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Biogeosciences Discussions

Interactive comment on "Nitrogen enrichment enhances the dominance of grasses over forbs in a temperate steppe ecosystem" *by* L. Song et al.

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Reply to Dr. Lucy Sheppard's comments General comments 1. The paper is interesting, timely and generally well written but would benefit from including more information and detail on both the soils and availability of other nutrients particularly P, the climate and the species of forbs. Response: Good suggestion. Soil nutrient availability (e.g., P) is included in the Section of Materials and Methods. We have integrated more information on other soil nutrients, the climate and the species of forbs in the Section of Discussion. 2. An indication of how these N loadings compare with the range of N deposition to similar steppe ecosystems would be useful to put the study into context. Response: Your suggestion is considered in the revision. In our study area, N (wet plus dry) deposition rate (15-20 kg N ha-1 yr-1, as shown in the Section of Materials

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Interactive Discussion

Discussion Paper

and Methods) is comparable to the lowest N addition treatment (30 kg N ha-1 yr-1). Other N addition rates in our experiment were much higher than the N deposition in steppe ecosystems of China. But this is a ‘simulation’ study to test the response of steppes to elevated external N inputs (including N deposition and fertilization in future). 3. Given the richness in forb species I presume the ecosystem is considered N limited? The results demonstrate clearly the plant responses with respect to forbs and grasses but leave the reader rather frustrated as to the underpinning processes and what is driving change. It would be helpful to know if P availability is likely to be important and whether the grass species are mycorrhizal? Response: Your concern is important to reveal the underpinning processes and what is driving change. Yes, N is the most limiting nutrient for plant growth at the study site, while P is not (soil Olsen-P is about 4-5 ppm). Most of the grass species can be infected by mycorrhizal in our case. 4. Given the soil pH, the main form of N in the soil would be nitrate and thus both the forbs and grasses would be conditioned to nitrate uptake, these points need to be brought out in the discussion of the 15N data. Response: In our grassland soil, ammonium N is the major form of available N while nitrate N will be dominant only at N saturation condition (i.e., N addition rate higher than 60 kg N ha-1 yr-1) (see Fig. 7 in the revised text). Therefore both ammonium and nitrate N are important for plant N assimilation. Anyway, as you mentioned, the forbs and grasses may be conditioned to nitrate uptake especially at higher N addition rates. We have discussed these points in the revision. 5. The data presented in fig 2 suggest the huge increase in grass biomass would have made conditions very difficult for the forbs which quickly accumulated N, which if they were starved of light may have also affected the activity of the nitrate reductase enzyme. Response: Yes, the data in Fig. 2 (now Fig. 3 in the revision) suggest that growth of forbs could be limited by light as well as lower activity of nitrate reductase enzyme to some extent at this experimental site. However, we did not measure the activity of nitrate reductase enzyme in our study, which restricts our further discussion about this point. 6. I would like to see the method of N application described in more detail, was the N added in solution or dry to the foliage? Response: We use foliar application to all N treated plots. First, N fertilizer (ammonium nitrate) was dissolved in water and form fertilizer N solution; then applied the N solution to our plots using a sprayer. There are three application times each year. Total water input is about 0.5 mm for each application. 7. I presume the inputs started in 2005. Background N deposition was relatively modest by comparison with the inputs and it would be useful to know the ratio of dry to wet deposition and if wet whether the majority falls in precipitation and how the quite low precipitation rates are distributed. Not all readers will be familiar with these types of ecosystems and in order to understand how these systems respond to N it is important to understand the relationship between N inputs and moisture. Response: Ratio of wet to dry deposition in our study site was about 1:1. More than 90% of annual precipitation was distributed during May and October (see Fig. 1 in the revised manuscript), which period is closely related to plant growth. Detailed relationship between N inputs and moisture or water supply can be found in Chen et al. (2011). (Chen, Q., Hooper, D.U., Lin, S.: Shifts in Species Composition Constrain Restoration of Overgrazed Grassland Using Nitrogen Fertilization in Inner Mongolian Steppe, China. PLoS One, 6(3), Article No.: e16909, 2011.) We have cited this reference in the revision. 8. Does the rain fall evenly or as heavy showers that would be likely to leach the nitrate down the profile and is the timing related to demand for growth? Response: No, the rain falls unevenly at the experimental site and heavy showers often occur during the summer season (e.g. June and July) and this may leach the nitrate down the soil profile, which is also the period with maximum nutrient demand for plant growth. It means some plant species with shallow root systems (most forbs) may be restricted by shortage of N supply. 9. Likewise more information on the forbs would be good, are they all perennials and what is their rooting depth and was a particular genera lost? Response: In our study, forbs include perennials, shrubs and semi-shrubs, and annuals, but for the deceased species richness mainly occurred for perennial forbs. We did not measure rooting depth in our study, but according to our observation the majority of the roots of forbs were distributed in the surface soil (0-10 cm). 10. What is meant by fencing off in

