

## ***Interactive comment on “Effects of mowing on N<sub>2</sub>O emission from a temperate grassland in Inner Mongolia, Northern China” by L. Zhang et al.***

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**General comments** The manuscript describes the results of a long term (2003–2009) grassland mowing experiment in a semi-arid Inner Mongolian steppe, reporting the effects in terms of N<sub>2</sub>O emissions of different mowing heights vs a no-mowing control. The overall conclusion is that mowing only marginally decreases N<sub>2</sub>O emissions (the differences are not statistically significant) vs the no-mowing control. While the paper is competently written, and the presentation of results is appropriately illustrated with tables and figures and adequately discussed, I have a small reservation as to the general design and objectives of the experiment. Namely: the introduction states that traditional (sheep) grazing and mowing are prevailing management practices in Inner Mongolia, and that mowing is increasingly recommended (as an alternative to

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traditional grazing) for sustainable grassland management, with a view to restore the degraded steppe ecosystem in western China. The paper proposes then to study the effect (on N<sub>2</sub>O fluxes) of the introduction of mowing as an alternative management practice to traditional grazing. The problem is that the control treatment is not grazed, but left uncut, unmanaged.

If the aim of the experiment was to make a comparative assessment of the net N<sub>2</sub>O budgets in the traditional grazing and in the alternative mowing management, then the control should have been a grazed paddock with a realistic livestock density, and the mowing treatments at different heights should have been complemented by N<sub>2</sub>O flux measurements in the stables, or wherever the grass, silage or hay is fed to the animals. Indeed, the change in management practice for the steppes (switch from traditional grazing to mowing) presumably still aims to maintain animal production (meat, milk, wool, etc) from the ecosystem, not to turn this into a nature reserve. Thus the N<sub>2</sub>O emissions associated with off-land animal feeding operations should be quantified.

I understand that such measurements were not carried out in this study. In this case, the scope, ambition and objectives of the paper must be confined to the effect of the mowing height on the N<sub>2</sub>O emission, but no statements should be made regarding the impact of the change of management practice (grazing to mowing) on the overall N<sub>2</sub>O budget of the grassland+herbivore production ecosystem. Statements such as "...the introduction of mowing as a management practice might decrease N<sub>2</sub>O emissions in grasslands..." (abstract) and "...by changing grassland management, such as introducing a proper mowing intensity, the greenhouse effects of N<sub>2</sub>O emission might be mitigated in the grassland..." (discussion) are in my opinion misleading for scientists, stakeholders and policy makers, even if *stricto sensu* it may be true (through not statistically significant in this study) that N<sub>2</sub>O emissions are smaller in mowed than in unmowed grassland.

The paper may be published after a careful screening of the text to change the wording of such statements, in order to make it clear that the N<sub>2</sub>O budgets shown are in no way

complete (animal emissions missing) and cannot be used by themselves to assess the overall impact of the change of management practice and production system in support of policy assessment. Response: Thanks for your valuable comments. We carefully revised the whole manuscript and concentrate on the effects of mowing heights on the N<sub>2</sub>O fluxes in the grassland following your suggestions.

Specific comments Abstract, p19220, p22-24: "...grasslands, along with proper management practices, can be a N<sub>2</sub>O sink mitigating the rise of N<sub>2</sub>O in the atmosphere." The potential for soil N<sub>2</sub>O sink activity has been demonstrated before, but the recent review by Schlesinger (2013) suggests that this effect is a very minor one on a global scale. Response: It might be true that this effect is a very minor one on a global scale-but on a smaller scale, for instance, local scale or regional scale. Our study was carried out on a field scale to represent regional scale, therefore, we changed the sentence to "...grasslands, along with proper management practices, can be a N<sub>2</sub>O sink mitigating the rise of N<sub>2</sub>O in the atmosphere in a temperate grassland, Inner Mongolia".

