Microcomputer Applications to Irrigation System Management

E.C. Stegman

The primary purpose of irrigation is to provide plants with sufficient water to prevent stress that may reduce crop yield or quality. The required timing and amount of applied water are governed by the prevailing climatic conditions, crop and stage of growth, the moisture-holding capacity of the soil, and the developed root depth. Need for irrigation can be determined in several ways. One way is to observe the crop for change of color or visual stress, but the timing of this information may appear too late to prevent yield or quality reduction. Direct or indirect soil-moisture monitoring methods are available. These methods measure the soil moisture content or the soil moisture potential (also called tension or suction) in the crop root zone. Instruments for monitoring soil moisture include the hand probe, tensiometer, gypsum block, and neutron probe.

Soil moisture monitoring instruments have been used on a limited scale by irrigation farmers because these methods are time-intensive to use and require considerable interpretive ability or experience on the part of the user. Also, if these data are not obtained frequently they may provide inadequate projections of irrigation need.

Technology advancements in irrigation scheduling have, for the past decade or more, focused on water balance forecasting methods (reviewed by Stegman et al., 1980). Applied irrigation scheduling is based on the water balance equation:

$$SMD_i = SMD_{i-1} - P_i - IR_i + ET_i + DR_i \qquad (1)$$

where SMD_i = root zone soil moisture deficit on day i (today), SMD_{i-1} = root zone soil moisture deficit on day i − 1 (yesterday), IR_i = net irrigation depth on day i, P_i = precipitation on day i, ET_i = evapotranspiration estimate for day i, and DR_i = root zone drainage loss.

The beginning SMD is usually estimated from soil moisture sampling by hand probe methods. Precipitation and irrigation amounts are locally measured by rain gauge and water meter methods. Drainage losses are usually assumed to equal the amounts of rainfall or precipitation excess. Thus, the daily estimate of crop ET is the major concern. Available (applied) methods rely on daily measurements of key weather variables such as maximum and minimum air temperature, solar radiation, mean dew point temperature, and total wind run.

In the following sections I will describe several microcomputer applications that allow North Dakota irrigators to utilize water balance technology for irrigation scheduling.

AUTOMATED WEATHER DATA COLLECTION

The North Dakota Agricultural Experiment Station began installing automated weather stations (Campbell Scientific[1]) at its branch stations in 1983. These stations have become operational (in the growing season) at Carrington, Oakes, Minot, Streeter, and Langdon.

The weather station microloggers can be programmed to output the following hourly information:

1. hourly average solar radiation
2. hourly average soil temperature (seed zone)
3. hourly average air temperature
4. hourly average relative humidity and/or vapor pressure
5. hourly maximum wind gust
6. hourly average wind speed
7. hourly average wind vector direction and magnitude
8. hourly total precipitation

The microloggers are also usually programmed to output the following daily parameters (midnight to midnight):

1. daily solar radiation
2. daily average soil temperature
3. daily maximum, minimum, and average air temperature
4. daily average relative humidity and vapor pressure
5. daily average wind speed
6. daily total precipitation

Data from the weather station microloggers can be stored on tape or eraseable solid state memory modules for subsequent transfer to computer for processing. A more direct link is achieved via modems and telecommunication

Stegman is professor, Department of Agricultural Engineering.

[1]Mention of tradenames does not imply endorsement by North Dakota State University.

transfer to desktop microcomputers. This method has been used for two seasons with the Oakes station. Data are retrieved by computer-initiated dial-up shortly after midnight. A computer program processes the "raw" (string) data files into a daily weather report that includes derived parameters of daily average dewpoint temperature and estimates of daily potential evapotranspiration (Jensen-Haise equation, 1963). The daily summaries are combined at seven-day intervals to compose a weekly summary. Both the daily and weekly summaries are uploaded to a host computer and stored as files that can be accessed by potential users.

Additional outlets for this data have also been utilized in the form of direct mailings to interested users, radio broadcast of estimated crop water use rates, and recorded telephone messages that can be accessed via toll-free number (1-800-OK2-SOAK in the '85 season).

MICROCOMPUTER SOFTWARE FOR IRRIGATION SCHEDULING

Stegman and Coe (1984a, 1984b) developed irrigation scheduling software for micropmuters (Apple or IBM) that includes crop curves for North Dakota conditions. This software is menu-driven in a user-friendly format that provides several options:

1. WEEKLY UPDATE PROGRAM
2. CHANGE SMD OR UPDATE DATE
3. INITIALIZE FIELD DATA FILES
4. EXIT PROGRAM

Option 3 allows the user to initialize data files for each field that is scheduled. The required data inputs and the number associated with each crop that can be scheduled are illustrated in Fig. 1. The program as currently dimensioned allows the scheduling of 20 fields. After the necessary initialization data have been entered for each field, the user subsequently utilizes menu option 1 for each update of the SMD level (root zone moisture deficit). Usually this update is performed at weekly intervals.

