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EC709

Irrigation Scheduling: Checkbook Method

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Irrigation scheduling helps determine when and how much water to apply to meet crop demand. The checkbook method considers rain and irrigation as deposits, and crop water use as withdrawals from the soil water.

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Irrigation scheduling helps determine when and how much water to apply to meet crop demand. Soil water status and current crop water use rates are key factors for scheduling irrigations, as are field observations, crop growth stage, time of year, and weather conditions. Taking the time to schedule irrigation results in better use of rainfall and avoids crop water stress or excessive irrigation. Where water supplies are short, irrigation scheduling allows the manager to decide how much water stress the crop must undergo and when.

Checkbook Irrigation Scheduling

The soil acts as a reservoir to store water for crop use until needed. Think of it as a checking account; rain and irrigation are deposits, and both water used by the crop and evaporation from the soil surface are withdrawals. Like a checking account, keeping a running balance of the deposits and withdrawals will give the current amount of water in the crop root zone.

The soil differs from a checking account in three ways:

- First, each soil texture has a maximum deposit or water storage limit called *field capacity*. Soil filled beyond field capacity may allow water to drain below the root zone (deep percolation), making it unavailable for crop use. The volume of water stored between field capacity and the permanent wilting point is called the plant-available water-holding capacity or simply *available water. Permanent wilting point* is the lower end of the available water range and refers to the soil water content at which plants permanently wilt and die.
- Second, the soil account has a minimum balance that is about 50 percent of the available water. A balance below this level could mean a reduction in crop yield resulting from water stress.
- Third, the soil account or soil can only take deposits from rain or irrigation so fast before runoff occurs (such as from a heavy rainfall event). Water that runs off or moves to another part of the field cannot be added as a deposit. See *Figure 1* for descriptive soil water definitions.

Checkbook irrigation scheduling is done for a point in the field. Each field must be scheduled separately because of variation due to crop, soil type, irrigation method, irrigation amount and rainfall. Within a field, you may need to calculate two points because of the time required to apply the irrigation to the field. Set one point where irrigation *begins* in the field. Set the second where the irrigation *ends*. Center pivots require only two to four days to cover the field, but it may require up to two weeks to complete the irrigation with a furrow system.

Before the irrigation has started for the season and after large rain events, the entire field will have similar soil water content. After you begin irrigation, a soil water content stagger will develop across the field equal to the crop water use for the number of days needed to irrigate. Using two locations to monitor soil water content allows the delay of irrigation until the soil can hold the irrigation water and yet still get the entire field watered before the last set suffers water stress. Having two set points becomes more critical the longer it takes to irrigate the field and/or the smaller the water-holding capacity of the soil.

Starting the Checkbook

Determine these five factors when you start the checkbook:

- soil texture,
- crop type and rooting depth,
- available water-holding capacity of the soil,
- minimum allowable balance, and
- an estimate of current soil water balance.

Soil Texture

Soils are classified by their texture. Fine-textured soils (silt and clay) hold more available water than coarse-textured soils (sand). If the soil texture is unknown, check with the local Natural Resources Conservation Service office (NRCS), look up the soil in the county soil survey book, or look online at *http://websoilsurvey.nrcs.usda.gov/app/*. Some fields will have several soil textures, requiring an irrigator to choose which soil to use for scheduling. Since the coarse-textured soils hold less available water than fine-textured soils, these soils will often require more frequent irrigations. Your decision will come down to either over-watering the finer-textured area or under-watering and losing yield on the coarser-textured areas.

Crop Root Zone

The depth of the active root zone for annually planted crops increases during the growing season, and is determined by crop type, growth stage, and restricting layers or other restrictive conditions in the soil profile. *Table 1* shows typical rooting depths at various stages of plant growth for several crops. The rooting depths indicate the active root development for an irrigated crop with no restrictive layers. Roots may penetrate deeper into the soil than indicated, but little water will be used from these depths. Some soils have root restricting layers from compaction, major change in texture (gravel layer), etc. If the field has any of these conditions, adjust the root zone accordingly.

