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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Sensitivity of water stress in a two-layered sandy grassland soil to variations in groundwater depth and soil hydraulic parameters" *by* M. Rezaei et al.

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We would like to thank Dr. T. Caldwell for the careful review of our manuscript and for providing us with his valuable and positive comments and the suggestions. For sure they further improve the manuscript accompany with the first referee's comments. The following responses have been prepared to address all of his comments in a point - by - point fashion. The page and line numbers refer to the current version.

Firstly, we agree with the referee for more clarification about the crop model setup. Therefore, this section was adopted:

In page 6888, line14-22 and pp 6889, lines 1-3: "The simple generic crop growth model, LINGRA-N model (Wolf, 2012) which can calculate grass growth and yields under potential (i.e. optimal), water limited (i.e. rain fed) and nitrogen limited growing conditions, was used to calculate the leaf area index (LAI) and grass yield. This tool was calibrated and tested for perennial rye grass and natural annual grass over Europe (Schapendonk et al., 1998; Barrett et al., 2004). LINGRA-N simulates the growth of a grass crop as a function of intercepted radiation, temperature, light use efficiency and available water (Wolf, 2012). The LAI and crop growth simulations were carried out from 1 January 2012 to 31 December 2013. The model calculated LAI and yield on a daily time intervals using daily weather data, solar radiation (kJ m-2 d-1), minimum temperature (0C), maximum temperature (0C), vapour pressure (kPa), wind speed (m s-1) and precipitation (mm d-1). A grass crop data file is available mainly derived from WOFOST. Soil data for our soil were produced using measured values of soil moisture content at air dry (pF=6), wilting point (pF= 4.2), field capacity (pF= 2.3) and at saturation and also percolation to deeper soil layers (cm day-1) in the laboratory. The maximum rooting depth was adjusted to 40 cm. Irrigation supply was imposed at the specific applied times with optimal nitrate application. The simulated LAI was scaled to an hourly basis using linear interpolation between two adjacent simulated daily values of LAI. The model was run for optimal (no water limitation) and realistic conditions (actual water inlet i.e. irrigation and rainfall) for each growing season. Figure 3 represents predicted LAI and grass yield of 2012 and 2013."

Secondly, the local sensitivity analysis as it is applied in the paper is just a direct implementation of the definition of sensitivity analysis itself, i.e. the partial derivative of the model output towards the individual parameter value in a specific point in the parameter space: $\partial y/\partial x$ with y the model output and x the model parameters. This is not new at all and is in most text books about dynamical modeling and/or sensitivity analysis described. For some models, it can be derived analytically (by hand or using symbolic manipulation software like sympy, mathematica, symbolic toolbox of matlab), but is in the case of environmental modeling mostly done using a numerical approximation as it is provided in the paper. By using a perturbation factor small enough to rely on the fact that the linear approximation of the partial derivative is accurate in the direct neighborhood of the parameter value, the sensitivity is calculated by approximating it as such (see paper). The numerical approximation is needed for closed software applications such as Hydrus. We've written a wrapper around, which is available on Github: https://github.com/stijnvanhoey/hydrus_wrapper. Choosing a local method does have some limitations, with the fact that it is only looking locally in the parameter space as a major drawback and the One-At-a-Time (OAT) property limiting the insight in higher order interactions. This comment is correct and already mentioned by the first referee. So we decided to adapt the text as follows to justify the usage of a local method an pointing out the limitations:

In pages 6891-6892 lines 17-23: "The effect of each input factor or parameter to the model output is determined by a local sensitivity analysis (SA), using a one-at-a-time (OAT) approach. We used this approach because it allows a clear identification of single parameter effects. Relevant parameters have major effects on output variables with only a small change in their value (Saltelli et al., 2008). Sensitivity analysis is, among other purposes, used to find the most relevant parameters which enable a reduction of the number of parameters that need to be optimized. In a local sensitivity analysis, only the local properties of the parameter values are taken into account in contrast to global sensitivity analysis which computing a number of local sensitivities. Since the interest in this study goes specifically to the measured (parameter) values in the field, a local sensitivity analysis is chosen. Furthermore, an OAT approach (local or global) does not provide direct information about higher and total order parameter interaction as is provided by variance based sensitivity analysis (Saltelli et al., 2008). However, by evaluating the parameter sensitivities in time, insight is given about potential interaction when similar individual effects are observed. The latter can be quantified by a collinearity analysis (Brun et al., 2001), but will be done graphically in this contribution. Here, a dynamic (time-variable) local. . ."

Line specific comments

p6886 l14: Despite topographic and groundwater depth variability, is there no variation in Ap thickness (33cm)?

In this study we excavated a profile at one location that the sensors war installed. Therefore in this line we just mentioned the first layer depth of the profile (i.e. 33cm). Indeed, Ap thickness varied between 30 to 50 cm. we would add the sentence as:

In page 6886, lines 2-4: "The measured depth of the groundwater table was between 80 and 150 cm and the Ap horizon thickness was between 30 and 50 cm below the soil surface at various locations across the field depending on the topography."

p6886 l18: how was rooting density measured or determined?

