irrigation scheduler mobile

http://weather.wsu.edu/is/

# Documentation and Users Manual

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## Introduction

Irrigation scheduling is finding the answer to two basic questions: "When do I turn the water on?" and, "How long do I leave it on?" Improved irrigation scheduling has tremendous public and private benefits. Irrigation scheduling has been shown in various studies to decrease irrigation water use by 10-30% while resulting in equivalent or better crop quality and yields. Since irrigation is responsible for 80-90% of the consumptive water use in the state of Washington, the total water and energy savings from improved irrigation management is tremendous. Irrigation scheduling has the following benefits:

Benefits to the grower:

- Improved crop yields,
- Improved crop quality,
- Lower pumping energy costs,
- Lower irrigation-related labor costs, and
- Decreased loss of expensive fertilizers to leaching.

Benefits to the environment:

- Less movement of fertilizers and pesticides with the water off of farms fields where they provide agricultural benefits and into streams, water-bodies, and groundwater

where they can cause environmental damage, and
- More water remains in groundwater and in streams for fish and wildlife habitat.

Benefits for energy supply:

- Decreased irrigation energy pumping costs (typical values are 10-20% savings), and
- Water remains in rivers to drive power-generation turbines at multiple dam sites.

There are many irrigation scheduling tools available including paper-and-pencil versions (e.g. Wright, 2002), spread sheet versions (e.g. Clark et al., 2001), compiled program versions (e.g. Rogers et al., 2009), and online versions (e.g. Hillyer and English, 2011). However these tools are not widely used and most of them are not readily adaptable to Washington State. The most common reason cited for not using these tools is that they are complicated and difficult to learn, time consuming to use, and that the grower does not feel that it is worth the time and effort required. Agricultural producers are also rarely in the office and don't get many chances for, and tend to not enjoy doing "desk-work." A simple, user-friendly, irrigation scheduling tool that is accessible from a smart phone is needed to increase the adoption of data-based irrigation scheduling.

This paper describes a tool that meets these requirements. Irrigation Scheduler Mobile is a free irrigation scheduling tool developed by Washington State University that is designed for use on a smart phone or on a desktop web browser for doing simplified check-book style irrigation scheduling. It is simple to set up. It uses tables of default crop and soil parameters, and automatically pulls daily crop water use (evapotranspiration, or ET) estimates from Washington State's AgWeatherNet. It is flexible enough to allow modifications for improved accuracy by educated users. The model can be corrected using soil water measurements or estimates. It readily displays useful charts and tables for visual evaluation of soil water status and model inputs. As it is designed as a web application, it can be run on any mobile platform, or directly from a full sized computer web browser.

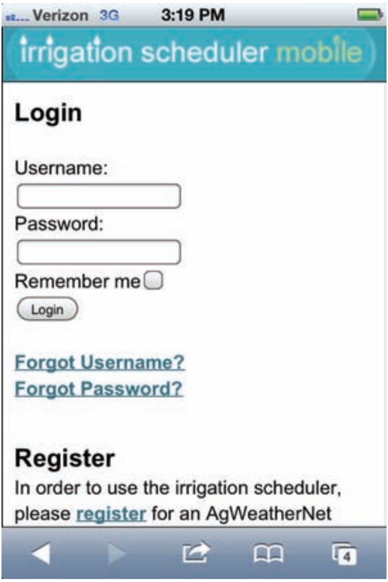


**Figure 1.** Login Page

## Quick Start

To use the mobile irrigation scheduler you must have an AgWeatherNet user name and password. This is free and easily set up on the AgWeatherNet website (http://weather.wsu.edu). To start using Irrigation Scheduler Mobile point your mobile browser to http://weather.wsu.edu/irrigation-scheduler/, or alternatively to http://weather.wsu.edu/is/ and log in (Figure 1). Bookmark this page, or better yet, put a shortcut icon on your mobile device's home screen for quick access in the future (Figure 2).

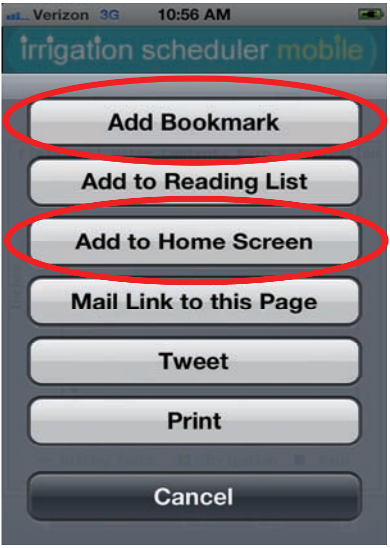


**Figure 2.** Bookmark ad/or add to your home screen.

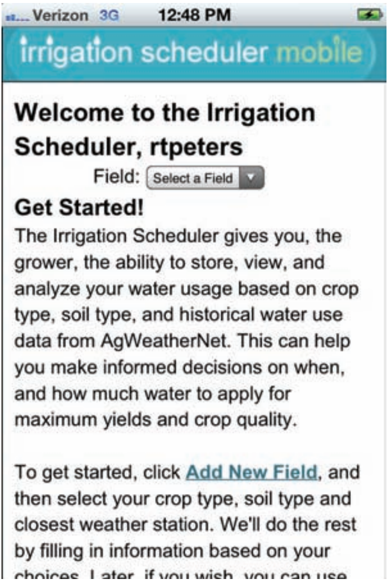


**Figure 3.** Welcome and Getting Started screen.

Logging in will bring up the screen in Figure 3. Click “Add New Field” to bring up the screen in Figure 4 where you can give the field a descriptive name, chose the growing year, select the nearest AgWeatherNet station to pull weather and rainfall data from for the model, and select the crop grown and the soil texture. Click “Add Field” and you’re done with the setup!


