

# Reviewer 1

Anonymous Referee #1:

Interactive comment on "Phosphorus Transport in Subsurface Flow at Beech Forest Stands: Does Phosphorus Mobilization Keep up with Transport?" by Michael Rinderer et al. Anonymous Referee #1

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*We thank the reviewer1 for his/her assessment of our paper manuscript and the useful comments to improve the text. We have uploaded a pdf file as supplement that provides a response (in red color) to each of the comments suggested by the reviewer. This way we hope to guarantee a better readability.*

General remark: The authors present data from sprinkling experiment in three forest sites, performed during two different seasons, where they analyzed water flow and soil solution P concentrations. The paper is generally well-written and easy to follow, and the results are interesting. However, from my point of view the motivation/objective of the paper is not yet properly addressed with the results. This needs to be addressed before the manuscript can be published. The stated objective of this paper to quantify P losses via subsurface flow (abstract, as well as 1.75 of introduction). This sets the reader up to expect to learn about phosphorus fluxes. More information on subsurface flow P losses would indeed be very interesting, also for the land surface modelling community, which is struggling to incorporate P cycling into C, N models. However, in the results no soil P fluxes [ $\text{g P m}^{-2} \text{ time}^{-1}$ ] are presented, only P concentrations [ $\text{mg P L}^{-1} \text{ water}$ ]. I suggest authors to bring the paper in line with the objectives. Firstly, in the introduction by introducing what are typical soil P stocks in forest ecosystems (see e.g. (Achat et al. 2016; Hou et al. 2018)), and further what are orders of magnitude for P flux losses (e.g. in  $\text{g P m}^{-2} \text{ yr}^{-1}$ ) as determined by earlier studies (see e.g. (Vitousek 2004) and others authors would have to search the literature a bit here). Perhaps also comparing to other P fluxes in forest ecosystems such as dust deposition, rock weathering, etc. This will set the scene for talking about P fluxes in forest ecosystems. I'm guessing that the losses will be several orders of magnitude lower than the stocks, and it will have to be argued why (if?) they are still important. Secondly, no P flux data is presented in the results. Is it possible to multiply water flow by P conc. to get P flux? Why is this not done?

We agree that P-fluxes are an interesting theme. In fact, we are preparing another paper manuscript that is addressing this topic. In the paper we submitted here we want to describe the experimental setup and focus on P-concentrations, the nutrient flushing and the chemostatic behavior towards the end of the experiments. We argue that there is not much literature that presents soil-depth specific P concentrations in high temporal resolution from forest stands measured under field conditions why we think it is worth to present this data and have a separate paper on the fluxes. As a response to the reviewer we however will consider to reformulate the title to be clearer.

The discussion should be developed further also. How do the results from this study tie into what we already know about P cycling in forests, and P loss pathways? At the moment the discussion mostly explains the results, but it needs to go further to show readers what has been learned. Again, given the setup of the paper, the focus should be on P fluxes. What do the results mean in terms of fluxes? What do we learn about P cycling in forest ecosystems?

We will revisit the discussion section and better address the topics suggested. P fluxes however are the topic of a second paper currently in preparation.

Just thinking out loud (authors may choose to followup on this or not): Apart from the nutrient flush in the first 1-2 hours, P concentrations were relatively constant regardless of SSF. On a methodological note, does this imply that we can (roughly) approximate annual P losses via SSF given the water balance of the site and the soil solution P concentration? What would that imply in terms of annual P loss [ $\text{g P m}^{-2} \text{ yr}^{-1}$ ] for these sites? How does that compare to the forest stocks and orders of magnitude that can be expected for other loss and input pathways such as dust deposition, weathering and erosion (Chadwick et al. 1999; Hartmann et al. 2014; Tipping et al. 2014; Aciego et al. 2017) ?

We are developing similar thought and will support these with data analysis but this is subject of a different paper manuscript in preparation.

Specific comments

Title: This is up to the authors, but if they want their article to also reach hydrologists, the title (and abstract?) should be revised. A good portion of the results and discussion as well as the conclusion

focus on water flow, which I did not expect from reading the title. E.g. something along the lines of  
“Beech forest stands sprinkling experiments: effects on sub-surface flow and phosphorus dynamics”

We will consider changing or adapting the title to address a broader audience. A revision will also update the abstract.

I. 23 Jumping on the “climate change” bandwagon here is unwarranted. There is no discussion of climate change in the article. Also, the data rather show that P conc. is constant and thus only dependent on water balance, right?

The idea of this sentence was to put the paper in a very broad, general context but we agree that climate change is not a main theme in the following paper analysis. Still, precipitation is predicted to change as a consequence of climate change, and by this will have an effect on SSF and thus P-transport. We will edit this part to be clearer.

