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Biogeosciences Discussions

Interactive comment on "Impacts of increasing water and nitrogen availability on ecosystem CO_2 fluxes in a temperate steppe of Northern China" *by* L. Yan et al.

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Thank you very much for your valuable comments and suggestions. We have carefully revised our manuscript and believe that we have addressed and answered the major comments and questions and the manuscript is in good shape now. Detail responses to the reviewer #1's comments as following:

Comment 1: I was not convinced the ïňĄndings advanced our understanding nor did the authors make a strong case for new learning. The discussion begins by describing how the results primarily corroborate many recent ïňĄndings by this group and others examining water additions independently and interactively with nitrogen addition.

Grasslands in Inner Mongolia were previously shown by this group to be strongly affected by water and nitrogen (Yan et al. 2009 Global Change Biology). Documenting the growing season increases following N and water additions does not advance the science. The most interesting ïňĄnding was the contrasting effect of growing season precipitation on the sensitivity to watering and nitrogen. I would expect this as during the dry year the system would be in severe moisture stress and during the wet year sufficient water would be present to allow full utilization of the nitrogen. However, these differences were not sufficiently quantiïňĄed or described to understand why.

Response: The reviewer is right that we have reported the responses of different components (auto- and heterotrophic) of soil respiration to water and N addition (Yan et al. 2009 Global Change Biology). We know that soil respiration only represents the belowground part of ecosystem carbon exchange and is strongly in conjunction with the aboveground carbon processes (Smith & Fang, 2010, Nature). Thus, it is critical important to study the ecosystem-level carbon exchange and its uptake and release components. Additionally, our study was conducted in a relative wet year and a relative dry year. Therefore, as the reviewer said, we had an opportunity to compare the different effects of water and N addition in two years with different precipitation amount and explained why. As the reviewer's suggestion, we added a quantitative description on the effects on the water and N addition between two years in the section of Results (Lines 229-243) and Discussion (Lines 277-279) in the revised version. In the section of Discussion, we had showed the different responses of ecosystem COÂň2 fluxes to water and N addition between the two growing season, and discussed the main reasons for these differences (the second paragraph of 4.1 and 4.2). Additionally, part 3 (4.3) had discussed the probable trend of ecosystem COÂň2 fluxes to the future increasing water and N availability.

Comment 2: Much of the continuing interest in understanding net carbon balance with altered water and nitrogen addition has moved to examining effects at individual event scales, more broadly across regimes of precipitation, and antecedent effects at multiple scales. The watering manipulation treatment, a regular watering schedule makes examining changes associated with either the event or regime scale difficult. How the effects at the individual scale inïňĆuenced the gas exchange measurements is unknown, but as previously shown by this group the effect could be high. The limitation of only 2 years of data prevents any examination of possible effects of the prior growing season. Extrapolating these ïňĄndings to predicting future carbon sequestration with likely climate changes (as in the discussion section labeled as such) is not supported by the experimental design. The watering treatment neither simulated a possible future climate nor tested predictions derived from likely climate scenarios.

Response: Increasing total precipitation combined with occurrence of extreme rainfall events at the multitude regions has been predicted (IPCC, 2007). Applying the IPCC SRES A2 and B2 scenarios with an atmosphere-ocean coupled general circulation model, Cholaw et al. (2003) suggested that the increase of summer precipitation in North China in the future (2071-2100) is about 93-136 mm. So, 120 mm water (about 30% annual precipitation) was added in this study. As you know, it is very difficult to exactly simulate the changes in precipitation pattern, which not only includes increasing precipitation amount, but also relates to the changes of the seasonal distribution, precipitation size and frequency of rain events. In this study, we only focused on the possible impacts of changes in precipitation amount on ecosystem CO2 fluxes and distributed the added water equally in the growing season, with 15 mm water each time. The amount of 15 mm water addition has been proved to be the most favorable rainfall for carbon sequestration in this ecosystem (Chen et al., 2009 Global Change Biology). We added this information and made it clearer in the revised version (Lines 117-121). Our data of two growing seasons was not sufficient to establish a precise model to predict accurate responses of this ecosystem to predicting increasing precipitation in the future. However, these data of the two hydrologically contrasting growing seasons showed us that the temperate steppe should be a C sink during the growing seasons in the last 50 years (canopy or ecosystem-level gas exchange measurements in Chinese steppe ecosystems only were conducted in recent years), and an enhancement of CO2

uptake should be expected in the future because of the predicting increasing precipitation and N enrichment in this region. Reference: Chen, S. P., G. H. Lin, et al. (2009). Dependence of carbon sequestration on the differential responses of ecosystem photosynthesis and respiration to rain pulses in a semiarid steppe. Global Change Biology 15, 2450-2461. Cholaw, B., U. Cubasch, et al. (2003). The change of North China climate in transient simulations using the IPCCSRES A2 and B2 scenarios with a coupled atmosphere-ocean general circulation model. Advances in Atmospheric Sciences 20, 755-766.

