

## ***Interactive comment on “Herbicide weed control increases nutrient leaching as compared to mechanical weeding in a large-scale oil palm plantation” by Greta Formaglio et al.***

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RC> My main comment is that the analysis/results of yield are not appropriately considered. The authors refer to previously published studies on the yield aspect but do not actually quote any data/numbers on yield. This is an important point that is missing. Any management options leading to more environmentally friendly or sustainable growing of oil palm will ultimately be scrutinised under the yield aspect. So it is important to include the actual figures in this assessment (even if they have been published elsewhere). Just saying there was no difference is not sufficient. Growers would like to know the actual yield to see that you were not working on a plantation with unusually

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high or low yield anyway which might have masked any management effects. So a revised version needs results and discussion sections that are expanded with details on yield.

AR> Thank you for this observation. We agreed that the focus on the yield is essential for the development of long-term more sustainable management practices. We will include appendix Fig A2 with the yield measured up to three years after the establishment of the experiment. We will expand the discussion about the yield in l 518 as follows: “The yield, measured up to three years after the establishment of the experiment, was on average 30 Mg of fresh fruit bunches ha<sup>-1</sup> yr<sup>-1</sup> and it was comparable among experimental treatments (Figure A2, Darras et al. 2019). This indicates that the reduced management intensity did not affect productivity in the first three years, but the long-term monitor is essential as it may take a longer time for the yield to respond to the treatments (Tao et al. 2017). Also, the cost of the two weeding treatments (i.e. herbicide vs mechanical) was comparable because it is standard practice to combine the use of herbicide with the periodic mechanical cutting of resistant ground vegetation (Darras et al., 2019; Pahan, 2010). Therefore, these results altogether advocate for the higher sustainability of mechanical weeding over herbicide application”.

[Figure A2 Annual yield for each experimental treatment from 2017 to 2019. Treatments: ch = conventional fertilization–herbicide; cw = conventional fertilization–mechanical weeding; rh = reduced fertilization–herbicide; rw = reduced fertilization–mechanical weeding. Notes: yield was measured by weighting the harvested fresh fruit bunches from each palm in the inner 30 x 30 m area of each plot.]

RC>There should be no space between number and %. Please revise this throughout the manuscript.

AR> We will it correct in the revised manuscript.

RC> The term 'stem' might be more appropriate to use than 'trunk'. Please replace 'trunk' with 'stem' throughout the manuscript.

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AR> We will replace it in the revised manuscript.

RC> The term 'conventional' is a bit misleading. Perhaps 'standard practice' or 'standard industry practice' would be a more appropriate term to use?

AR>We prefer to keep the term of conventional practice for consistency with other manuscripts published on this experiment, i.e. Darras et al. 2019, and others in preparation.

RC> Generally spelling and grammar need to be checked carefully, some sentences are too long and convoluted.

AR> Based on this comment we revised the manuscript and decide to modify the structure of a few sentences to improve clarity.

L 67 "Oil palm plantations can possibly have low leaching losses, as a consequence of high evapotranspiration and thus low drainage fluxes (Tarigan et al., 2020). However, most oil palm plantations are large-scale enterprises that are characterized by intensive management with high fertilization rates and herbicide application".

L 343 "On the other hand, base cation leaching fluxes had opposite patterns as their concentrations as Ca, K, and Mg leaching were higher in the frond-stacked area than the palm circle and inter-row (all  $P < 0.01$ ; Fig. 4)".

L 393 "Considering the areal proportions of the three management zones, the weighted-average drainage flux (1161 mm yr<sup>-1</sup>) was lower than that estimated for smallholder oil palm plantations near our study site (1614 mm drainage 396 flux with 3418 mm precipitation measured in 2013; Kurniawan et al., 2018). However, their ratios to annual precipitation were comparable, due to the relatively wet year of 2013. Also, evapotranspiration rate is higher in large-scale than smallholder oil palm plantations in our study area (Röll et al., 2019), which would lead to lower drainage flux in large-scale plantation".

