Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2020-274-RC2, 2020

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Deep desiccation of soils observed by long-term high-resolution measurements on a large inclined lysimeter" *by* Markus Merk et al.

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Received and published: 11 August 2020

The manuscript presents an interesting topic and shows long-term measurements of soil moisture at a municipal landfill site in Germany. The data covers a relatively large period with quite distinct climatic conditions (wet, dry years) and measurements on soil moisture are available for several depths and various profiles at the site. Despite the rich data set I found it difficult to read, because of the uncomplete description of the experimental data and the used methods in this study. The unclear description of the lysimeter/field cover and drainage data of each filed makes it difficult to interpret the results. The authors should include at least information on the land surface cover and

their change or development over time. The same should be done for the drainage data and interactions between climate, vegetation, and soil should be investigated and discussed. Hence I recommend the authors to include more data and consequently explore their data more in deep! In addition the authors should include a discussion of their results in the context of other study in the Results and Discussion section. Nevertheless it was an interesting read and I want to encourage the authors to carefully rewrite, revise and improve their manuscript.

Specific comments:

L13: Soil moisture is not a flux. Please reformulate the sentence.

L28: Change evaporation to evapotranspiration.

L31-36: Che authors may include also the discussion about soil moisture measured by different method see e.g. Jackisch et al. (2020).

L39-40: Change eg. to e.g.

L49:High precision and high temporal resolved measurement with lysimeter are also able to exactly determine incoming water at the land surface due to precipitation and non-rainfall-events like dew or fog. I suggest to add this point here.

L53: Not clear if observations from one or two lysimeters are used in this study? Please clarify this point.

L56-67: At this stage it is not clear to me why the authors need lysimeter in this study. Neither the introduction text nor the objectives are link to lysimeters. Please clarify this point! If not any soil profile with long term soil moisture measurements could be taken here instead of a more sophisticated measurement set-up with lysimeters.

L73-82: Please provide a table with detailed info on soil properties for all fields. This includes not only the basic info on soil texture but also other important information's, which are normally available at such municipal landfill experimental sites.

L85-86: The authors should explain the modification of the measurement devices in detail, if not study results might not be comparable to other studies.

L93: How does this number fit with the mean inclination angle of 23.5° for each field reported in L75 & L79?

L102: The authors should explain how the used uFC data were derived for this study. This includes the important assumption e.g. vegetation, model, boundary conditions and soil types/ properties.

L102-107: Totally unclear why the authors want to use the model uFC? This should be explained in the section.

L103: Which soil types are used for this uFC data? The authors should describe the soil properties to be able to compare it with the landfilled soil profiles.

L109-116: The authors should clarify why time series were transformed into a radial coordinate system. This was done only for soil moisture observations?

L117: Explain more in detail why the authors used linear regression and for what. Did the authors also check if the assumptions for using such a model are full filled?

L121: What happens in leap years? Why using 365.2425 instead of just using the length of the corresponding year, which can be 365 or 366 days long!

L134-137: Please explain the used method i.e. “Bayesian change point detection” and “time series decomposition” used in this investigation more in detail! The used methods should also be included in the introduction section and it should be shown why this kind of methods are appropriate for such an investigation.

L139: Please be precise: Figure 2 shows the monthly soil moisture profiles at the corresponding position, which were derived from the single measurements. I recommend also to add a) to the soil moisture and b) to the uFC subplot. I suggest in addition to use the same coloring scheme for both subplots. This makes it easier for the reader to

compare between soil moisture and uFC.

L142: Please explain why only RL will be evaluated?

L152: The authors should show this recharge data for each lysimeter in a separate figure! In addition to that the authors might show the precipitation data in the figure. Please discuss the different conditions during the observation period e.g. dry years, wet years and its implications for the observed soil moisture.

L153: Re-wetting 2018. This might be related to the in general wetter conditions in 2017! The authors should explore their data more in depth!

L139-165: The general patterns of the soil moisture can be seen relatively well from the figure 2. However, other results discussed here are difficult to see from this figure. I suggest the authors to re-think what the main purpose for showing the figure here is and change it in a way that main findings are clearly visible.

L139-165: Please discuss results in the light of soil properties at each plot and the vegetation of these fields/lysimeters.

L168: Please report which model bottom boundary was by the DWD to simulate uFC and discuss this in the light of the presented uFC values.

