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Dear reviewers,

Thank you very much for your constructive and valuable comments that helped us to improve the manuscript. Please find our answers below on how we revised the manuscript.

Author's response for reviewer #1

General response:

The authors present a manuscript that provides interesting data supporting some hypotheses raised during the last years: first, that the contribution of crop in soil Si bioavailability and Si uptake of crop; second, that authors point at some interesting findings regarding their Si flux via driving various Si distribution in plant. The experimental work has been well performed. It consisted of experimental analysis that yielded some interesting data. It is in general nicely documented by the authors, but some parts are not well introduced and discussed. It is a bit strange on missing the data from soils, while it may be improved by introducing recent findings from soils. Overall, I support publication of this work. Yet I have some comments to be considered before further publication.

Thank you for your overall positive feedback, supporting the publication of our work. We also thank you for pointing out that soil data is missing. We respond to this point in your comment below.

Detailed response:

Abstract

In Abstract. at line 15, to revise 'raised' to 'raise'; to revise 'if' to 'as'; in fact, high Si concentrations Oil-palm has been by Munevar and Romero (2015), suggesting a high Si accumulator.

lines 13 – 28: we have shortened and rephrased the abstract. In the rephrased abstract, this problem has been solved.

At line 20, Revise 'by NaCO3 extraction' to 'using NaCO3 extraction'; to revise 'are needed' to 'were'

lines 13 – 28: we have shortened and rephrased the abstract. In the rephrased abstract, this problem has been solved.

At line 35, [more Si can be returned to soils through pruned palm fronds than is lost 35 through fruit-bunch harvest….] is not right as it is hard to understand. Should be rephased.

lines 13 – 28: we have shortened and rephrased the abstract. In the rephrased abstract, this problem has been solved.

In addition, Abstract should be shortened and precise a bit to highlight the key significance and findings.

lines 13 – 28: we have considerably shortened and rephrased the abstract to highlight our key findings.

Introduction

In introduction. In introduction session, I encourage that authors carefully consider the previous studies on straw return regarding its silicon recycling and silicon uptake; what have it done? what should be considered on the Si status under the management of their return in cropland; next step to point at What is its existing gap in oil cultivation? Indeed, it is true that it is not well-investigated on the Si flux of oil palm. This is a key challenge, especially that their respective return on Si biological cycle is largely active in the highly weathered soil where oil palm grows. This needs to a better estimate on Si distribution in oil palm, bettering predicating their management in future. Indeed, crop straw return has gained increasing attention in recent years due to its importance as an approach to supply soil biogenic and plant available silicon (Si) for mitigating agricultural desilication due to its importance as nutrient for many plants. Recent research, for instance, has demonstrated that biological processes, such as plant-Si-uptake, phytolith production and recycling of phytoliths in soil, are important regulators of the Si cycle in the soil-plant ecosystems (Li et al., 2020, Geoderma 368, 114308; Puppe, et al., Geoderma 403 (2021): 115187, and so on). Returning their phytoliths into soil thus boosts the biological recycling of Si in agroecosystem, sustaining its health development, especially in highly weathered soils (Li and Delvaux 2019, GCB Bioenergy 11 (11), 1264-1282). But this effect is less studied in oil-palm plantations, as it is limited on a better understanding of Si distribution in oil palm.

Lines 64 –76: thank you for your comment. We added your suggested studies on straw management (e.g., studies on Si fertilization vs. Si losses through harvest, LULC change and degree of soil weathering on Si cycling) in the introduction to emphasize that this kind of knowledge is largely missing for oil-palm plantations.

At line 145, ‘The procedure was conducted on two replicate samples’, did each sample have two replicates? Why not three replicates?

Following line 157: we introduced the table to clarify the number of replicates for each sample.

Table 1 Sampling scheme and number of replicates providing the statistical basis of Figures 2 and 3

Oil-palm part	Water regime[b]	Palm trees (replicates per plot)	Plots (replicates per water regime)	Replicates of palm trees/plots used for Fig. 2	Replicates of palm trees/plots used for Fig. 3
Frond no. 9	WD	3	4	3/4	2 *(excl. tree 3)*/4
Frond no. 17	WD	3	4	3/4	2 *(excl. tree 3)*/4
Senescing frond	WD	3	4	3/4	2 *(excl. tree 3)*/4
Rachis	WD	3	4	3/4	***
Frond base	WD	3	4	3/4	***
Fruit-bunch stalk	WD	3	4	3/4	***
Fruit pulp	WD	3	4	3/4	***
Kernel	WD	3	4	3/4	***
Frond no. 22	WD	*2 (excl. tree 3)*	4	***	2 *(excl. tree 3)*/4
Frond no. 25	WD	*2 (excl. tree 3)*	4	***	2 *(excl. tree 3)*/4
Frond no. 9	RI	3	4	3/4	***
Frond no. 17	RI	3	4	3/4	***
Senescing frond[a]	RI	3	*3 (excl. HOr2)*	3/3	***
Rachis	RI	3	4	3/4	***
Frond base	RI	3	4	3/4	***
Fruit-bunch stalk	RI	3	4	3/4	***
Fruit pulp	RI	3	4	3/4	***
Kernel	RI	3	4	3/4	***

