Tree diversity patterns along the latitudinal gradient in the Northwestern Russia

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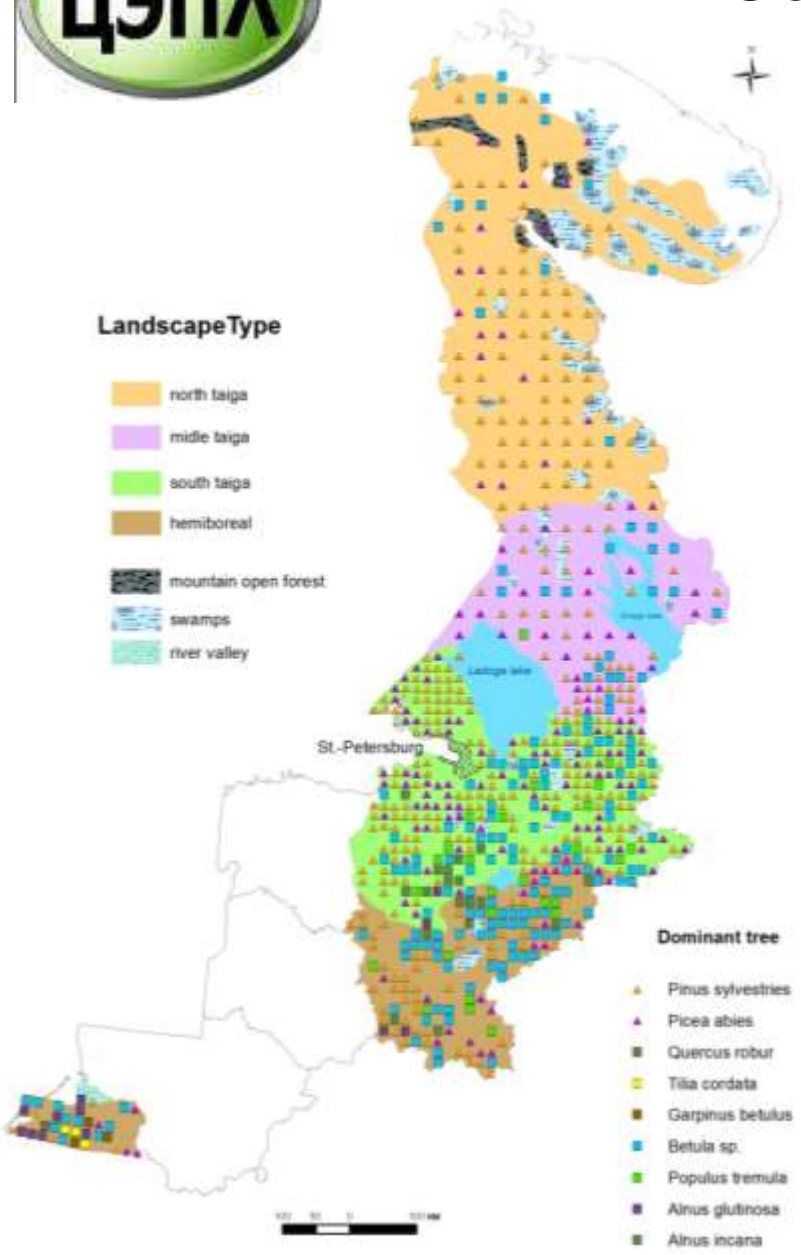
The aims of the study

- Assess the actual and potential distributions of tree species in the North-Western part of Russia and determine the key factors that are shaping the observed patterns.
- Determine the impacts of various environmental and anthropogenic factors that operate at different spatial scales (climate, habitat, disturbance, etc.) on forest communities. As several previous works suggested the dominating role of forest fires on the communities' structure and composition, we pay increased attention to pyrogenic factors.
- Evaluate the link between the tree stand age and the intensity of forestry.

Study area



The Northwestern Russia (54°20’N, 19°50’E ↔ 69°05’N, 37°45’E).

1700 km along the western Russian border.

6 federal states: Leningrad, Pskov Novgorod, Kaliningrad, Murmansk regions and Republic of Karelia.

