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Hydrology and Earth System Sciences Discussions

Interactive comment on "Integration of vegetation indices into a water balance model to estimate evapotranspiration of wheat and corn" *by* F. L. M. Padilla et al.

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We would like to thank Referee #1 for the helpful comments on the submitted manuscript.

General comments 1) "I must say that the model description is very poor and it was hard to understand what the authors tried to say/show in many places."

The model description have been extended with a more detailed and separate explanation of equation 1 variables to facilitate the comprehension.

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2) “One major problem I found is inherent within the model assumption. Authors chose values for some parameter (P. 8637 & Table 1) that are far away from the normal growth conditions. The maximum effective root depth was 1.25 m, and from my experience, root can reach even 2 m (if there is water in that layer). More important, the minimum effective depth which the seed can extract water to germinate was 40 cm. As seeds are sown in 2-3 cm, I cannot understand why do they need 40 cm of water to germinate. In addition, in the wilting point, the soil water content is not 0, crops can absorb water from soils even when the soil water content is below the wilting point. Lastly, why theTEW was only 24 (Tab. 2). Hence, all the whole work results are questionable.”

The selection of model parameter values have been performed according to the knowledge of local conditions, previous findings of other authors and following the calculation procedures and tabulated values supplied by FAO-56 manual (Allen et al. 1998), widely and successfully used all over the world for irrigation purposes. Nevertheless, we agree with the reviewer in the existence of some uncertainty in the selection of the mentioned parameters. For that reason we have performed a sensitivity analysis to address the importance of these three parameters (TEW and maximum and minimum root depth) in final ET values. We have included the results of this analysis in the revised text. Briefly, these results indicate that for the magnitude of variation considered for inputs TEW and Zrmin, its effect seemed to be negligible on seasonal ET. On the contrary the effect of Zrmax was significant and therefore, its calibration deserves higher effort. It follows a detailed explanation of each parameter value:

- The maximum effective root depth was 1.25 m because the Lubrican cultivar planted in this study was a spring wheat cultivar. All cultivars planted in southern Spain are spring cultivars developed by the CIMMYT or derived from those, but seeded in wintertime (December) in the study area. Several studies (Thorup-Kristensen et al., 2009) showed that the maximum effective root depth of spring wheat cultivars do not reach more than 1-1.5 m. The suggested root depth of 2 probably correspond to winter wheat cultivars, with longer maximum effective roots of 1.5-1.7m (Allen et al. 1998) or 2.2 m

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(Thorup-Kristensen et al. 2009). - Even when the rooting depth at planting is small, as referee 1 mentioned, the variable used by the model, the effective rooting depth at planting, Zmin, is defined as the soil depth from which the germinating seed or the young seedling can extract water, and it is larger than the sowing depth. Little attention have been paid to this parameter in previous works and the authors have found scarce references in literature for its selection. FAO Aquacrop (Steduto et al. 2009, Raes et al. 2009 and Hsiao et al. 2009), model designed to simulate yield response to water of several herbaceous crops, suggest the use of a minimum effective rooting depth of 0.3 for wheat. We have slightly reduced the original selected value 0.4 to adopt the recommended 0.3 and the new results are available in the revised manuscript. - An intermediate value in the interval suggested by Allen et al. (1998) for the type of soil of interest was initially used. After a careful revision, we have decided to used an equation for TEW calculation based on available water content at field capacity, θfc, at wilting point, θwp, and the depth of the surface soil layer that is subject to drying by way of evaporation, Ze, [TEW=1000(θfc –0.5 θwp)], resulting in new TEW values (21 and 19 for corn and wheat, respectively). The used of these new values effect on final ET estimation were insignificant (0.016% on average).

3) “The second major problem I found is inherent with the satellite data. Authors wrote that 8 and 7.4 ha fields avoiding edge effect (P. 8638, L. 10). However, it will be depend on the field shape and orientation. This problem even increased with Landsat 7 ETM+scan line corrector malfunction. It would be better to exhibit how many pure pixels are available for each field by image.”

The number of pure pixels for each field by image is now provided in the new manuscript, as suggested. In addition, the procedure used to avoid the gaps from ETM+ scan line corrector malfunction have been added to the text.

