Simulating Soil Organic Nitrogen and Grazing Effects on Arctic Tundra Vegetation Dynamics on Yamal Peninsula, Russia

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Paper Number:GC31A-0693

Introduction

Arctic tundra vegetation growth is affected by various environmental factors such as climate gradient, soil nutrients, animal grazing and climate warming. These control factors have been substantially studied in the field. However, few studies have collectively studied these four factors and can provide insights on how these factors may interact and affect tundra vegetation communities.

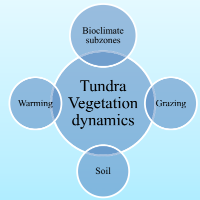


Fig. 1: Factors affect tundra vegetation dynamics

Research Questions

This study aims to answer the following questions:

- How do Soil Organic Nitrogen (SON) levels affect tundra vegetation in terms of total biomass and NPP response to warming ?
- How does grazing affect vegetation response to warming?
- How do SON, climate, and grazing interact and affect vegetation responses?

Study Area

The Yamal Peninsula is a large area of arctic tundra in northwestern Siberia, Russia that encompasses landscape to regional gradients of each of these three factors: climate, soil parent material, and grazing. An arctic transect was set up on the Yamal Peninsula since 2007.

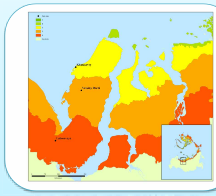


Fig. 2: Locations of field site along the Yamal Arctic Transect (YAT).

Table 1. Site name, bioclimate subzone and soil parameters on the Yamal Arctic Transect.

Subzone	sites	C%	N%	%Sand	%Silt	%Clay	Bulk Density (g/m^3)	Active Layer Depth(cm)	SON (g/m^2)
E	LV-1	1.72	0.06	18.00	59.32	22.68	1.21	81.20	570
E	LV-2	0.59	0.01	93.60	3.60	2.80	1.29	114.60	148
D	VD-1	1.25	0.03	28.90	60.80	10.30	1.34	71.75	271
D	VD-2	1.46	0.04	38.28	53.88	7.84	1.37	68.60	202
D	VD-3	1.31	0.05	92.80	4.64	2.56	1.18	113.80	498
C	KH-1	1.10	0.06	24.47	52.07	23.47	1.47	56.33	484
C	KH-2	1.18	0.07	65.60	26.60	7.80	1.22	75.50	599

Methods

We applied a nutrient-based transient vegetation dynamics model (ArcVeg) to examine how these three factors (climate zone, SON, and grazing regime) interact to affect tundra response to climate warming. We compared biomass generated by ArcVeg simulations using field collected SON data along the Yamal Arctic Transect (YAT) with 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. The control grazing regime was set as [0.1, 25%], indicating reindeer herds will graze on the same site every ten years and each visit a maximum of 25 percent of biomass will be removed. A more frequent grazing regime was set as [0.5, 25%], 25% of plant biomass will be removed every two years.

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.

SON & warming effects

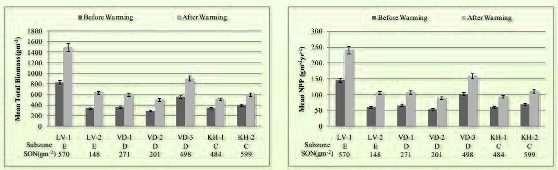
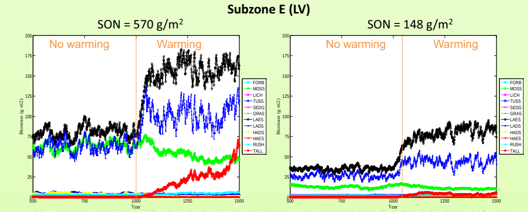


Fig. 3: Comparison of mean total biomass (left) and NPP (right) before and after warming along the YAT at the low grazing frequency regime for each site. Subzone and soil organic nitrogen (SON, g/m²) are noted on the x-axis.

