International Conference on
WATER MANAGEMENT IN ARID AND SEMI-ARID LAND, 2017
7-10 October 2017, Irbid, Jordan.

Determination of Irrigation Depths using a Numerical Model and Weather Forecast

Haruyuk Fujimaki 1, Iwao Sakaguch 1, Vinay Nangia 2, Thieb Oweis 2
1Arid Land Research Center, Tottori University, Japan
2 International Center for Agricultural Research in the Dry Areas
Email: fujimaki@alrc.tottori-u.ac.jp

Abstract

Effect of a scheme of determining irrigation depth using numerical simulation for crop response to irrigation and weather forecast was tested for wheat cultivation in semi-arid region of Jordan. Drip irrigation system, monitoring system for change in soil water content, and three different treatments (numerically optimized irrigation with this methodology, automated irrigation using solenoid valve, and rainfed) were prepared for the field experiment. Results showed that incomes of the irrigated-treatments predominated over that of the rainfed, while net incomes of the irrigated-treatments were smaller than that of the rainfed. Discrepancy between the numerically simulated soil water content and the measured one appeared, that is, the numerical simulation model overestimated the change in actual soil water content. Both of the decrease in the net income of the numerically optimized irrigation and the overestimated soil water content would result from the underestimated plant properties (drought tolerance, root zone depth) included in the input parameters of the numerical simulation.

Keywords: irrigation depth, net income, dryland

1. Introduction

To enhance net income from limited water resources, Fujimaki et al. (2014) presented a scheme for determining irrigation depth using a numerical model of crop response to irrigation and quantitative weather forecast. To optimize each irrigation depth, a concept of virtual income, which is proportional to an increment in transpiration amount during an irrigation interval, was introduced. Several field experiments applying this methodology have been carried out, but further case studies to various situation (combinations of climate, soil, and crop) are still required for validation and improvement of this methodology. The purpose of this study was to verify the methodology for wheat cultivation in semi-arid region in which the effectiveness of the methodology was expected to be significant.

2. Materials and Method

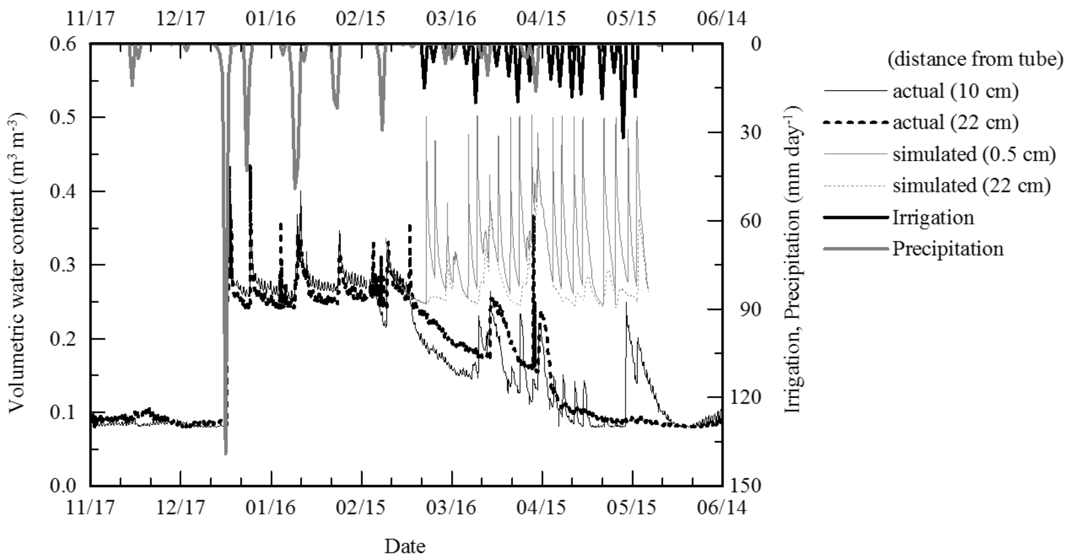

Figure 1 changes in soil water content of the treatment-S at the depth of 5 cm.

A field experiment was carried out in Mushaqar (31°46'N, 35°47'E), Jordan. Three experimental treatments were prepared: crop was grown with automated irrigation system (A), with the methodology we have presented (S), and with only rainfall (R). Each treatment had an area of 10 m length and 5 m width, and had two replicates. To monitor soil moisture, three WD-3-WET-5E probes were installed at depth of 15 cm for one of the treatment-A, and five 10HS probes were installed at locations of (distance from irrigation tube (cm), depth (cm)) = (5, 5), (22, 5), (10, 15), (0, 30), and (22, 30) for one of the treatment-S. Drip irrigation system with lateral distance of 50 cm and emitter distance of 20 cm was used. In the treatment-A, water was automatically supplied with a solenoid valve when volumetric water content reached as low as 0.25. Irrigation interval of the treatment-S was three or four days. Climatic data were measured with a monitoring system in the experimental field, and weather forecasts were downloaded from the website of AccuWeather.com (http://www.accumeather.com). Price of crop and water were set at 0.14 and 0.0002 \$ kg^{-1}, respectively.

