

Evaluation of soil carbon simulation in CMIP6 Earth System Models

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Supplementary Material

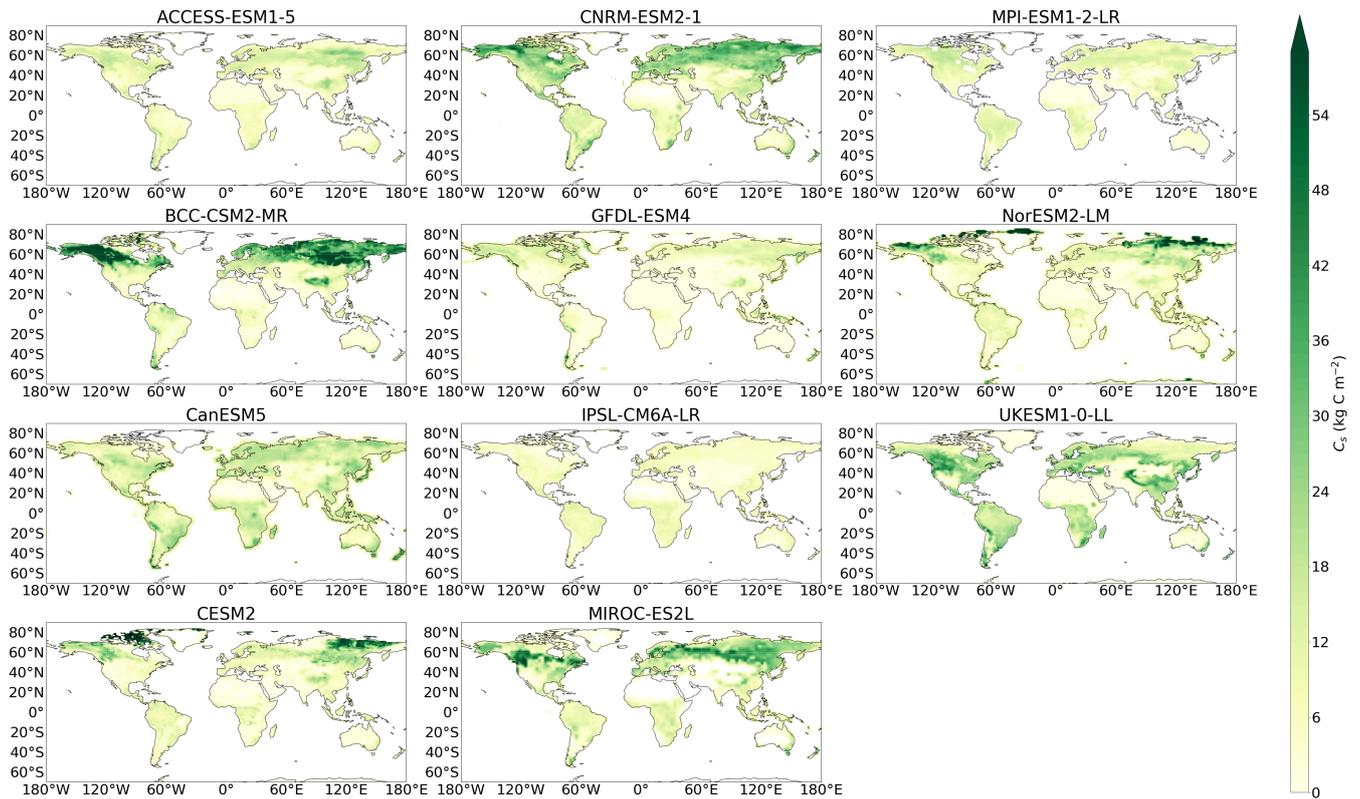


Figure S1. Maps of soil carbon (C_s) in the historical simulation (1950-2000) for the CMIP6 models.