**Figure 4.** Setup a new field.

The screen in Figure 5 will come up which now shows the basic menu options below the main screen. The menu options that are highlighted in blue (Manage Fields, and Daily Budget Table) are for user inputs while the model outputs are in green. Additional fields can be added, existing fields deleted, or the field setting can be changed using the “Manage Fields” link. Add irrigation amounts or correct the model using soil moisture measurements in the “Daily Budget Table.” Start viewing the results in the “Soil Water Chart.” The other charts will help you understand the various inputs and view season totals.

Help is available for each page by clicking the “Help” link.

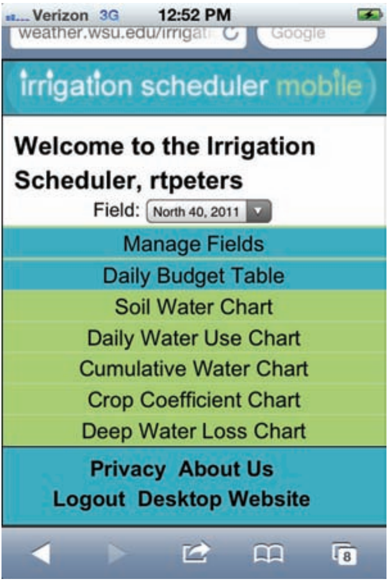


**Figure 5.** Base screen after field setup.

## Irrigation Scheduling Basics and Model Assumptions

Soil serves as a reservoir to store water and nutrients for use by the plant. Knowing when to irrigate and how much water to apply requires knowledge of three things:

1. How much water can the soil hold?
2. How much water is the plant using?
3. At what point (soil water content) will the plant begin to experience water stress?

## How Much Water Can the Soil Hold?

Water is held in the empty spaces between soil particles. When these empty spaces are completely filled, the soil is said to be saturated (Figure 6). Excess water will drain out over time until a point where the soil can hold a certain amount of water indefinitely against the downward pull of gravity. This soil water content is called ***field capacity (FC)*** and in this application is measured in inches of water per foot of soil depth. The excess water that drains will move down to lower soil layers. Applying more water than a soil can retain in the plant's managed root zone results in water loss to ***deep percolation (DP)*** or "deep water loss". Water loss to deep percolation wastes water, pumping energy, and vital plant nutrients that are held in the soil water solution.

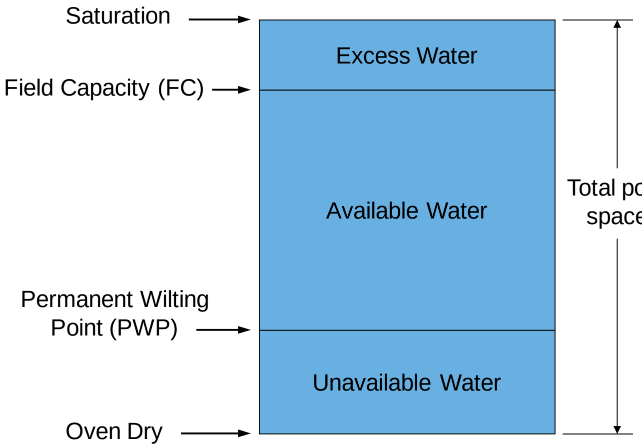


**Figure 6.** The various components of the soil water content.

As a plant's roots remove water from the soil, the soil dries out to the point where the suction or pull of the soil on the water is greater than the plant's ability to absorb water. At this point the plant will wilt and die. This soil water content is referred to as the ***permanent wilting point (PWP)*** and is measured in inches of water per foot of soil depth. The difference between field capacity and permanent wilting point is known as the ***available water-holding capacity (AWC)*** again given in inches of water per foot of soil depth.

$$AWC = FC - PWP$$

Different soils have different available water-holding capacities. For example, sand cannot hold as much water as a silt soil. The default values of FC, PWP, and AWC that are used in this model for different soil textures are given in Appendix A.

A plant's rooting depth is also an important consideration. A plant with deeper roots has access to much more soil and consequently has a larger reservoir of soil water to draw upon compared to plants with shallower roots. The FC, PWP, and AWC are multiplied by the rooting depth to get the *amounts* of water held at those points in inches. Rooting zone depths change over time as the plant and its roots grow. Root growth in this tool is assumed to increase linearly from a beginning depth at the planting or emergence date and is assumed to reach their maximum depth at the same time the crop canopy reaches full cover or covers (shades) 70-80% of the field area (Figure 7). After this time the root depth is assumed to remain constant until the end of the growing season.

Default values for the parameters that define the changing root zone depth for the various crops are given in Appendix B.

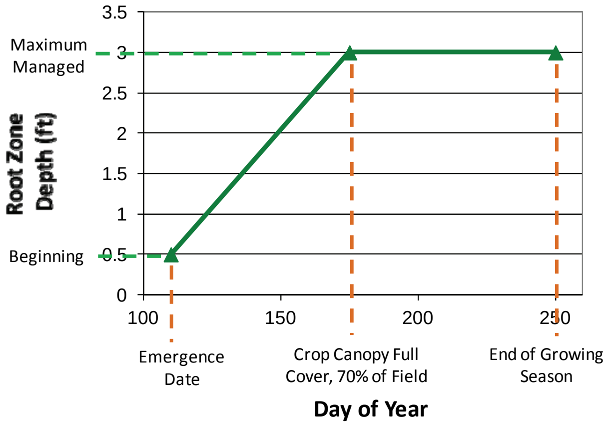


**Figure 7.** Parameters that define the changing root zone depth.

## How Much Water is the Plant Using?

The amount of water required to grow a crop consists of the water lost to evaporation from a wet soil surface and leaves, and transpiration of water by the plant. Together these are called ***evapotranspiration (ET)*** and are also referred to as crop water use. ET is measured in inches of water used per day. The crop evapotranspiration ($ET_c$) is calculated as:

$$ET_c = K_c \times ET_r$$

where $ET_r$ is the estimated evapotranspiration of a reference surface of full grown alfalfa that is calculated from measured weather parameters. The weather parameters used to calculate $ET_r$ include solar radiation, air temperatures, humidity, and wind speed data. Alfalfa reference $ET_r$ as calculated by the ASCE standardized Penman-Monteith Equation (ASCE – EWRI, 2005) is used in this model. $K_c$ is a crop coefficient specific to a crop and that crop's growth stage over the season. Crop coefficients in this model are mean crop coefficients and defined as in the FAO-56 publication (Allen et al., 1998; Figure 8). Default dates and crop coefficient values for different crop s are given in Appendix B.

