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Interactive comment on "Spatial Patterns of Phosphorus Fractions in Soils of Temperate Forest Ecosystems with Silicate Parent Material" *by* Florian Werner et al.

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Answers to Reviewer 2:

"1) They estimated "stage of pedogenesis" of their four soil samples. I wonder if it's reasonable to compare among soils with different parent material, moisture content or elevation. How were these four sites selected? Explanation of study sites and detailed soil property data are required. What does "mean" represent (i.e. entire soil depth)? What is the sample number (n=?)?"

In our manuscript, we used the term "stage of pedogenesis" to distinguish the "pedogenetic age" of our sites (referring to our sites as a "geosequence"). Not all studied

soils have the same pedogenetic age. In the revised version of the paper we intend to replace this ambiguous term using "stage of podzolization" instead to describe the pedogenetic age of our soils. The stage of podzolization is, of course, affected by parent material, climate, elevation and other factors. Our study focused on P distribution in four soils (Cambisols) with different stage of podzolization of forest soils (mainly European beech stands of similar age) with siliceous parent material under temperate climate (as part of the Priority Program 1685 funded by the German Research Foundation DFG). Pre-studies found different P availability, as described by foliar P contents, at these sites (LUE < CON < MIT < BBR). They also found differing P contents in these soils. In the revised manuscript, the soils CON, MIT and LUE will serve as representative examples for early, intermediate and later stages of podzolization in temperate soils with siliceous parent material. As already discussed in the manuscript, BBR is a special case of an early stage podzolization with large capacity to withstand podzolization. A revised manuscript will not use the term "sequence of soils" or "geosequence", but "soils with a different stage of podzolization".

"Mean" represented the mean content in the entire soil depth. A revised version of the manuscript will give the mean contents of the fractions from 0-60 cm depth, to better compare the properties (n = 49 to 56). In addition, we intend to create a new table with detailed information about soil and site properties, then also including stand age, tree composition and soil texture.

"P2 L9: I cannot find any data for LUE in the paper by Prietzel et al (2016b). In addition, the soil property data by Prietzel et al. (2016b) for BBR, CON and MIT were different from their data shown in Table 1. For instance, Prietzel et al. reported pH and TP of MIT (surface 0-2 cm) as 3.8 and 1.99 g P kg-1, respectively, whereas their data were 2.9 and 0.72 g P kg-1, respectively. Some soil properties such as texture and clay content should be added in Table 1."

Prietzel et al. (2016b) reported pH and other soil properties for three of the studied soils by soil horizons. The three soil pH values mentioned by the Referee are all derived from

Ah horizons which have a depth of 10 cm. Likewise, total P values were presented. The pH values shown in this manuscript are derived from 0-5 cm which can affect the estimation. In addition, all soil profiles were freshly prepared for our study which can also complicate comparison of parameters with previous studies from the same site.

"2) They discussed P adsorption mechanisms in acidic soils, yet completely ignored clay content or/and types of clay present in each soil."

This is an important advice and we agree that clay minerals should have been mentioned and discussed in more detail. The fractionation techniques that were used in our study also included dissolution of P adsorbed by clay-sized particles (clay minerals, pedogenic oxides and oxyhydroxides). Our manuscript focused much on Al- and Fe-oxyhydroxides, because P adsorption by clay minerals plays a minor role in P retention. Especially important for P retention by clay minerals is the Al-coverage of clay particles (which generally bind cations in acidic conditions). For most soils, the fraction of oxalate-extractable Al mostly consists of Al cations and $Al(OH)_3$ adsorbed to clay minerals. The latter thus are represented in our assessment of interrelation of P forms with other soil parameters. Moreover, Violante and Pigna (2002) reported that clay minerals (montmorillonite, kaolinite, nontronite, illite, smectite) sorbed less phosphate than poorly-crystalline metal oxides, allophane, mixed Fe-Al gels, organo-mineral complexes, goethite, and gibbsite, because of the smaller surface areas of the latter compounds. In addition, clay minerals mainly exert their influence on P retention by Al and Fe ions which are bound by the silicates. Therefore, the amount and type of Al and Fe oxyhydroxides present in soils is of greater importance than the type of phyllosilicates. Hints on P adsorbed to clay particles are included in the Pdi and Pox fractions, but the fractionation method used cannot distinguish between adsorbed P onto clay minerals and Fe/Al-oxyhydroxides. However, the revised manuscript will include a discussion of the influence of clay minerals and their saturation with different exchangeable cations to P adsorption.

"3) P5 L4:"The interpolated maps did not reveal a uniform distribution of P in any of the

studied soils". This sentence is odd since no one expects uniform distribution of P in soils."

We suggest introducing our results by: "As expected, the interpolated maps..."

"4) I found Figure 5 very confusing. The x-axis indicates, "stage of pedogenesis and soil acidification". However, according to Prietzel et al (2016b), the pHs of the soil samples are in the order of BBR (pH 3.1) > CON (3.6) > MIT (3.8) or according to their data, MIT (2.9) > LUE (3.0) > BBR = CON (3.2). Either way, they are not representing the stage of acidification. As I mentioned, I am not sure if they can compare the stage of pedogenesis among their soil samples."