L 410 "High drainage might have stimulated the downward transport of elements and

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decreased their residence time in the soil, and thus their adsorption onto the soil exchange sites (Lohse and Matson, 2005). At the same time, high water fluxes usually dilute the element concentrations in the soil-pore water; high concentrations were maintained because of fertilizer and lime applications in the same periods, resulting in parallel peaks of drainage and leaching fluxes (Figs. 2 and 4)".

L 441 "Contrary to our first hypothesis, leaching losses among management zones were generally higher in the inter-row, especially for mineral N (largely NO<sub>3</sub>; Fig. 3), and lower in the palm circle (Fig. 4)".

L 460 "The main accompanying cation for NO<sub>3</sub>- leaching in the inter-rows was Al<sup>3+</sup> (Figs. 3 and 4). This is because this zone's soil pH (Table 1) was within the Al-buffering range (pH 3–5; van Breemen et al., 1983) due to no direct lime application and thus low base saturation (Table 1)".

L 489 "Thus, the larger base cations leaching in the frond-stacked area compared to the inter-row (Fig. 4) merely mirrored their high exchangeable levels (Table 1)".

RC> Title remove 'as'.

AR> We will change this.

RC> I 39 replace 'have' with 'has'.

AR> We will correct this in the revised manuscript.

RC> I 40 remove 'and' .

AR> We will correct this in the revised manuscript.

RC> I 45 remove space between 57 and % (see general comment above).

AR> We will correct this in the revised manuscript.

RC> I 48 introduce N as nitrogen, I 59 introduce P as phosphor NO<sub>3</sub> as nitrate.

AR> We will insert "phosphor" and "nitrate" in the revised manuscript.

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RC> I 61 comma after reference before 'whereas'.

AR> We will correct this in the revised manuscript.

RC> I 68 remove 'of' in front of oil palm.

AR> We will correct this in the revised manuscript.

RC> I 80 herbicides needs to be plural.

AR> We will correct this in the revised manuscript.

RC> I 82 'herbicide weeding' perhaps clarify that this is chemical weeding with herbicides as supposed to mechanical weeding.

AR> The sentence will be modified in the manuscript as "Chemical weeding with herbicide is commonly practiced in large-scale oil palm plantations: herbicide is placed in the area where the fertilizers are applied, to reduce competition for nutrients and water with ground vegetation, and in the inter-rows, to facilitate access during harvest (Corley and Tinker, 2016)".

RC> I 97 circles needs to be plural.

AR> We prefer to keep it singular for consistency, as it is the management zone mentioned above (I 92).

RC> I 101 canopy interception will depend on the age of the plantation and whether there is canopy closure or not. Please elaborate here and say that there will be a difference between younger and older plantations.

AR> We agree that the age of the palm is important to determine the level of interception in the inter-row. However, we think that this sentence doesn't need to be modified because the interception in the inter-row will always be lower than in the palm circle, independently of the age of the palm. Even when the canopy closes, 7-8 years after planting, the interception is lower in the inter-row than in the palm circle (Banabas et

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al. 2008).

RC> I 131 Was the plantation terraced? This should be a discussion point generally as nutrient flows will be different in plantations with even terrain as supposed to terraced plantations. It seems to become more popular (also in Indonesia) to terrace plantations (when replanting) even if the terrain is not that hilly to begin with. This might have potentially large implications on nutrient leaching.

AR> The plantation was not terraced and it was not on a slope position. We will add at I 133 "The plantation was not terraced".

RC> I 135 remove space between number and %.

AR> We will correct this in the revised manuscript.

RC> I 137 chemically or mechanically weeded? Please clarify.

AR> We will specify that they were chemically weeded, as it is the standard practice in the investigated plantation.

RC> I 142 Is the fertiliser applied in pellets or granules? Broad spread? Please give details.

AR> The fertilizer was in the form of granulates and it was broad spread within the palm circle. We will specify this in the updated version of the manuscript.

RC> I 145 Were no EFB (empty fruit bunches) returned to the plantation? This is common practice and would add more organic matter to the plantation in addition to the palm fronds. If it wasn't done in your plantation, it still needs to be discussed in the discussion section.