The rectangular grid 16x16 km in Leningrad and Kaliningrad regions and 32x32 km in other regions.

710 sites in total with 16351 individual trees inventoried.

Number of trees in ICP Forests plots

Species	Landscapes							Total:
	forest tundra	northern taiga	middle taiga	south taiga	hemiboreal	swamps and river valleys	mountain forests	
Acer platanoides	0	0	0	0	2	0	0	2
Acer pseudoplatanus	0	0	0	0	3	0	0	3
Alnus glutinosa	0	0	0	91	296	24	0	411
Alnus incana	0	1	11	200	194	1	0	407
Betula sp.	48	613	804	1437	1659	130	4	4695
Carpinus betulus	0	0	0	0	79	0	0	79
Fraxinus excelsior	0	0	0	0	10	0	0	10
Larix sp.	0	0	0	0	3	0	0	3
Picea abies	2	473	696	1226	642	84	48	3171
Pinus sylvestris	0	1725	972	2487	931	241	24	6380
Populus tremula	0	14	154	382	444	3	0	997
Quercus robur	0	0	0	0	71	0	0	71
Salix sp.	0	6	3	3	0	0	0	12
Sorbus aucuparia	0	0	0	1	1	0	0	2
Tilia cordata	0	0	0	0	107	0	0	107
Ulmus sp.	0	0	0	0	1	0	0	1
Total:	**50**	**2832**	**2640**	**5827**	**4443**	**483**	**76**	**16351**

Climatic characteristics

Landscape	Average annual temperature	Max warm month temperature	Min cold month temperature	Annual precipitation	Summer precipitation	Winter precipitation
Forest tundra	0.1	14.6	-13.6	344	126	38
North taiga	0.2	16.2	-15.3	523	161	67
Middle taiga	3.6	20.1	-11.4	751	197	108
South taiga	3.7	20.3	-10.5	752	211	107
Hemiboreal	6.4	21.6	-7.0	788	222	116

The values are based on the averaging of long term (1930-2010) observations from 25 meteorological stations located in the study area.