Table 1. Suggested root depth versus stage of growth for irrigation scheduling.

Root Depth (ft)	*Corn*	*Soybeans*	*Grain sorghum*	*Spring grains*	*Winter wheat*	*Alfalfa*	*Sugarbeets*	*Dry beans*	*Established pasture*	*Potatoes*
1.0	Vegetative	Vegetative	Vegetative					Vegetative		Seeding
1.5								Initial flower pod set		Bloom
2.0	12 leaf	Early bloom			Fall growth		June 1	Beginning pod fill	Cool season	
2.5	16 leaf	Full bloom	Flag leaf	Joint	Spring growth		July 1	Full seed fill		Maturity
3.0	Silking	Pod elongation	Boot	Boot	Joint		July 15		Warm season	
3.5	Blister		Bloom	Flowering	Boot		Aug. 1			
4.0	Beginning dent	Full seed fill	Dough	Dough	Dough	Established stand	Sept. 1			

Available Water

There are two general approaches to expressing soil water status: soil water balance and soil water deficit.

Soil water balance refers to the available water remaining in the soil (the glass is half full).

Soil water deficit refers to the portion of available water already used (the glass is half empty).

As an example, when 25 percent of the available water has been used (deficit), **75 percent of the available water is remaining (balance)**, or to say it another way, 75 percent of the **available water**. In this discussion we will use the soil water balance method (the glass is half full) where field capacity would be 100 percent and permanent wilting point would be 0 percent.

Available water refers to the amount of crop-useable water that can be held in the soil. The top soil layer will get wetter (i.e., 125 percent of available water) from rain and irrigation at times throughout the season. However, if the deeper layers were this wet, it would result in deep percolation. Gravity will drain excess water below the crop-rooting zone making it unavailable for plant use.

Table 2 gives the available water for a variety of soil textures. Multiplying the available water per foot of soil by rooting depth will determine the available water in the active root zone.

Table 2. Available water and minimum water balance to maintain maximum ET rates for soil textural classes.

		Minimum water balance[1] —% of available water—			
Soil textural classification		*100% Available water*	*75% Potatoes*	*60% Alfalfa, dry beans, cool season pasture, or small grains*	*50% Corn, warm season pasture, sorghum, soybeans, or sugarbeets*
		in/ft[2]			
Fine sand		1.0	0.8	0.6	0.5
Loamy sand		1.1	0.8	0.7	0.6
Sandy loam		1.4	1.0	0.8	0.7
Silty clay or clay		1.6	1.2	1.0	0.8
Fine sandy loam, Silty clay loam, or Clay loam		1.8	1.4	1.1	0.9
Sandy clay loam		2.0	1.5	1.2	1.0
Loam, Very fine sandy loam, or Silt loam topsoil	Silty clay loam or silty clay subsoil	2.0	1.5	1.2	1.0
Loam, Very fine sandy loam, or Silt loam topsoil	Medium textured subsoil	2.5	1.9	1.5	1.3

[1]Lower minimum water balances may be desirable during some crop growth stages in water-short areas or if pumping costs are high. A minimum water balance of 40 percent is generally recommended for late season water management.
[2]Inches of water per foot of active root zone.

Minimum Balance

The minimum balance, set by a management decision, refers to the lowest soil water content or the driest the soil will be allowed to get. Set the level just high enough to prevent the crops from experiencing water stress. The minimum balance is usually about 50 percent of the available water, but ranges from 40 percent to 60 percent. The crop can continue to use water below this level, but stress may begin (*Table 2*). Minimum balance (in/ft) times rooting depth (ft) equals the minimum balance in the active root zone.

Current Soil Water Balance

A current soil water balance is like the current checking account balance — it's a required input to start the system. Determine a current balance by using soil water sensors or the hand-feel method (using appearance and feel of the soil to indicate water content) to give the starting point for the checkbook.

