Ecography

E4873

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Appendix 1. Source references to build tree richness maps for North America (1) and Europe (2).

1. North America

The database comprises 676 North American tree species (defined as any woody plant growing to ≥4 m anywhere in its range). Range maps were available for every species and were taken primarily from Little (1971), supplemented with Elias (1980) and Hosie (1990).

North American refrences:

Elias, T. S. 1980. The complete trees of North America. – Reinhold, New York.
Little, E. J. Jr 1971. Atlas of United States trees Vols 1–5. – US Govt. Printing Office, Washington, DC.
Hosie, R. C. 1990. Native trees of Canada. – Fitzhenry and Whiteside, Markham, Notario.

2. Europe

Plant families and their 187 tree species native to western Europe were included. For each species, the "source type" code indicates whether its range map was established by digitizing published maps ("m"), through written descriptions of its distribution ("d"), or by combining both methods ("m/d") when published maps only covered its range partially (see references included in the last column and below the Table). Complete and partial range maps were used for 158 (84.5%), and 9 (5%) species, respectively; and written descriptions of range distributions for 20 (11%) species. The latter were converted into maps following a three step process. First, we checked the digital version of Flora Europaea (ref. 28) to know the countries in which each species was present. Second, we searched national and regional floras, as well as the electronic database EUNIS (ref. 8) for written descriptions of the presence of each species in specific areas and localities. And third, we reconstructed the range distribution map of the species by taking into account these informations. For one species (*Arbutus andrachne*) it was necessary to take into account its habitats combined with the CORINE Land Cover database (ref. 9) to attain a finer picture of its distribution.

Family	Genus	Species	Source type	References
Aceraceae	*Acer*	*campestre*	m	10
Aceraceae	*Acer*	*granatense*	m	10
Aceraceae	*Acer*	*heldreichii*	m	11, 28
Aceraceae	*Acer*	*hyrcanum*	m	11, 28
Aceraceae	*Acer*	*lobelii*	m	10
Aceraceae	*Acer*	*monspessulanum*	m	10
Aceraceae	*Acer*	*obtusatum*	m	10
Aceraceae	*Acer*	*opalus*	m	10
Aceraceae	*Acer*	*platanoides*	m	10
Aceraceae	*Acer*	*pseudoplatanus*	m	10
Aceraceae	*Acer*	*tataricum*	m/d	11, 13, 28
Anacardiaceae	*Pistacia*	*atlantica*	m	11, 28
Anacardiaceae	*Pistacia*	*lentiscus*	m	10
Anacardiaceae	*Pistacia*	*terebinthus*	m	10
Anacardiaceae	*Rhus*	*coriaria*	m	10
Apocynaceae	*Nerium*	*oleander*	d	5, 21, 22, 23, 24, 26, 28
Aquifoliaceae	*Ilex*	*aquifolium*	m	10
Betulaceae	*Alnus*	*cordata*	m	10, 17
Betulaceae	*Alnus*	*glutinosa*	m	10, 17
Betulaceae	*Alnus*	*incana*	m	10, 17
Betulaceae	*Betula*	*pendula*	m	10, 17
Betulaceae	*Betula*	*pubescens*	m	10, 17

