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EcoTWIN 1.0: a fully distributed tracer-aided ecohydrological model tracking water, isotopes, and nutrients

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16

17 **Tables**

18 Table S1. The parameters in EcoTWIN 1.0.

Parameters	Description	Dependency	Unit	Min	Max
d_3	Depth of soil layer 3	Global	m	0.2	2
α	Coefficient for canopy storage estimation	Land use	-	1e-5	5e-2
rE	Extinction coefficient for PE/PT seperation	Land use	-	-3	-0.1
w_{irr}	The coefficient for irrigation water deficit	Land use	-	1e-2	1
$Thre_{SN}$	Temperature threshold for snow/rain separation	Soil	°C	-5	5
dd_{min}	Minimum of degree day factor	Soil	-	0	2e-3
dd_{max}	Maximum of degree day factor	Soil	-	2e-3	1e-2
dd_{inc}	Increase in degree-day factor based on temperature	Soil	-	0.1	0.9
$\theta_{s,ref}$	Reference porosity	Soil	-	0.3	0.99
$PTF_{VG,clay}$	Pedotransfer function parameter to estimate porosity from clay content	Soil	-	5e-8	5e-3
$PTF_{VG,BDdd}$	Pedotransfer function parameter in for estimate porosity from bulk density	Soil	-	5e-4	5e-1
Ks_{ref}	Pedotransfer function parameter linked to reference hydraulic conductivity	Soil	-	-3	-0.1
$PTF_{Ks,sand}$	Pedotransfer function parameter to estimate hydraulic conductivity from sand content	Soil	-	6e-3	3e-2
$PTF_{Ks,clay}$	Pedotransfer function parameter to estimate hydraulic conductivity from clay content	Soil	-	3e-3	2e-2
SWP	Soil water potential for field capacity estimation	Soil	kPa	10	33
w_{Ks}	Anisotropy ratio of vertical to horizontal Ks	Soil	-	1e-2	0.9
ψ	Soil air entry pressure	Soil	m/s	1e-2	1.3
β	Exponential parameter links percolation to the extent of soil saturation	Soil	-	1	50
γ_{root}	Parameter to estimate the root distribution along soil depths	Land use	-	0.8	0.999
p_{GW}	Weighting parameter for groundwater recharge	Soil	-	1e-6	1
p_{Ovf}	Parameter constraining the channel recharge from overland flow	Soil	-	1e-3	1
p_{Inf}	Parameter constraining the channel recharge from interflow	Soil	-	1e-2	10
p_{GWf}	Parameter constraining the channel recharge from groundwater flow	Soil	-	1e-3	10
K_{vadose}	Dimensionless lateral hydrological conductivity in vadose zone	Soil	-	1e-3	1
K_{GW}	Dimensionless lateral hydrological conductivity in groundwater	Soil	-	1e-9	1
exp_{Inf}	exponential parameter link interflow with vadose storage	Soil	-	1e-2	10
exp_{GW}	exponential parameter link groundwater flow with groundwater storage	Soil	-	1e-5	1
$roughness$	Dimensionless channel roughness	Land use	-	1e-4	10
$SrfMixing$	Mixing ratio between ponding water and top soil water storage	Land use	-	0	1

n	Advection term in diffusion-controlled kinetic isotopic separation	Global	-	0.5	1
$ref_{Dgd,s}$	Reference rates of soil degradation	Land use	g/m^2 S	1e-6	1e-4
$ref_{Minr,s}$	Reference rates of soil mineralisation	Land use	g/m^2 S	1e-4	0.4
$ref_{Deni,s}$	Reference rates of soil denitrification	Land use	g/m^2 S	1e-4	0.8
$ref_{Deni,w}$	Reference rates of in-stream denitrification (dimensionless)	Land use	-	1e-5	1e-1
$p_{\theta,deni}$	Saturation threshold for soil denitrification	Land use	-	0.5	0.85

