Table S1: Full summary of Earth system models including model names, history of development, number of soil/litter pools, temperature/moisture functions, link to nitrogen cycling, the CMIP5 variables used to construct total soil carbon, and the years analyzed for each CMIP5 experiment. (adapted from Todd-Brown et al., 2013)

Model Center	Model name	Soil model history	Litter	Soil	Temperature	Moisture	Nitrogen	Reported CMIP5 variables			Years considered for analysis	
								cSoil	*cLitter*	*cCwd*	*Historical*	*RCP 8.5*
Beijing Climate Center, China Meteorological Administration (BCC)	BCC-CSM1.1 BCC-CSM1.1(m) (Wu et al., submitted)	AVIM2 (Huang *et al.*, 2007; Ji *et al.*, 2008) CEVSA (Cao and Woodward, 1998) CENTURY (Parton *et al.*, 1987, 1993)	2	6	hill[a]	hill	no[d]	X	X	--	1850-2005	2006-2099
College of Global Change and Earth System Science, Beijing Normal University (GCESS)	BNU-ESM (Personal communication Qian Zhang, 2013)	CoLM (Dai *et al.*, 2003, 2004) LPJ-DyN (Xu-Ri and Prentice, 2008) LPJ-DGVM (Sitch *et al.*, 2003) DEMETER-1 (Foley, 1995) CENTURY (Parton *et al.*, 1987, 1992)	2	2	Arrhenius	increasing	no[d]	X	X	--	1850-2005	2006-2100
Canadian Centre for Climate Modeling and Analysis (CCCMA)	CanESM2 (CMIP5 output)	CTEM1 (Arora and Boer, 2005; Arora, 2003; Arora et al., 2011)	1[b]	1[b]	Q10[c]	hill	no	X	X	--	1850-2005	2006-2100
National Center for Atmospheric Research (NCAR)	CCSM4 (Gent *et al.*, 2011)	CLM4 (Oleson *et al.*, 2008) CN (Thornton *et al.*, 2007) Biome-BCG 4.1.2 (Kimball et al., 1997; Thornton and Rosenbloom, 2005; Thornton, 1998; Thornton et al., 2002)	4	3	Arrhenius	increasing	yes	X	X	X	1850-2005	2006-2100

Model Center	Model name	Soil model history	Litter	Soil	Temperature	Moisture	Nitrogen	Reported CMIP5 variables			Years considered for analysis	
								cSoil	*cLitter*	*cCwd*	*Historical*	*RCP 8.5*
		(Olson, 1963; Veen and Paul, 1981; Veen et al., 1984)										
Community Earth System Model Contributors (NSF-DOE-NCAR)	CESM1(BGC) CESM1(CAM5) (Keppel-Aleks *et al.*, 2013; Lindsay *et al.*, 2013)	CLM4(Oleson *et al.*, 2008) CN (Thornton *et al.*, 2007) Biome-BCG 4.1.2 (Kimball et al., 1997; Thornton and Rosenbloom, 2005; Thornton, 1998; Thornton et al., 2002) (Olson, 1963; Veen and Paul, 1981; Veen et al., 1984)	4	3	Arrhenius	increasing	yes	X	X	X	1850-2005	2006-2100
NOAA Geophysical Fluid Dynamics Laboratory (NOAA GFDL)	GFDL-ESM2G GFDL-ESM2M (CMIP5 output)	LM3 (LM3p7_cESM, M45) (Shevliakova *et al.*, 2009) ED (Moorcroft *et al.*, 2001) (Bolker *et al.*, 1998) CENTURY (Parton *et al.*, 1987)	--	2	hill	increasing	no	X	--	--	1861-2005	2006-2100
Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espacials) (MOHC additional realizations by INPE)	HadGEM2-ES HadGEM2-CC (Jones *et al.*, 2011)	(Collins *et al.*, 2011; Martin *et al.*, 2011) TRIFFID (Cox, 2001)	--	4	Q10	hill	no	X	--	--	1860-2005	2006-2099
Institute for Numerical Mathematics (INM)	INM-CM4 (Volodin *et al.*, 2010)	(Volodin, 2007) LSM (Bonan, 1995, 1996; Bunnell et al., 1977)	--	1[b]	Q10 [c]	hill	no	X	--	--	1850-2005	2006-2100

