

AZSCHED - AriZona Irrigation SCHEDuling System

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ABSTRACT

Water for irrigation is quickly becoming a scare commodity in the western US. This is especially true in Arizona, where the state is in the sixth year of below normal precipitation. An irrigation scheduling program called AZSCHED (AriZona Irrigation SCHEDuling) has been developed by researchers at the University of Arizona, Tucson, AZ. The program utilizes real-time weather data from the AZMET (AriZona METeorological system) system in conjunction with user entered soil, water and crop inputs to recommend irrigation dates and amounts. The program is Windows-based and is can be downloaded from the Internet. Growers in Arizona and surrounding states have used to the program to schedule cotton, wheat, alfalfa and vegetable crops.

INTRODUCTION

As the quantity and quality of irrigation water is reduced in the West, agricultural producers are constantly being pressured to reduce their water use. Although newer, more water efficient irrigation systems can be installed, often these systems are not economical for growers. Thus, growers are looking for ways to better manage their water with the systems already in place. Several options are available including irrigation scheduling.

To help growers increase their water use efficiency, the University of Arizona's Department of Agricultural and Biosystems Engineering developed a computerized irrigation scheduling program called AZSCHED (AriZona irrigation SCHEDuling) (Fox et al., 1992; Martin, et al., 2003). AZSCHED calculates the crop evapotranspiration (ET_c) as the product of a crop coefficient (K_c) and a reference evapotranspiration (ET_o). ET_o is estimated from real time weather data using the modified Penman equation (Doorenbos and Pruitt, 1977). Crop coefficients are taken from 22 crop curves developed from existing water use data and normalized by heat units to account for climatic variability (Slack et al., 1996; Martin et al., 1996). In this paper, we discuss the use and operation of the AZSCHED system. Originally developed in 1992 by Fox et al., the program is now a Windows-based program available for downloading on the Internet (Martin, et al., 2003).

AZSCHED can only be run under Windows-based operating systems. These systems include Windows NT, Windows 98, or Windows XP. If real time weather is to be used, then an internet connection may be useful. It is recommended that the computer used to run the software have at least 20MB of free hard disk space for the program files and associated Visual Basic .DLL files.

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PROGRAM STRUCTURE

AZSCHEDED can be downloaded directly from the Internet from <http://ag.arizona.edu/crops/irrigation/irrigation.html>. In addition to the program itself, a Users Guide is downloaded. This handbook is available by clicking “Help” on the first screen of AZSCHEDED. There are four options on the initial screen: Field Options; Weather Data; Configuration and Exit. Figure 1 shows the initial screen. The following is a brief description of the first three options.

Field Options

This is the portion of the programming where the majority of the user/program interface takes place. Choosing this option, the user is given five additional options plus a “Go Back” button to return to the main menu. A diagram of the screen is shown in Fig. 2.

Field Display

This option will display all of the fields currently being scheduled. The user can choose on how the fields are displays (i.e., according to planting date, crop type, next irrigation or field name). The total number of fields displayed on the screen at one time is determined by the user entered value from the “Configuration” option in the main menu. The fields are displayed in color according to their irrigation needs. Green fields are within the specified soil moisture, yellow fields are closing approaching irrigation or harvesting and red fields are in need of irrigation immediately.

Field Selection

In this option, the user can either select a field to be updated, create a new field, or select a field to be harvested/deleted. Harvested/deleted fields are removed for the field list but the data is saved. Thus, if the user wanted to review data from a field harvested several years ago, it would still be possible to go back and printout a summary/history of that field.

Creating a new field

The creation of a new field requires several inputs from the users and it would be best to gather the information prior to initiating a field. The first screen asks for crop type and soil data format. Crop type is selected from a list. For the soil format, there are two choices: Fixed soil layers – Soil are defined by “fixed” layers of a certain thickness. For example, the soil can be defined every 6 inches... or every 12 inches. Or, the soil format can be defined as Variable soil layers – where each individual layer is defined. Thus, if the soil has about 3 inches of top soil, then 6 inches of clay, then 7 inches of sandy clay, etc., this option will allow the user to define the thickness of each individual layer.

