Irrigation Management of Corn on the Delmarva Peninsula: A 2005 Case Study from New Castle County, Delaware

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Research Question

Rainfall during the crop season in the mid-Atlantic region of the United States is usually sufficient to produce a corn crop, but obtaining maximum yield often requires supplemental irrigation. Even when total rainfall during the season is sufficient to meet crop water requirements, it may be poorly distributed in amount and timing. Periods of drought during which rainfall is not sufficient to maintain soil water content within the desired range are common. These periods of drought are exacerbated by the low water holding capacity of the sandy soils that predominate in the coastal portions of the region. Irrigation management is a challenge under such conditions.

Center-pivot is the predominant irrigation method in the region. The irrigation amount is a function of travel speed (which is controlled by the "percentage timer") and the flow rate, which in turn is determined by the sprinkler package. When a system is purchased, the dealer will provide a chart with irrigation amounts at various timer settings. Over time, this chart may no longer be available, or may not reflect changes to the system such as sprinkler wear or replacement. Good irrigation management with a center-pivot requires knowledge of:

- The performance of the center-pivot in terms the depth of irrigation water applied over the range of travel speeds, and the uniformity of water application.
- The depth of irrigation water necessary to prevent crop moisture stress from occurring before the next irrigation without exceeding soil water holding capacity in the root zone.

The question posed in this study was whether the combination of an irrigation system evaluation and the use of a simple spreadsheet to estimate soil water content using daily weather information are tools that growers would use to improve their irrigation management.

Literature Summary

The American Society of Agricultural and Biological Engineers (ASABE) has published a standard for evaluating center-pivots, based on using catch cans to measure area weighted irrigation amount and uniformity.

One approach to irrigation management is to estimate water content in the root zone using the "check book" method, which accounts for additions (primarily rain and irrigation) and withdrawals (crop water use, evaporation, and drainage). Reference evapotranspiration (ET_0) is the water use of a standard vegetated surface such as clipped grass. It can be estimated using weather measurements. Crop water use and evaporation (or evapotranspiration, ET) can be estimated by multiplying ET_0 by coefficients specific to a particular crop (k_c), wetness of the soil surface and degree of crop cover (k_e) and degree of crop water stress (k_s). The international standard reference for estimating ET_0 is FAO Publication 56 (Allen, et al. 1998), which includes a simple spreadsheet model to implement the checkbook method for irrigation scheduling.

Study Description

To help provide the information needed for good irrigation management, the Natural Resources Conservation Service (NRCS) and the University of Delaware (UD) have initiated a cooperative program for producers that includes an irrigation system evaluation and a checkbook spreadsheet based on FAO Publication 56 modified for easier use and interpretation.

The user enters initial information such as water holding capacity, planting date, and crop into the spreadsheet for a particular field. Daily values of ET_0 are entered (obtained from the UD website www.rec.udel.edu/irrig/MONTHirt.HTM) for the closest automatic weather station. Daily rainfall amounts, ideally from an on-site rain gauge, are also entered. Daily crop water use is calculated using ET_0 and a crop coefficient that is automatically estimated by the program. If measured, or known values, of soil water content are available for any given date during the growing season, they can be entered to correct the estimated soil water content. For example, after a sufficiently large rainfall, soil water content on the following day will likely be at field capacity. For days when irrigation occurs, the irrigation amount and the percentage timer setting are also entered.

The spreadsheet graphically displays soil water content for the current day and previous two weeks, and allows users to see the effect of irrigation or rainfall on soil water content during the following week (Figure 1). From this graphic display a grower can evaluate the past impact of weather and irrigation patterns on available soil moisture and view the projected trend for the coming week. The critical period for corn begins as early as the V-5 or fifth true leaf stage (5 leaf collars visible) but stress is especially damaging just prior to tassel emergence through the soft dough stage. Any water stress during this period can reduce grain yield significantly. To minimize yield losses due to moisture stress, irrigation should occur before available soil moisture falls below the predetermined amount (50% in this case) by the time it will take the irrigation system to complete the irrigation on the entire field.

