

Review of “Does drought alter hydrological functions in forest soils? An infiltration experiment” hess-2015-255 by K. Gimbel, H. Puhlmann, and M. Weiler

Summary of Changes

First, we would like to thank the referees for the review and the helpful comments to improve the paper. We have addressed all the comments as explained below.

Comments of Anonymous Referee #1

COMMENTS TO AUTHORS:

This manuscript, “Does drought alter hydrological functions in forest soils? An infiltration experiment”, studies the effect of drought events on soil properties through dye tracer experiments. While the manuscript addresses an interesting research topic, which is the correct understanding of drought effects on soils, the paper lacks clarity and organization. The manuscript is suitable for publication in HESS Journal after addressing the both major and minor recommendations provided below.

MAJOR COMMENTS:

1. The manuscript is very hard to read unless the reader is very familiar with dye tracer experiments. This work would make a far greater and more accessible contribution with some major reorganization and explanation of both experimental setup and background information.

Answer: We agree with the referee and added much more information. For specific changes, please see comments 8, 10, and 14.

2. Until section 2.6 I had no idea the authors were using a soil moisture model. The authors should make clear in the introduction that both dye tracer experiments and simulations were used to address their research question. Furthermore, the soil moisture model is used to state that differences in the infiltration patterns are due to changes in soil properties. This statement is at the basis of the whole work and, in order to infer this from some simulations, the authors should, at least, provide some model validation (even as supplementary information). In section 3.1 the authors say that measurements support the modeling results but this validation is not shown, why? Also, if soil moisture measurements are available, why would the authors use a model?

Answer: We agree with the referee and decided to removed that results of the model. Instead, we show now the measured soil moisture data of the experimental plot. Therefore, we changed the sections 2.6 and 3.1 accordingly. Please see also Referee #3, comment 2.

3. The paper is poorly written: most sentences lack of clarity.

Answer: We improved the manuscript considerably and focused on making the sentences more clear.

OTHER COMMENTS, QUESTIONS AND LINE EDITS:

1. Pag. 7690, lines 1-3: the climate is expected to change and thus have an effect on the water cycle. The sentence is not clear, please rephrase.

Answer: We agree with the referee and changed the sentence to:

“Climate change is expected to change the water cycle and severely affect precipitation patterns across central Europe and in other parts of the world in future, leading to more frequent and severe droughts.”

2. Pag. 7690, line 3: “Usually..” When is this assumption usually made? In modeling frameworks? Please be more specific.

Answer: We agree with the referee and clarified the sentence to:

“Usually when projecting drought impacts on hydrological systems, it is assumed that system properties, like soil properties, remain stable and will not be affected by drought events.”

3. Pag. 7691, line 27: the manuscript investigates only the impact of drought on soil properties, I would remove “and climate change”.

Answer: We agree with the referee and changed the sentence; the new sentence read now as follows:

“To assess the impacts of drought, rainfall exclusion experiments are valuable and often applied tools (e.g. English et al., 2005; Phillips et al., 2009; Da Costa et al., 2010; Kopittke et al., 2014), often in addition to elevated CO₂ concentrations (e.g. Dermody et al., 2007) and night-time warming (e.g. Albert et al., 2011; Selsted et al., 2012).”

4. Pag. 7692, lines 2-6: the study of drought effects on forest ecosystems is also the study of a single aspect in a particular ecosystem. Please rephrase with something like: “While most studies focus on drought effects on plant growth and seedling activity and focus on grasslands and heather ecosystems, only few...”

Answer: We agree with the referee and clarified the sentence; the new sentences read now as follows:

“While many studies focus on single aspects of drought effects like plant growth and seedling activity (Meijer et al., 2011; Wu and Chen, 2013) or focus on particular ecosystems like grassland (Suttle and Thomson, 2007; Bütof 5 et al., 2012) or heather ecosystems (Albert et al., 2011; Selsted et al., 2012), only few studies focus on forest ecosystems or take a closer look at drought impacts on soils where often only soil moisture is observed and no change other soil properties are monitored (Ozolinčius et al., 2009; Albert et al., 2011; Glaser et al., 2013).”

5. Pag. 7692, line 7: where often only soil moisture is observed”, what does it mean?

Answer: Drought impacts on soils are often reduced to changes in soil moisture alone without taking other soil properties into account. We clarified the sentence to:

“...only few studies focus on forest ecosystems or take a closer look at drought impacts on soils where often only soil moisture is observed and no change other soil properties are monitored...” See also comment 4.

6. Pag. 7692, lines 23: “objectives of this study ARE: first, to INVESTIGATE WHETHER droughts”

Answer: We agree with the referee and clarified the sentence to:

“The objectives of this study are: first, to investigate whether droughts predicted by climate projections affect the infiltration behavior of forest soils, and second, whether changes in infiltration patterns can be attributed to changes in the hydrologic properties of the soils.”