Next, the user needs to input a field ID, planting date, a weather station nearest the field being scheduled, an irrigation efficiency and the maximum allowable deficiency (MAD). The MAD should be in percent and is the threshold of the percent of soil water deficit in the plant rootzone

at which the user wants an irrigation to occur. There is also a selection for soil, asking whether the user wants to enter new soil data, use soil data from an existing field or use soil data from a harvested/deleted field. Then the user is given the option to alter the crop's maximum rooting depth.

If the crop to be scheduled is alfalfa, then there are two more entries. One is the Critical MAD and the other is the Field Drying Time. The Critical MAD is a depletion percentage that you never want the field to fall below. Quite often, the cutting date and the scheduled irrigation date conflict. Thus, the program may be calling for irrigation the day before a scheduled cut. In order to avoid this, the program will use the Critical Mad and the Field Drying Time. The default for the Field Drying Time is 7 days. This means that the field can be safely entered with machinery 7 days after an irrigation event. The program will calculate this and may ask for an irrigation earlier than the entered MAD to assure that the hay will be cut and removed before the soil water falls below the Critical MAD. Normally, the Critical MAD is set 5-10% higher than the MAD.

Once this information is entered, the program will automatically check to see if there is weather data available for the field created. If not, a window will now pop up saying that weather data is required. The user can then either download data automatically from the Internet or use default data. The internet data will be automatically downloaded from the AZMET (the University of Arizona's weather station system; Brown, 1998) website and will download data from the weather station the user entered. The second option is to allow the program to use default weather data. The program automatically computes weather data for your station based on the average over many years. This data is not the best to use for scheduling since it uses averages.

Soils Data

When initially setting up the field, the user had the option to either enter soil water data one of three methods: 1) Enter new data; 2) Use data from an existing field; or 3) Use data from a harvested/deleted field. If the user chose to enter new data, a soil screen will appear requesting information of the soil's available water holding capacity and the initial soil water content at planting. If options 2 or 3 were chosen, the user is given a list of existing or harvested/deleted fields to choose from. Once the soils data is entered, the program then predicts the next irrigation.

Field Options

The *Field Options* pull-down menu allows the user to enter data throughout the season on water added to the field. It also allows the user to change certain parameters such as the MAD, irrigation efficiency or field depletion. The user can also get a quick view of the Field Summary and Field Details.

Field Reports

This pull down menu has three options: 1) Print/Save/View irrigation schedule for all fields; 2) Print/Save/View the field report for the field selected; 3) Print the field report for a

harvested/deleted field. The irrigation schedule gives a list of all fields presently being scheduled, their present soil water status and the predicted next irrigation date, along with irrigation amount. For alfalfa, the next predicted cutting data is also give.

The field report (Fig 3) contains daily data on the selected field including the following (Text in **bold** is how the data is reported in the field report):

Date	ETR (Cumm) – cumulative ETR
Day (DAP) - days after planting	Kc – crop coefficient
Avail (in) - available water in inches	Kd – soil dryness coefficient
Depl (%) – percent available water depletion	ETC (in) – crop ET. It is the ETR times the Kc times the soil dryness factor, in inches
GDD (F) – growing degree days in Fahrenheit, for that day	ETC (Cumm) – cumulative ETC
GDD (Cumm) – cumulative growing degree days in Fahrenheit	Irr (in) – irrigation amounts
ETR (in) – Reference Evapotranspiration (ET) for that day, in inches	Rain (in) – rainfall amounts
	Cut No. – the number of the cut that was taken off a field (for hay only)

The final option is to print a field report of a harvested/delete field. This report is the same as previously described in the last paragraph. However, since these are harvested/deleted fields, only printed copies can be obtained.

Weather Data information section

The “Weather Data” is chosen from the main menu and gives the user several options of adding or viewing weather data. If not previously done, the program will first prompt the user to choose a weather station. Then the user can choose from two pull down menu: 1) Add Weather Data; 2) View Weather Data (Fig. 4).

