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Interactive comment on "Soil CO_2 efflux in an old-growth southern conifer forests (*Agathis australis*) — magnitude, components, and controls" *by* L. Schwendenmann and C. Macinnis-Ng

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Referee #3 We highly appreciate the referee's comments and suggestions, which helped improve the quality of the manuscript. Please find below a detailed response to the each of the comments.

General comments

This study reports measurements of soil respiration and their component parts in a kauri forest in New Zealand. Both trenching and statistical techniques are used to partition the total soil efflux into auto and heterotrophic respiration. Statistical methods

are then used to investigate the temporal controls by environmental parameters. Tree root biomass and "tree influence" are used to look for controls on the spatial variability in soil CO2 efflux. There are extensive references and good comparisons with data from the NH. The interest in this manuscript doesn't so much lie in its respiration results and partitioning, but rather its combination of soil respiration and spatial patterns relating to root biomass.

Specific comments

1. An attempt was made to test soil respiration methodology with comparisons between surface and inserted rings. However, this was not well described in the introduction and I was confused to why they did this.

Response: We revised section 1 as follows: "The aim of this study was to determine the magnitude, components and the driving factors of soil CO2 efflux in an old-growth southern conifer forest. The specific objectives of our study were: (i) to quantify total soil CO2 efflux, (ii) to test the effect of collar depth on soil CO2 efflux, (iii) partition total soil CO2 efflux into autotrophic and heterotrophic respiration, (iv) to identify the factors controlling the temporal variation of total soil CO2 efflux and its component fluxes, and (v) to test the effect of kauri tree size and distribution on total soil CO2 efflux and soil properties. In order to achieve the objectives we measured soil CO2 efflux in an old-growth kauri stand over 18 months. We used direct (trenching) and indirect (regression technique) approaches to partition total soil CO2 efflux (organic layer plus mineral soil to 30 cm depth) into the autotrophic and heterotrophic components. Given that old-growth kauri forests are often characterised by thick organic layers we used deep collar insertion to assess the effect of insertion depth on soil CO2 efflux and to quantify to proportion of autotrophic and heterotrophic respiration in this layer."

2. In the Experimental Setup the reason for the inserted and surface chambers should be explained.

Response: We revised the methods section to improve the links between objectives and the experimental set up as follows. We decided not to include the data from the "Outside_Trench_Inserted" sampling points as the results confirmed the findings in the plot (17% reduction in total CO_2 efflux due to deep collar insertion).

2.2. Experimental set-up "To quantify the effect of insertion on total soil CO_2 efflux and to determine the proportion of autotrophic and heterotrophic respiration to total soil CO_2 efflux in the organic layer, a cluster of three 'deep' PVC collars (10 cm in diameter, 20 cm in height) was inserted next to each sampling point for surface soil CO_2 efflux measurements. Three collars per cluster were spaced evenly around the circumference of a circle 2 m in diameter, with small adjustments in the spacing to accommodate large roots. Each collar was driven right through the organic layer and 1-2 cm into the mineral soil layer to cut off the roots growing in the organic layer. In order to prevent CO_2 uptake, any vegetation inside the collars was regularly removed. The thickness of the organic layer at each grid point was measured using a ruler outside each collar. The 'deep' collars were inserted in November 2011 and left in place over the measurement period. Efflux was measured from August 2012 to January 2014. Here after, these sampling points are known as Plot_Inserted."

"We used the trenching approach to separate heterotroph and autotrophic respiration in the organic layer plus mineral soil to 30 cm depth. To avoid disturbing the long-term research plot the trenching experiment was set-up directly adjacent to the research plot. In July 2012, six 2 x 2 m plots were trenched to 30 cm depth based on a preliminary study showing that the majority of fine roots (over 80%) are located in the organic layer and top 30 cm of the mineral soil. The trenches were double-lined with a water permeable polypropylene fabric and backfilled. During trenching, trampling and disturbance inside the 2 x 2 m plots were avoided as far as possible. Two types of measurements were conducted in the trenched plots. First, surface soil CO_2 efflux was measured at two sampling points outside each trenched plot (Outside_Trench_Surface) in the same way as the Plot_Surface samples were measured (see above. Second, two collars were randomly placed inside the trenched plot (Trench_Inserted) and were inserted

1-2 cm into the mineral soil layer (deep collars) as described above. Soil CO_2 efflux was measured bi-weekly to monthly from August 2012 until December 2013."

3. I found the overall aims of the manuscript confusing and this wasn't helped by the description of the methods and the 5 different types of soil surface measurements. A better way to arrange this might be to describe each aim and then the methods that go with it. Eg Collar insertion depth, respiration partition, annual soil respiration, spatial variability vs temporal variability.

Response: We modified the methods section as suggested (see response 2). We decided not to include the data from the "Outside_Trench_Inserted" sampling points as the results confirmed the findings in the plot (17% reduction in total CO_2 efflux due to deep collar insertion).

4. It would be good to see the data, especially the relationship between soil respiration (total, Ra, Rh) and temperature.