AR> In our studied plantation there is a certain amount of EFB returned to the plantation (mainly in the form of compost). The 2025-ha plantation investigated is owned by the company PTPN6, which has a total of 90122 ha of oil palm plantations in Jambi province. Once the fruits are processed in the mill, the EFB (also in the form of compost

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or ashes) is redistributed across all the plantations of PTPN6 in a rotation. In addition, within the same plantation, the application of EFB follows a rotation system based on management blocks. Therefore the timing and the amount of EFB distributed are quite complicated to predict. In our experimental plots, we did not include the EFB compost in the treatments. This is for two reasons: 1) our experimental plots encompassed different management blocks and therefore the different timing of the EFB application might have biased the results; 2) the aim of the experiment is to compare the most standardized management practices with the reduced of management intensity, and the application of EFB is not done regularly and in all the plantations (it is normally applied just to the area next to the mill). Since we didn't include the practice of using EFB in our experiment, we cannot discuss its effects on leaching, but we will hint to it in I 438 as follows: "One other option is the use of organic amendments, such as empty fruit bunches, compost, palm oil mill effluent, or slow-release fertilizers, which have been shown to reduce N leaching in tropical cropping systems (Nyamangara et al., 2003; Mohanty et al., 2018; Steiner et al., 2008). In addition, organic fertilizer can improve soil fertility in oil palm plantations (Comte et al., 2013; Boafo et al., 2020), as was also evident with mulching of senesced oil palm fronds (i.e. high SOC, total N, ECEC and base saturation in the frond-stacked area; Table 1)".

RC> I 170 replace 'till' with 'to'.

AR> We will replace in the revised manuscript.

RC> I 182 check reference, should only be (2018) in brackets.

AR> Thank you for noticing this, it will be corrected in the revised manuscript.

RC> I 191 not clear what (2018) is suppose to mean? Should there be a reference? And do you mean combined bicarbonate and organic acids? Please clarify (also in Fig 3).

AR> Yes the (2018) was supposed to be the reference "Kurniawan et al. 2018", it will

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be corrected in the revised manuscript. We will also add the word "combined" to avoid confusion.

RC> I 205 do you have anything to base your assumption on? Any measurements/references?

AR> For example, Khasanah et al., Agriculture, Ecosystems and Environment 211 (2015) 195–206 found no differences in bulk density among management zones. This reference will be included in the revised manuscript.

RC> I 209 insert 'The' in front of Expert-N model.

AR> We will insert it in the revised manuscript.

RC> I 211 insert 'the' after using.

AR> We will insert it in the revised manuscript.

RC> I 217 add reference for Richards' equation.

AR> We will add the reference in the revised manuscript.

RC> I 224 'stem' instead of 'trunk'.

AR> We will replace this in the revised manuscript.

RC> I 237 space between 1 and um.

AR> We will add a space in the revised manuscript.

RC> I 246 remove 'to' in front of 192.

AR> We will remove it in the revised manuscript.

RC> I 306 replace 'high' with 'strong'.

AR> We will replace it in the revised manuscript.

RC> I 318 specify here the months for typical dry and wet season.

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AR> We think that specify the typical months will be confusing. The dry period is clearly indicated in the picture that is referred in the text.

RC> I 424 But as you are saying elsewhere, they would not fertilise in the dry season either. So you might have to elaborate here.

AR> It is true that the farmers don't fertilise in the dry season, which is also not advisable for the reasons explained in I 429 but they could fertilize for example one month later, avoiding the peaks of drainage. Unfortunately, as explained in the manuscript, this is not practical because it is difficult to predict the period of high drainage fluxes from the precipitation pattern and so the most viable solution to reduce leaching is to reduce fertilization rates and increase nutrient retention efficiency.

RC> I 438 Mention EFB, POME, compost or a combination of these as they are all commonly used types of organic fertiliser in oil palm plantations.

AR> This will be mentioned in the revised manuscript (see answer to comment to I 145).

RC> I 443 circle closest to the roots for direct uptake of the fertilisers?

AR> We prefer to explain this in detail later in the manuscript (starting at I 466).

RC> I 453 replace 'highest' with 'higher'.

AR> We will correct this in the revised manuscript.

RC> I 458 trunk = stem.

AR> We will replace it in the revised manuscript.

RC>I 464 insert 'will' in front of largely.

