High-resolution projections for soil frost conditions in Finland with regard to timber harvesting and transport availability

Ilari Lehtonen[1], Ari Venäläinen[1], Juha Laitila[2], Mikko Strahlendorff[1], Matti Kämäräinen[1], Juha Aalto[1,3], Andrea Vajda[1], Hilppa Gregow[1] and Heli Peltola[4]

[1] Finnish Meteorological Institute, Helsinki, Finland
[2] Natural Resources Institute Finland, Joensuu, Finland
[3] Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland
[4] School of Forest Sciences, University of Eastern Finland, Joensuu, Finland

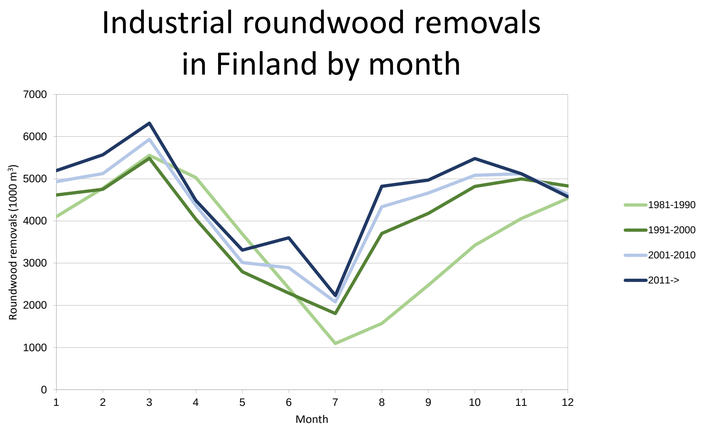

Fig. 1. Average industrial roundwood removals in Finland by month during the periods 1981–1990, 1991–2000, 2001–2010 and 2011 onwards.

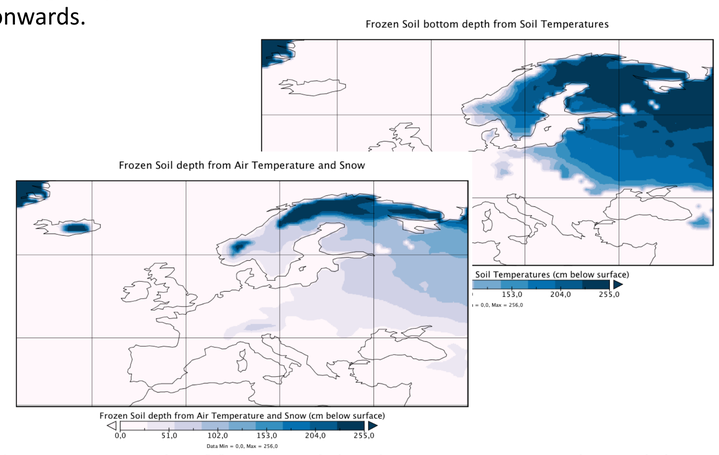

Fig. 3. An example of frozen soil depth on 20 Mar 2006 derived directly from the ERA-Interim soil layer temperatures (top) and calculated with a simple soil frost model by using the ERA-Interim air temperature and snow data (bottom).

Background

- Timber has been traditionally harvested in Finland mainly in wintertime.
- This is partly due to historical reasons; in countryside agriculture has been traditionally practised in summer and forestry in winter.
- Nowadays, approximately 60% of logging in Finland is carried out while the soil is frozen, although logging in late summer and early autumn has increased during the recent decades (Fig. 1).
- Bearing capacity of frozen soil enables the use of heavy forest harvesters (Fig. 2).
- Small forest truck roads having light foundations do not bear heavy timber trucks in wet road sections unless the soil is frozen.
- Climate or numerical weather prediction models do not capture the freezing of the soil correctly. Freezing in the model soil layers is typically too intense (Fig. 3).

Fig. 2. Poor bearing conditions decrease the efficiency of forest harvesting operations.

Motivation

- Climate change is expected to have a negative impact on timber harvesting and transport conditions due to reduced soil frost depth and shorter duration of soil frost period.

Materials and methods

- We used a soil frost model (Rankinen *et al*., 2004; Jungqvist et al., 2014) to calculate soil temperatures at different depths.
- The coefficients in the model were optimized for three different soil types: clay/silt, sand and peat.
- The soil frost model was used in combination with a snow depth model following largely Vehviläinen (1992).
- The snow depth model was parameterized for open areas as well as for forests with different density classes corresponding roughly to deciduous forest/sparse mixed forest, pine forest and dense spruce forest.
- We estimated the number of days with good bearing capacity (at least 20 cm of soil frost or 40 cm of snow) for different soil and forest class combinations until the end of the 21st century with two different climate model ensembles:
    1) Six global climate model simulations downscaled onto a 0.1° × 0.2° grid covering Finland by using quantile mapping bias-correction technique (Fig. 4)
    2) 11 bias-adjusted (cumulative distribution function method) EURO-CORDEX regional climate model simulations (Fig. 5)

Results and conclusions

- The soil frost season is projected to dramatically shorten over most of Finland (Figs 4 and 5).
- Peatlands may have in southern Finland on typical year less than one month of good bearing capacity in the late 21st century (Figs 4 and 5).