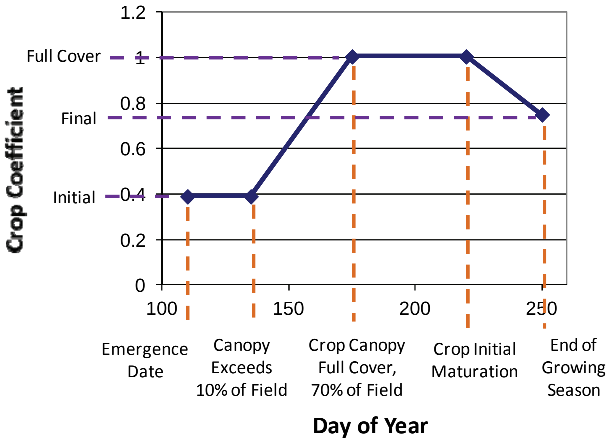


**Figure 8.** Parameters that define the crop coefficient curve. Crop coefficients are multiplied by the alfalfa reference ET rate to determine the crop water use for that day.

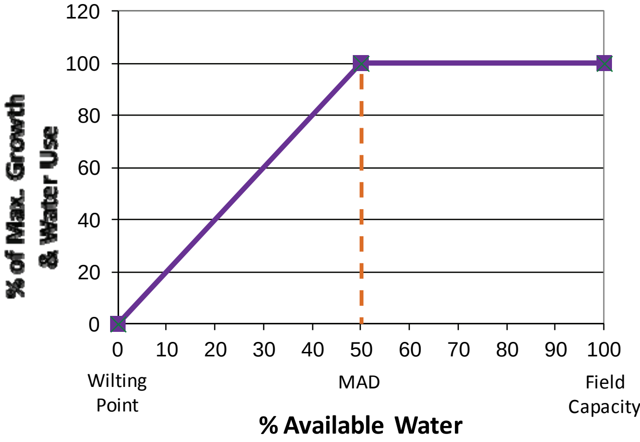


**Figure 9.** Water use is proportionately decreased as the % of available water goes below the MAD.

## At What Point Will the Plant Experience Water Stress?

As water is removed from the soil through ET there is a point below which the plant experiences increasing water stress. This point is known as the ***management allowable depletion (MAD)***. To manage the soil water for maximum crop growth, depletion below this point is undesirable. As the soil water content decreases below MAD the stomata in the plant leaves will begin to close, the leaves will often curl or droop, and the plant will use less water and the growth will decrease. The model estimates this decrease in water use according to Figure 9. Daily crop water use is proportionately decreased as the % of available water decreases below MAD towards the PWP (Allen et. al., 1998). Irrigation scheduling for maximum crop growth requires maintaining the soil water content between field capacity and the MAD.

Different plants are more resistant to water stress than others and therefore the MAD for each crop may be different. Default MAD values for the various crops are given in Appendix B.

# Using the Model / Various Screens

## Manage Fields Screen

Clicking the “Manage Fields” (Figure 10) will bring up options to edit the field information to improve the model accuracy, or to add, or delete fields.

Additional information about each option on the Manage Fields screen follows:

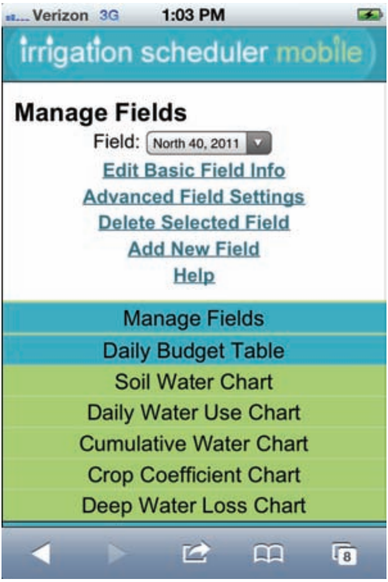


**Figure 10.** Manage Fields Screen

**Edit Basic Field Info**: Based on your crop and soil selections defaults will be loaded in to populate the parameters in the "Advanced Field Settings".

**Advanced Field Settings**: These settings allow you to fine tune the model based on your particular field information. See the help menu in that page for more information.

**Delete Selected Field**: Permanently removes the selected field and all of its settings and associated data.

**Add New Field**: Use this to add a new field.

## Edit Basic Field Information Screen

Shown in Figure 11, this allows the user to change the basic field information entered when the field was set up. **Clicking the update field button on this screen will overwrite any changes you made in**

**the "Advanced Field Settings" for this field.** If you don't wish to save any changes, hit the browser's back button instead of clicking the "Update Field" button.

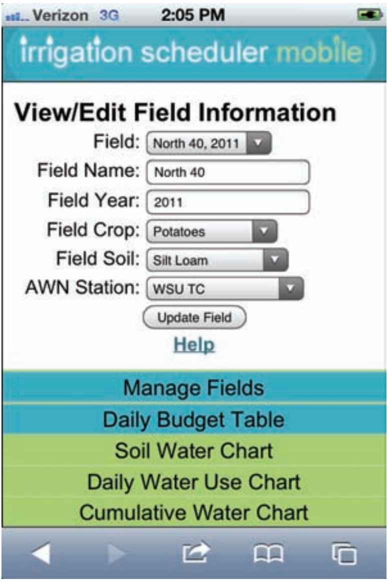


**Figure 11.** View/Edit Basic Field Information Screen

Additional information about each option follows:

**Field Name**: Use this to name/rename the field.

**Field Year**: This is the growing year. If a previous year is selected, then that previous year's weather data will be used in the water budget. Use the current year for ongoing irrigation scheduling.

