Soil Greenhouse Gas Emissions under Different Land-Use Types in Savannah Ecosystems of Kenya

Authors Response:

Two reviewers have reviewed the manuscript and an additional comment was made in the open discussion. Before, responding to each reviewer and comment individually, we would like to thank for the constructive comments and informative feedback.

The document is structured as follows: each of the reviewer's comment (indicated by RC) is first repeated followed by our response (indicated as AC and in italic). Where relevant we either include a rephrased sentence already or explain on how we intent to implement suggested changes.

RC 2

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RC: This is interesting study conducted in semi-arid parts of Kenya, where similar data are quite scarce. The set-up is an area characterized by a series of activities. It is a surprised that there is some form of cultivation/farming in an area that looks more like Tsavo national Park. Nonetheless, the study provides valuable data that extend our knowledge of ecosystem gas fluxes in this part of the world.

AC: *We would like to thank Mr. Otieno for this review and his valuable comments.*

RC: The study was conducted in a relatively poor soil. What the authors failed to mention, especially for the cropped and grazed sites was the slope of the field. I tend to imagine that erosion must be playing a critical role in mineralization processes in this place. It looks like the organic/humus, top soil layer is completely gone and what remains is mainly the mineral soils. Unfortunately, the paper is already too long and I will not recommend inclusion of more information on land use history, which would have been helpful in understanding/interpreting these results.

AC: *The study area are located is the lowland of the Taita Taveta county, which is very flat. The cropland is at 1070 m a.s.l, bushland at 1076 m a.s.l, grazing land at 970 m a.s.l, and conservation land at 928 m a.s.l. The cropland is received very small quantities of manure and no chemical fertilizer inputs and thus no significant difference in soil C content with the other land use types. In the grazing area, overgrazing was evident as most of the soil was bare especially in dry season. This contributes to soil erosion and compaction of the land by wind and rain and even the livestock while grazing. We will add this information briefly in the revised manuscript.*

RC: It's very surprising that temperature and soil moisture had no influence on soil CO2 fluxes. Could it be the method of data collection, with significant data collection gaps that led to this?

AC: *Soil CO_2 emissions were positively correlated to soil moisture. However, variation in soil temperature for the time of measurements during the day in both dry and the wet season were minor, and thus we found no statistically significant effect of soil temperature upon CO_2 emissions for the dataset. Other studies by Brümmer et al. (2009) and Livesley et al. (2011) also found that soil moisture controlled CO_2 emissions from savanna soils, rather than soil temperature. However, if we have had the opportunity to measure more frequently – i.e. following a diurnal course – we are confident that an effect of temperature exists. For instance, we found such diurnal course in GHG emissions in a similar ecosystem in Kenya. This was part of another project and is consequently not shown here.*

RC: For future, the authors need to consider higher frequencies of data collection. In such arid ecosystems, evaporation is quite high and it is likely that critical information is lost by not collecting data more regularly.

AC: *For this study, the sampling frequency was based on seasonal variation, thus the campaigns were targeting the wet, transition and dry season and when moisture and/or management practices are likely to impact GHG emissions. Certainly, we would have preferred more frequent measurements, though given the research question asked and the available resource for this project, we had to make a compromise. However, there is a follow-up study in other Land Use Types with measurements that are more frequent.*

RC: CH_4 seems to contribute little to this paper, why not exclude it completely? I do not see the two lines of discussion on CH_4 are of major benefit to the readers. The paper is already too long and probably removing all the descriptions on CH_4 could reduce the number of pages.

AC: *We agree that the importance of methane emissions is negligible when compared to the other gases. However, our aim was to look at all three GHGs in this study and due to the lack of available GHG emissions data from such land cover types in this region of the world we still think its beneficial to report these here. Certainly, in order to not further lengthen the paper, we decided to keep this information as short as possible.*

RC: The word "Soil Organic Carbon SOC" is introduced in the introductory part of the Ms. In the methods, there is total soil carbon and in the results, I met Soil Carbon. In the discussions, SOC becomes the main discussions line. The authors need to be consistent in the use of these terms, otherwise the readers get confused.

AC: *We thank the reviewer for pointing this out and we will harmonize in the revised manuscript accordingly.*

RC: Ln 65. Not all savannah belongs to the ASALs. The humid savannas are relatively wet, with green vegetation almost throughout the year. It is therefore not right to make such a sweeping statement.

