Influence of shrubs invasion to mountain tundra and alpine grassland ecosystems on soil properties and plant nutrition

M.I. Makarov, T.I. Malysheva, M.S. Kadulin, R.V. Sabirova

Department of Soil Science, Moscow State University, 119991 Moscow, Russian Federation

Motivation

Invasion of shrubs with ericod mycorrhiza (ERM) and ectomycorrhiza (ECM) to the mountain tundra and alpine grassland ecosystems with arbuscular mycorrhiza (ARM) during the last decades is the widespread phenomenon. ECM and ERM fungi are characterized by higher enzymes activity capable to transform soil organic matter and mobilize nutrients.

Hypothesis

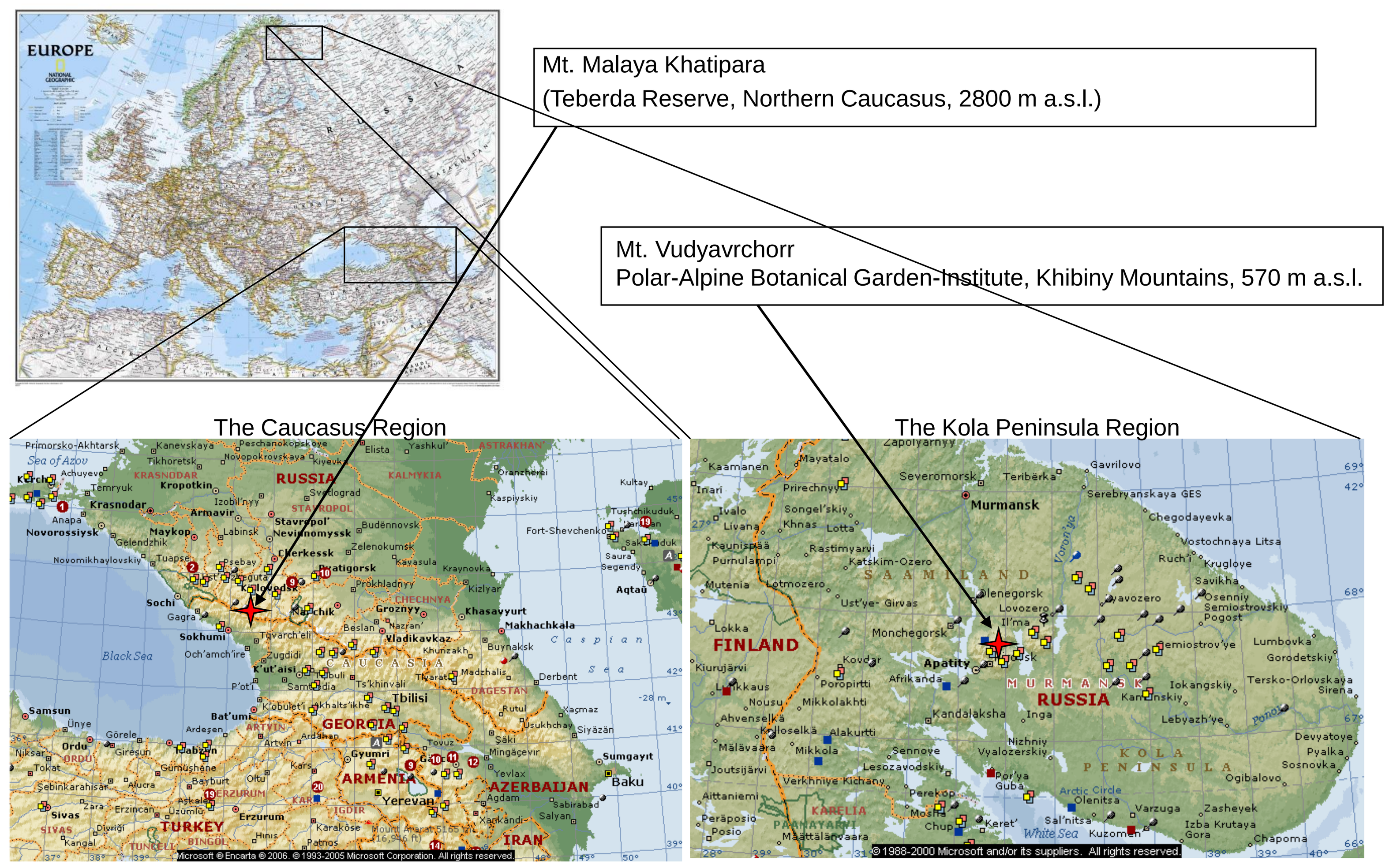
We assume that appearance of plant species with ERM in grassland ecosystems can change soil properties. Such change can influence on soil microbial community and nutrition of the neighboring plant species with ARM or non mycorrhizal species, and therefore affect biogeochemical cycles of C, N, P.