19

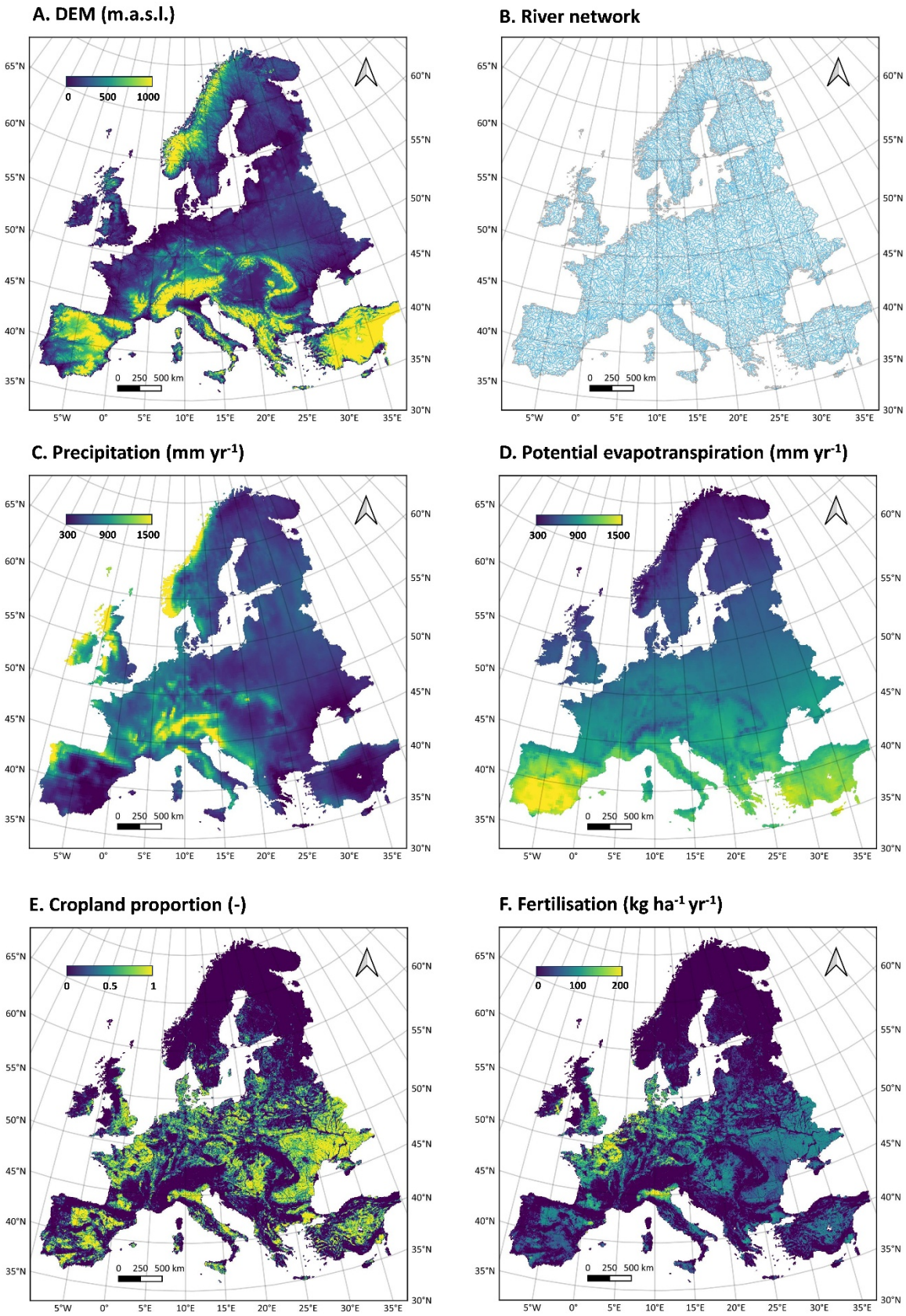

Figure S1. The overview of key geographic (A-B), climatic (C-D), and nitrogen (E-F) inputs for model simulation. Panel C, D, and F show the annual average from 1980 to 2024.

