IRRIGATION SCHEDULING

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INTRODUCTION

The results of the High Plains, Ogallala Aquifer study indicate that many areas in the High Plains of New Mexico will be facing a serious water supply situation within the next 20 years. Various forecasts of the future indicating technologies that might alleviate these projected conditions were developed by the High Plains Council. These scenarios are being described in detail by several presentations at this meeting. Potential technologies range from very costly water importation, both intrastate and interstate, to the less exotic modifications such as improved water conveyance and application systems and improved irrigation farming practices including irrigation scheduling.

The purpose of my presentation is to describe the current irrigation water management (irrigation scheduling) procedures which can be used to reduce the amount of water pumped and how they might be used in New Mexico. Irrigation is a major consumer of three scarce commodities: energy, water and fertilizer. The need for conservation through good irrigation management practices is urgent -- especially in view of the cost price squeeze facing many U.S. farmers and the rapidly declining water supplies.

To help meet these needs, the agricultural engineering department at the University of Nebraska has developed an irrigation scheduling program which has been used by a variety of clientele including professional consultants and individual grower-operators. While the concepts developed in the program can be applied using relatively simple methods, its primary usage has been through a computer network.

BACKGROUND

Before describing the irrigation scheduling model in detail, I want to discuss some general concepts describing an overall irrigation water management program. Such a program considers an individual irrigator's agricultural production system including the crop, irrigation system, soil, labor supply, energy supply and economic situation. Irrigation water management is important to the grower for a number of reasons including water conservation, energy conservation, reduced production costs and, of course, yield improvements.

One of the primary components of an irrigation water management program is the incorporation of an irrigation scheduling procedure. I prefer to define irrigation scheduling as a scientific determination of when to irrigate and how much to apply to meet specified management objectives. While this definition includes the timing of the irrigation and how much to apply, it also includes a very important additional component, that being specified management objectives. These management objectives may include such goals as: maximum yield, maximum economic benefit, maintenance of a favorable salt balance, minimum leaching and perhaps others. Thus, to develop an irrigation scheduling procedure one must first specify the management objective desired.

For our discussions in this paper I want to define the following management objective which we are striving for. Presently, most of the irrigation scheduling procedures which have been developed are primarily for those conditions when water is not limiting. Thus, our management objective is to minimize water application but not to reduce yields. In some cases in the High Plains the water supply is already diminished to a point where there is not sufficient water to meet the plant water requirements. Thus, the procedures I will be discussing may not be directly applicable. However, these concepts combined with other techniques may be applicable to conserve the available water supply.

The inefficient use of irrigation water results from both the physical conditions of the off-farm conveyance systems and the on-farm irrigation system, as well as the improper management of these systems.

In addition, the efficient use and management of irrigation water may be influenced by existing institutional and social factors. In the High Plains of New Mexico, most of the water is derived from individual wells pumping from ground water sources. Thus, the efficient use of water is primarily a function of the management of the on-farm irrigation systems by the individual grower-operators. Irrigation scheduling could be a key management component for many of these growers.

IRRIGATION SCHEDULING MODEL

The agricultural engineering department at the University of Nebraska has developed an irrigation scheduling model called IRRIGATE for the AGNET (AGricultural computer NETwork) system. This network serves the University of Nebraska and the state of Nebraska as well as several other states. As with all AGNET programs, the irrigation scheduling model is designed for teaching, research and extension programs. Access to AGNET can be made through small portable computer terminals. These are priced from $2,000 and are about the size and shape of a portable typewriter. They can be used wherever there is a telephone and an electrical outlet -- the IRRIGATE program even could be run on a farmer's kitchen table!

The basic component of the irrigation scheduling model is the on-farm water balance. Irrigation water is applied in areas where natural precipitation and stored soil water is insufficient to meet the crop water requirements during the growing season. This water is applied to the soil surface through a number of different types of systems ranging from the most elementary to the more sophisticated. The disposition of water during and after an irrigation event is called the on-farm water balance. The irrigation scheduling model maintains a field's daily soil moisture status since planting, and answers the important questions of when and how much water should be applied in future irrigations.

Kincaid and Heermann (1974) provide an excellent treatment of the basic scheduling theory followed in IRRIGATE, and especially in the use of the modified Penman equation to predict a crop's evapotranspiration

(ET) from the climatic variables: daily maximum and minimum air temperatures, average dew point temperature, daily solar radiation, and the daily wind run. Heermann et al. (1976) presents a detailed description of the output format of the irrigation scheduling program.

