

Table S1 Summary of the eddy covariance instrumentation at the study sites

Site code	Gas analyzer	Sonic anemometer	Open/closed path	Canopy/instrument height (m)
CH-Dav	LI-7500 ¹	Gill R3-50 ²	Open	25/35
CZ-BK1	LI-7200 ¹	Gill HS-50 ²	Closed	16/20.5
DE-Lkb	LI-7500 ¹	Campbell CSAT-3 ³	Open	2/9
DE-Obe	LI-7000 ¹	Metek USA-1 ⁴	Closed	21/30
DE-Tha	LI-7000 ¹	Gill R3-50 ²	Closed	29/42
IT-Ren	LI-7200 ¹	Gill HS-100 ²	Closed	29/41
DE-Bay	LI-7500 ¹	Metek USA-1 ⁴	Open	27/36
NO-Hox	LI-7200RS ¹	Gill HS-50 ²	Closed	1/1.8

¹LI-COR, Inc., Lincoln, USA

²Gill Instruments Limited, Hampshire, UK

³Campbell Scientific, Inc., Logan, USA

⁴METEK Meteorologische Messtechnik GmbH, Elmshorn, Germany

Table S2 Summary of the parameters in the XGBoost model.

Parameter	Initial value	Tuning range	Step	Description
η	0.1	0.05-0.3	0.05	The learning rate.
max_depth	1	0-10	1	The depth of the tree.
min_child_weight	0	0-10	1	The minimum number of instances required in a child node.
γ	0	0-10	1	Controlling regularization to prevent overfitting.
subsample	1	0.5-1	0.1	Controlling the number of observations used in a tree.
colsample_bytree	1	0.5-1	0.1	Controlling the number of variables used in a tree.
nrounds	1	1-400	1	The maximum number of iterations