Response: A figure showing the relationship between total soil CO_2 efflux, heterotrophic and autotrophic respiration has been included. We re-analysed the data set (combing the plot and trench sampling points) using the most commonly used temperature response functions (linear, exponential Q10 and modified Arrhenius function, see Figure 4 below).

5. The comparison of average soil respiration with other sites does not take temperature into account. It would be better to compare R10 or Q10 values. Alternatively you could use your know relation with temperature to adjust your values to the same temperature at other sites.

Response: We calculated the Q10 values and modified the results and discussion sections accordingly.

Results Section 3.3 "The linear temperature function explained around 44% of the temporal variation in total soil CO_2 efflux (Figure 4A, Table 3). Exponential (R^2=0.13) and modified Arrhenius ($R2=0.17$) functions resulted in lower R2 values (Table 3). The Q10 values for total soil CO2 efflux was 1.6 (Table 3). A slightly stronger soil temperature response was found for heterotrophic respiration (linear function R2=0.530, Figure 4B) with a Q10 value of 2.2 (Table 3). No significant relationship was found between soil temperature and autotrophic respiration (Figure 3C).

Neither a linear nor a quadratic function resulted in a significant relationship between SWC and total soil CO2 efflux (Figure 4D). Heterotrophic respiration decreased significantly with increasing SWC (R2=0.590, Figure 4E). In contrast a weak, but significant positive relationship was found between SWC and autotrophic respiration (Figure 4E). Bivariate polynomial functions did not result in higher R2 values compared to univariate models (Table 3)."

Discussion Section 4.1: "While mean annual soil temperature partly explains the overall high mean soil CO2 efflux measured in this forest, soil temperature was not a very good predictor of the temporal variation in total soil CO2 efflux. Independent of the regression model used, soil temperature explained a small proportion ($< 44\%$, Figure 4A, Table 3) of the seasonal variation in total soil CO2 efflux. In temperate forest ecosystems in the Northern Hemisphere (Ngao et al., 2012; Bond-Lamberty and Tompson, 2014) soil temperature often explains more than 50% of the temporal variability in total soil CO2 efflux. It is important to note that the soil temperature range in this kauri forest was narrow (around 7°C) compared to other temperate forests with a larger seasonal soil temperature amplitude (> 10°C, Paul et al., 2004). Thus, a seasonal temperature effect may not have been visible in this kauri forest. The Q10 value (1.6, R2=0.172, Table 3) was at the lower end of the range reported for mixed and evergreen forests (Q10_10-20°C; 0.5-5.6; Bond-Lamberty and Tompson, 2014). However, low Q10 values have also been reported for other conifer forest, especially at sites characterized by mild winters (Borken et al. 2002; Curiel Yuste et al., 2004; Sulzman et al., 2005). Low Q10 values in evergreen forests have been explained by the lack of a distinct seasonality in photosynthesis and substrate supply (Curiel Yuste et al., 2004)."

6. The collars were inserted in November 2011 and efflux measurements commenced in January 2012. This does not leave enough time for the roots to decompose; therefore this is not truly a measurement of heterotrophic respiration. How was this accounted for and was there a decrease in RH over time as the roots decayed?

Response. We installed the collars in November 2011. Only measurements conducted after August 2012 have been included in this study. We did not correct our estimate of soil CO2 efflux for decomposing root-derived CO2 flux. We did not observe a significant insertion/trenching related change in heterotrophic respiration. We don't have data on kauri root decomposition but previous studies showed that kauri litter is characterized by very long residence times (between 9 and 78 years, Silvester and Orchard, 1999). To address the effect of root decomposition-derived CO2 fluxes we included a statement in the methods section and modified the discussion as follows: "Cutting roots through inserting deep collars and trenching increases the dead root biomass (Heinemeyer et al., 2011). As we did not correct our estimates of soil CO2 efflux for decomposing root-derived CO2 fluxes the heterotrophic respiration may have been slightly overestimated (Hanson et al., 2000; Kuzyakov, 2006; Ngao et al., 2012)."

7. In the study site description, it would be good to know that the forest had been disturbed by tree removal and may not be in equilibrium.

Response: The following statement has been added in section 2.1 (Study site) "Four emergent kauri trees (up to 180 cm in DBH, approx.. 300 year-old) are found on the upper slope of the plot. At the lower slope tree fall and removal of five large kauri trees in the 1950s created gaps which are now dominated by a cohort of younger kauri trees".

L 187 states that efflux was measured on a number of days immediately after trenching, but this data are not presented.

Response: We removed this statement.

L 203 Where was this temperature measured, in the chamber?

Response: The temperature was measured next to (outside) the collar.

L 221 delete "of", also (45% C, 25 2.3% N) doesn't make sense.

Response: corrected (45% C, 2.3% N)

L 236 You state that there are two replicates, but on L 182 it says "one location"

Response: Thanks. We corrected the statement.

L 255 spelling of "Surfave"

Response: This has been changed.

L 263 Table 3 is referenced before Table 2

Response: Reference to Table 3 has been removed.

L 294 Please state which subplot is being referred to (Fig 2.?), also what is 14.2 +/- 0.1 a SD of a SEM.

Response: The subplot (Figure 2 A, B, C) has been included. Values are means $\pm$SE.