Methods

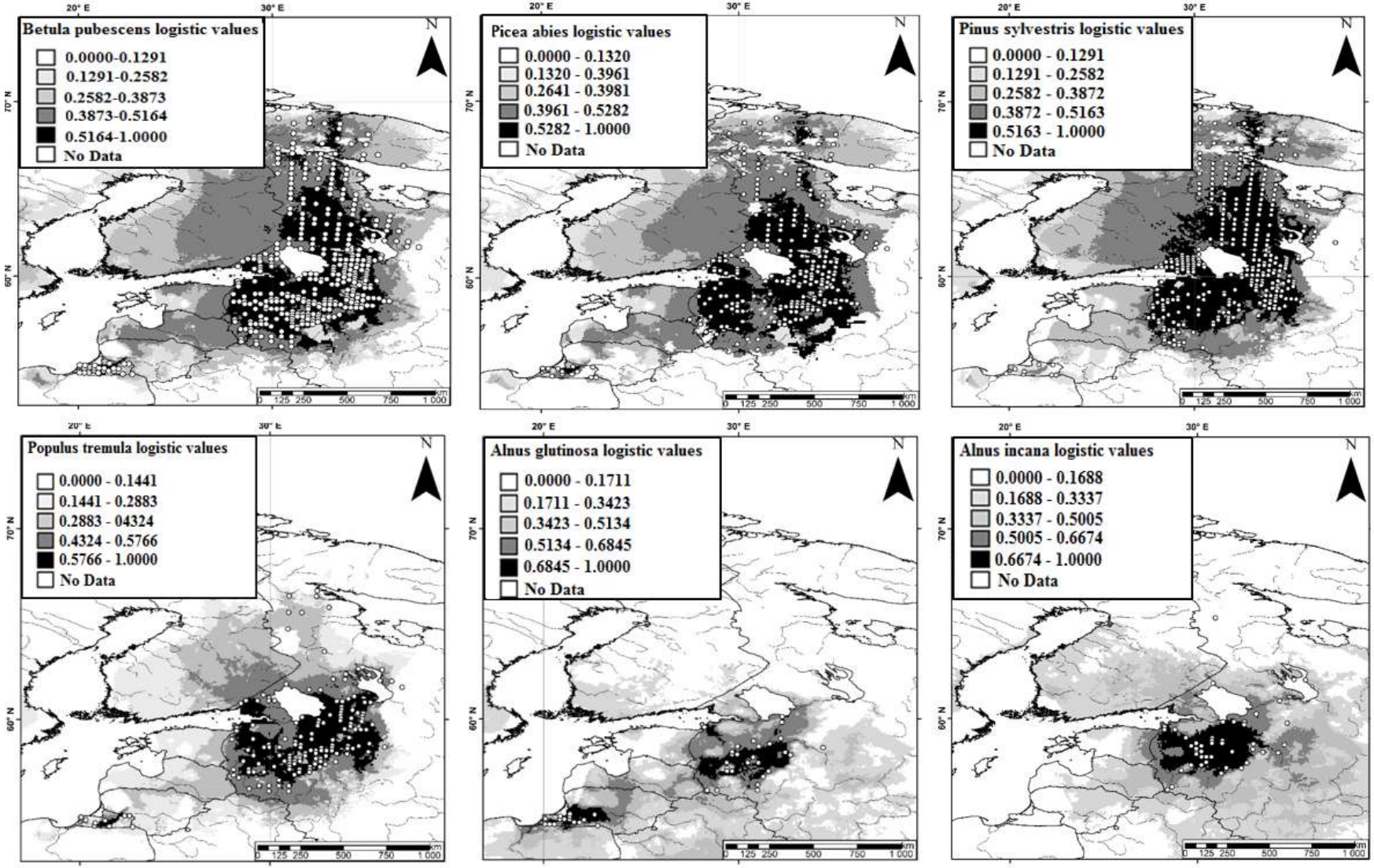
- We exploited various descriptive analyses to visualize and assess the patterns of community diversity and composition in relation to environmental factors, fire stress and the dominant tree age. We used Spearman rank coefficient as a measure of correlation. All descriptive analysis was run using the core R software (R Core Development Team 2016).
- We analyzed the distributions of individual species using the maximum entropy method (Phillips et al. 2006; Phillips and Dudík 2008) with MaxEnt software (version 3.3.3k).
- We analyzed the species-to-species associations, explicitly accounting for the spatial structure of observed plots, with the Hierarchical Model of Species Communities (Ovaskainen et al. 2017; Warton et al. 2015).
- We analyzed wildfire activity in 2006-2016 using MODIS spectra-radiometric observations data obtained through Vega satellite imaging service (Lupian et al. 2014).

