Answers to reviewer#3

There is an unredeemed potential for interesting publications in the large databases of national forest/soil inventories. This is also the case for the Swedish Forest Soil Inventory, publications using these data are highly welcome. The present study focuses on carbon (C), nitrogen (N)and phosphorus (P) and the ratios C:N, C:P, and N:P in both organic and mineral soil layers which particularly the P and the ratio aspect are novel. After reading the paper, I am however, a bit puzzled. The manuscript/tittle and objective promises to explore relationship with climate, tree species and soil texture, and it delivers on showing these relationships, but the discussion offers very little or patchy interpretation. My greatest concern with regard to this manuscript is the lack of discussion of the results and relationship against important factors known to regulate the accumulation/loss of C from soil -the balance of input of organic material against decomposition. Instead the main part of the discussion is linked to changes in N and here the focus is on three hypotheses *" first, the higher N deposition towards the south/southwest of Sweden that enriches the organic layer in South/Southwest Sweden with N. Second, it could potentially be that the rate with which N is taken up by trees increases with decreasing MAT, leading to N depletion of the organic layer at sites with low MAT. Third, it might be that N2 fixation decreases strongly with decreasing MAT."* While I do not dispute that these could be relevant hypotheses, I find it strange that forest productivity and decomposition processes are not discussed more in full. The same criticism could be directed towards the discussion of the P, here I had expected that the regional distribution of P in parent material (geology) would have included, also a reflection regarding limits P nett-immobilisation and nett-mineralisation. The text is also drawn down by some unnecessary errors which could easily have been corrected before submission (see comments below). My conclusion is therefore that the manuscript is not ready for publishing, there are too many errors, and insufficient discussion of the results, see comments below for more specific reasons for my conclusion.

In this study, we use data of the Swedish Forest Soil Inventory to elucidate the abiotic and biotic factors that control the ratios of carbon, nitrogen, and phosphorus in the organic matter of 309 forest soils. We concentrated the analysis on the effects of climate, dominant tree species, and soil texture on soil organic matter stoichiometry because we have data on these variables. In contrast, we do not have data on organic matter decomposition rates in these 309 forest soils or on net P immobilization and mineralization.
In the section cited by the reviewer, we discuss why the N stock of the organic layer changes more strongly than the organic layer stock with increasing mean annual temperature. We now added the following lines about N mineralization and decomposition to the manuscript "Mineralization of N is also expected to increase with increasing temperature, and hence should counteract the accrual of N with increasing temperature. Our finding that the N stock of the organic layer increased with increasing MAT thus suggests that MAT has a larger positive effect on N_2 fixation than on net N mineralization. Similarly, the increase in the organic layer stock with increasing MAT (Fig. 2b) suggests that MAT has a larger positive effect on plant productivity (Fig. 2d) than on decomposition."
We now also discuss decomposition in section 4.5 in the following way. "Further, it could be that the decomposition rate of the organic layer is positively related with the organic layer P concentration since it has been shown that P is the most limiting element for microbial activity during the first phase of decomposition of pine needles in Sweden (Staaf and Berg, 1982)."

We now included the P concentration of the parent material and the mineral topsoil (0-10 cm) in the regression analysis (see Table 1) showing that P was only very weakly related with latitude and mean annual temperature. We mentioned already in the previous version of the manuscript that the P concentration of the soil parent material did not differ much between the soils (see end of section 3.4). Hence we see no need for a detailed discussion of the "regional distribution of P in parent material" that the reviewer suggests.

We also added another figure showing the total P contents in soils of different texture class (see below).

Does the paper address relevant scientific questions within the scope of BG? a. yes

2. Does the paper present novel concepts, ideas, tools, or data? a. Novel concepts: to some degree

b. Novel Ideas: the background for the first hypotheses is not clearly stated, but with better explanation it could be considered novel. I suggest that the authors should consider e.g. Sundqvist, M. K., Liu, Z. F., Giesler, R., Wardle, D. A., 2014, Plant and microbial responses to nitrogen and phosphorus addition across an elevational gradient in subarctic tundra, Ecology 95(7):1819-1835. Which presents N:P ratios in relationship with temperature gradient that coincide with the findings in the current study. *The background of hypothesis 1 was (and is) explained in lines 41-55. The study mentioned by the reviewer is not very well comparable since it is about a N and P addition experiment conducted in a tundra at different elevations.*

c. Novel tools: no

d. Novel data: yes

3. Are substantial conclusions reached? a. To some degree (hypothesis 1 is not treated satisfactory)

4. Are the scientific methods and assumptions valid and clearly outlined? a. More or less - with some concerns the most important listed here:

How are the ratios calculated, are they based on mass (concentration) or are they base on Molar ratio. The standard method in soil science is on mass - this is not that apparent for C:N ratio but will have large implications when calculating C:P and N:P ratios. Clarity in method is essential to know when comparing with other studies - though the relationship with MAT, tree species, texture will not be affected. Please check the C:P ratios given in figure 3e. *Most studies on stoichiometry in ecosystems report molar ratios. We now explain more explicitly how they were calculated in the Material and Method section. The ratios in Fig. 3e are correct.*

c. What is "organic lay stock" and how is it calculated

d. Several analyses that are referred to in the materials and methods are not used in the texts, Two of them I would hope you have considered and probably you have reason for not including - the pH and the P in the parent material?