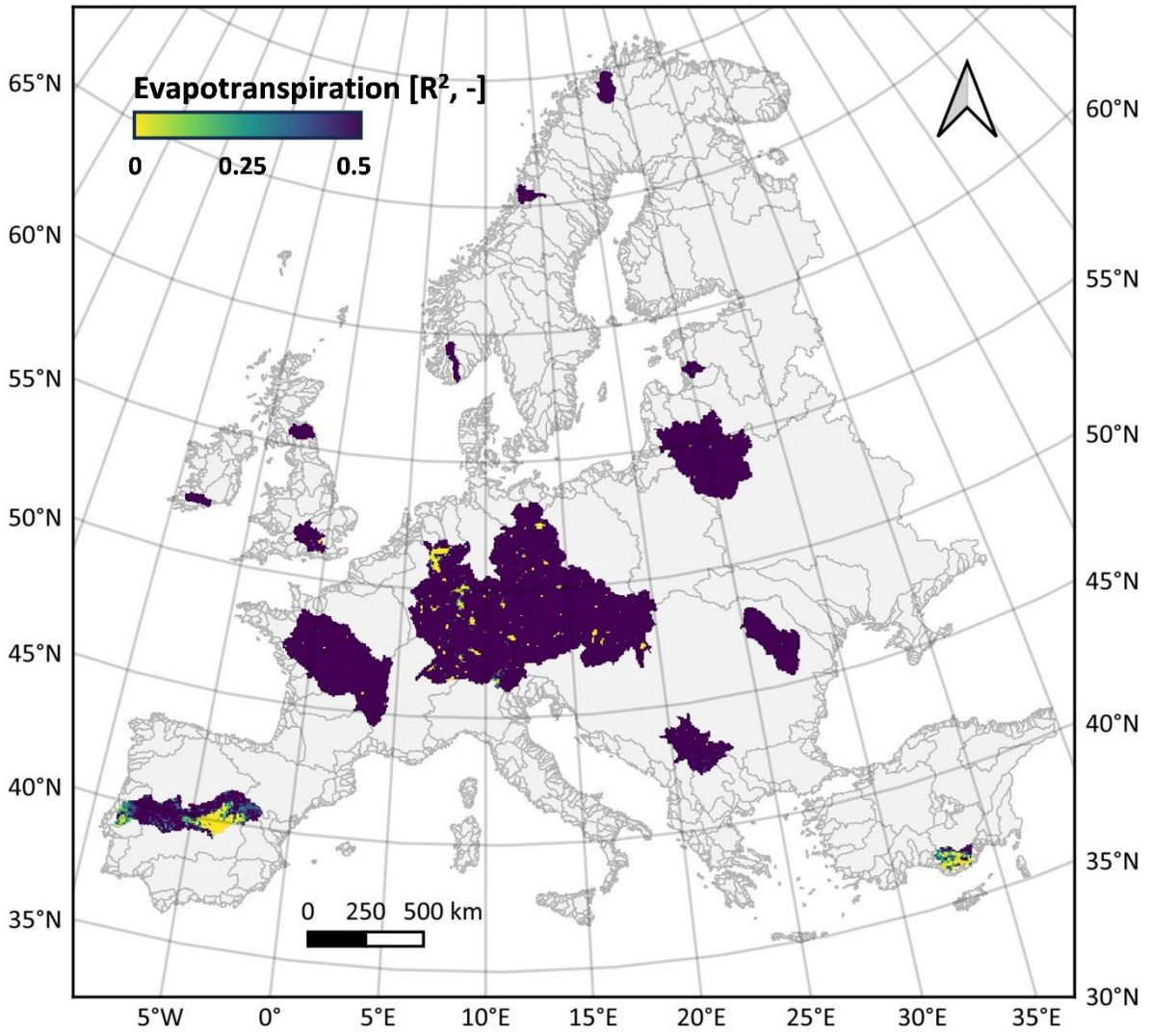

Figure S2. Grid-to-grid comparison between simulated and MODIS evapotranspiration time series, evaluated using coefficient of determination (R^2).