Buxaceae	*Buxus*	*balearica*	m	4, 28
Buxaceae	*Buxus*	*sempervirens*	m	10
Caprifoliaceae	*Sambucus*	*nigra*	m	10
Celastraceae	*Euonymus*	*europaeus*	m	10
Celastraceae	*Euonymus*	*latifolius*	m	10
Cornaceae	*Cornus*	*mas*	m	10
Corylaceae	*Carpinus*	*betulus*	m	10, 17
Corylaceae	*Carpinus*	*orientalis*	m	17
Corylaceae	*Corylus*	*colurna*	m	10, 17
Corylaceae	*Corylus*	*maxima*	m	10, 17
Corylaceae	*Ostrya*	*carpinifolia*	m	10, 17
Cupressaceae	*Cupressus*	*sempervirens*	m	10, 17
Cupressaceae	*Juniperus*	*communis*	m	10, 17
Cupressaceae	*Juniperus*	*drupacea*	m	18
Cupressaceae	*Juniperus*	*excelsa*	m	10, 17
Cupressaceae	*Juniperus*	*foetidissima*	m	10, 17
Cupressaceae	*Juniperus*	*navicularis*	d	6, 28
Cupressaceae	*Juniperus*	*oxycedrus*	m	10, 17
Cupressaceae	*Juniperus*	*phoenicea*	m	10, 17
Cupressaceae	*Juniperus*	*thurifera*	m	10, 17
Cupressaceae	*Tetraclinis*	*articulata*	m	10, 17
Elaeagnaceae	*Hippophae*	*rhamnoides*	m	10
Ericaceae	*Arbutus*	*andrachne*	d	8, 9, 12, 21, 28
Ericaceae	*Arbutus*	*unedo*	m	10
Ericaceae	*Erica*	*arborea*	m	10
Ericaceae	*Vaccinium*	*arctostaphylos*	d	8, 28
Fagaceae	*Castanea*	*sativa*	m	10, 17
Fagaceae	*Fagus*	*sylvatica* + subsp. *orientalis*	m	10, 17
Fagaceae	*Quercus*	*canariensis*	m	10, 17
Fagaceae	*Quercus*	*cerris*	m	10, 17
Fagaceae	*Quercus*	*coccifera*	m	10, 17
Fagaceae	*Quercus*	*congesta*	m	10, 17
Fagaceae	*Quercus*	*dalechampii*	m	10
Fagaceae	*Quercus*	*faginea*	m	10, 17
Fagaceae	*Quercus*	*frainetto*	m	10, 17
Fagaceae	*Quercus*	*hartwissiana*	m	17
Fagaceae	*Quercus*	*ilex*	m	10, 17
Fagaceae	*Quercus*	*macrolepis*	m	10, 17
Fagaceae	*Quercus*	*mas*	m	19
Fagaceae	*Quercus*	*pedunculiflora*	m	10, 17
Fagaceae	*Quercus*	*petraea*	m	10, 17
Fagaceae	*Quercus*	*polycarpa*	m	10
Fagaceae	*Quercus*	*pubescens*	m	10, 17
Fagaceae	*Quercus*	*pyrenaica*	m	10, 17
Fagaceae	*Quercus*	*robur*	m	10, 17
Fagaceae	*Quercus*	*suber*	m	10, 17
Fagaceae	*Quercus*	*trojana*	m	10, 17
Hippocastanaceae	*Aesculus*	*hippocastanum*	m	10
Juglandaceae	*Juglans*	*regia*	m	10, 17
Lauraceae	*Laurus*	*nobilis*	m	10, 17
Leguminosae	*Ceratonia*	*siliqua*	m	10
Leguminosae	*Cercis*	*siliquastrum*	m	10
Leguminosae	*Laburnum*	*alpinum*	m	10
Leguminosae	*Laburnum*	*anagyroides*	m	10
Moraceae	*Ficus*	*carica*	m	10, 17
Oleaceae	*Fraxinus*	*angustifolia*	m	10
Oleaceae	*Fraxinus*	*excelsior*	m	10
Oleaceae	*Fraxinus*	*ornus*	m	10
Oleaceae	*Fraxinus*	*pallisiae*	m	11, 28
Oleaceae	*Olea*	*europaea*	m	10
Oleaceae	*Phillyrea*	*latifolia*	m	10
Oleaceae	*Syringa*	*josikaea*	d	2, 28
Oleaceae	*Syringa*	*vulgaris*	m	10

