AZSCHED Computer Software for Irrigation Scheduling

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ABSTRACT

AriZona irrigation SCHEDuling (AZSCHED) software provides irrigation scheduling information on 15 crops in up to 60 fields, with different planting dates, soil types and irrigation strategies. AZSCHED uses the soil water balance method for irrigation scheduling with water-use being estimated by a Modified Penman equation and heat-unit based crop coefficients. The weather data are supplied by localized historical weather data supplemented with real-time weather data. Weather data can be input manually or from computer files. An irrigation prediction report is generated in which fields being scheduled are prioritized by date and the amount of water needed to restore the soil profile to field capacity. The program was written in Quick Basic and compiled into a compact, user-friendly and attractive package.

INTRODUCTION

Irrigation scheduling programs have been in use for many years. Of those programs that have been developed, many have had an "Achilles heel" which is evidenced in the fact that they are not widely used. The weakness may have been that: it didn't track water use well, it required too expensive hardware, it used too much memory, it wasn't easy to run, it required too many inputs, it was only useful in a very small geographical area, or it didn't fit a large farm with many fields. These weakness were considered in the development of this software.

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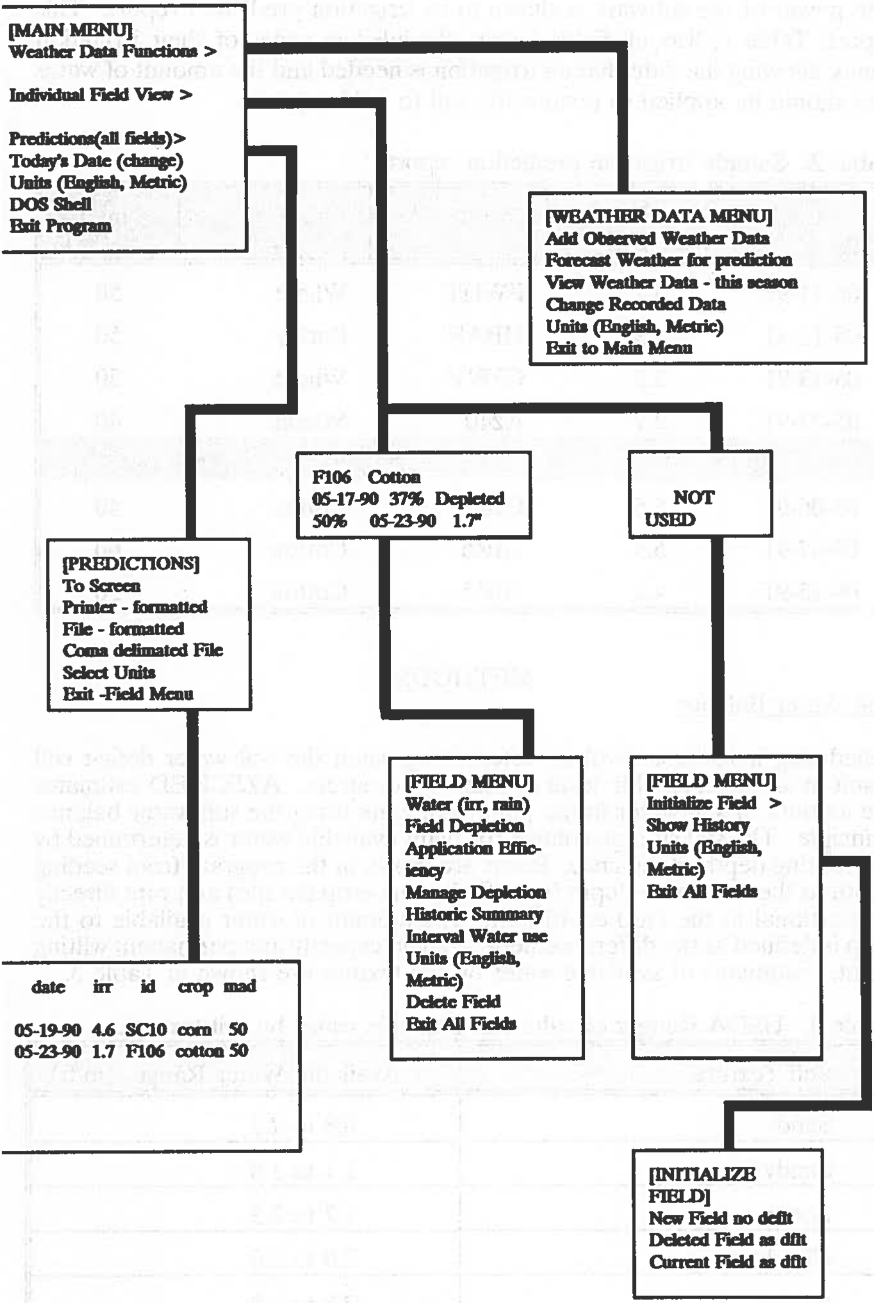
DESCRIPTION

AZSCHED (AriZona irrigation SCHEDuling) software (Fox, etal, 1992) provides a computer based information system for the management of water applications on up to 60 fields with different crops, planting dates, soil types and irrigation strategies. Twenty field summaries are shown on one screen and three screens make up the 60 fields that can be run by the program at one time. If more than 60 fields are needed, more than one subdirectory can be created so any number of fields could be scheduled. Each of the subdirectories would have to have the weather updated independently. This would give the user the opportunity to schedule fields in different geographical areas with different weather bases. Nine crops were available in the first release of the software, these 9 crops are listed in Table 1 along with 6 new crops which are being tested this year.