7. Pag. 7693, lines 19-22: “The underlying... precipitation is 533 mm”. Please connect these sentences to show that information regards the same site.

Answer: We agree with the referee and clarified the sentence to:

“The underlying geology of the Hainich-Dün is Triassic limestone. The soils at this site are loamy Stagnosols with depths between 45 and 65 cm. The Hainich-Dün site experiences a mean annual temperature of 7.2 °C and a mean annual precipitation of 533 mm.”

8. Pag. 7694, lines 20-21: the experimental setup is not very clear, unless the reader is very familiar with this type of experiments. For example, why do the authors want an application amount of 20, 40 and 60 mm in the three sub-regions?

Answer: We agree with the referee and changed the section to:

“For an overall application amount of 20, 40 and 60 mm, each sub-area was sprinkled with an intensity of 20 mm/h. The applied rainfall intensity of 20 mm/h reflects a heavy rainfall event in all regions, therefore the sprinkling amounts simulate one, two, and three hours of heavy rainfall. The advantage of using three sprinkling amounts is to better understand the temporal infiltration processes, since the 20 and 40mm amounts can be considered as the pattern as it would have occurred after one or two hours for the 60mm experiment (details in Bachmair et al. 2009).”

9. Figure 1: consider combining this figure with Figure 3.

Answer: We disagree with the referee here. Combining Figure 1 (location map) and Figure 3 (excavation and WDPT experiment scheme) in one panel (?) holds no advantages, except space saving. However, if during typesetting process a combination of this both figures is requested, we will not decline.

10. Figure 3a: I would add more details in the figure to make the experimental setup clearer (e.g. write what are the 20, 40, 60 mm; point where the soil profiles were taken in each sublayer and not just in one).

Answer: We agree with the referee concerning the sprinkling volumes, and changed the figure caption accordingly (see below). Concerning the soil profile lines, we do not agree with the referee. Additional soil profiles lines – which would follow equidistant the scheme showed in the front part of the figure (which is clear from the text) – were omitted for the sake of clarity.

“Figure 3. Scheme for profile excavation **(a)** and WDPT experiment **(b)**. The 20 mm, 40 mm, and 60 mm in (a) denote the applied sprinkling volumes. For the WDPT experiment (b), five sampling locations (boxes) were used traverse the profile. On every sampling location, the tests were repeated three times.”

11. Pag. 7606, line 1: “For objective measures to compare the dye patterns...”. What does it mean? The sentence is not clear.

Answer: We agree with the referee and clarified the sentence. The sentence reads now as follows:

“To obtain objective measures to compare the dye patterns of the different profiles and sites, we derived three depth related variables of the binary images: (1) volume density, (2) surface density and (3) stained path width as basis for further delineation and comparison of flow processes.”

12. Pag. 7696, lines 1-12: please move the definition of the abbreviations (sd, vd, SPW) to lines 2 – 4 where volume density, surface density, and stained path width are first defined. Also, I would suggest using uppercase for all abbreviations.

Answer: We partly disagree with the referee here: The variables are first named AND immediately defined in the next sentence. To move the definition would not enhance readability or understandability, but the opposite. Nevertheless, all abbreviations are converted in to uppercase.

13. Pag. 7696, line 12: “As third variable... was calculated”. The authors already said that SPW was calculated. Remove this sentence.

Answer: We agree with the referee here and removed the sentence.

14. Pag. 7696, lines 15-19: since this classification is used in the text, more information should be provided. For example, how are the SPW values related to the different flow processes? Also, please add a quick definition of what homogeneous/heterogeneous matrix flow are and what low, mixed and high interaction with matrix mean. This would make the reading more accessible.

Answer: We agree with the referee and in accordance with referee #2 (comment 1), we changed the section and added more information. The section reads now as follows:

“To obtain objective measures to compare the dye patterns of the different profiles and sites, we derived three depth related variables of the binary images: (1) volume density, (2) surface density and (3) stained path width as basis for further delineation of flow processes. The volume density (VD) is similar to the frequently used dye coverage. It is defined as stained volume divided by the

reference space and is originating from the methods of stereology, which relates a three-dimensional parameter to two-dimensional measurements (Weibel 1979). Surface density (SD) is defined as surface area of an object divided by the volume of the reference space. Surface density provides information on the size and number of features: a high SD is caused by a large number of small objects, whereas a low SD indicates less but larger objects (Weiler 2001). The stained path width (SPW) is derived by measuring the width of every stained object at a certain depth. The SPW of every depth were classified into three classes of < 20 mm, 20 – 200 mm, and > 200 mm (Weiler and Flühler 2004). The sum of the three SPW classes per depth corresponds to the VD of the regarding depth. Using the frequency distribution of the SPW of every depth, the dye pattern can be related to distinct flow processes. For example, macropore flow with low interaction can be identified by long and narrow stains, whereas macropore flow with mixed interaction shows a broader distribution of shapes (Weiler and Flühler 2004). The classification introduced by Weiler and Flühler (2004) was used to distinguish five flow processes, depending on the proportion of stains in each SPW class: two types of matrix flow ((1) homogeneous and (2) heterogeneous) and three types of macropore flow ((3) low, (4) mixed and (5) high interaction with matrix), where interaction is understood as the lateral water flow from macropores into the surrounding soil matrix (Weiler and Naef 2003).”