p19224, N<sub>2</sub>O flux measurements: the fluxes measured in this experiment were generally extremely small, as one would expect in an unfertilized, ungrazed grassland, ranging from -32 to +67 g N<sub>2</sub>O m<sup>-2</sup> hr<sup>-1</sup>, ie from -9 to +19 ng N<sub>2</sub>O m<sup>-2</sup> s<sup>-1</sup>. In some N<sub>2</sub>O flux measurement systems, many of these fluxes would not be considered significantly different from zero. Please provide an estimate of your flux detection limit, as well as the N<sub>2</sub>O precision by GC. Response: Thanks for the comments. It is very small for the N<sub>2</sub>O flux in our study area. The rational of the N<sub>2</sub>O measurement is of high potent of warming. The detection limits for our approach were 3  $\mu$ g N m<sup>-2</sup> h<sup>-1</sup> for N<sub>2</sub>O based on the chamber dimensions, the sampling time, and the reproducibility of repeated measurements for standard gases (0.6% for N<sub>2</sub>O). And we added these information in our revision.

p19225, l18: total nitrogen (TN) was measured, but later in the text (p19231, l20) it is suggested that mineral N (NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup>) were also determined. If that was the case, it would be arguably more informative to show the mineral N data in Table 2 and

Fig.4 than TN, as N<sub>2</sub>O production proceeds directly from mineral N by nitrification and denitrification. Response: we only measured the TN in this study. The (NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup>) presented here just highlight our TN included mineral N. To avoid misleading , we deleted the “(including NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup>)” in our revision.

p19226, l12-14: is there a substantial snow cover in winter? what is its contribution to total precipitation? Could there be substantial N<sub>2</sub>O emissions during freeze-thaw events and at snowmelt, as observed in many studies? (eg, the Wolf et al paper, Vol 464, 8 April 2010, doi:10.1038/nature08931, reports that “: : :short-lived pulses of N<sub>2</sub>O emission during spring thaw dominate the annual N<sub>2</sub>O budget : : :” at their 10 Inner Mongolian study sites). In this case the N<sub>2</sub>O budgets presented here on the basis of the summertime measurements are obviously far from representative of the whole year. Please discuss. Response: Yes. And we discussed this in our discussion section

p19226, l15-16: please make it clear that the min and max T are for the N<sub>2</sub>O measurement period only (summer), but please also provide the temperature range for the whole year. Response: We have given the temperature range for the whole year and summer in the section of the Study site.

p19227, Temporal dynamics in N<sub>2</sub>O fluxes: having determined your flux detection limit in the M&M section, please indicate the fraction of the flux distribution that is not significantly different from zero. Response: Though it is small for single measurement, the seasonal cumulative N<sub>2</sub>O fluxes is significantly different from zero.

p19228, l21-22: it is not clear here and in Fig. 4 whether the data from all treatments were pooled for this analysis; please provide details of the analysis. Response: We added the statements “the data from all treatments were pooled for this analysis” in our revision.

p19228, 24-26 "...above-ground biomass ... and microbial nitrogen...": the R<sup>2</sup> values provided are calculated from fitted non-linear (seemingly quadratic) regression curves, the shapes of which are not convincing, unjustified and counterintuitive; for example

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why should N<sub>2</sub>O emission increase as microbial biomass nitrogen tends towards 0? I suggest to remove such regressions for microbial N, above ground plant biomass and total phosphorus, as the data do not indicate any clear relationship or trend. On the other hand, I wonder why the N<sub>2</sub>O data are not plotted in Fig. 4 versus microbial biomass carbon, temperature, and mineral N if this was measured? Response: Yes. Thanks for the comments. We removed the regressions for microbial N and total phosphorus, as the data does not indicate any clear relationship. But we kept the regression for above ground plant biomass because of the relationship is statistically significant. Because there were no significant relationships between N<sub>2</sub>O and microbial biomass carbon as well as temperature during the two growing seasons, we did not present them in Fig.4. As mentioned above, we didn't measure it in this study.

