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NebGuide

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Irrigation Scheduling Using Crop Water Use Data

This NebGuide describes using the "checkbook" method to schedule irrigations based on crop water use data.

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Irrigation scheduling determines when and how much water to apply to meet crop demand. Soil water status and current crop water use are key factors for scheduling irrigations. Field observations and crop growth stage are important, but scheduled irrigations result in better rainfall use while avoiding crop water stress or excessive irrigation.

Checkbook Scheduling Using Crop Water Use

The soil acts as a "bank" or reservoir to store water for crop use. Rain and irrigation are deposits to the bank, and water used by the crop and soil evaporation are withdrawals. Like a checking account, a weekly or semiweekly balance of these deposits and withdrawals will give the amount of water remaining in the soil profile. The bank has limitations, however, and crop water stress can occur if the balance goes below a minimum allowable balance, which will be referred to as minimum balance. Each soil type also has a maximum deposit or water storage limit, which is called field capacity. If the soil is filled beyond field capacity, deep percolation occurs; that is, excess water is drained below the root zone. Available water capacity is the volume of water stored between field capacity and the permanent wilting point. See *Figure 1* for descriptive definitions.

Steps to Scheduling Irrigation

A. **Starting the Checkbook**
   Determine the following:
   1. Soil type.
   2. Crop type and rooting depth.
   3. Available water capacity.
   4. Minimum balance.
   5. An estimate of beginning soil water balance.

B. **Updating the Checkbook**
   1. Determine effective rainfall.
   2. Determine net irrigation.
   3. Determine crop water use.
   4. Calculate current soil water balance.
   5. Estimate next irrigation date and amount.

C. **Restarting the Checkbook**
   1. Estimate current soil water balance.
   2. Estimate next irrigation date and amount.

Starting the Checkbook

Soil Type

Soils are classified by their texture. Fine textured soils (silt and clay) hold more available water than coarse textured soils (sand and gravel). If the soil type is unknown, check with the Soil Conservation Service (SCS) or use a soil survey map.

Crop Root Zone

The size of the crop's active root zone changes during the growing season, and is determined by crop type, growth stage, and restricting layers or conditions in the soil profile. *Table I* shows typical rooting depths at various stages of plant growth for several crops. If unrestricted, rooting depth increases as the plant matures. The rooting depths indicate the active root development for an irrigationd crop with no restrictive layers. Roots penetrate deeper into soil if unrestricted, but the percentage of deep moisture uptake is small in comparison to the upper layers.

Table I. Root depth versus stage of growth.

Assumed root depth (ft.)	Corn (3)*	Grain Sorghum (3)	Soybeans (3)	Alfalfa (4)	Dry beans (2.5)	Sugar Beets (3)	Spring grains (3.5)	Potatoes (2)	Pasture (3)	Winter wheat (4)
1.0	Vegetative	Vegetative	Vegetative		Vegetative			Seeding		
1.5					Initial flowering pod set			Bloom		
2.0	12 leaf		Early bloom			June 1				Fall growth
2.5	Early tassel 16 leaf	Flag leaf	Full bloom		Beginning pod fill	July 1	Joint	Maturity		
3.0	Silking	Boot	Pod elongation		Full seed fill					Spring growth
3.5	Blister	Bloom				July 15	Boot			
4.0	Beginning dent	Dough	Full seed fill			Aug. 1	Flowering		Established stand	Joint
5.0							Dough			Boot
6.0				Estab-lished stand						Dough

*Maximum crop root depth for irrigation management.

Available Water Capacity

The available water capacity is the maximum amount of water held in the soil that the crop can use. *Table II* gives the available water capacity for a variety of soil textures. Multiply the available water capacity by the rooting depth to determine the available water capacity in the active root zone.

Table II. Available water capacity and minimum water balance for soil textural classes.

Soil textural classification		Available water capacity	Minimum water balance: Potatoes	Minimum water balance: Dry beans, corn sorghum, soybeans small grains, or sugarbeets	Minimum water balance: Pasture, alfalfa
		----------------------Inches/ft*------------------			
Fine Sands		1.0	0.6	0.5	0.4
Loamy Sand		1.1	0.7	0.6	0.4
Sandy Loam		1.4	0.8	0.7	0.6
Silty Clay or Clay		1.6	1.0	0.8	0.6
Fine Sandy Loam, Silty Clay Loam, or Clay Loam		1.8	1.1	0.9	0.7
Sandy Clay Loam		2.0	1.2	1.0	0.8
Loam, Very Fine Sandy Loam, or Silt Loam Topsoil	Silty clay loam or silty clay subsoil	2.0	1.2	1.0	0.8
Loam, Very Fine Sandy Loam, or Silt Loam Topsoil	Medium textured subsoil	2.5	1.5	1.3	1.0

*Inches of water per foot of active root zone.

