"The estimate of MRT deserves an encouragement, because it provides a fundamental and quantitative insight into the dynamics of P in soil. In this regard, I would like to support the publication of this work. However, before this, I have some concerns for the authors to address."

Thank you very much for taking the time to review our manuscript and for your supportive and constructive comments. Below, we have addressed your comments point by point and described our changes to the revised manuscript.

"I am curious about why the MRT of HCl-P can be estimated in the way used by the authors. HCl-P is mainly of apatite P in neutral and alkaline soils. The dynamics of apatite P should be unidirectional, that is apatite P is always depleted without a formation during the experimental duration (90 mins). So, an exchangeable between resin P and HCl P is unreasonable at least for neutral and alkaline soils (Fig. 1), although it's possible if HCl P is largely of Fe/Al associated P, as in acidic soils."

Indeed, exchange between HCl- P and the soil solution is often considered to be unidirectional in model formulations, i.e. a slow one-way flow of phosphates from the HCl-P pool to the soil solution via dissolution. This holds effectively true if we consider the net change of this pool over a pedological time scale (e.g. the Walker and Syers model). However, as pointed out by the reviewer, HCl-P may also contain secondary P forms, such as Fe/Al associated P. Even in neutral/alkaline soils, Ca-P forms extracted by HCl may be secondary because phosphate ions easily precipitate with Ca in systems containing carbonates (Frossard et al., 1995)*.*

Analysis of stable oxygen isotopic ratios in phosphate have also confirmed the dynamics of the HCl-P pool. There, on all soils studied except for young/unweathered soils, oxygen in phosphate carried the biological signature, suggesting re-precipitation of phosphate from the soil solution into the HCl-P pool after cycling through the biosphere (Helfenstein et al., 2018; Tamburini et al., 2012)*. Similarly, radioisotopic tracing shows radioisotope tracer incorporation over time scales of days-weeks into HCl-P* (Buehler et al., 2002)*. Due to the empirical evidence, we propose that future P model formulation should consider bi-directional exchange between HCl-P and the soil solution.*

We explain why we propose bi-directional exchange in a new section in the discussion (p. 13, l. 10-18).

"All the estimates of MRT are obtained based on laboratory incubation. The estimates therefore should be much different from those in field, which can be affected by soil moisture and temperature and many other factors. This limitation and their potential effects on the estimates should be noted. Are the estimates comparable to the estimates of Hou et al. (2019) based on greenhouse experiments?"

We agree that MRTs in field situations are likely to be vary from MRT estimates based on laboratory experiments. Hou et al. 2019 calculated MRTs of P in P pools based on changes in P pool sizes over time with data from a pot experiment growing plants on 8 different soils (Guo et al., 2000). *Below we compare the MRT of Hou et al. 2019, calculated as the inverse of the reported turnover rates for the respective pools, to the median MRTs of our study (see Table 3).*

Pool	*MRT in Hou et al. 2019 (means)*	*MRT in our study (medians)*
Labile P	*25 days*	*<< 1 day*
NaOH-Pi	*43.5 days*	*25 days*
HCl-P	*3.1 years*	*2.6 years*

While MRT estimates for NaOH-Pi and HCl-P are similar, the range in MRTs was much larger in our study than in Hou et al. (2019). Also, the MRT for labile P is one order of magnitude lower in Hou et al. (2019) than in our study. These differences are not surprising given the different approaches used to estimate MRT of P in these pools. By measuring changes in P pool sizes, only net P fluxes are considered. The radioisotopic approach on the other hand also measures exchange fluxes not leading to changes in pool sizes. This is important because sorption/desorption fluxes without net changes in P pool sizes are the main process driving P cycling between the soil solution and inorganic P pools, and thus important for P bioavailability (Frossard et al., 2000; Syers et al., 2008).

To address the reviewer's concerns, we expanded on the discussion of limitations arising from laboratory estimates (p. 11, l. 3-5). Also, we point out how our estimates are different from MRT estimates considering net changes in P pool sizes (p. 3, l. 14-16).

"The Figure 1 and the calculation of MRT of NaOH-P and HCl-P are weird. MRT-NaOHP is estimated based on the sum of labile P and NaOH-P (while not only NaOH alone?). MRT-HClP is estimated on the sum of labile P, NaOH-P, and HCl P (while not on HCl P alone?). This will at least confuse readers, which do MRT-NaOHP and MRT-HCl really measure?"

We realize that the calculation was not properly described, making the understanding of the approach difficult. Hence, we added the following sentence: "The summation of more labile pools to estimate MRT of more recalcitrant pools is necessary because in this model "slow" exchanging pools can only exchange once "faster" exchanging pools have fully exchanged." (p. 6, l. 2-3). The explanation is followed by the justification of this assumption (p. 6, l. 6-9).