5. Are the results sufficient to support the interpretations and conclusions? a. Yes and No, see specific comments below

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? a. Some improvements needed - se comments below

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution? a. yes

8. Does the title clearly reflect the contents of the paper? a. yes

9. Does the abstract provide a concise and complete summary? a. The abstract only refers to relative distributions - I would recommend to include the range or levels of the ratios, concentrations, stocks.

10. Is the overall presentation well-structured and clear? a. Yes, in general

11. Is the language fluent and precise? a. Yes in general, see comments below

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? a. Formulas for calculation of stocks is missing and should be better explained, Also a specification of how the ratios were calculated should be included - from the figures I gather it is Molar ratio, but in the text it is not specified (both ratio and molar ratio is referred to) *In the previous version of the manuscript, we already explained how the stocks were calculated ("Organic layer element stocks were calculated by multiplying the organic layer stock with the respective element concentration") We now added the following information in the section 2.3: "All element ratios were calculated on a molar basis (mol mol^{-1})."*

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? a. See comments below

14. Are the number and quality of references appropriate? a. Yes, sufficient

15. Is the amount and quality of supplementary material appropriate? a. yes

Specific comments:
L 15-16, repetition of >60 years- consider deleting one place or merging the two sentences
We deleted "with a stand age >60 years" in line 15.

L17, and L26 "organic layer stock" stock of what? should be it be "organic layer C stock"? or are we talking about layer thickness? volume? density? Mass?
We are talking about the organic layer stock, which is the mass of the organic layer on an area basis (t ha^{-1}).

Line 19: "went along with" - better "followed" *There is no temporal order involved here. Therefore we think that "went along with" is better than "followed".*

L24-25 "OP adsorbs very rigidly to mineral surfaces." Could this not also be an effect of higher P availability in fine textured soils? *Yes, in theory this could be. However this was not the case in the soils under study here. In order to show this we added a new figure to the supplement (now Fig. S3, see below), and we added the following lines to section 3.3.*

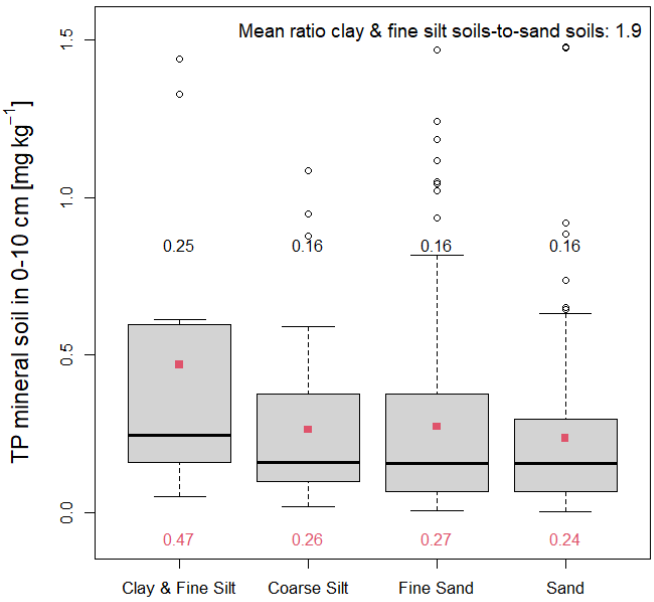

Figure S3: *The total phosphorus concentration in the mineral soil in a depth of 0-10 cm depending on the soil texture (clay and fine silt n=11, coarse silt n=52, fine sand n=136, and sand n=110) in 309*

Swedish forest soils with a stand age >60 years. The texture class called sand here encompasses sand and coarse sand. Black numbers give the median, red dots and red numbers depict the arithmetic mean.

"In contrast to OP, the total P concentration did not differ between soils with the texture class sand, find sand and coarse sand. Only soils with the texture clay had elevated P concentrations compared to soils of the other three texture classes (Supplement Fig. S3). TP concentrations were higher in soils with the texture clay or fine silt than in soils with the texture sand or coarse sand by a factor of 1.9 (Supplement Fig. S3)."

