Deficit Irrigation Reliability Analysis: Application of Constraint State Formulation and AFOSM

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Abstract:

Rainfall is the main source of uncertainty that affects irrigation scheduling. In response to this uncertainty, the first and the second moments of soil moisture and actual evapotranspiration are developed. The later moments is used in AFOSM analysis of the relative net benefit in deficit irrigation case. Also the moments of a proposed crop stress index are developed based on the Double-bounded density function method. The results indicate that the achievement higher portion of benefit, applying the deficit irrigation strategy and cropping area increasing, is not possible.

Research outline:

As an outline for this research, the seasonal crop-water production function by Jensen (1968) is discussed. Then the first and the second moments of soil moisture and first moment of actual evapotranspiration are presented, as developed by Ganji et al. (2006). In the following, a formulation for the second moment of the actual evapotranspiration is developed which will be used in AFOSM analysis of the relative net benefit in deficit irrigation case. Also the moments of a proposed crop stress index are developed based on the Double-bounded density function method. Finally, AFOSM is discussed and the overall results of the model is presented briefly.

Moment analysis:

To deal with the uncertainty in calculation of the relative yield and crop water demand, Ganji et al. (2006a) developed a stochastic optimization framework to incorporate the crop demand uncertainty in the irrigation scheduling problem. Their proposed method is modified to consider the randomness in irrigation policy by Ganji et al. (2006b). Their proposed methods are extended to estimate the ET's second moment in this paper, considering the randomness in irrigation policy for deficit irrigation. Also using the second-order Taylor series approximation method, expectations of equations for water stress's first and second moments was developed. As an example, the actual mean evapotranspiration which is determined based on the developed moment of the actual evapotranspiration for different weeks during the growing season, is compared with simulation results in Figure 1

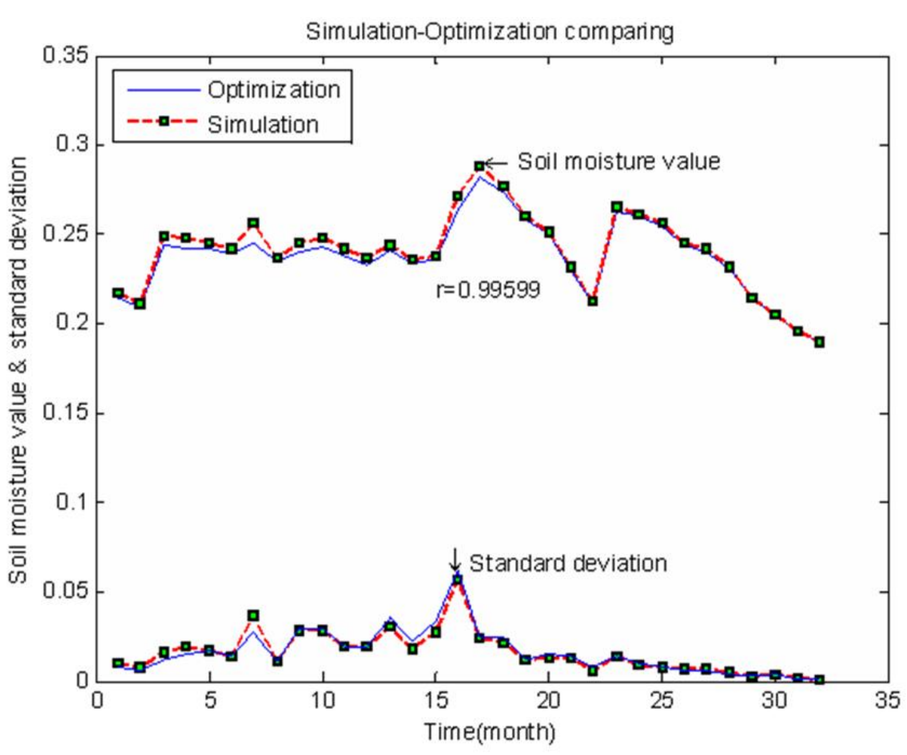

Figure 1. Comparison of mean and standard deviation of the soil moisture, and actual evapotranspiration for winter wheat as resulted from applied deficit irrigation strategy

Fitting the double-bounded density function to the stress index:

The soil moisture state density function is hybrid in nature, with spikes at maximum and minimum soil moisture capacities (bounds), representing the probability of saturation and soil moisture deficit. Considering a reasonable general form for the static stress, this property is transformed to the proposed stress index, and as a result should be considered as a double-bounded random process. The result of this analysis is shown in Figure 2 for the winter wheat.