**Field Crop**: Based on the selected crop, default growing season dates, crop coefficients, management allowable deficit (MAD) rates, and rooting depths are chosen. These crop parameters can be later edited in the "Advanced Field Settings" Page.

**Field Soil**: Based on the soil texture chosen, default field capacity, wilting point, and water holding capacity values are chosen. These soil parameters can be later edited in the “Advanced Field Settings” Page.

**AWN Station**: Choose the AgWeatherNet weather station that is nearest, or whose weather conditions are closest to your field. More information on each station is located on the AgWeatherNet website (weather.wsu.edu). Calculated daily reference evapotranspiration (ET) rates from weather data from this station, and rainfall data from this station will be used in the soil water balance.

## Advanced Field Settings

Also from the “Manage Fields” screen (Figure 10), “Advanced Field Settings” can be chosen (Figures 12& 13). Defaults for these values were chosen based on the information entered based on the crop and soil type chose on the “Basic Field Info” page based on values in Appendix A & B. Entering alternate values here overwrites these defaults. If you don’t wish to save any changes, hit the browser’s back button instead of clicking the “Update Field” button.

Additional information about each option follows:

**Soil Water Content at Field Capacity**: This is the maximum amount of water that the soil can hold long term against gravity. After a soil is at field capacity adding more water will result in the water moving down through the soil profile and possibly past the bottom of the root zone (tracked on the

"Deep Water Loss Chart"). Field Capacity is measured in inches of water per foot of soil depth.

**Soil Available Water Holding Capacity (AWC)**: This is field capacity minus wilting point, or the amount of water the soil can hold between full and empty. AWC times the soil depth gives the available water supply. Wilting point is calculated using this number and field capacity. Soil Available Water Holding Capacity is measured in inches of water per foot of soil depth.

**Management Allowable Deficit (%)**: Abbreviated MAD, this is the % of the total available water below which the plant experiences increasing water stress. Daily ET values are proportionately decreased from the full value to zero as the soil water content decrease from MAD to the soil's wilting point as shown in Figure 9. You may want to decrease this number for more clayey soils, and increase it for sandier soils.

**Planting/Emergence Date**: Date the plant that the crop emerges and/or the plant starts using water. This is the start date for the soil water budget model.

**Crop Canopy Cover Exceeds 10% of Field**: The date that crop water use starts increasing.

**Crop Canopy Exceeds 70% of Field (Full Cover) Date**: The date that the crop canopy exceeds 70% - 80% of the field area or shades 70% - 80% of the ground area. At this point the crop coefficient reaches a maximum and stays at this maximum until the Initial Maturation Date (below).

**Crop Initial Maturation Date**: After this date the crop begins to dry up, senesce or otherwise shut down and water use begins to decrease.

**End of Growing Season Date:** Water use stops on this date. Often this coincides with harvest, or the first killing frost. This is the last date of the model.

**Root Depth on Start Date**: The effects of a growing root depth is included in the soil water budget model. This is the root depth in inches on the starting or plant emergence date.

**Maximum Managed Root Zone Depth**: This is the maximum root depth reached in the season. It is assumed that the plant root reaches this depth on the Crop Canopy Full Cover Date.

**Initial Crop Coefficient**: The crop coefficient (Kc) from emergence to the 10% Cover date. This Kc is based on alfalfa reference ET.

**Full Cover Crop Coefficient**: The crop coefficient (Kc) at full cover. This is the peak, or maximum crop coefficient. This Kc is based on alfalfa reference ET.

**Final Crop Coefficient**: Crop coefficient (Kc) at the end of the season. This Kc is based on alfalfa reference ET.


**Figure 12.** Advanced Field Information Setup Screen

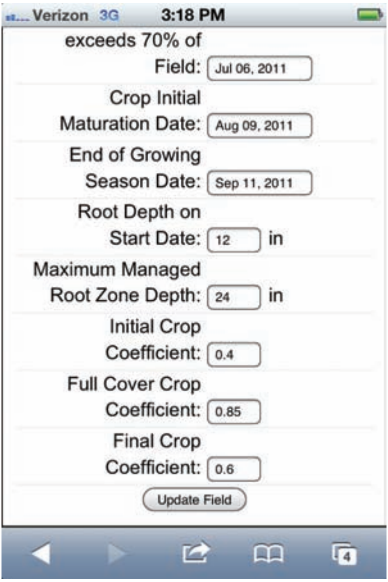


**Figure 13.** Advanced Field Information Setup Screen Continued.

## 7-Day Daily Budget Table Screen

This screen (Figure 14) shows the most useful numerical values from the daily soil water budget and allows the user to edit the inputs for each day using the “Edit Data” link.

When the calculated soil water content is well above the MAD point and the plant growth should be at maximum, then the row is highlighted green (Figure 14). When the soil water content gets close to the MAD line (only 15% of the readily available water remaining) then the row turns yellow. And when the soil water content goes below the MAD line the row is highlighted red as a warning that the crop might be experiencing water stress.

Additional details of the daily soil water budget are available by clicking on the date (Figure 15). This will expand the table to show these details. The table can be returned to normal again by clicking the date again.