The weekly SMD update calculation begins with the entry of daily weather data (rainfall, maximum and minimum temperatures, and solar radiation). These data should be obtained from a station that is representative of the given area. However, for the user choosing to observe maximum and minimum temperatures locally, an option has been added that allows the estimation of solar radiation (Samani and Pessarakli, 1985) from the temperature data.. Limited testing has suggested (not published) that these estimates are a usable substitute for measured solar radiation, particularily if the weather station is many miles away.

As the new SMD updates are computed for each field, the user must enter the irrigation amounts and dates of application. Rainfall amounts and dates are likewise entered with the weather data.

An example of program output is displayed in Fig. 2. Irrigation need is ascertained by comparing the predicted SMD update with the irrigation timing criteria portrayed by the 30 percent depletion or 50 percent depletion limits.

An option also allows the advance forecast of SMD development in the next seven days (assuming no rainfall). This forecast is based on average climatic curves (built into the software) or on user-supplied estimates of advance weather (average temperature and solar radiation). Fig. 3 illustrates an SMD forecast output from the scheduling software. This projection provides the user with advance indication of the net irrigation amount that is required in

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INITIALIZE FIELD DATA FILES

ENTER FIELD #
(0 TO ESCAPE)—>1

CROP NUMBERS
..............................
1=SUNFLOWERS
2=CORN
3=WHEAT
4=PINTO BEANS
5=SOYBEANS
6=ALFALFA
7=BARLEY

FIELD #1
ENTER CROP #—>2
ENTER CROP EMERGENCE DATE (MONTH,DAY)—>5,21
ENTER THE PRESENT DATE (MONTH, DAY)—>6,1
ENTER IRRIGATION EFFICIENCY, IN PERCENT—>85
ENTER TOTAL SOIL MOISTURE HOLDING CAP., IN INCHES—>4
ENTER PRESENT SMD IN INCHES—>1.8
ENTER 30% DEPLETION LEVEL IN INCHES—>1.2
ENTER 50% DEPLETION LEVEL IN INCHES—>2
ENTER IRRIGATIONS TO DATE IN INCHES—>0
ENTER RAINFALL AMOUNT TO DATE IN INCHES—>0
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Figure 1. Example of inputs that are required to initialize data files for each field that is scheduled.

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RESULTS FOR INTERVAL ENDING 6/8
FIELD #1:CORN

THE LAST UPDATE 6/1
.....................................................................
                                                      INCHES
                                                      ......
SOIL MOISTURE TO DATE                                   1.55

IRRIGATION AMOUNT TO DATE                               0.00
RAINFALL AMOUNT TO DATE                                  .75
SOIL MOISTURE HOLDING CAP                               4.00

30% DEPLETION LEVEL                                     1.20
50% DEPLETION LEVEL                                     2.00
   CROP COEFFICIENT—>.41
   SURFACE WETNESS COEFFICIENT—>.05
   DAYS AFTER EMERG.—>18
.....................................................................

ARE THESE RESULTS OK? (N TO REENTER) Y
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Figure 2. Example output of the irrigation scheduling program for a given field as the result of a seven day update.

SMD FORECAST STARTING 6/8		
DAY	SMD	DAILY WATER USE.
1	1.64	.09
2	1.73	.09
3	1.83	.10
4	1.93	.10
5	2.04	.11
6	2.15	.11
7	2.27	.12

30% DEPLETION LEVEL=1.2
50% DEPLETION LEVEL=2

PRESS RETURN TO CONTINUE........

Figure 3. Example seven day forecast of the expected soil moisture deficit development (assuming no rainfall or irrigation).

the next seven days just to maintain the root zone at about the present deficit level.

Menu option 2 allows the user to examine the SMD estimates for each field as of the last update. When periodic in-the-field measurements indicate a need for a correction, this option permits the input of these data to the scheduling program.

ON-SITE SCHEDULING AND MANAGEMENT OF CENTER PIVOTS

Microprocessor technology provides the potential for direct implementations of new agronomic and/or management advancements in production agriculture. This technology is particularily well-suited to direct on-site management of electrically driven center pivot irrigation systems.

