Ref: hess-2020-146
Title: Combined Simulation and Optimization Framework for Irrigation Scheduling in Agriculture Fields
Journal: Hydrology and Earth System Science

Response to Reviewer #3 Comments
####Authors' response in Blue####

Review on hess-2020-146 "Combined Simulation and Optimization Framework for Irrigation Scheduling in Agriculture Fields"

We are grateful to you for the time and effort spent on the review of our manuscript. Our detail response and comments raised by you is attached. We believe our responses and the revisions made to the manuscript fully address the issues raised by the review. These revisions have helped clarify some aspects of our work and improve its interpretation.

The paper suggests a procedure for identifying the optimal irrigation schedule that maximize the net margin of the crop production. Irrigation scheduling is defined by

i) a threshold of the soil matric potential observed at a given depth (e.g. 20 cm in the sample case study);

ii) ii) event irrigation depth (or irrigation duration with a predefined irrigation rate). The procedure exploits Hydrus-1D as soil water and solute transport model. Plan transpiration is modelled as fraction of the potential transpiration. The fraction is computed accounting for water and salinity stress. The potential transpiration and evaporation are computed as fractions of the crop evapotranspiration under standard conditions (ETc), accounting for the soil canopy cover. ETc is computed according to FAO-56 single crop coefficient approach. Crop yield is assumed to be proportional to the ratio of the actual ET to ETc.

GENERAL COMMENTS

Tabulated FAO 56 crop coefficients were proposed as a simple approach for assessing crop water requirements. The application of the single crop coefficient approach for estimating the crop evapotranspiration under standard conditions and the crop yield is too simplistic and not suited for the proposed optimization. By taking the tabulated crop coefficient in the proposed procedure is equivalent to assume that the crop is a stationary system, where phenology and water requirements are simply identified by the calendar days rather than the result of the crop response to the environmental conditions.

We agree with the reviewer in that estimating water requirements based on tabulated crop coefficient is too simplistic. There was a mistake in the manuscript and we did not specify that we used single crop coefficients. We used Kc values from Domínguez et al. (2012) and Martínez-Romero et al. (2017). They define maize Kc values calculated based on Growing Degree Days (GDD). The study area was located in Castilla la Mancha, where weather conditions are quite similar to that of Foradada. Thus, we assumed that these Kc values are good proxies for calculating water requirements. We added this information in the manuscript (Line 280):

“K_c coefficients were extracted from the works of Domínguez et al.(2012) and Martínez-Romero et al.(2017), conducted in a maize field located in Castilla la Mancha, Spain. K_c coefficients were determined field temperature and an estimation of the Growing Degree Days (GDD). Weather conditions from Foradada field and Castilla la Mancha are similar. During the field campaigns, we visually corroborated the time duration of the different phenological stages proposed by Domínguez et al.(2012) and Martínez-Romero et al.(2017).”

We did not used the dual crop coefficient, who estimates evaporation and transpiration separately, because during the field campaign we estimated the canopy cover (Raes et al., 2010). The estimation of the soil fraction cover allows separating evaporation and transpiration from ETc. We assumed that it would be more realistic to apply the canopy cover based on field measurements than dual crop coefficient.

Similarly, Eq. 13 was proposed by FAO papers as a simple empirical equation for estimating crop yield. However, crop biomass and yield development depend on the transpiration rate rather than on the evapotranspiration.

We agree with the comment raised by the reviewer. Stewart (1977) model is a simple empirical model based on ETc values. Yet, it was proposed by FAO and has been widely used by several authors in the recent years (Domínguez et al., 2012; Irmak et al., 2016; Martínez-Romero et al., 2017; Saadi et al., 2015). In accordance with (Raes et al., 2010), we think that Stewart (1977) model is adequate for maize because these types of fields are totally covered most of the time We agree that transpiration is direclty related to crop yield, but in this case, soil evaporation is a minimum part of the total ETc. As we mentioned before, we used the canopy fraction cover for separating evaporation and transpiration. This canopy fraction cover, assumes that in systems with full canopy cover, such as maize, ETc is assumed to be equal to transpiration. In fact, Kool et al. (2014) reviewed the approaches for evapotranspiration partitioning and validate this assumption.

We want to hihgly that the methodoogy does not impose Stewart (1977) model and allows to use another kind of crop productivity fuction. We clarify this in the mansucript as follows (Line 189):

“The model presented by Stewart et al. (1977) Eq. (13) has been widely accepted and recommended by the Food and Agriculture Organization of the United Nations (FAO) (Doorenbos and Pruitt, 1975, hereafter FAO24). In addition, it has been recently used by several authors (Domínguez et al., 2012; Irmak et al., 2016; Martínez-Romero et al., 2017; Saadi et al., 2015). Note though that methodology proposed is not limited by this model and can also be used with other soil – water – crop productivity models if needed.”