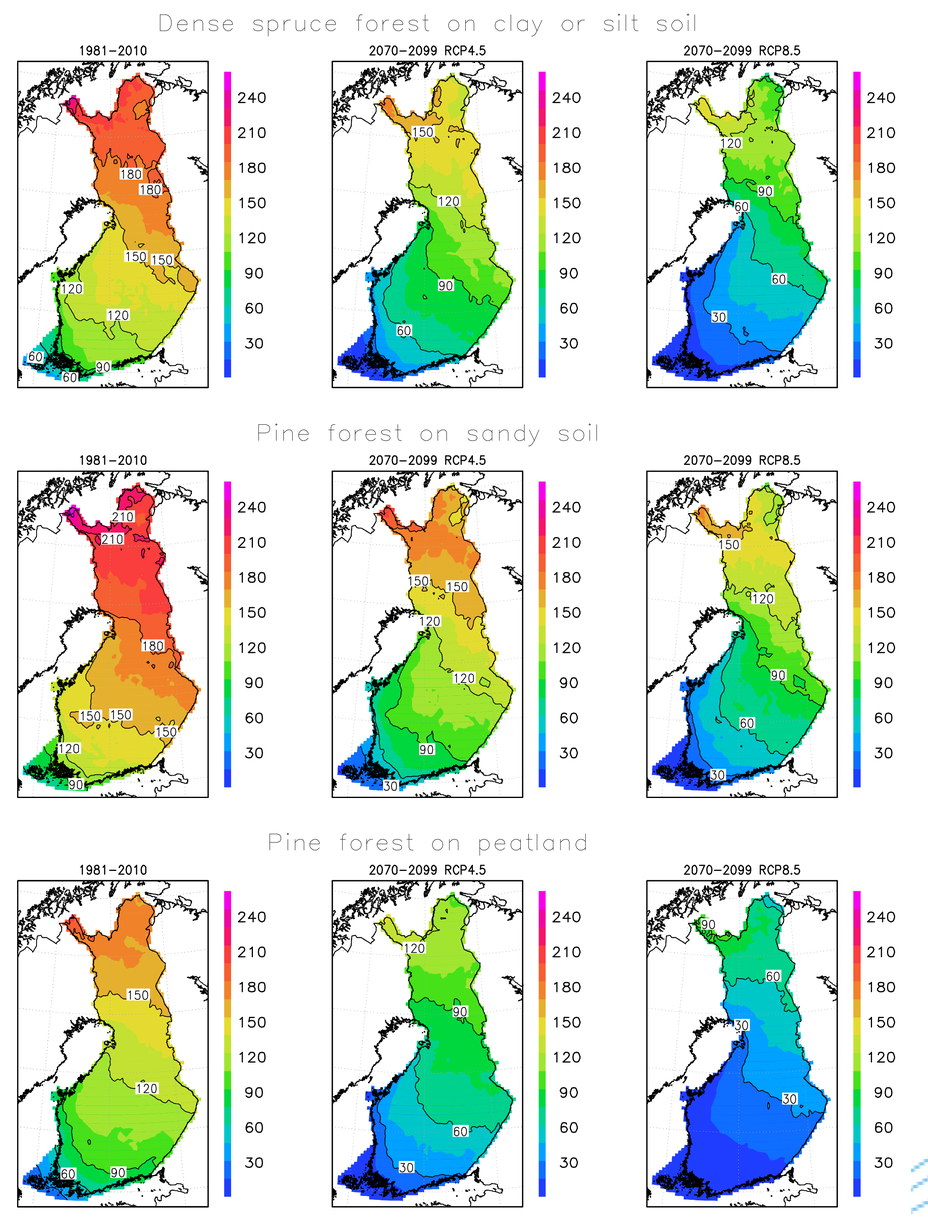

Fig. 4. Average annual number of days with good bearing capacity in three different combinations of forest and soil types during 1981–2010 and 2070–2099 under the RCP4.5 and RCP8.5 scenarios as indicated by the soil frost model and multi-model mean of six global climate models downscaled onto a 0.1° × 0.2° grid covering Finland.

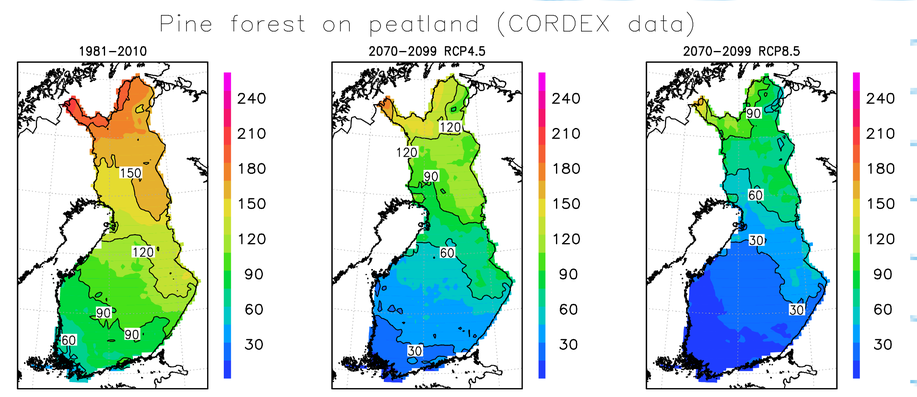

Fig. 5. As in Fig. 3 but only for pine forests on peatlands and by using data from 11 bias-adjusted EURO-CORDEX regional climate model simulations.

- Jungqvist G., Oni, S.K., Teutschbein, C. and Futter, M.N., 2014. Effect of climate change on soil temperature in Swedish boreal forests. PLoS ONE 9, e93957, doi:10.1371/journal.pone.0093957.
- Rankinen, K., Karvonen, T. and Butterfield, D., 2004. A simple model for predicting soil temperature in snow-covered and seasonally frozen soil: model description and testing. Hydrology and Earth System Sciences, 8, 706–716.
- Vehviläinen, B., 1992. Snow cover models in operational watershed forecasting. National Board of Waters and the Environment, Finland, 112 p.