Evaluating Environmental Controls on Arctic Tundra Vegetation Dynamics on Yamal Peninsula, Russia

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Introduction and objectives

Arctic tundra ecosystems are affected by many environmental factors, such as climate, soil parent material, and grazing. It is presently unclear which of these factors are dominant in controlling regional-scale patterns of arctic tundra and how the interactions of these factors affect tundra dynamics. The Yamal Peninsula is a large area of arctic tundra in southwestern Siberia, Russia that encompasses landscape to regional gradients of each of these three factors. The Yamal is not only the source of much of Europe's current and future energy resources (and as a result is of enormous strategic importance to Russia), but it is also the home of the world's largest area of reindeer husbandry. Understanding how different tundra vegetation communities on different soils will respond to climate change, oil and gas development, and high intensity grazing disturbances is crucial for the sustainability of this region.

This study is to evaluate the dynamics of tundra ecosystems on the Yamal Peninsula with different soils (both sandy and clayey soils with different soil organic nitrogen-SON levels) across a latitudinal climatic gradient under warming scenario. We expect:

- higher SON and warming will increase total productivity
- warming and soils effects are at the plant functional level

Methods

We applied a nutrient-based transient vegetation dynamics model (ArcVeg) to examine how these three factors (climate zone, soil texture, and grazing regime) interact to affect tundra response to climate warming. We compared biomass generated by ArcVeg simulations using field soil organic nitrogen data along the Yamal Arctic Transect (YAT) for sites of different soil organic nitrogen levels within bioclimate subzones C (High Arctic), D (northern Low Arctic) and E (southern Low Arctic).

Grazing intensity was represented by the combination of annual probability of grazing and percentage of biomass removed by grazing: (0.25, 25%) or low grazing intensity indicating the system would be grazed every four years, and 25% of plant biomass was removed by grazing.

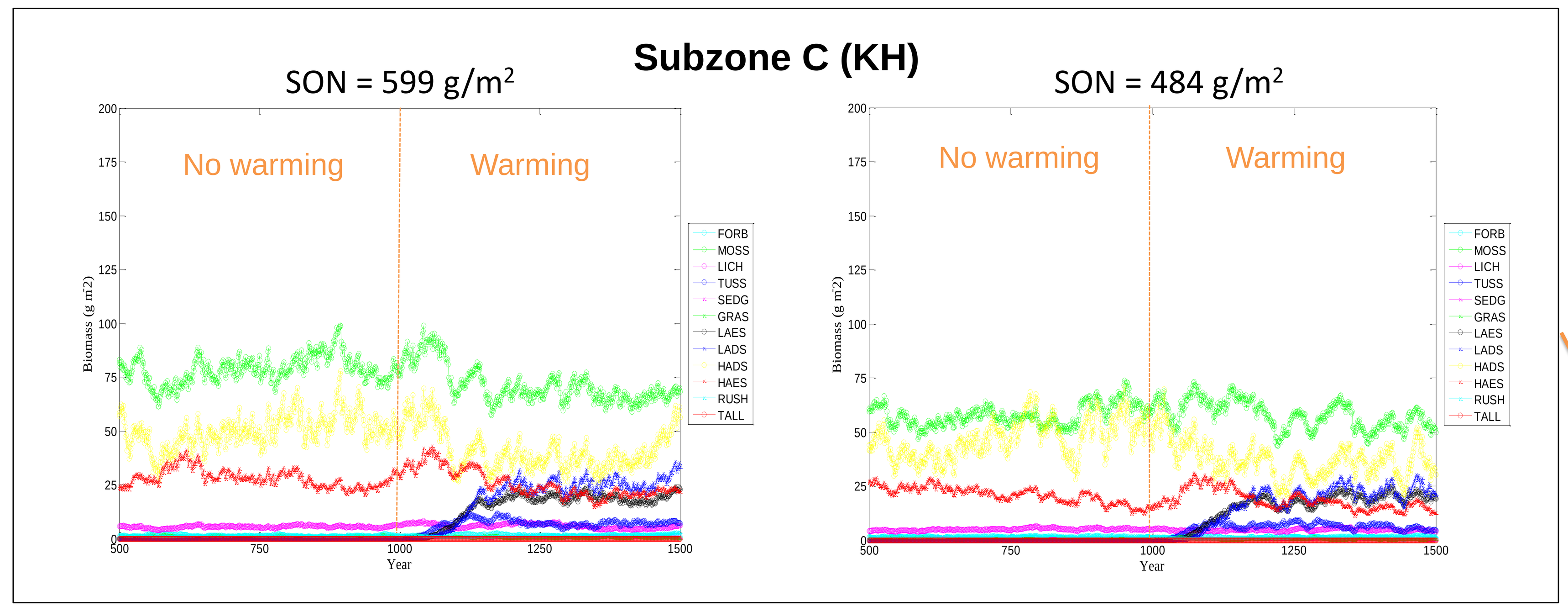
We also manipulated climate in model warming scenarios. The warming scenario for our simulation was assumed to be a 2°C temperature increase linearly ramped over a 50-year period after year 1000.

