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Interactive Comment

Interactive comment on "Impact of nitrogen fertilization on carbon and water fluxes in a chronosequence of three Douglas-fir stands in the Pacific Northwest" *by* X. Dou et al.

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Dear Reviewer #1, We greatly appreciate your comments, which are helpful in improving our manuscript. Please find our point by point responses to your comments below.

Comment #1: Dou et al. present results from a 12-year eddy-covariance study across a forest chronosequence in British Columbia. They used the first 9 years as a control before adding N fertilization. The last 4 years of the study were used to estimate the GPP, respiration, NEP, and ET response to N fertilization. Traditional nitrogen experiments that use concurrent control and fertilization treatments are very challenging when using the EC technique, primary due to the footprint size and costs. Since the study lacked a traditional control treatment, the authors used the 7 years before the N fertilization to develop an empirical model, based on environmental variables, that was used to predict what GPP, respiration, NEP, and ET would have been without the N fertilization. Therefore, the core of the study lies in ability to predict the control treatment. This study does not represent the first analysis of how N fertilization alters carbon fluxes using the same data. Chen et al. 2011 estimated the N fertilization impact on carbon cycling for the first year after N fertilization in the oldest site using a model data fusion technique. Jassal et al. 2010 reported the N fertilization impact on carbon cycling for the first 2 years after N fertilization in same three sites as this study but used an alternative empirical model. The main goal of this manuscript was to estimate the N fertilization effect for 4 years after N fertilization on both carbon and water fluxes and to compare methods for estimating the control carbon and water fluxes during the period of N fertilization. Successfully predicting the control treatment during the post-fertilized years requires generating a model that fits observed pre-treatment data. This is addressed using two different approaches and using a 7-year training period. They clearly demonstrate that the ANN method achieved a better fit than the multiple linear regression in generating a model that fit the observed pre-treatment EC data. Successfully predicting the control treatment during post-fertilization years also requires using a model that can provide good predictions outside the training period. To demonstrate the ability to prediction outside the training period, 2-years of data between the training period and the N fertilization treatment was used to evaluate the model. Successful prediction outside the training period also requires: 1) No major change in environmental conditions between pre- and post-fertilization periods or generating a model that can handle the variation in environmental conditions. The authors show that the environmental conditions were similar before and after the N fertilization so the models did not need to handle unique environmental conditions. 2) No major change in forest structure and function that was not associated with N fertilization. They addressed this challenge by focusing on short-term (4 yrs) responses where successional changes may not be as pronounced. If there were changes in forest structure that increased

GPP independently of N fertilization then it would be most pronounced in the youngest stand where the GPP increase attributed to N fertilization was largest. I recommend adding discussion about how stand-development through succession could lead to error in the attribution of the impact of N fertilization on EC fluxes. Response: We thank the reviewer for these comments. We agreed that there was a significant effect of stand development on C fluxes in the two younger stands as we demonstrated in Fig. 3 in the revised manuscript. However, our earlier findings showed that adding age as another variable to describe C fluxes in the two growing stands (i.e., HDF88 and HDF00) did not improve the model fits (Jassal et al., 2010). We further verified that, regardless of stand age, the ANN model for the calibration period in this study was still able to capture the relationship between environmental variables and C and water fluxes with explaining approximately 99% of the variance in monthly C fluxes and ET. On the other hand, although we didn't consider stand age as an input variable in ANN model, we believe that the ANN model considers the information on stand development in responses to C and water fluxes by the variations of C fluxes and ET in a chronosequence in an implicit way. Because we used measured C fluxes and ET to train the network during the period of pre-fertilization. It is worthy to note that the C fluxes varied with the stand development in a chronosequence, especially in the two younger stands, which was different from environmental variables. As a consequence, we may deduce that the trained ANN model had captured the information of stand development. This has been added to the revised manuscript in Section 4.4 (see lines 7 to 21 page 25).