IRRIGATE is designed to be user oriented; very little knowledge of computer operation is required. The computer interacts with the user by asking questions. Special detailed help messages are available throughout the program if particular questions are not understood. If certain input parameters are not known by the user, the program will assume standard values for the given type of irrigation system, soil and crop.

IRRIGATE can be used with a wide variety of irrigation systems (center pivots, solid set, gated pipe, siphon tube, etc.); with nine commonly grown crops (small grains, beans, soybeans, potatoes, sugar beets, corn, alfalfa, pasture and sorghum); with eight common soil types (silty clay loam to fine sand); and with a mimimum of climatic data (maximum and minimum temperature only) if necessary.

While the entire scheduling procedure could be done using today's programmable calculators, the computer offers the convenience of easy access to an entire season's data and a neat, readily obtained record of a field's soil water condition. This is even more convenient if a few field parameters are changed and a new season's run is made. This is frequently required in answer to "what if" questions -- important in management planning.

Irrigation scheduling is much like managing a checkbook. The season begins with an initial soil moisture content (beginning account balance). Daily evapotranspiration by the crop depletes the soil water (daily withdrawals). Irrigations and rains represent deposits to the soil moisture account. Future irrigations (deposits) are then scheduled based on an estimated average rate of evapotranspiration (estimated future withdrawals) and the irrigation system's capacity to apply water. Soil moisture depletions should not exceed a particular value to prevent crop stress and a resulting yield decline. For most soils and crops this is estimated at 50 percent of the available water holding capacity of the soil although different values can be used in the model. Irrigations are scheduled to avoid undue stress on any part of a field before the next irrigation.

The model automatically builds and maintains a field data file to store the data pertinent to any one field. The first time the program is used for each field, the program will ask for details describing the crop including the planting date and expected maturity date; soil texture; location and types of soil moisture blocks (if used); type of water meter (if used); desired scheduling method; field area; and irrigation system parameters (such as system capacity, cycle time and application in inches).

The field file also stores the rainfall, irrigation and soil moisture data for the field. On subsequent scheduling sessions the user only enters new data for rainfall, irrigation and soil moisture data. Other field data are automatically recalled from the field data file.

Irrigations are scheduled based on the soil moisture depletions at the two extreme positions of a field, the normal "start" and "stop" position of an irrigation cycle. The program assumes that field positions in between these two extremes follow the same rhythmic cycle as the "start" and "stop" positions. The earliest starting date is based upon the soil moisture depletion at the "start" position. The recommended starting date is the day when the expected soil water depletion at the starting point is greater than or equal to the irrigation depth applied. This is the earliest starting date that will avoid deep percolation losses. The "no later than" date is the time when the system must be started to irrigate the "stop" position before the soil water depletion exceeds some predetermined value (typically 50 percent). To avoid plant stress at the "stop" position, particularly during early growth stages, the "start" position should be irrigated before the soil water depletion in the area reaches the mimimum application depth, even though there will be some deep percolation losses.

Because the three key parameters of rain, irrigation and infiltration variability are often not well defined, field feedback is necessary for accurate scheduling. Thus, periodic soil moisture readings are recommended to provide the needed feedback to ensure that the scheduling is based on the best possible estimation of soil moisture depletion. These readings help to ensure that the ET estimates are correct. They also act as a check on factors such as irrigation efficiency, uniformity of irrigation, rainfall variability and non-uniformity of the soil. Soil moisture updates usually are advised at least every 10 days.

The monitoring of soil moisture may be accomplished by a variety of methods including the soil probe, gypsum resistance blocks, tensiometers, neutron probe and others. Each method has advantages and disadvantages depending upon soil type, cost, etc. The proper soil moisture monitoring technique for the given situation must be carefully determined. Soil moisture blocks are a convenient method to measure soil water status in the finer textured soils (they don't respond well in sandy soils). Block readings can be entered directly into IRRIGATE for the particular soil. Soil moisture block stations are located near the normal starting and stopping location of the irrigation system cycle.

Besides the field data file, which is maintained for each individual field, a weather data file also is kept. The weather data file contains daily maximum and mimimum air temperatures, solar radiation, wind run and dewpoint temperatures for a climatic region. However, that data need not be an input to the model if the Penman option of estimating ET is not used. Because such weather data can be used throughout a climatic region, that data file could be maintained by an irrigation district.