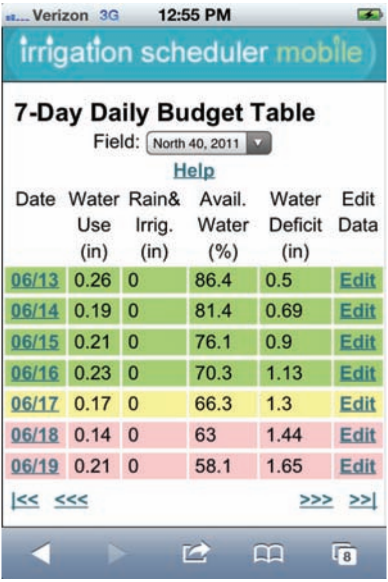


**Figure 14.** Daily Budget Table screen

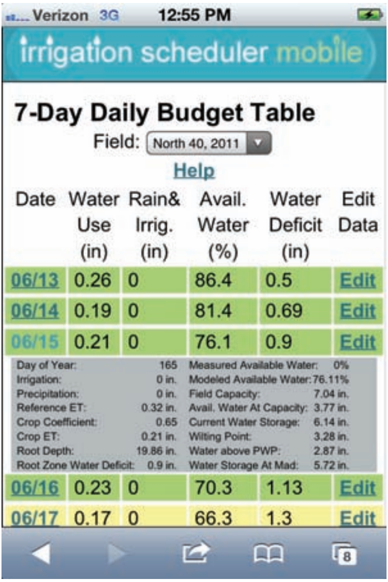


**Figure 15.** Expanded information for a date.

Additional information about each column in the daily budget table follows:

**Water Use (in/day)**: This is the daily crop water use (evapotranspiration or ETc) estimated from measured weather parameters from the selected AgWeatherNet station, and the entered crop coefficients. This model uses alfalfa reference evapotranspiration calculated using the standardized ASCE Penman-Monteith method.

**Rain& Irrig. (in)**: This is the rainfall for that day and/or and irrigation amount that is stored in the soil. Irrigation events must be entered here (Edit link) for the model to be accurate. Data from a local rain gauge can also be used to correct the measurement from the chosen weather station using the Edit link. Some applied irrigation water is lost to evaporation. Therefore gross irrigation amounts must be discounted for irrigation efficiency. Typical irrigation efficiency values are: drip-95%, center pivot-85%, wheel/hand lines/lawn sprinklers-70%, big guns-60%. For example a gross depth of 1 inch of water is applied by a center pivot, enter 0.85 here (1 inch x 85%/100). If you use measured application depths, don't correct for efficiency. For surface irrigation, a reasonable assumption is that you completely refill the soil to field capacity, or replace the soil water deficit.

**Soil Water (%)**: This is the calculated daily soil water content expressed as a percent of the available soil water. 100% is equivalent to field capacity, and 0% is equivalent to wilting point. Entering a measured or estimated soil moisture value here (using the Edit link) will correct the model to the entered value from that day forward.

**Water Deficit (in)**: The soil water deficit in the root zone. This is the amount of "space" in the soil, or the depth of irrigation water that can be applied before the soil is full again (reaches field capacity).

**Edit Data**: Use this link at each line to add irrigation amounts or correct the model for measured soil water contents (Figure 16).

## Edit Daily Data

Clicking the Edit Data link in the Daily Budget Table (explained above) brings up the screen in Figure 16. From this page you can correct rainfall amounts using data from a local rain gauge, add or edit irrigation amounts (Figure 17), or overwrite the percent of available water to correct the model for a measured soil water content.

Additional information about each option follows:

**Measured Rainfall (in)**: Here you can overwrite the rainfall measurement from the selected weather station with a measurement from a local rain gauge on this date.

**Irrigation (in)**: Enter the net amount of irrigation applied to the field on this date in inches. Some applied irrigation water is lost to evaporation. Therefore gross irrigation amounts must be discounted for irrigation efficiency. Typical irrigation efficiency values are: drip-95%, center pivot-85%, wheel/hand lines/lawn sprinklers-70%, big guns-60%. For example a gross depth of 1 inch of water is applied by a center pivot, enter 0.85 here (1 inch x 85%/100). If you use measured application depths, don't correct for efficiency. For surface irrigation, a reasonable assumption is that you completely refill the soil to field capacity to 100% Available Water, or completely replace the soil water deficit.

**Soil Water Availability**: The default value in this is the calculated percent of available soil water. Overwrite this number to correct the model using data from a soil moisture measurement, or if the model gets off over time and needs to be corrected based on estimated values.

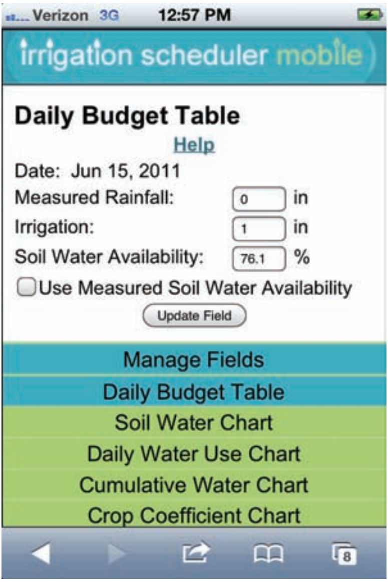


**Figure 16.** Edit Budget Table screen.

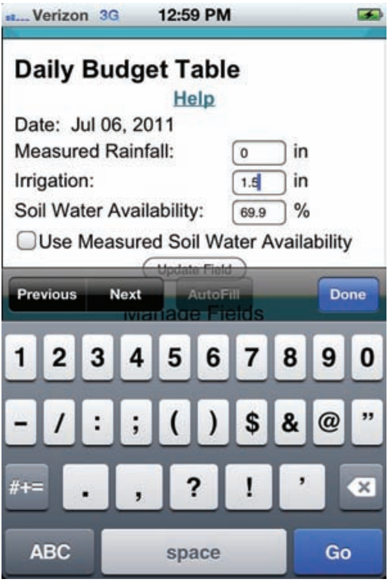


**Figure 17.** Editing irrigation amounts.

## Soil Water Chart

The soil water chart (Figure 18) shows the estimated soil water content (blue line) over time in relation to the field capacity (light green line), management allowable depletion (MAD; red line), and the wilting point (black line). All of these may change over time as the soil volume available to the plant increases with the growing plant roots. Enter irrigation events (green points), or correct the estimated % available water content based on soil moisture measurements or estimates in the "Daily Budget Table" to make the soil water content better represent your field conditions. Rainfall amounts are pulled from the weather station, but can also be modified based on actual rain gauge measurements in the "Daily Budget Table." If you find that this model is consistently off, try editing the dates and crop coefficients in the "Advanced Field Settings".