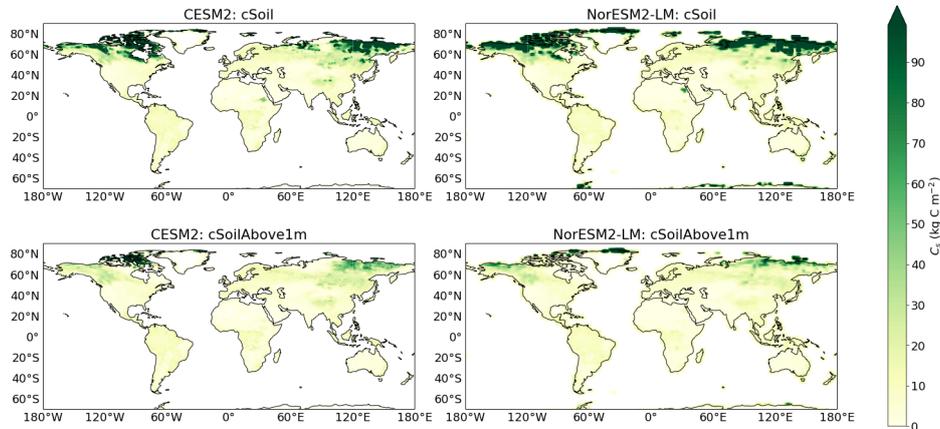


Figure S2. Maps comparing the soil carbon (C_s) output variables $cSoil$ and $cSoilAbove1m$ in the historical simulation (1950-2000) of the CMIP6 models CESM2 and NorESM2-LM.