In page 6886, lines 18-19: "Maximum grass root density was found at about 6 cm and decreased from 6 to 33 cm (based on field observation)."

p6888 l17: I am not following how LINGA-N was integrated into HYDRUS. At a minimum,tell me what the forcing functions are for LINGA-N. Was it only used to parameterize a time-varying LAI in hydrus?

As explained in the first general comment we used a time variant LAI provided by LINGRA-N in Hydrus.

p6689 l17: ... air entry or hysteresis ...

We used van Genuchten-Mualem model without air entry value and with no hysteresis condition. We stated at the text as:

In page 6689 lines 17-18: "To solve the Eq. 5, the van Genuchten-Mualem (MVG) soil hydraulic model (Eqs. 1-4) without air entry value and hysteresis was used."

p6890 eq8: add 'DWS =' to this equation - it will make it a little easier to figure out what DWS means throughout the manuscript.

We agree with the reviewer. This suggestion was taken into account.

DWS=T_a/T_p $=\int\_Lrw(h)R(x)dx(8)$

p6891 l8: the subscript of ET are coming and going - I suggest sticking with the subscripts on ETo and ETp, ETa, etc.

This suggestion was taken into account.

p6892 eq. 11: S(h) was previously defined - seems odd to now have 'S' be a function of another variable, time. Obviously they aren't related but perhaps you could change this for clarity.

In eq. 11, S denotes as Sensitivity function we will change it to SF(t) as:

SF(t)=(∂y(t))/∂x (11) where SF(t), y(t), and x denote the sensitivity function, output variable and parameter respectively.

p6893 l17: what error term was used for the objective function? And how was this optimization performed? You present 3 different cost functions later. Also, did you use the Levenberg optimization routine built into Hydrus?

We used Levenberg–Marquardt optimization procedures which were implemented into Hydrus. We also referred to this in the introduction on p 6884, line l29. The inverse solution is finalized when the Value of the objective function is being minimized during the parameter optimization process (SSQ). Indeed we evaluated the simulated results comparing with measured ones using three different statistics criteria (at Model evaluation and statistical analysis section). We did not represent the objective function formula in the text since it is available in the literature.

p6898 l23: 'model performance during the calibration was superior to the validation period' or something to replace 'less well'.

This suggestion was taken into account. The text was changed as:

In page 6898 line 23-24: "...boundary conditions, show that model performance during the calibration was superior to the validation period at all observation depths (Fig. 5, Table 3)...."

p6908 Table 1. Where did this data come from? Lab analysis? How many samples make up the average? You note 'measured values' on p6896 l23 - unless this data is in another manuscript - you need to present the methods for C, texture and hydraulic properties.

We performed all analysis on soil characterizations. As mentioned in material and methods section, pp 6887 l 8-29 and p6888 l1-11, we explained number of samples and the method to determine each parameter.

p6910 Table 3: Node Depth - not Nodes

This comment was taken into account.

p6920 Figure 8: the units on the y-axis could use a space between mm and h - it looks like there's a millihour in there.

Indeed it is necessary to use a space between mm and h. The figure was adopted now.

***The pdf format of this reply is also attached.

Reference

Barrett, P.D., Laidlaw, A.S., Mayne, C.S., 2004. An evaluation of selected perennial ryegrass growth models for development and integration into a pasture management decision support system. J Agr Sci, 142: 327-334. DOI:Doi 10.1017/S0021859604004289 Brun, R., Reichert, P., Kunsch, H.R., 2001. Practical identifiability analysis of large environmental simulation models. Water Resour Res, 37(4): 1015-1030. DOI:Doi 10.1029/2000wr900350 Saltelli, A. et al., 2008. Global sensitivity analysis. The Primer, John Wiley & Sons. Schapendonk, A.H.C.M., Stol, W., van Kraalingen, D.W.G., Bouman, B.A.M., 1998. LINGRA, a sink/sourced model to simulate grassland productivity in Europe. European J. of Agronomy 9: 87-100. Wolf, J., 2012. LINGRA-N a grassland model for potential, water limited and N limited conditions (FORTRAN), Wageningen University, Wageningen, The Netherlands.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C3802/2015/hessd-12-C3802-2015-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 6881, 2015.

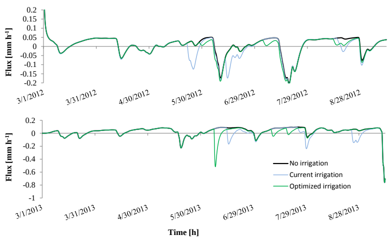

Figure 8. Actual flux of farmer’s conventional irrigation (current irrigation), without irrigation and optimized irrigation scheme (guided irrigation) for 2012 and 2013.

Fig. 1.