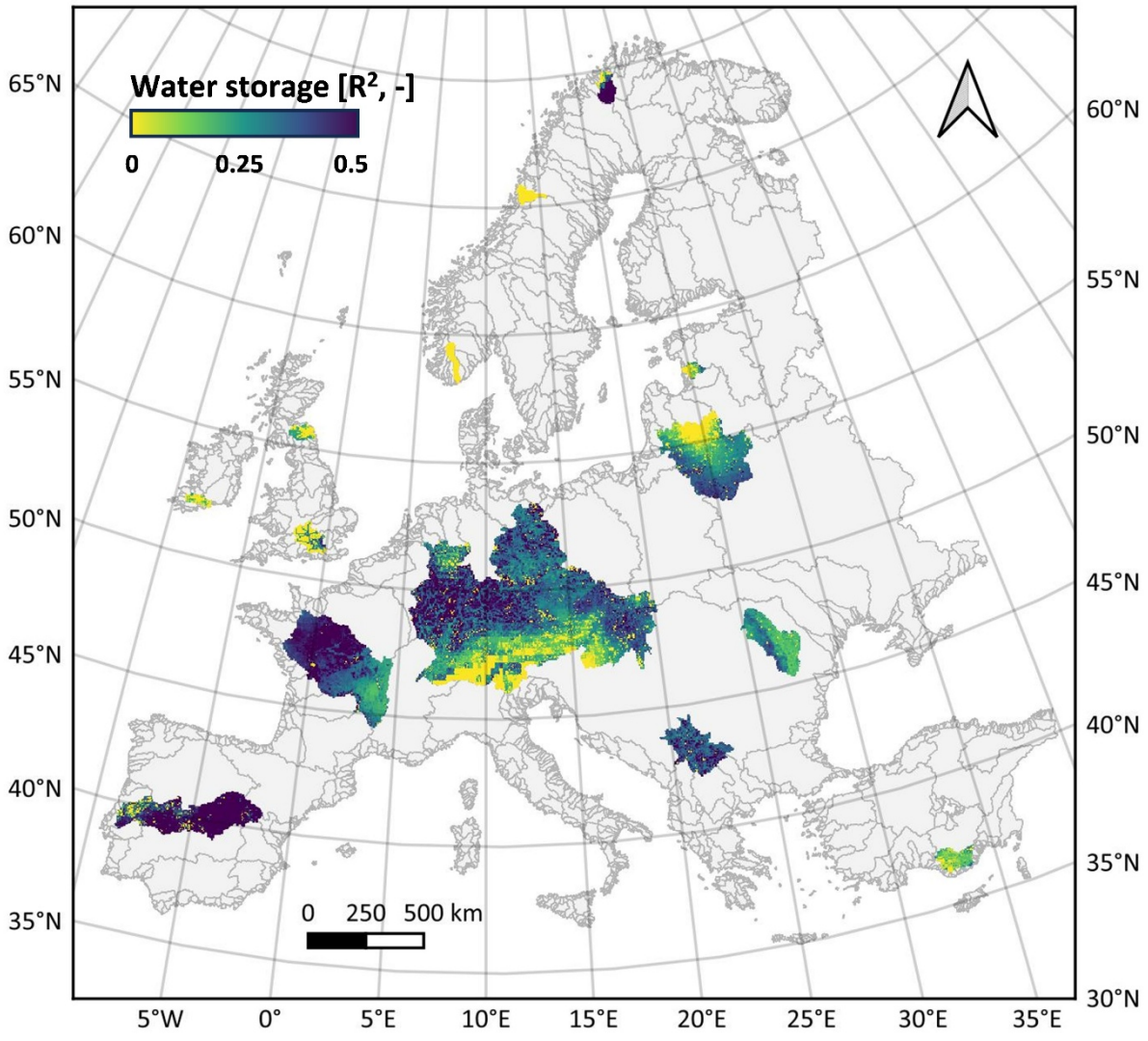

Figure S3. Grid-to-grid comparison between simulated anomaly of water storage and surface water mass anomaly from GRACE, evaluated using the Kling–Gupta efficiency (KGE).