Marzolf et al. (1985) and Wagner et al. (1985) recently described a hardware-software design for low-cost irrigation scheduling and control of center pivot irrigation systems. Their design is based on the development of a Data Acquisition and Control Integrated Circuit (DACIC) board (see Fig. 4) that interfaces to a Commodore 64 microcomputer. As illustrated in Fig. 4, the DACIC board allows the computer to access (via software control) data from sensores that measure temperature, solar radiation, rainfall, system pressure status and location of the center pivot in the field. The weather data provide input to the irrigation scheduling model that resides in the system software. The data acquistion process is regulated by interrupt cycles from an on-board real-time clock.

When irrigation need is indicated by the water balance model, the DACIC board (under software control) initiates and performs the necessary control actions (Fig. 4) to start the pump motor and start the center pivot in either the forward or reverse direction. The travel speed of the system is also controlled. While operating, both the center pivot's location and pressure status are monitored. Should pump failure, loss of pressure, or misalignment problems occur, the system shuts down automatically.

To achieve operational flexibility, the irrigated field is divided into 12 sectors. Two crops can be accomodated. Thus, at initialization, the user completes the entry of the following inputs:

1. Pivot orientation in the field
2. Desired system travel speed per crop
3. Crop types
4. Current SMD's per crop
5. Maximum allowable SMD per crop
6. Available water holding capacities per crop
7. Days since crop emergence per crop
8. Number of sectors occupied per crop
9. Last seasonal irrigation date per crop
10. System pumping rate
11. Acres covered by the pivot
12. Estimated water application efficiency
13. Hours required to complete a field revolution at 100% speed setting

Each day (at midnight) the water balances for each crop are updated. The software-supplied logic then determines which crop has the greater irrigation need (based on comparison of current SMD with maximum allowable). Irrigation is initiated when the current SMD exceeds the maximum allowable level. While a crop is being irrigated, the DACIC system continues to collect data and monitor the irrigation system. If rainfall occurs and exceeds the current SMD in the remaining unirrigated sectors for the crop being irrigated, the irrigation is terminated and the center pivot lateral is driven automatically at maximum (100 percent speed setting) speed to the nearest boundary for that crop. The system will wait at this location until the water balance model again schedules another irrigation.

When the center pivot system completes an irrigation pass over a crop, that irrigation amount is subtracted from the SMD for all sectors that are occupied by that crop. At this time, while the system is still running, the software logic determines whether further irrigation is required. Thus, one of three things can happen:

1. If neither crop requires irrigation, the pivot system is shut down.
2. The system continues to run in the current direction to irrigate the next crop if the water balance model determines that irrigation is required.
3. The system is stopped and restarted in the reverse directon if the current crop still has an irrigation need (i.e., SMD has not been reduced to near zero).

When the program flow is interrupted by user request, a user update menu is displayed. Six options may be selected. Option 1 displays the current SMD estimates for each crop and allows the user to update these values if they depart from current field-check measurements. Option 2 displays the current speed settings, allowing new speeds to be entered. Option 3 allows the user to enter an alfalfa cut-