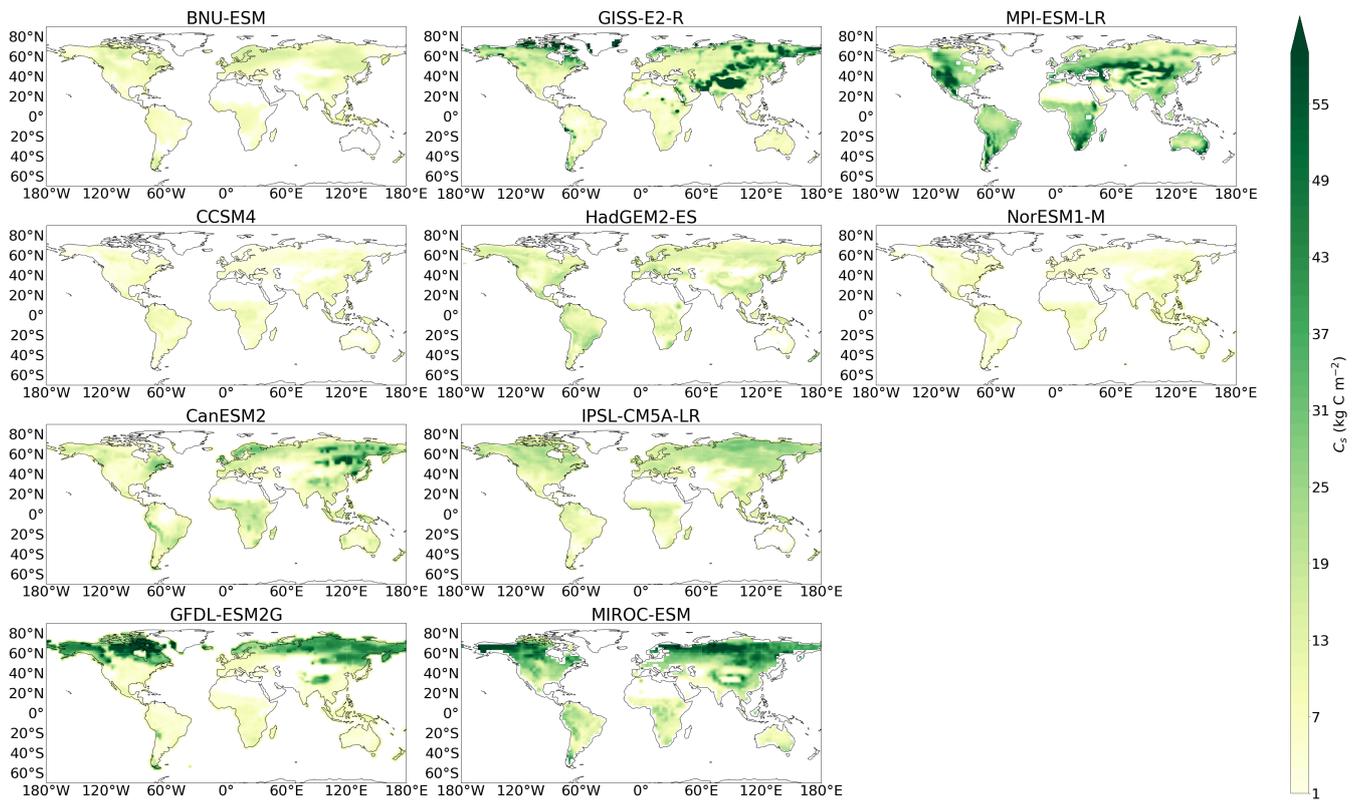


Figure S3. Maps of soil carbon (C_s) in the historical simulation (1950-2000) for the CMIP5 models.

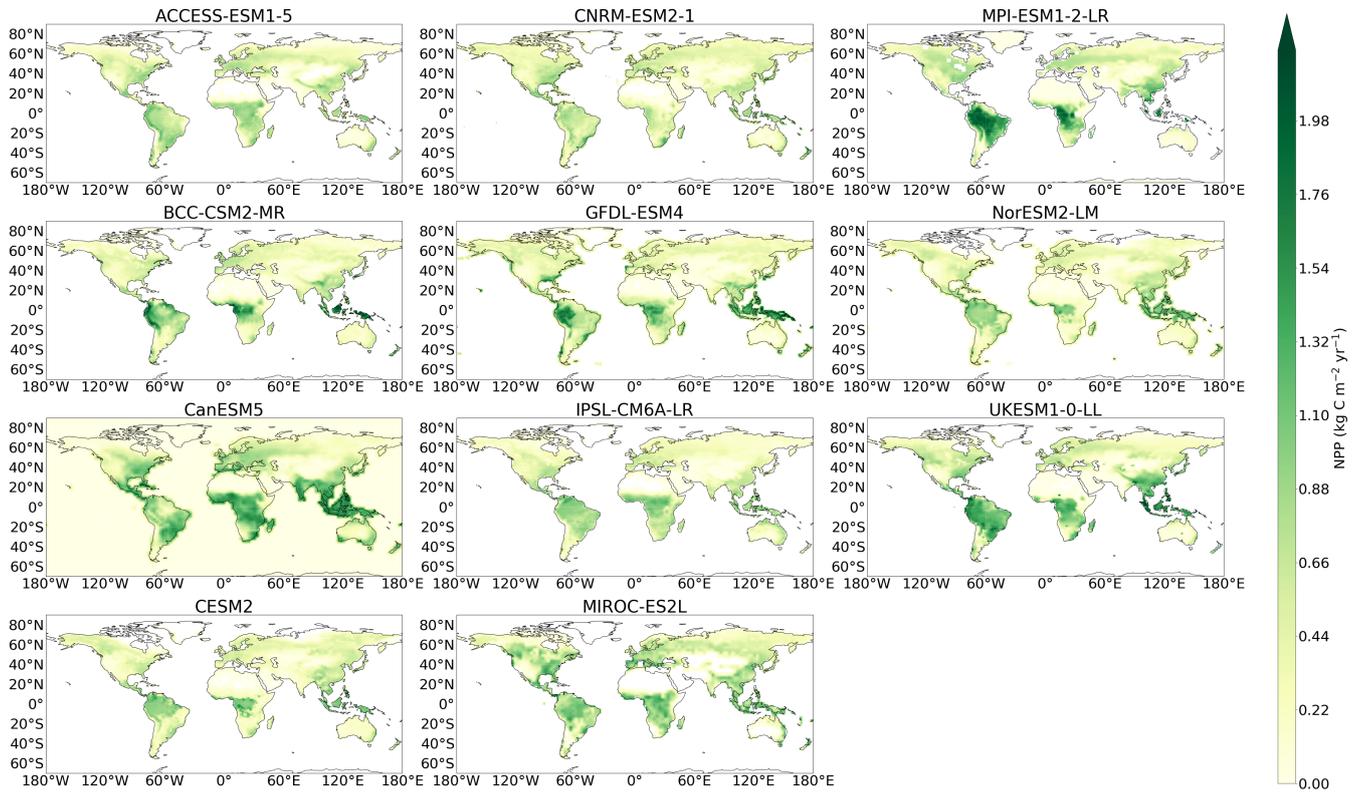


Figure S4. Maps of Net Primary Productivity (NPP) in the historical simulation (1995-2005) for the CMIP6 models.