Even the most simple and conceptual agro-hydrological model, such as AquaCrop (which does not rely on the numerical solution of the Richards Equations) provides a comprehensive description of the crop dynamics and crop yield development and, thus, allows optimizing the irrigation scheduling accounting for the crop response to environmental stresses.

The methodology proposed in this work aims to optimize the irrigation scheduling based on soil water content and pressure head status. For this, it is important use a model who simulates unsaturated water flux applying Richards equation, in this case HYDRUS. It is true that AquaCrop provides comprehensive description of the crop dynamics, but it provides approximated soil moisture data. Thus, AquaCrop does not follow the essence of our work, which is based on physical principles.
As we have specified before, another kind of crop yield functions can also be used with the methodology proposed.

Indeed, an optimization procedure should consider that environmental stresses do not affect the yield uniformly across the entire growing cycle.

We agree with the comment raised by the reviewer. This is why Stewart (1977) model applies a crop response factor (Ky). This coefficient penalizes crop yields depending on crop phenology. For instance, during flowering stage, Ky = 1.05. It means that if actual evapotranspiration is not close to the potential water requirements (ETa/ETc <1) crop yield will be reduced at the end of the campaign.

Overall, it is not clear the motivation of this study. How should this procedure be applied from an operational perspective? The optimization procedure seems to be designed for running in batch mode, i.e. it can be used to identify the optimal irrigation schedule for a reference climatic condition, but it cannot be used to adapt the irrigation schedule to the actual environmental conditions, in real-time.

Thanks, this was not properly written in the paper. In principle, the combined simulation-optimization framework permits to find the optimal control settings of an irrigated field that maximize the net profit obtained in a period of time T given some forecasted climatic conditions. We have clearly state this now in Line 105. The method is not meant to update parameters in real-time based on new information. One should then incorporate a Bayesian statistical framework or similar which is not clearly included in the framework.

Line 99 "*The framework permits to find the optimal control settings of an irrigated field that maximize the net profit obtained in a period of time T, given some forecasted climatic conditions.* "

SPECIFIC COMMENTS
Line 50 – The crop coefficient is designed for assessing crop water requirements and not for irrigation scheduling. The estimated crop water requirements should be then used for designing the irrigation scheduling.

We have modified the sentence to clarify this (Line 49):

"*This method requires accurate estimations of weather conditions and does not provide the frequency and duration of irrigation (stakeholders do not know when to apply this volume of water) unless water requirements are combined with soil moisture data.*"

Section 3.2 Model setup: Root depth is assumed to be constant in time, while it is highly variable in time, especially for crops like maize. A soil depth of 60 cm with free drainage as bottom boundary conditions does not seems to be realistic. Moreover, this seems even more improbable with crops like maize. The impact of the initial conditions can be high.

We did not describe this in the initial manuscript but we actually measured the root depth evolution during the field campaign. We introduced those measurements in the model. We have added this information in section 3.1, where we describe how and when we measured root depth (Line 237):

"*In order to evaluate the vertical distribution of water uptake by plants we measured the root depth by pulling a plant off twice a month during the field campaigns. The maximum root depth registered was 55 cm after 78 days from sowing.*"

In section 3.2 we described the root growth model as follow (Line 266):

"Based on the root depth measurements taken during the field campaigns, we represent the vertical spatial distribution of water uptake by plants through Hoffman and Van Genucghten model (1983) with a root depth L_R of 55 cm,

$$\beta(z) = \begin{cases} \dfrac{1.66667}{L_R} & z > z_{top} - 0.2L_R \\ \dfrac{2.0833}{L_R}\left(1 - \dfrac{z_{top} - z}{L_R}\right) & z \in (z_{top} - L_R, z_{top} - 0.2L_R) \\ 0 & z < z_{top} - L_R \end{cases}$$

We considered that it is appropriate consider 60 cm as a soil depth in the model, and also impose free drainage as a boundary condition. The reason is why we are interested in what happens in the root zone (how water moves thought the soil, roots water uptake, water evaporated…), but not what happens below this zone. Thus, considering that the maximum root depth was 55 cm, we assume that water percolates the root zone is lost by drainage. For this reason, we have to impose free drainage at the bottom of the soil profile.

Lines 325 – The irrigation strategy presented as traditional does not seem to be realistic

Based on our experience dealing with agricultures in Spain, we considered that irrigation scheduling based on water requirements can be simulated by adding the amount of water evapotranspired in the past during a certain period of time. We define that this period of time was a week instead of a day because it is the easier for agricultures to handle. If we define a new volume of water to apply every day (reschedule the irrigation every day), the agricultures will have to reprogram the irrigation controller every day, which is time consuming and not realistic.