Objectives

To study how shrubs with ERM influence on soil characteristics: labile organic and inorganic fractions of carbon, nitrogen and phosphorus; structure and functioning (activity) of soil microbial community.

Objects

The study was done in the alpine belt of the Caucasus and tundra belt of Khibiny Mountains within the sites of the alpine and tundra grassland ecosystems on which the shrubs with ERM are present.



The studied soils of the Caucasus and Khibiny Mountains differ significantly in N and P availability.

In the Caucasus *Vaccinium vitis-idaea* occupies sites with poor soil.

In the Khibiny Mountains a range of shrubs, that are the main component of tundra plant communities, are also settled on the richest soil of tundra grasslands.

Results

Soil properties of the Caucasian alpine grassland with and without *Vaccinium vitis-idaea* in plant community. Red color indicates significant differences, *P*<0.05, n=10

	Without *Vaccinium vitis-idaea*	With *Vaccinium vitis-idaea*
Moisture, vol. %	25.4 ± 3.8	27.2 ± 2.9
Soil depth, cm	15.4 ± 4.1	10.1 ± 2.3
Stony, %	3.6 ± 2.1	11.9 ± 5.3
pH	5.62 ± 0.17	5.40 ± 0.13
P_{min}, mg/kg	6.5 ± 2.8	9.9 ± 3.0
$C_{org\ extr}$, mg/kg	187 ± 49	307 ± 129
$N_{org\ extr}$, mg/kg	20.3 ± 4.9	24.9 ± 5.4
$P_{org\ extr}$, mg/kg	0.52 ± 0.11	0.63 ± 0.14
C_{org}/N_{org} (extractable), mg/kg	8.5 ± 2.0	12.5 ± 3.4
C_{org}/P_{org} (extractable), mg/kg	216 ± 36	285 ± 43
$N\text{-}NH_4^+$, mg/kg	4.84 ± 1.16	3.93 ± 0.82
$N\text{-}NO_3^-$, mg/kg	0.62 ± 0.21	0.38 ± 0.16
N-mineralization, mg/kg/d	0.23 ± 0.45	-0.51 ± 0.38
Nitrification, mg/kg/d	0.87 ± 0.59	0.22 ± 0.06
C_{micr}, mg/kg	1300 ± 474	1649 ± 640
N_{micr}, mg/kg	73 ± 24	112 ± 42
C_{micr} / N_{micr}	17.4 ± 2.2	14.6 ± 1.2
BR, mg CO_2/kg/h	5.7 ± 1.6	7.8 ± 2.3
qCO_2, µg C-CO_2/mg C_{micr}/h	2.4 ± 0.4	3.4 ± 1.0
Glucosidase, µmol MUF/g/h	0.72 ± 0.22	2.04 ± 0.71
Chitinase, µmol MUF/g/h	0.19 ± 0.09	0.48 ± 0.19
Phosphotase, µmol MUF/g/h	4.13 ± 1.46	12.74 ± 3.73

Soil properties of the Khibiny tundra grassland soil under different plants. Red color indicates significant differences, *P*<0.05, n=10

	Moisture, vol. %	Soil depth, cm	Stony, %	pH	P_{min} mg/kg
Grasses	30 ± 2.4	16.5 ± 5.1	0.3 ± 0.6	4.93 ± 0.10	132 ± 77
All plants with ERM and ECM	26±2.7	12.9 ± 3.5	4.2 ± 6.0	4.86 ± 0.15	408 ± 349
Betula nana	27 ± 2.9	14.6 ± 5.6	4.8 ± 7.1	4.79 ± 0.10	597 ± 316
Empetrum hermaphroditum	22 ± 2.8	10.8 ± 5.5	5.5 ± 6.7	4.75 ± 0.06	747 ± 373
Vaccinium myrtillus	28 ± 1.7	13.9 ± 5.5	2.4 ± 4.4	4.97 ± 0.07	251 ± 234
Vaccinium uliginosum	102 ± 20	13.9 ± 5.4	2.9 ± 4.5	4.80 ± 0.21	236 ± 235
Vaccinium vitis-idaea	125 ± 24	11.4 ± 4.2	5.6 ± 5.2	4.98 ± 0.08	244 ± 263