4) “The third major problem I found is inherent with the field canopy reflectance measurements. There are no data about the ASD height above the ground/canopy, and the included area within the field of view. If I assume working 1.5 m above ground,

the spectral sampling procedure seems to under-sample the canopy. For maize, the diameter of field of view of the spectrometer at 1.5 m above the crop is 0.66 m which is less than the row spacing (0.95 m?). As the crop grows, the altitude decreases to 0.3 m and the field of view is only about 0.13 m which is much less than the row spacing. If the optic is positioned directly over the row, the spectra are biased toward the vegetation. Thus, multiple observations spanning several rows are required to estimate true canopy reflectance when the diameter of the field of view is less than the row spacing (e.g., Agronomy Journal 74:744-751, 1982). Similarly, does sonic anemometer, hygrometer and the net radiometer locations were fixed z=1.5 m, or above the canopy (P. 8640, L. 19-20, 24). If it was above the canopy, how often along the growing season was the placement changed?"

The field canopy reflectance measurements are more clearly described in the text now. A fiber optic jumper cable with a field of view (FOV) of 25° was used in this study. Twenty-point regularly distributed measurements were taken over each field at midday and under cloudless conditions. A sampling scheme based on the knowledge of the row spacing (pairs "on row and off row") was selected for this study. Two field canopy measurements were performed over each point measurement. First of them was taken directly over the plants (on row) and the second measurement was taken halfway between adjacent rows. The sensor altitude above soil was 4.5 m. Thus, the diameter of FOV at soil surface (m) was 2.66 times greater than the row spacing (0.75 m) in corn. The sonic anemometer, hygrometer and the net radiometer locations were fixed z=1.5 m above the canopy. The total height of the instruments was checked twice a week (together with the data downloading and a general verification of instruments functioning operations) and changed when it was necessary.

5) "The last major problem is with data analysis. SAVI index values were averaged for each day of measurements (P. 8639, l. 24-25), and only up to 11 measurement days have been done (Table 3). So, where did all the data points included in figures 2 & 4 come from? Furthermore, SEP data must be added for both figures 2 & 4, and for

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model estimations figures 3 & 5."

This point has been clarified in the text. ET measurements were performed for all days shown in figures 2 and 4 (figures 3 and 5 in the new text), n= 96 for corn and n= 112 for wheat. The 11 days presented in Table 3 correspond to days when either radiometer or satellite spectral data were available. These values were used as input to the water balance model producing the daily ET estimations depicted in the figures. The change over time in SAVI was calculated by linear interpolating the available SAVI values obtained from remote sensors.

Technical corrections. P. 8634, L. 18-20: "The authors ignore the saturation problem that limits LAI estimation by the common VI."

We agree with the referee and we have changed this sentence in the text.

P. 8635, L. 21:" "This coefficient" – which one? Reader does not have to guess."

We referred to the soil evaporation coefficient. We have reworded this sentence to clarify it.

P. 8636, L. 21: ""fc" – what does this stand for? Reader does not have to guess."

"fc" is the ground cover fraction. This has been clarified in the revised text.

P. 8636, L. 23: ""fcmax is the fc" – not clear."

fcmax is the ground cover fraction at which Kcb is maximum (Kcbmax).

P. 8637, L. 13: "replace "period," with "period respectively, "."

This has been fixed.

P. 8638, L. 6: "add botanical names".

As suggested, botanical names are now included.

P. 8638: "add precipitation and temp data for the experiment seasons".

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Precipitation and temperature data for the experiment seasons are now provided.

P. 8639, L 15: “ASD sampling interval is not 1 nm!”

This is corrected now in the text.

P. 8640, L 16: “delete space, replace "(Radiation" with "(Radiation".”

This has been fixed.

P. 8641, L. 1-7: “too many terms without explanation. What are "rainy days"?”

We have clarified in the text that we did not used days with rain above 0.2 mm.

P. 8641, L. 8-12: “doesn’t belong to M&M.”

We quite agree with the referee that this part does not belong strictly speaking to M&M. However, the eddy covariance system is presented here as a tool and it is not in the focus of our discussion. In an attempt to keep the results and discussion section focused on work main goals and we have preferred to include the energy balance closure brief discussion together with the system description.

P. 8641, L. 19-28: “What did the weighing lysimeter contain bare soil or crop? If a crop, how did authors take crop weight into account?”