Also, periodically (every one or two weeks) measure the soil water balance in the field and compare it to the checkbook balance. This is like reconciling a checking account. If discrepancies appear, use the newly measured soil water status to schedule irrigations.

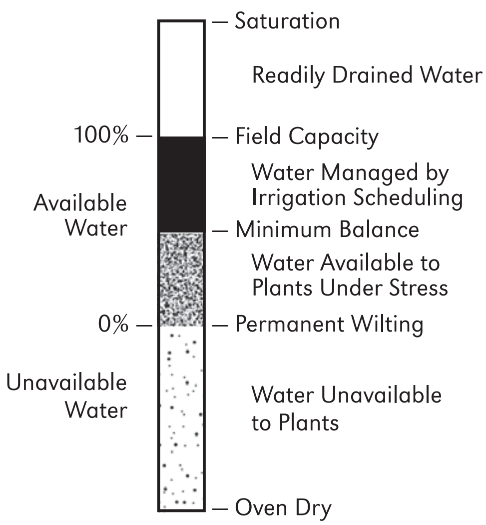

Figure 1. Soil water reservoir (definitions).

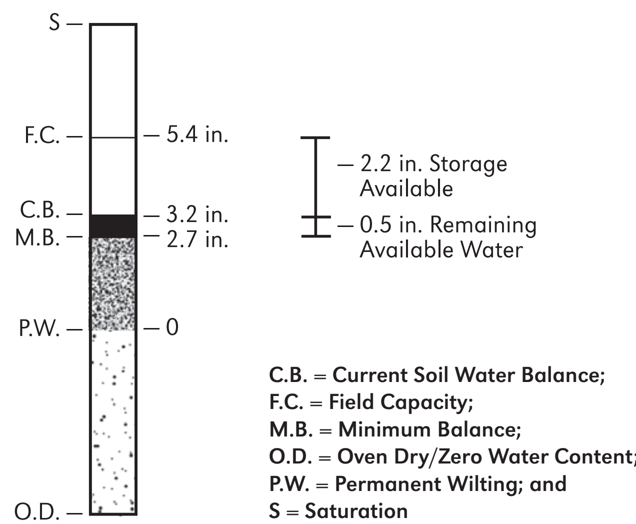

Figure 2. Soil water reservoir (Example I).

Example I:

Determine the current water balance for corn at silking stage, grown in a fine sandy loam soil. *Figure 2* illustrates the following example.

1. Determine soil texture (NRCS soil survey map): Fine, sandy loam.
2. Determine crop rooting depth (*Table I*): 3.0 ft (corn at silking).
3. Determine available water per foot in the active root zone (*Table 2*). Available water times active root zone equals available water for the root zone (1.8 in/ft × 3.0 ft = 5.4 in).
4. Determine the current water balance if 60 percent of the available water is remaining in the active root zone (60 percent of available water) as determined by soil water sensing equipment: Available water times active root zone depth times percent of available water equals current water balance (1.8 in/ft × 3.0 ft × 60% = 3.2 in). Note: a current water balance exceeding 100 percent is possible. If this occurs, it is important to know which soil layer is above field capacity. If it is the top layer, several days will be required for the water to move below the root zone, and with the crop using water each day, it is likely that the water will be used before it is lost or will be stored in a deeper layer. However, if the wet layer is lower in the soil profile or the entire root zone is wet, some of the extra water may drain below the root zone in just a few days and be unavailable for plant use.

Table 3. Form for determining current water balance from field observations filled in with numbers from Example I.

Current Available Water Balance from Field Observations		
Determine soil texture (NRCS soil survey map)	Fine sandy loam	
Available water (in/ft) (*Table 2*)	1.8 in/ft	
Active root zone (ft) (*Table 1*)	x 3 ft	
Available water in root zone (in)		5.4 in
Current percent of available water from field observations	60%/100	x 0.60
Current available water balance (in)		3.2 in

Updating the Checkbook

Weekly, or as needed, update the checkbook balance using the actual soil water content of the soil or the previous water balance, in addition to these three factors: 1) effective rainfall, 2) net irrigation, and 3) crop water use.

