Review of the paper: The relationship between termite mound CH_4/CO_2 emissions and internal concentration ratios are species specific

Reviewer comments in **bold** and response in normal font

Response to the comments of anonymous Referee #1

General comments

This paper by Jamali et al. presents data on CO_2 and CH_4 fluxes from soil and termite mounds in North Australian tropical savanna. Gas fluxes and gas concentrations inside the termite mounds were measured from February to November 2009 every four to six weeks with closed dynamic chambers with a fast greenhouse gas analyzer at four different sites, including one ephemeral wetland site, not far from Darwin, NT, Australia. Gas concentrations inside the mounds were also determined with the fast GHG analyzer from air sampled with a syringe connected to a nylon tube reaching into the mound interior. At every time point and site, flux measurements were replicated 5-7times for the dominating termite species. Additionally, soil and mound temperatures as well as gravimetric soil moisture content was determined at each sampling date at each site.

The objective of the paper was to "investigate the relative importance of CH_4 and CO_2 fluxes from soil and termite mounds" and to study the relationship between mound gas fluxes and gas concentrations. The authors found that termite-related CO_2 fluxes were 5-46 larger than termite CH_4 fluxes on a CO_2-equivalent basis at the different sites, but that the termite CO_2 + CH_4 flux contributed only 0.3-0.8% to the total soil flux on a CO_2-equivalent basis at the different sites. They also found significant relationships between termite mound CO_2 and CH_4 fluxes, between mound CO_2 concentrations and mound CO_2 fluxes, mound CH_4 concentration and mound CH_4 fluxes, and finally mound CO_2 concentrations and mound CH_4 fluxes. However, there were large interspecific differences between the ratio of mound CO_2 to CH_4 fluxes, but also between mound gas concentrations and corresponding gas fluxes, making the application of a simple generic regression function between e.g. mound CO_2 and CH_4 fluxes, or between mound CO_2 concentrations and CH_4 fluxes impossible, rather requiring the establishment of species-specific relationships.

The paper presents valuable data on the importance of different termite species for total soil CO_2 and CH_4 emissions and especially the relationship between the two gas fluxes themselves as well as between the gas concentrations inside termite mounds and the related gas fluxes. The paper reveals that there are consistently strong relationships between the two gas fluxes and also between the gas concentrations inside the mounds and the gas fluxes out of the mounds in the different termite species, pointing towards the termites themselves as dominant source of the two gases inside the mounts. However, the authors also found significant interspecific differences with respect to slopes of the regression lines between the different parameters, unfortunately impeding the establishment of generic relationships across termite species. The presented work is solid, and the data add important information to the understanding of the role of termites in ecosystem gas fluxes. Especially the very clear picture of the tight link between mound gas concentrations and mound gas fluxes is new in this detail presented and helps to disentangle pure soil microbial-derived gas fluxes from termite-derived gas fluxes. The significant interspecific differences in this respect call for further more detailed studies of gas formation and consumption processes in the different species and their mounts. At the end, though, the authors have missed to clearly state that the termites' contribution to total soil gas fluxes is only of minor importance. This should be taken into account for the discussion and conclusions, especially with respect to management effects on termite abundance and, hence, on gas fluxes. To summarize, I recommend publication of this paper after the specific comments below have been addressed properly.

We appreciate the invaluable feedback and have revised the manuscript in the light of feedback from the reviewer as explained below:

Specific comments

p. 17314, 1st sentence: You state that you "investigated the relative importance of CH_4 and CO_2 fluxes from soil and termite mounds" in this study, but you never come back to this objective, i.e. you never give any relative number of the contribution of termite-related CO_2 and CH_4 fluxes to total soil fluxes, although you present the absolute numbers in Table 6. For getting the right perspective right at the beginning of the

paper, you should already mention in the Abstract that termite-related CO_2-e fluxes contributed 0.3-0.8% to total soil CO_2-e fluxes at the four sites of your study.
As suggested, following sentence has been added: “The contribution of CH_4 and CO_2 emissions from termite mounds to the total CH_4 and CO_2 emissions from termite mounds and soil in CO_2-e was less than 1%.”