I. 29 How much P is in forest soils? How big are these losses?

We will address P-stocks and fluxes in the second paper.

I. 32 remove period after “SSF”

We will address that

I. 34 remove period after “nutrients”

We will address that

I. 45 The way this sentence is written makes it sound like it was done in this study. I suggest to change tense to “has been” or state “in previous studies”

We will address that

I. 52 add “, USA”

We will address that

I. 54-62 This is too detailed and should be condensed

We will address that

I. 66 “In biopores...” ?

We will address that

I. 74 “We performed....to capture potential differences in P fluxes.” However, in the research questions the focus is on dynamics of P concentrations. This should be aligned.

We will address that

I. 99 231 g at CON is very similar to 209 g at TUT, especially given heterogeneity inherent to soils. I don't think you can argue that TUT is “less rich in soil P” than CON.

We realize that the way we wrote the sentence is maybe misleading to the reader. We will state the P-content but not rank it relative to each other.

I. 99 So that the reader can put these numbers into relation (is 209 – 678 g P m<sup>2</sup> really a large range in P, justifying calling one P poor and the other P rich?), I again suggest presenting orders of magnitude ranges in soil P stocks in forests (see comment I. 29)

We argue that between the MIT (ca. 700 g P m<sup>2</sup>) and the other two sites ( ca. 200 g P m<sup>2</sup>) there is a factor of >1/3. At least for forests in Central Europe this is a significant difference. However, we agree that we can avoid the terms “rich” and “poor” and talk about “higher” and “lower” instead.

I. 102 Add period before “Bulk”. I stop correcting spelling / grammar mistakes at this point, but there are more in the remaining text. Please proof read the next version carefully.

We will work on this

I. 136 I'm no expert here, but I'm guessing rain water is far from de-ionized. How do you think using deionized water affected the results? Does that need to be discussed?

Collecting 60.00 L of rainfall for the experiment was not an option. So, we were left with using groundwater from the drinking supply system. We argue that using untreated groundwater as sprinkling water would have been unacceptable from an experimental design point of view simply because it is an unnatural source of hydrochemical compounds (including P) to the system. We think that the term “deionized” might make some readers think of purified water like in a lab environment. To show that this was not the case, we had added in L 136 that the water had an electrical conductivity of 20 µS/cm. This is comparable to some natural rainfall. The 20 µS/cm is a

result of the efficiency of the industrial deionizer and processing 60.000 L of water. However, to avoid irritation, we will avoid the term “deionized water” as much as possible.

l. 170-177 Nice setup to let the reader now what to expect, look for and interpret in the results! That’s an example of great scientific writing .

We appreciate your positive comment

Table 1: Please also add pH to the table. pH is an important indicator of soil P forms and dynamics and may be important to explain the results, e.g. the difference between TUT, CON and MIT.

We will add pH to Tab 1

Fig. 1 and others: colors are not grayscale print-friendly:

We argue to keep figures in color-scheme as showing all in gray scale is even harder to indicate the information included in the plots.

Fig. 2 Very nice overview figure. This makes it a lot easier to understand what was done.

We appreciate your positive comment

Fig 3. also this is a nice figure. I suggest to move spring before summer. I understand that spring experiments were carried out a year later, and that’s ok since you have the dates there and it can be noted in the figure caption. But it makes more sense to have the plots in seasonal order for interpreting the plots

We consider changing the order of the final graphs.

Section 3.4 It would have been interesting to measure inorganic and organic P as opposed to only total P.

We see the reviewer’s point but  $P_{tot}$  is the data that we have at hand.

Results section 3.5: multiplying conc. by water flow = element flux. Why not present these data in a section 3.5 “Soil P fluxes”

We prepare a second paper that has the focus on P fluxes.

l. 256-260 (p. 8-9): I’m not surprised that P conc. in the soil solution remains relatively constant. If we consider the very fast turnover time of P in the soil solution of only seconds to minutes (Helfenstein et al. 2018).