Model Center	Model name	Soil model history	Litter	Soil	Temperature	Moisture	Nitrogen	Reported CMIP5 variables			Years considered for analysis	
								cSoil	*cLitter*	*cCwd*	*Historical*	*RCP 8.5*
Institut Pierre-Simon Laplace	IPSL-CM5A-LR IPSL-CM5A-MR IPSL-CM5B-LR (http://icmc.ipsl.fr)	ORCHIDEE (http://orchidd.ipsl.jussieu.fr) STOMATE (Krinner *et al.*, 2005) CENTURY (Parton *et al.*, 1988)	3	4	Q10	increasing	no	X	X	--	1850-2005	2006-2100
Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies (MIROC)	MIROC-ESM MIROC-ESM-CHEM (Watanabe *et al.*, 2011)	SEIB-DGVM (Sato *et al.*, 2007) Roth-C (Coleman and Jenkinson, 1999) DEMETER-1 (Foley, 1995) CENTURY (Parton *et al.*, 1987, 1992)	--	2	Arrhenius	increasing	no	X	X	--	1850-2005	2006-2100
Max-Planck-Institut für Meteorologie (Max Planck Institute for Meteorology) (MPI-M)	MPI-ESM-LR MPI-ESM-MR (CMIP5 output)	JSBACH (Raddatz *et al.*, 2007) BETHY (Knorr, 2000) CENTURY (Parton *et al.*, 1993)	--	3	Q10	increasing	no	X	X	--	1850-2005	2006-2100
Norwegian Climate Centre (NCC)	NorESM1-ME NorESM1-M (Tjiputra et al., in prep)	CLM4 (Oleson *et al.*, 2008) CN (Thornton *et al.*, 2007) Biome-BCG 4.1.2 (Kimball et al., 1997; Thornton and Rosenbloom, 2005; Thornton, 1998; Thornton et al., 2002) (Olson, 1963; Veen and Paul, 1981; Veen et al., 1984)	4	3	Arrhenius	increasing	yes	X	X	X	1850-2005	2006-2100

[a] We define a hill function as a function that increases to a maximum and then decreases.
[b] Turnover parameterization dependent on biome or vegetation type.

[c] Q_{10} value dependent on temperature.
[d] Nitrogen option available but not turned on for CMIP5 run

	CESM1(BGC)	NorESM1-ME	BNU-ESM	BCC-CSM1.1(m)	HadGEM2-ES	IPSL-CM5A-MR	GFDL-ESM2G	CanESM2	INM-CM4	MIROC-ESM	MPI-ESM-MR	Multi-model mean	Multi-model standard deviation
Tundra and boreal	3.9	5.0	4.6	3.1	7.8	6.5	4.6	7.3	3.1	8.0	5.6	5.4	1.8
Other biomes	3.7	3.8	4.2	4.0	5.9	6.0	3.5	5.6	3.1	5.5	4.9	4.6	1.0
Global	3.8	4.2	4.3	3.8	6.4	6.1	3.8	6.1	3.1	6.2	5.1	4.8	1.2

Table S2: Mean soil temperature change for tundra and boreal forest biomes, all other biomes, and the globe for each ESM. Soil temperatures are area weighted means for the top 10 cm of the reported soil column.