Pinaceae	*Abies*	*alba*	m	10, 17
Pinaceae	*Abies*	*cephalonica*	m	10, 17
Pinaceae	*Abies*	*pinsapo*	m	10, 17
Pinaceae	*Abies*	*sibirica*	m	10, 17
Pinaceae	*Larix*	*decidua*	m	10, 17
Pinaceae	*Larix*	*sibirica*	m	10, 17
Pinaceae	*Picea*	*abies*	m	10, 17
Pinaceae	*Picea*	*omorika*	m	10, 17
Pinaceae	*Pinus*	*cembra*	m	10, 17
Pinaceae	*Pinus*	*halepensis*	m	10, 17
Pinaceae	*Pinus*	*heldreichii* + var. *leucodermis*	m	10, 17
Pinaceae	*Pinus*	*nigra*	m	10, 17
Pinaceae	*Pinus*	*peuce*	m	10, 17
Pinaceae	*Pinus*	*pinaster*	m	10, 17
Pinaceae	*Pinus*	*pinea*	m	10, 17
Pinaceae	*Pinus*	*sylvestris*	m	10, 17
Pinaceae	*Pinus*	*uncinata*	m	10, 17
Platanaceae	*Platanus*	*orientalis*	m	20
Rhamnaceae	*Frangula*	*alnus*	m	10
Rhamnaceae	*Rhamnus*	*catharticus*	m	10
Rosaceae	*Cotoneaster*	*granatensis*	d	6, 28
Rosaceae	*Crataegus*	*calycina*	m	16, 28
Rosaceae	*Crataegus*	*laciniata*	d	1, 6, 8, 12, 27, 28
Rosaceae	*Crataegus*	*monogyna*	m	10
Rosaceae	*Crataegus*	*nigra*	d	1, 3, 7, 14, 25, 26, 28
Rosaceae	*Crataegus*	*pentagyna*	d	1, 2, 7, 14, 26, 28
Rosaceae	*Malus*	*dasyphylla*	d	1, 2, 7, 12, 25, 26, 27, 28
Rosaceae	*Malus*	*florentina*	m/d	13, 22, 28
Rosaceae	*Malus*	*sylvestris*	m	10
Rosaceae	*Mespilus*	*germanica*	m	10
Rosaceae	*Prunus*	*avium*	m	10
Rosaceae	*Prunus*	*brigantina*	m/d	5, 22, 28
Rosaceae	*Prunus*	*cerasifera*	m	10
Rosaceae	*Prunus*	*cocomilia*	m/d	8, 22, 28
Rosaceae	*Prunus*	*domestica*	m	11, 28
Rosaceae	*Prunus*	*laurocerasus*	m/d	11, 13, 28
Rosaceae	*Prunus*	*lusitanica*	m	10
Rosaceae	*Prunus*	*mahaleb*	m	10
Rosaceae	*Prunus*	*padus*	m	10
Rosaceae	*Prunus*	*webbii*	m	22, 28
Rosaceae	*Pyrus*	*amygdaliformis*	m	10
Rosaceae	*Pyrus*	*austriaca*	d	14, 15, 28
Rosaceae	*Pyrus*	*bourgaeana*	m/d	6, 11, 28
Rosaceae	*Pyrus*	*cordata*	m	10
Rosaceae	*Pyrus*	*elaeagrifolia*	m	11, 28
Rosaceae	*Pyrus*	*magyarica*	d	26, 28
Rosaceae	*Pyrus*	*nivalis*	m/d	1, 3, 13, 15, 22, 23, 25, 26, 28
Rosaceae	*Pyrus*	*pyraster*	m	13, 28
Rosaceae	*Sorbus*	*aria*	m	10
Rosaceae	*Sorbus*	*aucuparia*	m	10
Rosaceae	*Sorbus*	*austriaca*	d	13, 28
Rosaceae	*Sorbus*	*dacica*	d	2, 28
Rosaceae	*Sorbus*	*domestica*	m	10
Rosaceae	*Sorbus*	*graeca*	d	1, 2, 3, 12, 13, 15, 25, 27, 28
Rosaceae	*Sorbus*	*hybrida*	m	16, 28
Rosaceae	*Sorbus*	*intermedia*	m	10
Rosaceae	*Sorbus*	*latifolia*	d	1, 6, 13, 23, 28
Rosaceae	*Sorbus*	*meinichii*	m	16, 28
Rosaceae	*Sorbus*	*mougeotii*	m/d	11, 13, 28
Rosaceae	*Sorbus*	*torminalis*	m	10
Rosaceae	*Sorbus*	*umbellata*	m	11, 28
Salicaceae	*Populus*	*alba*	m	10, 17
Salicaceae	*Populus*	*canescens*	m	10, 17