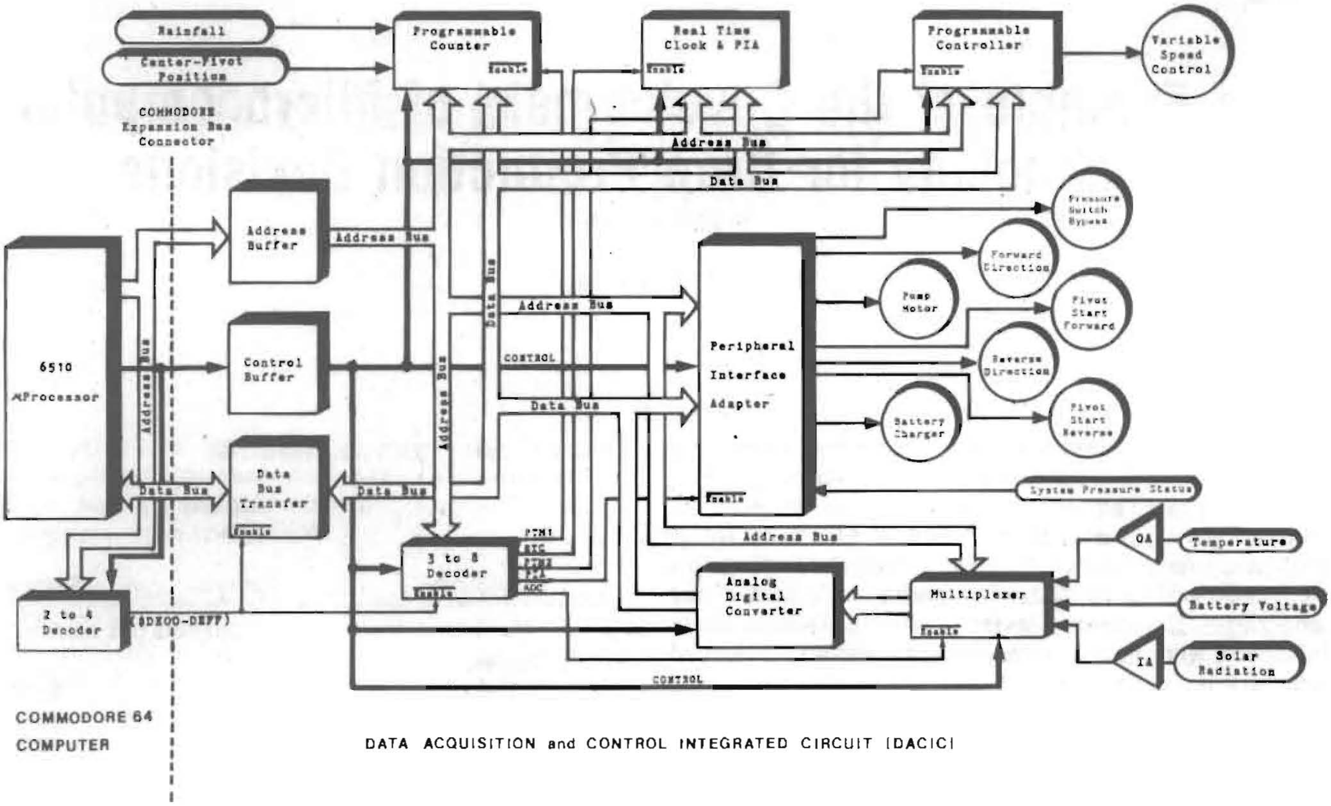

Figure 4. Schematic of an interface for Commodore 64 microcomputers that achieves on-site irrigation scheduling and control of electronically driven center pivot irrigation systems (from Marzolf et al., 1985).

ting date (if required). Option 4 allows the user to stop the irrigator at any point in the field. This stop option allows the irrigator-farmer to prevent irrigations of a crop while cultural practices take place (i.e. hay baling, cultivation, system servicing, etc.) Option 5 is exercised to restart the irrigator. Option 6 returns system control to the main program.

SUMMARY

Water balance models and their implementation with microcomputers provide farmer-irrigators with efficient management tools. These models require the availability of near-real time weather data. Automated weather stations are being utilized to collect these data at a number of sites in North Dakot. At present, data summaries are directly available from the branch stations that possess these stations. As user demand increases, the data files will likely become more widely available from host computers that users can electronically access with their personal microcomputers.

Microcomputer software has been developed for irrigation scheduling. This software is available on floppy disk for a nominal handling charge from the Agricultural Engineering Department, North Dakota State University.

As microprocessor technology applications continue to be developed, it is highly likely that on-site irrigation scheduling and system management systems will become commonplace. These systems offer tremendous potential for the effective implementation of irrigation technology advancements. Future developments may well include the concepts of Expert Systems (also called artificial intelligence) technology to provide automated management capability in irrigation scheduling, crop nutrition, and pest control.

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90-day weights by 7 pounds and pounds of lamb produced per ewe lambing by 24 pounds. Death loss has decreased from 25 percent to 13 percent. The North Dakota Swine Testing Program is in its initial years of utilization and progress cannot be truly evaluated yet.

Computer technology has enabled workable scientific record programs to be developed for livestock producers which provide information that when properly utilized can improve production efficiency and enterprise income. Both commercial and seedstock producers can benefit from performance records.

The current level of production and quality in a herd (flock) should be documented at the beginning of performance testing and goals for future performance should be set. Goals should reflect changes in production and quality which individual producers consider necessary to establish the most profitable system based on the conditions imposed within their own operation. Whether performance records are simple or complex, computers help in their evaluation and use.

Some may say that they do not understand and therefore do not trust all of the new computer technology being used in the livestock record programs. However, most don't question the high technology that went into the development of the seedcorn they utilize. Does anyone really need to know any more about the livestock performance testing programs than that they are the most accurate evaluation method that is practical to use today? Or that they are formulated using all of the best genetic research as the base? Hopefully producers will trust, like so many other things in our modern-day lives, the ability of the programs to do what they are developed to do without understanding all the details within the programs.

Each producer has the right to choose what he wants to do and how much of what he wants to do, but making **real** genetic improvement requires measuring traits by performance records. Decisions made today are consequences tomorrow.

Through the use of computers, the late 1980s and the 1990s offer possibilities for genetic improvement not previously seen. The challenge to livestock producers will be to use and incorporate the available modern computer technology in a manner which is both cost effective and genetically sound.

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