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Estimating Irrigation Water Requirements to Optimize Crop Growth

Why Estimate Water Needs?

Predicting water needs for irrigation is necessary for developing an adequate water supply and the proper size equipment. The value of irrigation is significantly reduced if the water supply or the irrigation equipment cannot deliver the amount of water your crops need during a drought.

Irrigation supplements probable rainfall so a crop's seasonal water needs are satisfied. Water should be delivered at a rate sufficient to meet the crop's peak water use rate. Seasonal water needs and peak use rates are directly related to yield goal. High-yield goals have a high water demand.

A water supply that restricts either the seasonal amount or rate of application limits the potential yield.

Amount of Water Needed During Growing Season Depends on Many Factors

The crop, yield goal, soil, temperature, solar radiation, and other cultural factors determine the amount of water needed during the growing season. Long-season crops require more water than short-season crops. Some crops such as corn require irrigation during the entire growing season and use more water than other crops such as soybeans, which benefit mostly from additional water at specific critical stages of maturity. High-yield goals require more water than lower-yield goals for the same crop.

(High yields cannot be obtained with additional water only. All other cultural practices must be intensified.) Table 1 lists some typical Maryland crop yield goals and growing season lengths.

The amount of irrigation required for crop production depends on the particular season's useful rainfall, the soil's water-holding capacity and the crop water needs. Useful rainfall is the portion of the rain that is stored in the soil root zone (rainfall minus surface runoff, and leaching below the root zone).

Table 1. Yield goals and season lengths for common crops vary

Crop	Yield goal		Growing season (days)
	Moderate	High	
Field Crops (bushels/acre)			
Grain corn	180	240	120
Soybeans[a]	50	70	120
Vegetable Crops (tons/acre)			
Cantaloupes	4	6	90
Cucumbers	6	10	60
Lima beans	1.5	2.5	80
Peas	2.5	4	100
Small vegetables	--	--	60
Sweet corn	6	8	90
Sweet potatoes	8	10	120
Tomatoes	20	30	100
Watermelons	20	30	110

[a]Although a 120-day crop, soybeans are irrigated primarily from flowering to maturity.

Fine-textured soils (clays, silts, loams) can store more water than coarse-textured soils (sands and gravels) (table 2). Therefore, coarse-textured soils dry faster and require more frequent irrigation than fine-textured soils. If corn is grown on coarse sand with a 1.5-foot root zone, rainfall amounts over 1.88 inches are not beneficial since only 1.25 inches of water are held per foot of soil.

Table 2. Clays, silts and loams can store more water than coarse-textured soils

Soil texture	Inch/foot total moisture capacity	Inch/foot available moisture[a]
Coarse sand	1.25	0.9
Fine sand	1.75	1.2
Loamy Sand	2.25	1.4
Sandy Loam	2.5	1.6
Fine sandy loam	2.75	1.8
Silt loam	3.0	1.9
Silty clay loam	3.25	2.0
Silty clay	3.5	2.1
Clay	4.0	2.25

[a] Some of the moisture held in the soil is not available to plants as it is held tightly to the soil particles.

Sands do not have high water-holding capacity, but most of it is available. Small rainfall events are not beneficial to crops on heavy soils when they are severely dry because the unavailable portion is replaced first. Using long-term average rainfall amounts, table 3 gives estimated irrigation requirements.

Table 3. Corn has highest estimated irrigation water requirement to grow

Crop	Yield	
	Moderate	**High**
Field Corn	10	15
Soybeans	5	8
Sweet Corn	6	8
Peas	3	4
Short season Vegetables	4	5
Tomatoes	5	7
Watermelons	6	8
Hay	4	6

Based on light textured soils. Heavier soils will require less. Severe drought years will require more and rainy years will require less water.
*an acre inch of water = 27,154 gallons

Water Use Rates by Plants (Evapotranspiration or ET) Change with Environmental Conditions and Plant Maturity

Plants have specific critical periods when they need more water (table 4). Hot, dry, and windy conditions will cause rapid water loss from the soil and plant. If the soil becomes excessively dry during critical water-need periods, yield can be significantly reduced. Irrigation must be able to supply water at the expected peak water use in order to be of the greatest benefit to crops during rain-deficient periods.

The peak water use rate for vegetables and most grain crops falls between 0.2 and 0.25 inches per day per acre. The peak water use rate for high—yielding grain corn can reach 0.33 inches per day.