The weighing lysimeter and the field around were grown with wheat. The daily increment in crop weight is considered negligible because it is below the lysimeter precision. Numerous studies around the world followed the same measurement procedure and their results support this decision in crops such as wheat (Zhang et al., 2002), corn (Tolk et al., 1998), cotton (Chavez et al., 2009) or grass (Steduto et al., 2003, Gavilan et al. 2007, Gavilan and Berengena, 2007).

P. 8641, L. 28: “What are "rainless days"?”

Days with a total amount of rain less than 0.2 mm. This definition has been included in the text.

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P. 8642, L. 3: “Aren’t these calibration sites?”

No. In fact, these sites have not been used to calibrate any parameters of the model. These sites have been selected as validation sites to measure ET and validate the daily estimated ET from the model.

P. 8643, L. 3-8: “can authors relate it to the ASD FOV?”

The sensor altitude above soil was 4.5 m. Thus, the diameter of FOV (25°) at soil surface (m) was 2 m, 2.6 times greater than the row spacing (0.75 m). A total of 40 measurements (in pairs) were taken over each field. However, it is known that all plants in a given field are not in the same phenology stage at the same time [eg. when staging a field of corn, each specific V or R stage is defined only when 50 percent or more of the plants in the field are in or beyond that stage (Ritchie and Hanway, 1982)]. This suggests that at the beginning of the growing cycle, when lower ground-crop cover tends to be lower, field-measured SAVI could be less representative than satellite-derived SAVI as we mentioned in the text.

P. 8643, L. 15, 27: “I don’t agree with "good agreement" and "reasonable agreement". At least the SEP for corn must be too high.”

We have rewritten these sentences to better explain the performance of the model. We consider that it exists a good agreement between the estimated and measured deficit in wheat (RMSD= 9.78 mm). However there are some discrepancies at the end of the corn season during senescence that are now commented in the text.

P. 8644, L. 1-4: “Why? Why does model accuracy decrease with uniform and organized irrigation?”

Even when a uniform and organized irrigation is the goal of these systems, problems arising from low uniformity, poor maintenance of the irrigation system by the farmer or troubles with the pipes and drippers during the growing season are common under field conditions. These reasons lead us to mention in the text that the amount of irrigated water may represent a source of error.

P. 8644, L. 10-11: “Why?”

The final purpose of the method under development is to be applied over large areas in a regular and operative way using satellite inputs. Field radiometer data are used here to support the ET modelling, and the relationship between satellite and radiometer data is analysed in previous sections of the manuscript. The fact that field radiometer is not an operational tool for large-areas observations, lead us to present water stress monitoring application using only the targeted source of data and avoiding a discussion about measurement types that might repeat the one addressed in previous sections.

P. 8645, L. 4: “Only 2 t per 600 mm of rain?! What happened in the field? What limits production? I'm not sure that we can learn from this field.”

We provided misleading information in the manuscript that is now corrected. Even when the annual average precipitation in the area is around 600 mm (P 8638, L16), only 301 mm of rain were measured from planting date to harvest date in the wheat field in 2009. This precipitation did not satisfy the water requirement of the crop, especially during entire grain-filling stage, resulting in a lower yield. We controlled the field weekly and disease, invertebrate pests or weeds did not influence yield.

P. 8645, L. 19: “"without any loss" - exaggeration!”

This expression was changed from “without any loss” to “without a significant loss of accuracy” in response to this comment from referee 1.

P. 8652: “Add two columns- DAE (days after emergence); Pure pixel no.”

Both DAE and pure pixel numbers have been add to the table 3, as suggested.

P. 8653: “delete table 4”.

Table 4 has been deleted.

P 8654: “Start the sentence with a word, and explain what is (5-4-3).”

The figure 1 caption has been corrected and the meaning of (5-4-3) has been explained in the text.

P 8656 & 8658: “Start figures with DAE=1. How much rain fell prior DAE (or DOY)=1?”

This figures start now with DAE=1, as suggested. A precipitation of 310 and 370 mm was measured from 1 September to 1 Mach of 2008 and 2009 in Hornachuelos. This information has been also added to the text.

P 8659: “Add corn phenology data, and increase wheat phenology data resolution.”

Corn phenology data are now included and wheat phenology data resolution has been improved in fig. 6.

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