

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 #3

### COMMENTS TO AUTHORS:

The study of the effects of drought on altered functions of soil is of great interest for the HESS community. The authors combine an elaborate experimental setup at three sites in Germany with a hydrological model to study the impact of a moderate drought with a repeat time of 40 years on soil water repellence/wettability and infiltration patterns. Unfortunately the current manuscript suffers from large gaps in the explanation, making the manuscript arduous to read. It is almost imperative to first read Gimbel et al (2015) in Biogeosciences to be able to understand this manuscript. Below my concerns and comments.

### MAJOR COMMENTS:

1. The Material and methods are not complete. While I do not expect to see a complete repetition of Gimbel et al. (2015) it should not be necessary to read that paper first before grasping the nuances in this manuscript. This is already clear from comparing Fig 1 in both manuscripts. Statements like P7693L12-13 “similar with respect to topography and soil type (Fig 2) but differ in tree species composition” do not do justice to what can be seen in Fig 2. Also, in the discussion I would have like to read about possible differences in infiltration as a result of a rock fraction of 80% occurring 10 cm lower in the deciduous plot in Schwabische Alp compared to the coniferous plot, but nothing is mentioned. P7694L7 “a level equivalent to annual drought with a return period of 40 years” is vague wording, please give amounts.

**Answer:** We agree with the referee and added more information about the drought set up (section 2.1) and added statements on the rock fraction in the Discussion section (4). The section 2.1 reads now as follows:

To identify the influence of drought on infiltration patterns of forest soils, six plots in three different regions across Germany were selected. The plots were located in Schwäbische Alb (South-West Germany), Hainich-Dün (Central Germany) and Schorfheide-Chorin (North-East Germany) (Figure 1). All plots are part of the Biodiversity Exploratories framework that incorporates, in total, 150 sites on grassland and 150 sites in forest (for more information on the Biodiversity Exploratories, refer to Fischer et al. 2010). In each of the Exploratories, two forest plots were selected, which are – within each Exploratory – similar with respect to topography and soil texture type (Figure 2) but differ in tree species composition. In each site, one plot with a coniferous and one with a deciduous main tree species was selected. At the Schwäbische Alb and Hainich-Dün sites, beech (*Fagus sylvatica*) and spruce (*Picea abies*) were chosen, in Schorfheide-Chorin beech and pine (*Pinus sylvestris*), respectively.

The Schwäbische Alb soils are shallow (25 to 35 cm) Leptosols on Jurassic shell limestone with high stone content (Figure 2, top). The mean annual temperature at this site is 6.5° C and the mean annual precipitation amounts to 940 mm. 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 is 7.2° C and a mean annual precipitation of 533 mm. The Schorfheide-Chorin plots are located in a young glacial landscape where the dominant geological substrate is glacial till covered by glacio-fluvial and aeolian sands. The soils at this site are deep, sandy Cambisols. At the Schorfheide-Chorin site, mean annual temperature is 8.5° C and the mean annual precipitation amounts to 589 mm. All climate data are taken from nearby stations of the German weather service (DWD, years 1950–2010).

The experiments of this study are part of the interdisciplinary project 'Global Change Effects on Forest Understorey: Interactions between Drought and Land-use Intensity' (Gimbel et al. 2015). The artificial imposed drought was created by a 10 m x 10 m partially roofed subplot, covered with transparent panels. In addition, a control plot with the same technical equipment, but without the roofing was installed. The control and roofed plots include a central adult overstorey tree, which are similar in age, size, and canopy structure between control and the drought imposed plot. To provide sufficient exchange with ambient air (avoiding of a "greenhouse effect"), all four sides of the roof are open. To collect water from the roof, rain gutters are mounted alongside the timber construction. The roof is designed to reduce precipitation between 11 and 100 %; 11 % already intercepted by the roofing construction and rain gutters itself. The incoming precipitation was reduced between March and November to the level equivalent to an annual drought with a return period of 40 years by adapting the proportion of panels at each site separately at a monthly interval. The resulting annual target precipitation inputs under the roofs were 700 mm (26 % reduction) for Schwäbische Alb, 355 mm (33 % reduction) at the Hainich-Dün, and 395 mm (27 % reduction) at the Schorfheide-Chorin site. For a more detailed description of the whole experimental drought setting and of the study plots see Gimbel et al. (2015).