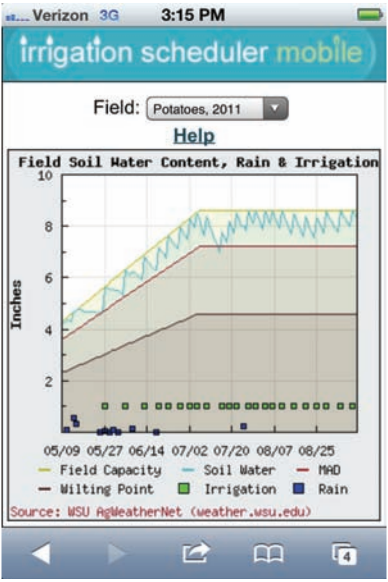


**Figure 18.** Soil Water Chart

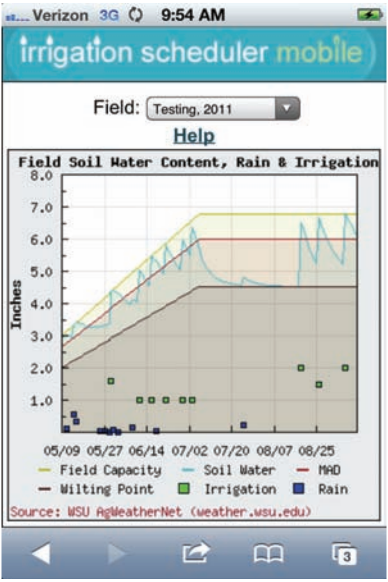


**Figure 19.** Shows how water stress (below the MAD line) causes daily water use to decrease.

Figure 19 shows how the model will modify daily crop water use numbers using the assumptions shown in Figure 9. After irrigations were stopped the rate of drop in the soil water content decreases over time as the plant shuts down.

## Cumulative Water Chart

Figure 20 shows the cumulative crop evapotranspiration (ETc, or crop water use), irrigation, and rainfall over the specified growing season. The season totals are given in the chart legend.

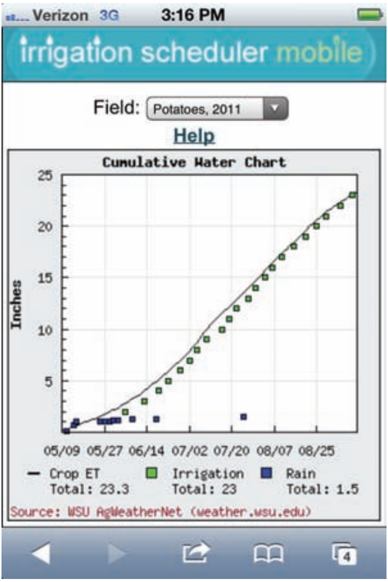


**Figure 20.** Cumulative Water Chart

## Crop Coefficient Chart

Crop coefficients (Kc) are multiplied by the daily reference alfalfa evapotranspiration (ETr) rate that is calculated from the measured weather parameters from your chosen weather station. The Crop Coefficient Chart (Figure 21) shows the crop coefficient curve used for this field over the growing season. Also shown is the root zone depth over time. The values that define these curves can be viewed and edited on the “Advanced Field Settings” page.

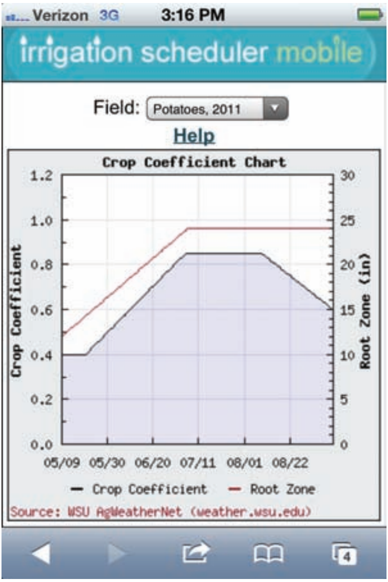


**Figure 21.** Crop Coefficient and Root Depth Chart.

## Daily Water Use Chart

The Daily Water Use Chart (Figure 22) shows the daily crop water use (evapotranspiration, or ETc) over the specified growing season. This is calculated as ETc = ETr x Kc where ETr is alfalfa reference evapotranspiration and Kc is the crop coefficient for that day. These values are affected by the weather (hot, dry, sunny, and windy days cause the plants to use more water), the crop coefficients, and the water stress status of the plant (below MAD, the crop water use is proportionately decreased as described in the user's manual).

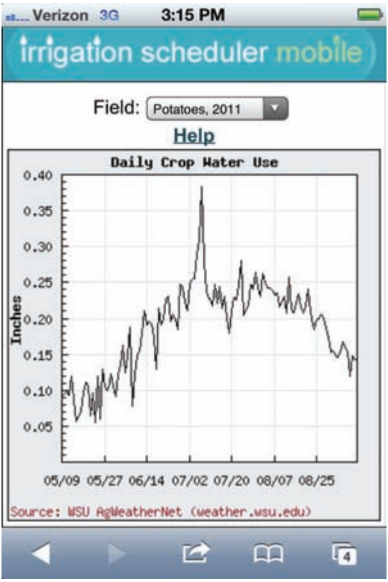


**Figure 22.** Daily Crop Water Use Chart

## Deep Water Loss Chart

When more water is applied than can be held in the root zone (soil water content exceeds field capacity), then this water moves down past the bottom of the root zone and is lost to deep percolation. The deep water loss chart (Figure 23) shows the cumulative water losses to deep percolation.