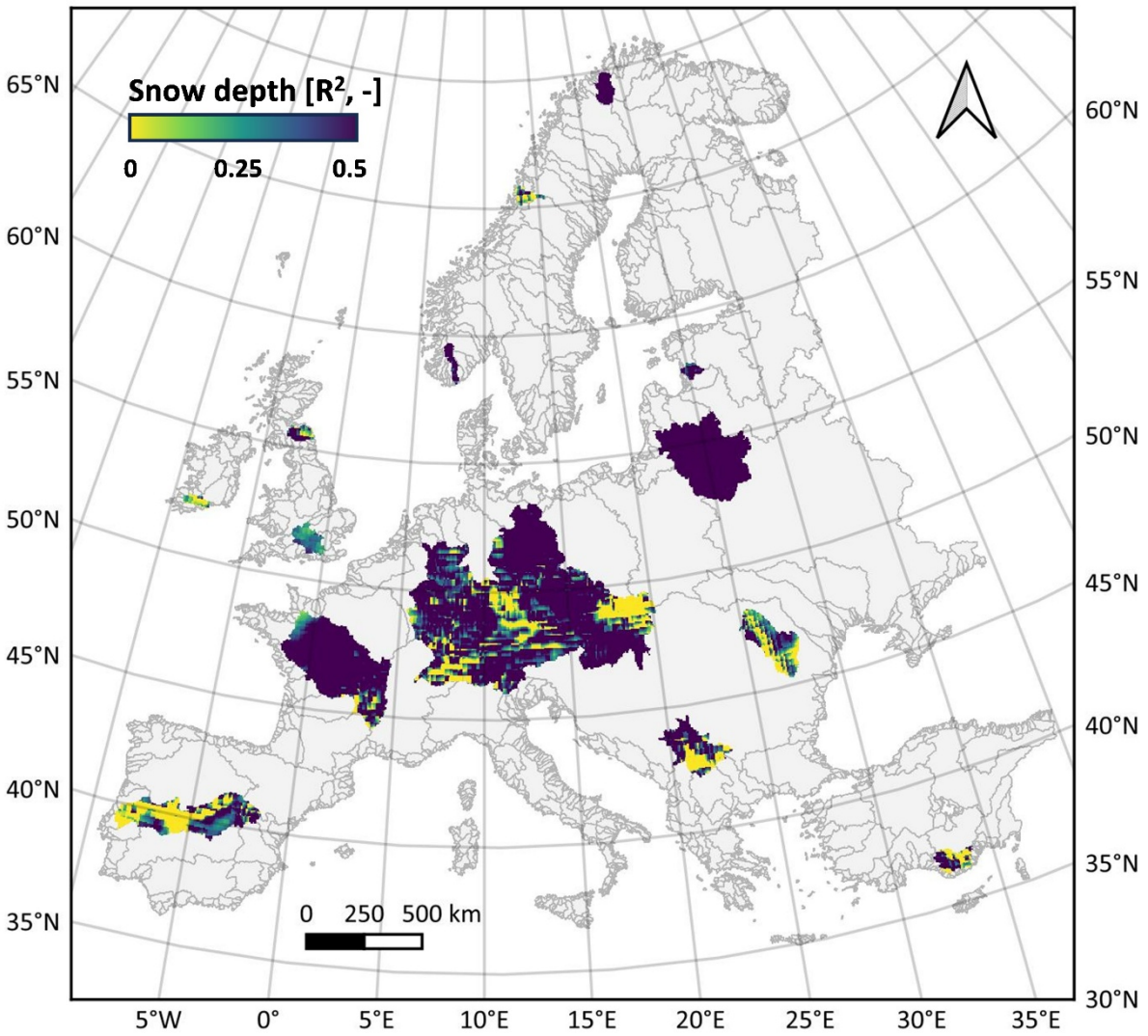

Figure S4. Grid-to-grid comparison between simulated and ERA5 snow depth time series, evaluated using the Kling–Gupta efficiency (KGE).