	$\Delta C = C_{start}$	$\Delta C = \left(\frac{I_{start}}{k_{start}}\frac{k_{end}}{I_{end}} - 1\right) C_{start}$ (Eq 2)	$\Delta C = \frac{I_{start}}{I_{end}}$	$\Delta C = \frac{k_{end}}{k_{start}}$
CESM1(BGC)	0.139	0.818	NS	NS
NorESM1-ME	0.277	0.501	NS	NS
BNU-ESM	0.019	NS	0.008	0.018
BCC-CSM1.1(m)	0.692	0.777	0.036	0.074
HadGEM2-ES	0.305	0.324	NS	NS
IPSL-CM5A-MR	0.000	0.456	NS	0.041
GFDL-ESM2G	0.253	NS	NS	0.005
CanESM2	0.038	0.878	0.195	0.036
INM-CM4	0.113	0.262	0.009	NS
MIROC-ESM	0.052	NS	NS	0.073
MPI-ESM-MR	0.205	0.183	NS	NS

Table S3: Within-model explanation of variation (R^2) in the change in soil carbon over the 21th century by modern soil carbon, Eq 2) relative change in soil inputs, and relative change in decomposition. Decomposition rate (k) was calculated from global heterotrophic respiration divided by soil carbon stock. Regressions used gridded mean differences (2090-2099 versus 1997-2006) and initial gridded means (1997-2006). All models have $p < 0.05$, unless marked as not significant (NS).

		CESM1(BGC)	NorESM1-ME	BNU-ESM	BCC-CSM1.1(m)	HadGEM2-ES	IPSL-CM5A-MR	GFDL-ESM2G	CanESM2	INM-CM4	MIROC-ESM	MPI-ESM-MR
$R = \kappa C$	$1/\kappa$ [yr]	14.5	14.7	22.9	28.2	20.2	31.0	72.5	42.6	36.3	87.6	56.2
(Eq. 3)	ρ	0.861	0.868	0.493	0.367	0.707	0.555	0.043	0.413	0.491	0.133	0.42
$R = \kappa Q_{10}^{(T-15)/10} C$	$1/\kappa$ [yr]	15.9	15.5	16.7	19.1	16.9	18.5	15.0	26.2	24.3	42.9	50.5
	Q_{10}	1.55	1.53	2.18	2.09	1.67	1.56	2.29	1.79	2.09	2.13	1.55
	ρ	0.96	0.961	0.974	0.957	0.911	0.913	0.831	0.93	0.88	0.828	0.619
$R = \kappa Q_{10}^{(T-15)/10} W^b C$	$1/\kappa$ [yr]	12.9	11.5	7.8	13.7	9.4	15.5	11.7	16.7	23.7	39.6	25.1
(Eq. 5)	Q_{10}	1.54	1.53	2.12	2.06	1.78	1.71	2.27	1.64	2.10	2.16	1.44
	b	0.15	0.09	0.61	0.20	1.06	0.60	0.53	0.20	0.03	0.27	0.69
	ρ	0.962	0.963	0.984	0.963	0.958	0.974	0.876	0.955	0.882	0.842	0.69

Table S4: Reduced complexity model parameters and fit to gridded mid-19th century 10-year mean. The first RCM depends solely on the soil carbon stocks and global decomposition rate (Eq. 3). The second RCM depends on soil carbon stocks, intrinsic decomposition rate, and temperature sensitivity. The final RCM depends on soil carbon stocks, intrinsic decomposition rate, temperature sensitivity, and moisture sensitivity (Eq. 5). All RCMs are optimized to their gridded initial 10-year *historic* mean and their associated Pearson's correlation (ρ) with ESM heterotrophic respiration. HadGEM2-ES and GFDL-ESM2G are measured at 1860-1869 instead of 1850-1859 where their *historic* scenarios begin.

