Impacts of climate change on the distribution of palsas in the discontinuous permafrost zone of Northern Europe

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Introduction and objectives

Figure 1: Palsa mire in Paistunturit area, Utsjoki, northern Finland, August 1999 (photo taken by Maria Rönkkö).

Permafrost landforms and habitats are highly dependent on climatic conditions and have therefore been recognised as sensitive indicators of climate change [1, 2].

Palsas, small mounds with a permanently frozen peat and mineral soil core, are characteristic geomorphological features of subarctic mire landscapes. They are known to be biologically heterogeneous environments with rich bird species diversity.

Palsa mires are mire complexes which occur in the northern hemisphere, representing one of the most marginal permafrost features at the outer limit of the discontinuous permafrost zone. The marginal locations of palsa mires make them sensitive to climatic fluctuations [3]. Figure 1 shows a palsa mire in northernmost Finland. The European distribution of palsas includes areas of the Kola Peninsula in Russia, Norway, Finland, Sweden and Iceland (cp. fig. 2 for the palsa distribution in northern Fennoscandinavia).

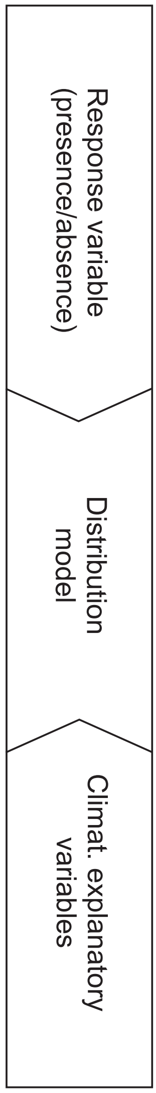
Local studies suggest that subarctic palsa mires in Europe [4, 5, 6] and in North America [7, 8] are degrading. A potential explanation for that is the influence of climatic changes during the 20th century.

The climate in Northern Europe has experienced a warming in most areas during the 20th century; e.g. the mean annual temperature for Finland has increased by about 0.7°C [9]. Increasing precipitation trends have been observed for regions in Norway [10], for Sweden [11] and for Northern Finland [12]. These trends are projected to continue and strengthen during the 21st century according to climate scenarios derived from Global Circulation Models (GCMs). Projections for Finland based on six GCMs give a range of changes for mean annual temperature between 2.4°C and 7.4°C and for annual precipitation of 6% to 34% between the baseline period 1961-1990 and the period 2070-2099 [12].

These changes in temperature and precipitation could have a profound impact on the distribution of palsas in Northern Europe. The objective of this study is to assess these potential impacts, specifically to:

1. investigate the sensitivity of the palsa distribution with respect to changes in climate,
2. define a critical climate change for the European palsa distribution that constitutes a risk of total disappearance of palsas,
3. assess the impacts of climate change on the Northern European distribution of palsas according to projections from state-of-the-art climate models throughout the 21st century.

Data & methods



Aerial photography, published maps

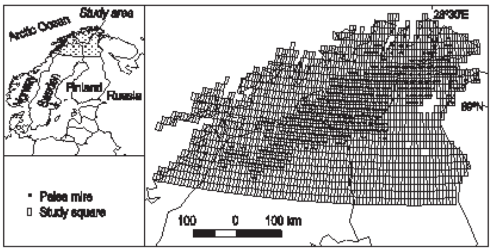


Figure 2: Study area and palsa distribution in Fennoscandinavia.

Table 2: Parameters of the palsa distribution model.

	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	149.200	76.410	1.953	0.051 .
FROST	-299.000	148.600	-2.012	0.044 *
$FROST^2$	-273.000	112.500	-2.428	0.015 *
APREC	0.013	0.008	1.678	0.093 .
$APREC^2$	45.100	7.960	5.665	1.47E-08 ***
CONT	-0.208	0.162	-1.288	0.198
$CONT^2$	-101.100	10.960	-9.229	< 2E-16 ***
MAT	-11.580	3.733	-3.103	0.002 **
MAT^2	127.100	80.430	1.58	0.114
TDD*APREC	-1.629E-05	7.04E-06	-2.313	0.021 *

Signif. codes: ***: 0.001, **: 0.01, *: 0.05, .: 0.1

Table 1: Climatological explanatory variables.

Abbr.	*Variable name*	*Definition*
APREC	annual precipitation	January-December sum of monthly precipitation
MAT	mean annual temperature	Jan-Dec-average of the monthly mean temperature
TDD	thawing degree days	accumulated daily temperature sum above 0ºC; Gaussian distribution of daily mean temperature around the monthly mean is assumed
FDD	freezing degree days	accumulated daily temperature sum below 0ºC
FROST	frost number	combination of FDD and TDD
CONT	continentality	annual thermic interval, maximum – minimum of all monthly mean temperatures

Observed climate, climate scenarios

The distribution of palsas in Fennoscandinavia has been mapped onto a regular grid with a cell size of 10'x10' using aerial photography and previously published maps. A baseline climate in the same spatial resolution with monthly mean values for temperature and precipitation for 1961-1990 has been used to derive explanatory variables (cp. table 1). The climatological variables were related to the palsa present/absent data to calibrate a multiple logistic regression model (summarized in table 2). This palsa distribution model was studied with respect to its sensitivity to changes in temperature (-2°C to +6°C changes applied to all months of the year) and precipitation (-20% to +30% changes applied to the annual precipitation sum). The model was also applied to climate change scenarios derived from 7 GCMs for the 2020s, 2050s and 2080s, each for the SRES emission scenarios A2 and B2.