Add Weather Data

In this section the user can: 1) download data from AZMET; 2) enter/edit weather data; or 3) load default weather data. Downloading AZMET data allows the user to download weather data without having to have a field to schedule. This way, the user can view weather data from any available AZMET station. Option 2, enter or edit weather data, allows the user to enter weather data for any AZMET station. Caution must be used here because the entered data will be saved by the program and used to schedule irrigations. This option should only be used when it is known that the weather data already saved by AZSCHED is incorrect. Loading default weather data can be helpful if there is no Internet connection and the user wants to view historical averages.

View Weather Data

This selection allows the user to view the weather data from the selected station for years that have been downloaded, either directly in the menu or automatically through scheduling. The user also has the option of printing the weather data shown on the screen or printing the entire weather file.

Configuration section

This section allows the user to change the date the program has set as today's date, set units to English or metric, and set field display – which allow the user to change the number of fields that are displayed on your computer screen when the Field Options > Field Displays menu choice is selected. Figure 5 shows an example of the Field Display.

ESTIMATING CROP WATER USE

AZSCHED uses the “water-balance method” to estimate daily crop water use. In this approach, the soil is viewed as a water storage reservoir from which plants extract water. This water is then replaced by either irrigation or precipitation. In using this method, reliable information on the soil available water holding capacity (AWC) is essential. The AWC is generally defined as the amount of water retained in the soil between “field capacity” (FC) and the “permanent wilting point” (PWP).

Crop water use is estimated using a calculated reference crop evapotranspiration (ET_o) data and a crop coefficient. The method used in AZSCHED for estimating ET_o is the FAO Modified Penman equation (Doorenbos and Pruitt, 1977). This equation estimates the ET of a healthy, cool season grass, 8-15 cm in height maintained in a well watered environment. The Modified Penman equation requires daily information on max/min temperatures, max/min relative humidity, net radiation, wind speed and the day/night wind ratio. The equation, often referred to as the combination equation, has the form:

$$ET_o = c * [W * R_n + (1 - w) * f(u) * (e_a - e_d)] \quad (1)$$

Where c is an adjustment factor to compensate for the effect of day and night weather conditions; W is a temperature related weighing factor, $f(u)$ is a wind function, R_n is the net radiation equivalent in mm/day and $(e_a - e_d)$ is the vapor pressure deficit.

To estimate actual crop water use, AZSCHED uses the ET_o data with crop coefficient values (K_c), derived from several sources (Erie, et al., 1982; Sammis et al., 1985; Martin, et al., 1996). The crop coefficient is defined as:

$$K_c = \frac{ET_c}{ET_o} \quad (2)$$

Where ET_c is the actual crop evapotranspiration and ET_o is calculated as previously described.

A unique feature of AZSCHED program is the use of growing degree days (gdd) as the unit of time measurement. Growing degree days (gdd) are often referred to as heat units or thermal time. In its simplest form, gdd are defined as:

$$gdd = T_{mean} - T_{base} \quad (3)$$

Where T_{mean} is the daily mean air temperature and T_{base} is the minimum daily mean air temperature required for crop growth. The value of T_{base} is unique to the crop. Equation 3 is only valid when $T_{base} < T_{mean} < T_{max}$. In areas such as Arizona, where summer temperatures often rise well above 100 °F, an upper threshold temperature similar to T_{base} , and referred to as T_{max} is required. If $T_{mean} > T_{max}$, then formula for computing gdd is:

$$gdd = T_{max} - T_{base} \quad (4)$$

Where T_{mean} is the daily mean air temperature and T_{max} is the maximum daily mean air temperature that once reached, no additional significant crop growth occurs. Snyder (1985) developed a method for calculating gdd for a variety of temperature scenarios. This method was used in the AZSCHED program to determine daily gdd accumulation.