p. 17318, l. 1f: Isn’t it problematic to infer total termite-related fluxes for a specific site, if fluxes are measured for a species that only represents 10-21% of the total termite population, as it was the case for site 1 and 2?
It was logistically difficult to measure fluxes from all termite mounds on a site. Therefore, we decided to measure fluxes only from the mounds of the dominant species at a particular site. However, additionally, we surveyed and measured the basal area of all mounds on that site. For the species whose mound fluxes were not measured at that site, an average flux value of all species measured on other sites was used. We believe this was the best possible approach that could be used for scaling up the fluxes to a site level in these circumstances.

p. 17319, l. 21f: Even though you cite your own work here, please provide the basic information with respect to time of the day at which the measurements were performed, chamber closure time, calibration procedure for the gas analyser, sensitivity of the gas analyser to temperature changes (i.e. instrument drift).
The following sentences have been added in the section 2.2 to adress these concerns:

l. 19. “Fluxes from termite mounds were always measured between 10:00 and 12:00 hours as this time best represents the daily average flux (Jamali et al. 2011a).”

l.24. “Chamber closure time was five and ten minutes for mound and soil fluxes, respectively.”

In regard to calibration procedure and instrument drift: the FGGA it is not sensitive to pressure and temperature changes in a wide measurement range of 0 – 50°C and does not need calibration. Maximal instrument drift is 0.8 ppb for CH_4 and 120 ppb for CO_2 over 24 hour. The potential error introduced by this instrument drift would translate to 0.0005 ppb CH4/min and 0.083 ppb CO_2/min and is negligible and absolutely superior to any current GC setup. The instrument has internal pressure compensation. For more information on the used measurement technique, Off-Axis Integrated Cavity Output Spectroscopy (OA-ICOS,) and its advances over classic cavity ringdown spectroscopy we refer to the Los Gatos webpage (http://www.lgrinc.com/advantages/unique-technology.php). This instrument has been used under extreme conditions and tested has been employed by NASA. Furthermore the gas analyser does not need to be calibrated but we checked internal standard calibration regularly buy attaching it - flushing the measuring cell - with known standards in the lab.

p. 17319, chapter 2.2: How did you calculate the "truly" mound-derived gas flux, i.e. how did you quantify/estimate the area that was covered by the measured mound within your chamber frame? In other words, how did you differentiate between soil-derived and mound-derived gas fluxes in your chambers? This is crucial information for the upscaling.

We agree that, although we used multiple-sized chambers matching closely with mound size, a small area in the chamber frame was still covered by soil and not mound. However, for scaling purpose, we assumed that all area within a chamber frame was covered by mounds because mounds of all species investigated in this study had an unknown portion belowground, similar to an iceberg. As in a cone, the circumference was in general higher for the belowground portion of the mound as compared to circumference at ground level. Therefore, the emissions arising from soil within a chamber frame would in fact be originating from below-ground portion of the mound.

p. 17320, l. 8-10: Were the analyses of mound air done in the field? I assume that you get a pulse-function-type curve when you inject gas to the fast GHG analyzer. How did you analyze these curves? Did you apply a standard of known gas concentration in the same way? Please add this basic information here.

As suggested, a brief experimental procedure of sample injection and concentration analysis has been added as shown below:

"Gas samples of 20 ml were collected from inside the mounds by connecting a syringe to the stopcock immediately after measuring mound fluxes, and manually injecting these into the Fast Greenhouse Gas Analyser (hereon referred to as FGGA) in the field. The concentrations of CH_4 and CO_2 in the gas samples were determined by using a calibration equation developed in the laboratory by manually injecting 20ml samples of known concentrations of CH_4 and CO_2 in the same way as in the field."

p. 17320, l. 15-16: Did you also analyze the water content of the mound material? If not, why not?