Minimum Balance

The soil moisture content at which crops begin to come under water stress is called the minimum balance. Water use can continue beyond this level, but stress may begin (*Table II*). Minimum balance times rooting depth equals the minimum balance in the active root zone.

Soil Water Balance

The current soil water balance can be determined by using a soil probe. The appearance and feel of the soil indicates the current water balance. This technique is described in NebGuide *G84-690, Soil Moisture Estimation by Appearance and Feel.* Gypsum blocks or tensiometers can also be used to estimate soil water in fine and coarse textured soils, respectively. These devices are described in extension circulars *EC79-723, Irrigation Scheduling Using Soil Moisture Blocks in Deep Soil*, and *EC84-724, Irrigation Scheduling Using Tensiometers in Sandy Soils.* The total available water capacity of the soil can also be used as the beginning water balance if a rain or irrigation has completely filled the profile.

Example I:

Figure 1. Soil water reservoir (definitions).

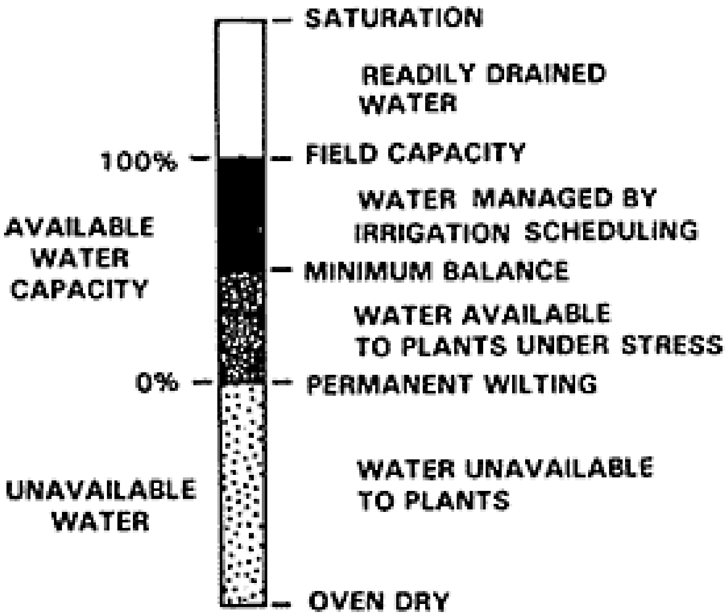
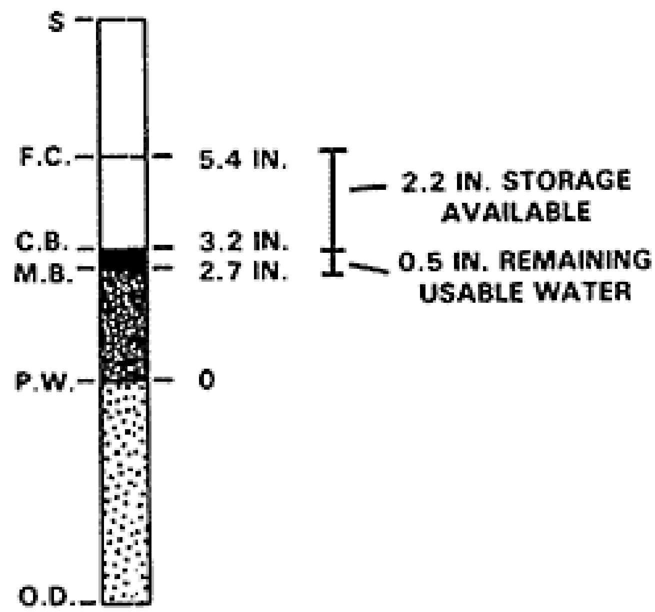


Figure 2. Soil water reservoir *(Example I).*



S = SATURATION
F.C. = FIELD CAPACITY
C.B. = CURRENT SOIL WATER BALANCE
M.B. = MINIMUM BALANCE
P.W. = PERMANENT WILTING
O.D. = OVEN DRY