Salicaceae	*Populus*	*nigra*	m	10, 17
Salicaceae	*Populus*	*tremula*	m	10, 17
Salicaceae	*Salix*	*acutifolia*	m	10, 17
Salicaceae	*Salix*	*aegyptiaca*	m	10, 17
Salicaceae	*Salix*	*alba*	m	10, 17
Salicaceae	*Salix*	*appendiculata*	m	10, 17
Salicaceae	*Salix*	*atrocinerea*	m	10, 17
Salicaceae	*Salix*	*borealis*	m	10
Salicaceae	*Salix*	*caprea*	m	10, 17
Salicaceae	*Salix*	*daphnoides*	m	10, 17
Salicaceae	*Salix*	*fragilis*	m	10, 17
Salicaceae	*Salix*	*pedicellata*	m	10, 17
Salicaceae	*Salix*	*pentandra*	m	10, 17
Salicaceae	*Salix*	*pyrolifolia*	m	10, 17
Salicaceae	*Salix*	*salviifolia*	m	10, 17
Salicaceae	*Salix*	*triandra*	m	10, 17
Salicaceae	*Salix*	*viminalis*	m	17
Salicaceae	*Salix*	*xerophila*	m	10, 17
Styracaceae	*Styrax*	*officinalis*	m	11, 28
Tamaricaceae	*Tamarix*	*africana*	m	10
Tamaricaceae	*Tamarix*	*boveana*	m	10
Tamaricaceae	*Tamarix*	*canariensis*	m	10
Tamaricaceae	*Tamarix*	*dalmatica*	m/d	8, 22, 28
Tamaricaceae	*Tamarix*	*gallica*	m	10
Tamaricaceae	*Tamarix*	*hampeana*	d	8, 12, 28
Tamaricaceae	*Tamarix*	*parviflora*	d	12, 28
Tamaricaceae	*Tamarix*	*smyrnensis*	d	2, 8, 12, 28
Tamaricaceae	*Tamarix*	*tetrandra*	d	8, 12, 28
Taxaceae	*Taxus*	*baccata*	m	10, 17
Tiliaceae	*Tilia*	*cordata*	m	10
Tiliaceae	*Tilia*	*platyphyllos*	m	10
Tiliaceae	*Tilia*	*rubra*	m	11, 28
Tiliaceae	*Tilia*	*tomentosa*	m	11, 28
Ulmaceae	*Celtis*	*australis*	m	10, 17
Ulmaceae	*Celtis*	*caucasica*	m	10, 17
Ulmaceae	*Celtis*	*tournefortii*	m	10, 17
Ulmaceae	*Ulmus*	*glabra*	m	10, 17
Ulmaceae	*Ulmus*	*laevis*	m	10, 17
Ulmaceae	*Ulmus*	*minor* + subsp. *canescens* + *procera*	m	10, 17

