#153

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Scheduling Irrigations with Computers

MARVIN E. JENSEN

IS irrigation scheduling using climate-crop-soil data practical? Is this a service that farm managers might use to increase their management skills and, hence, their net returns? Tests using a computer program to predict the time and amount of the next irrigation indicate this type of scheduling is practical and is a service many farmers would like.

Marvin E. Jensen is an agricultural engineer at the Snake River Conservation Research Center, Agricultural Research Service, U.S. Department of Agriculture, in Kimberly, Idaho. This article is a contribution from the Northwest Branch, Soil and Water Conservation Research Division, ARS, in cooperation with the Idaho Agricultural Experiment Station and the U.S. Weather Bureau, Environmental Science Services Administration, U.S. Department of Commerce.

The computer program employs estimates of daily evaporation and transpiration for a crop. When combined with experimental data on allowable soil moisture depletion for the crop and various soils, the date of the next irrigation can be estimated immediately following each irrigation. The computer not only predicts the date of the next irrigation but estimates the optimum amount of water to apply as well.

This article summarizes the scheduling procedure being developed and the results to date, which have been discussed in more detail elsewhere.[1]

Background

During irrigation water management studies at the Snake River Conservation Research Center in 1966, all irrigations on one irrigation treatment on sugar beets were scheduled using climate, crop, and soil data. The results compared favorably to treatments where irrigations were based on tensiometer readings.

In 1967 the scheduling tests were expanded to 13 fields on the farms of six cooperators. The cooperators reacted favorably to the program, and all requested further testing. The following year the program was expanded to other crops and 26 fields on the six farms.

Other farmers in the Twin Falls-Burley area also wanted to try this experimental service. The Idaho Ex-

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[1] Jensen, M. E., D. C. N. Robb, and C. E. Franzoy. "Scheduling Irrigations Using Climate-Crop-Soil Data." Presented at the American Society of Civil Engineers meeting on water resources engineering in New Orleans, Louisiana, February 3-7, 1969. (To be published in the ASCE *Journal of Irrigation and Drainage Division Proceedings*.)

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tension Service selected additional cooperators near Idaho Falls and Caldwell, and the U.S. Weather Bureau solicited cooperators in the Boise area. By June, 22 farms and 48 fields were involved.

Time-sharing computer facilities located in Phoenix, Arizona, with a remote terminal at Kimberly, performed the thousands of computations involved. The U.S. Weather Bureau provided solar radiation and other climatic data for each area via its teletype network.

The computer program was also adapted for use at the Salt River Project in Arizona and is being tested on 19 farms and 2,162 acres in the Salt River Valley by Franzoy and his staff.

The A&B Irrigation District, headquartered in Rupert, Idaho, is also providing an irrigation scheduling service to its water users this year on an experimental basis. To date, 86 fields are involved. The cost of the A&B District's service is initially being borne by the Bureau of Reclamation since the methodology is still in a developmental stage.

Within 3 years, many projects in the West and the Great Plains are expected to provide a scheduling service to their water users. Private firms will undoubtedly integrate the technique into their present irrigation management services to reduce costs and extend their coverage to a larger number of users.

The art of irrigation or experienced judgment is still important and can not be replaced, merely supplemented with irrigation science. Periodic field monitoring by experienced personnel is essential to provide computer input data. Without this input data, the computer generates numbers with only limited value.

Basic Principles Involved

Using climatic data, the computer program first estimates the daily potential evapotranspiration rates since the last date of computation. Then a crop coefficient, which is primarily a function of growth stage and soil moisture, is applied to estimate evapotranspiration. Crop coefficients based on experimental data are automatically adjusted to take into account the influence of changes in surface soil moisture caused by irrigation or precipitation. The optimum soil moisture depletion values used are based on available soil moisture characteristics, crop tolerance to soil moisture stress, rooting depth, and experimental data. With some irrigation systems, optimum depletion is that amount of soil moisture that normally can be replenished by an irrigation system and, within limits, may be independent of the soil and rooting depth. Optimum depletion can be adjusted to maximize production per unit of water used in water-short areas.

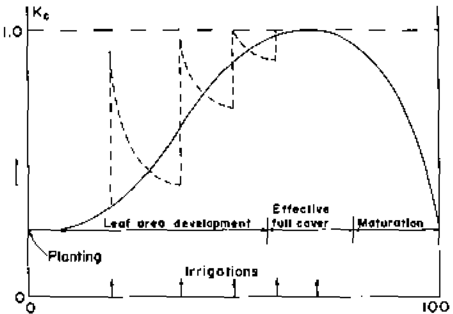

Figure 1. Diagrammatic illustration of changes in crop coefficients as influenced by stage of growth and wet soil caused by irrigation or rainfall.