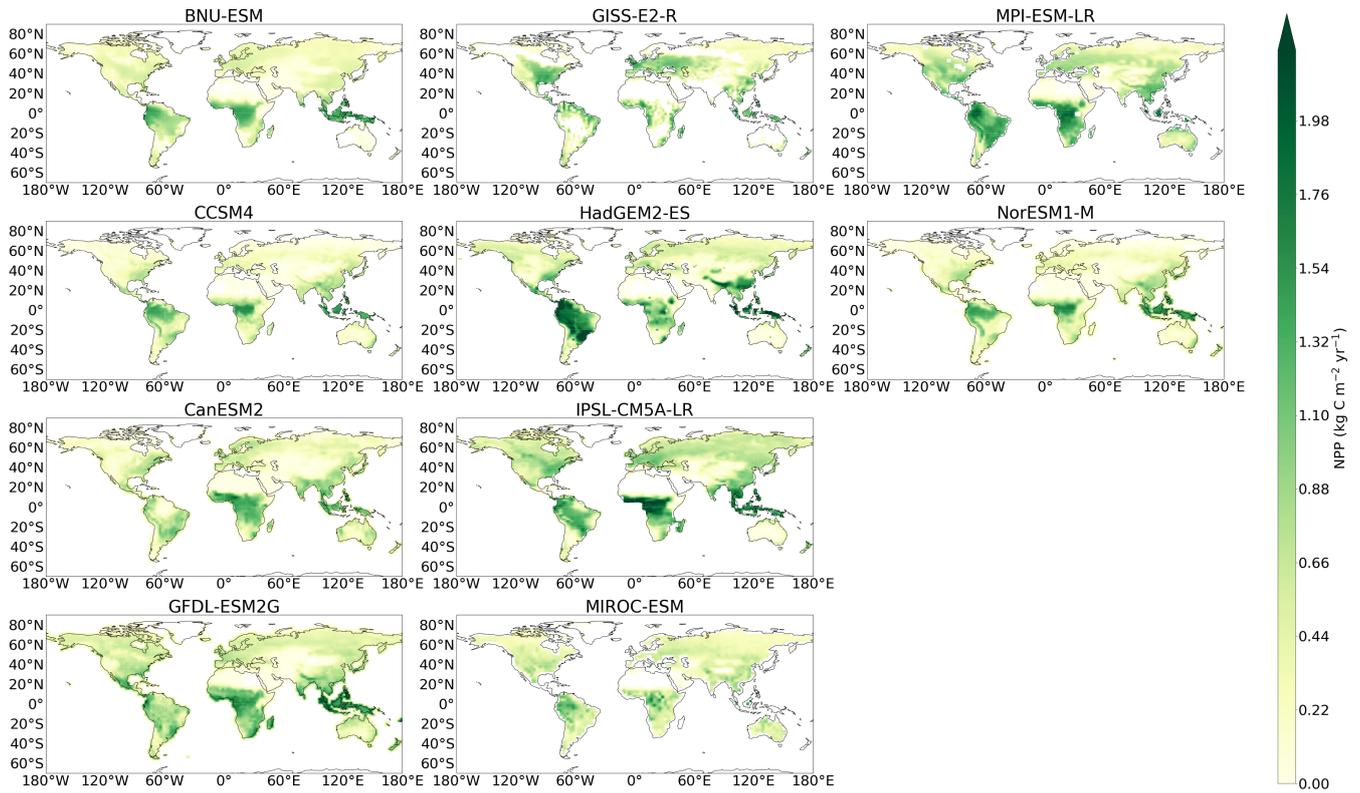


Figure S5. Maps of Net Primary Productivity (NPP) in the historical simulation (1995-2005) for the CMIP5 models.