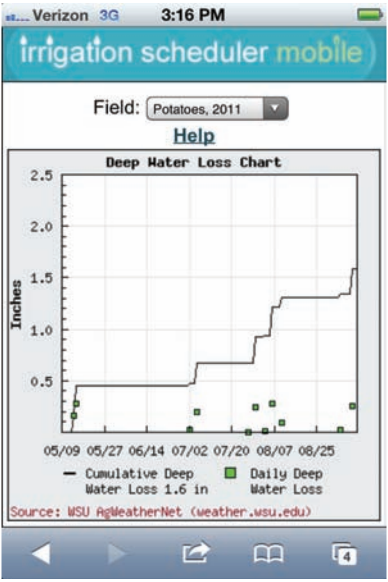


**Figure 23.** Cumulative Deep Water Loss

# Suggestions for Particular Irrigation/Cropping Systems

**Rill or Furrow Irrigation**: With surface irrigation methods it is difficult to know exactly how much water infiltrated into the soil. A good assumption is that at each irrigation event you completely refill the soil water deficit to field capacity in the entire root zone. Simulate this by either entering a large number at each irrigation event (3-4 inches), entering a number equivalent to the soil water deficit, or resetting the Percent Available Water number to 100% at each irrigation event. The model is still useful and will indicate when the soil is getting dry again and when to irrigate. To be the most efficient with your water resources, wait to irrigate when the soil water content is near the MAD. Irrigation scheduling helps many surface irrigators save an irrigation or two.

**Moving Irrigation Sets**: With many irrigation systems it takes many days to irrigate an entire field. This brings up the question, "Which date should I put the irrigation on?" Simply choose one part of the field and throughout the whole season enter the irrigation on the date that that part of the field receives irrigation water. Be aware that the soil water content in the other parts of the field will either be slightly ahead or behind the model. It might be easier if you choose a location that is easier to remember when it was irrigated, such as the first set. If correlating/correcting with soil moisture measurements, be sure to choose the part of the field where the moistures are being taken.

**Multiple Harvested Forage Crops**: The model currently does not include the effects of decreased water use of forage crops or mint following a mid-season cutting. This feature will be included in a future release. Therefore, the model will overestimate crop water use during the period that the crop is cut and re-growing. For now, the soil water content must be adjusted *up* following a cutting.

**Use with Soil Water Content Sensors**: Updating the model with periodic soil moisture measurements will greatly improve the accuracy of the soil moisture estimate. These can be used to fine-tune the model as well. For example, if you find that the soil moisture measurement is consistently higher than the estimated, then the model is over-estimating crop water use and the crop coefficients should be adjusted down for that time period. Be aware that soil moisture measurements are highly variable and may be high one time, then low the next, then high again. Use seasonal trends and your good judgment to adjust the model.

**Use with Soil Water Tension Sensors**: Tensiometers and Watermark sensors don't measure soil water content and therefore it is very difficult to compare the measurements directly with the model. However, these sensors should indicate that the soil is dry (greater soil water tension) as the soil water content approaches and goes below the MAD line.

# References

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**Appendix 1**: Defaults by Soil Texture. More accurate estimates for your particular soil are available from the NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm)

| | **Soil Water Content (in/ft)** | | |
|---|---|---|---|
| Soil Texture | Field Capacity | Wilting Point | AWC |
| Coarse Sand | 1.2 | 0.6 | 0.7 |
| Fine Sand | 1.5 | 0.7 | 0.8 |
| Loamy Sand | 2.2 | 1.2 | 1.0 |
| Sandy Loam | 2.7 | 1.3 | 1.4 |
| Fine Sandy Loam | 3.4 | 1.6 | 1.8 |
| Sandy Clay Loam | 4.0 | 2.0 | 2.0 |
| Loam | 4.0 | 1.8 | 2.2 |
| Silt Loam | 4.3 | 2.0 | 2.3 |
| Silty Clay Loam | 4.6 | 2.8 | 1.8 |
| Clay Loam | 4.8 | 3.0 | 1.8 |
| Silty Clay | 4.8 | 3.2 | 1.6 |
| Clay | 4.8 | 3.4 | 1.4 |
| Peat Mucks | 5.0 | 2.6 | 2.4 |

