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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 #1 We thank the referee for the constructive comments which helped to improve the quality of the paper. Please find below a detailed response to the each of the comments.

General comments The manuscript describes a study of soil respiration in a native forest of New Zealand. It is well written, meaning correct and fluent language, a clear introduction and presentation of the methods and results. It manages to describe well the characteristics of soil CO2 efflux in this type of forest and has the advantage of

being the first such study in this particular ecosystem. The originality of the study is mostly if not entirely the result of this last point. While it presents correlation analyses and finds temperature and root biomass as the most important factors explaining the CO2 fluxes, it remains otherwise mostly descriptive. Some results, interpretations and conclusions are not entirely convincing. In particular, I would question the correctness of the model fitting section.

Response: We re-analysed the data set using the Q10 and modified Arrhenius (Lloyd and Taylor 1994) function to test the temperature response of total soil CO2 efflux and heterotrophic (for details see response 2 regarding section 3.3)

Specific comments 1. Introduction and Methods are well written. Here I find nothing to question. When trenching or inserting deep collars, severed roots can add to the decomposing pool and change the estimate of heterotrophic respiration. How were decomposing roots accounted for in this study?

Response: 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)."

2. In section 3.3 you describe fitting models for the T response but fail to mention the most common used i.e. Q10 or LT, etc. The Q10-function is usually equivalent to an exponential function and has only 2 parameters, i.e. a * Q10ËĘ((T-Tref)/10). Why

do you have 3 parameters for the Q10 function? Is one a constant? Please check your functions in Table 3. Everything in the exponent should be closed by parenthesis. Also, the fact that you improved your R2 with a bivariate model but have much larger RMSE is not consistent. Check that your calculations are correct. Adding explanatory variables should only reduce the RMSE if you are using the same data. It would be good to have plots showing the response to T and M.

Response: The Q10 function (Schlentner and van Cleve, 1985) we used is a sigmoid function with three parameters (a = lower limit of soil CO2 efflux, a+1/b = maximum flux, c = Q10 related parameter).

Based on the recommendation by referee 1 and referee 3 we re-analysed our data set using the most commonly used temperature response functions (linear, exponential Q10 and modified Arrhenius function). The linear temperature response function provided the best fit, explaining 44% of total soil CO2 efflux and 53% of the heterotrophic respiration (see Figure below). This new figure (Figure 4) will be included in the manuscript. The methods, results and discussion sections have been modified as follows:

Methods Section 2.5 Data analysis "Univariate and bivariate models were used to investigate the relationship between total soil CO2 efflux, heterotrophic and autotrophic respiration and the abiotic factors soil temperature and volumetric soil water content. Data from within the research plot and trench sampling points were combined. The temperature response of soil CO2 efflux was tested using a linear, exponential Q10 (van't Hoff 1898) and modified Arrhenius function (Lloyd and Taylor, 1994). Linear and hyperbolic functions were used to assess the soil water dependence of soil CO2 efflux. The combined effect of soil temperature and soil water content on soil CO2 efflux was tested using a polynomial function. Coefficient of determination (R2) and standard error of estimate (SEE) were used to evaluate model performance."

Results Section 3.3 "The linear temperature function explained around 44% of the tem-

poral variation in total soil CO2 efflux (Figure 4A, Table 3). Exponential (R2=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)."

Figure 4 (see below).

3. In the discussion you calculate an average and compare with other ecosystems. Using the average of your measurements is incorrect. Since there is a T and root effect you should account for these when getting yearly estimates. At least use the T relationship, since T at night is probably lower, so the yearly average is lower than that of your measurements.

Response: The yearly estimate was re-calculated using the linear response function (best fit) and soil temperature data (5 cm depth, 30 min averages). The revised annual estimate resulted in a slightly higher annual estimate (1324 $\pm$ 121 g C m-2 yr-1).

4. You discuss how the vegetation may control the amount of CO2 efflux. The question of whether your system is near equilibrium is important here. If a forest is near equilibrium, the quality of the litter is important only in determining the stock sizes, not the CO2 fluxes. The latter will be equal to the amounts of input.

Response: The forest stand is dominated by a few emergent (up to 300 year-old) kauri trees. It is unlikely that this forest in near equilibrium as 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. The following statement has been added.

2.1 Study site "Kauri tree size distribution differs within the plot. 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."

5. When discussing the effect of T, make clear that your T range is small, which does not mean there is little T effect, just that you cannot see it. In terms of the average yearly T, this will probably have a larger effect in how it affects the productivity of the vegetation, so indirectly through litter input.

Response: The discussion on the effect of temperature on soil CO2 efflux has been

modified (see above, Response 2).

6. In conclusions, you state that the study has found that the vegetation type exerts a strong influence on soil carbon related processes. This is an effect of all land vegetation and is no finding by itself, thus making for a very weak conclusion. An insight on the vegetation effect on the soil C stocks or some other more specific observation should come here. Also, you mention that species effects were should in the study, however no species comparison was made, so mentioning species effects is incorrect, here and in the abstract.

Response: We found strong relationships between the "index of local contribution" (a measure of kauri tree size and distribution) and total soil CO2 efflux, root biomass and mineral C:N ratio suggesting that the spatial arrangement of kauri trees influences soil characteristics and soil CO2 efflux. This is in line with previous findings showing that kauri trees exert a strong control on soil pH and soil nitrogen (Silvester 2000; Jongkind et al. 2007; Verkaik et al. 2007; Wyse et al., 2014). In our conclusion we wanted to highlight the importance of investigating biotic factors (here: kauri tree distribution and size as a measure of forest structure) in soil carbon related studies.

The abstract and conclusion sections have been revised accordingly ("Our findings suggest that biotic factors such as tree structure should be investigated in soil carbon related studies.")

7. Lines 317-319 This line is not clear to me

Response: This statement has been deleted.

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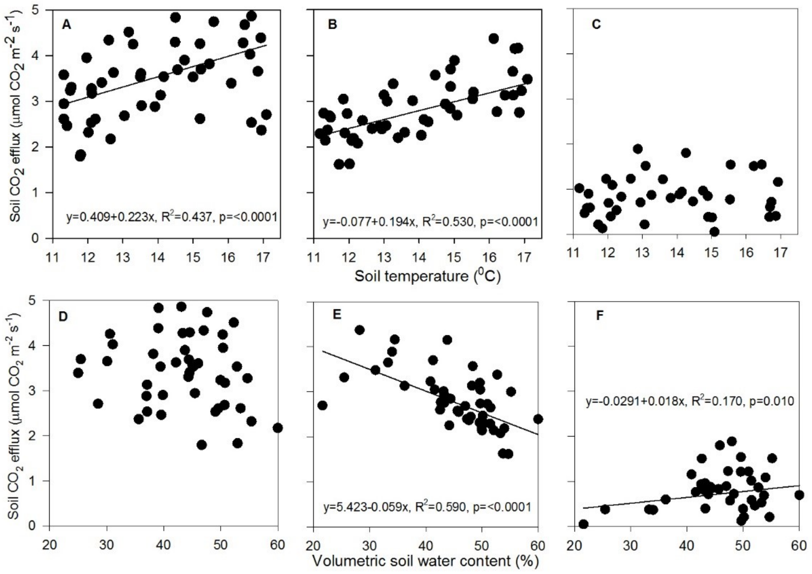

Fig. 1. Upper panel. Relationship between soil temperature and total soil CO2 efflux (A), heterotrophic respiration (B) and autotrophic respiration (C). Lower panel: Relationship between volumetric water cont