In the revised version of the manuscript, the term "stage of pedogenesis and soil acidification" will be reformulated into "stage of podzolization". We already argued that the studied soils share commonalities. In our manuscript we ordered our sites into a broader figure of P distribution during pedogenesis. We recognize that it might be difficult to draw the bigger picture of the changes in P binding form and distribution (manuscript Fig. 5) with one replicate per site. However, Fig. 5 and the comparison of the sites should be seen as a conceptual model of relationships between stage of podzolization and the distribution of different P forms and important P fluxes as derived from our results. The discrepancy between the pH values from the publication of Prietzel et al. 2016b and this study has been discussed previously.

"5) Prietzel et al (2016b) estimated ∼65% of total P in the upper layer (0-10cm) of BBR was inorganic P, such as $Ca(H_2PO_4)_2$ (11%), apatite (11%) and $FePO_4$ (41%). Also ∼40% of total P in the upper layer of MIT was inorganic P, such as $AlPO_4$ (18%) and $FePO_4$ (22%). Yet, Figure 5 shows no inorganic P in the upper layer of BBR or MIT. Any reason why?"

Fig. 5 showed white bubbles with a "P" inside which represented inorganic phosphorus. A revised figure will replace those bubbles further up and also address P adsorption by clay minerals (s. answer to comment 2).

"6) P12 L8: How about adsorption of inorganic P onto clays in the upper layer? According to Prietzel et al. (2016b), the texture of BBR (0-10cm) is silty clay."

We agree that the influence of clay minerals must be discussed (s. answer to comment 2).

"7) P12 L24: Effects of root interaction on P transformation in soils should be included when thinking of distribution of forms of P. It will help to add approx. age of trees in each study site. I imagine that when they collected soil samples, they should have observed plant roots in different layers."

It is true that rooting interacts with the P distribution in soils. We have observations of rooting from the soil sampling campaign which we will include in a revised manuscript. Furthermore, the approximate age of the stands will be included in Table 1.

"8) Figure 2 and 3: I liked the way they showed the distribution patters of TP and different P fractions. However, the range of proportion of each color is not clear. (i.e. what does the range high concentration of P represent?)"

We decided not to insert scale bars for two reasons: 1) the profile images would be far smaller, and 2) we focused on the distribution of P. In the revised manuscript, we intend adding the highest and lowest value of every fraction in the respective image to span the scale. See also example figure (total P at CON).

"9) Table 3: I would like to see actual mean data in addition to the correlation."

We propose compiling a new table (as new Table 2), in which we describe the mean data of the fractions in the full soil profile (0-60cm depth) and in the different compartments (upper, middle and lower profile section). Also n-values will be included.

"10) In conclusion, I suggest adding some sentences to explain how their study can be useful to others and what might be the next step."

We started to address how others can profit from our study by discussing the impli-

cations of our results on nutritional strategies (e.g. importance of P recycling). The revised manuscript will work out the benefit for others more clearly (e.g. grid sampling of soil profiles, assessment/evaluation of P bioavailability, implications on bioelement-cycling and ecosystem nutrition strategies, s. Lang et al. (2016), JPNSS, vol. 179 (2), pp. 129-135) and mention next steps, such as studying calcareous soils or including advanced techniques of P speciation (e.g. NMR, XANES).

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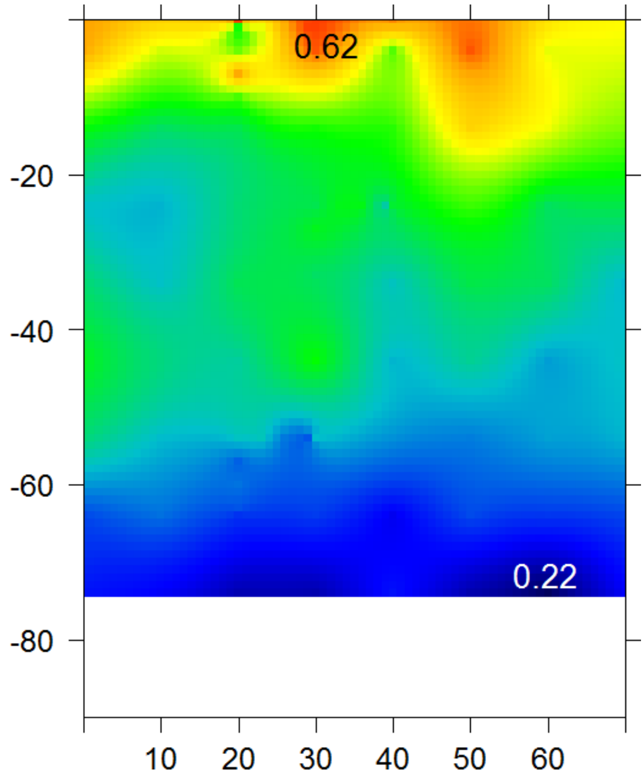

Fig. 1. Total P at CON, numbers spanning the range of the color pattern