CONCLUSION

The use of irrigation scheduling and scheduling tools such as soil moisture measuring devices, flow rate measuring devices and knowing crop water requirements have all helped growers in Arizona save water. Reports in the state have shown that growers have reduced or eliminated irrigations due to the implementation of information provided by this program. For example, in 1998, the Pima County, AZ, Active Management Area used AZSCHED in their water management program. They reported that two growers eliminated an irrigation saving almost 400 acre-feet of water and over \$13,000. They also reported many growers reduced the amount of irrigation water applied for each irrigation.

More than 200 copies of the new AZSCHED program have been downloaded from the Irrigation website since it became available in June 2003. Additionally, 30 copies have been sent out on CD disks to extension, state and federal personnel (both in and out of state). Personnel from ADWR used AZSCHED to determine crop water needs for state programs that regulate water allocations. They also list irrigation scheduling as one of their acceptable Best Management Practices (BMP) for their water conservation program.

Discussions with growers have helped to reprogram much of the new AZSCHED version. In one case, working with a grower who used a low-flow sprinkler system, the default rooting depth did not fit his field situation. As a result, a new option allowing the user to better define crop-rooting depth was installed.

AZSCHED has also gain acceptance outside the state. In New Mexico, AZSCHED has been used for several years as a recommended scheduling tool. Researchers there have even developed crop data that can be used with AZSCHED. In Iowa, AZSCHED was used to

schedule sweet corn (Taber and Smith, 2000) and bell peppers (Taber and Lawson, 2001). A sunflower study in North Dakota (Ashley, et al., 2002) utilized the AZSCHEd program to help with irrigation management. In Mexico, the AZSCHEd has been presented at conferences and taught in grower workshops as a viable irrigation scheduling tool.

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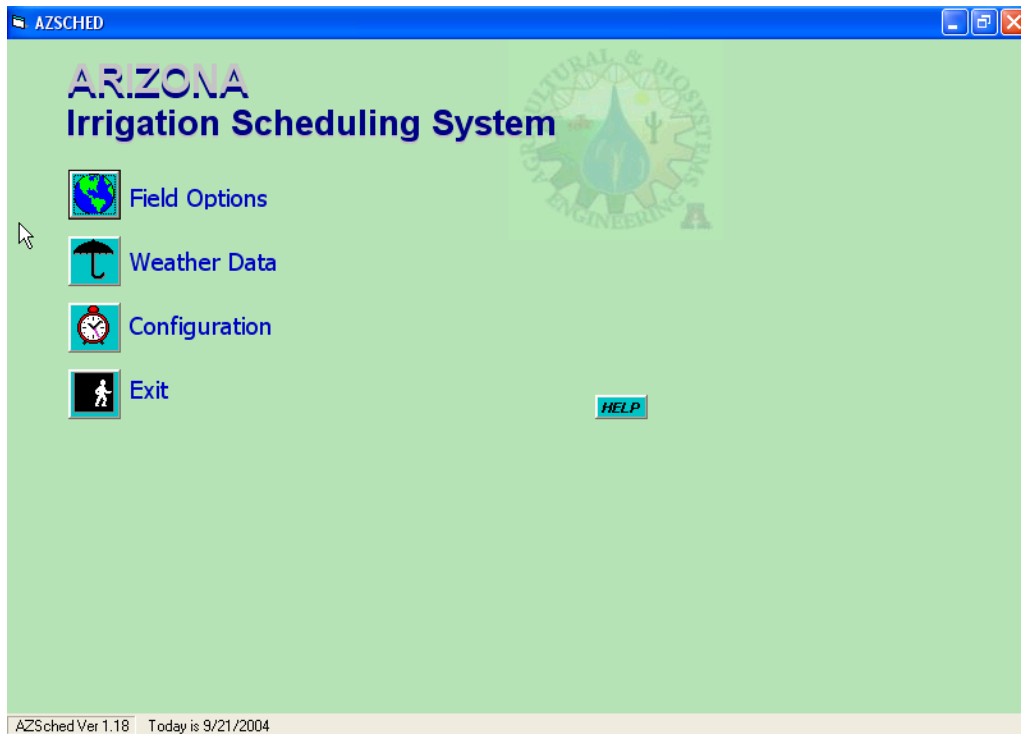


Figure 1. The main menu screen for the AZSCHED program.