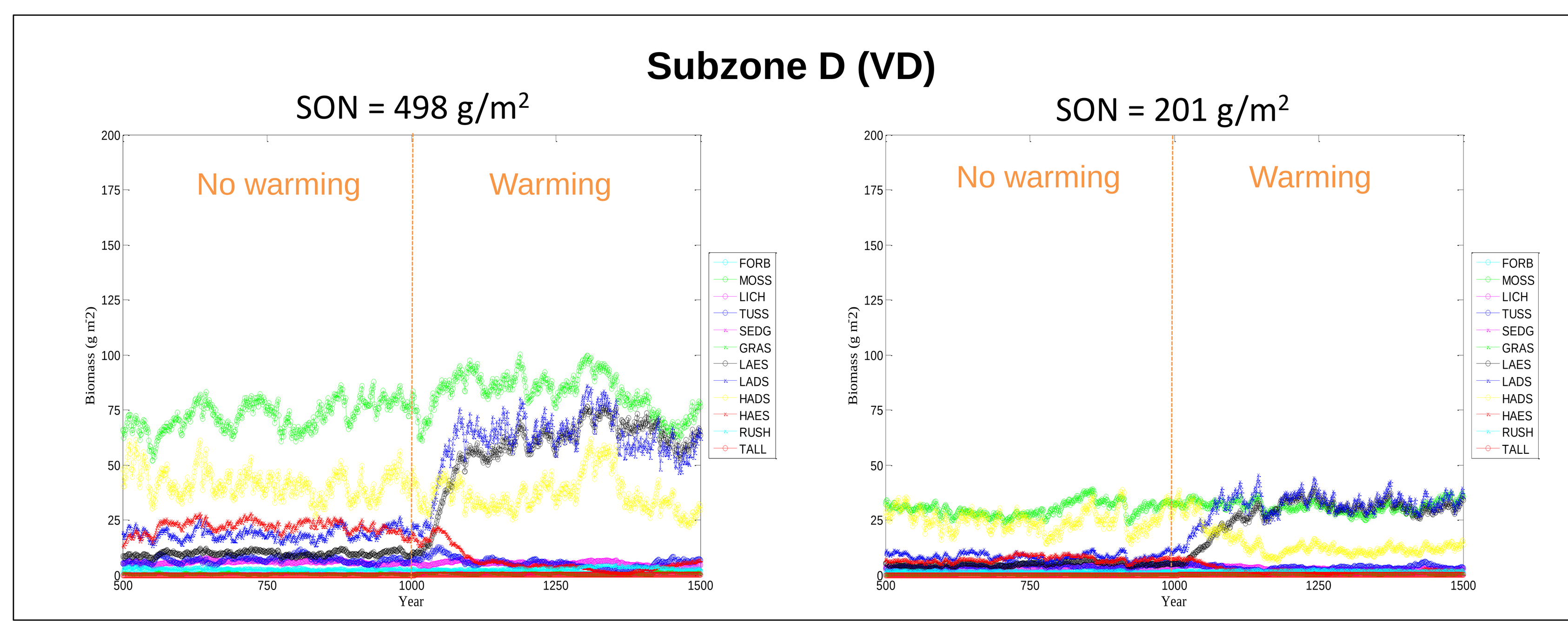
Table 1 Field soil organic nitrogen (SON) (g/m^2) for model input: KH-Kharasavey, VD - Vaskiny Dachi, LA – Laborovaya.

