DEVELOPMENT OF IRRIGATION SCHEDULING AT THE WHOLE FARM LEVEL

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ABSTRACT

The average cotton farmer in the Mid-South works with large numbers of fields. Different crops, soil types, and planting times complicate irrigation scheduling at the whole farm level. This is probably the main reason why many farmers still do not use the irrigation scheduling tools. Results of irrigation scheduling in different counties in Arkansas during the last five years show that a developed potential evapotranspiration (PET)-based irrigation scheduler is an effective at the whole farm level. Main tools of this method are evapotranspiration (ET) and rain gauges. Comparison different ET tools shows that the atmometer is better suited to farm irrigation scheduling purposes in terms of price, accuracy of data, easy installation, and monitoring. PET data of different atmometers installed in the same place may differ by 1.69 % from the average PET during a three-month period. Evaluating a water deficit level of the particular field is very important. Soil type, tillage system and field configuration may affect the water deficit level of the field. The field water deficit method helps to evaluate the soil moisture level between irrigation or rainfall intervals and to determine the next irrigation time.

INTRODUCTION

Irrigation is one of the main farm operations in maximizing crop yield. Irrigation practices have sharply changed since the sensor base remote sensing technology began offer new opportunities in measuring soil moisture, canopy temperature, and ET. Irrigation scheduling experiments in drip, furrow and pivot irrigation systems shows that soil moisture sensors, wireless internet connections, and scheduling tools have worked satisfactorily in experimental fields and in research stations where the number of fields is just a few. However, irrigation scheduling in whole farm level is different due to different conditions. The average cotton farmer in the Mid-South works with large number of fields, sometimes more than one hundred fields. Each field is divided into several irrigation sections. There are different, at least three soil types, two or more crops, and planting times. All of these factors complicate irrigation scheduling at the whole farm level. This is probably the main reason why many farmers still do not use irrigation scheduling tools. Finding an effective solution to this issue can help farmers to save water and energy resources by applying irrigation scheduling at the whole farm level.

According to the “Cotton Farming” magazine web poll, 86 % of respondents named drought as the main factor that had the most influence on the crop yield and quality potential in 2011. Another poll shows 62 % farmers prefer to increase irrigation acreages

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and 38 % of them prefer to improve drainage. Nevertheless, a very small percentage of farmers use irrigation scheduling methods today. Recommended scheduling tools are expensive, require a lots of field data and input them in the calculation tables. Therefore, creating simple, easy to use and inexpensive irrigation scheduling method is an important task.

MATERIALS AND METHODS

Irrigation scientists and farmers use several irrigation scheduling methods. One of them is based in field water balance. According to this method irrigation water and rainfall, supplied to the field, should be equal to or greater than evapotranspirated, deep percolated, and runoff water during the irrigation season. It is difficult to measure deep percolation and runoff water properly. ET is measured by different tools such as standard evaporation pans, weather stations, and atmometer or ET gauges. Some methods are based on calculating ET depending on air temperature for the particular months of the year.

Second option of the irrigation scheduling is based on measuring or monitoring soil moisture. By observing ground by hand push probe or kicking, we are in reality testing and evaluating the soil moisture. Soil moisture more exactly may calculated also by the gravimetric method. Sensor based soil moisture measuring tools improved irrigation scheduling methods. Industry supplies gypsum blocks, electrical and electromagnetic conductivity soil moisture sensors that could be used in irrigation scheduling.

Another irrigation scheduling option is based on observing plant development that may help to evaluating plant water stress. Plant observing, measuring canopy temperature or leaf water potential measurements give the information that could be used in irrigation scheduling.

According to the field water balance or check book method, the amount of existing and incoming water in the field should be equal to the amount of outgoing water. Existing water consists soil moisture which is depends on field water capacity. Incoming water includes rainfalls and irrigation water. Outgoing water includes ET, infiltration and runoff water. ET calculated through PET, which is maximum possible ET in sufficient available water source conditions: ET=PET*C, here C is crop coefficient. PET calculated by weather station data, standard evaporation pan, and atmometer readings. Accuracy of atmometers' readings found by comparing PET data all of these tools and group of atmometers installed in the same place of the field. We observing PET for a 24-hour period during the two months: Atmometers' data was taken at 7 AM, 1 PM and 7 PM. This allows compare PET differences during the morning, afternoon and night hours.

Irrigation water amounts were measured by the flow meters. Soil moisture in the fields was monitored by EC-5 Decagon soil moisture sensors, installed at 6 and 12 inches depths and also by gravimetric method. To determine the effective scheme of atmometers' and rain gauges' installation in the farmlands, 9 atmometers and 15 rain gauges, including 5 digital rain gauges, were installed in the fields of McClendon's farm, Lee County AR in 2010 (Figure 1). They covered about 10000 acres of cotton fields with maximum distance between atmometers is about 10 miles.

