. Thus, 9 additional irrigations for onions would increase yield from 54,000 to 80,600 kg/ha (948 to 1421 sacks/ac) and 5 additional irrigations for chile would increase yield from 25,800 to 35,800 kg/ha (23,000 lb/ac to 32,000 lb/ac).

Increased yield also can be accomplished by applying frequent, light irrigations but this would require changing from flood irrigation to sprinkler or micro-irrigation systems because under flood irrigation, the depth of applied water is the amount necessary to get the water to three-quarters the length of the field. When the water reaches this point, the irrigation gates are closed and the water coasts to the end of the field. Usually, this amount of water is more than the amount the soil can hold in the root zone. Thus, some water is lost to deep drainage.

High irrigation efficiencies and high yields are more easily obtained with a deep-rooted crop, such a chile, than with a shallow-rooted crop such as onion. Deep-rooted crops extract water from a deeper soil profile, and the total depth of water that can be stored in the root zone at the time of irrigation is equal to the readily available water (RAW) that has been extracted from the soil profile. This is equal to the available water-holding capacity of the soil per unit depth (AW) multiplied by the depth of the root zone (RD) and the percent available water that has been depleted at the time of irrigation, also called the management allowed depletion (MAD):

$$RAW = AW \times RD \times MAD.$$

Consequently, deep-rooted crops have a larger soil moisture reservoir at the time of irrigation than do shallow-rooted crops. Also, high irrigation efficiencies are easier to obtain on clay and clay loam soil, which have higher available water-holding capacities than sandy soils.

Changing from surface irrigation to sprinkler or micro-irrigation must be cost-effective. That is, the increased cost of irrigation must be recouped from increased yield and profit. For this to occur, the farmer must change the irrigation scheduling procedure. Irrigation should be scheduled using a water balance approach where the water use of the crop is determined from climate data to estimate the evapotranspiration by the onion or chile crop. Irrigating less than the nonstressed evapotranspiration will cause yield reduction, but overirrigating can lead to disease problems and leaching of nitrates below the root zone.

Before any change in irrigation technology is adapted, all the ramifications of the change should be evaluated. Increased profits must first be evaluated. An analysis of onions and chile in the Mesilla Valley show that changing to micro-irrigation could result in a 17% return on investment (Buchanan 1997). The Buchanan economic model was modified to include chile and onions grown in the Mesilla Valley. Changing to micro-irrigation assumes that the irrigation district can supply water at the frequency needed for a trickle system or that the farmer has a well with good quality water.

Cities have saved about 15% on their water bill by decreasing water applications on parks using a computer irrigation controller that calculates the amount of water to apply based on climate data and a soil water balance. Previously, cities were scheduling sprinkler irrigation amounts and timing based on experience. The operators of the computer system had to go through several training courses to learn how to operate the new system and maintain the climate station. The same type of savings can accrue to farmers with similar training and equipment.

Because soil type can have a significant impact on the irrigation efficiency of a micro-irrigation system, care should be taken when thinking of using a micro-irrigation system on a sandy soil with a shallow-rooted crop. Trickle irrigation systems probably should be placed on the surface of sandy soils and under plastic mulch to control weeds. This would solve the problem of having to run the system for long periods of time in order for the water to sub to the surface and wet the total width of the beds.

Micro-irrigation can increase yields and irrigation efficiency. However, total water used by the crop also will increase with increasing yield. Micro-irrigation also has the capability of producing crops using water with increased salinity. As surface _water is diverted to domestic use, micro-irrigation can be used to irrigate with more saline groundwater or even with sewage effluent so that the effluent is not put back into the river.

Sustainable agriculture will require many changes in the future. Perhaps the most significant will be the change in water management. Sustainable agriculture will require high profits that will be generated by higher financial inputs. The most critical technology in an arid environment is the irrigation system. Farmers will need up-to-date climate information and sophisticated equipment to apply water where and when it is needed in the exact amount required.

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