Effective Rainfall

Effective rainfall is the amount of rain actually stored in the soil. The portion of rainfall that infiltrates into the soil is influenced by soil texture, residue cover, no-till/tillage practices, field slope, crop canopy, and rainfall intensity.

Effective rainfall is best determined through observation. If little or no runoff occurs, rainfall efficiency will be near 100 percent. If runoff occurs, the efficiency will be reduced. Rainfall amounts of less than .05-.10 inch are not very effective as these small quantities are quickly lost to evaporation.

Net Irrigation

Net irrigation is the amount of water actually stored in the soil profile that adds to the water balance. Gross irrigation is the total amount of water pumped by the irrigation system. Gross irrigation multiplied by irrigation system water application efficiency equals net irrigation (see *Table 4* for suggested system efficiencies). This procedure requires measuring the amount of water pumped onto the field.

Crop Water Use

Crop water use or evapotranspiration (ET) is the sum of the water evaporated from the soil surface plus the amount transpired by the plant. Crop water use changes as the crop grows and/or responds to changes in the weather (temperature, wind, clouds, humidity, etc.).

There are a number of sources of crop water use information including atmometers (ET gage), telephone hotlines, newspapers, radio, Internet, and television. An estimate of future crop water use may also be obtained from these sources or *Table 5*.

Daily crop water use updates can be received via email by contacting the High Plains Regional Climate Center (HPRCC) at either *http://www.hprcc.unl.edu* or (402) 472-6706. The local UNL Extension office or Natural Resources District office can give the availability of crop water use reporting in the area.

Table 4. Average irrigation system efficiency when the crop is fully irrigated and when good water management practices are used. Deficit irrigation practices will result in a greater efficiency.

Irrigation system type	*Efficiency (%)*
Sprinkler	
Center pivot and lateral move	85-90
Skid tow/Side roll	75-80
Big gun traveler	70-75
Subsurface Drip	
SDI	90-95

Irrigation system type	*Efficiency (%)*
Surface	
Gated pipe with reuse	70-75
Gated pipe without reuse	50-55
Gated pipe with surge	75-80
Siphon tube without reuse	45-50
Siphon tube with reuse	65-70

Table 5. Approximate water use rates by stage of growth for various crops.

Water use rate in/day	*Corn*	*Grain sorghum*	*Soybeans*	*Alfalfa**	*Dry beans*	*Sugarbeets*	*Winter wheat*
0.18						June 15	Spring growth
0.20							
0.22			Full bloom			July 1	
0.24	12 leaf				Rapid vegetative growth		Joint
0.26		Flag leaf	Begin pod				
0.28	Early tassel	Boot		June 15			
0.30	Silking	Half bloom	Full pod	July 1	Flowering and pod devevelopment	July 15	Boot
0.28				August 1			
0.26	Blister	Soft dough				August 1	
0.24	Milk		Seed fill	August 15			
0.22				Sept 1			Dough
0.20	Begin dent						
0.18	Full dent	Hard dough			Pod fill and maturation		

*Alfalfa water use rates should be multiplied by 0.50 during the first 10 days following cutting and by 0.75 for the 10th to 20th days following cutting.

Example II:

Schedule the next irrigation for the corn in *Example I*. Since the last update, there's been 1.0 inch rainfall, 2.5 inches gross irrigation applied with a center pivot, and 1.4 inches of crop water use.