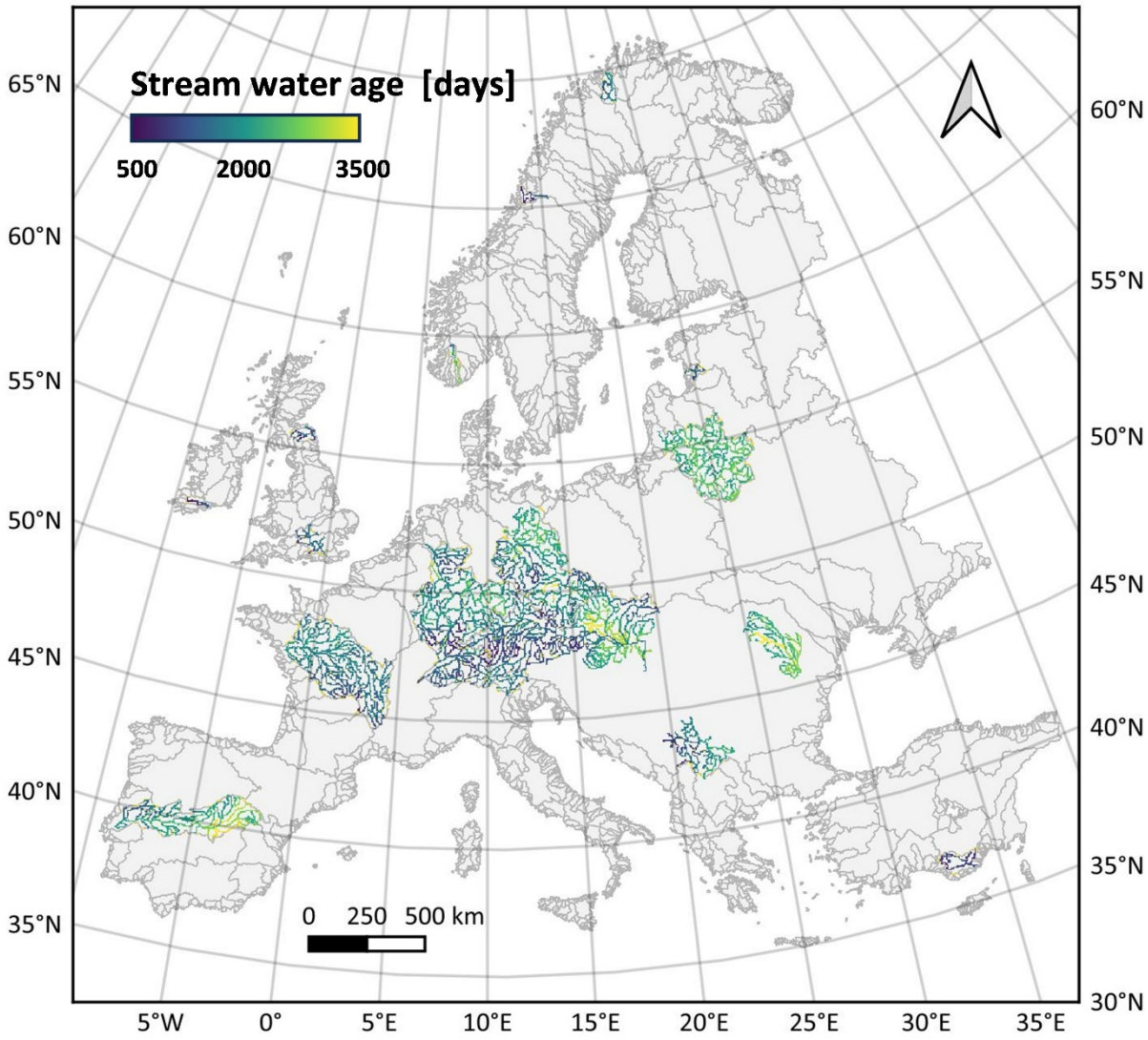

Figure S5. The average of simulated stream water age during 1982-2024.