Table 4. Crops have different critical periods of water needs

Crop	Critical period
Alfalfa	Start of flowering and before cutting
Apples	Bud stage and fruit enlargement
Beans, lima	No particular period
Carrots	Root enlargement
Cabbage	Head development
Corn*	Tasseling through ear development
Cucumbers	Flowering through harvest
Lettuce	Head
Melons	Blossom to harvest
Onions	Bulb enlargement
Peaches	Final fruit enlargement and pit hardening
Peas	Flowering and seed enlargement
Peppers	Planting to fruit set
Potatoes, Irish	Blossom to harvest
Potatoes, sweet	At transplant
Soybeans*	Flowering to seed enlargement
Strawberries	Fruit enlargement and bud set, August and September
Tomatoes	Early flowering, fruit set, and enlargement
*** see figure 1**	

Daily Peak Water Use Rates Translate into Pumping Rates Based on Total Hours of Time Available for Operating Irrigation System

As pumping time decreases, the flow rate of the pump must increase to provide the necessary daily volume of water (table 5).

Table 5. To meet peak irrigation water demand[a], use rates must increase as pumping hours decline

Daily pumping hours	Water use rate (inches per day)		
	0.2	0.25	0.33
24	3.8	4.8	6.3
20	4.6	5.7	7.6
15	6.1	7.6	10.1
10	9.1	11.4	15.1

[a] Gallons per minute per acre

For example, if you irrigated your entire 20 acres of sweet corn (peak-use rate 1.25 inches per day) for 24 hours every day, the application rate would be 4.8 gpm (gallons per minute) per acre. If you irrigated only 15 hours per day, every day, the application rate would be 7.6 gpm per acre.

Water losses occur between the water source and the plant through leaks, runoff, and evaporation. These losses are variable depending on the irrigation equipment. High-efficiency pivots (low-pressure and low-efficient nozzles) may lose 10 percent of total irrigation water, while drip systems may lose less than 5 percent. However, hand-move sprinkler and aluminum pipe irrigation systems could lose 25 percent or more.

To ensure that plants receive the necessary amount of water, the water supply would have to provide for the peak use plus the expected loss. Table 6 lists typical systems and water loss factors.

Table 6. Typical water loss factors depend on the type of irrigation system

Drip trickle	1.03
Low pressure spray **-pivots with efficient nozzles**	1.07
High pressure spray **-pivots** **-traveling guns**	1.1
Hand-move spray **-sprinklers** **-big guns**	1.15

If you used a traveling gun to irrigate sweet corn that required 0.33 inches/day, you would actually need to pump almost a half-inch more per week—0.4 inches/day (0.33 x 1.2)—to account for water loss.

An irrigated area may be so large that it takes several days to irrigate the entire field. In this case, calculate the pumping rate using the area irrigated each day. For example, a center pivot system that completes a circle every 3 days irrigates, one-third of the total field area daily. The irrigation frequency for any part of the field is once every 3 days.

The application rate of water should not exceed the ability of the water to enter the soil (infiltration rate). However, the amount of water in the soil should not decline below 50 percent of the maximum amount stored. These conditions, related to soil properties and plant rooting depth, determine the frequency of water application and are an important part of irrigation system design. Regardless of irrigation frequency, the cumulative daily peak water use must be satisfied.

Some Farms Must Manage with a Minimal Water Supply

Due to high crop prices, there is interest in installing irrigation on farms with minimal water supplies.

Suppose you have a 100-acre field with a water supply of 300gpm. If you are growing corn, 3gpm/ac is not sufficient in most years. There are a couple strategies that you could adopt to manage reduced supplies:

1) Plant half the field in one crop and the other half in a crop that has a different daily maximum water use time. For example, plant corn that will require 0.3 inches/day in July/early August and beans that will need 0.3 inches/day late August/September.
2) Plant half the field with a short-maturity variety and the other half with a long-season variety (group III and group IV beans, or 105 day and 115 day corn) the same day. This will enable you to concentrate irrigation on the early maturing variety at a different time than the late one.
3) Plant crops with the same maturity a few weeks apart (plant 110 day corn on April 20th on half of the field and plant the other half on May 20th)
4) Practice "water banking;" that is, irrigate more than necessary when the crop is not at peak water use to build soil moisture reserves to be used later. This works well with heavier soils that will hold more water. For example, irrigate 0.25" per day when corn is young and only using 0.15" per day in order to build soil reserves to be used when it needs 0.35" per day.

