We want to thank the referee for the positive and encouraging comments. See our numbered responses (bolded) to the comments below.

On behalf of all authors,

Mika Korkiakoski

Referee #1

Recent reports on greenhouse gases budget reveal that CH4 emissions have been increasing over the past decade, raising concerns for the role of CH4 on global warming. Warming may also contribute to the increase in CH4 emissions. As the authors mention, high latitude regions contribute substantially to CH4 emissions due to the large areal extent of wetlands. Although forest soils partially offset such emissions by oxidizing some of the atmospheric CH4, it is very important to understand how such a balance will be altered by warming. In this regard, this manuscript is timely and addresses an important question, which --in my opinion-- is relevant to the readership of this journal and beyond.

The paper is well written and clear. I only have a couple of concerns that I believe the authors should address for the sake of clarity.

It is not clear the amount of water that is being delivered through irrigation and how this amount was decided. Because the research question has to do with soil water content, it seems logical to me that the irrigation water should be decided based on the soil water content. Furthermore, to really trigger methane production (as well as other anaerobic processes), it is well known that the soil water content should rise above the soil water at field capacity. For methanogenesis, we also know that with soils at (or almost) saturation, it still takes 1 to 2 weeks (sometimes more) before methane starts being produced. There is a lot of literature from rice cultivation on this, for example. Thus, with irrigation active only once a week it is not surprising that methane production was low, or perhaps even absent, from the plots.

1. Concluding from this and the other referee's comment (see our answer #10), we see that the description of the irrigation can be confusing (page 4, lines 22-25). To clarify, we rewrote those lines as follows and hope it is clearer now: "The amount of rainfall added with irrigation was 11 mm on two days a week during 28 May–1 June 2018, after which the amount was increased to 11 mm on three days a week during 7–18 June 2018 and eventually to 21 mm on five days a week during 20 June 2018–7 September 2018. In 2019, the plot was irrigated with 11 mm three times a week throughout the summer."

Generally, in 2018, we irrigated the plot five times a week (every weekday) with 2000 liters of water. In the first half of June, we started with a lesser amount but noticed that it would not be enough as the summer turned out to be exceptionally dry. Initially, the amount of irrigation was decided to double the amount of summertime rainfall. However, practically, we had to vary the irrigated amount based on soil water content and what was practical. We did not know the exact soil field capacity value, so we could not base our irrigation amount on that. Irrigating five times a week with 2000 liters was pretty much the maximum amount we could do because

we had one 1000 liter tank that had to be towed for almost 6 km on top of a hill on small dirt roads twice each workday. Daily irrigation with 2000 liters took 4 hours to do and it had to be timed at late afternoon/early evening to minimize the evaporation of the irrigated water. In 2019, we, unfortunately, had to decrease the amount of irrigation to three times a week with 1000 liters at a time due to practical reasons.

Also, rainfall (which this irrigation aimed to mimic) is intermittent but not at regular intervals. This is very important for biogeochemical processes. The fact that sometimes two rain events happen very close with each other may cause soil water content to reach very high values, necessary for anaerobic processes. An equal amount of rainfall delivered over regular interval may not lead to very high water contents. This may also explain why in a wet year you can observe CH4 production, whereas an equal amount of water delivered more regularly through irrigation may not lead to CH4 production.

2. See also our answer #1. The irrigation was actually done at regular intervals and not intermittently.

The problem was that especially 2018 was so dry that the soil water content had usually returned to the pre-irrigated level before the next irrigation on the following day, which happened likely because of evapotranspiration of a significant amount of irrigated water even though we did the irrigation on late afternoon/early evening. The soil water content usually returned to the pre-irrigated level even with 2000 liters of daily irrigation, which corresponded to 21 mm of precipitation (page 4 lines 29-30).

We were aware that, to initiate net CH4 emissions, we will probably need to reach both a high soil moisture level for a longer period and, in addition, have enough fresh carbon substrates for the methanogenic archaea. We expected that by conducting regular irrigation, the soil water content would gradually increase and by the end of the summer, we would have a higher base level (the lowest points of the highly variable soil moisture values) of soil water content. Then, with the low diffusion of oxygen into wet soil + the irrigation, we could create anoxic conditions for longer periods and promote CH4 emissions. We expected CH4 emissions to occur somewhere in August when fresh carbon substrates were available and soil moisture content would be high, resulting from our regular irrigation mimicking a wet summer. This was discussed on page 20 lines 6-18.

Lastly, if the authors wanted to find the threshold in soil water content (or rainfall) leading to soils becoming a CH4 source, why not increasing irrigation (in frequency and amount)? This is also connected to my first point. It should be the soil water content to dictate the amount of water needed for soils to become anaerobic. I find this an interesting question and it is very unfortunate that the authors were not “successful” in finding this rainfall threshold. It would have been a very useful result, but I do not follow entirely why the authors did not explore higher water contents and irrigation water amounts.

3. See also answers #1 and #2 above. The referee is right that by increasing irrigation frequency and its amount, the experiment may have led to finding a threshold for methane production but, unfortunately, due to the location of the study site on a remote upland forest, many kilometres to the closest water tap, we had limited resources for transporting the required amount of water into the site. In future replications of this experiment, it is definitely recommended that the experiment is set in a location where the irrigation system can

distribute higher amounts of water and at a higher frequency than what was practically possible in this experiment.

We modified lines 12-13 on page 20 as follows: "... summer in 2019. Unfortunately, due to the remote location of the experimental site and a distance of several kilometres to the closest water tap, we were not able to counter the effect of the droughts. As a result, our control plot could be considered a drought experiment, while the irrigated plot followed the moisture and CH4 flux patterns of a "normal" summer. Therefore, it is definitely recommended that in future similar studies, the experiment is set in a location where the irrigation system is able to distribute higher amounts of water and with higher frequency than what was practically possible in this study. In the Lohila et al. (2016) study…"

I believe the authors should discuss these points in depth for a stronger and more sound paper. Hope my comments are useful.

4. We want to thank the referee for the encouraging and helpful comments. They definitely helped to improve the paper!

Minor points:

The need of labile C (e.g., sugars) is also needed from an energetic perspective, as anaerobic processes in general are not very favorable thermodynamically.

5. The referee is absolutely right about that, but we think that it is not that relevant in our manuscript and have decided not to discuss it further.

There are also recent methane budgets to consider. See for example:
https://essd.copernicus.org/articles/12/1561/2020/

6. To indicate the contribution of northern wetlands and mineral soils to the global CH4 budget in more detail, we modified the end of the paragraph on page 3 lines 1-2 as follows:"... those from northern peatlands, which contribute ~2 % to global CH4 emissions (Lohila et al., 2016; Saunois et al., 2020). Even though the global CH4 uptake by mineral soils is only ~5 % of global CH4 sink (625 Tg CH4 yr-1; Saunois et al., 2020), it has already been suggested…"