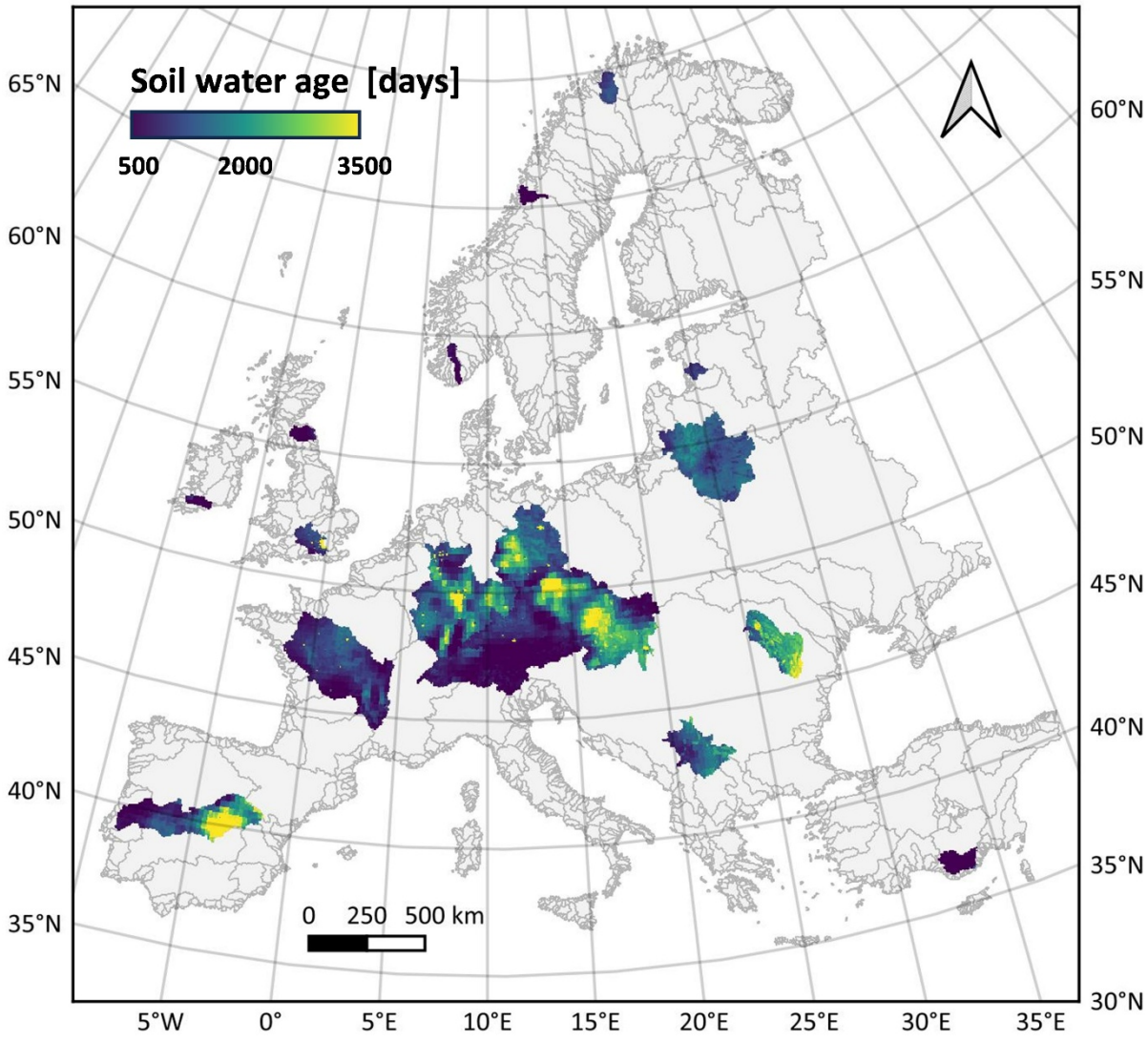

Figure S6. The average of simulated soil water age during 1982-2024.

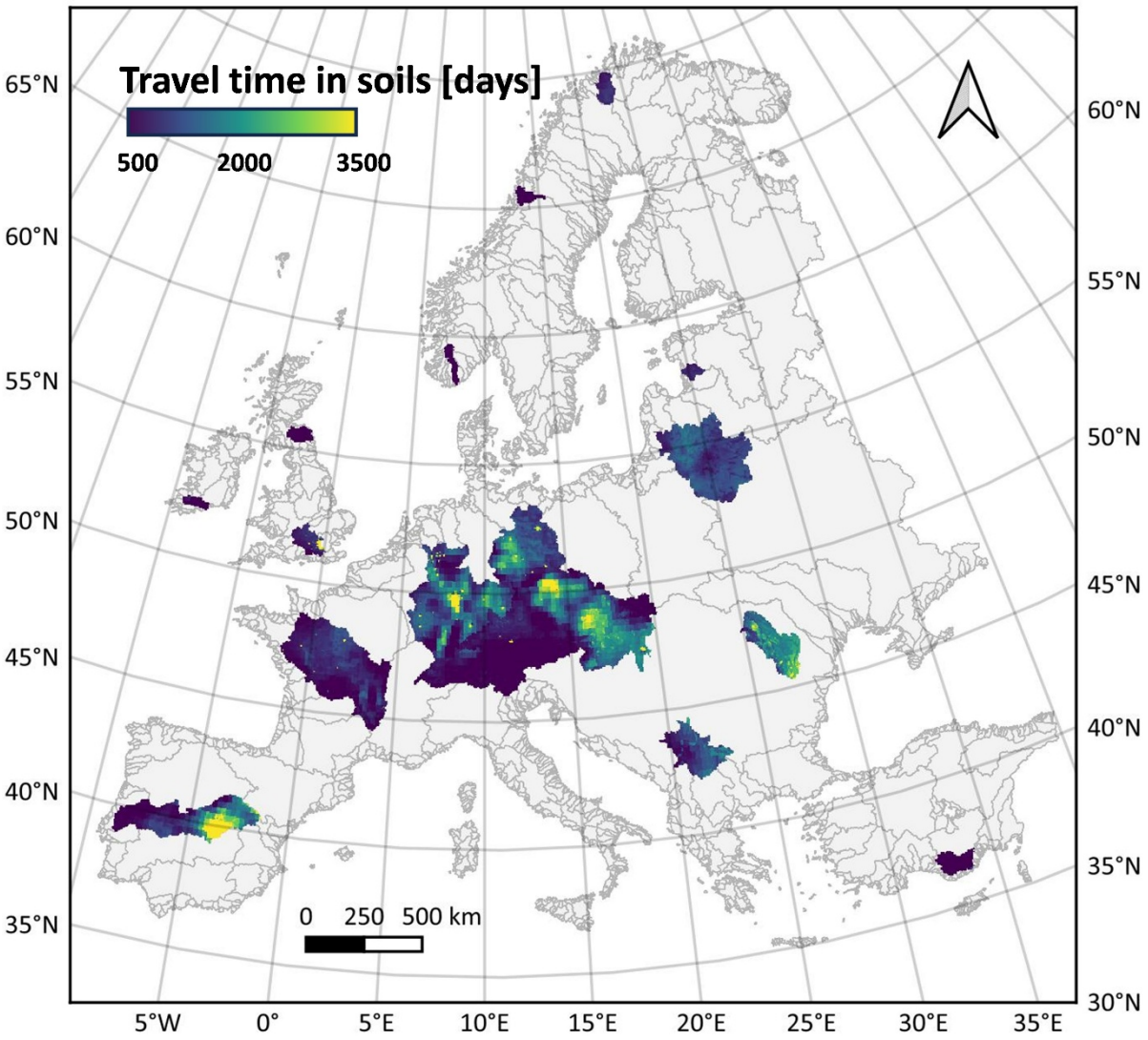

Figure S7. The average of simulated travel time in soil profile during 1982-2024.