We will include this in the discussion

I. 300 What about biopores? Is there evidence to suggest that CON and TUT have more earthworms or other large soil fauna

Biopores can also make a contribution to preferential flow. We will address this in the text. Due to the low pH, there are no or only a few earthworms to be found at MIT and CON. In TUT, earthworms are present. However, due to the clay content, we consider it very likely that cracks originating from shrinking and swelling processes make the largest contribution to preferential flow.

section 4.2 This section could be re-written to make it more focused. At the moment there is a mix of rather trivial findings, such as that P stocks are higher in the forest floor than in the mineral soil, while the interesting things are not discussed in-depth enough. The discussion of P concentration dynamics should be better linked to existing literature, e.g. what is known about turnover time of P in the soil solution and phosphate buffering capacity. Phosphorus-buffering capacity (PBC) is defined as the ability of soil to moderate changes in the concentration of soil solution P (Beckett and White 1964; Olsen and Khasawneh 1980; Barrow 1983; Pypers et al. 2006), and would be interesting to bring in here. Soil solution P turnover, a related concept, has been shown to be negatively correlated with P conc. in the soil solution (Helfenstein et al. 2018), which authors might consider discussing as well. (i.e. the more P in the soil solution (forest floor), the slower the turnover time; the less P in the soil solution (mineral soil), the faster the turnover time.

Thank you for your valuable input. We agree that including the mentioned issues can improve the discussion. We will revise this section

I. 347 As with the plots, I would take spring before summer.

We consider to change this in the final version

I. 364 not exactly true that you have six different experiments. It's one experiment carried out on three sites and at two time points.

We will change this to be more precise

I. 371 It's quite well known that soil solution P concentrations are lower with increasing soil depth. I would rather focus on novel findings in the conclusion.

We will rewrite the text

I. 372 "it was especially strong..." What is it? I. 373 It is obvious that P concentrations are highest in the P-rich site. Again, the conclusion should focus on the novel findings.

We will rewrite the text and remove parts that are meant to summarize the paper.

I. 374 “Particularly high”. Please be concrete. How much higher? Are we talking 1.5x,2x or 10x higher than during the rest of the experiment?

We will change this to be more precise

I. 375 – 379 This is interesting and in my opinion the main finding of the study. This should be placed more prominently and discussed appropriately.

We will extend this part

I. 380 Conclusion not supported by the data. There was no discussion of climate change in the article.

The last sentence of the paper will be removed.

I. 436 “DWD, 2010” please provide complete citation reference

Will be completed

## References

Thanks for pointing out to these references. They are valuable for our paper

Achat DL, Pousse N, Nicolas M, et al (2016) Soil properties control-ling inorganic phosphorus availability: general results from a national forest net-work and a global compilation of the literature. *Biogeochemistry* 127:255–272. doi:10.1007/s10533-015-0178-0

Aciego SM, Riebe CS, Hart SC, et al (2017) Dust out-paces bedrock in nutrient supply to montane forest ecosystems. *Nat Commun* 8:14800. doi: 10.1038/ncomms14800 Barrow NJ (1983) A mechanistic model for describing the sorption and desorption of phosphate by soil. *J Soil Sci* 34:733–750. doi:10.1111/j.1365-2389.1983.tb01068.x

Beckett PHT, White RE (1964) Studies on the phosphate potentials of soils. *Plant Soil* 21:253–282. doi: 10.1007/bf01377744

Chadwick OA, Derry LA, Vitousek PM, et al (1999) Changing sources of nutrients during four million years of ecosystem development. *Nature* 397:491–497. doi: 10.1038/17276

Hartmann J, Moosdorf N, Lauerwald R, et al (2014) Global chemical weathering and associated P-release – The role of lithology, temperature and soil properties. *ChemGeol* 363:145–163. doi: 10.1016/j.chemgeo.2013.10.025

Heltenstein J, Jegminat J, McLaren TI, Frossard E (2018) Soil solution phosphorus turnover: derivation, interpretation, and insights from a global compilation of isotope exchange kinetic studies. *Biogeosciences* 15:105–114. doi: 10.5194/bg-15-105-2018

Hou E, Tan X, Heenan M, Wen D (2018) A global dataset of plant available and unavailable phosphorus in natural soils derived by Hedley method. *Sci Data* 5:180166. doi: 10.1038/sdata.2018.166

Olsen SR, Khasawneh FE (1980) Use and limitations of physical-chemical criteria for assessing the status of phosphorus in soils. In: Khasawneh FE, Sample EC, Kamprath EJ (eds) *The Role of Phosphorus in Agriculture*. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, WI, pp361–410

Pypers P, Delrue J, Diels J, et al (2006) Phosphorus intensity determines short-term P uptake by pigeon pea (*Cajanus cajan* L.) grown in soils with differing P buffering capacity. *Plant Soil* 284:217–227. doi: 10.1007/s11104-006-0051-y

Tipping E, Benham S, Boyle JF, et al (2014) Atmospheric deposition of phosphorus to land and freshwater. *Environ Sci Process Impacts* 16:1608–1617. doi: 10.1039/c3em00641g  
Vitousek PM (2004) *Nutrient Cycling and Limitation: Hawai'i as a Model System*. Princeton University Press, Princeton