Irrigation system evaluations were conducted using catch cans following the method recommended by the ASABE. In this standard, two radial lines of cans are used to measure the irrigation amount after the center-pivot has completely passed over them. We used fabricated catch cans and installed them at a 10 ft spacing. The lines extended the length of the center-pivot (except the first span) and, where possible, beyond to the area covered by the end gun. Relevant parameters were recorded for each evaluation; including the GPS coordinates, the percentage timer setting, wind speed and temperature, and the operating pressure and the supplier's chart of timer setting vs. irrigation amount where available.

Seven producers recorded their irrigation management on corn fields using the spreadsheet. One producer did not irrigate at all. The irrigation systems on four of the fields were evaluated prior to the season. The results were used to determine the irrigation amount applied at the recorded percentage timer settings.

Applied Questions

How successful was the method when used by farmers?

Figure 2 (a, b and c) show ET_0 and rainfall for the 70 day period from 01 June to 08 August 2005, after which there were a number of days that weather data

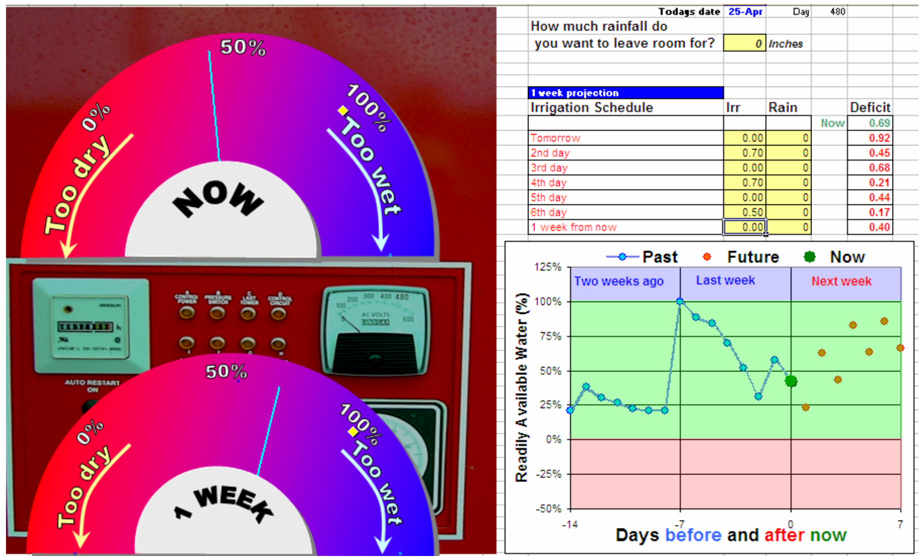

Figure 1. Example page from the irrigation scheduling spreadsheet. The left top shows a gauge indicating current estimated soil water content, relative to the readily available water content for the particular soil. 100% is field capacity, and 0% is the lower limit of readily available water. The gauge at bottom left shows the same information projected forwards one week based on ET assumptions and rain and irrigation entered in the irrigation schedule table (top right). Also at the top right is projected soil water deficit (irrigation required to increase soil moisture to field capacity). The graph (bottom right) gives the two week history of estimated soil water content, and the projections for the coming week. The green shaded area represents the desired range of soil water content.

were not available. However, most of the season is included in the available data. Figure 2a shows daily rainfall, figure 2b shows daily ET_0, and figure 2c cumulative rainfall and ET_0 during this period. It was relatively dry during the first half of this period (high ET_0 and low rainfall), and relatively wet during the second half (low ET_0 and high rainfall).