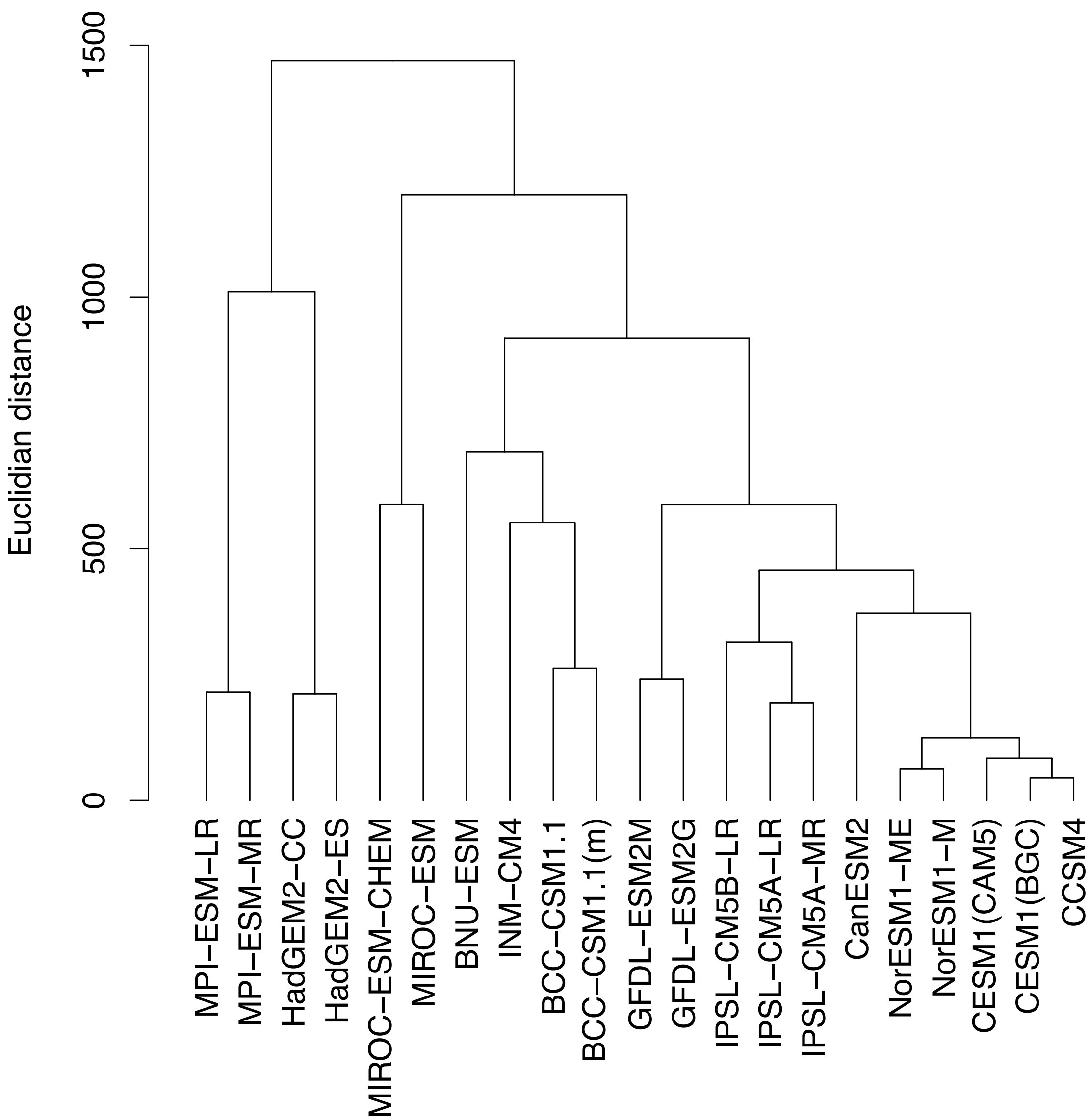

Figure S1: Cluster analysis of model outputs based on the spatial pattern of change in soil carbon between the 10-year means from 1997-2006 and 2090-2099. Dissimilarities within model centers are as follows: BCC <3% dissimilar, CESM1 <1%, GFDL <3%, HadGEM2 <2%, IPSL <3%, MIROC <6%, MPI <2%, and NorESM1 <1%. The entire NorESM-CCSM-CESM1 cluster is <2% dissimilar.