[a] only 3 replicate plots as no senescing fronds were left hanging on palm trees at site HOr2 (differing management practice)
[b] WD = well-drained, RI = riparian / [c] Italics = differing from general sampling scheme / *** = not relevant for statistics

DeMaster technique using 1% Na2CO3 can underestimate amorphous silica (i.e., phytogenic silicon, phytolith; Meunier et al., 2014; Li et al., 2019; Puppe, et al.,2019). Author should refer this issue, as this directly impact the Si content in the analyzed plant tissue and then its budget.

Lines 162 – 169: yes indeed, we agree that we need to explicitly explain our choice of Na_2CO_3 instead of NaOH. In Chapter 2.3.1, we stated that we did a pre-test series which showed that NaOH generally extracted Si more efficiently from those plant parts remaining in the system, whereas Na_2CO_3 extracted Si more efficiently from those plant parts leaving the system through harvest, such as kernels and fruit pulp (not the fruit-bunch stalk). As plant parts leaving the system are more important for calculating the final Si budget of the system, we decided to use Na_2CO_3.

In addition, we repeated the calculation of Si export through harvest considering 8% Si underestimation for the fruit-bunch stalk. In the discussion (Chapter 4.1), we now address Si losses through harvest as follows: “This corresponded to an export of 54 – 72 kg ha^{-1} Si from the system (56

– 74 kg ha^{-1} Si if 8% underestimation by Na_2CO_3 extraction from fruit-bunch stalks is considered as reported in chapter 2.3.1). In 2018, the yield was lower in plantations of both well-drained and riparian areas, with 9 – 14 Mg ha^{-1} dry biomass, corresponding to an Si export of 32 – 50 kg ha^{-1} (33 – 52 kg ha^{-1} if 8% underestimation is considered)."

Also a bit strange is that soil data is missing in this section

Lines 64 – 74 and 80 – 84: we added a section on the effects of land-use change from forests to arable soils on soil Si pools and potential causes of desilication. We added references that give information on the soil Si status under oil-palm plantations in Sumatra as well as phytolith dissolution rates in the oil-palm system.

Cited literature: von der Lühe et al. (2020); von der Lühe et al. (2022); Greenshields et al. (2022); Tarigan et al. (2020)

At line 260-265, these sentences look much more discussion than results.

Lines 288 – 290: we agree that the sentences (previously in lines 260-265) looked more like a discussion rather than results. Therefore, we changed this paragraph to "Calculating Si storage in the aboveground biomass of oil palms required biomass data for all plant parts. As we were not permitted to cut-down oil palms to determine the stem and frond-base biomass per palm tree, we used mean biomass estimates from mature oil palms in SE Asia from literature (Table 2a)" to avoid the impression that we are mixing results and discussion.

In conclusion, To add 'that' before 'mean Si concentration increases with leaf age'; what do you mean 'In fact, Si availability could suffice for a second generation of oil-palm plantations'? is it soil Si availability? If yes, could authors offer these data referring soil analysis?

Lines 428 – 444: both reviewers stated that the conclusions needed further editing and fine tuning to highlight our key findings. For this reason, we rephrased the conclusions substantially. In this process, we also solved the issues addressed in this comment.

I am not native English speaker but still found some grammatic errors in this manuscript, but I feel that it will be better to improve its English a bit. Personally, it also needs to enhance its readily for reader, to concentrate its key finding and significance to be highlighted.

We have reformulated sentences that are too long and cumbersome throughout the entire manuscript. In addition, we have shorted and rephrased sentences to improve readability and to highlight our key findings. We have also had the manuscript edited (spelling, grammar).

Please also note the supplement to this comment:

Thank you, we did.

Author's response for reviewer #2

General response:

The research motivation and research questions are sound and will be of interest to the broader community. The methods also appear sound, although I worry a bit about the sample size (see comments within). The addition of Si/Ca data for the various plant parts is a nice addition, as that data is fairly scarce in the literature.