Correlation analysis results

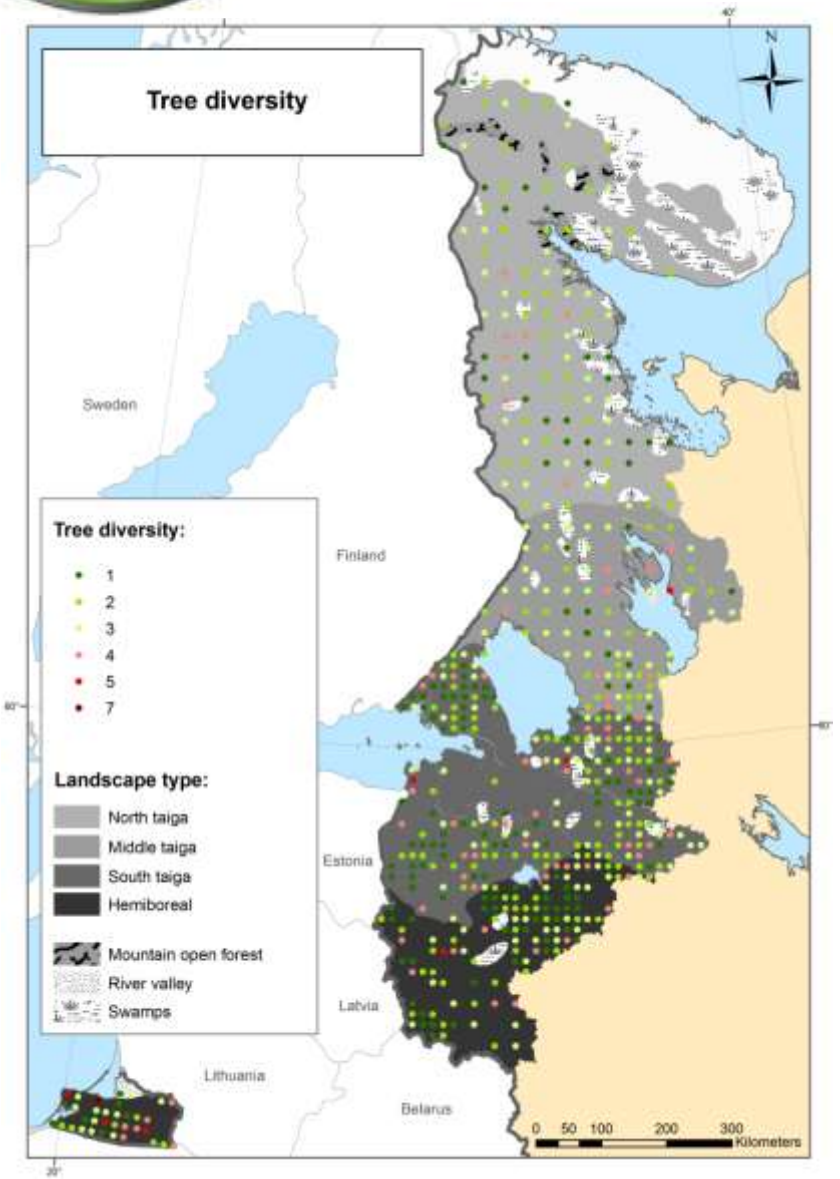
	Pinus	Picea	Betula	Broadleaf	Biodiversity	Age	Fertility	Moisture
Pinus	1	-0.41	-0.61	-0.2	-0.43	0.23	-0.82	0.02
Picea	-0.41	1	0.09	-0.02	0.58	0.22	0.24	-0.16
Betula	-0.61	0.09	1	0.03	0.45	-0.26	0.46	-0.01
Broadleaf	-0.2	-0.02	0.03	1	0.2	0.01	0.22	-0.03
Biodiversity	-0.43	0.58	0.45	0.2	1	-0.02	0.31	-0.12
Age	0.23	0.22	-0.26	0.01	-0.02	1	-0.26	0.01
Fertility	-0.82	0.24	0.46	0.22	0.31	-0.26	1	0
Moisture	0.02	-0.16	-0.01	-0.03	-0.12	0.01	0	1
Number of fires	-0.18	-0.11	-0.03	0.25	0.03	-0.11	0.28	0.01
Area of fires	-0.16	-0.09	-0.03	0.2	0.03	-0.09	0.24	0.01

Spearman rank correlations between proportions of forest species and stand, habitat, and pyrogenic activity properties