AR> We will insert it in the revised manuscript.

RC> I 492 replace 'increased' with 'increases'.

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AR> We will correct this in the revised manuscript.

RC> I 494 The last part of the sentence doesn't fit the first. Please rephrase.

AR> We will remove the last part of the sentence for more clarity, as the study is not investigating soil fertility.

RC> I 502 replace 'influence' with 'effect'.

AR> We will replace this in the revised manuscript.

RC> I 505 Please rephrase this sentence, it sounds a bit clumsy and i is not that clear what you are trying to say.

AR> For more clarity, we will rephrase the sentence as follows: "In line with our second hypothesis, the weeding methods clearly influenced leaching losses: the mechanical weeding treatment had generally lower leaching fluxes than the herbicide treatment (Fig. 5; Table 5)."

RC> I 508 Replace 'have' with 'has'.

AR> We will correct this in the revised manuscript.

RC>I 519 Start a new sentence after the reference as the second half doesn't follow the first.

AR> We will modify this in the revised manuscript.

RC> I 525 replace 'conventional' with 'standard practice'?

AR> We prefer to keep the word "conventional" for consistency throughout the manuscript.

RC> I 527 This is where you need to expand on the yield aspect and include data etc.

AR> We decided that is was better to talk about the yield in I 518 where we first mention the economic aspects of the treatments (see answer to the first comment).

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RC> I 553 Insert 'the' in front of majority.

AR> We will insert it in the revised manuscript.

RC> I 559 Remove 'to' in from of streams.

AR> We will remove it in the revised manuscript.

RC> Table 1 call this soil physicochemical parameters as it's not really biochemical.

AR> We agree with this comment and we will change it accordingly.

RC> Table 4 Did you quote the decimals to significant figures?

AR> We reported the values to their significant digit based on their standard error.

RC> Figures 2,3 and 5 either call the x axis 'month' or remove 'months' all together as it is obvious that is a data axis (just add years).

AR> We will modify the pictures by removing "months" and leaving just the years in the x-axis.

RC> Figure 3 are RCOO and HCO<sub>3</sub> combined or separate? Please clarify. If it is combing perhaps say '+'?

AR> We prefer to not modify this in the picture but we will clarify that it is the combined contribution in the picture description (as it will be done in the text in accordance with the comment above).

RC> I 1010 with 'unpublished' do you mean not yet published? If it is in prep, please add, otherwise remove this citation. You are contracting 'reported' with 'unpublished'.

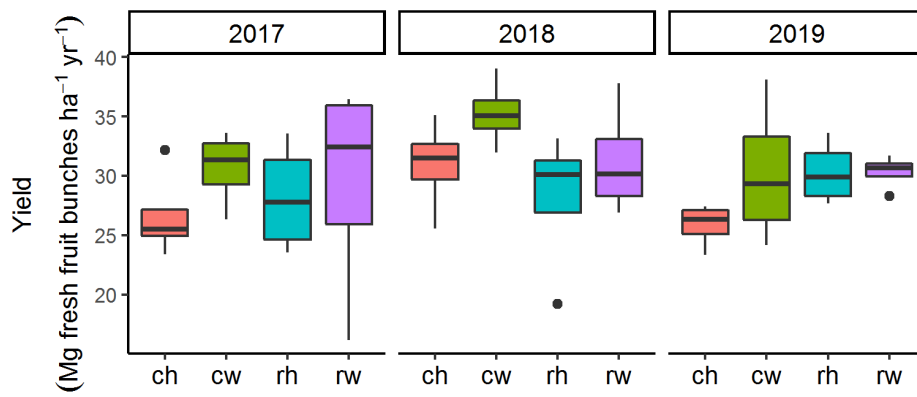
AR>The data are reported as unpublished because they are presented as original data in a manuscript currently under review in another journal. To avoid confusion we will modify the note as: "These data are not included in the manuscript to avoid double-publication as they were already included in another manuscript not yet published".

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Interactive comment on Biogeosciences Discuss., <https://doi.org/10.5194/bg-2020-153>, 2020.

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**Fig. 1.** Figure A2 Annual yield for each experimental treatment from 2017 to 2019.