L171: Not sure from which observations I can see evaporation depths over 200cm from Figure 2? Please explain your findings more in detail! Augenstein et al. (2015) reports that the fields are covered by grass, so the authors should discuss also here the vegetation development of the lysimeters/fields and refer in the manuscript consequently to evaporation and transpiration. Was there any change in the vegetation over the observation period? From my perspective higher soil moisture values at the beginning of the period might be rather related to the establishment of vegetation on the fields i.e. change from bare soil with only evaporation to a field cover with grass including evaporation and transpiration. Please clarify this point!

L171: After looking at Augenstein et al. (2015) the authors should also clarify in the

M&M section that the depths across the inclined field varied. In addition the authors should include the info that layers of the profiles e.g. in field 2B are not the same missing mineral clay liner (referring Fig. 1b in Augenstein et al. (2015))

L176: For a better comparison of the time series I recommend to put both in on plot. This makes it easier to compare.

L177: Mean soil moisture of what depths or measurement profiles?

L175-181: It would be interesting to see this time series for the field 1 as the time series of this plot is much larger than for field 2.

L175-181: First: I can see from the time series specific changes after the extremely dry year 2003. Please discuss here possible reasons! You might have a look at e.g. Robinson et al. (2016) or Groh et al. (2020), which showed within their investigations a change in the soil moisture level after drought events. Rahmati et al. (2020) showed for two grassland site a trend of decreasing seasonal minimal soil moisture after drought event in 2015. I guess there is much more literature on that point and I suggest the authors to include a more profound discussion/comparison of their findings.

L139-187: I recommend the authors to use additional methods to analyze the soil moisture time series. It would be worth also to include time series of precipitation and potential evapotranspiration. The authors could also look at the relations between those variables and soil moisture observations e.g. by Wavelet-analysis (see e.g. Graf et al., 2014; Bravo et al., 2020; Rahmati et al., 2020).

L-Figure 2: The authors should explain visible artefacts, i.e. strange lines between 2007 and 2008, white points, and strange lines in 2004 [. . ..].

L188 & 200: Did the authors check the important assumptions associated with a linear regression model? The questions arises as I can see a change in soil moisture level after drought event in 2003, which might affect the distribution of the data.

L198-199: Please reformulate the sentence.

L201: Please show also the values for field 1 below 100 cm in figure 5.

L205-206: Please explain in detail why data for field 1 before 2003 where excluded here.

L207-208: Not sure why the inclusion of data before 2003 would bias the results of field 1?

L215: The authors should show and discuss this percolation data.

L215-218: The authors should clarify to which field this results are related.

L219-229: The authors should as already mentioned provide the background info of this model simulation in the M&M section. This is important to better understand and especially discuss the results. So e.g. which vegetation was used in the simulation, which model, does this model provide a coupling of plant and soil dynamically or use of a fixed LAI and so on.

L227: Unclear how the authors come to this conclusion. Please clarify this!

L230: I could not fully evaluate this section as there is very few information on the used methods in the M&M section.

L235: The authors should explain why 2003 was that important for the soil moisture and actually discuss reason for this observations. Please do this in the whole manuscript.

L238: Is this related to climatic conditions, evolution of the land surface cover or due to changes in the soil after packing the lysimeter? Please clarify this point! The authors also should be aware that landfill soils might behave different than natural developed soils.

L262: Yes indeed that might be a reason! This is actually the first line where discussion of the results starts! However I want to point out that current lysimeters might overcome such issues as those systems are able mimic not only a more dynamical recharge but also the capillary rise from shallow groundwater or deeper soil layers. For further

details on this lysimeters see Unold and Fank (2008); Pütz et al. (2016); Herbrich et al. (2017); Groh et al. (2020); and the effect of shallow groundwater table on land surface water fluxes Kollet and Maxwell (2008); Groh et al. (2016).

L263: This is not truth as the model used by the DWD accounts also for capillary rise. See https://www.dwd.de/DE/fachnutzer/landwirtschaft/dokumentationen/allgemein/bf_erlaeuterur at the chapter “Hintergründe zum Modell”.

L271: I could not find any data in the manuscript that actual shows that hysteresis plays are role at this site. So please clarify the following sentence: “There are clearly hysteresis effects during drying and re-wetting of the soil”.

L278-280: Very vague statement! Please discuss this in a broader context and compare findings with other studies!

L300: Not sure if the observation provide the info if this processes are irreversible or reversible! Please discuss this before in the Results & Discussion section.