Table 1. Crops incorporated in the current version of AZSCHED and new crops that will be included in the next version.

No.	Original crops	No.	New crops
1	Cotton	10	Broccoli
2	Sweet corn	11	Lettuce
3	Wheat	12	Carrots
4	Barley	13	Cauliflower
5	Soybeans	14	Green onions
6	Cantaloupe	15	Potatoes
7	Grain sorghum		
8	Safflower		
9	Late grapes		

The program is menu driven and the user begins by initializing a field. To initialize a field, the following data are needed: The planting date, the crop selection, management allowed deficiency (MAD), irrigation efficiency, the available water holding capacity of the soil and the initial available water content. After these inputs are entered, the program sets up the field using these parameters, a historical weather data base and the Modified Penman equation (Doorenbos and Pruitt, 1977) to predict when the field would next need water. Current weather data and predicted weather data can be added to improve the accuracy of the irrigation prediction. An overview of the menu structure is shown in Figure 1.



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  date     irr   id    crop   mad

05-19-90  4.6  SC10  corn   50
05-23-90  1.7  F106  cotton 50
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Figure 1. Menu tree from main menu.

The power of the software is shown in its irrigation prediction report. This report, Table 2, lists all fields being scheduled in order of their irrigation needs, showing the date that an irrigation is needed and the amount of water that should be applied to restore the soil to field capacity.

Table 2. Sample irrigation prediction report.

date	irr (in)	id	crop	mad (%)
05-11-91	3.2	FWHT	Wheat	50
05-11-91	4.3	HBAR	Barley	50
05-13-91	3.3	C3WV	Wheat	50
05-23-91	2.7	A240	Wheat	40
09-06-91	3.6	GIR4	Cotton	40
09-07-91	5.4	GIR6	Cotton	60
09-13-91	4.5	GIR5	Cotton	50

METHODS

Soil-Water Balance

Scheduling irrigations involves determining when the soil water deficit will result in an unacceptable level of plant water stress. AZSCHED estimates the amount of soil water in the plant root zone using the soil water balance principle. The soil storage volume for plant available water is determined by the rooting depth of the crop. Roots are grown in the program from seeding depth to the maximum depth (specified in the crop.dat file) at a rate directly proportional to the crop coefficient. The amount of water available to the crop is defined as the difference between field capacity and permanent wilting point. Estimates of available water by soil texture are shown in Table 3.

Table 3. USDA Ranges of values of available water by soil texture.

Soil Texture	Available Water Range (in/ft)
Sand	0.8 to 1.2
Sandy loam	1.1 to 1.8
Loam	1.7 to 2.3
Clay loam	2.0 to 2.6
Silty loam	2.2 to 2.8
Clay	2.4 to 3.0

As soil water is depleted, the plant has more difficulty removing water from the soil, thus decreasing the evapotranspiration from the plant. This decrease in evaporation is accounted for by the use of a dryness coefficient (Kd) developed by Jensen, etal (1971). Soil surface evaporation is estimated using a factor (Ks) from Kincaid and Heerman (1974), which decreases wet soil surface evaporation as the crop coefficient (Kc) increases. The adjusted crop coefficient then is KC = Kc * Kd + Ks.

Heat unit based crop coefficients

Calculation of actual crop evapotranspiration (Eta) using a reference evapotranspiration (ETo) multiplied by a crop coefficient (Kc) is the basis for most irrigation scheduling programs. Many crop coefficient curves relate Kc to the stage of crop development as a function of time from planting or emergence. For many crops, however, it is recognized that physiological development is more closely related to heat units than to calendar date. Thus in AZSCHED, crop coefficients are developed as a function of heat units. With crop coefficients developed by heat units, the program tracks crop water use more accurately in years that differ from the norm and in different climatic regions.

Crop coefficients are supplied to the program from the crop.dat file. The crop coefficients in this program were normalized by heat units (Scherer etal, 1990a) and are created for use in a location based on the heat units that are received. Figure 2 shows three crop coefficient curves developed from two different sites. Differences are seen at a particular site on two different years. Yuma is a much warmer site than Safford and the year 1991 had a much cooler spring than 1989. It can be seen from the curves that if the heat units are accumulated faster the curve is shifted to the left. This indicates that the crop is developing faster and will need water earlier. In 1991 the Safford curve did not drop off at the end of the season. This indicates that the crop was terminated before its full potential was reached.