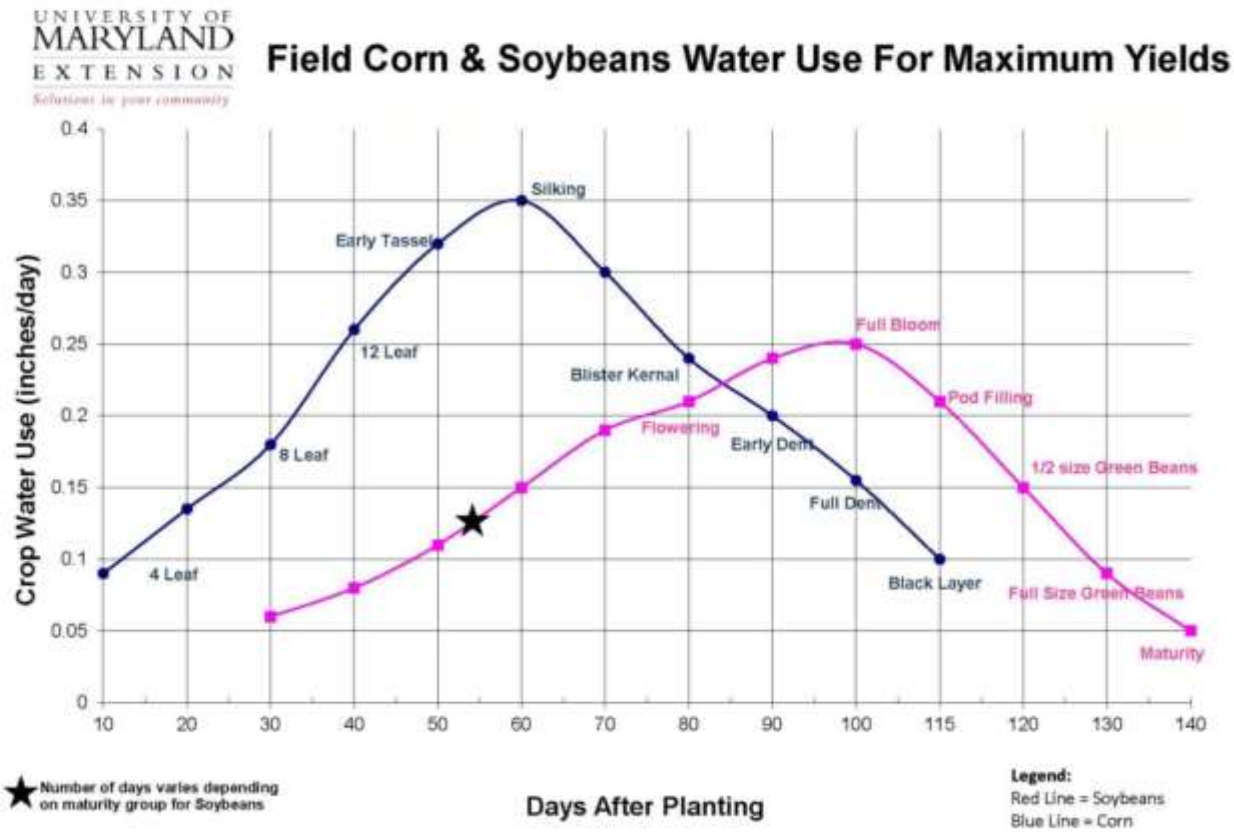
The other important management strategy is to start irrigating before the soil moisture reserves are completely depleted. This is especially important with large pivots, since it may take two days for them to make a circle or irrigate the entire field.

Volume of Water Used for Irrigation is Highly Variable and Depends on Soil, Crop, Yield Goal, and Weather

Irrigation needs will vary from year to year depending on rainfall. If corn is grown on a sandy soil with no rainfall in a hot, dry and windy summer, 25 acre inch (an acre inch of water equals 27,154 gallons) would be needed. Conversely, in a wet year, no irrigation may be necessary to obtain high yield. The in-between years are harder to predict, as are yield expectations with minimal water supplies.

The information in this fact sheet will facilitate the computation of needed seasonal water volumes and peak pumping rates. If you cannot develop water supplies to meet these needs, establish a different crop or a lower-yield goal or reduce the acres irrigated.

Figure 1. Seasonal water needs and peak water use rates are directly related to yield goal



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