Responses to reviewer #1

Suggestion to change the title. The title has been adjusted to reflect your suggestions and now is "Decadal and long-term boreal soil in carbon and nitrogen sequestration rates across a variety of ecosystems".

Please be more specific regarding the mechanisms in lines 20-21. This information has been added: "Our results suggest that the controls on long-term C and N cycling at the rich fen is fundamentally different from the other ecosystems, likely due to differences in the predominant drivers of nutrient cycling (oxygen availability, for C) and reduced amounts of disturbance by fire (for C and N)"

Introduction is well written. Thank you.

Please extend the descriptions of the ecosystems. We have addressed this comment by adding the following text after these ecosystems are introduced (line 106): "This transect extends from the toe slope of an adjacent upland forest into a ~1.8 km2 fen complex. Although in the Tanana floodplain, the sites are ~1.5 km from the current location of the river and appear to be relatively stable since site initiation in 2005. These sites have also been a part of other studies, including examining controls on ecosystem respiration (McConnell et al., 2013), examining differences in the soil biotic community and their impact on soil C turnover (Waldrop et al., 2012), understanding how changing water table level impacts C cycling within the fen (Kane et al., 2013; Chivers et al., 2009), and using eddy covariance methods to calculate net ecosystem productivity (Euskirchen et al., 2014)."

Which sedge species is dominant in the sedge ecosystem? The text (line 104) now reads "4) a peatland dominated by emergent vegetation such as *Equisetum fluviatile* ("sedge"), …".

Please give an indication of the thickness of the sample soil horizons. We have added a sentence to reflect this information (line 118): "Soil horizon thicknesses ranged between 2-14 cm, with 85% of samples having a thickness ≤5 cm."

How likely is it that the black spruce and grass ecosystems have a similar age as the shrub and sedge ecosystem? … Without information on the development of these ecosystems I find this difficult to assess. We have added some information to help the reader understand why we feel that this assumption is justified (line 186): "We feel that this assumption is justified because a) the grass ecosystem lies between the shrub and sedge ecosystems, and b) the black spruce would need a dramatically different initiation age (<250 yrs) for the long-term C storage at this ecosystem to be significantly different than the other non-fen ecosystems, indicating that even if this age is not accurate for the black spruce ecosystem changes to this date would not change our results."

Lines 224-227: Phrase more carefully, there is uncertainty for two of these ecosystems. While there is uncertainty in the two undated ecosystems, we feel that due to the justification, as written above, this statement holds true.

If soil temperature would be a driver for C cycling in these ecosystems I would expect the lowest (thus not the highest) C accumulation rate in the rich fen as it has (by far) the highest soil temperatures, promoting

decomposition of the organic material. This statement would be true if temperature was the regulating factor for C at the rich fen. However, McConnell et al. found that temperature was not the main driver for ecosystem respiration (ER) at the rich fen site. Instead, it appears that the availability of oxygen is the primary factor in determining C cycling. The text that explains this can be found on line 300: "Another mechanism for reducing rates of C cycling is oxygen availability. McConnell et al. (2013) found lower Q10 values at the rich fen, indicating less temperature sensitivity. Instead, with the shallowest water table (Table 1), it is thought that oxygen availability plays a dominant role in the protection of deep C at the rich fen (McConnell et al., 2013)."

Here I would like to see more discussion of the N accumulation rates. What is your explanation for the high N accumulation in the rich fen? The very high accumulation rate cannot originate from atmospheric N deposition alone; there must be other sources of nitrogen. Do the mosses in the rich fen have associations with N-fixing bacteria? Is there inflow of water relatively rich in nitrogen?
We had expanded the N paragraph greatly, examining several theories as to why the rich fen might have high N. In addition, the manuscript discusses the fact that reduced disturbance due to fire (line 307) would impact both C and N storage. The expanded paragraph (line 254) is as follows: "Nitrogen accumulation rates have been studied much less frequently than rates of C accumulation. The long-term N accumulation rate for the rich fen in this study (2.66 g N m-2 yr-1) is five times higher than the 0.5 g N m-2 yr- estimated by Loisel et al. (2014). There are several potential reasons for this discrepancy. First, Loisel et al. (2014) synthesized data from a wide range of peatland sites, including bogs, fens, and permafrost peatlands and thus included ecosystems with a broad spectrum of peat properties. In addition, Loisel et al. (2014) used time-dependent C:N ratios of 65 and 40 to assign % N values for their soil horizons, resulting in average % N values that never exceed 1.7 %. In contrast, the average % N value for our rich fen organic soil horizons was 2.4 %, resulting in an average C:N ratio of 17 (Fig S1). In general, our results support Treat et al. (2015), who showed that fen C:N ratios can be much lower than estimates used by Loisel et al. (2014), despite high variability (fen C:N averaging 29 +/- 15). Regardless, the amount of N within the rich fen ecosystem is relatively high. Reasons for this high N storage could include high rates of N inputs, either through high rates of biological N2 fixation or through high N concentrations in source water. The majority of studies on N fixation in peatlands have focused on Sphagnum species (Larmola et al., 2014; Vile et al., 2014). However, over 70 % of the ground cover in our rich fen site is composed of brown mosses (Churchill, 2011), some of which have been shown to fix N when exposed to enough light (Basilier, 1979). Therefore, moss-based N2 fixation may play a role in the N dynamics of the rich fen. High N inputs could also result from inflows of N-rich surface or ground water. Wetlands in the Tanana River floodplain are influenced by both surface runoff and river-based groundwater, as evidenced by Ca++ values (Racine and Walters, 1994). All ecosystems along the gradient, with the exception of the black spruce forest, have been known to experience flooding during years of very high precipitation, with these flooding events dependent on the behaviour of the Tanana River. During one of such events, Wyatt et al. (2011) found that dissolved inorganic N (DIN) at our rich fen site peaked post-flood at ~0.50 mg L-1. Dissolved organic N (DON) at this site has been measured from ~ 0.86 – 1.42 mg L-1 (Kane et al., 2010). While these DIN and DON concentrations are not uncommon for a northern peatland (Limpens et al., 2006), the hydrologic connection between the fen and river is undoubtedly important to the total N budget of the wetland."

What about the Sphagnum mosses in the rich fen? Sphagnum mosses are known to be very recalcitrant to decomposition and could therefore contribute substantially to long-term C accumulation. The fact that Sphagnum mosses do not comprise the majority of groundcover. This fact and the possible influence of mosses on our N results is now discussed in the paragraph above. The text regarding mosses can be found on line 265: "The majority of studies on N fixation in peatlands have focused on Sphagnum species (Larmola et al., 2014; Vile et al., 2014). However, over 70 % of the ground cover in our rich fen site is composed of brown mosses (Churchill, 2011), some of which have been shown to fix N when exposed to enough light (Basilier, 1979). Therefore, moss-based N_2 fixation may play a role in the N dynamics of the rich fen."

Can you support this discussion with observations of charcoal in the organic soil profiles? Unfortunately, we only found one soil horizon with charcoal in it during our visual inspections. While there is likely much macroscopic charcoal within these samples, that examination is beyond the scope of this study.

Table 2: Could you add a line to the legend to explain what Unsupported ^{210}Pb indicates/represents? The following text has been added: "Unsupported ^{210}Pb stocks represent the total atmospheric input of ^{210}Pb to that site."

Table 2: A number is missing in the value for C storage in the rich fen. Thanks for catching this error. The number has now been corrected to 61500 gC / m^2.

Table 3: Why not use the same layout as in Tables 1 and 2 with the ecosystems in columns. Good suggestion. This change has been made.