15. Pag. 7697, lines 1-2: “depending on... of the profile”. What does this sentence mean? Are the measures made all at the same depths in the different sections? If not, why? What depth, on average, was investigated? I suppose 50-80 cm (looking at the results) but I would make this clear in the figure (both 3a and 3b) and in the text when explaining the experimental set up. Also, I would suggest why different depths were investigated at different sites.

Answer: A misapprehension might have occurred here: The WDPT tests were performed in every plot 15 times (five locations times three replicates) per depths. As is clearly visible in figure 5, we tried to cover the whole profile, according to the main soil horizons, and NOT only an average depth of 50 – 80 cm (given the fact, that four out of six plots not even reach 60 cm soil depth...).

To make that more clear, we added the following sentence:

“Depending on the profile depths, WDPT tests were performed in several depths of the profile, covering the main soil horizons (Figure 2).”

16. Figure 3b: please provide in the figure some explanations (e.g. All the 20 boxes are the locations of the WDPT measures? The small rectangle with 3 boxes inside represents the 3 time repetition of the measure?

Answer: We agree with the referee here and changed the caption (see #10).

17. Pag. 7697, line 5: should be Table 1?

Answer: We agree with the referee here and corrected the sentence. The sentence reads now as follows:

“The mean and maximum values of the WDPT test were classified after Bisdom et al. (1993) (Table 1).”

18. Figure 4: what is the green line?

Answer: The figure has been removed. Please see comment 2 and Referee comment #3, No. 2

19. Pag. 7697, section 2.6: Only at this point of the paper it is clear that the authors used a soil moisture model. I would suggest explaining this earlier in the text

Answer: The model and the results thereof are being removed. We now show the results from the soil moisture measurements.

20. Pag. 7697, lines 21-22: which parameters were available and which are the assumed ones? A full list of parameters and references for the assumed values (maybe in the supplementary material) would be useful. Also, some model validation should be added (maybe always as supplementary information). How can we assess the ability of the model without any comparison with data?

Answer: The model and the results thereof are being removed.

21. "Results" section: I would suggest following the same structure of the "Methods" – in the results the authors start with soil moisture simulations, which is the last thing explained in the methods. Consider reordering the methods section in order to follow the results.

Answer: We agree with the referee and reordered the method section. The section is ordered now as following: 2.1 Study sites, 2.2 Soil moisture, 2.3 Soil water repellency, 2.4 Dye tracer experiments, 2.5 Image processing, and 2.6 Dye pattern analysis.

22. Pag. 7698, lines 1-2: "All soils..during the summer months" - do the authors show any modeling results for year 2011 in Figure 4? Where can we see the drop in soil moisture during 2011?

Answer: The model and the results thereof are being removed. The figure has been removed. Please see comments 2 and 18 and Referee comment #3, No. 2

23. Figure 4: Precipitation measurements are related to what year? 2011 or 2013? More information should be provided in the caption.

Answer: The model and the results thereof are being removed. The figure has been removed. Please see comments 2 and 18 and Referee comment #3, No. 2.

24. Pag. 7698, lines 7-8: "soil moisture contents are observed". Are these observations or modeling results?

Answer: The model and the results thereof are being removed. We now show the results from the soil moisture measurements.

25. Pag. 7698, lines 12-13: again, why isn't the comparison with data shown? The authors need to validate the modeling results against measurements in order to use those numerical experiments to infer something. Also, if measurements are available, why would they use a model?

Answer: The model and the results thereof are being removed. The figure has been removed. Please see comments 2 and 18 and referee #3, comment 2. We now show the results from the soil moisture measurements.

26. Pag. 7698, lines 13-15: I do not understand why the different patterns are due only to soil properties. How can the authors exclude any other effect? In general, this section (3.1) is not very clear to me. What is the soil moisture model used for?

Answer: The model and the results thereof are being removed. Instead, we provide the measured soil moisture data to show the development of differences between the drought and control soils.