L 294 Please refer to the months as well as the season

Response: This has been changed

L 300 Fig 2A

Response: Changed accordingly

L 303 Change "locations" to times.

Response: This has been changed

L 313 I couldn't see an increase in variability during the dry summer of 2013 (I gather this is Jan – Mar 2013?)

Response: The statement has been modified. We included the monthly rainfall in Figure 2.

L 317 The data for summer/early autumn 2012 is not presented.

Response: This statement has been deleted.

L 329 Was SWC really affected by collar insertion, if so how?

Response: This section was deleted. Outside_Trench_Inserted data are no longer presented.

L 367 I am not sure how we can see in the table that there is a sign changes around 40% soil water content.

Response: We pooled all surface and inserted/trenched sampling points (plot and trench) and re-analysed the data (now shown in Figure 4D-E, see above).

L 377 Change Table 1 to Table 2

Response: Thanks, this has been corrected

L 381 Table 1 does not show the 0-30 cm values

Response: The root biomass values for 0-30 cm and total root biomass (organic layer plus mineral soil to 30 cm depth) have been added.

L 399 3.47 umols is 3.6 umol on line 303

Response: This has been changed.

L 458 Fig 2 the temperature difference is > 5 degrees" but Table 2 shows 6.6 degrees. Maybe there is a temperature response but it doesn't show up with such a small temperature range.

Response: This has been changed.

L 466 This sentence doesn't make sense.

Response: We re-phrased the statement.

L 482 Are the mature kauri at the site emergent? If so then state this in the site description.

Response: The mature kauri are emergent. The site description has been modified accordingly.

L 516 State early on that you are going to test the effect of collar depth on effluxes.

Response: See response comment 1.

Table 1 It would be good to have the litterfall summed over a year so it can be compared with other sites.

Response: Annual litterfall estimates are now included.

Table 2 I don't think it is necessary to show both the STD and the SE. Outside is misspelt as "Outsite_Trench_Surface". Using x, y and z for significant differences is confusing, stick with "c, d, e".

Response: We modified the table as suggested.

Table 3. Why are some numbers italicized? You need to define what a, b and c are.

Response: the italicized numbers indicated "significance". However, the table had been modified and p values are now included.

Fig 1 "Unknown"? – seems like it should be possible to get an identification of the tree species over the two years of the study, surely it can be classified as a broadleaf or not. The unknowns are filled circles, but open circles in the legend. There are two types of stars. How much are the size of the circles are scaled by the diameter? The 0.5 m contour lines are not really needed unless referred to in the manuscript. The plot has "trenched plots" as a title, this should be removed.

Response: We revised the figure.

Fig 2. These plots need to be labelled a, b, c. The sample points are joined up with lines; I cannot see why this can't be done in the SWC graph. The figure caption should indicate that these are means and state which soil efflux is being referred to (surface, trenched, inserted, plot or outside).

Response: The plots are now labelled A, B, C. the samples points for SWC cannot be joined up as measurements for two sampling dates are missing due to equipment failure. The figure caption has been revised as suggested.

Fig 4. Subplots should be labelled a-f. On subplot 4.2b the equation is wrong and ends up outside the 2nd x axis.

Response: The plots are now labelled A-F. The equations have been corrected.

L 984 is missing a ")", S is given in cm2 but the units along the x axis are in m2. Is m-2 m-2 correct? A is described as coefficient form, but does not appear in the equation.

Response: The equations have been corrected.

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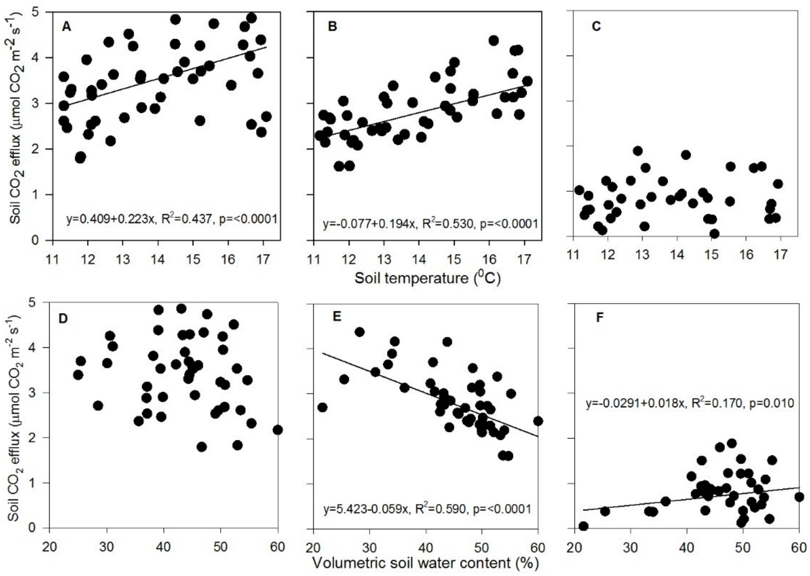

Fig. 1. Figure 4. Upper panel. Relationship between soil temperature and total soil CO2 efflux (A), heterotrophic respiration (B) and autotrophic respiration (C). Lower panel: Relationship between volumetric