Extractable C, N, P and nitrogen transformation activities in the Khibiny tundra grassland soil under different plants. Red color indicates significant differences, P<0.05, n=10

	$C_{org\ extr}$	$N_{org\ extr}$	$P_{org\ extr}$	C_{org}/N_{org}	C_{org}/P_{org}	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	N-mineralization	Nitrification
	mg/kg					mg/kg		mg/kg/d	
Grasses	364 ± 44	28±4	0.84±0.12	13.1±1.3	435±45	21±4	10.6±2.8	4.4±1.1	5.1±1.1
All plants with ERM and ECM	400±109	39±14	1.21±0.49	10.6±1.5	350±83	18±6	3.2±3.4	2.8±1.2	3.2±1.3
Betula nana	497±148	53±22	1.36±0.65	9.8±1.5	392±82	22±7	1.5±0.7	3.2±1.4	3.5±1.3
Empetrum hermaphroditum	441±116	41±11	1.71±0.56	11.0±2.1	270±64	17±7	1.0±0.7	1.7±1.4	2.3±1.4
Vaccinium myrtillus	321±41	29±5	0.93±0.11	11.3±1.2	347±36	20±3	9.3±3.0	3.4±1.3	3.9±1.5
Vaccinium uliginosum	345±33	34±6	1.11±0.30	10.4±1.2	322±54	15±4	2.7±0.5	3.0±0.9	3.3±1.0
Vaccinium vitis-idaea	399±71	38±7	1.01±0.26	10.6±1.1	413±90	17±4	1.5±0.5	2.8±0.5	2.7±0.5

Microbial biomass C and N, microbial and enzime activity of the Khibiny tundra grassland soil under different plants. Red color indicates significant differences, *P*<0.05, n=10

	C_{micr}	N_{micr}	C_{micr}/N_{micr}	BR, C-CO_2, mg/kg/h	qCO_2, µg C-CO_2/mg C_{micr}/h	Glucosidase	Chitinase	Phosphotase
	mg/kg					µmol MUF/g/h		
Grasses	817±78	84±8	9.7±1.1	3.0±0.5	3.7±0.5	0.51±0.12	0.31±0.11	1.59±0.32
All plants with ERM and ECM	801±195	74±18	10.9±1.2	3.6±2.2	4.5±2.1	0.94±0.37	0.63±0.26	2.81±1.28
Betula nana	788±167	76±20	10.5±1.3	5.8±3.0	7.1±2.4	0.48±0.12	0.40±0.14	1.53±0.36
Empetrum hermaphroditum	979±286	90±20	10.8±1.4	5.0±1.9	5.1±1.2	1.07±0.32	0.64±0.29	2.39±0.70
Vaccinium myrtillus	843±104	82±12	10.4±1.3	3.2±0.6	3.8±0.9	1.09±0.34	0.82±0.23	3.58±1.61
Vaccinium uliginosum	714±162	62±13	11.5±0.7	2.1±0.5	3.1±1.3	1.06±0.35	0.61±0.18	2.74±0.66
Vaccinium vitis-idaea	699±111	62±9	11.2±0.6	2.2±0.3	3.2±0.6	1.01±0.32	0.66±0.29	3.83±1.21

Conclusion

The presence of shrubs with ERM in mountain tundra and alpine grasslands is definitely related to differences in soil properties.

I. Some differences are unidirectional regardless of soil N and P availability. Soil under ERM plants is characterized by:

1. Increased stony material and smaller profile depth,
2. Increased acidity,
3. Increased concentration of extractable P but less nitrate content and low activity of nitrification.
4. Increased enzymatic activity.

II. Other differences depend from soil N and P availability:

1. At low concentrations of inorganic N and P in alpine soil, nitrogen- and phosphorus-containing organic molecules, mobilized by ERM fungi, are actively used for nutrition of microorganisms and plants (higher C/N, C/P in extractable organic matter).
2. In contrast, at high concentrations of inorganic N and P in tundra grassland soil, organic compounds, even if mobilized from a stable organic matter, are not actively absorbed by mycorrhizal fungi and saprotrophic microorganisms (lower C/N, C/P in extractable organic matter).

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