Comment 3: SpeciïňĄc Comments – How much did the nitrogen treatment increase deposition above background levels?

Response: The N deposition is 1.8 g N m-2 yr-1 in this experimental site during the growing season in 2006 (Zhang et al., 2008a, Atmospheric Environment). It is true that that level of N addition is very high and far exceeds natural future deposition in this ecosystem. However, the N addition treatment in this study was not a simulation of N deposition. To determine the N addition level, we referred to the N-fertilized studies conducted in the same ecosystem. Zhang et al. (2008b) found that in term of the microbial biomass and functional diversity, an N optimum exists between 16-32 g N m-2 yr-1 in the same area. Bai et al. (2010) also reported that no significant effects of N addition on aboveground productivity were found till N amounts of 28 g N m-2 yr-1 in the first two years after N treatment. Therefore, to evaluate the potential responses of ecosystem CO2 fluxes, we selected 28 g N m-2 yr-1 as N addition treatment in our study. We added this information in the revised version (Lines 121-126). References: Bai, Y. F., J. G. Wu, et al. (2010). Tradeoffs and thresholds in the effects of nitrogen addition on biodiversity and ecosystem functioning: evidence from inner Mongolia Grasslands. Global Change Biology 16, 358-372. Zhang, Y., L. X. Zheng, et al. (2008a). Evidence for organic N deposition and its anthropogenic sources in China. Atmospheric Environment 42, 1035-1041. Zhang, N. L., S. Q. Wan, et al. (2008b). Impacts of urea N addition on soil microbial community in a semi-arid temperate steppe in northern China. Plant and Soil 311, 19-28.

Comment 4: I think many of the statistical analyses should use as repeated measures ANOVA.

Response: As the reviewer' suggestion, we added the repeated-measures ANOVAs to test the effects of the sample time, water and N treatment in each growing season (refer to Table 3 in the revised version).

Comment 5: Figure 3: Why doesn't this ïňĄgure break out the different treatments as in Figure 4? For the relationships, statistical tests should be conducted to determine if the slopes are different.

Response: In this study, ANPP and BNPP were measured once in the peak period (August) of plant growth. So, we used seasonal mean of ecosystem CO2 fluxes to test their relationships with ANPP and BNPP. If we separate the data into different treatments, it is hard to fit curves for most treatments because of the limited data (only 5 points for each treatment). Therefore, we put the seasonal mean values of all plots together into this analysis (Fig. 3).

Comment 6: Table 4, Figure 4, Figure 5 – I'm not sure how to interpret Q10 across the growing season other than as a proxy for seasonality. These results were not directly referenced in the discussion.

Response: The reviewer is right that the Q10 came from the ecosystem CO2 flux and soil temperature across a growing season, which involved the effects of soil moisture and phenology. In this study, the Q10 values are not used to exactly quantify the temperature sensitivity of GEP and ER, but to compare the difference between the response of GEP and ER to temperature (GEP and ER experience the same changes in soil moisture and phenology). Additionally, we added relative discussion about Q10 in the revised version (Lines 330-338)

Comment 7: Figure 4 and 5 have as a caption – "temporal dependence" but focus

either moisture or temperature. It would be useful to see pattern of soil moisture and temperature as for ïňĆux measurements in Figure 2.

Response: The temporal dependence of ecosystem CO2 fluxes with soil temperature and moisture was used to descript the relationships between ecosystem CO2 fluxes and soil temperature/moisture across the two growing seasons. The seasonal patterns of soil temperature and moisture had previously been published in another paper (Fig.1 in Yan et al. 2009 Global Change Biology). Therefore, we only use these data to fit relationships in this manuscript.

Comment 8: Pg 11 Paragraph starting at ln 16: While the effect of water addition is visually much greater in 2007 than 2006 a quantiïňĄcation of this effect would be useful.

Response: Thanks for the reviewer's thoughtful and valuable comments. We added a quantitative description about the effects of water addition on ecosystem C fluxes in 2006 and 2007, respectively, in the section of Discussion in the revised version (Lines 277-279).

Comment 9: Pg 11 ln 20: I don't follow the relevance of the Potts et al. 2006 New Phytologist paper, which looked as sensitivity to speciïňĄc wetting events rather than whole season patterns.

Response: Yes, the study reported by Potts et al. (2006) was to see the responses of canopy gas exchange to a rain pulse. However, their findings about the dependence of carbon exchange on antecedent moisture are very important not only for one specific wetting event but also for seasonal or longer time scale precipitation researches. In our study, a greater natural precipitation in 2006 than that in 2007 resulted in a consequent higher soil moisture in 2006, which is very important for determining the response of ecosystem carbon exchange to water addition.

Interactive comment on Biogeosciences Discuss., 7, 5829, 2010.