We inserted following paragraph in section 4:

"The examined soils of Schwäbische Alb and Hainich-Dün have high stone contents. Stones can act during infiltration either as impeding barrier or as conveyor fostering preferential flow along the stone surfaces. The soil profiles of the three different soils revealed high spatial variability in stone content between the pre-drought and the control plots (distance between 15 m and 30m, e.g. Schwäbische Alb deciduous plot) and between pre-drought and drought plots (distance 0.5 m – e.g. in Schwäbische Alb deciduous plot and Hainich-Dün deciduous plot). Furthermore, the stone content differed substantial between the profiles of a single experiment (e.g. Schwäbische Alb coniferous drought plot below 30 cm depth). However, with the used methods, no conclusion about interrelation between dye pattern or flow type and stone content could be drawn."

2. The soil moisture model is not well described. Reader needs to read Hammel and Kennel (2001) for any specifics of the model. Input parameters are not given. There is no indication of use of or comparison with data from Gimbel et al. (2015). Values for water retention curve, soil hydraulic functions, and vegetation parameters are not given. Also, given the title of the manuscript, do the authors expect the soil hydraulic functions to change? And if so, did they accommodate for this in the model? And why did the authors use pedotransfer functions if they had such a laborious experiment and could have sampled to measure these soil hydraulic functions? In the results section the performance of the model is only described by “additional soil moisture measurements on the plots support the modelling results (not shown)”. No validation. A Nash-Sutcliffe coefficient would also be appropriate. Differences at the start of the simulation in Fig 4 between the deciduous and coniferous plots are not mentioned.

**Answer:** We agree with the referee and discarded the model in agreement with the other referees. We now show the measured soil moisture contents of the drought and control plot. The sections 2.6 and 3.1 are changed accordingly. Please see also referee 1#, comment 2.

3. The manuscript is overly qualitative when it comes to describing results. For example P7699L13-15 “By comparing the pre-drought pattern and the pattern for the control plots time dependent changes as a reason for differences in pre-drought and drought treated dye pattern can be excluded”. How was the comparison done? How different are these patterns? And why are inherent spatial differences between different sampling locations within the same plot not mentioned here? The authors chose 3 samples within one treatment, is this enough? P7700L22 “showed only small differences” Can these be quantified? The rest of the manuscript follows a similar style in qualitative statements.

**Answer:** To improve the comparability between the pre-drought and the control profiles as well as between the pre-drought and drought profiles, we provide now boxplots of the volume densities in 10 cm steps. In addition, we overhauled the sections 3.3.1 and 3.3.2 (see referee #1, comment 29). The above mentioned sentence is deleted – the paragraph in question now reads as follows:

“Differences between pre-drought and control plots (without drought treatment) reflect differences in soil structure, texture and moisture due to a distance of 20 - 40 m between the drought and reference plot, but may also include time dependent changes of the soil characteristics, which are independent from the drought treatment. To ensure validity of the dye pattern analyses, it is necessary to assure comparability among the plots. To exclude time dependent changes as reasons for differences in pre-drought and drought treated dye patterns, the pre-drought pattern were checked against the pattern of the control plots. Figure 6 compares the pre-drought pattern and the control pattern of the deciduous plots. In addition, Figure 7 provides VD boxplots of the pre-drought and the control profiles for direct comparison. The VDs of one plot are assumed to be significantly different from the VDs of another plot, when the corresponding boxes of the boxplots do not overlap in their spreads.”

4. The discussion mainly focuses on water repellency, but the rationale for the paper, namely drought, is only mentioned at the last five lines. Considering the justification for this study (moderate drought with a 40 yr return instead of 100yr or 1000yr) it would enhance the impact of this particular study to include discussion on aspects of drought.

