Evaluation of Colorado Irrigation Scheduler (CIS) for Furrow-Irrigated Corn in Northeast Colorado

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Introduction

Irrigation scheduling depends on answering the two main questions of when and how much water to apply to the crops. Irrigation scheduling is an important management tool because it is used to increase the efficiency of water usage and reduce runoff or deep percolation during the irrigation season (Pereira et al., 2002). Crop water requirements are fundamental to irrigation scheduling. Excessive irrigation which exceeds crop water requirement can lead to negative impacts on soil, crops and the environment (Stockle, 2002). Over irrigation can have a negative effect on root respiration (Maier and Kress, 2000), and contributes to rising water tables, which ascend to the surface by capillary action (Sophocleous, 2002). This is one of the main causes of soil salinity (Rengasamy, 2006). Deep percolation is the result of heavy irrigation and can lead to groundwater pollution by leaching chemical nutrients beyond the root zone (Mmolawa and Or, 2000). In addition to that, excessive irrigation can lead to an increase in the amount of runoff, and this has a significant impact on soil erosion, which also has a negative effect on the soil environment (Pimentel, 2006). Information on crop ET rates combined with knowledge of local weather, soil, and crop conditions can be used to determine irrigation amounts and scheduling. A local irrigation scheduling tool that keeps track of the soil water balance and required irrigation amounts throughout the growing season can help irrigators keep track of water requirements and make more efficient use of their limited water supplies. The objectives of this study were:

(1) Field test and evaluate the accuracy of an irrigation scheduling spreadsheet tool for calculating soil water deficits (D) in a furrow-irrigated corn (*Zea mays* L) field located near Greeley, Colorado during years 2010, 2011 and 2012.

(2) Determine the effect of frequency of mid-season corrections of D on the accuracy of the irrigation scheduler.

Materials and Methods

Field Site

The furrow-irrigated field was located 40° 26' 42.93" North, 104° 38' 4.76" West near Greeley, CO; adjacent to the Limited Irrigation Research Farm (LIRF; USDA and CSU). A corn crop was grown in 2010, 2011 and 2012 with a row-spacing of 30 cm. Furrow irrigation was applied using gated pipe with water coming from a groundwater well (electric pump). Gross irrigations applied to the field were measured using a flow meter installed after the pump outlet. Weekly measurements were taken of gravimetric soil water content (SWC; 15-cm increments down to 105 cm), leaf number and leaf area of 2 representative plants, and crop height. Gravimetric SWC values were converted to volumetric SWC using measured soil bulk density of each layer. The farm has an automated weather station (Colorado Agricultural Meteorological Network; CoAgMet GLY04 station) that recorded hourly solar radiation (MJ m^{-2}), air temperature (°C), relative humidity (%), mean wind speed (m s^{-1}) at 2.0 m height, and precipitation (mm).

Colorado Irrigation Scheduler

The Colorado Irrigation Scheduler (CIS) for annual crops was developed in Microsoft Excel using Visual Basic for Applications (Gleason, 2013). It was used to calculate the daily soil water deficit (D, difference between field capacity and actual SWC) of the corn root zone (105 cm). The CIS calculated daily D (mm) as: $D_i = D_{i-1} + ET_c - P - Irr$, where i represents the current day, i-1 represents the previous day, ET_c is crop evapotranspiration (mm), P is precipitation (mm), and Irr is net irrigation (mm). The D_i was set equal to zero whenever it became negative. Negative D_i values meant that water additions (P + Irr) exceeded lasses ($D_{i-1} + ET_c$), and the soil was at field capacity. ET_c and P were obtained from CoAgMet while Irr values were inputted according to actual amounts. Irrigations are recommended when D_i approaches or exceeds a specified management allowed depletion (MAD).

CIS Evaluation

For each growing season (2010-2012), planting date, emergence date, initial SWC, available water capacity, and actual Irr were inputted into CIS. Hourly weather data from CoAgMet GLY04 station were used to calculate alfalfa reference crop ET (ET_r) using the standardized Penman-Monteith equation (ASCE-EWRI, 2005). Daily corn ET_c was calculated from ET_r and a corn crop coefficient (K_{cr}) curve developed for northeast Colorado (Gleason, 2013). A soil water stress coefficient (K_s, Allen et al., 1998) was used to reduce ET_c under stress conditions. The calculated D_i values from the CIS were compared to measured values on measurement dates. Root mean square error (RMSE) and the index of agreement (d) were used to quantify CIS accuracy. Also, the CIS D_i was corrected at different time intervals during the growing season to determine the effect of mid-season corrections on accuracy.