- ✓ Plant total biomass and growth rate is determined by SON levels.
- ✓ Absolute increases in total biomass and NPP caused by warming were significantly greater in sites with higher SON levels.
- ✓ SON levels limited vegetation response to warming in nutrient poor sites.



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

Fig.4: Above ground biomass of tundra plant functional types in response to warming in subzone E with two different soil organic nitrogen levels

- ✓ In sites with high SON levels, the PFT richness is higher than in sites of low SON.
- ✓ Different plant functional types (PFT) may respond differently to the warming scenario. High SON sites support more woody PFT (Tall shrubs, Low Arctic shrubs).
- ✓ The decline in moss biomass in most sites may be caused by warming and species competition.

SON & grazing effects on Total Biomass and NPP

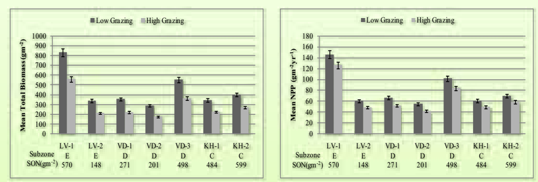


Fig. 5: Comparison of change in mean total biomass (left) and NPP (right) for each site under two grazing regimes (low frequency grazing: [0.1, 25%] and high frequency grazing: [0.5, 25%]).

- ✓ Grazing generally caused plant total biomass and NPP to decrease.
- ✓ The greatest decline in total biomass and NPP was found in high SON sites.

Summary

The statistical analyses show that bioclimate subzones, SON, warming, grazing and their interactions have significant effects on tundra vegetation in terms of total biomass and NPP.

- Soil nutrients are a limiting factor to plant growth, and also limit the plant responses to climate warming.
- Warming and grazing are affecting plant biomass and NPP in opposite directions.
- Grazing suppresses plant responses to warming effects.
- High grazing led to either slower SON accumulation rates or SON depletion rates than low grazing. Warming accentuated these differences caused by grazing, suggesting the interaction between grazing and warming may yield greater differences in SON levels across site.

SON, Grazing & Warming Interaction Effects

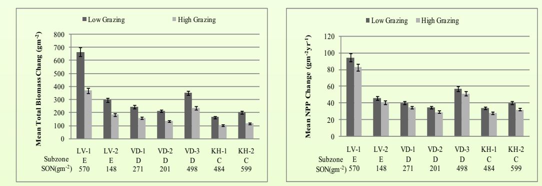


Fig. 6: Comparison of absolute increase in mean total biomass (left) and NPP (right) caused by climate warming for each site under two grazing regimes (low frequency grazing: [0.1, 25%] and high frequency grazing: [0.5, 25%]).

- ✓ Grazing also interacted with warming and caused a reduction in plant biomass and NPP responses to warming.
- ✓ The interaction effects were greater on total biomass in sites of high SON.

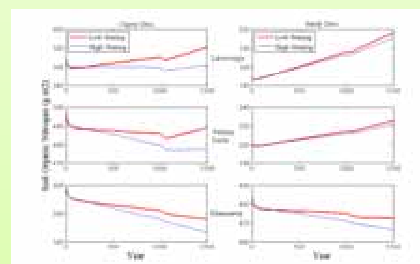


Fig 7. Grazing effects on soil organic nitrogen pool in each site over time.

- ✓ High grazing led to either slower SON accumulation rates or SON depletion rates.
- ✓ Warming accentuated these differences caused by grazing.
- ✓ The interaction between grazing and warming may yield greater differences in SON levels across site.

Acknowledges

Support came from NASA/NEESPI Land Cover Land Use Change Initiative, Grant No. NNG6GE00A, NSF Grant No. ARC-0531180, part of the Synthesis of Arctic System Science initiative and NSF Grant No. ARC-0902152, part of the Changing Seasonality of Arctic Systems initiative.

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