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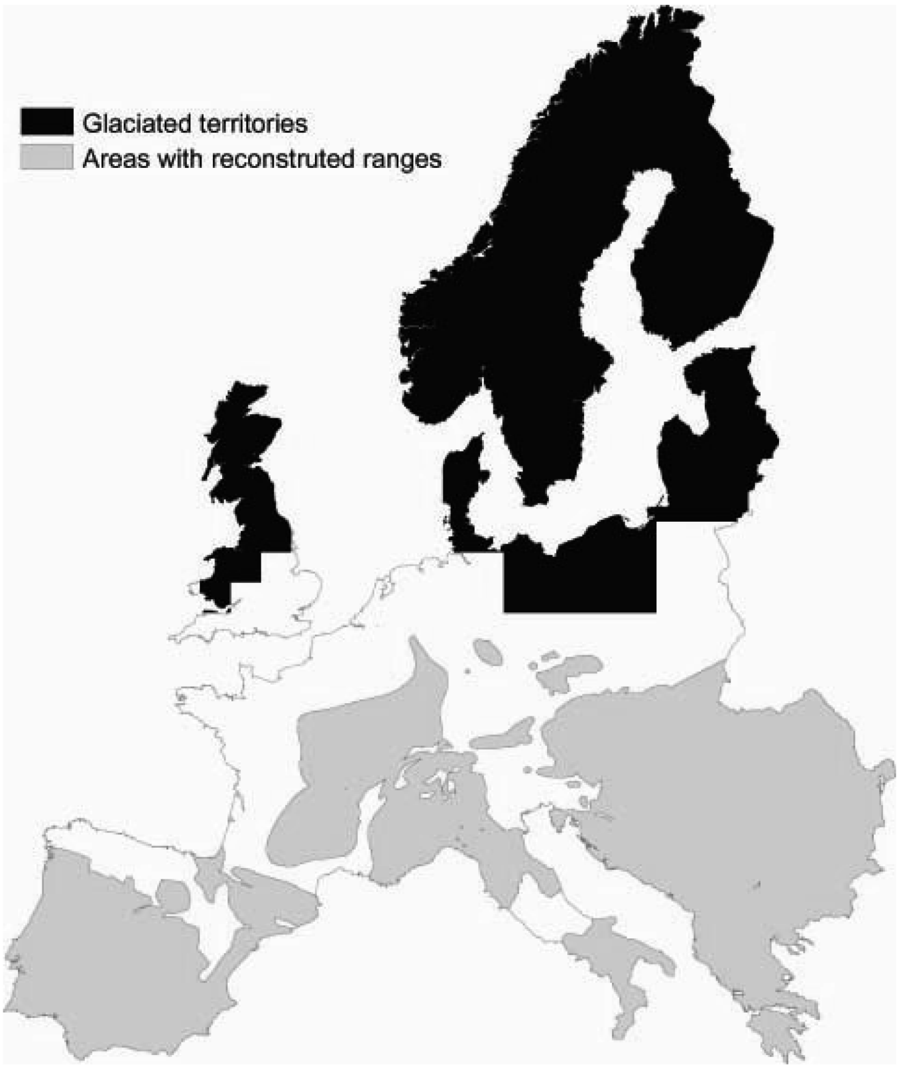

Fig. 1. European territories covered by ice during the last Pleistocene glaciation and areas including tree species for which only partial range maps (*Acer tataricum, Malus florentina, Prunus brigantina, P. cocomilia, P. laurocerasus, Pyrus bourgaeana, P. nivalis, Sorbus mougeotii, Tamarix dalmatica*), or no maps were found (*Arbutus andrachne, Cotoneaster granatensis, Crataegus laciniata, C. nigra, C. pentagyna, Juniperus navicularis, Malus dasyphylla, Nerium oleander, Pyrus austriaca, P. magyarica, Sorbus austriaca, S. dacica, S. graeca, S. latifolia, Syringa josikaea, Tamarix hampeana, T. parviflora, T. smyrnensis, T. tetrandra, Vaccinium arctostaphylos*). The range maps of these species were drawn by taking into account published descriptions of their areas of distribution. This was not necessary for any of the tree species present in the glaciated territories, as for all of them a complete range map was found in the literature.

Appendix 2. Coefficients of regression models.

Table 1. Summary of regression models for tree richness using four modelling frameworks. The best model under each framework not including cell age is given, coupled with the equivalent model after adding cell age.