Figure 3 shows the percentage timer settings, from 01 June until 31 August used by each of the 6 farmers who irrigated. The number of irrigations ranged from 2 to 9. The top four graphs also show the cumulative irrigation amount estimated from the irrigation system evaluations completed on these fields. Three of these four fields each received 9 irrigations, with total irrigation amounts between 2.5 and 3 inches. Each irrigation was in the range 0.25 to 0.38 inches. Yields on these three fields, as reported by the producers, ranged from 220 to 240 bushels/acre. The remaining field on which the irrigation system was evaluated received 1.2 inches in two irrigations of 0.6 inches each. However, this field was not typical in that it was planted late (at the end of May) with a short season variety that yielded less than 150 bushels/acre.

This sample of producers operated their irrigation systems at only one or two timer settings and varied the frequency of irrigation. The irrigation amounts were relatively small. If all the irrigation water recharged the root zone, it would typically be sufficient to meet ET for about 2 days, less if the weather was hot, dry and windy. However, not all the irrigation will effectively recharge the root zone because some of it will be intercepted by the plant canopy and subsequently evaporate. The relative importance of this interception increases as the irrigation amount decreases.

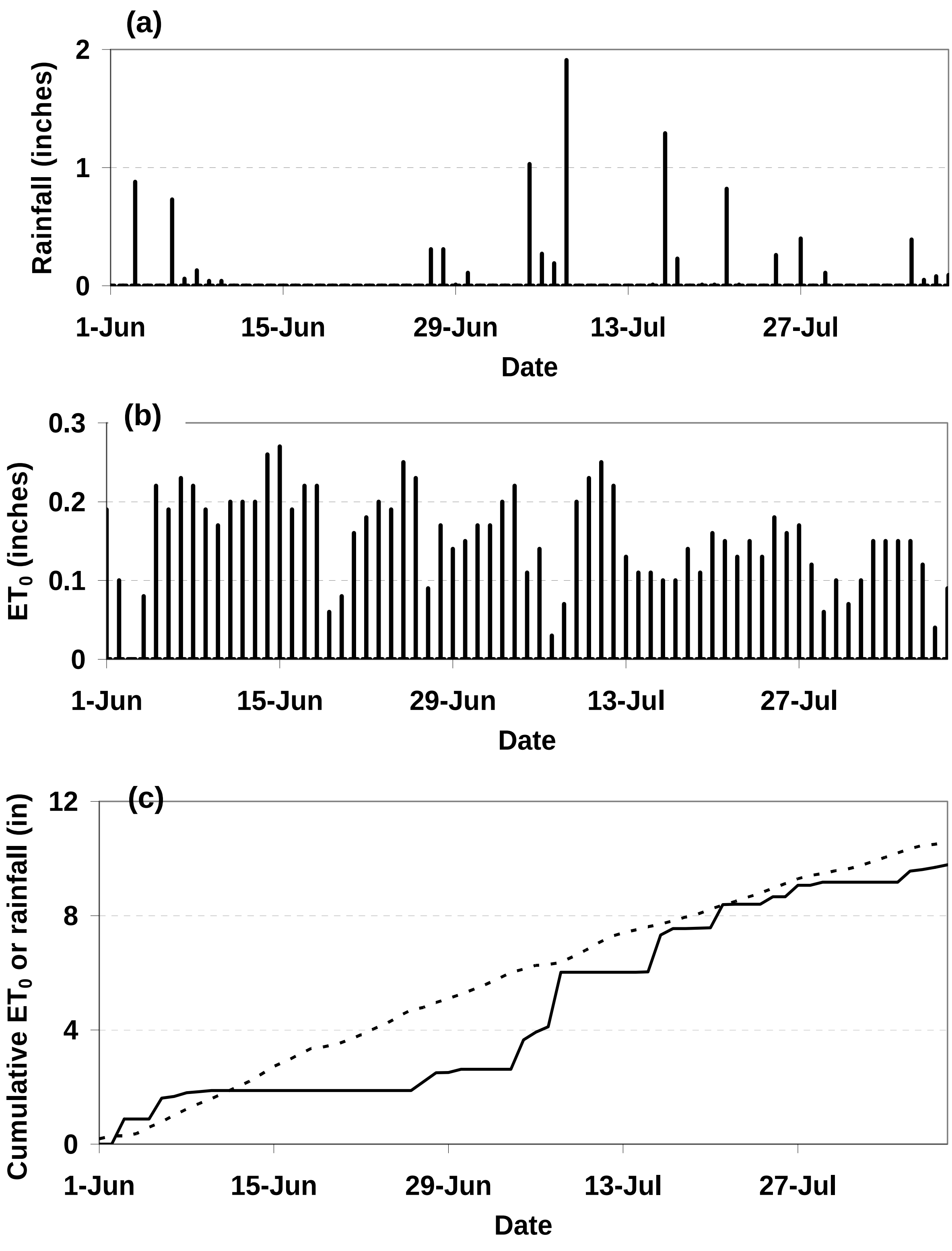

Figure 2. Daily rainfall (a), ET_0 (b), and cumulative rainfall and ET_0 (c) for the 70 day period beginning 01 June 2005, from the University of Delaware weather station at Townsend, New Castle County, DE.