Line26. "C and N concentration in the mineral soil" is a rather unprecise term as these concentrations normally are measured in several different horizons and are expected to differ significantly with depth and genetic horizon. If you were talking about stocks however, the correlations would appear more valid/informative. *We added "(0-10 cm depth)".*

L51: «most soils in Northern Europe are only between 9,000 and 14,000 years old". I believe you should then define Northern Europe - you need only to go to Denmark to find older soils. Perhaps I it is better to write "Sweden" or "Scandinavia" instead of "Northern Europe". *We replaced "Northern Europe" by "Scandinavia", as suggested.*

L50-55. It would be interesting to know at what limit, N:P ratio, you would expect P to become limiting. *We added "indicated by molar needle N:P ratio >12" in line 49.*

L78-80 "The soils are a representative subsample of Swedish forest soils with a stand age >60 years that were sampled for the Swedish Forest Soil Inventory. We selected sites with a stand age >60 years in order to minimize the effect of forest management on the results" will these cover both self-drained and poorly drained soils? *This is (and was) specified at the end of section 2.1.*

L104 - what are the numbers in the brackets referring to? - are they necessary? *They refer to the code in the database. We now removed them, as suggested by the reviewer.*

L 105-106: "and living and dead roots >1 mm diameter are removed." This is nearly an impossible task on dried soils - and according to personal experience would also introduce a bias - thin roots are easier to remove from coarse textured soils than from fine textured soils. I suggest that a better description would be " (where possible) living and dead roots were removed from the sample prior to sieving (<2mm) and homogenizing" of cause only if this is the case. *The separation was feasible since as much as 96% of the samples were on coarse silt or coarser soil texture. We now clarified that this sentence referred to the mineral soil.*

L109 -use "covered" instead of "vegetated" *We did as suggested.*

L113-114: "each three soils were classified as either leptosol, gleysol or cambisol, while one soil was an umbrisol" - Here I suggest a rephrasing: 3 were leptosol, 3 were gleysol, 3 were cambisol, and one was umbrisol *We did as suggested.*

L145: unclear "Organic layer element stocks were calculated by multiplying the organic layer stock with the respective element concentration." What is the "organic layer stock"? how is it calculated? *The organic layer stock is the mass of the organic layer on an area basis (t ha^{-1}). The determination of the organic layer stock is (and was) described in section 2 as follows "The organic layer is sampled volumetrically using a 10 cm diameter corer in a 3.14 m^2 subplot within each circular plot throughout the entire depth of the organic layer (up to 30 cm depth), excluding the litter layer. (…) the stock of the organic layer is calculated based on the weight of the fraction <2 mm of the organic layer"*

L168-169: There must be an error "The C:N ratio of the organic layer was negatively correlated with MAT (R2=0.08, Supplement Fig. S1) and with the log-transformed N deposition (R2=0.11) and latitude

(R2=0.08; Table1).” C:N ratios cannot be negatively correlated to latitude - they must be positive. It would have been better to have r values in table 1 showing either negative or positive correlations not just “R^2”. *Yes, we corrected this by inserting “and positively with”.*

L169-170: The molar C:N ratio is referred to for the first time -- are all ratios molar ratios? - not described in the M&M *We added the following sentence in section 2.3. “All element ratios were calculated on a molar basis (mol mol^{-1}).”*

L178-179: “Furthermore, C, N and OP in the mineral soil were only weakly correlated with latitude, MAT, and N deposition (Table 1).” Table may show correlations but no indication whether positive or negative. *We added this information in Table 1.*

L185.” the C:N ratio of the mineral soil in spruce forests” should it not be pine? The same error applies for L189 with regard to C:P ratio *Yes, correct this now.*

L187: “Some pine forests had very high C:N and C:P ratios due to low N and P contents.” In the materials and methods you should introduce some rules for discarding “unusual” ratios based on the detection limits of the elements. These ratios are “artifact” and any interpretation of these may be useless. *The samples are above the quantification threshold. We added the following lines in the Results “it needs to be taken into account that there is some uncertainty regarding the samples with very low N and P concentration since the determination of N and P contents in very nutrient poor samples is more affected by sample in homogeneities than the measurement.”*

L192-194, “The organic layer stock differed also between forests with different dominant tree species (Supplement Fig. S2b). In deciduous forests, it was on average 2.2 times higher than in pine forests and 1.9 times higher than in spruce forests.” This does not sound right - what is “organic layer stock”? *The organic layer stock is the mass of the organic layer on an area basis (t ha^{-1}), this was (and is) explained in section 2.1 (line 106 in the previous version of the manuscript).*

