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Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Capillary rise affecting crop yields under different environmental conditions" *by* Joop Kroes et al.

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Concern 1: Lack of Clarity Regarding Experimental Design Comment from reviewer: I do not understand the implementation of hydrological boundary condition b ("free"drainage with capillary rise"). In my understanding, free drainage is typically implemented by setting the bottom boundary condition to a 0 pressure head gradient, which means that the total hydraulic head gradient is equal to 1 (dH/dz=dz/dz). In the SWAP manual, and it states that under free drainage boundary conditions there is downward flow out of the bottom boundary at a rate equal to the hydraulic conductivity of the bottommost soil layer (see equation 2.20 in SWAP manual), which would mean capillary rise through the bottom boundary is not possible.

Our reply: We agree with the reviewer; the explanation was not very clear. We adapted

the text and introduced a new Figure 2 that explains the 3 hydrological conditions and its corresponding fluxes in the model simulations.

Comment from reviewer: Therefore, it seems that the authors define capillary rise as any water that moves upward across the depth in the soil column which is defined as the bottom of the root zone (line 180, "We calculated capillary rise as the upward flux at the bottom of the root zone"). Several points of clarification are needed. Is this the same boundary at which the free drainage condition is defined, or is free drainage defined at the bottom of the soil column (the depth of which is not stated) and the capillary rise boundary condition turned on/off at the bottom of the root zone? Could the authors describe in more detail how the Richards Equation is implemented such that water movement is only permitted in a downward direction – are there separate upwards and downwards hydraulic conductivities in the vertical direction, as implied in lines 190-192, or are both upwards and downwards conductivities reduced at the bottom of the root zone? If so, is this physically realistic, or simply a modeling experiment? I note that the authors of the study are the developers of the SWAP model, so perhaps things which seem obvious to them are not quite as clear to the readers (such as myself). Given that the difference between the three boundary conditions is the fundamental concept upon which the entire study is based, it is essential that these boundary conditions are clear and defensible, and they currently are not. They reference a previous study (Kroes and Supit, 2011) which introduces the coupled SWAP-WOFOST model, but this boundary condition is not used in the previous study.

Our reply: We clarified our definition of capillary rise in Figure 2 and at several points in the text. Also fluxes at the bottom of the profile are better defined as well as fluxes across the bottom of the rootzone. The way we implemented the reduction of vertical flow is now explained in more detail at the lines 215-220. It is an option we build in the model to adjust the numerical solution of the Richards equation. We explained our model adjustments as being a synthetic modeling option (line 214) which has the purpose to distinguish and quantify the contribution of capillary rise from internal recycling.

Comment from reviewer: Also, if my above interpretation of the boundary conditions are correct, it seems that the authors' results would be highly sensitive to the depth of the soil column relative to the depth of the rooting zone, as the difference between these two depths provides the "deep soil moisture" that is allowed to move upwards through the bottom boundary of the root zone and therefore constitutes capillary rise in their simulations. How was the total soil column depth selected, and how sensitive are the results to this decision?

Our reply: The depth of the soil column has been defined at a depth of 5.5 m below the soil surface. This is explained in lines 198-201.

CONCERN 2: Lack of Narrative Discretion

Comment from reviewer: Overall, the paper's narrative requires significant work. I feel that the authors include too much information. While it is evident that the authors did quite a bit of work, it is also important to distill the results to aid the reader in interpreting and understanding how they relate to the study's research questions; I am reminded of the quote, "If I had more time I would have written a shorter letter" (http://quoteinvestigator.com/2012/04/28/shorter-letter/). Their figures and tables seem to consist of a laundry list of all their results, when it is the job of the author to synthesize and condense their results to a coherent message. A more effective paper would synthesize the key messages from these plots to a smaller number of figures targeted closely at their specific research questions, and present the full results in the supplementary material as necessary. For example, figures 4, 6, and 8 only have a few actual observed data points in them; they could easily be condensed into a single scatterplot, color-coded by research site.

Our reply: There was too much information indeed. So we moved the bulk of the results to a supplementary material and in the main text we show and discuss the main results. We split the paper in more logical subsets that are grouped around one subject.

Comment from reviewer: The other aspect of the narrative, the framing of the study in

the Introduction section and situating their results in the literature via the Discussion section, seem incomplete. In the Introduction section, they describe several studies that find that capillary rise from groundwater into the root zone can be an important source of water to crops. The importance of capillary rise to crops in shallow groundwater environments is well known; in addition to the studies cited, many others have found this to be the case (Kang et al., 2001; Sepaskhah et al., 2003; Ghamarnia et al., 2010; Luo and Sophocleous, 2010; Huo et al., 2012; Xu et al., 2013; Talebnejad and Sepaskhah, 2015; Han et al., 2015).