2001 to preserve the grazing disturbance, were grazers excluded? Response: Yes, our study site was fenced off to avoid disturbance by grazers. 11. I found the paper raised many unanswered questions concerning what was driving the response and I found the description of the soil changes rather confusing. Given the relatively high ....neutral soil pH I would have expected much of the ammonium to be nitrified until the fall in pH acted to feedback on this, some soil pH data would be helpful. Response: We think it's clear that external N supply (which gradually leads to N saturation and nutrient imbalance in soil) is the driving factor in our grassland ecosystem. Different from your expectation, although soil pH is relatively high (above 7.0), temperate grassland soil shows high N immobilization rates and substantial nitrification process happens only at higher N addition rates, based on our Nmin data. However, the change in soil pH value after N addition was not measured in this study. 12. I'm a little puzzled as to why denitrification leads to nitrate enrichment, measures of the denitrification fluxes and soil moisture rather than just citing the Tilsner study would be helpful to understanding what is happening to the N. Response: This is a misunderstanding due to unclear expression. In fact, nitrate enrichment is mainly caused by nitrification while denitrification consumes nitrate. Denitrification fluxes were not measured in this study and their values were not the main objectives of our study. Soil moisture was measured only on August each year. The transformation of added N in soils is another story and will be investigated in further study. 13. The %N concentrations seem quite low on the whole for grasses, though I appreciate I'm not very familiar with the species described. Do the authors mean N use efficiency? I would suggest that the authors are describing an increased ability in grasses to upregulate their ability to use the additional N to fix carbon, increase their productivity and potentially shade out the forbs? A conceptual model showing how the authors believe the discrimination between 14N and 15N enrichment would help to clarify the text. Response: The %N concentrations are average of various grasses or forbs. We do not think %N concentrations reflect N use efficiency. For grasses, with increased N addition they can use additional N to fix carbon dioxide and increase their productivity which potentially

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Interactive Discussion
Discussion Paper

shade out the forbs. In our experimental condition, the difference of delta 15N between added N (NH4NO3, delta 15N: 6.3‰ and soil N (delta 15N: 0.2‰ sources is key to delta 15N changes for both grasses and forbs; while the discrimination between 14N and 15N in soils (or fertilizers) ranks second. The latter may explain the higher delta 15N in forbs (compared with grasses) and/or in 2010 (than in 2009). In the revision (discussion), we have explained the roles of different N sources and the discrimination between 14N and 15N enrichment, which would help to clarify the delta 15N results in the text. Specific comments: Abstract L5 change temperature to temperate Response: Agreed and revised accordingly. P 5068 L19 change level to load. . .Critical Levels relate to gaseous pollutants ..the authors are discussing the effect of a N load and for clarity it is preferable not to use level. Response: Agreed and revised accordingly. Fig 2 again I wonder if the message would be clearer if the axes for forbs and grasses were kept the same Response: Because the biomass for grasses was many times higher than forbs, it would be difficult to see the biomass for forbs clearly if we keep the same axes for the two groups. Fig 3 you could try plotting the cover of the forbs and grasses in relation to the total N load ie the sum of each years loadings this would help us examine the relationship between forb and grass cover. Response: The question is that if we plot the cover of forbs and grasses in relation to the total N loads it will be difficult for readers to follow annual changes of each treatment. Fig 4 the y axis on D is wrongly labelled as grass should be forbs Response: Agreed and revised accordingly. Fig 5 why have the relationships excluded the higher N loading? Dose responses could also be included for some of the other metrics as they help the reader to appreciate the nature of the responses. Response: Plant δ15N in our plots increased with both time and N addition rate, but N addition were ceased in the 480 kg N ha-1 yr-1 treatment in 2009 and 2010. Therefore we have excluded this treatment in the Figure (now changing to Fig. 6). Fig 6 would be clearer if the y axes were kept the same for 10 and 20 cm. Response: Agreed and revised accordingly. This Figure is numbered as Fig. 7 in the revision.

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8, C2414–C2419, 2011

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/8/C2414/2011/bgd-8-C2414-2011-supplement.pdf

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8, C2414–C2419, 2011

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