# Appendix 2: Crop Defaults Used in the Model.

| | Crop Development Dates for Crop Coefficient Curve (DOY) | | | | | Crop Coefficients | | | Root Depths (ft) | | MAD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Crop Name | Planting/ Emergence | > 10% of Field | Full Cover/ > 70% | Initial Maturation | End of Season | Initial | Full Cover | Final | Starting | Max. | MAD |
| Alfalfa | 91 | 100 | 122 | 139 | 278 | 0.32 | 1.00 | 1.00 | 60.0 | 4.0 | 4.5 |
| Apples | 110 | 112 | 145 | 244 | 278 | 0.39 | 1.10 | 0.50 | 50.0 | 3.5 | 3.5 |
| Apricots | 110 | 112 | 141 | 220 | 278 | 0.39 | 1.10 | 0.50 | 50.0 | 3.5 | 3.5 |
| Asparagus | 120 | 130 | 214 | 240 | 278 | 0.36 | 1.03 | 0.87 | 55.0 | 3.5 | 3.5 |
| Bean (dry) | 146 | 156 | 191 | 211 | 242 | 0.25 | 0.95 | 0.20 | 45.0 | 0.4 | 2.5 |
| Beans (green) | 146 | 150 | 180 | 200 | 211 | 0.25 | 0.95 | 0.80 | 45.0 | 0.4 | 2.5 |
| Blueberries | 85 | 95 | 150 | 240 | 278 | 0.80 | 1.05 | 1.00 | 50.0 | 3.0 | 3 |
| Bluegrass Seed | 72 | 80 | 126 | 155 | 192 | 0.40 | 0.95 | 0.25 | 50.0 | 1.0 | 2.5 |
| Cabbage | 91 | 92 | 160 | 185 | 243 | 0.35 | 1.00 | 0.25 | 40.0 | 0.5 | 2 |
| Canola | 76 | 83 | 122 | 164 | 183 | 0.20 | 1.05 | 0.30 | 55.0 | 0.5 | 4 |
| Carrots | 91 | 119 | 160 | 220 | 243 | 0.70 | 0.85 | 0.75 | 35.0 | 0.2 | 2 |
| Cherries | 110 | 112 | 149 | 220 | 278 | 0.39 | 1.12 | 0.50 | 50.0 | 3.5 | 3.5 |
| Clover | 91 | 152 | 182 | 244 | 278 | 0.91 | 0.91 | 0.91 | 50.0 | 2.0 | 2 |
| Corn (grain) | 129 | 151 | 201 | 230 | 259 | 0.20 | 1.05 | 0.76 | 55.0 | 0.4 | 3 |
| Corn (sweet) | 130 | 152 | 201 | 222 | 240 | 0.20 | 1.00 | 0.85 | 55.0 | 0.4 | 3 |
| Cucumbers | 136 | 140 | 174 | 240 | 278 | 0.35 | 0.70 | 0.70 | 40.0 | 0.5 | 2 |
| Grain (Spring) | 92 | 99 | 160 | 195 | 214 | 0.20 | 1.00 | 0.70 | 55.0 | 0.3 | 4 |
| Grain (Winter) | 66 | 85 | 128 | 184 | 196 | 0.30 | 1.00 | 0.90 | 55.0 | 1.0 | 3.5 |
| Grapes (juice) | 110 | 112 | 169 | 244 | 278 | 0.30 | 0.85 | 0.75 | 40.0 | 3.0 | 3 |
| Grapes (wine) | 110 | 112 | 169 | 253 | 278 | 0.30 | 0.65 | 0.65 | 65.0 | 3.0 | 4 |
| Grass (Hay) | 72 | 80 | 120 | 209 | 278 | 0.50 | 0.95 | 0.72 | 55.0 | 1.0 | 3 |
| Grass (Pasture) | 80 | 92 | 137 | 244 | 278 | 0.87 | 0.87 | 0.87 | 55.0 | 2.0 | 3 |
| Grass (Turf) | 80 | 92 | 108 | 244 | 278 | 0.80 | 0.80 | 0.80 | 50.0 | 1.0 | 1.5 |
| Hops | 110 | 158 | 206 | 250 | 274 | 0.20 | 1.15 | 0.20 | 50.0 | 3.0 | 4 |
| Lentils | 105 | 115 | 155 | 188 | 215 | 0.25 | 1.02 | 0.30 | 50.0 | 0.5 | 2.5 |
| Melons | 136 | 140 | 174 | 240 | 278 | 0.30 | 0.70 | 0.60 | 40.0 | 0.5 | 2 |
| Mustard | 76 | 83 | 122 | 164 | 183 | 0.30 | 1.00 | 0.30 | 55.0 | 0.5 | 3 |
| Onions (dry) | 90 | 105 | 130 | 212 | 239 | 0.70 | 1.00 | 0.50 | 35.0 | 0.2 | 1.5 |
| Onions (green) | 74 | 99 | 129 | 139 | 144 | 0.70 | 1.00 | 0.86 | 35.0 | 0.5 | 1.5 |
| Peaches | 110 | 112 | 149 | 220 | 278 | 0.39 | 1.15 | 0.50 | 50.0 | 3.5 | 3.5 |
| Pears_Plums | 110 | 112 | 149 | 244 | 278 | 0.39 | 1.15 | 0.50 | 50.0 | 3.5 | 3.5 |
| Peas | 90 | 97 | 156 | 174 | 198 | 0.30 | 1.00 | 0.50 | 35.0 | 0.5 | 2.5 |
| Peppermint | 119 | 124 | 160 | 270 | 278 | 0.30 | 0.95 | 0.85 | 40.0 | 1.5 | 2 |
| Peppers | 136 | 153 | 195 | 232 | 243 | 0.50 | 0.85 | 0.71 | 35.0 | 0.5 | 2 |
| Potatoes | 128 | 140 | 186 | 220 | 253 | 0.40 | 0.85 | 0.60 | 35.0 | 1.0 | 2 |
| Radishes | 74 | 79 | 120 | 123 | 125 | 0.48 | 0.70 | 0.65 | 40.0 | 0.5 | 1 |
| Raspberries | 90 | 95 | 144 | 259 | 278 | 0.33 | 1.00 | 0.70 | 50.0 | 3.0 | 3 |
| Safflower | 91 | 100 | 145 | 195 | 220 | 0.20 | 1.08 | 0.20 | 55.0 | 0.5 | 5 |
| Sorghum | 130 | 150 | 185 | 230 | 260 | 0.30 | 1.00 | 0.85 | 60.0 | 0.5 | 2 |
| Soybeans | 121 | 140 | 175 | 235 | 260 | 0.36 | 0.95 | 0.14 | 65.0 | 0.5 | 3 |
| Spearmint | 119 | 124 | 160 | 212 | 243 | 0.30 | 0.95 | 0.85 | 40.0 | 1.5 | 2 |
| Spinach | 88 | 120 | 168 | 206 | 215 | 0.70 | 0.95 | 0.75 | 40.0 | 0.5 | 1.5 |
| Squash | 136 | 161 | 212 | 250 | 278 | 0.40 | 0.80 | 0.60 | 50.0 | 0.5 | 2.5 |
| Strawberries | 80 | 93 | 164 | 207 | 278 | 0.33 | 0.70 | 0.55 | 30.0 | 1.0 | 1 |
| Sugarbeets | 117 | 135 | 195 | 239 | 276 | 0.25 | 1.00 | 0.70 | 50.0 | 0.5 | 3 |
| Sunflower | 105 | 130 | 165 | 210 | 234 | 0.40 | 1.00 | 0.20 | 65.0 | 0.5 | 4 |
| Tomato | 136 | 153 | 195 | 229 | 243 | 0.50 | 0.85 | 0.70 | 40.0 | 0.5 | 3 |