1. Determine beginning water balance or use previous current water balance: 3.2 inches initial soil water status (*Example I*).
2. Determine effective rainfall for previous week: 1.0 inch of rainfall with no apparent runoff. (Use only if storage is available in the root zone at time of rainfall.)
3. Determine net irrigation for previous week: The pivot went around two times applying 1.25 inch each pass: gross irrigation times efficiency (*Table 4*) equals net irrigation (2.5 in × 85% = 2.1 in net irrigation).
4. Determine crop water use for previous week: From crop water use information source, past week's water use was 1.4 inches and next week's estimated water use is 0.3 in/day or 2.1 in/7 days.
5. Calculate current water balance: Starting with the previous current water balance (from *Example I*), add the effective rainfall and the net irrigation and subtract the crop water use for previous week (3.2 in + 1.0 in + 2.1 in -1.4 in = 4.9 in).
6. Calculate the current water storage available for rain and irrigation in the root zone. Available water minus current water balance equals storage available (5.4 in - 4.9 in = 0.5 in).
7. Estimate maximum rain and irrigation that can be stored within the next seven days. Estimated crop ET per day (*Table 5*) times seven days plus current storage equals the maximum rain and irrigation that can be stored within the next seven days (0.30 in/day × 7 days + 0.5 in = 2.6 in). Calculate the gross irrigation the center pivot will need to apply if no rain occurs (2.6 in ÷ 0.85% = 3.05 in gross). The active root zone will only hold 0.5 inch of water at present. If corn is silking, it would be best to keep the field fairly wet (60 to 90 percent of available water). However, at least two days of crop water use at 0.30 in/day are required to make room for the 1.25 inch irrigation application.
8. Determine minimum allowable balance in active root zone (*Table 2*). Note: The minimum balance depends on crop type, crop growth stage, and soil texture. Minimum allowable balance times active root zone equals minimum allowable balance for the root zone (0.9 in/ft × 3.0 ft = 2.7 in).
9. Estimate number of days until irrigation is required. Current water balance minus minimum balance equals remaining useable water (4.9 in - 2.7 in = 2.2 in).
10. Remaining useable water, divided by daily water use, equals the days until irrigation is needed to prevent crop water stress (2.2 in ÷ 0.3 in/day = 7 days). Irrigation should be completed within seven days to avoid crop water stress.
11. Using this information, the recommendation would be to wait at least two days, but have the irrigation completed on the entire field before the end of seven days.

Evapotranspiration values are determined by HPRCC, using a region-wide weather station network connected by a computer system. The weather data is downloaded daily and used to calculate crop water use. Water use information is reported as either daily crop water use or crop water use for a given period of time, such as a week. Add the daily crop water use for each day since calculating the last water balance to obtain total water use for the desired time period.

Calculate Water Balance

A new water balance is calculated by adding the effective rainfall and the net irrigation (deposits to the account) since the last water balance update. The total crop water use (withdrawals from the account) for the same period is subtracted from this sum to obtain a current water balance.

Periodically (every one or two weeks) measure the soil water balance in the field and compare it to the checkbook balance. This is like reconciling a checking account. If discrepancies appear, use the newly measured soil water status to schedule irrigations. Some producers measure the soil water each week and skip this calculation.

Estimate Next Irrigation

Current water balance minus the minimum balance equals remaining useable water. To determine the days until irrigation is needed, divide the remaining useable water by the estimated daily crop water use shown in *Table 5*.

The difference between available water and current water balance is the amount of soil water storage currently available to store rain and irrigation. A sample form for collecting data and calculating an irrigation schedule is given in *Table 6*.

The scheduled timing of the irrigation for a field will depend upon the available water in the active root zone and the amount of time it takes to irrigate. Irrigation on the entire field needs to be completed before reaching the minimum water balance. So if it takes four days to irrigate the entire field, irrigation should start at least four days before reaching the minimum balance at the location in the field where irrigation will be applied last. Application amounts should not exceed the storage available in the active root zone.

Surface Irrigation

Surface irrigation may refill the active root zone to field capacity each application. Determining the actual soil water content using soil water sensing equipment after each irrigation is the only way to know current soil water balance. If the root zone is *filled*, the total available water for that soil texture will be the beginning water balance. If this is the case, simply subtract crop water use and add any rainfall to the available water to determine current water balance.

