# IRRIGATION SCHEDULING FOR FARM CROPS[1]

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This paper summarizes the needs of managers of modern irrigated farms and the status of a user-oriented irrigation-scheduling computer program designed to provide managers with estimates and predictions required for optimum irrigation water management.

Evaluations of farm irrigation practices in the West during the late 1950's and early 1960's (12, 19)[2] showed little change in irrigation scheduling practices in 25 years (6). During this same era, irrigation science and technology have made significant advancements.

There are two major reasons why irrigation scheduling, involving both timing and amount of water applied, has not changed substantially: (a) The needs of managers of irrigated farms have not been clearly defined and the acceptability of suggested management procedures has not been evaluated adequately; and (b) the cost of irrigation water often has not been a major item. Also, indirect costs such as yield reductions caused by delayed irrigations, and additional nitrogen requirements created by excessive water applications are not easily recognized or quantified.

Modern irrigation equipment enables farm managers to apply the amount of water needed at the optimum time it is needed--but farm managers still must decide "when" and "how much" water to apply. They need to predict, several days in advance, when to irrigate in order to plan other work and complete the required irrigations. This is especially important when the capacity of the irrigation system is limited.

Instruments are available for directly or indirectly measuring soil moisture or the plant-water status, but farm managers have not used them extensively because they must be serviced regularly and read frequently. This activity competes for limited available manpower. Furthermore, these instruments provide only part of the information needed. They indicate the present status of soil moisture or the plant water--not the expected date of the next irrigation and the amount of water needed.

Evapotranspiration (evaporation from the soil surface and transpiration by plants) accounts for most of the depletion of soil moisture, and tremendous advances have been made in technology for measuring and predicting daily evapotranspiration. However, the results of these developments generally are not being made available, or they are not available in a form that managers of ir-

1 Contribution from the Northwest Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture; Idaho Agricultural Experiment Station cooperating.
2 Numbers in parentheses refer to the appended references.

rigated farms can use. Irrigation scheduling is a decision-making process requiring current information, trends, projections, and alternatives much the same as are required in managing large industries. Modern farm managers want a service that estimates the present soil moisture status, predicts irrigation dates, and indicates the amount of water to apply for each field. They also could use predictions of the adverse effects of delaying or terminating irrigations. This information would increase management skills through better and more profitable irrigation decisions than are now possible. This information essentially supplements practical irrigation experience with irrigation science.

## SWC-ARS-USDA IRRIGATION-SCHEDULING COMPUTER PROGRAM

The USDA computer program was developed cooperatively with farm managers and service groups as a modern tool for service groups to provide managers of irrigated farms with the best scientific estimates of irrigation needs for each field. This is not the only approach to this problem, but is one that has gained rapid acceptance. The program requires limited input data and uses simple, basic equations so that each can be replaced as more accurate ones are developed. The principles and procedures involved are described in detail in several recent publications (7, 8, 9, 10, 11) and will not be repeated here. The computer program is available on request from the author. Service groups and companies have gained experience in the use of this basic concept of irrigation scheduling. For example, the Salt River Project, Phoenix, Arizona has used the basic program for three years. After the first two years the original program was revised. It retained the basic components, but the input-output data and format, and some of the crop curves were changed to fit local facilities and crops (5).

The U.S. Bureau of Reclamation modified the program to provide general irrigation forecasts for the major crops in a soil-climate (2). These forecasts were updated once or twice a week and distributed to cooperators who provide their own field monitoring. This service was evaluated in 1970 by the USBR and Idaho Agricultural Extension Service concurrently with individual field scheduling. Additional changes are being made and will be evaluated by these agencies in 1971.

An agricultural service company at McCook, Nebraska is using a modified version of an earlier computer program in Nebraska and Kansas (3). Other groups are evaluating the program in the Great Plains.

Approximately 20,000 acres were scheduled in 1970 by various groups in Idaho, Nebraska, and Arizona. An estimated 100,000 acres will be scheduled in 1971, with half of the acreage (50,000 acres) involving cotton on the Salt River Project.

The concept of scheduling irrigations using climatic data is not new. Penman (15), for example, discussed this approach in 1952 as have many others since then (1, 16, 17, 18, 20, 21). However, prior to 1965, this method had not been adopted for general practical use or tested extensively in the USA. The computer program, which was developed for this purpose, is briefly described in this paper.