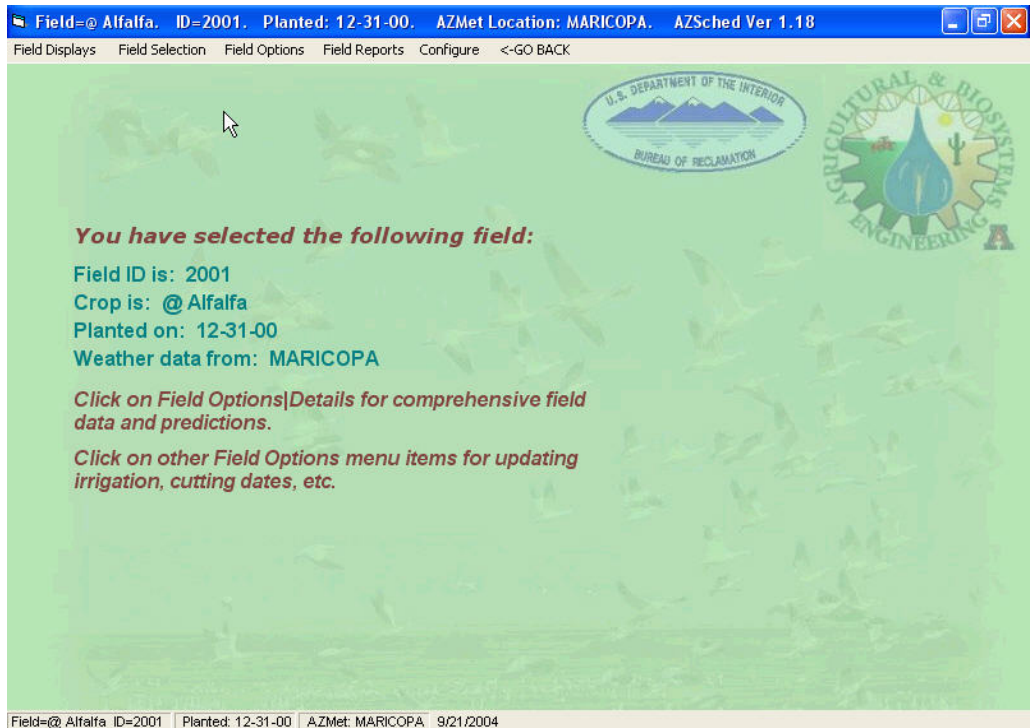


Figure 2. The Field Options screen from AZSCHED. This screen shows data from an alfalfa crop planted in late December, 2000.