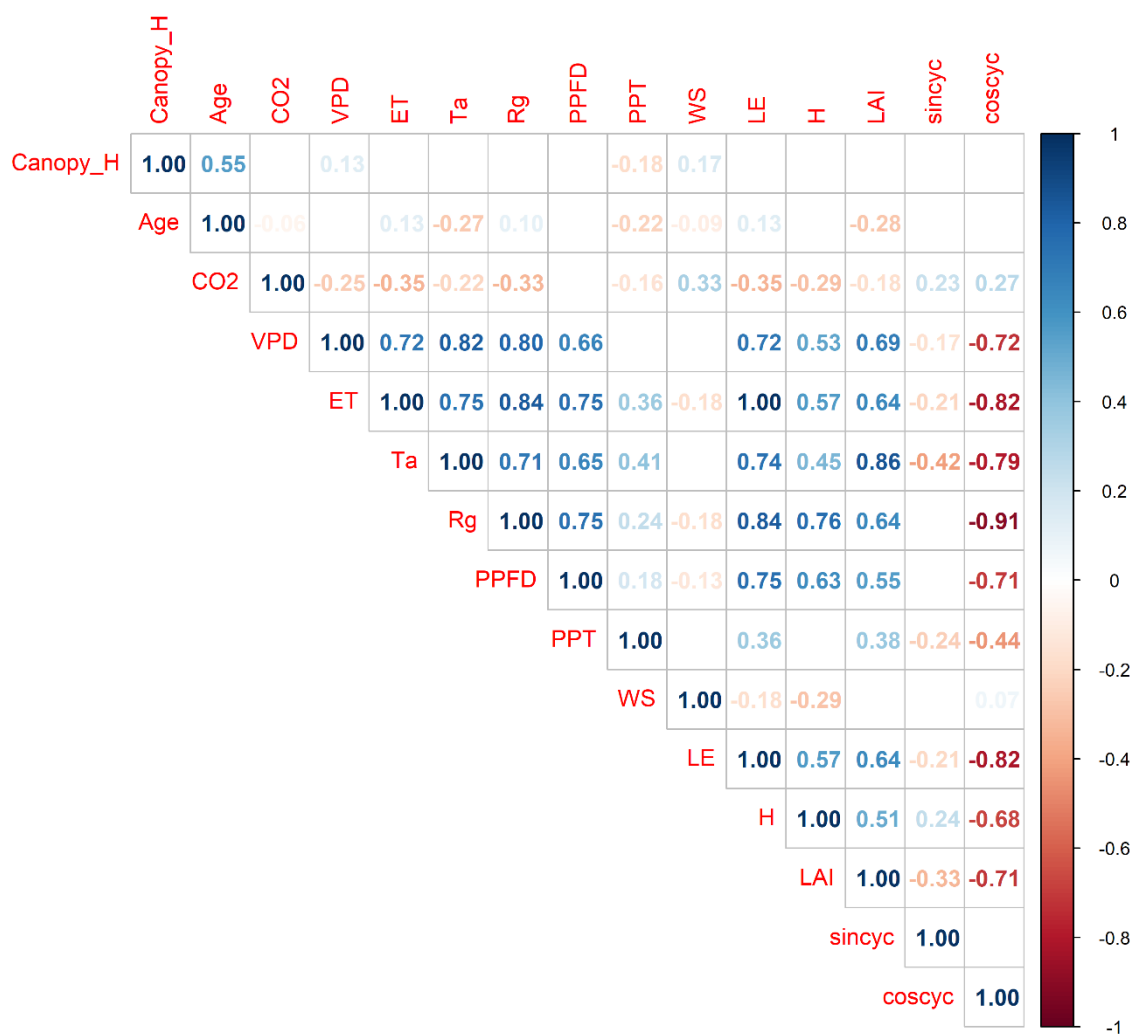


Figure S1 Spearman correlation matrix for monthly biotic and abiotic variables. Numbers in the cells indicate correlation coefficients. Empty cells indicate insignificant correlations ($P > 0.05$). Canopy_H: canopy height. CO2: CO2 concentration. VPD: vapor pressure deficit. ET: evapotranspiration. Ta: air temperature. Rg: global radiation. PPFD: photosynthetic photon flux density. PPT: precipitation. WS: wind speed. LE: latent heat flux. H: sensible heat flux. LAI: leaf area index. sincyc: sine seasonal cycle. coscyc: cosine seasonal cycle.

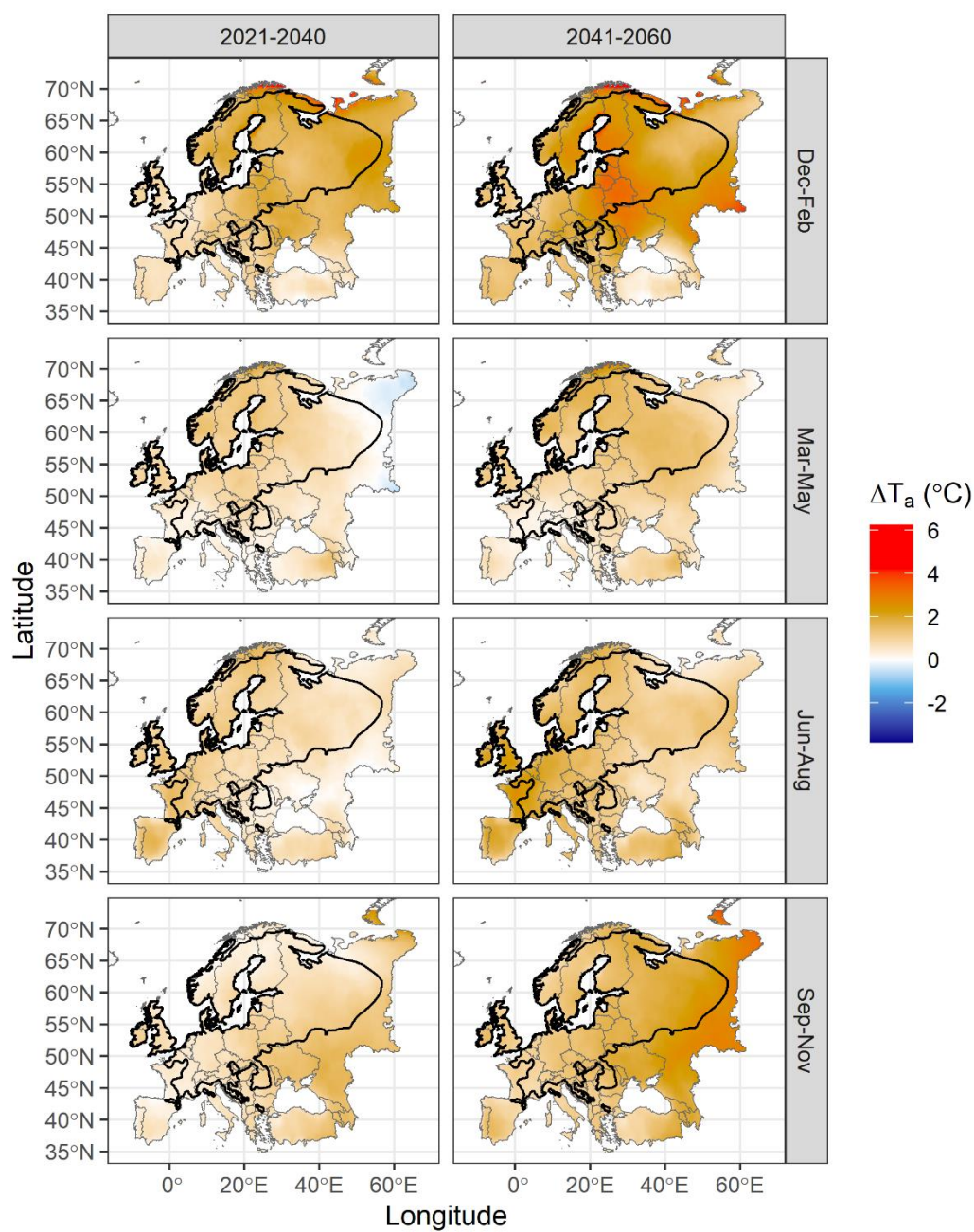


Figure S2 Air temperature changes (ΔT_a) in 2021-2040 and 2041-2060 under the SSP2-4.5 scenario as compared to the temperature in 2010-2018. The regions with Norway spruce distributions are marked with black lines.