Results and Discussion

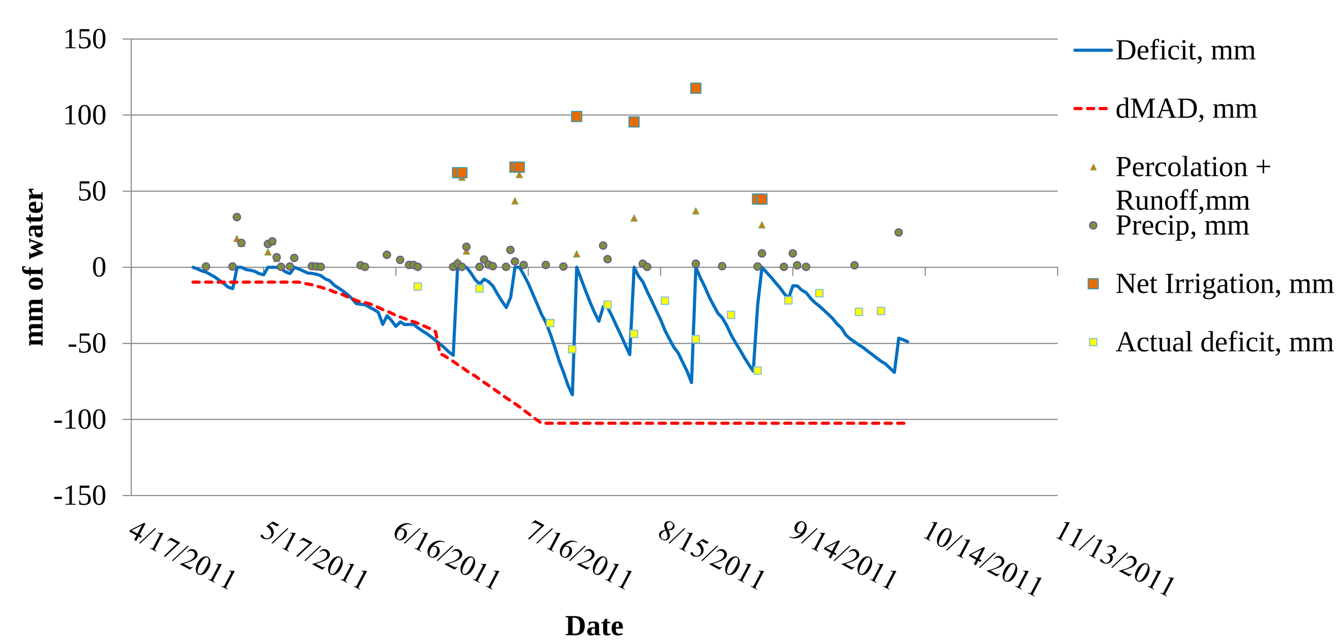

Figure 1: Simulated deficit (D) for a corn field near Greeley, CO using weekly observed D and daily climate data in 2011.