Potential vs realized species distributions



Tree species diversity

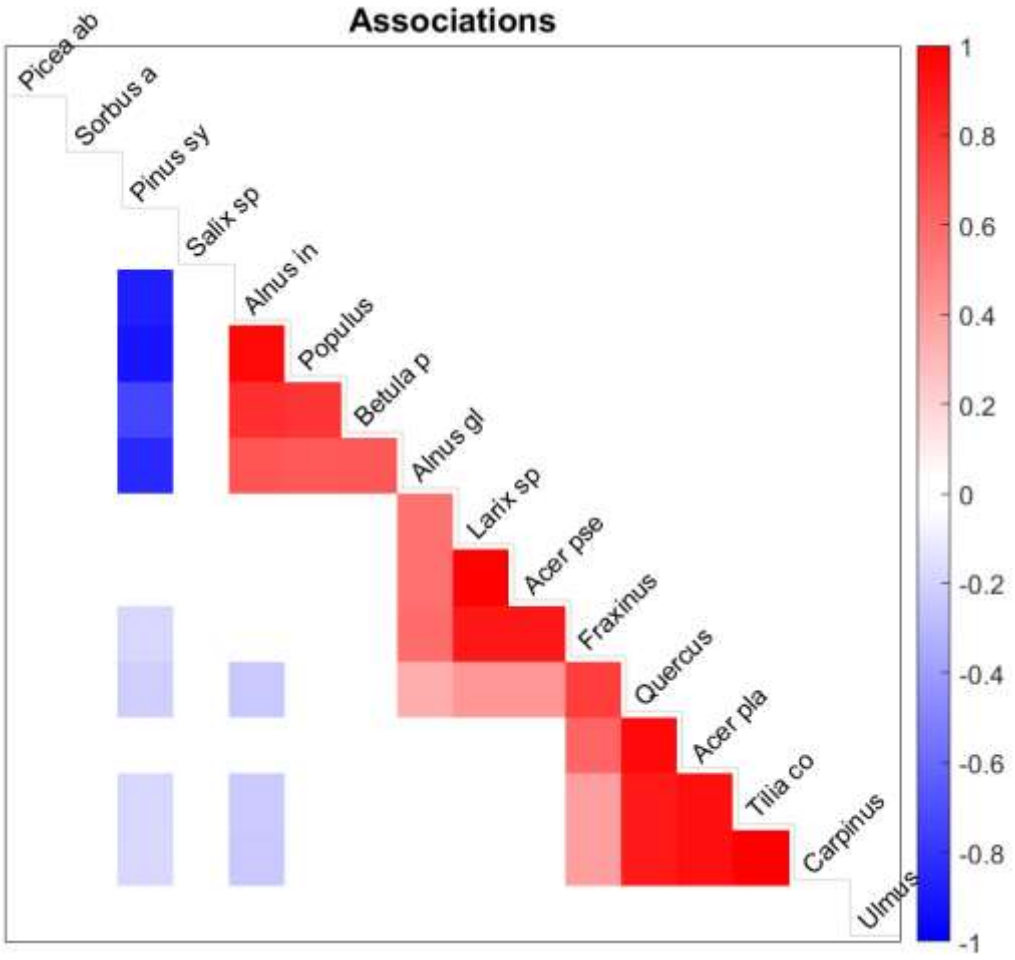


The maximum biodiversity from 1-3 species in the north taiga sites to 5(7) species in south taiga and hemiboreal sites.

Monospecies communities are rather abundant in all bioclimatic zones, with the highest proportion observed in south taiga. Among the monospecies communities 72% are pine forests and 12% - birch forests.

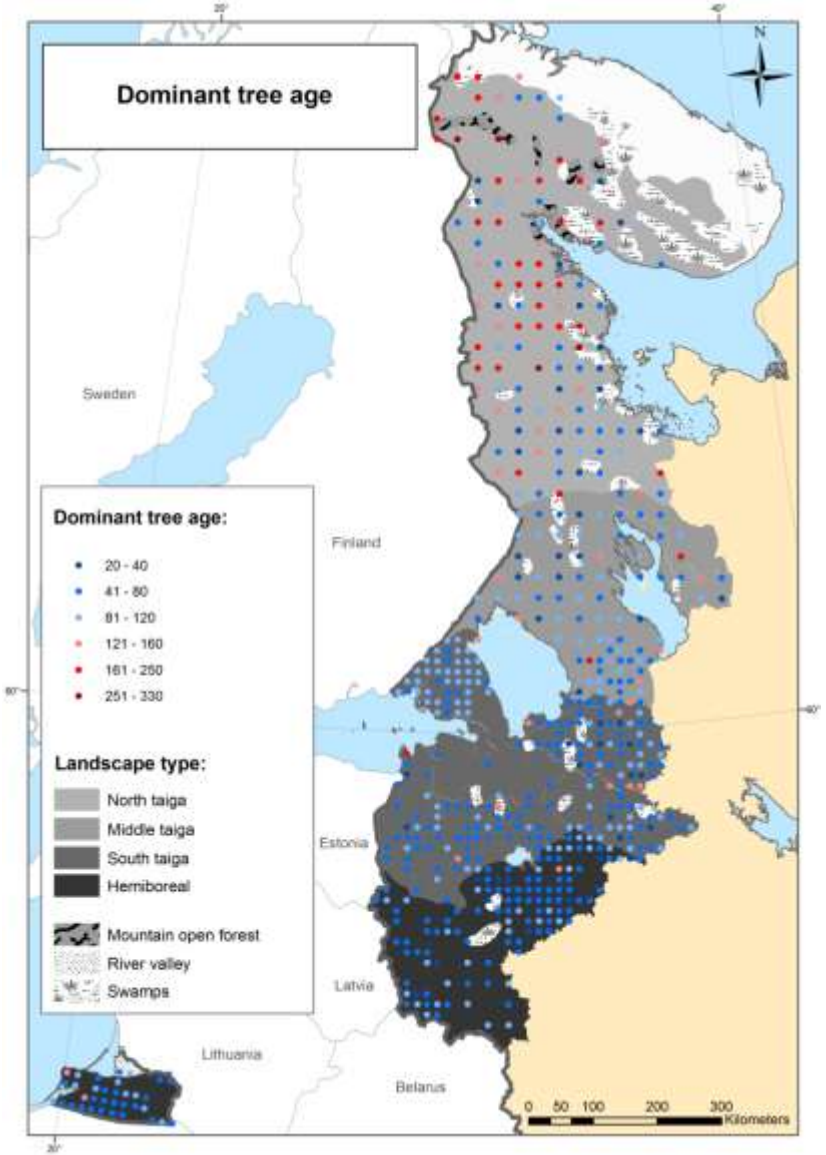
Rich species communities mainly consisted of spruce and broadleaf species.