L301: I am confused about this statement as the authors used a simple linear model in this manuscript!

L301-303: That’s truth! Thus I recommend the authors to include also vegetation and drainage data to further explore their already rich data set and to include possible interactions between land surface cover, soil moisture and drainage.

Augenstein, M., Goeppert, N., Goldscheider, N., 2015. Characterizing soil water dynamics on steep hillslopes from long-term lysimeter data. Journal of Hydrology, 529: 795-804, https://doi.org/10.1016/j.jhydrol.2015.08.053. Bravo, S., González-Chang, M., Dec, D., Valle, S., Wendroth, O., Zúñiga, F., Dörner, J., 2020. Using wavelet analyses to identify temporal coherence in soil physical properties in a volcanic ash-derived soil. Agricultural and Forest Meteorology, 285-286: 107909, https://doi.org/10.1016/j.agrformet.2020.107909. Graf, A., Bogena, H.R., Drüe, C.,

Hardelauf, H., Pütz, T., Heinemann, G., Vereecken, H., 2014. Spatiotemporal relations between water budget components and soil water content in a forested tributary catchment. Water Resources Research, 50(6): 4837-4857, 10.1002/2013WR014516. Groh, J., Vanderborght, J., Pütz, T., Vereecken, H., 2016. How to Control the Lysimeter Bottom Boundary to Investigate the Effect of Climate Change on Soil Processes? Vadose Zone Journal, 15(7): 1-25, 10.2136/vzj2015.08.0113. Groh, J., Vanderborght, J., Pütz, T., Vogel, H.J., Gründling, R., Rupp, H., Rahmati, M., Sommer, M., Vereecken, H., Gerke, H.H., 2020. Responses of soil water storage and crop water use efficiency to changing climatic conditions: a lysimeter-based space-for-time approach. Hydrol. Earth Syst. Sci., 24(3): 1211-1225, 10.5194/hess-24-1211-2020. Herbrich, M., Gerke, H.H., Bens, O., Sommer, M., 2017. Water balance and leaching of dissolved organic and inorganic carbon of eroded Luvisols using high precision weighing lysimeters. Soil and Tillage Research, 165: 144-160, 10.1016/j.still.2016.08.003. Jackisch, C., Germer, K., Graeff, T., Andrä, I., Schulz, K., Schiedung, M., Haller-Jans, J., Schneider, J., Jaquemotte, J., Helmer, P., Lotz, L., Bauer, A., Hahn, I., Šanda, M., Kumpan, M., Dorner, J., de Rooij, G., Wessel-Bothe, S., Kottmann, L., Schittenhelm, S., Durner, W., 2020. Soil moisture and matric potential – an open field comparison of sensor systems. Earth Syst. Sci. Data, 12(1): 683-697, 10.5194/essd-12-683-2020. Kollet, S.J., Maxwell, R.M., 2008. Capturing the influence of groundwater dynamics on land surface processes using an integrated, distributed watershed model. Water Resources Research, 44(2): W02402, 10.1029/2007WR006004. Pütz, T., Kiese, R., Wollschläger, U., Groh, J., Rupp, H., Zacharias, S., Priesack, E., Gerke, H.H., Gasche, R., Bens, O., Borg, E., Baessler, C., Kaiser, K., Herbrich, M., Munch, J.-C., Sommer, M., Vogel, H.-J., Vanderborght, J., Vereecken, H., 2016. TERENO-SOILCan: a lysimeter-network in Germany observing soil processes and plant diversity influenced by climate change. Environmental Earth Sciences, 75(18): 1-14, 10.1007/s12665-016-6031-5. Rahmati, M., Groh, J., Graf, A., Pütz, T., Vanderborght, J., Vereecken, H., 2020. On the impact of increasing drought on the relationship between soil water content and evapotranspiration of a grassland. Vadose Zone Journal, 19(1): e20029,

10.1002/vzj2.20029. Robinson, D.A., Jones, S.B., Lebron, I., Reinsch, S., Domínguez, M.T., Smith, A.R., Jones, D.L., Marshall, M.R., Emmett, B.A., 2016. Experimental evidence for drought induced alternative stable states of soil moisture. Scientific Reports, 6: 20018, 10.1038/srep20018. Unold, G., Fank, J., 2008. Modular Design of Field Lysimeters for Specific Application Needs. Water Air Soil Pollut: Focus, 8(2): 233-242, 10.1007/s11267-007-9172-4.

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