A summary of the steps involved follows:

1. Daily potential evapotranspiration, E_{tp}, for a reference crop like alfalfa is estimated using either an approximate energy balance (*1*) or a combination (Penman) equation. In some areas an evaporation pan can be used.

2. A crop coefficient for the stage of growth and the time since an irrigation or rainfall is selected (Figure 1). The crop coefficient represents the following energy balance components (*2*):

$$K_c = \frac{1 + \beta_o \quad (R_n + G)}{1 + \beta \quad (R_{no} + G_o)}$$

wherein K_c is the crop coefficient, $\beta = (A/E_t)$, R_n is net radiation, A is sensible heat flux to or from the air, G is sensible flux to or from the soil, and β represents the ratio of sensible heat flux to latent heat flux (the Bowen ratio). The subscript 0 designates concurrent values for the reference crop in the immediate vicinity. The energy terms are positive for input to the crop-air zone and negative for outflow. Increases in daily evapotranspiration as a result of a wet soil surface due to rainfall cannot exceed the sum of previous increases from a given rain.

3. From the values obtained in steps 1 and 2, daily evapotranspiration for each day since the previous date of computation and for the next 3 days based on weather forecasts is calculated using the equation

$$E_t = K_c E_{tp}$$

4. Soil moisture depletion to the current day is then estimated:

$$M_d = \sum E_t - \sum R_e$$

wherein M_d is estimated soil moisture depletion and R_e is effective rainfall or rainfall that is retained in the soil. After an adequate irrigation, estimated soil moisture depletion is assumed to be zero.

5. The first primary result is an estimate of the number of days before irrigation is needed. The average evapotranspiration, $\bar{E}_t$, for the 3 preceding days and the 3 forecast days is used for this purpose:

$$N = \frac{M_o - M_d}{\bar{E}_t}$$

$$(N = 0 \text{ for } M_d > M_o)$$

wherein N is the number of days until the next irrigation and M_o is the optimum or maximum allowable soil moisture depletion for the present stage of growth.

6. In many cases an estimate of the total amount of water to be delivered to the field per unit area is as important as the date of the next irrigation in order to avoid over-irrigation. This estimate is obtained as follows:

$$W_d = \frac{M_o}{E}, \; M_o > M_d$$

$$W_d = \frac{M_d}{E}, \; M_d > M_o$$

wherein W_d is the total depth of water per unit area to be delivered to the field and E is the attainable irrigation efficiency with the system involved. Where and when necessary, the depth of water per unit area to be delivered can be adjusted to provide the necessary leaching requirement.

Cooperators are furnished several charts and tables that serve as an introduction to an irrigator's handbook. Each farmer and field man receives the following information (automatically printed by the teletype terminal) by mail after each run, which is about once a week in the spring and fall and twice during the summer:

1. Crop and field identification
2. Date of last irrigation
3. Rainfall since last irrigation
4. Estimated depletion of soil moisture
5. Optimum depletion (varies with growth stage)
6. Estimated days before the next irrigation
7. Approximate amount to apply
8. General climatic forecast

The general reception to this approach has been favorable. Common reactions to the experimental scheduling are that the service increases yields, reduces time involved in checking fields, results in better management of the water supply for the entire farm, and results in more uniform quality of crops.

The Salt River Project in Arizona has provided a direct visit, soil sampling service for its water users since 1965. During 1968, this service and the irrigation scheduling service described herein were combined and tested. This combination offers the potential of providing the best service for the least cost.

The basic concept of this combined approach is the application of scientific irrigation principles to estimate depletion and allowable depletions and direct observation by experienced, trained personnel to monitor and verify predictions. Regular weekly visits are made to evaluate existing soil moisture regimes and biweekly estimates of evapotranspiration rates. This feedback is essential to the success of the service. In addition, the regular visits instill confidence among farmers in the predictive approach.

The cost of providing this management service is low when serving fairly large acreages (estimated at $1.00 per acre). Irrigation districts with small fields and low-value crops may find the per-acre cost too great to be justified unless the level of service, frequency of visits, etc., are reduced. The least expensive service, but one which would not have the feedback for individual fields, would be for the Extension Service or a similar agency to publish or broadcast daily reports such as "If you haven't irrigated beets for 8 days, you should plan to irrigate within 3 days."

Summary

Irrigation scheduling using climate-crop-soil data and computers to facilitate the tedious computations accompanied by field observations by experienced personnel is a service that appears to be very attractive to the modern irrigation farm manager. This service has the potential of increasing the management skills of the farmer at a reasonable cost. It supplements the art of irrigation or experienced judgment with the results of recent advances in irrigation science.

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2. Jensen, M. E. 1968. *Water consumption by agricultural plants.* In *Water Deficits and Plant Growth.* Academic Press, New York, N.Y. pp. 1-22.