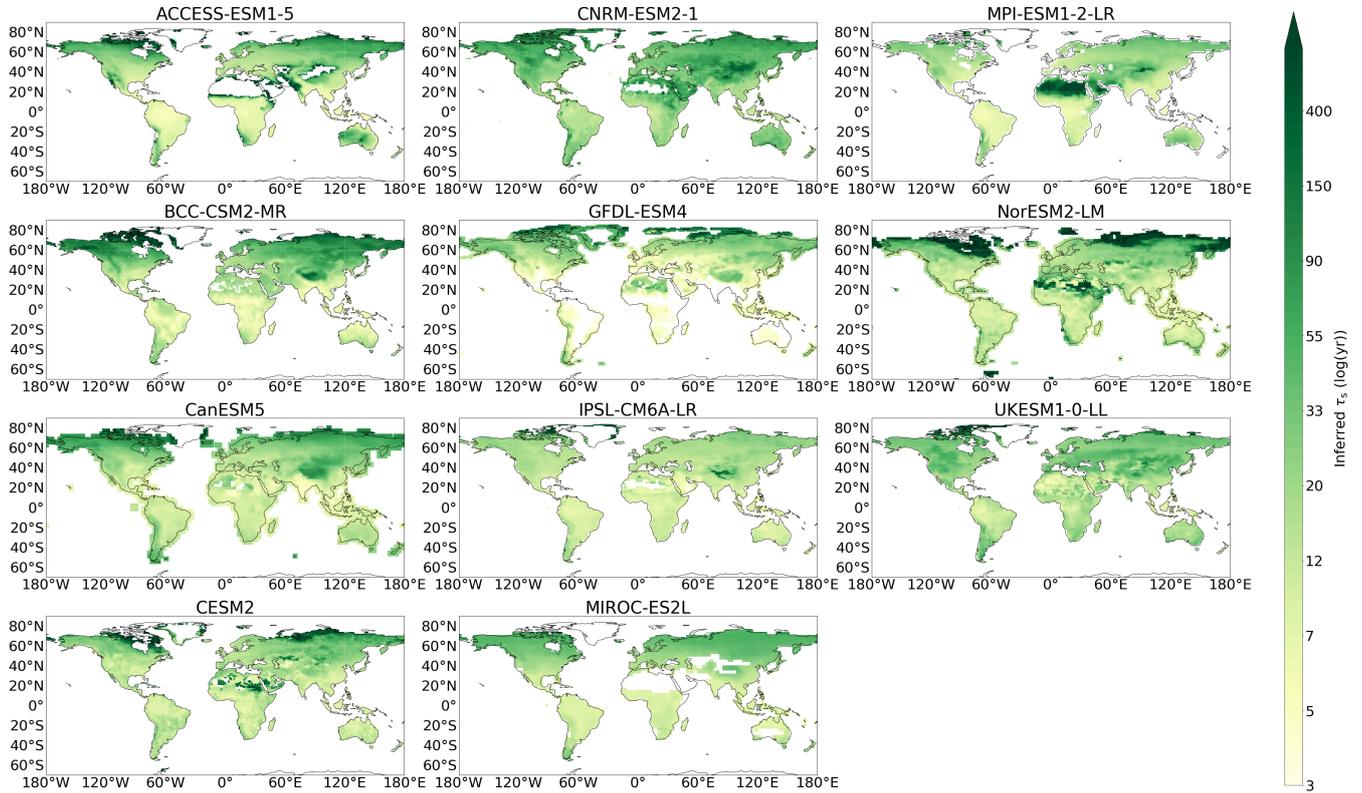


Figure S6. Maps of soil carbon turnover times (τ_s) in the historical simulation for the CMIP6 models, where τ_s is defined as the ratio of C_s (1950-2000) to R_h (1995-2005).