Overall this is a robust study that eventually deserves publication. However, it needs more flushing out in terms of motivation for the study and relating the results to what others have found – many of the observations agree with what others have found in other systems, so this needs to be highlighted.

The text needs revision/editing throughout for ease of reading – I suggest a native English speaker help with the sentence structure and grammar throughout. Many of the sentences could use some revision for structure/grammar. I refrain from pointing out where because it was such a common issue.

Thank you for your overall positive feedback supporting the publication of our work. We will respond to the sample-size questions in the detailed response section. Likewise, we thank you for pointing out that we shall i) better highlight the motivation for this study, ii) compare our results to the work of other researchers and iii), have the manuscript edited for ease of reading and grammar. We completely agree and revised the manuscript accordingly: we rephrased several sentences and paragraphs in the introduction to highlight the motivation for our study more clearly. Furthermore, we compared our results to the work of other researchers, and we have had the manuscript edited for ease of reading and grammar throughout the entire manuscript. Finally, some sections of the manuscript, e.g., the abstract, introduction, section 4.2 of the discussion and the conclusions have been substantially rephrased for better understanding.

Detailed response:

Section 1

Line 47 – 48: it would be clearer to say "transported…to the shoot with water flow" rather than sap flow.

Line 47: we have changed the sentence to "transported … to the shoot with the xylem flow". We hope that the term "xylem" is clearer than the term "sap".

Line 48: need to clarify that the "increase in Si concentration" occurs in the leave tissue.

Line 48: we have changed the sentence accordingly.

Line 53: clarifying these crops are classified as "high" or "active" Si accumulators, as all plants accumulate some amount of Si.

Lines 53 – 60: thank you for addressing this point. We originally used the term "Si accumulator" because it has been well established in literature. We completely agree that all plants accumulate some amount of Si and that for this reason, this term is not appropriate. Therefore, we have now specified the classification scheme given by Ma and Takahashi (2002) and introduced the term "Si hyper-accumulator" to emphasize which plants take up very high quantities of Si from soil solution. Following this terminology, the oil palm is considered a Si hyper-accumulator.

Line 58: point iv is true for all plants, not just high accumulators.

True. Point iv has been deleted.

We now use a different classification, which we believe is clearer, starting this whole paragraph as follows:

"Plants can be grouped into three categories based on the Si concentration and Si/Ca ratio in their dry leaf tissue (Ma and Takahashi, 2002):

I. *Non-accumulators or excluders (Si concentration < 0.5 wt.%; Si/Ca < 0.5)*
II. *Intermediate accumulators (Si concentration 0.5 – 1 wt.%; Si/Ca 0.5 –1)*

III. Accumulators (Si concentration > 1 wt.%; Si/Ca > 1)

To better distinguish between plants of group II and III, we now use the term "hyper-accumulator" for plants of group III throughout this manuscript."

Line 61: this point about Si accumulating w/ plant age and not translocating is not specific to oil palms – this is true for all plants.

Yes, we agree. The point about Si accumulating with plant age and not translocating has been deleted.

Line 65: again, specify "high" or "active" Si-accumulating crops (all plants accumulate some amt of Si so "Si-accumulating" is not a meaningful term). (I make this comment here but it applies throughout paper, including beginning of discussion – I'll stop making this comment now but I see this issue throughout the paper.)

Lines 56 – 57: yes, we now introduced the term "Si hyper-accumulator" and use it throughout our manuscript.

Lines 65-67: this is a valid research question but it would be helpful to readers unfamiliar with Si literature to first point out that others (Clymans et al. 2011 for ex) has found soil Si depletion with continual plant harvest. Then your question here would make more sense and be more compelling.

Lines 64 – 67: thank you for this comment. We added a short section on soil Si depletion with continual plant harvest by referring to findings of other researchers. The suggested literature has been cited.

Line 71: add more refs to this sentence that plant Si returning to soil again b/c plant-available – many studies highlight this and your argument would be stronger with more refs.

Line 80: yes, true. We added more references.

Line 82: How important are oil palms relative to other crops globally and/or Asia? A bit more (1 sentence) motivation on why studying oil palms is important would be helpful.

Lines 31 – 40: thank you for this comment. Indeed, oil-palm cultivation has such a great importance globally that it would have been a pity to not have made this clear enough in the introduction. We have added a new first paragraph in the introduction to highlight the global importance of oil-palm cultivation.

Section 2.2

Can you add rachis to the diagram of the oil palm parts? (Fig 1)

In Fig. 1a, we have illustrated the rachis, leaflets, and petiole on a separate palm frond.