Species-to-species association



Species-to-species association matrix, estimated by Hierarchical Model of Species Communities. Each cell corresponds to the pair of different species and gradation of blue-red colors depict the species-to-species estimated association strength measured at correlation scale. White cells stand for those pairs, where the null hypothesis of no association between given pair of species could not be rejected at the statistical significance level 0.05.

Dominant tree age



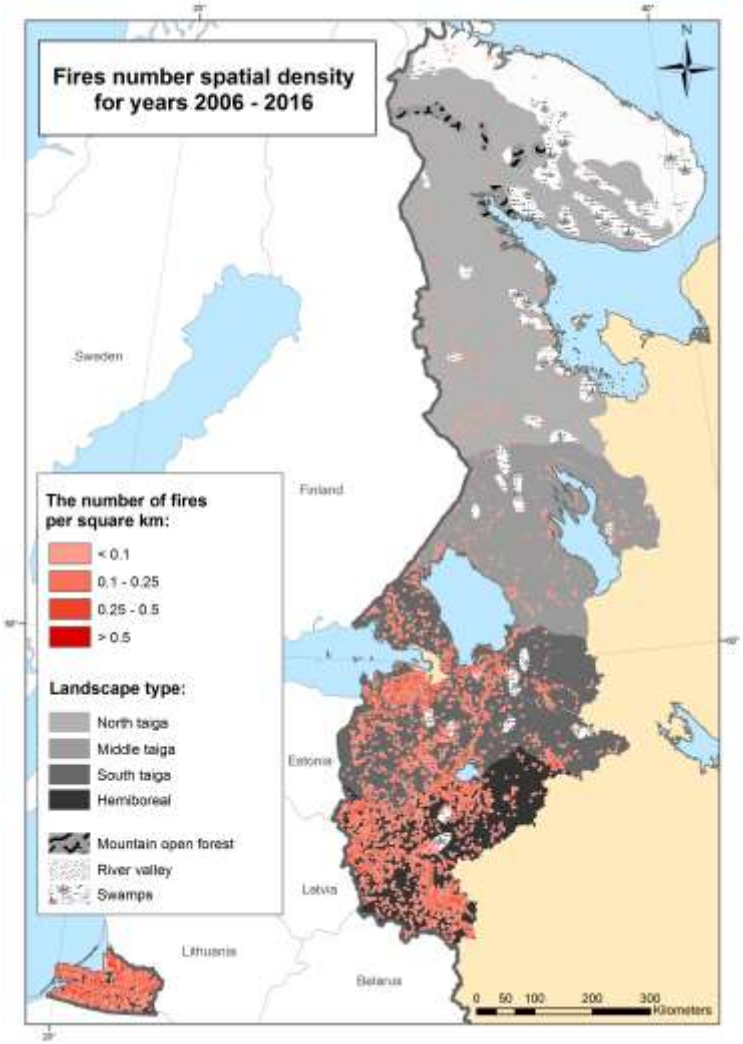
Highly mature forests (>160 years) are mostly found in the north taiga. The most aged trees (300-330 years) are pines and spruces.