A cultivar of wheat was sown on 16th November 2015. Because the stress response function of the crop was unidentified, assumed parameter values were used. Parameter values for root distribution and leaf area index were determined concerning the observation through growth measurement. Irrigation was terminated on 16th May 2016, and wheat was harvested on 15th June 2016.

3. Results and Discussion

Although mean annual precipitation of the place is 280 mm, it had 487 mm during the experimental period. Totally applied depth for treatment-A was 218 mm. Even though the trigger water content for the automated irrigation was approximately 0.25, water contents less than the trigger value were often observed during the irrigation period. This would be due to low pressure of water caused by the insufficient water level inside the reservoir tank of the irrigation water and unexpected delays of water supply for the tank.

Figure 1 shows the changes in soil water content at the depth of 5 cm of the treatment-S. Regarding to the horizontal distance from the irrigation tube, the simulated water content at 22 cm away from the irrigation tube was constantly smaller than that at 0.5 cm away from the tube, while the actual data did not show such trend at the depth. The simulation consistently over-estimated the water content and discrepancy widened with time. This might be due to underestimated root water uptake rate under high suction range.

Figure 2 compares the cost, net income for each treatment. The cost was calculated by multiplying total amount of irrigation water and the price of water. The net income was the difference between the income and the cost. Totally applied depth for treatment-S was 238 mm. The income was obtained from the averaged actual yield of each treatment (2.44 t ha^{-1} for R, 3.20 t ha^{-1} for A, and 3.94 t ha^{-1} for S) and the price of crop. The incomes of the irrigated-treatments predominated over that of the Rainfed, while the net incomes of the Rainfed was the highest. This might be caused by the unexpectedly large yield of the Rainfed possibly due to the abnormally large precipitation and underestimated drought tolerance and root growth in the numerical simulation.

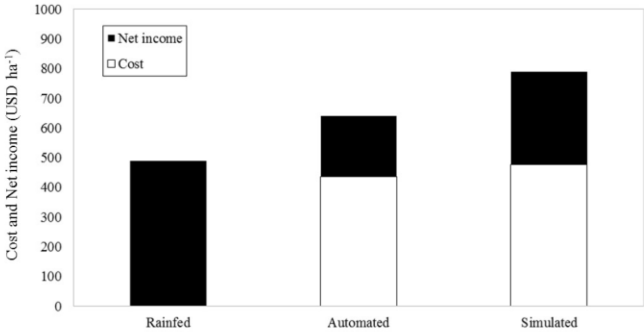

Figure 2. Cost and net income for each treatment.

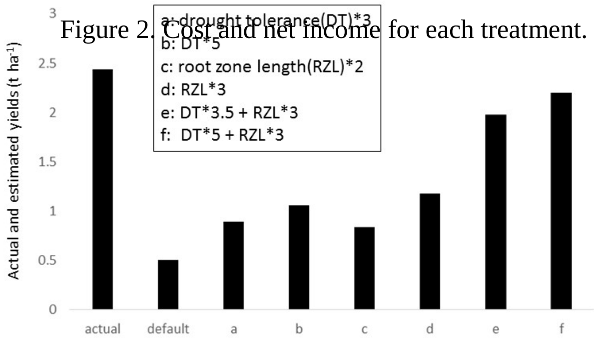

Figure 3. Actual and simulated yields using different parameter sets for treatment-R.

Figure 3 lists simulated yields using different parameter sets for treatment-R. Result from parameter sets used in the optimization was marked as “default” and it is clear that our simulation underestimated transpiration and growth under drought condition. Thus, we simulated water flow and yield at different rooting depth (refered as “RZL”) and h50 which is suction value at which root water uptake rate is halved from its potential rate (DT). When we used five-fold larger h50 and three-fold larger rooting depth, simulated yield matched with measured value.

4. Conclusion

Proper calibration of parameter values for stress response and plant growth functions is critical for the presented scheme.

References

1. Determination of irrigation depths using a numerical model and quantitative weather forecast and comparison with an experiment. Laj R. Ahuja, Series Editor, in Practical Applications of Agricultural System Models to Optimize the Use of Limited Water, Advances in Agricultural Systems Modeling, Vol. 5. (ISBN978-0-89118-343-3)4-1087.