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

1. Determine soil type (SCS soil survey map): Fine, sandy loam.
2. Determine crop rooting depth (*Table I*): 3.0 ft (corn at silking).
3. Determine available water capacity in the active root zone (*Table II*). Field capacity times active root zone equals available water capacity (1.8 × 3.0 = 5.4 inches).
4. Determine minimum balance in active root zone (*Table II*). Note: The minimum balance depends on both crop type and soil texture. Minimum balance per foot times active root zone equals minimum balance (0.9 × 3.0 = 2.7 inches).
5. Determine the current water balance if 60% of the available water is remaining in the active root zone as determined by the feel method (NebGuide G84-690): Field capacity times active root zone times percent available water equals current water balance (1.8 × 3.0 × 60 = 3.2 inches). The current water balance can never exceed the available water capacity. The available water remaining in the root zone is 3.2 inches. If tensiometers or gypsum blocks are used, the current water balance equals the available water capacity minus the deficit or depletion in the root zone.

Updating the Checkbook

Weekly, or more often, the checkbook should be balanced using four factors: 1) the previous water balance, 2) rainfall, 3) irrigation, and 4) crop water use.

Effective Rainfall

Effective rainfall is the amount of rainfall actually stored in the soil. The portion of rainfall that infiltrates into the soil is influenced by soil type, slope, crop canopy, and storm intensity. Effective rainfall is best determined through observation. If little or no runoff occurs, rainfall efficiency will be near 100%. If runoff occurs, the efficiency will be reduced. Rainfall amounts of less than 0.3 inch are not effective as these small quantities are quickly lost to evaporation.

Irrigation

Net irrigation is that amount of water actually stored in the soil profile which adds to the water balance. Gross irrigation is the total amount of water applied by the irrigation system. Gross irrigation multiplied by irrigation system efficiency equals net irrigation (see *Table III* for system efficiencies). Pump irrigators can use flow meters to measure the gross irrigation; surface irrigators can use weirs or flumes. See NebGuide *G78-393, Water Measurement Calculations*, to calculate the amount of water applied to a field.

Table III. Efficiency of irrigation systems.

Irrigation System Type	Efficiency (percent)
SPRINKLER	
Center pivot and lateral move	80
Skid tow	75
Solid set	75
Side roll	75
Big gun traveller	70
SURFACE	
Gated pipe with reuse	70
Gated pipe without reuse	50
Siphon tube with reuse	65
Siphon tube without reuse	45
Auto-Surface with reuse	80

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 also responds to changes in the environment. There are a number of sources of crop water use information including telephone hotlines, newspapers, radio, AGNET, and television. An estimate of future crop water use may also be obtained from these sources. Contact your Cooperative Extension Service or Natural Resources District offices for availability of crop water use reporting.

Water use information is reported as either daily crop water use or an average daily crop water use value for a given period of time. Multiply the appropriate average daily water use by the number of days since calculating the last water balance to obtain the total water use for the desired time period.

Calculate Water Balance

A new water balance is calculated by adding rainfall and irrigation since the last water balance update to the previous water balance. Total crop water use for the same update period is subtracted from this sum to obtain a new current water balance.

Estimate Next Irrigation

Current water balance minus minimum balance equals remaining useable water. To determine the days until irrigation is needed and before water stress will begin, divide the remaining useable water by the estimated daily crop water use. The difference between available water capacity and current water balance is the amount of soil water storage that is currently available to store rain or irrigation water.

Example II:

Estimate the next irrigation date for *Example I*. given the following information that has occurred since the water balance was updated: 1) 0.5 inch of effective rainfall, 2) 1.1 inch of net irrigation applied by a center pivot. 3) 1.4 inches of crop water use, and 4) estimated future water use is 0.2 inches per day.

1. Calculate water balance.

   Previous current water balance = 3.2 inches (from *Example I*).

Effective rainfall	+ 0.5 inches
Net irrigation	+ 1.1 inches
Crop water use	- 1.4 inches
Current water balance =	3.4 inches

   Note: Minimum balance is 2.7 inches; current water balance minus minimum balance equals remaining useable water (3.4 inches - 2.7 inches = 0.7 inches).