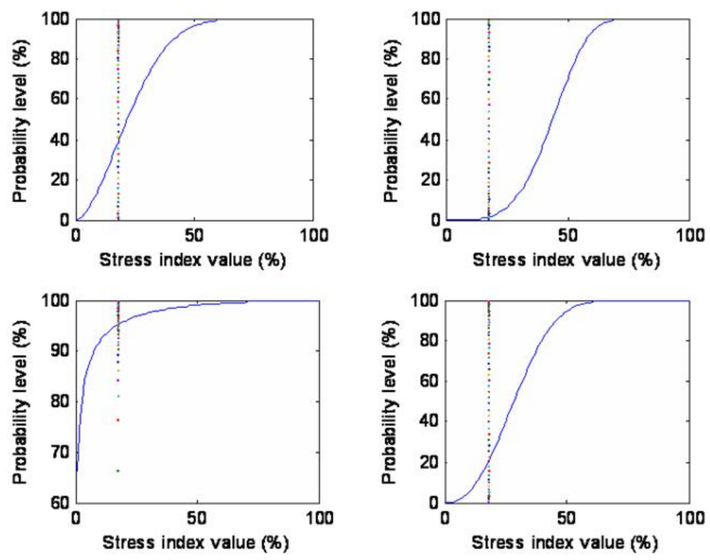

Figure 2. Cumulative probability function of the weekly stress index as resulted from optimization model and DB-F analysis

Advanced First Order Second Method (AFOSM):

To explore the effect of the water stress on the final relative net benefit, AFOSM reliability analysis is applied based on the results of the optimization model. Figure 3 shows the AFOSM results for winter wheat. According to this figure, the achievement probability of more than 100 % relative net benefit, applying the deficit irrigation strategy and cropping area increasing, is about 0%. .

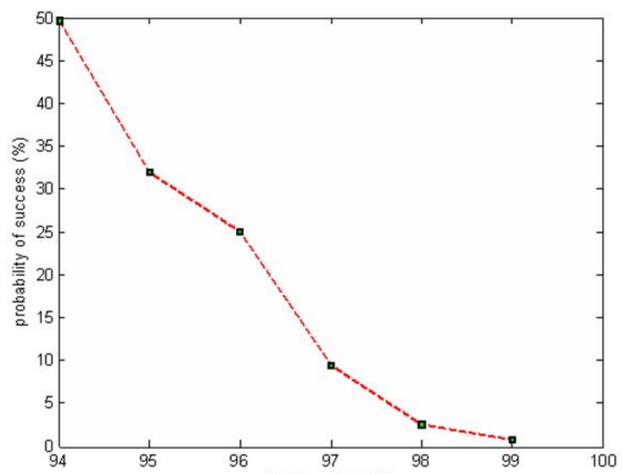

Figure 3. Cumulative probability function of the relative yield for deficit irrigation case as resulted from AFOSM reliability analysis

Summery and Conclusion

The reliability analysis of the relative net benefit indicated using deficit irrigation strategy for the winter wheat can not increase the relative net benefit in long term. The results are also justified by moment analysis of a weekly crop-water stress index, which shows the high probability of crop stress in some weeks of the growing period.

References

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Ganji A, Ponnambalam K, Khalili D, Karamouz M (2006b) Grain yield reliability analysis with crop water demand uncertainty. Stoch. Environ. Res. Risk Assess., DOI 10.1007/s00477.