Arkansas irrigation scheduling program and UGA Easy Pan are used according producers' instructions. Arkansas irrigation scheduler program needs daily entering temperature data and rainfall amounts, choosing recommended water deficit level depending on planting date, crop and soil type.

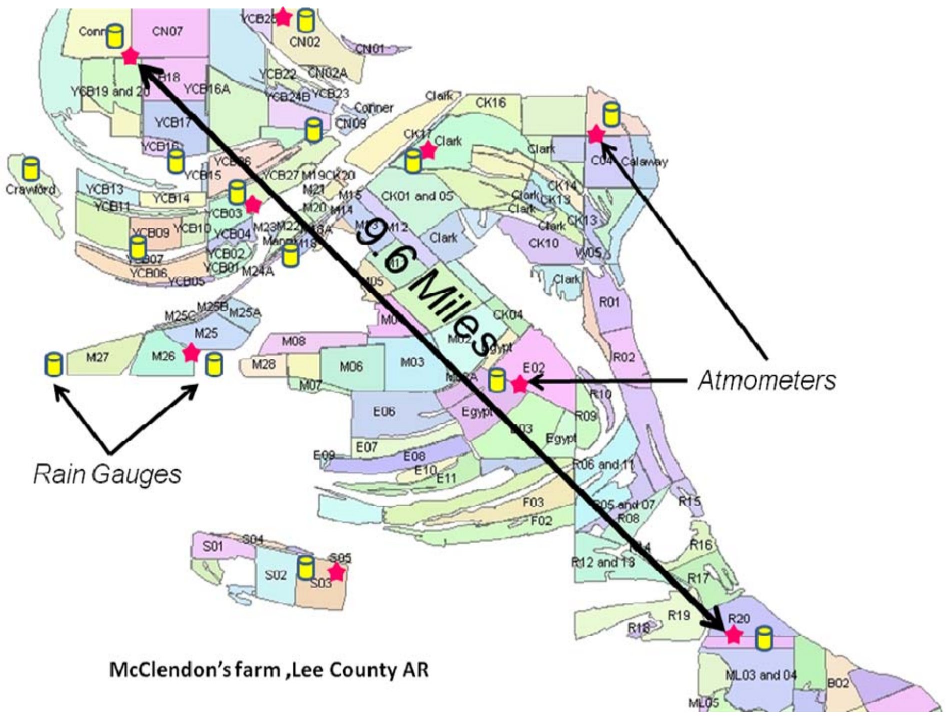

Figure 1. Map of installation atmometers and rain gauges

RESULTS AND DISCUSSION

The weather history in Marianna AR, during the last 50 years shows that yearly precipitation has varied from 32.7 to 73.5 inches. The ratio of maximum to minimum precipitations is 2.2. Summer precipitation differs more sharply; the same ratio here is more than 5. This means that summer rainfall may change many times from year to year. Summer precipitation trend almost is not changing for during the 50 years period. But in last 15-20 year period it has decreased significantly. Yearly precipitation trend has slightly decreased. Records show that now we have about an inch less precipitation than we had 50 years ago. The heat unit's accumulation during the summer time has increased in observing period. The trend of summer heat units has increased to 110 units in the last 50 years. This may be effect of global warming or result in local weather changing cycles. The fact is that weather is changing and we are getting hotter and drier summers.

How do farmers schedule irrigation? The survey provided by Cotton Incorporated shows that the majority of farmers schedule their irrigation by visual assessment. Just a few of them use irrigation monitoring tools.

We divided the irrigation options into four categories:

1. Farmer's experience
    - Visual assessment,
    - Weekly scheduling,
    - Taking cue from the neighboring farmers.
2. Monitoring soil moisture
    - Hand push probes,
    - Gravimetric method,
    - Tensiometers or Gypsum blocks,
    - Soil electric or electromagnetic conductivity sensors,
3. Monitoring plant development or crop appearance
    - Plant response to water deficit: plant height, width, biomass, color,
    - Leaf water potential: color or thickness,
    - Canopy temperature.
4. Field water balance or check book method
    - U of A Irrigation Scheduler,
    - UGA Easy Pan Irrigation Scheduler,
    - Using weather motoring tools: weather station, atmometer, and standard evaporation pan.