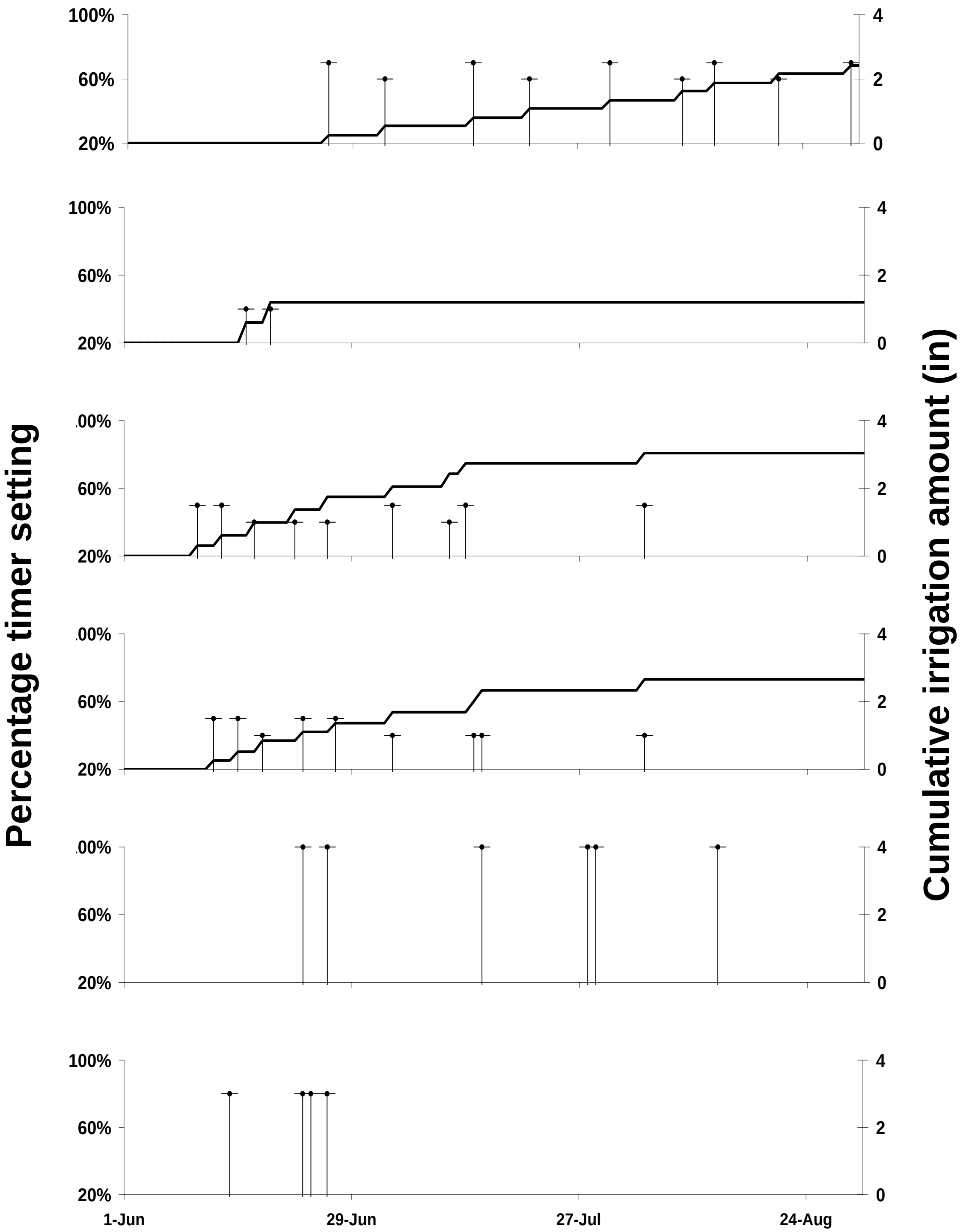

Figure 3. Irrigation management reported by six producers. The vertical lines indicate the center-pivot percentage timer settings (left axis) The right axis shows the cumulative irrigation amount using data from system evaluations where available (top 4 graphs).

The water inputs (rainfall plus irrigation) from the first irrigation until 08 August are in the same range as the total ET_0 during the same period for the four producers whose irrigation systems were evaluated. This approximate balance, however, does not consider non-effective irrigation or rainfall and the fact that actual water use by the corn crop will likely be higher than ET_0.

Compared with many of the sandy soils in coastal areas of the Mid-Atlantic region, the water holding capacity of the soil in New Castle County is relatively high, allowing larger irrigations without deep percolation. However, the maximum irrigation amount as compared with sandier soils may be limited by the infiltration rate of the soil. Further investigation would be needed to determine if runoff under higher irrigation amounts would occur. Larger irrigations may be more effective in that proportionately more water would enter the soil, but at the same time higher soil water content before a rainfall event would mean less effective "space" within the root zone to store and fully utilize rainfall.

A benefit of irrigation scheduling such as required by this program is that soil water measurements must be made periodically. While it is unlikely that growers will purchase expensive instruments to make the measurements, it should encourage them to make more measurements than they might have otherwise, even if the measurements are only made by visual inspection and feel. Some consultants have shown interest in this program, and they may have the resources to use it effectively.

Is good irrigation management important in areas with significant rainfall during the season?