Comment #2 Below are recommendations for improving the manuscript: 1) Add more discussion of the uncertainties in the EC estimates of GPP and R. GPP and R are derived from models that had uncertainty. However, the manuscript currently appears to treat GPP and R as without uncertainty. The fact that the GPP and R responses to N fertilization were less than 10% could be within the uncertainty in the measurement. Since there is less uncertainty in the NEP (NEE) measurements than the modeled GPP and R, the presentation of the results could start with the NEE response and then break NEE into GPP and R responses. Response: Regarding calculations with the BPNN

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model, parameters such as the hidden layer node number, momentum coefficient and learning rate and its shortcomings such as slow convergence rate and local minimum have extremely restricted its application and lead to uncertainties in the estimate of N effect. Because of the limitations of the BPNN model, a hybrid BPNN model with an optimized algorithm such as a genetic algorithm and particle swarm optimization could possibly be used to further improve the estimate of the N addition effect. As for uncertainties in the EC-measured C fluxes that can arise from empirical relationships used for partitioning and gap-filling, the uncertainty in GPP has been determined to be around 50 g C m-2 y-1 with uncertainties of 75 and 25 g C m-2 y-1 in R and NEP, respectively. All these aspects have been discussed in Sections 4.1, 4.2 and 4.5 of the revised manuscript.

Comment #3 2) I would avoid discussing temporal trends in the 4 years post-fertilization data because the time period is short. For example Page 2018 lines 5-9 talk about stand productivity to N fertilization being temporary despite only 4-years of data. Response: We have deleted the stated distracting discussion in the revised manuscript.

Comment #4 3) It is not clear how the N-use efficiency is calculated on Page 2020. This number is tricky to calculate because there was only 1 addition of nitrogen. The calculation should be the sum of NEP response divided by the N addition amount. This recognizes that the N fertilization has a multi-year effect. Also, how is the range calculated? Overall, more description of the calculation is needed since readers will be interested in the reported N-use efficiency because it helps compare these results to other studies. Response: After examining the reviewer's comments carefully, we realize we did not express N-use efficiency correctly in the original manuscript. In the revised version, C:N response [kg C (sequestrated) kg -1 (N added)] has been defined as the increase in net C sequestration (i.e., NEP) per unit of N application. We now report the cumulative NUE as the sum of C sequestered in four years divided by the N application (i.e., 200 kg ha-1). The 4-yr cumulative NUE was 53, 97 and 51 kg C (kg N)-1 for DF49, HDF88 and HDF00, respectively. All these details have been added to the revised manuscript in Section 4.3 (see line 8 Page 21 to line 9 page 22).

Comment #5: 4) The discussion section needs to reintroduce the differences among this study, the Chen et al. 2011 study, and the Jassal et al. 2010 study. For example, the time period analyzed, the forest stands used, and the methods used are different among the studies. The discussion could also benefit from more insight into why the results from studies differed from one another. How different are the methods? Which one should we believe or should the three studies be combined to get the best estimate of the N fertilization response? Response: Since the previous two studies used only one (Chen et al. 2011) and two years (Jassal et al. 2010) post-fertilization data, we wanted to study the effect of a large N application over a longer period, i.e., 4 years. Also the above two studies used different modeling approaches (BEPS and MLR, respectively). Furthermore, Jassal et al. (2010) used an entirely different procedure to partition NEE into GPP and R, which was calculating daytime R from the relationship between NEP [or NEE] and PAR. The differences among these studies above have been improved in Tables 2 and 3.

Comment #6 5) Figure 3 isn't clear and needs improvement. What is the connection among the points? Why are some black and some white? The caption needs to be greatly expanded so that the reader can interpret the figure. Response: Following the reviewer's suggestion, we have re-drawn Figure 3 to clearly distinguish the symbols and have also expanded the caption to the figure. We also added the connection among the points by fitting using a quadratic equation and changed the caption to interpret the figure more easily.

Comment #7 6) In figure 9, the 'This Study (MLR)' and 'Chen et al. 2011' symbols are exactly the same. Please use two different symbols to make the figure clearer. Response: Figure 9 (Figure 8 in the revised manuscript) has been re-drawn using different symbols in which are consistent with other figures in the manuscript.

Refferences Chen, B., Coops, N. C., Andy Black, T., Jassal, R. S., Chen, J. M., and

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Johnson, M.: Modeling to discern nitrogen fertilization impacts on carbon sequestration in a Pacific Northwest Douglas-fir forest in the first-postfertilization year, Glob. Change Biol., 17, 1442-1460, 2011. Jassal, R. S., Black, T. A., Cai, T., Ethier, G., Pepin, S., Brümmer, C., Nesic, Z., Spittlehouse, D.L., and Trofymow, J. A.: Impact of nitrogen fertilization on carbon and water balances in a chronosequence of three Douglas-fir stands in the Pacific Northwest, Agr. For. Meteorol., 150, 208-218, 2010.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/11/C3128/2014/bgd-11-C3128-2014-supplement.pdf

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Interactive comment on Biogeosciences Discuss., 11, 2001, 2014.