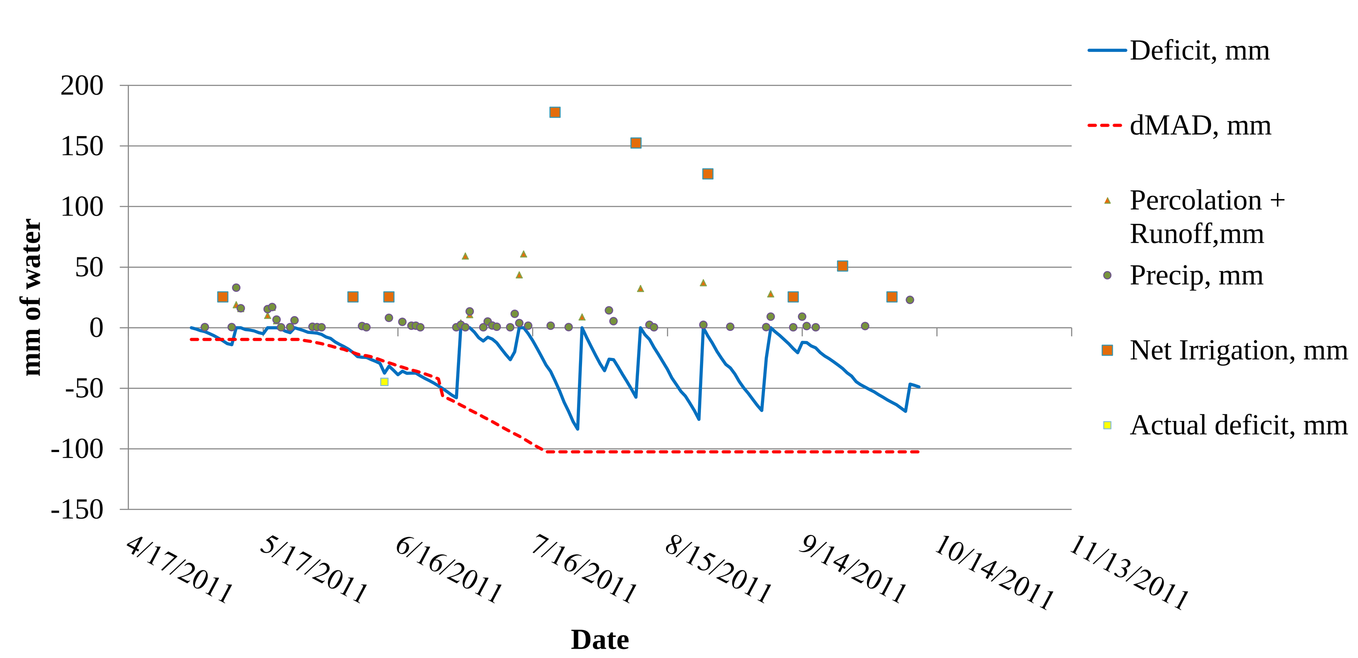

Figure 2: Simulated D for a corn field near Greeley, CO using only one initial observed D and daily climate data in 2011.

Table 1. Comparison of calculated and actual deficits (D) using bi-weekly, monthly and once per season (only initial D) inputs of actual D for the years 2010, 2011 and 2012.

Times	Bi-weekly			Monthly			Once per Season		
Year	2010	2011	2012	2010	2011	2012	2010	2011	2012
RMSE	0.81	0.27	2.55	3.08	2.80	6.69	3.74	2.65	6.32
Index of Agreement (d)	0.96	0.99	0.70	0.72	0.43	0.63	0.65	0.43	0.32
No. Obs.	8	8	8	12	11	12	16	14	16

Table 2. Comparison of actual and simulated (with irrigation scheduling) total applied water for years 2010, 2011 and 2012.

Year	P, mm	Irr, mm	Simulated Irr, mm	Actual Irr + P mm	Simulated Irr + P mm	Difference between actual and simulated Irr + P mm
2010	167	1285	521	1452	687	765
2011	228	1096	569	1324	797	527
2012	131	787	718	917	848	69

Conclusion

Soil water deficit estimated by the CIS was shown to effectively determine recommended amounts and timing of irrigation. The CIS model provided increasingly more accurate D_i estimates as mid-season corrections were increased from once, to monthly, and to bi-weekly inputs of observed D_i. Most values of the index of agreement between calculated and measured D_i were > 0.6 and showed that the model worked satisfactorily for furrow irrigation during most seasons. To get satisfactory results from the model, it is recommended to take mid-season measurements of D_i to occasionally correct the daily value calculated by CIS.

References

Allen R., Pereira L, Raes D and Smith M. 1998. Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. FAO, Rome.

ASCE-EWRI. 2005. The ASCE standardized reference evapotranspiration equation. Allen, R., Walter, I., Elliot, R., Howell, T., Itenfisu, D., and Jensen M. (Eds.). American Society of Civil Engineers Environmental and Water Resource Institute (ASCE-EWRI). 59 pp.

Gleason, D. J. 2013. Evapotranspiration-Based Irrigation Scheduling Tools for Use in Eastern Colorado (Master thesis, Colorado State University).

Maier, C. A. and L. Kress. 2000. Soil CO2 evolution and root respiration in 11 year-old loblolly pine (Pinus taeda) plantations as affected by moisture and nutrient availability. Canadian Journal of Forest Research 30(3): 347-359.

Mmolawa, K. and D. Or. 2000. Root zone solute dynamics under drip irrigation: A review. Plant and Soil 222(1-2): 163-190.

Pereira, L. S., Oweis, T. and Zairi, A. 2002. Irrigation management under water scarcity. Agricultural Water Management 57(3): 175-206.

Pimentel, D. 2006. Soil erosion: a food and environmental threat. Environment, development and sustainability 8(1): 119-137.

Rengasamy, P. 2006. World salinization with emphasis on Australia. Journal of Experimental Botany, 57(5), 1017-1023.

Sophocleous, M. 2002. Interactions between groundwater and surface water: the state of the science. Hydrogeology Journal 10(1): 52-67.

Stockle, C. O. 2002. Environmental impact of irrigation: a review. Washington DC: Washington State University.