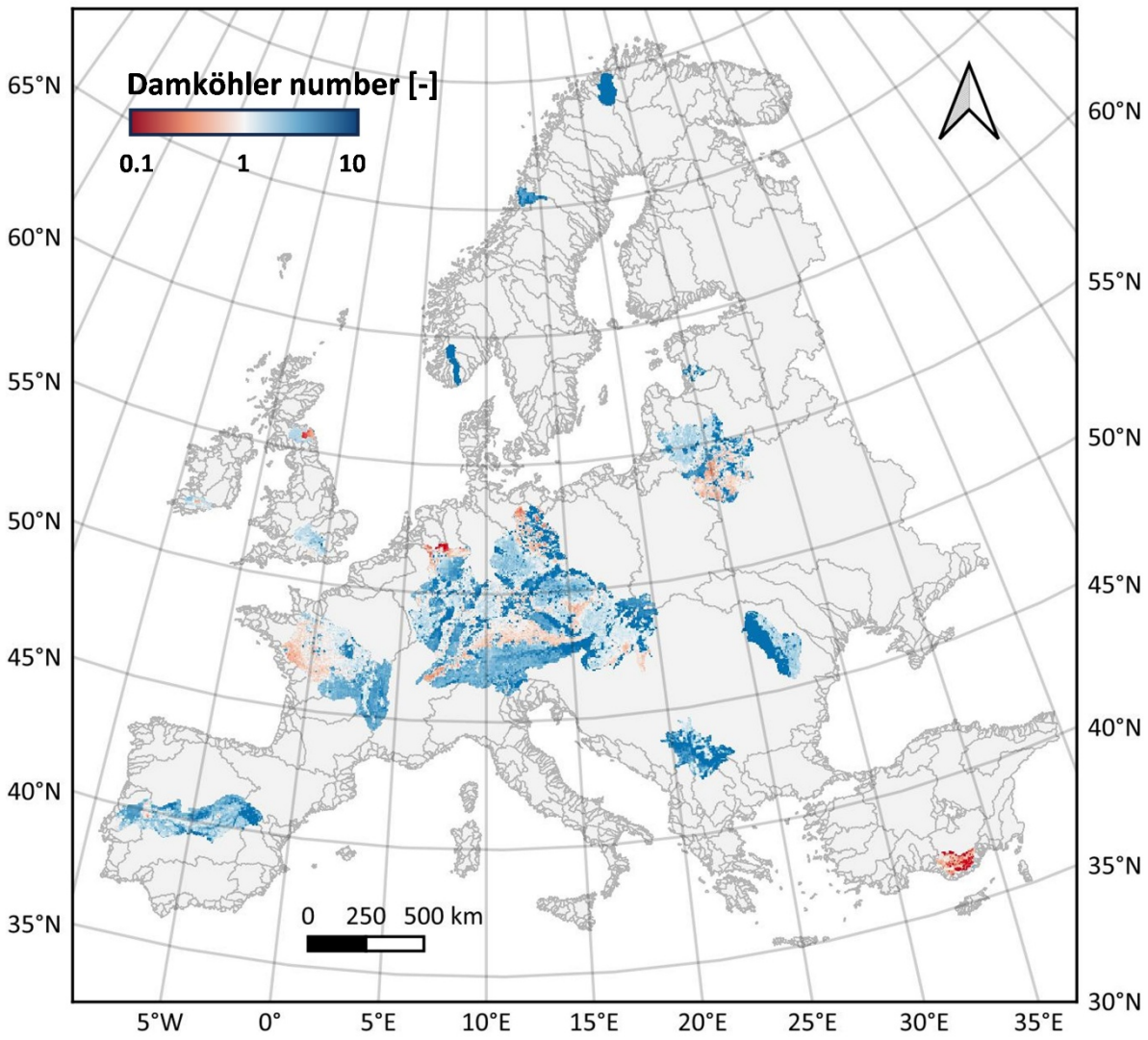

Figure S8. The average of Damköhler number in soil profile during 1982-2024. Note that logarithmic scale is used.