The section 3.1 read now as follows:

“Figure 4 shows the normalized cumulated sums of the soil moisture measurements of the control and the drought plots over the course of two years. All plots developed a soil moisture deficit compared to the control plots in the upper 5 cm of the soil (cumulative sums are below the 1:1 line). The water deficit is also transduced to the 15 cm and 30 cm depths in both Schwäbische Alb plots and in the coniferous plot of Hainich-Dün, but is generally less pronounced. The plots at the Schorfheide-Chorin site show no deficit (deciduous plot) or even a small plus in soil moisture (coniferous plot) compared to the control plot. The sandy soils of Schorfheide-Chorin are already very dry without drought treatment. The reverse moisture effect might be caused by root effects, for example hydraulic redistribution. However, we did not find any signs for hydraulic redistribution in the data. The deciduous plot of the Hainich-Dün site experienced major probe failures due to animal damage during the summer month of 2012 and again in 2013. Therefore, only the data taken during the winter month could be used for the comparison.”

27. Figure 5: write a label for the x-axis (e.g. WDTP).

Answer: We added an x-axis. The x-axis now reads: “water drop penetration time in s”.

28. Figure 6: what is on the x-axis of these figures (SPW or VD)? What are the orders of magnitude?

Answer: The convenience of this type of plot is, that the sum of the SPW (<20 mm, 20 – 200 mm, and >200 mm) are the VD. This plot is therefore showing the SPW values AND the VD values. Because the SPW and VD are referenced to the profile width, both values range between 0 and 1. Nevertheless, we added an x-axis, changed the caption of Figure 6 and 8, and added information in the section 2.6.

The captions read now as follows:

Figure 6: Comparison between the stained path width (SPW) of pre-drought (2011) and control (2013) plot. The graphs show the proportion of SPW of the total profile width. Blue shades indicate the SPW classes. The sum of SPW is the volume density (VD) per depth. Grey and black indicate the VD of stones (sum of stone widths, same classes as for SPW are used).

Figure 8: Comparison between before drought (2011) and after drought (2013) stained path widths (SPW) and flow processes for coniferous and deciduous stand plots. The graphs show the proportion of the SPW of the total profile width. The sum of SPW is the volume density (VD) per depth. Grey and black indicate the VD of stones (sum of stone widths, same classes as for SPW are used).

29. Pag. 7700, lines 21-25: I am not very familiar with this type of measurements, but I do not see a strong similarity between pre-drought and control plots.

Answer: The chapter was rewritten and comparisons of the volume density using boxplots are now provided to underline our arguments. The part in question now read as follows:

“To summarize, the comparison between the pre-drought and control plots showed a broad agreement. Differences, that need to be accounted for, are the lower VD in the profile top layers of all sites. These differences might be due to spatial heterogeneities, given the distance between the control and the pre-drought plots (15 m to 30 m). The pre-drought and drought experiment were performed in close vicinity (0.5 m). In the Hainich-Dün, the drop and rise of VD in all profiles points to a soil layer boundary effect on infiltration. This is not time dependent and present in both pre-drought and control profiles, therefore the comparability between the pre-drought and drought pattern is not affected.”

30. Pag. 7703, lines 23-25: not clear: no differences which can be addressed”?

Answer: We agree with the referee and changed the paragraph; the paragraph reads now as follows:

“The comparison of pre-drought infiltration patterns of the drought plots with patterns of the control plots (without drought treatment) showed broad agreements. All control plot profiles are comparable to the pre-drought plot profiles, including differences that can be addressed to small scale heterogeneities of soil properties. When interpreting the patterns, the differences in VD in the top layers of all plots need to be taken into account. When doing this, at all sites, the dye experiments before and during drought conditions can be directly compared.”

31. Pag. 7703, line 26: can be assumed to be comparable? Are the results comparable or not? And then “therefore it can be assumed..”. This first lines of discussion are not clear.

Answer: We changed the paragraph, please see comment 30.

32. Pag. 7704, line 8: “the tree main species” – not clear.

Answer: We agree with the referee and clarified the sentence. The sentence reads now as follows:

“In this study, it was hypothesized that the induced drought alters infiltration patterns due to changes in soil hydraulic properties (e.g., soil water repellency and forming of shrinkage cracks) which depends in addition on the main tree species having an effect on the magnitude of the response.”

33. Pag. 7706, lines 12-14: “The authors...repellent agents” : not clear.

Answer: We agree with the referee and clarified the sentence. The sentence reads now as follows:

“The authors explained this fact by the lower specific surface of the coarse textured samples compared to fine textured samples, which have therefore a smaller area that has to be covered by water repellent agents.”

34. Conclusions are too “fast”. I would suggest adding some comments about the different effect of deciduous/coniferous species.

Answer: It is not clear to us, what the referee refers to that the conclusion is too “fast”. We did also consider the effects of coniferous and deciduous trees.