The first category is based on the farmer's experience. Many farmers use calendar-based irrigation scheduling or simply take their cue from the neighboring farmers. The second option is based on soil moisture monitoring. This ranges from simple ways of soil moisture measuring to sensor-based monitoring with wireless internet connections. This is one perspective of irrigation scheduling option, but is complicated at the whole farm level due to the large number of fields, sections, planting times, and crop and soil types. We may say the same thing about the third irrigation scheduling option, which is based on monitoring plant or crop appearance depending on water deficit. The fourth category of irrigation scheduling options is based on field water balance or the checkbook method. University of Arkansas irrigation scheduler program and UGA Easy Pan irrigation scheduler are based on this method. Field water balance method needs measuring PET by several tools like as weather station, atmometer, and standard evaporations pan.

We cannot exactly measure infiltrating and runoff water for the particular field of the farm. However, we may exactly measure or monitor ET through PET and crop coefficients. We can determine PET from weather station data, standard evaporation pan, and atmometer readings. Our experiments show that PET data found by these tools are close to each other, so we can use all of them in irrigation scheduling. 2011 field experiments show that PET data from the atmometer and weather station are similar even for long term usage during three months. Experiments also show that UGA Easy Pan PET data are also similar with weather station and atmometr's data for short term usage: during 10-15 days.

PET data from four atmometers installed in the same place of the field differ by just 1.69 % from the average PET data in a three-month period. These shows that atmometers are can give PET data with a sufficient accuracy for irrigation scheduling. A comparison of prices shows that the atmometer is better suited to farm irrigation scheduling purposes in terms of price, accuracy of data, easy installation, and monitoring.

Solar radiation causes PET. The Earth receives 340 W/m^2 of solar energy. Just less than half of this incoming solar radiation reaches the surface of the Earth. Half of this energy, or a quarter of the solar energy, is lost on evaporation. Consequently the evaporation and transpiration - ET is the main process that consumes solar energy. It plays a tremendous role in balancing Earth's surface temperature. Theoretically ET should be equal in the same parallels of the Earth. We compared PET in different parts of Arkansas about 135 miles apart from each other. Results show that the shapes of PET curves are similar for different parts of the state. If we put them on the same time table, then we can see just a little difference, probably due to local weather conditions—cloudy days, rainfall and temperature. For example, PET difference between Pine Bluff AR and Marianna AR is just 2 inches during the two months. It is interesting to note that PET in Pine Bluff was less than in Marianna or Edmondson even though Pine Bluff is more southerly than Marianna or Edmondson.

PET for a 24-hour period show (Figure 2) that PET mainly occurs in the daytime (92 %) versus nighttime (8 %). PET during the morning hours is less than in the afternoon hours. This is the reason why we may prefer night time irrigation, for example, with pivot irrigation systems to save significant irrigation water.

Is there a relation between ET and soil moisture? To determine this we compared the field water balance and soil moisture graphs. The field water balance includes infiltrated and runoff water. The field water balance and soil moisture curves are almost similar and parallel between irrigations and rainfalls. This shows that through field water balance or water deficit graphs we may evaluate soil moisture content between irrigations.

We recommend using irrigation notebook that helps better manage the farm irrigation. All field information, including the scheme of the irrigation sections and their watering times will be recorded in this notebook. To simplify the irrigation method we recommend creating a single irrigation table for the whole farm. The actual water deficit and irrigation events of the each field of the farm are represented with the two columns in this table. Actual water deficit is determined through the daily ET, crop coefficient and rainfall data. The water deficit level was chosen for each field depending on soil type, field configuration, and irrigation method. Pivot irrigation systems have less water deficit level than furrow irrigation. Every furrow irrigation method has more water deficit level than every other furrow irrigation.

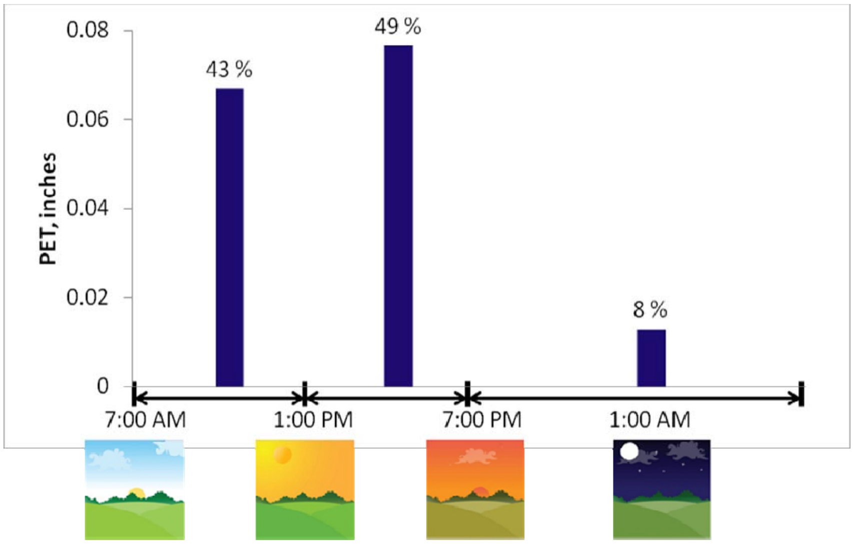

Figure 2. PET during the day.