The frond numbers are confusing – how were those identified? You reference them like they frond 9 was the same on all the trees, but how was that number identified? Can you clarify your total sample size for each plant part in each plot type (riparian vs. upland)?

Lines 134 – 139: thank you for this comment. Indeed, we need to keep in mind that most readers are not familiar with the numbering system that is commonly used in oil-palm sampling and analyses. As this cannot easily be described in words, we included two additional illustrations in Fig. 1 for clarification: one of the oil-palm phyllotaxis and another one of a palm crown. Furthermore, we added a section explaining the importance of palm frond no. and ranking with respect to Si concentrations in leaf tissue.

Following line 157: we also added a table (Table 1) to clarify the total sample size for each plant and replicates in each plot type (riparian and well-drained).

Section 2.3.1: the methods look good, although next time it's best to digest in a flat bottom tube, not a centrifuge tube to make sure material doesn't get stuck in bottom. But with the shaking and centrifuge, I imagine your digestion was complete.

Thank you for pointing this out. We ran pre-tests to ensure that we really achieved a complete digestion by shaking the samples. In general, we agree that it would be better to use flat-bottom tubes.

Table 1b: I see some commas where periods should be I believe in the provided values. Also, can you add error terms to the Si concentrations or would it be correct to assume you only measured Si in 1 Frond no 9 in the WD, for example? (again, I'm confused on the sample size).

Following line 157: we corrected Table 1b accordingly (changing commas for periods). In Table 1b we specified that we used <u>mean</u> Si concentrations in our calculations and that Si storages were <u>estimates</u>. We clarified our sample size and number of replicates in Table 1 and additionally refer to Table B1 in the appendix, where we have listed our total Si concentrations including error terms for each oil-palm plant part.

Fig 2: can you add sample size to legend or figure itself?

We added the sample size in the figure caption.

Discussion

See comment above re: term "Si accumulator". Many others have found more Si in leaves relative to other plant parts…maybe have sentence saying that your results correspond to others and add appropriate refs.

We now use the term "Si hyper-accumulator" throughout the manuscript and have added references accordingly.

Line 347-348: your recommendation here is rationale and supported by the data. However, similar to my comment in the intro, the motivation for this comment is needed for readers unfamiliar with Si literature. Soil Si depletion with continual crop harvests have been observed (e.g. Clymans et al. 2011, Guntzer et al. 2012, Keller et al. (2012) are a few examples) so please highlight for readers that this is an serious issue…you might also want to add that because of that reason, people are now starting to fertilize certain crops with Si (see work by Datnoff I believe).

Lines 394 –395: thank you for this comment. Indeed, we should have known that not everybody is familiar with Si literature which is the precondition to understand our motivation. We have now included additional references on this topic in the introduction and discussion section accordingly.

Line 382: The sentence, "these data suggest that Si cycling is maintained in this system" needs clarification – "Si cycling" is too vague. What you're saying is maintenance of a bio- available Si supply is maintained in this system. Please revise. (Similar comment for Line 24 in abstract – please revise for precision.)

Lines 428 – 444: both reviewers stated that the conclusions needed further editing and fine tuning to highlight our key findings. For this reason, we rephrased the conclusions substantially. In this process, we also solved the issues addressed in this comment.

In general, the discussion is strong, especially the sections on straw management – and economic tradeoffs. It agrees with work by Guntzer et al. (2012) that suggest leaving the straw of crops on fields so I would reference that to show this alignment. (This is a different Guntzer et al. 2012 paper than the one you already reference.) Your conclusions also aligns with work of Carey & Fulweiler 2016 that highlights the importance of Si uptake by agricultural crops so I would also incorporate this agreement into the discussion.

Thank you for suggesting these references which indeed fit well into our discussion. We included all of them.

References:

Carey, J. C., & Fulweiler, R. W. (2016). Human appropriation of biogenic silicon–the increasing role of agriculture. Functional Ecology, 30(8), 1331-1339.

Clymans, W., Struyf, E., Govers, G., Vandevenne, F., & Conley, D. J. (2011). Anthropogenic impact on amorphous silica pools in temperate soils. Biogeosciences, 8(8), 2281-2293.

Keller, C., Guntzer, F., Barboni, D., Labreuche, J., & Meunier, J. D. (2012). Impact of agriculture on the Si biogeochemical cycle: input from phytolith studies. Comptes Rendus Geoscience, 344(11-12), 739-746.

Guntzer, F., Keller, C., Poulton, P. R., McGrath, S. P., & Meunier, J. D. (2012). Long-term removal of wheat straw decreases soil amorphous silica at Broadbalk, Rothamsted. Plant and Soil, 352(1), 173-184.