Predicting the Last Irrigation of the Season

Determining when and how much water to apply during the last few irrigations of the season are some of the most important water management decisions. An additional irrigation may mean wasting one to three inches of water and two to five gallons of diesel fuel per acre. On the other hand, if the crop needs water, applying that extra inch of irrigation could mean three to eight additional bushels of corn or sorghum and two to three extra bushels of soybeans per acre. NebGuide 1871, *Predicting the Last Irrigation of the Season,* may help you make this critical decision. It's available at *www.ianrpubs.unl.edu/sendit/g1871.pdf.*

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Table 6. Form for scheduling irrigation filled in with the information in *Example II.*

Current Water Balance (Checkbook)		
Beginning/previous soil water balance		3.2 in
Effective rainfall this period		+ 1.0 in
Gross irrigation this period	2.5 in	
Efficiency factor *(Table 4)*	x 0.85 in	
Net irrigation this period		+ 2.1 in
Crop water use this period		- 1.4 in
Current water balance*		4.9 in
Maximum Rain and Irrigation That Can Be Stored Next 7 Days		
Available water *(Table 2)*	1.8 in/ft	
Active root zone *(Table 1)*	x 3 ft	
Available water in root zone		5.4 in
Current water balance from above		- 4.9 in
Current water storage available in root zone		0.5 in
CAUTION: If this number is less than the irrigation application amount, plus 2 days crop water use, delay irrigation until adequate water storage is available		
Estimated Crop ET per day next 7 days	0.30 in/day x 7 days	+ 2.1 in
Net rain and irrigation that can be stored next 7 days		2.6 in
Irrigation system efficiency factor *(Table 3)*	85%/100	÷ 0.85
Maximum gross irrigation to apply next period		3.05 in
Days until Irrigation Required		
Current water balance*		4.9 in
Active root zone *(Table 1)*	3	
Minimum water balance *(Table 2)*	x 0.9 in/ft	
(Minimum allowable balance)		- 2.7 in
Remaining useable water		2.2 in
Estimated daily water use		÷ 0.3 in/day
Maximum days until irrigation is required		7 days

*If the root zone is still increasing, update the current water balance with field soil water sampling.

Irrigation Scheduling Worksheet

Determining Current Water Balance From Field Observations

Determine soil texture (NRCS soil survey map)		______________		
Available water in/ft (*Table 2*)		______________ in/ft		
Active root zone (*Table 1*)	x	______________ ft		
Available water in root zone				______________ in
Current percent of Available Water from field observations		______________%/100	x	______________
Current water balance				______________ in

Current Water Balance (Checkbook Method)

Beginning/previous soil water balance				______________ in
Effective rainfall this period			+	______________ in
Gross irrigation this period		______________ in		
Irrigation system efficiency factor (*Table 3*)	x	______________ in		
Net irrigation this period			+	______________ in
Crop water use this period	-	______________ in		
Current water balance*				______________ in

Maximum Rain and Irrigation That Can Be Stored Next Period

Available water in/ft (*Table 2*)		______________ in/ft		
Active root zone (*Table 1*)	x	______________ ft		
Available water in root zone				______________ in
Current water balance from above			-	______________ in
Current water storage available in root zone **CAUTION: If this number is less than the irrigation application amount, plus 2 days crop water use, delay irrigation until adequate water storage is available**				______________ in
Estimated Crop ET per day next period		______________ in/day		
(usually this period is 7 days)	x	______________ days	+	______________ in
Net rain and irrigation that can be stored next period				______________ in
Irrigation system efficiency factor (*Table 3*)		______________%/100	÷	______________
Maximum gross irrigation to apply next period				______________ in

Days Until Irrigation Required

Current water balance*				______________ in
Minimum water balance (*Table 2*)		______________/ft		
Active root zone (*Table 1*)	x	______________ ft		
(Minimum allowable balance)			-	______________ in
Remaining useable water				______________ in
Estimated daily water use			÷	__________ in/day
Days until irrigation required				____________ days

*If the root zone is still increasing, update the current water balance with field soil moisture sampling.