Example of evaluating different irrigation scheduling options by the field water balance method is given in Figure 3. Rainfalls are shown as blue columns and irrigation events are shown as green columns in the diagrams. Soil type is silt loam and water deficit recommendation is 2.5 inches. The farmer six times irrigated this field in 2011. As seen from the graphs that the water deficit level is around an inch between second and third, third and fourth, and fifth and sixth irrigation events. This means that the soil was still wet before the next irrigation event in these intervals and therefore water use efficiency is low. Arkansas irrigation scheduler program recommends four irrigations for this field. However actual water deficit reaches more than 4 inches level between the first and second irrigations. Field water balance method based on actual atmomer's ET data recommends five irrigation events for this field. The distribution of irrigation events keeps the water deficit or soil moisture always at a uniform level that improves the plant development and water use efficiency.

ET readings of the atmometers show that difference between outlying atmometers is 1.29 inches and closest ones 0.56 inches in the end of the season. The statistical average of daily ET is 0.25 inches, this means that possible error from using remote atmometers may 5 days 3 hours. Therefore we may conclude that it is effective install at least one atmometer in 5 miles farmland distance. We recommend installing two atmometers for average farmer in Arkansas.

Rain gauge data are very different even for close fields. Even a small amount of rainfall may change the irrigation schedule. Results show that rainfall differences of the fields located more than three miles apart are significant. We recommend install one rain gauge in 3 miles distance in middle Arkansas area.

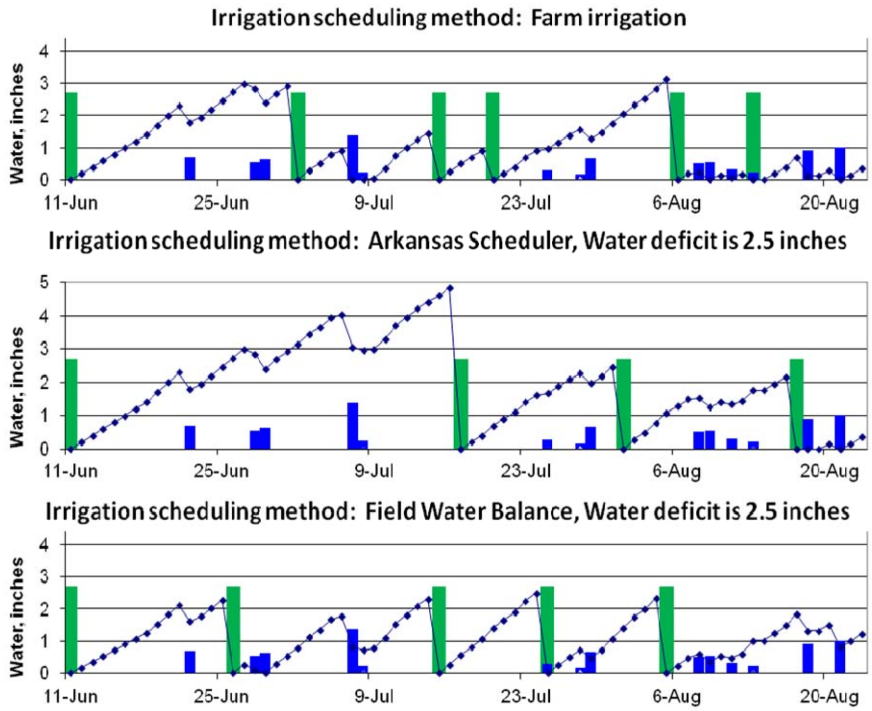

Figure 1. Results of different irrigation scheduling options.

CONCLUSION

The existence of large numbers of fields and dividing them into several irrigation sections, different crops, planting times, and soil types are complicating the use of the irrigation scheduling tools at the whole farm level.

The weather history in Marianna, AR, shows that the summer heat unit accumulations trend has increased about 110 units and yearly precipitation trend has decreased about an inch during the last 50 years.

PET data from weather stations, standard evaporation pan, and atmometers are similar. The atmometer is better suited to farm irrigation scheduling purposes in terms of price, accuracy of data, easy installation, and monitoring. PET data of different atmometers installed in the same place may differ by 1.69 % from the average PET during a three-month period. Experiments show that at least one ET gauge in 5 miles and one rain gauge in 3 miles will be effective in weather conditions in Middle Arkansas.

Field water balance or water deficit method helps to evaluate the soil moisture level between irrigation or rainfall intervals and helps to determine the next irrigation time for the field with given water deficit or capacity levels.

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