The output of the scheduling program is shown in Figure 1 (p. 91). The output is divided into three basic components: 1) the update; 2) the forecast; and 3) the schedule. The top portion of Figure 1 is the update of the water budget computed with climatic data collected since the previous output. Tabulations include daily water use, irrigation and rainfall amounts, irrigation dates and calculated soil water depletion at the "start" and "stop" positions.

The center part of Figure 1 (the forecast) indicates the maximum useful rain and irrigation amounts that could be applied at any given date. This part of the output represents estimated water use calculated from average climatic conditions for a given area. It can be used by management to evaluate the effectiveness of rainfall which comes during the week and the actual timing of the irrigations.

The bottom portion of Figure 1 (the schedule) shows the recommended starting dates based upon the system capacity and amount of rainfall. In addition, alternate dates are given for the second irrigation assuming that the system was started on the previously recommended "start" date. The operator must judge when to start a system. He has the latitude of starting the system any time between the "start" and "no later than" date. On sandy soils, the center-pivots generally are started on the first recommended "start" to maintain a full soil water profile and avoid excessive depletion should the system malfunction. The time interval between the "start" and "no later than" dates is generally smaller for coarse textured soils than for finer textured soils. Operators with finer textured soils tend to delay an irrigation until after the first recommended starting time which allows them to more effectively use any rainfall that may occur.

Growers whose management objectives are obtaining maximum yields tend to start an irrigation at the first recommended starting time. Others who operate their systems more extensively to minimize irrigation and fertilizer costs tend to start their systems closer to the "no later than" date.

RESULTS

Because the irrigation scheduling program is intended to be used under the guidance of qualified irrigation schedulers, the University of Nebraska periodically offers short courses to train irrigation schedulers.

The irrigation scheduling model is available for use on the AGNET system by university personnel, private individuals, private irrigation scheduling companies, irrigation districts and others. While the exact area being scheduled using the IRRIGATE program has not been determined, Fischback (1981) estimated that more than 1.5 million acres of irrigated land were scheduled in Nebraska in 1979. This area included those scheduled by county agents as demonstration projects, consultants and irrigators themselves.

REGION EXAMPLE (ALL WATER AMOUNTS ARE INCHES)

FARM EXAMPLE CORN DATE Aug 10

UPDATE

DAY	WATER USED	IRRIGATION AND RAINS	IRRIGATION DATES	DEPLETION WHERE SYSTEM STARTS	STOPS
Aug 4	.15	0.00		.15	.15
Aug 5	.22	0.00		.37	.37
Aug 6	.26	.80	STARTED	0.00	.63
Aug 7	.27	0.00		.27	.10
Aug 8	.19	0.00		.46	.28
Aug 9	.25	.80	STARTED	0.00	.53
Aug 10	.28	0.00		.28	.01

FORECAST

MAXIMUM USEFUL RAIN AND IRRIGATION AMOUNTS

LARGER AMOUNTS WILL BE LOST

DATE	AMOUNT
Aug 11	.58
Aug 12	.88
Aug 13	1.17
Aug 14	1.45
Aug 15	1.68
Aug 16	1.90
Aug 17	2.11

SCHEDULE

IF THE SYSTEM APPLIES .8 INCHES AND MAKES A REVOLUTION
In 51. HOURS, THE RECOMMENDED STARTING TIMES ARE:

AMOUNT OF RAIN	START	NO LATER THAN
No rain	Aug 13	Aug 19
0.25	Aug 14	Aug 20
0.50	Aug 15	Aug 22
1.00	Aug 17	Aug 24

ASSUME THE SYSTEM WAS STARTED AUG 13
THE NEXT STARTING TIMES ARE:

AMOUNT OF RAIN	START	NO LATER THAN
No rain	Aug 16	Aug 22
0.25	Aug 17	Aug 23
0.50	Aug 18	Aug 24
1.00	Aug 20	Aug 27

Figure 1. Sample Irrigation Scheduling Output (Heermann et al., 1976).

REFERENCES

Fischback, P. E. 1981. Irrigation management (scheduling) application. Proceedings of the Second National Irrigation Symposium, ASAE, St. Joseph, Mich. pp. 185-193.

Heermann, D. F., H. R. Haise and R. H. Mickelson. 1976. Scheduling center pivot sprinkler irrigation systems for corn production in Eastern Colorado. Transactions of the ASAE 19(2):284-287, 293.

Kincaid, D. C. and D. R. Heermann. 1974. Scheduling irrigations using a programmable calculator. USDA-ARS. Paper No. ARS-NC-12, 55 pages.