Effects of Conversion from Boreal Forest to Arctic Steppe on Soil Communities and Ecosystem Carbon Pools

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Introduction:

- As much as 1300 Pg of organic carbon are stored in soils in the northern cryosphere, with 500 Pg in active layer and 800 Pg in permafrost. In a warming world with deepening active layers, there is a risk that more of this carbon will become available for microbial respiration.
- The Pleistocene extinctions marked the end of many arctic megafauna, including several species of horses and mammoths. The loss of these animals may have helped spur the transition from Arctic Steppe to modern Boreal Forest.
- This vegetation shift is a critical for global climate because the Arctic Steppe has higher albedo than Boreal Forest.
- The presence of large herbivores may also have protected permafrost through trampling the snow, which reduces insulation, resulting in cooler winter soil temperatures.

Objective:

Investigate differences in soil invertebrate communities and ecosystem carbon pools between Boreal Forest and Arctic Steppe.

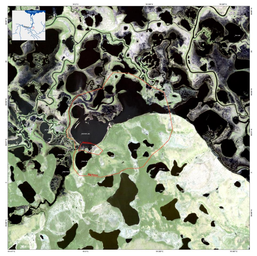


Figure 1 – The North East Science Station, Cherskiy, Russia (Image by Greg Fiske)
Figure 2– Visually assessing understory cover (Photo by Chris Linder)

Pleistocene Park:

- Large herbivore introduction began in 1988 (Sergei Zimov).
- Experimental disturbances (fire, bulldozing) coupled with animal reintroduction to replicate a Pleistocene ecosystem.
- Park contains 23 horses, 3 musk ox, 1 bison & several moose.
- Fencing around 16 square km, with major concentration of animals in 1 square km.

Figure 2– The fence enclosing Pleistocene Park, and a sharp divide between steppe and forest.

Methods:

- Soils: gravimetric water content, organic matter content (LOI, loss on ignition), extractable dissolved organic carbon and total inorganic nitrogen. %C estimated from LOI
- Vegetation: Understory % cover and biomass from destructive harvest; tree biomass using allometric relationship with tree diameter
- Invertebrates: Quantitatively collected using Berlese funnels.

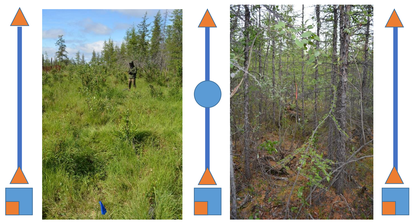
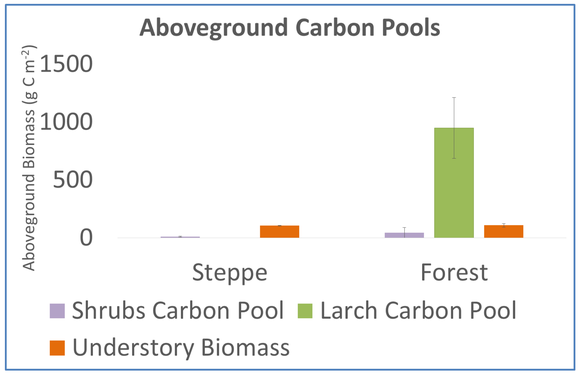


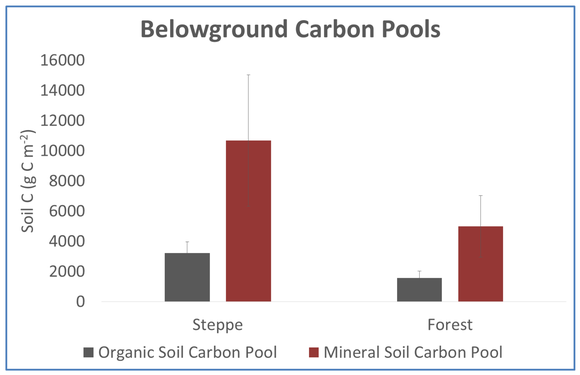
Figure 5 – Typical steppe (left) and forest (right) transects

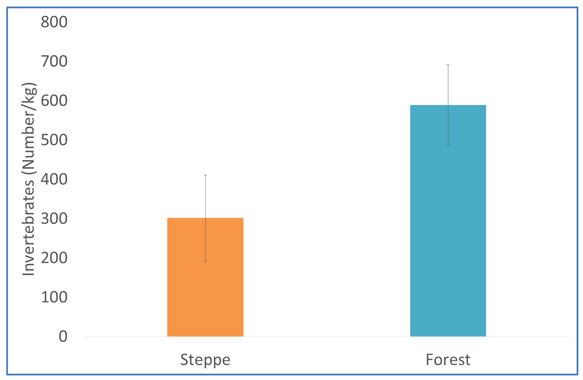
Field Methods:

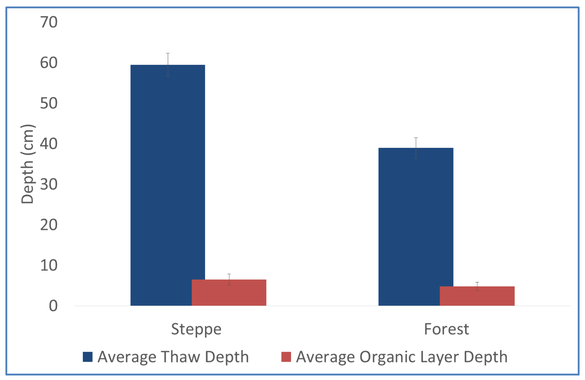
Field sampling design for 3 steppe and 3 forest sites.

- Soil Samples
- Temperature sensors
- Understory biomass c
- Understory % cover
- 10 m transect: thaw depth (every m), trees, shrubs, scat









Figures 6-9: There was more larch biomass in the forest than the steppe,* close to equal amounts of understory biomass, and quite variable shrub biomass. There was a greater amount of carbon in the organic soil in the steppe than the forest*, and a larger carbon pool in the mineral soil of the steppe than the forest. The difference in soil fauna between the two sites was not significantly significant. We found a greater thaw depth in the steppe than the forest.*
*indicates significance ($p < 0.05$).

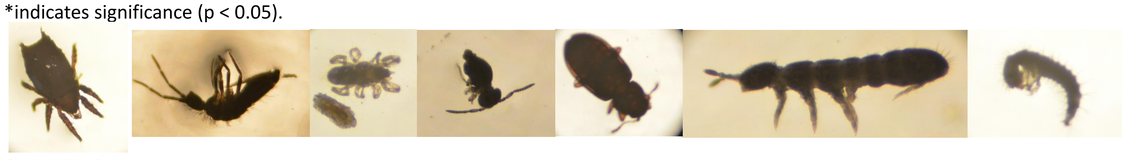


Figure 5 – Several of the invertebrates collected from the organic layer.

Figure 7 – The bison and a musk ox (Photo by Chris Linder)

Conclusions:

•Thaw depth was deeper in the steppe than in the forest. This points towards more metabolic activity within the soil *in the summer* in the steppe.

•Microinvertebrate density was higher in the forest than the steppe, suggesting a shift in the primary metabolic pathways within the soil.

•Organic and mineral soil carbon pools were larger in the steppe than in the forest, showing that the experimental park has made a significant impact on the soil structure and soil carbon pools.

•These results demonstrate the importance of large herbivores on permafrost vulnerability and C storage in the Arctic.

Figure 7 – Taking notes on the grazers (Photo by Chris Linder)

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