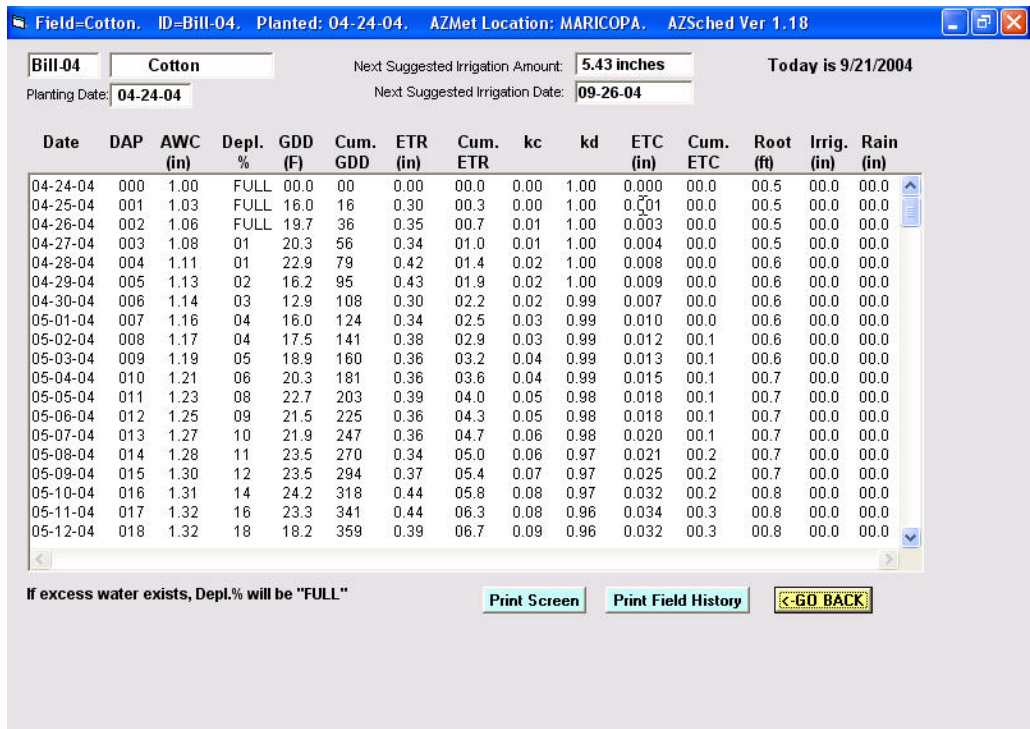


Figure 3. A sample of the Field Report from AZSCHED.



Figure 4. The Weather Menu from the AZSCHED program.

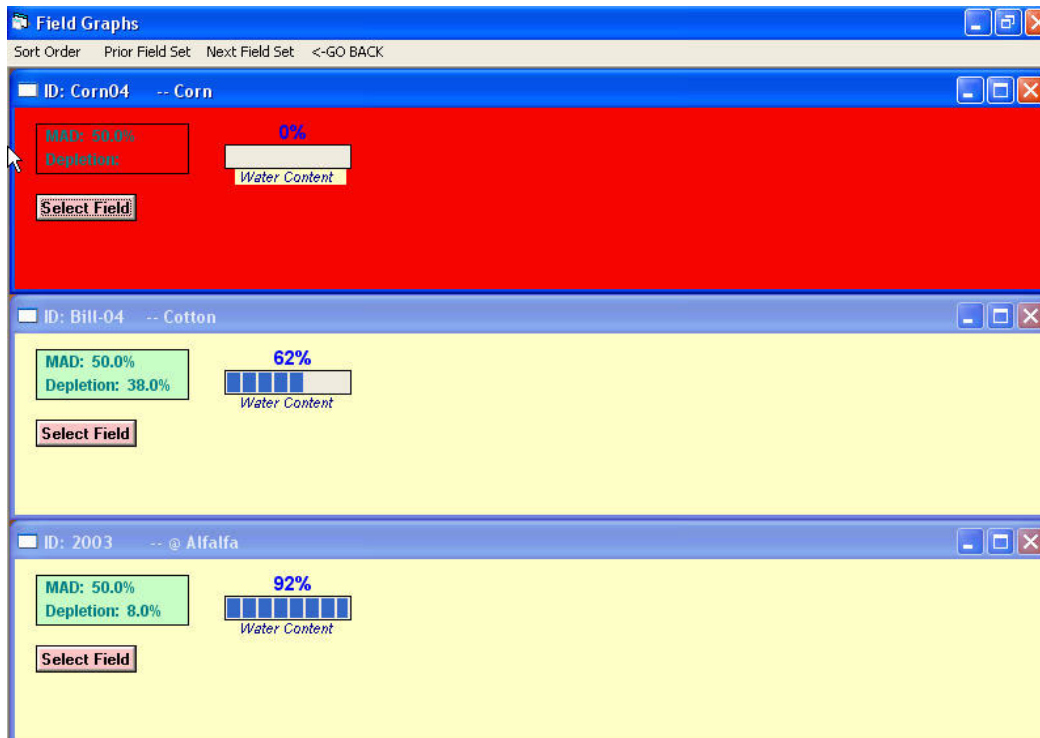


Figure 5. The Field Display screen from AZSCHED.