As mounds were being repeat-measured, it was important to keep the mound intact throughout the measurement campaign. Measuring mound water content would have required destructive sampling. This is now explained at l. 16 as below:

"Mound water content was not measured as it would have required destructive sampling which was not possible as it was important to keep the mounds intact for repeat-measurements. As our previous data (not shown) showed a strong relationship between soil water content and mound water content (R^2>0.8), we decided to use soil water content instead of mound water content in our statistical analysis."

p. 17320, l. 23-24: Why did you analyze the relationship between gas fluxes from termite mounds with SOIL moisture, and not with the moisture content of the mound material, as you have done analogously with temperature? This difference might be relevant, as you also discuss (chapter 4.3) the importance of the microbial activity in mound walls for total mound CO_2 (and perhaps also for CH_4) fluxes. Thus, looking at the relationship between mound fluxes and mound water content would have been more appropriate.

This is now explained at l. 16 as below:

"Mound water content was not measured as it would have required destructive sampling which was not possible as it was important to keep the mounds intact for repeat-measurements. As our previous data (not shown) showed a strong relationship between soil water content and mound water content (R^2>0.8), we decided to use soil water content instead of mound water content in our statistical analysis."

p. 17324, l. 6: The significant relationship of soil CO_2 fluxes with soil water cannot be seen in Fig. 2.

This was a typing error. "Fig.2" has now been replaced by "Table 4".

p. 17326, l. 24-26: This is per se not a reason for the lowest CO_2-e emissions at the wetland site. These specialized termites could still fully compensate the lack of other termite species in terms of GHG emissions. What seems more obvious is a strong contribution of microbial respiration to mound CO_2 efflux, which would explain the obvious covariance between soil and mound CO_2 fluxes not only at this wetland site, but also at the other sites.

Agreed, this sentence has been deleted as the preceding explanation may be sufficient.

p. 17327, l. 1-2: If soil microbial activity is inhibited by high soil moisture (or water saturation), then litter should accumulate, and not litter accumulation be inhibited.

Agreed, this sentence has been deleted.

p. 17330, l. 1f: Somewhere in this last paragraph of the discussion the statements should be put into the perspective that the contribution of termite-derived CO_2+CH_4 emissions on a CO_2-e basis were less than 1% of total soil CO_2-e emissions, at three of the four sites even less than 0.4%.

As suggested, the following sentence has been added at l.1: "The contribution of CH_4 and CO_2 emissions from termite mounds to the total CH_4 and CO_2 emissions from termite mounds and soil in CO_2-e was at maximum less than 1%."

Table 2: Add information on the feeding guild for the different termite species (e.g. wood-feeding, grass-feeding, soil-feeding).

Agreed, this information has been added.

Technical corrections

Order of references in the main text: should be either alphabetical or chronological. Currently it is neither nor.

This has been done.

p. 17318, l. 13: Change "dominate" to "dominant"

This has been done.

p. 17319, l. 7: Does the "2" mean "twice" here?

Yes. "2" has been replaced by "twice".

p. 17321, l. 16: What is the difference between "preceding" and "antecedent"? The latter should read "successive" or so, shouldn't it?

This mistake has now been corrected. This sentence now reads as:

"For months without direct flux measurement, the mean daily flux for that month was estimated as being the average of the nearest preceding 'measured' month and nearest successive 'measured' month."

p. 17324, l. 9: Change "Fig. 3" to "Fig. 2".

This has been corrected.

p. 17326, l. 6f: Here you should also mention the relative contribution of termite-related GHG fluxes as compared to soil-derived fluxes, i.e. between 0.3% and 0.8%.

As suggested, following sentence has been added at l.12: "The contribution of CH_4 and CO_2 emissions from termite mounds to the total CH_4 and CO_2 emissions from termite mounds and soil was between 0.3 and 0.8% in CO_2-e (Table 6)."

Table 4: Change "sOIL CH4 flux" to "Soil CH4 flux"

This has been done.