G85-753 Irrigation Scheduling Using Crop Water Use Data

C. Dean Yonts  
*University of Nebraska - Lincoln*, cyonts1@unl.edu

Norman L. Klocke  
*University of Nebraska - Lincoln*

Follow this and additional works at: [http://digitalcommons.unl.edu/extensionhist](http://digitalcommons.unl.edu/extensionhist)

Part of the [Agriculture Commons](http://digitalcommons.unl.edu/extensionhist) and the [Curriculum and Instruction Commons](http://digitalcommons.unl.edu/extensionhist)
Irrigation Scheduling Using Crop Water Use Data

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

C. Dean Yonts, Extension Irrigation Engineer
Norman L. Klocke, Extension Agricultural Engineer

- Checkbook Scheduling Using Crop Water Use
- Steps to Scheduling Irrigation
- Starting the Checkbook
- Updating the Checkbook
- Restarting The Checkbook
- Applying The Checkbook Scheduling Method
- Surface Irrigation

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.
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.
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 irrigation 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.**

<table>
<thead>
<tr>
<th>Assumed root depth (ft.)</th>
<th>Corn (3)*</th>
<th>Grain Sorghum (3)</th>
<th>Soybeans (3)</th>
<th>Alfalfa (4)</th>
<th>Dry beans (2.5)</th>
<th>Sugar Beets (3)</th>
<th>Spring grains (3.5)</th>
<th>Potatoes (2)</th>
<th>Pasture (3)</th>
<th>Winter wheat (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>---</td>
<td>Vegetative</td>
<td>Vegetative</td>
<td>Vegetative</td>
<td>Initial flowering pod set</td>
<td>Bloom</td>
<td>Fall growth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>12 leaf</td>
<td>Early bloom</td>
<td></td>
<td></td>
<td>June 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>Early tassel 16</td>
<td>Flag leaf</td>
<td>Full bloom</td>
<td>Beginning pod fill</td>
<td>July 1</td>
<td>Joint</td>
<td>Maturity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Soil textural classification</th>
<th>Available water capacity</th>
<th>Minimum water balance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Potatoes</td>
<td>Dry beans, corn sorghum, soybeans, small grains, or sugar beets</td>
</tr>
<tr>
<td></td>
<td>Inches/ft*</td>
<td>Inches/ft*</td>
</tr>
<tr>
<td>Fine Sands</td>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>1.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>1.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Silty Clay or Clay</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Fine Sandy Loam, Silty Clay Loam, or Clay Loam</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>2.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Loam, Very Fine Sandy Loam, or Silt Loam Topsoil</td>
<td>2.0</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Silty clay loam or silty clay subsoil</td>
<td></td>
</tr>
<tr>
<td>Loam, Very Fine Sandy Loam, or Silt Loam Topsoil</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Medium textured subsoil</td>
<td></td>
</tr>
</tbody>
</table>

*M*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:**

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**

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.

---

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.

**Updting the Checkbook**

---

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.

---

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.

**Updting the Checkbook**

---

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.

---

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.

**Updting the Checkbook**

---

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.

---

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.
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.**

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

**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.


   - 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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.2</td>
<td>.5</td>
<td>.8</td>
<td>1.7</td>
<td>2.6</td>
<td>-0.1</td>
<td>.2</td>
<td>0 days</td>
</tr>
<tr>
<td>2</td>
<td>2.6</td>
<td>0</td>
<td>2.0</td>
<td>1.6</td>
<td>3.0</td>
<td>.3</td>
<td>.2</td>
<td>1 day</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
<td>.5</td>
<td>2.0</td>
<td>1.6</td>
<td>3.9</td>
<td>1.2</td>
<td>.2</td>
<td>6 days</td>
</tr>
</tbody>
</table>

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 \([0.6 \text{ inch} \times 70\% \text{ (estimated)} = 0.4 \text{ inch}].\) (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:
   \[
   \begin{align*}
   \text{Available water capacity} &= 5.4 \text{ inches} \\
   \text{Rainfall} + 0.4 \text{ inches} \\
   \text{Crop water use} - 1.4 \text{ inches} \\
   \text{Current water balance} &= 4.4 \text{ inches}
   \end{align*}
   \]

Current water balance minus minimum balance equals remaining useable water \((4.4 \text{ inches} - 2.7 \text{ inches} = 1.7 \text{ inches})\). Current water balance cannot exceed the available water capacity. Remaining useable water divided by water use per day equals days before irrigation is needed \((1.7 \text{ inches} / 0.2 \text{ inch per day} = 8 \text{ days})\). 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.