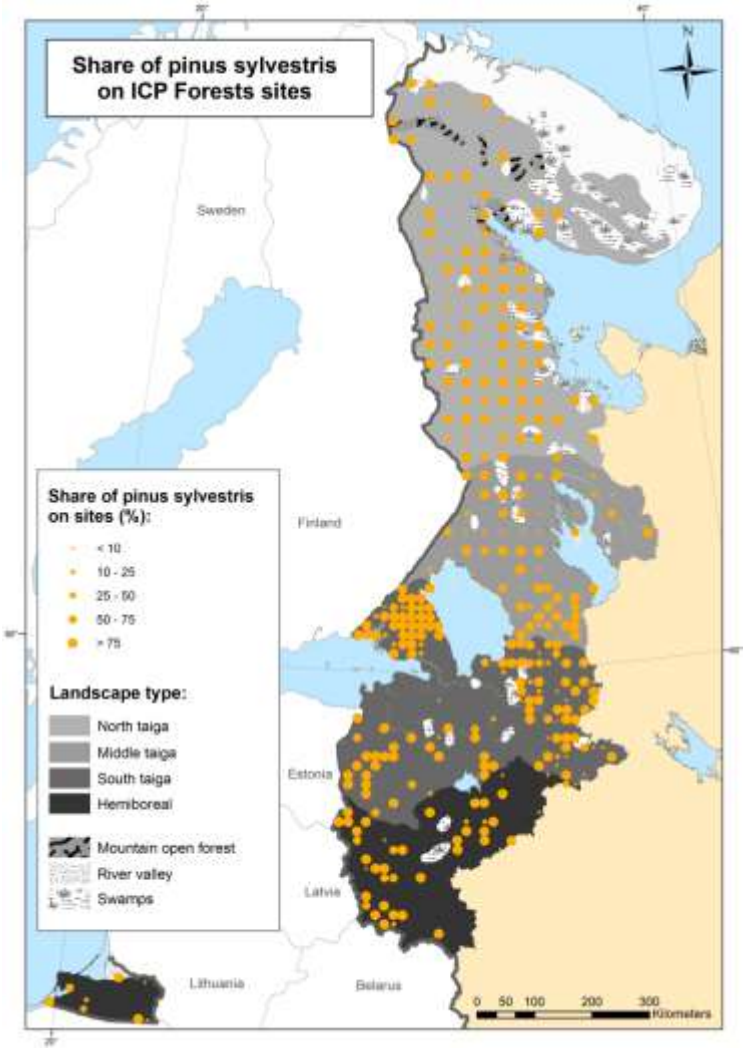
In the Karelian Isthmus the age group of 80-120 years is vastly prevailing.

The Karelian middle taiga features more heterogeneous age distribution mainly represented by mid-aged stands (40-80 years) with occasional more mature stands (120-160 years).

More southern regions of Pskov, Novgorod and Kaliningrad generally covered by mid-aged forests.

Density of fires and distribution of pine





Conclusions

Local biodiversity of tree species in the Northwestern Russia is determined by a set of environmental and anthropogenic factors.

The north taiga is distinguished for its lowest biodiversity with no more than 3 species being observed at same location. On the opposite edge of the latitudinal range lie the areas with highest biodiversity, caused by high proportion of broadleaf species in community compositions.

Monospecies stands could be found through the whole study area, being typically represented by pine and corresponding mainly to sandur and lake-glacial landscapes.

We have demonstrated that ICP Forest monitoring network enables to successfully establish the main qualitative and quantitative relationships of the spatial variation of biodiversity with respect to climatic, landscape, soil and disturbance factors.

However, regular resampling of sites in the monitoring network is required to obtain robust inference of the ongoing dynamics.

Thank you for your attention!