## WHAT DOES THE PROGRAM DO?

The computer program uses available, or easily obtainable meteorological, soil and crop data. It first calculates estimates of daily evapotranspiration, $E_{tp}$ from a well-watered reference crop like alfalfa with 12 to 18 inches of top growth. Daily values of $E_{tp}$ are then related to specific crops at various stages of growth by crop coefficients, $K_c$. The crop coefficients currently in use were derived from experimental data and vary with stage of growth, wetness of the soil surface, and available soil moisture. The product, $K_c E_{tp}$, is the estimated daily depletion of soil moisture by evaporation and transpiration. The cumulative depletion of soil moisture by evapotranspiration minus effective rainfall is tabulated for each field and compared with the optimum depletion. The optimum depletion is dependent on the stage of growth, rooting depth, and soil water-holding characteristics when water is readily available; and on yield-soil moisture relationships where water is scarce or expensive. The remaining amount of soil moisture that can safely be depleted under the existing conditions is divided by the average expected daily date of evapotranspiration to determine the projected rate of the next irrigation. The amount of water to be applied is that amount plus unavoidable losses and the leaching requirement,if needed.

The type of information provided is optional. Generally, each farm manager receives a weekly or semiweekly printout of the status of each of his fields listing: (a) crop and field identification; (b) date of last irrigation; (c) rainfall since last irrigation; (d) estimated depletion of soil moisture; (e) optimum depletion at the current stage of growth; (f) days before next irrigation; (g) approximate amount of water to apply; and (h) a general climatic forecast. Heermann and Jensen (7) modified the program in 1970 to include expected rain in determining the expected date of the next irrigation. This feature, which is more significant in the Great Plains and semihumid areas as compared to the arid West, will provide two estimates of the date of the next irrigation--one assuming no rain, and one with expected rainfall.

## INPUT DATA

Three categories of input data are required. These are provided by the service groups working with the farm managers: (a) basic or fixed data for each region and field, (b) current meteorological data for each region, and (c) current data for each field.

### Basic Data

The basic data consist of regional constants for the potential evapotranspiration equations, and crop-soil-irrigation system data for each field. The latter involves the farm name, crop code number, crop and field identification, planting date, estimated effective cover date, estimated harvest date, estimated overall irrigation efficiency for each field based on the system being used, and the maximum amount of soil water that could be depleted by evapotranspiration for each crop. The maximum depletion by evapotranspiration is an important limit that is used to decrease the rate of depletion as depletion approaches this value. It is estimated as the difference between the soil-water content about four days after an irrigation on a soil that is about two to three feet deep (covered to prevent evaporation, Miller (13), and the soil-water content reached en the given crop with a fully developed root system is allowed to grow without irrigation until growth ceases.

Current Meteorological Data

Current meteorological data required for each region are: daily minimum and maximum air temperatures, solar radiation, dew point temperature, and wind run for each day since the last date of computation. An optional, brief weather forecast can be included for each region. Mean maximum potential evapotranspiration expected in the area at mid-season and a time constant are also needed in the latest revision.

Current Field Data

Current data for each field are: the date of the last irrigation, the allowable soil moisture depletion at the present stage of growth (this can be included in the program), a code date for an irrigation if it falls within the present computation period, and the rainfall and/or irrigation amount and its date of occurrence.

## MODIFICATIONS UNDERWAY

This computer program has only opened the door to better irrigation water management. The present program considers the major factors involved, but refinements and additional options are being developed. Where the water table is high, for example, part of the water may be supplied from the saturated zone. When this occurs, soil moisture is not depleted as rapidly. An automatic adjustment for this can be added, but additional information on the soil, rooting depth, and depth to the water table will be needed.

When the amount of irrigation water applied is known, an optional drainage component can be added to the program. This also will require additional data for the soils involved since the maximum amount of water that can be depleted from the soil must include the drainage component.

An additional, optional, subroutine is being developed to predict the optimum timing of limited irrigations for water-short areas or where irrigation water is expensive. Each time the program is run it will predict the soil moisture depletion for the balance of the season and the probably yield reduction if no further irrigation is given. It will then predict the optimum time for applying specified increments of water if climatic conditions are normal. This procedure requires rainfall probabilities, the distribution of expected potential evapotranspiration, $\overline{E}_{tp}$, and the effect of limited water on yields. The latter item is the most difficult to define at this time for most crops. Data such as that provided by Musick and Dusek (14) can be used to develop approximate relationships, and approximate models are now available for this purpose (4).

everal other modifications and refinements are being considered, which should be available for use in 1972. For example, information on the probable effects on yields if irrigations are delayed or perhaps even terminated would be very useful in water-short areas, or where water is expensive.

SUMMARY

A simple procedure for providing current information to the farm manager for irrigation scheduling has been needed for many years. Irrigation scheduling, using meteorological techniques and a computer, is now practical. Such irrigation scheduling would be a boon to managers of irrigated farms even while further refinements are underway. Potential economic returns can exceed the costs of such a service by severalfold, and computer facilities are presently available to anyone with a telephone in the United States. The interest and enthusiasm for a service that can provide data and forecasts of this type to the modern farmer are high. The information provided with this computer program has also been educational to the irrigation farm manager because it has increased his understanding of the soil moisture reservoir and its management

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