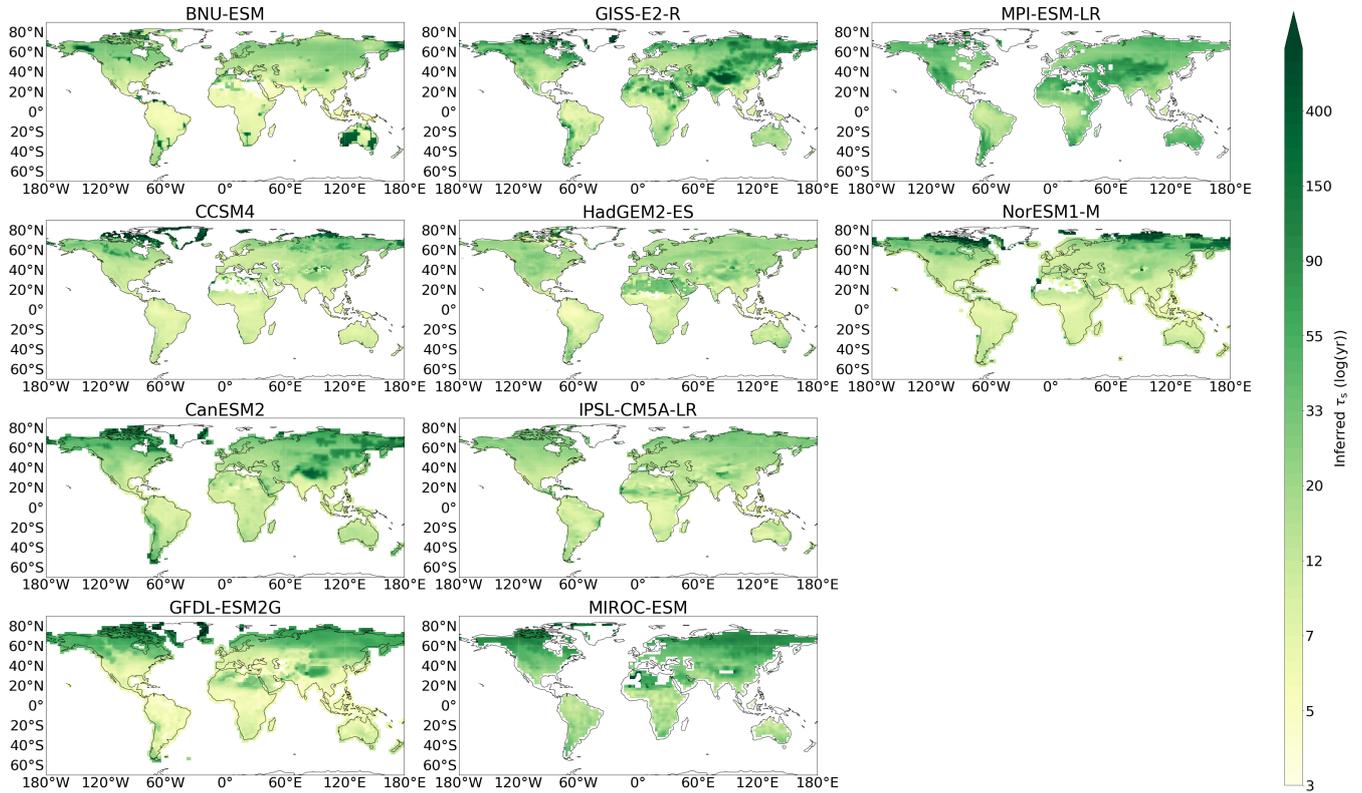


Figure S7. Maps of soil carbon turnover times (τ_s) in the historical simulation for the CMIP5 models, where τ_s is defined as the ratio of C_s (1950-2000) to R_h (1995-2005).

Table S1. CMIP6 Spatial Correlations: The table presents correlation coefficients (r-values to 3 s.f.) showing the spatial correlation between the CMIP6 ESM and observations, for the following climate variables: soil carbon (C_s), soil moisture (θ), net primary productivity (NPP), heterotrophic respiration (R_h) and soil carbon turnover time (τ_s).