p19229, l11-12: "...stepwise regression analyses show that microbial biomass nitrogen was a major controlling factor in N<sub>2</sub>O fluxes...". Related to the above comment, where in Fig.4 a quadratic regression was performed for MBN: was a quadratic regression also used in the stepwise regression mentioned here? I expect not. I am not overall convinced of the usefulness of such stepwise regressions in the case of N<sub>2</sub>O emissions, because the shapes of the relationships of the different variables to N<sub>2</sub>O can be very different (for example, linear or exponential for temperature, gaussian for soil moisture, etc), whereas a stepwise regression might apply linear regressions automatically and in blind fashion. Response: Thanks. Here "Using the pooled data of the whole growing season in the different treatments, stepwise regression analyses show that microbial biomass nitrogen was a major controlling factor in N<sub>2</sub>O fluxes in the control and the M2 treatment, explaining 25% and 27% of the variation in the N<sub>2</sub>O fluxes, respectively ( $P = 0.01$ ,  $P = 0.008$ ). Please note that we analyzed in the CONTROL and M2 TREATMENT here, but the data is pooled all the treatment together in Fig.4. And because of the relationship between N<sub>2</sub>O and MBN is not significant for all the treatment data together, we deleted the regression in our revision.

p19229, l19-21: please change the sentence to: "Our observations, showing a de-

crease in N<sub>2</sub>O EMISSION with mowing height, generally supported the hypothesis that A LONG TERM MOWING MANAGEMENT would decrease the grassland N<sub>2</sub>O emissions into the atmosphere." I believe it is useful to change the wording from "mowing" to "long term mowing management", in order to distinguish the event (the act of mowing or cutting the grass on a given day, which might well trigger an N<sub>2</sub>O emission pulse - see Fig.3 in Flechard et al., Global Change Biology (2005) 11, 2114–2127, doi: 10.1111/j.1365-2486.2005.01056.x), as opposed to the grassland system resulting from the management practice. Response: Yes, thanks very much! We accepted the suggestion and revised it in our revision.

p19229, l24: it would appear that "Grazing-induced reduction of natural nitrous oxide release from continental steppe" by Wolf et al. (2010) was delivering a different message from yours, if you argue that a mowing management leads to a reduction of N<sub>2</sub>O emission compared with the traditional grazing system of Inner Mongolia? Please explain. Response: In the revision, we focus on the effects of mowing heights on N<sub>2</sub>O fluxes following your suggestions in General comments with no longer comparing the effects between mowing and grazing.

p19230, 23-28: the reasoning is sound (senescence, high temperature, mineralisation, rainfall are conducive to N<sub>2</sub>O emissions), except that according to Fig.3, the N<sub>2</sub>O fluxes in August are not clearly larger than in other months, but indeed much lower than June in 2008 and much lower than May-June in 2009. Response: N<sub>2</sub>O flux is generally positive during the whole growing season in previous studies. It is also strange to us that we detected negative fluxes in July and positive fluxes in August, We tried to figure out the possible mechanism underlying the difference in July and August in our study.

p19232, l20-21: the moisture effect is a well documented one. Response: Yes.

p19232, l14-21: for this concluding paragraph, it could be useful to indicate that the paper does not present a complete N<sub>2</sub>O budget (fluxes for the growing season only, no emissions from herbivores and from freeze-thaw cycles) and that the results need

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to be complemented by other studies to assess the overall impact of the change of management practice (grazing to mowing) on the total N<sub>2</sub>O budget. However, given the revised scope of this paper, it can be interesting to reflect on which mowing height (and, why not, the timing? the frequency?) might have the best potential to reduce field emissions within a mowing-based animal production system. Response: Done following your suggestions.

Technical corrections p19221, l22: change to "Denitrification is one of the key ecological processes that determine N<sub>2</sub>O production...". p19221, l27: (Cavigelli and Robertson, 2001) p19222, l8: (Yamulki et al., 1998) p19226, l23: "... biomass and litter measured in 2009..." p19227, l9: "... were significantly different ..." Response all of the above: Accepted all the suggestions.

p19227, l21-22: "...variation in the monthly cumulative N<sub>2</sub>O flux, with a range of 0.48 to -0.35 kg N<sub>2</sub>O ha<sup>-1</sup> ..." : the data shown in Fig.3 show a much larger range in monthly cumulative fluxes, from -4 to +5 kg N<sub>2</sub>O ha<sup>-1</sup>, which surely indicates a unit error in Fig.3 . Please correct Fig.3. Response: The actual Y scale of Fig.3 is "-0.4 to 0.6" but showing as "-.4 to 0.6", which is default format of the plotting software of SigmaPlot we used.

p19230, l17: change "bound to" to "associated with" Response: Accepted the suggestion

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