"In Fig. 1 the conceptual diagram differs from many other diagrams, such as Hou et al. JGR Biogeosciences (2019) and Tiessen et al. (1984). The model structure (conceptual diagram) affects the estimate of MRT. I think this should be discussed to let readers know there are other possible exchange pathways among soil P pools that will affect the estimate of MRTs."

We realize that one of the difficulties in P modelling is that many empirical studies and also many models are based on slightly different conceptual diagrams of P cycling. In preparing this paper, we had a lot of discussions with Daniel Goll (as a representative of the P modelling community and co-author on this paper) on how our approach relates to existing model formulations. Our approach has been to clearly state the assumptions (p. 6, l. 6-22) and discuss the limitations (p. 11, l. 22- p. 12, l. 9). Also, we made sure that our conclusions go beyond our conceptual model and apply to all P model formulations.

To address the reviewer's comments, we added an additional sentence to make it explicit that we did not consider exchange between NaOH-Pi and "occluded pools" (p. 6, l. 10-12).

Also, we adapted the concluding paragraphs to make them more appropriate also to other conceptual model formulations of P cycling (see section "implications for land surface modelling").

"Give units in Figs. 2 and 5. Give Y axis lab (MRT?) in Fig. 4"
Thank you for spotting this. We added units to the x- and y-axes in Fig 2 (in the figure legend because the axes labels are already crowded). Figure 5 already has units (no changes made). In Fig. 4 the y-axis is indeed MRT. We added that.

"In L15, "and call these soil P pools", I think I understand what you mean, but it reads a bit weird."

We deleted the sentence fragment because it is unnecessary and can lead to confusion.

"L24-25: which two studies? Does the filled data affect much of the results?"

The two studies that didn't have information on soil texture were Borda et al. 2014 and Helfenstein et al. 2018. This is listed in supplementary table 1, "Sources for data on soil and other properties for each site". Additionally, we now referenced the studies in the sentence (p. 4, l. 11).

To test if the "filled data" affects the results, we repeated the analysis while excluding the Borda and Helfenstein samples (Fig 1 below. Compare to supplementary figure 3). The F and p values changed slightly, but the general conclusion is the same: significant regressions for MRT of labile P and NaOH-P, but not for HCl-P, though all models point at the same trend. Because the "filled data" does not affect the results we made no changes in the manuscript.

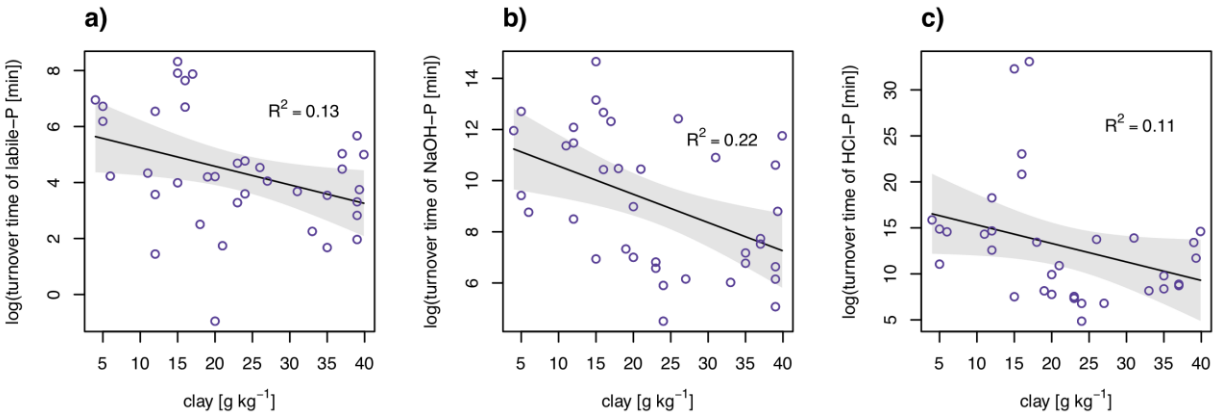

Figure 1. Simple regression of calculated mean residence time of P with clay concentration, excluding samples for which soil texture data was taken from SoilGrids. The model values changed slightly, but show the same trend. For labile P (F-statistic = 5.4, p = 0.03) and NaOH-P (F-statistic = 9.8, p < 0.01), but not for HCP (F-statistic = 3.8, p = 0.06).

"I think the data used by the authors are valuable. Why not make the raw data and the fitted m and n values open access?"

Thank you for finding our data valuable. We will provide it as a supplementary csv table in the revision. See "all_data.csv" file.

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