Earth System Model	C_s		θ		NPP		R_h		τ_s	
	r-value	RMSE	r-value	RMSE	r-value	RMSE	r-value	RMSE	r-value	RMSE
ACCESS-ESM1.5	0.324 (0.298)	9.58 (19.4)	0.592	0.0658	0.753	0.265	0.761	0.247	0.226 (0.241)	510 (496)
BCC-CSM2-MR	0.490 (0.345)	15.1 (21.1)	0.657	0.0700	0.782	0.261	0.779	0.243	0.313 (0.400)	217 (177)
CanESM5	0.298 (0.245)	9.79 (18.9)	0.612	0.0811	0.655	0.404	0.568	0.472	0.464 (0.497)	184 (175)
CESM2	0.225 (0.101)	16.7 (23.4)	0.428	0.157	0.749	0.254	0.720	0.259	0.294 (0.260)	362 (329)
CNRM-ESM2-1	0.630 (0.457)	8.84 (17.1)	0.684	0.0866	0.782	0.245	0.699	0.263	0.319 (0.360)	208 (181)
GFDL-ESM4	0.458 (0.319)	10.6 (20.6)	0.667	0.0654	0.759	0.255	0.716	0.258	0.277 (0.346)	229 (202)
IPSL-CM6A-LR	0.104 (0.104)	11.1 (21.1)	0.726	0.0504	0.733	0.262	0.752	0.242	0.332 (0.344)	193 (186)
MIROC-ES2L	0.437 (0.363)	10.5 (18.7)	0.687	0.0793	0.763	0.291	0.731	0.283	0.247 (0.367)	186 (165)
MPI-ESM1.2-LR	0.422 (0.375)	8.70 (18.0)	0.682	0.0607	0.785	0.362	0.811	0.302	0.138 (0.154)	122 (144)
NorESM2-LM	0.222 (0.183)	11.3 (19.6)	0.410	0.163	0.734	0.271	0.706	0.264	0.232 (0.231)	772 (710)
UKESM1-0-LL	0.115 (0.168)	13.1 (19.8)	0.653	0.0944	0.816	0.305	0.760	0.319	0.265 (0.354)	180 (175)
Ensemble mean	0.250 (0.233)	8.20 (13.7)	0.648	0.0974	0.836	0.200	0.816	0.315	0.267 (0.333)	223 (187)

Table S2. CMIP5 Spatial Correlations: The table presents correlation coefficients (r-values to 3 s.f.) showing the spatial correlation between the CMIP5 ESM and observations, for the following climate variables: soil carbon (C_s), soil moisture (θ), net primary productivity (NPP), heterotrophic respiration (R_h) and soil carbon turnover time (τ_s).

Earth System Model	C_s		θ		NPP		R_h		τ_s	
	r-value	RMSE	r-value	RMSE	r-value	RMSE	r-value	RMSE	r-value	RMSE
BNU-ESM	0.332 (0.253)	10.4 (20.8)	0.420	0.0760	0.652	0.318	0.703	0.279	0.0177 (0.023)	233 (212)
CCSM4	-0.0193 (-0.140)	11.7 (22.1)	0.622	0.122	0.753	0.284	-	0.242	0.349 (0.206)	143 (155)
CanESM2	0.325 (0.225)	10.7 (19.8)	0.581	0.0855	0.469	0.388	0.548	0.376	0.285 (0.294)	212 (189)
GFDL-ESM2G	0.492 (0.321)	12.3 (20.0)	0.627	0.0594	0.589	0.385	0.618	0.325	0.156 (0.330)	262 (194)
GISS-E2-R	0.126 (0.0607)	22.1 (26.3)	0.595	0.0773	0.274	0.403	0.425	0.327	0.257 (0.266)	163 (166)
HadGEM2-ES	0.230 (0.211)	9.87 (19.4)	0.581	0.0920	0.764	0.425	0.744	0.437	0.123 (0.118)	174 (176)
IPSL-CM5A-LR	0.587 (0.413)	7.95 (17.3)	0.539	0.130	0.647	0.463	0.650	0.352	0.229 (0.269)	205 (190)
MIROC-ESM	0.596 (0.463)	15.6 (18.5)	0.641	0.0746	0.606	0.299	0.675	0.253	0.200 (0.240)	180 (169)
MPI-ESM-LR	-0.114 (-0.367)	22.1 (25.0)	-	-	0.764	0.450	0.766	0.311	0.321 (0.334)	109 (132)
NorESM1-M	0.0112 (0.0869)	11.4 (21.5)	0.665	0.0585	0.674	0.327	0.734	0.267	0.284 (0.226)	153 (160)
Ensemble mean	0.380 (0.332)	8.93 (18.4)	0.675	0.0861	0.711	0.277	0.709	0.317	0.188 (0.337)	228 (192)