**Answer:** We agree with the referee and inserted a new paragraph in the discussion section:

In this experiment, a moderate drought with a 40-year reoccurrence probability already changed water repellency and flow pathways. But the applied drought stress was not intensive enough to induce plant mortality or strong changes in biomass of particular species on the time span of the experiment (Gimbel et al. 2015). Under more extreme conditions an even more extreme soil responses might be possible. Higher level of water repellency and the establishment of more preferential pathways might change the water availability of the whole ecosystems. The formation of non-wetting soil layers may trigger drought stress for shallow rooting plants that might even lead to die-off of. Enhanced overland flow, due to water repellency and general reduced infiltration capacity might increase flooding risks and erosion (Doerr and Ritsema 2006). On the other hand, preferential infiltration might even facilitate transport of pollutants into the soil via omitting the degradation in the microbiotic active top layer (Hendrickx and Flury 2001, Keesstra et al. 2012).

#### **OTHER COMMENTS, QUESTIONS AND LINE EDITS:**

1. Page 7690 line 15: Do not use abbreviations in the abstract

**Answer:** We agree with the referee and changed the sentence in accordance with referee #2. The sentence reads now as follows:

“This was 15 confirmed by water drop penetration time (WDPT) tests, which revealed, in all except one plot, moderate to severe water repellency.”

2. Page 7692 line 9-16: The sentence is confusing by using occurrence equivalents, I suppose the authors mean drought events equivalent to those occurring maybe once every 100 to 1000 years?

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

“To achieve drought effects, often extreme short-time events equivalent to droughts with occurrence probabilities of up to 100 or even 1000 years, are introduced to the examined soils (e.g. Glaser et al. 2013).”

3. Page 7692 line 26-30: The hypothesis give away the conclusions, and not referred back to at the discussion except in one place (Page 7705, line 23-24), but further not proven or falsified except when the reader tries to deduce it from the results/discussion. I do not entirely agree with the phrasing of hypothesis one; it refers to soil hydraulic properties, but to me this is too broadly formulated, the wettability and infiltration of the soils will be “tested” as mentioned in line 26.

**Answer:** We agree with the referee and inserted a new paragraph in the discussion section:

“In this paper, three hypotheses were tested: (1) Induced drought alters infiltration patterns due to changes in soil hydraulic properties; e.g. soil water repellency and forming of shrinkage cracks, leading to preferential flow paths and faster infiltration. (2) The main tree species have an effect on the magnitude of the observed response. (3) The drought will increase water repellency depending on tree species and soil properties.

The results of the infiltration experiments support our first hypothesis: applied drought changed the infiltration pattern of all examined soils. Water repellency was found in eight out of nine soils and signs of preferential flow could be observed in all soils. The observed changes in infiltration pattern were more pronounced for the coniferous plots than for the deciduous plots, therefore the second hypothesis can be accepted. Water repellency was higher on the coniferous than on the deciduous plots of the clayey and loamy soils (Schwäbische Alb and Hainich-Dün); and higher in the deciduous plot of the sandy soil (Schorfheide-Chorin). Therefore, the third hypothesis can be accepted.”

4. Page 7694 line 19-20: “ was sprayed with a backpack nozzle for even distribution” Was even distribution achieved? From what I know of dye tracer experiments it is quite hard to achieve an even distribution. Perhaps a backpack nozzle sprayer does spray rather homogeneous, but it also depends on the persons handling the sprayer. Did the authors test evenness in a test setup beforehand?

**Answer:** We agree with the referee here: the evenness of dye tracer distribution, when using a backpack nozzle sprayer, depends on the person handling the sprayer. Therefore, the tracer application was carried out with great care. Dye tracer experiments are frequently performed in our working group; tests performed before other experiments using the same equipment exhibit a uniformity coefficient ( $1 - s/x$ ) of 0.89, suggesting reasonably uniform application (e.g. Bachmair et al. 2009).

Reference:

Bachmair, S., Weiler, M., and Nützmann, G.: Controls of land use and soil structure on water movement: Lessons for pollutant transfer through the unsaturated zone, *Journal of Hydrology*, 369, 241–252, doi:10.1016/j.jhydrol.2009.02.031, 2009.

5. Page 7695 line 24: What is IDL?

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

“All calculations were done with the programming language IDL (Interactive Data Language, Exelis Inc.)”

6. Page 7700 line 8: “medium to high stone content” vague wording.

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

“All profiles have a medium to high stone content (30 – 60 %) below 30 cm depth.”

7. Page 7703 line 24-25: that instead of which

**Answer:** In accordance with referee #1, comment 30 and referee #2 comment 3 we changed the whole 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.”