2. Estimate next irrigation date. Remaining useable water, divided by daily water use equals the days until irrigation is needed (0.7 inches / 0.2 inches per day = 3-4 days). Irrigation must occur within 3 to 4 days to avoid crop water stress. Available water capacity minus current water balance equals storage available (5.4 inches - 3.4 inches = 2.0 inches). The active root zone will hold 2.0 inches of water at present. If corn is silking, it would be best to irrigation now as it will be difficult to apply the total amount in a single irrigation with a center pivot.

The schedule for irrigating any field will depend upon the storage capacity of the soil in the active root zone and the amount of time it takes to irrigation. Irrigation should occur before reaching the minimum water balance. Application amounts should not exceed the storage available in the active root zone.

Restarting The Checkbook

If for any reason the schedule is interrupted and the last water balance is not accurate, start over by determining the soil water status as described in *Example I, Step 5*. Update the water balance by measuring soil water every two weeks. If discrepancies appear, use the newly measured soil water status to schedule irrigations.

Applying The Checkbook Scheduling Method

Follow the steps given for "Updating the Checkbook" to schedule irrigations.

Example III:

A sample form for collecting data and calculating an irrigation schedule is given in *Table IV*.

Schedule the next irrigation for corn on fine sandy loam soil given: 0.5 inch rainfall, 1.0 inch gross irrigation applied with a center pivot since last update.

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: rainfall times rainfall efficiency equals effective rainfall [0.5 inch × 60% (estimated) = 0.3 inch]. (Use only if storage is available in the root zone at time of rainfall.)
3. Determine net irrigation for previous week (*Table III*): gross irrigation times efficiency equals net irrigation [1.0 inch × 80% (estimated) = 0.8 inch].
4. Determine crop water use since last irrigation: from crop water use information source, past week's water use was 1.7 inches and next week's estimated water use is 1.8 inches.
5. Calculate current water balance:

Previous current water balance = 3.2 inches	
Rainfall	+ 0.3 inch
Irrigation	+ 0.8 inch
Crop water use	- 1.7 inches
Current water balance =	2.6 inches

Note: Minimum balance is 2.7 inches; the remaining useable water is -0.1 inches (2.6 inches - 2.7 inches = -0.1 inch) and stress may already be occurring. irrigation immediately. Available water capacity minus current water balance equals water required to fill the active root zone (5.4 inches - 2.6 inches= 2.8 inches).

Table IV. Form to schedule irrigations.

	Beginning soil water balance or previous current water balance	(plus)	Effective rainfall this period	(plus)	Net irrigation this period	(minus)	Crop water use this period	(equals)	Current water balance	(minus)	Minimum allowable balance	(equals)	Remaining useable water	(divided by)	Estimated daily water use	(equals)	Days until irrigation needed
Period 1	3.2	+	.3	+	.8	-	1.7	=	2.6	-	2.7	=	-0.1	÷	.2	=	0 day
Period 2	2.6	+	0	+	2.0	-	1.6	=	3.0	-	2.7	=	.3	÷	.2	=	1 day
Period 3	3.0	+	.5	+	2.0	-	1.6	=	3.9	-	2.7	=	1.2	÷	.2	=	6 days
Period 4	3.9																

Surface Irrigation

Surface irrigation often refills the active root zone to field capacity. If the root zone is *filled*, the total available water capacity will be the beginning water balance. Subtract water use from, and add any rainfall to, the available water capacity to determine current water balance. *Example IV* illustrates this technique.

Example IV

Schedule the next irrigation for corn on a fine sandy loam soil with 0.6 inch rainfall since surface irrigation filled the active root zone.

1. Determine minimum balance: 2.7 inches (*Example I*).
2. Determine effective rainfall since last irrigation: rainfall times rainfall efficiency equals effective rainfall [0.6 inch × 70% (estimated) = 0.4 inch]. (Use only if storage is available in the root zone at time of rainfall.)
3. Determine crop water use since last irrigation and expected water use: from crop water use information source, since last irrigation, water use was 1.4 inches and next week's estimated use is 0.2 inches/day.
4. Calculate current water balance:

Available water capacity =	5.4 inches
Rainfall	+ 0.4 inches
Crop water use	- 1.4 inches
Current water balance =	4.4 inches

Current water balance minus minimum balance equals remaining useable water (4.4 inches - 2.7 inches = 1.7 inches). Current water balance cannot exceed the available water capacity. Remaining useable water divided by water use per day equals days before irrigation is needed (1.7 inches / 0.2 inch per day = 8 days). if the next irrigation again *refills* the active root zone, the schedule can be started over using the available water capacity as the beginning water balance.

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