Table S3. CMIP6 Spatial Correlations: The table shows r-values representing the spatial correlation between soil carbon (C_s) and climate variables (NPP, soil moisture and temperature) from each ESM and the observations. EXTRA NPP ONES. The table shows r-values representing the spatial correlation between soil carbon turnover time (τ_s) and climate variables (soil carbon, NPP, soil moisture and temperature) from each ESM and the observations. All rounded to 3 significant figures.

Earth System Model	C_s -NPP	NPP- θ	NPP-T	C_s - τ_s	τ_s - θ	τ_s -T
ACCESS-ESM1.5	0.644	-0.288	0.566	-0.181	-0.0871	-0.0872
BCC-CSM2-MR	0.214	-0.329	0.543	0.129	0.229	-0.368
CanESM5	0.789	0.0423	0.301	-0.216	0.430	-0.781
CESM2 (cSoilAbove1m)	0.134	0.0211	0.549	-0.00142	0.242	-0.266
<i>CESM2 (cSoil)</i>	<i>-0.00720</i>	-	-	<i>0.214</i>	<i>0.335</i>	<i>-0.287</i>
CNRM-ESM2-1	0.645	0.0102	0.594	0.0188	-0.0533	-0.314
GFDL-ESM4	0.573	0.697	0.196	-0.100	0.0420	-0.537
IPSL-CM6A-LR	0.871	0.333	0.541	-0.219	0.431	-0.431
MIROC-ES2L	0.630	0.154	0.545	0.144	0.111	-0.268
MPI-ESM1.2-LR	0.704	0.657	0.548	-0.278	-0.319	0.158
NorESM2-LM (cSoilAbove1m)	0.261	0.499	0.232	0.153	0.357	-0.448
<i>NorESM2-LM (cSoil)</i>	<i>0.0293</i>	-	-	<i>0.308</i>	<i>0.252</i>	<i>-0.317</i>
UKESM1-0-LL	0.749	0.587	0.563	-0.0933	0.0618	-0.299
Ensemble mean	0.424	0.494	0.257	-0.0605	0.198	-0.398
Benchmark datasets	-0.0229	0.646	0.435	0.232	-0.239	-0.296

Table S4. CMIP5 Spatial Correlations: The table shows r-values representing the spatial correlation between soil carbon (C_s) and NPP from each ESM and the observations and r-values representing the spatial correlation between soil carbon (C_s) and soil moisture (θ) from each ESM and the observations. All rounded to 3 significant figures.

Earth System Model	C_s -NPP	NPP- θ	NPP-T	C_s - τ_s	τ_s - θ	τ_s -T
BNU-ESM	0.623	-0.420	0.513	-0.131	0.0351	-0.0775
CCSM4	-0.00541	-0.348	0.551	-0.181	0.450	-0.301
CanESM2	0.687	0.0603	0.212	0.188	0.357	-0.689
GFDL-ESM2G	0.428	0.767	0.213	0.0337	-0.0889	-0.293
GISS-E2-R	-0.156	0.492	-0.0113	0.897	-0.0382	-0.473
HadGEM2-ES	0.776	0.558	0.529	-0.165	0.0317	-0.355
IPSL-CM5A-LR	0.500	0.302	0.201	0.379	0.492	-0.685
MIROC-ESM	0.466	0.649	0.702	0.119	0.0432	-0.236
MPI-ESM-LR	0.681	-	0.653	0.0682	-	-0.159
NorESM1-M	0.898	0.0987	0.228	-0.150	0.0836	-0.242
Ensemble mean	0.222	0.258	0.230	0.108	0.210	-0.314
Benchmark datasets	-0.0229	0.646	0.435	0.232	-0.239	-0.296