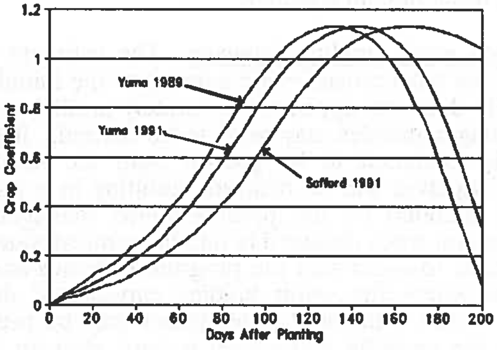

Figure 2. Variation in crop coefficients for cotton at two locations in Arizona

Weather data bases

For accurate predictions into the future, the program uses a historical weather data base. AZSCHED contains historical data bases for the agronomically important regions in Arizona. For areas outside of Arizona, one must select an Arizona region that is similar or develop a separate weather file. The historical weather files contain the following data for each day of the year: Maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, 24 hour wind (at 2 meters), day/night wind ratio, and horizontal solar radiation. All of these parameters are used in the Modified Penman equation. Local 5-day forecasts can be entered into the program to supplant the historical weather data base and increase the accuracy of predictions. Real-time weather data from local instrumentation must be entered for maximum accuracy in water use calculations. This data can be inputted directly as raw data files from the AZMET system in Arizona or can be added manually. Locally available data normally consists of maximum and minimum temperatures and sometime humidity information. This information is inadequate to determine evapotranspiration, so default weather data from the historical file supplies the rest of the data necessary for the calculations.

Adapting the program to specific field conditions

Default weather vs. AZMET weather vs. on-farm weather: Default weather is the average of long term historical weather taken from National Weather Service and AZMET records. Long term average values do not reflect the variation of weather from year to year and therefore provide the lowest level of prediction accuracy. On-farm weather information is best if the instruments are properly installed and all the required weather parameters are measured. AZMET (or comparable) weather station data, if located in the same climatic area, will provide prediction accuracy approaching that of good on-farm weather measurements and in most cases exceed that of poor on-farm measurements. In a warmer than normal year, the predicted date of irrigation using good weather data could be as much as 5 days earlier than the date predicted using default weather.

The estimate of soil water holding capacity: The estimate of soil water holding capacity is the most crucial value entered at the initialization of the field. If AZSCHED does not appear to accurately predict irrigation dates, the soil water holding capacities may need to be revised. If the soil water holding capacity is estimated to be greater than the actual value, the predicted date of irrigation will be delayed, resulting in a greater level of water stress than intended by the predetermined management allowed depletion. The program is not designed to handle perched water tables. The plants will have access to water that the program indicates has been lost to leaching. In cases where the water holding capacity of the soil is not accurately known or where perched water tables may be present, percent water depletion in the program may be set to zero after an irrigation that restores the soil profile to field capacity. This will allow the program to run without cumulative errors. Initializing a new field with better estimates of the soil water holding capacity is the best solution, however.

The Estimate of Initial Water Content: Early season irrigation prediction are highly dependent on this estimate. Estimating the initial soil water content at a value higher than the actual value will delay the first irrigation, resulting in higher water stress levels than intended. Estimating a lower initial value will predict a first irrigation date earlier than needed and decrease the irrigation efficiency.

The Measurement of Water Applied: The program accuracy is only as good as the measurements entered. This is particularly true for the volume of water applied. Over estimation of the water volume applied will result in greater stress to the plants, since the volume of water delivered will be less than that entered into the program. Under estimation will result in more frequent irrigations and more water loss through leaching.

The Estimate of Irrigation Efficiency: This value may be quite difficult to estimate depending on the irrigation system. Water may be lost by deep percolation through the root zone, through evaporation or by surface drainage at the bottom of the field. Irrigation efficiency in surface systems will also change during the season, especially when cultivation is stopped and the surface becomes sealed and compacted from the flow of water. Over estimation of irrigation efficiency can result in under application of water and will result in a greater stress for the plants.

CONCLUSIONS

The AZSCHED program has been successfully used for scheduling irrigation on cotton at two locations in Arizona (Clark, etal, 1990b; Clark, etal, 1991a, Scherer, etal, 1990b) and on wheat at one location (Clark, etal, 1990a; Clark, etal, 1991b). As with any irrigation scheduling method, a certain amount of time must be invested to have a successful program. Because of the menu driven structure, the program is easy to learn and can be run by a user with little computer skill. After the fields are initialized the program should be updated at least weekly with weather, irrigation and rainfall data. With practice, the weather data can be downloaded from AZMET and loaded into AZSCHED in less than 15 minutes. Updating each field takes less than 5 minutes. To print out a prediction sheet with all fields listed is almost instantaneous (depending on the speed of the printer).

The AZSCHED program runs on IBM-PC or compatible computers running DOS 2.0 or higher and required less than 512 Kilobytes of RAM.

A manual describing the software and a diskette containing the program are available at a cost of $10. They can be ordered from:

Agricultural Communications and Computer Support
Department of Agricultural Education
The University of Arizona
715 North Park Avenue
Tucson, AZ 85719
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