L202-204 : “The mean C:N ratio and C:OP ratio were 1.5 and 1.4 times higher in soils with the texture clay or fine silt than in soils with the texture sand or coarse sand (Fig. 4d and e).” Error - the opposite The mean C:N ratio and C:OP ratio were 1.5 and 1.4 times **lower** in soils with the texture clay or fine silt than in soils with the texture sand or coarse sand (Fig. 4d and e). *Yes, we now corrected this.*

L244-246. Both “organic layer stock” and “organic matter stock” are used about the same parameter - stick to one (I believe it should be either better described and defined as well, see earlier comments) *In these lines, we refer to the organic layer stock as well as to the N stock of the organic layer. Both variables are well defined and it is clearly stated in the Material and Methods section how they were determined (see also comments above).*

L253 254: “the stem growth rate of trees decreased with MAT (Fig. 2d)” but figure 2 d show that the growth rate increases with MAT! *We corrected this.*

L279 “foliage N:P ratio decreases with increasing N inputs” should be increase? *Yes, we corrected this.*

L307 “miner” should be “mineral”? *Yes, we corrected this.*

L309-310 “ However, this is the first study to show that this difference in the C:N ratio between forest dominated by different tree species is also visible in the mineral subsoil, in a depth of 55-65 cm, to our knowledge.” But is this really confirmed by figure 3d? How have you handled the very low concentrations and detection limits? *The samples are above the quantification threshold. We added the following lines in the Results “It needs to be taken into account that there is some uncertainty regarding the samples with very low N and P concentration since the determination of N and P contents in very nutrient poor samples is more affected by sample in homogeneities than the measurement.”*

L320 “changed” should be “charged”, *We corrected this.*

L337 “changed” should be “charged” *We corrected this.*

L320-340 -4.4. Organic P and N contents are high in fine-textured soils, I find this paragraph too superficially discussed. *We added the following lines “The fact that the total P concentration differed much less than the OP concentration between the soils of different texture class (Fig. S3) supports our interpretation that the strong enrichment of OP in the fine-textured soils is mostly caused by rigid adsorption of OP compounds and much less by a higher P concentration of P availability in these soils.” (Section 4.4). See also the new figure added (see above).*

L337: “Thus, the high capacity of N- and P-containing organic compounds to adsorb to changed surfaces in soils is likely the reason why N, and particularly OP has higher concentrations in the fine-textured soils compared to the coarse-textured soils than C.” - this is not only due to sorption. These fine textured soils are more productive nutrient rich system - (P -rich included) - also the water holding capacity and pH increases fine textured soils. and what about regional distribution of P containing minerals? *See previous comment.*

L345 - 355 : 4.5 P and K contents are negatively related to the organic layer stock. The discussion in this paragraph is poor. These two elements behave very different in soil the potassium is a cation more or less only found in inorganic forms, while P mostly would be present as a anionic molecule and in organic form be part of organic molecule . K+ could easily be leached, even more so in acid conditions, while P-is retained and we would not expect any “fast leaching of P” I would find it highly unlikely that “P follows the same dynamic as K” *We revised this sentence, deleting “follows the same …”. We wrote: “The reasons for this might be that the decomposition rate of the organic layer is positively related with the organic layer P concentration. This is supported by a study showing that P is the most limiting element for microbial activity during the first phase of decomposition of pine needles in Sweden (Staaf and Berg, 1982). Further, it could be that there is a higher contribution of fine woody debris, which is P-poor (Spohn et al., 2020b) to the organic layer in forests with high organic layer stock.”*

365 “the results show that the N:P ratio of the organic layer was most strongly related to MAT” showing a positive relationship, while the CN ratio showed a negative relationship with MAT. This confirmes that the boreal forest are N deprived, any increase in N availability will increase forest productivity P is not the limiting factor *This argument this not clear to us.*

L570 figure 3e the molar C:P ratio of the organic layer is high - are you sure they are correct? *The C:P ratios of the organic layers are close to the mean C:P ratio of the organic layer in temperate forests (1411) found in a meta-analysis that synthesizes the results of many studies (Spohn, 2020 in GCB). Hence, they are not extraordinarily high.*

L570 figures b, c, d, and f, why do some of the means depict “Inf”? *This was a mistake. We corrected this and replaced Inf by the correct numbers.*

References

Staaf, H., & Berg, B. (1982). Accumulation and release of plant nutrients in decomposing Scots pine needle litter. Long-term decomposition in a Scots pine forest II. Canadian Journal of Botany, 60(8), 1561-1568.

Spohn, M. (2020b). Increasing the organic carbon stocks in mineral soils sequesters large amounts of phosphorus. Global Change Biology, 26(8), 4169-4177.