Model type	Predictors in model					
A) Glaciated regions						
RWEM1	0.724*Rainfall	–0.740*minPET$_{Th}$	0.486*minPET$_{Th}^{2}$			
	0.548*Rainfall	–0.590*minPET$_{Th}$	0.295*minPET$_{Th}^{2}$	0.445*Age		
RWEM2	0.731*Rainfall	–0.740*minPET$_{Th}$	0.482*minPET$^{2}_{Th}$	0.064*Ln(ER)		
	0.551*Rainfall	–0.590*minPET$_{Th}$	0.295*minPET$^{2}_{Th}$	0.024*Ln(ER)	0.443*Age	
F&C	–0.530*WD	0.518*PET$_{PT}$	0.600*PET$^{2}_{PT}$			
	–0.480*WD	0.386*PET$_{PT}$	0.578*PET$^{2}_{PT}$	0.278*Age		
ad hoc	0.229*Rainfall	0.443*PET$_{PT}$	0.133*PET$^{2}_{PT}$	0.089*Ln(ER)	0.207*PGS	
	0.238*Rainfall	0.422*PET$_{PT}$	0.110*PET$^{2}_{PT}$	0.039*Ln(ER)	0.067*PGS	0.238*Age
B) Entire regions						
RWEM1	0.791*Rainfall	0.204*maxPET$_{Th}$	–0.130*maxPET$^{2}_{Th}$			
	0.710*Rainfall	0.234*maxPET$_{Th}$	–0.180*maxPET$^{2}_{Th}$	0.207*Age		
RWEM2	0.820*Rainfall	0.293*maxPET$_{Th}$	–0.210*maxPET$^{2}_{Th}$	0.122*Ln(ER)		
	0.736*Rainfall	0.289*maxPET$_{Th}$	–0.230*maxPET$^{2}_{Th}$	0.079*Ln(ER)	0.188*Age	
F&C	–0.730*WD	1.510*PET$_{PT}$	–0.350*PET$^{2}_{PT}$			
	–0.730*WD	1.340*PET$_{PT}$	–0.250*PET$^{2}_{PT}$	0.145*Age		
ad hoc	0.650*Rainfall	0.781*PET$_{PT}$	–0.450*PET$^{2}_{PT}$			
	0.612*Rainfall	0.715*PET$_{PT}$	–0.420*PET$^{2}_{PT}$	0.060*Age		

Table 2. Summary of regression models for tree richness in the glaciated parts of Europe and North America, using four modelling frameworks. The best model under each framework not including cell age is given, coupled with the equivalent model after adding cell age.

Model type	Predictors in model						
A) Glaciated Europe							
RWEM1	–0.350*Rainfall	–0.950*maxPET$_{Th}$					
	–0.400*Rainfall	–0.650*maxPET$_{Th}$	0.553*Age				
RWEM2	–0.440*Rainfall	–4.200*maxPET$_{Th}$	3.200*maxPET$^{2}_{Th}$		–0.470*Ln(ER)		
	–0.400*Rainfall	–2.300*maxPET$_{Th}$	1.500*maxPET$^{2}_{Th}$		–0.290*Ln(ER)	0.368*Age	
F&C	0.086*WD	0.036*PET$_{PT}$	0.757*PET$^{2}_{PT}$				
	0.022*WD	0.284*PET$_{PT}$	0.296*PET$^{2}_{PT}$	0.369*Age			
ad hoc	–0.200*Rainfall	–0.450*TempRange	0.755*PET$_{PT}$				
	–0.180*Rainfall	–0.300*TempRange	0.615*PET$_{PT}$	0.273*Age			
B) Glaciated North America							
RWEM1	0.703*Rainfall	–0.130*minPET$_{Th}$					
	0.534*Rainfall	–0.120*minPET$_{Th}$	0.478*Age				
RWEM2	0.706*Rainfall	–0.130*minPET$_{Th}$	0.056*Ln(ER)				
	0.520*Rainfall	–0.120*minPET$_{Th}$	–0.080*Ln(ER)	0.501*Age			
F&C	–0.520*WD	0.625*PET$_{PT}$	0.492*PET$^{2}_{PT}$				
	–0.480*WD	0.433*PET$_{PT}$	0.524*PET$^{2}_{PT}$	0.246*Age			
ad hoc	0.093*Rainfall	0.386*PET$_{PT}$	0.551*PET$^{2}_{PT}$	–0.430*WD	0.095*Ln(ER)	0.109*PGS	
	0.132*Rainfall	0.356PET$_{PT}$	0.480*PET$^{2}_{PT}$	–0.410*WD	0.021*Ln(ER)	0.003*PGS	0.243*Age