In years with adequate and well distributed rainfall, total irrigation amounts are relatively low, as in 2005. However in a dry year, such as last occurred in 2002, optimal crop water use is high and rainfall is low. This requires substantial irrigation, considerably more than was applied in 2005. An irrigation scheduling tool such as the spreadsheet used in this study would enable growers to develop better irrigation strategies by showing estimated soil water trends over time. Some growers may be unable to keep up with crop water requirements because of inadequate system capacity, while others may have the capacity to irrigate at the best time and so may be able to eliminate or reduce a number of applications. Irrigation costs money in terms of pumping costs and increased wear and tear on equipment, and poor irrigation management can have an impact on associated costs such as nitrogen. As energy and related costs rise it will become even more important to manage irrigation well.

Will growers use a spreadsheet to aid in irrigation scheduling?

Growers in New Castle County, Delaware, successfully used the supplied spreadsheet and the web-generated data to assist in their irrigation management. Because of the amount of rainfall received during the growing season, not all producers reached critical soil water content values at which irrigation was required.

Recommendations

The producers in this relatively small sample seemed to manage irrigation reasonably well. However, 2005 was not a challenging year for irrigation management. A dry year with high irrigation requirements and some additional irrigation system evaluations would enable a more complete assessment. As the costs of energy and energy based inputs such as fertilizer continue to increase, the value of good irrigation management will increase. The ability to use nearby automated weather station data and a spreadsheet that can graphically represent the potential crop need for irrigation will be beneficial for irrigation managers.

References

Allen, R. G., et al. 1998. Crop evapotranspiration - guidelines for computing crop water requirements, FAO Irrigation and drainage paper 56. Food and Agriculture Organization of the United Nations, Rome, Italy.