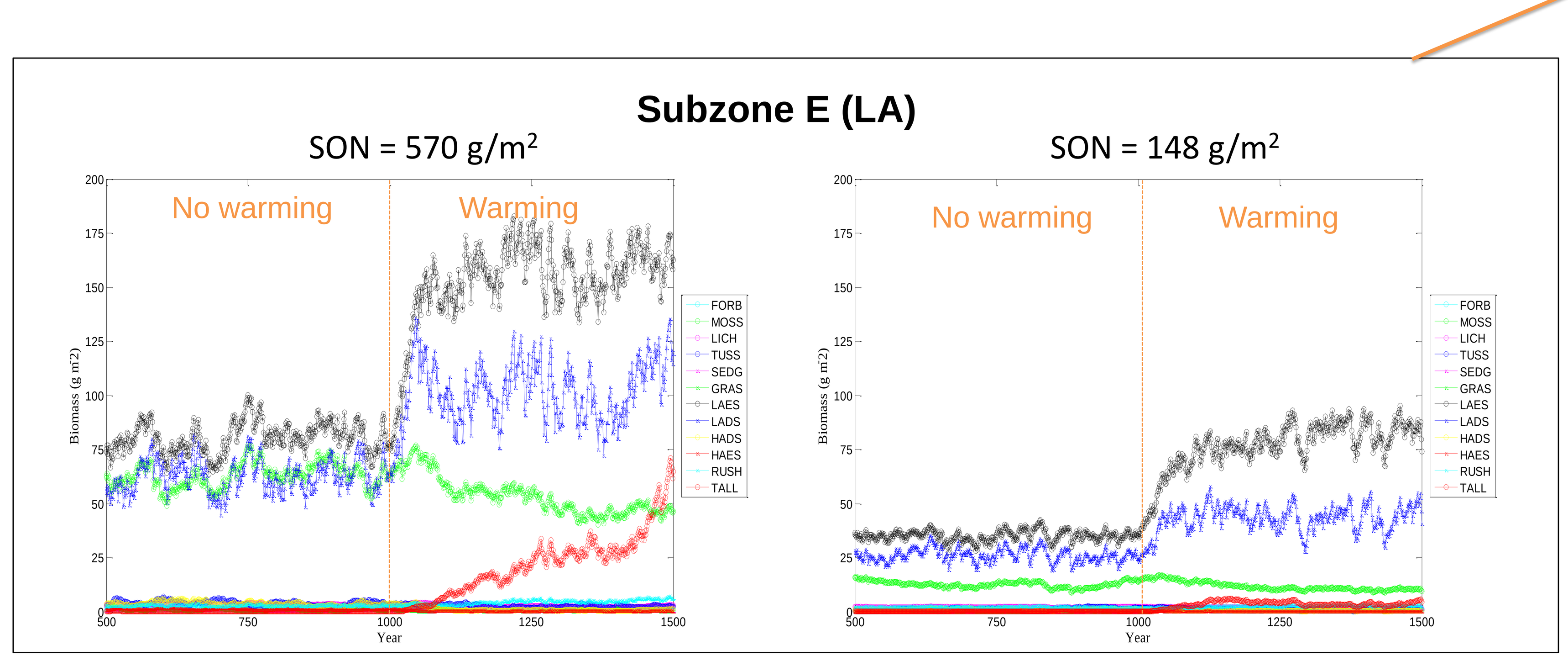
sites	subzones	HSON(g/m^2)	LSON(g/m^2)
KH	C	599	484
VD	D	498	201
LA	E	570	148

Results

Above ground biomass of tundra plant functional types in response to warming in three bioclimate subzones and two different soil nitrogen levels







Plant Functional Types are: Forbes, Mosses, Lichen, Tussock tundra, Sedges, Grasses, Low and High Arctic evergreen and deciduous shrubs, Rushes and Tall shrubs.

Table 2 Mean total biomass changes after equilibrium with warming in relative percentage and absolute amount (g/m^2)
LSON= low SON; HSON = high SON

warmer →

		C	D	E
Relative Change	LSON	27.78%	36.46%	43.66%
	HSON	27.21%	38.70%	39.15%
Absolute Change	LSON	113.11	129.62	206.78
	HSON	129.32	287	427.5

Total biomass – Soil & Warming

- Total plant biomass increases with warming more in regions with higher SON levels than in regions with lower levels. Relative changes in total plant biomass are similar. For example, in subzone E (LA), compared to its original biomass before warming, tundra in sandy soils may respond more strongly to warming than tundra in clayey soils.
- Most of the increase in biomass with warming happens in below-ground biomass (about 80%).

Above ground Plant Functional Types (PFT) biomass – Soil & Warming

Different plant functional types (PFT) may respond differently to the warming scenario.

- Across bioclimate subzones, the biomass of lichen, high arctic deciduous and evergreen shrubs declines with warming in most sites.
- The decline in moss biomass in most sites may be caused by warming and species competition.
- Low arctic deciduous and evergreen shrubs increase significantly. Tall shrub biomass in the clayey site in subzone E also increases greatly.
- The biomass of rushes, sedges and tall shrubs also increases slightly in subzone D and in the sandy site within subzone E.

Major Results

- Across bioclimate subzones, tundra plants in warmer zones show the greatest increase in total biomass.
- Most biomass increase with warming happens in below-ground biomass (about 80%).
- Different plant functional types (PFT) may respond to warming differently.
- Soil nutrient level can control the magnitude of plant responses.

References

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