Table 1, 2. Legend and model coefficients.
Predictors: rainfall = total precipitation in months when mean temperature >0°C; maxPET$_{Th}$ = maximum monthly potential evapotranspiration (Thornwaite's formula); minPET$_{Th}$ = minimum monthly potential evapotranspiration (Thornwaite's formula); ER = Elevation Range (O'Brien 1993, 1998; Field et al. 2005); PET$_{PT}$ = annual potential evapotranspiration (Presley-Taylor formula); WD = Water deficit (Francis and Currie 2003); PGS = Potential growing season (O'Brien 1993, 1998); TempRange = Annual Temperature Range (Currie and Paquin 1987, Adams and Woodward 1989); Age = number of years cell exposed after glacial retreat; RWEM1 = Regional Water-Energy Models (O'Brien 1998, Field et al. 2005); F&C = The water-energy model of Francis and Currie (Francis and Currie 2003).

Essentially, the relationship between tree richness and water and energy is positive across Europe and North America (Table 1B), with higher energy-water inputs increasing richness levels: highest richness is found in hot and wet areas. Water deficit is negatively related to tree richness, indicating that water stress constraints the number of species. Elevation range, a measure of the mesoscale vertical climatic variation, is positively associated to richness, given that highly heterogeneous regions encompass more species. For glaciated regions together and glaciated North America (Tables 1A, 2B), these relationships hold except for $minPET_{Th}$, which has negative coefficients. We believe this is because $minPET_{Th}$ represents the energy of the coldest month and above a certain line of latitude its value drops to zero. This is the likely reason why RWEMs generally perform worst in our study areas. PGS reflects favourable conditions for trees to grow and reproduce and is positively associated to tree richness in the models. Glaciated Europe (Table 2A) shows some intriguing coefficients which differ from the general pattern. Rainfall is negatively associated with richness. That tree richness at higher latitudes is not restricted by water but energy is commonly argued, but North America indeed has positive rainfall coefficients. One possible explanation is that different climatic patterns between the continents result in trees growing in glaciated Europe more stressed by excessive water and flooded soils. This is supported by the WD coefficients: richness increases with WD, in contrast to glaciated North America. Also, historical factors might be driving richness in glaciated Europe more strongly than in glaciated North America, as paleoecological studies have shown. $MaxPET_{Th}$ also has negative coefficients. We believe $maxPET_{Th}$ is not a good energy measure (it measures energy in the warmest month); in fact, a positive relationship between energy and tree richness is shown in F&C model, which uses PET_{PT} instead of $maxPET_{Th}$, and the F&C model globally performs better than RWEMs in temperate regions. Elevation range is negatively associated with tree richness. In northern regions, high altitudes represent cold conditions unfavourable to tree's growth, and elevation range consequently relates negatively to richness. Although ln(ER) has positive coefficients in glaciated North America (Table 2B) and across both glaciated regions (Table 1A), its coefficients are very low, even shifting to negative values (RWEM2 + Age, Table 2B). Range in elevation may have more influence on tree richness at more local scales. Age is positively associated with tree richness in every model and region analyzed (Tables 1, 2), indicating that longer times of land availability for trees (free of ice) are associated with higher richness.

Appendix 3. Tree richness distribution for Europe and North America at 110 km^2 grain. Scale is provided.