AC: *Noted with thanks and we adjust the revised manuscript accordingly and use drylands instead of ASALs.*

Specific comments

RC: Ln 67. Note that shrubs are woody vegetation

AC: *Noted with thanks.*

RC: Ln 88. Revise the sentence. Overstocking leads to grazing pressure. The way the sentence is written is redundant.

AC: *Done*

RC: Ln 96-7. ---Croplands are still being cleared from natural vegetation----re-write the sentence, it's not making the intended meaning.

AC: *Done. Revised --Natural vegetation is being cleared to make way for the expansion of cropland*

RC: Ln 104, what's "cropland farming"?

AC: *Here we refer to cropping agriculture in the savanna.*

RC: Ln 153. The authors need to be clear on the physiognomic characterization of the vegetation they are studying. Here you have woodlands, bushlands and on line 155 you have wood bushlands, which is which?

AC: *We harmonize this in the revised manuscript to bushland as found in Tsavo East and West national park.*

RC: Ln 156 are Lions also grazers?

AC: *Lion are not grazers. On this line, we were mentioning the fauna that the ecosystem supports in general to highlight the importance and the functions of the park.*

RC: Ln 160 –other important land use(s)

AC: *Corrected*

RC: Ln 173. Is the farm rain-fed or not? Are there other sources of moisture input apart from rain?

AC: *The farm is totally rain fed.*

RC: Ln 237, how deep was the collar inserted into the soil?

AC: *The collars we inserted between 5cm to more than 8cm into the soil. We ensured the collars were inserted so the extend above the surface did not hold water during the rainy season and the collars were less likely to be trampled on and broken by large animals*

Result

RC: Label Fig. 3 as a and b

AC: *Done*

RC: Ln 377, Sand proportion was lower than what? In comparative sentences, learn also to use "lowest" or "highest" see ln 417.

AC: *Sand proportion was lowest in the grazing land (64.3±0.4 %) than in the other study three sites. We will adjust the phrasing in the revised manuscript.*

RC: Ln. 456 present data/results according to the chronology of the figures and avoid this back and forth.

AC: *Done*

RC: Ln 481. Delete (in) before during.

AC: *Done*

Discussion

RC: SOC is only mentioned in the introduction but not in the methodology or results, yet it becomes very prominent in the discussions. Be consistent in the use of terms.

AC: *Noted with thanks.*

RC: Ln 525 is not correct. You cannot attribute the differences only to vegetation. It is definite that land use itself leads to the differences in soil C. Although this is argued correctly in the later sections, this section should be revised.

AC: *Corrected*

Ln 548. The argument with clays is a bit far-fetched anyway.

AC: *We removed this argument in the revised manuscript.*

RC: Ln 592. ---temperature was measured "down" to 5 cm. I would imagine that 5 cm depth is almost at the surface. What was the deciding factor for installing temp/moisture sensor at this depth? This depth, being close to the surface is associated with very strong temperature fluctuations. It may be one of the reasons why the authors found no temperature correlation with CO_2 efflux. Most grass

roots, cereals included, have roots located within 10 cm, and may extend down to 30 cm. the woody vegetation in such dry places have their roots even deeper. Trying to establish relations with variables measured at 5 cm may not yield positive results.

AC: *According to a study by Pavelka et al. (2007), daily dynamic of soil CO_2 fluxes are affected by soil temperature near the soil surface and hence for correlation between soil CO_2 emissions and soil temperature, the measurement of soil temperature at the soil surface, is highly recommended to avoid the inaccuracies. Coupled with this, the ProCheck handheld GS3 sensor (Decagon Devices Inc) for soil moisture and temperature that we were using could only measure up to 5cm. Because, we were taking measurement within or close to the chamber collars, we did not want to cause any soil disturbance. This is also recommended by the GRACENet protocol we were using as our reference protocol.*

RC: Ln 593 check the sentence. How does root respiration tap moisture?

AC: *Noted. Here we mean roots can still tap moisture from deeper profile and thus root respiration can continue even after the surface moisture has dried up.*

RC: Ln 640. Consider soil erosion and volatilization also.

AC: *This is an important point and we thank the reviewer for pointing this out.*

RC: Ln 651. Use “dung” instead of faeces.

AC: *Corrected*

RC: Ln 665 what’s T? From nowhere, you introduce T.

AC: *T stands for soil temperature.*