Our reply: The importance of capillary rise is well known, but to our knowledge it has not been quantified for different hydrological conditions (including free drainage). We therefore adjusted the title (new title: "The impact of capillary rise on crop yields quantified under different environmental conditions") to demonstrate that this quantification is an important objective of this study. Most of the literature suggestions are used and became part of the references.

Comment from reviewer: Similarly, their comparison of yield difference between cases including groundwater vs those with free drainage seems analogous the concept of groundwater yield subsidy of Zipper et al. (2015). Therefore, it is key for the authors to identify a knowledge gap in the literature that they propose to fill; the closest they come is the statement, "This paper quantifies the effects of capillary rise on crop growth under different conditions of soil hydrology, soil type and weather." (Lines 94-95). Identifying the relative importance of different drivers (soil, crop choice, weather) to variability in the capillary contribution of groundwater to crop water requirements, but this is not clearly motivated in the introduction, included in the research questions, or answered by the results. (And, as noted in concern #1, I am not convinced their method is appropriate to answer this question). there is no analysis conducted or information given about weather conditions, which is presumably driving much of the interannual variability observed in plots. Nor are any conclusions discussed regarding the impact of weather on capillary rise. Nor are there any cross-site analyses or discussion of variability in soil texture or crop type. Thus, it is hard to say what lessons can be learned from the data presented here. The Discussion is brief (<1 page) and could be enhanced by situating their results within the existing body of literature detailing the importance of capillary rise to crop water requirements; see the studies referenced above. As mentioned above, the questions the authors' research questions are broad, so expanding the discussion can help make clear what new contribution their results add to the existing body of literature.

Our reply: We identified the knowledge gap and we introduced the following lines in the main text: "The importance of capillary rise as supplier of water to crops has been shown by many researchers (e.g. Huo et al., 2012; Talebnejad, and Sepaskhah, 2015; Han et al., 2015); however we found only a few studies that use an integrated modelling approach (Xu et al., 2013; Zipper et al. 2015) to quantify capillary rise for different hydrological conditions (including free drainage) using physically based approaches. In this study we explicitly consider the effect of crop type, soil type, weather year and drainage condition on capillary rise. Zipper et al. (2015) introduced the concept of a groundwater yield subsidy which is the increase in yield in the presence of shallow groundwater compared to free drainage conditions. Following their line we introduce the concept of capillary soil moisture subsidy as additional yield increase in free drainage conditions due to internal recirculation of soil moisture"(lines 85-95) We extended the Discussion including special sections about different soil types for which we also added a new table (Table 6) with results from potatoes to illustrate the differences in capillary rise and yield under water stress conditions in different soil types (lines 376-391).

CONCERN 3: Issues in Tables/Figures

Comment from reviewer: Figures are the key to any paper and there are many fundamental flaws or oversights here. Figure 2 does not have a legend explaining what the colors mean. I understand that 72 different types of soils is too many to display in a legend, but perhaps there are general categories such as those used in Figure 9?

Figures 3-8 do not have axis labels. In Figure 7 (top panel), the observed groundwater levels are provided to the model as a bottom boundary condition, and are therefore not an appropriate validation dataset. In general it is takes quite a lot of effort to determine what plots correspond to what scenarios. For example, in the text it states "Observed groundwater levels were used as a lower boundary condition for Borgerswold" (lines 166-167). To determine which plot this was, I then had to go to Table 1 (or Table 3) to determine the case study number, and then look at plots until I found the groundwater levels corresponding to Case Study 5. Perhaps the case studies could be given more descriptive names based on the location and crop (e.g. case study 1 = DM-Grass, case study 2 = DM-Maize, case study 3 = C-Maize, etc.) to aid in interpretation of the figures. In the context of yield, I do not understand what the continuous lines showing simulation results are (e.g. in Figure 8); yield is typically measured at the time of harvest. Perhaps "dry biomass" would be a more accurate term? The axes chosen cut off parts of data in some plots; for example, parts of the boxplots are missing from Figures 9, 11, 12 (upper right panel). There are also quite a few tables, which could be condensed: Tables 1-3 all have the same first column and can be combined. Table 4 has no information which is not already presented in the text In Table 5, I do not think that Nash-Sutcliffe Efficiency is an appropriate metric for evaluating yield, as the authors are typically comparing a single annual observed point to a timeseries of model output; typically, NSE is used for comparing timeseries data (e.g. a hydrograph).

Our reply: Various figures have been moved to the supplementary material. The remaining figures have been improved and colours are better explained. Figure 2 (Soil Map) has been simplified as suggested. Tables have been merged as suggested and were restructured.

see supplement for text of adapted manuscript and new supplementary material

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-598/hess-2016-598-SC1-

supplement.zip

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