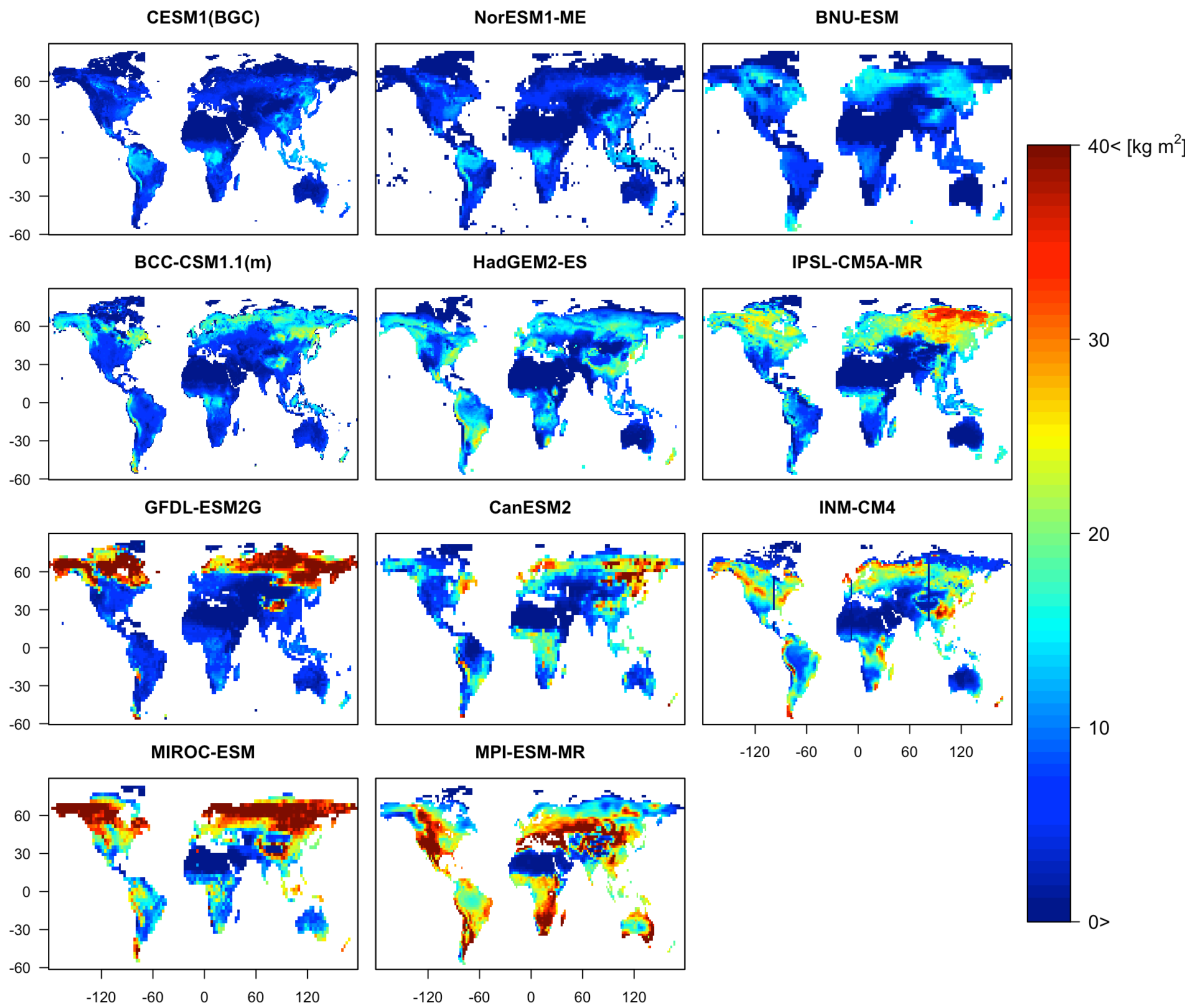

Figure S2: Modern soil carbon density [kg m^{-2}] for all models (10-year average; 1997-2006).

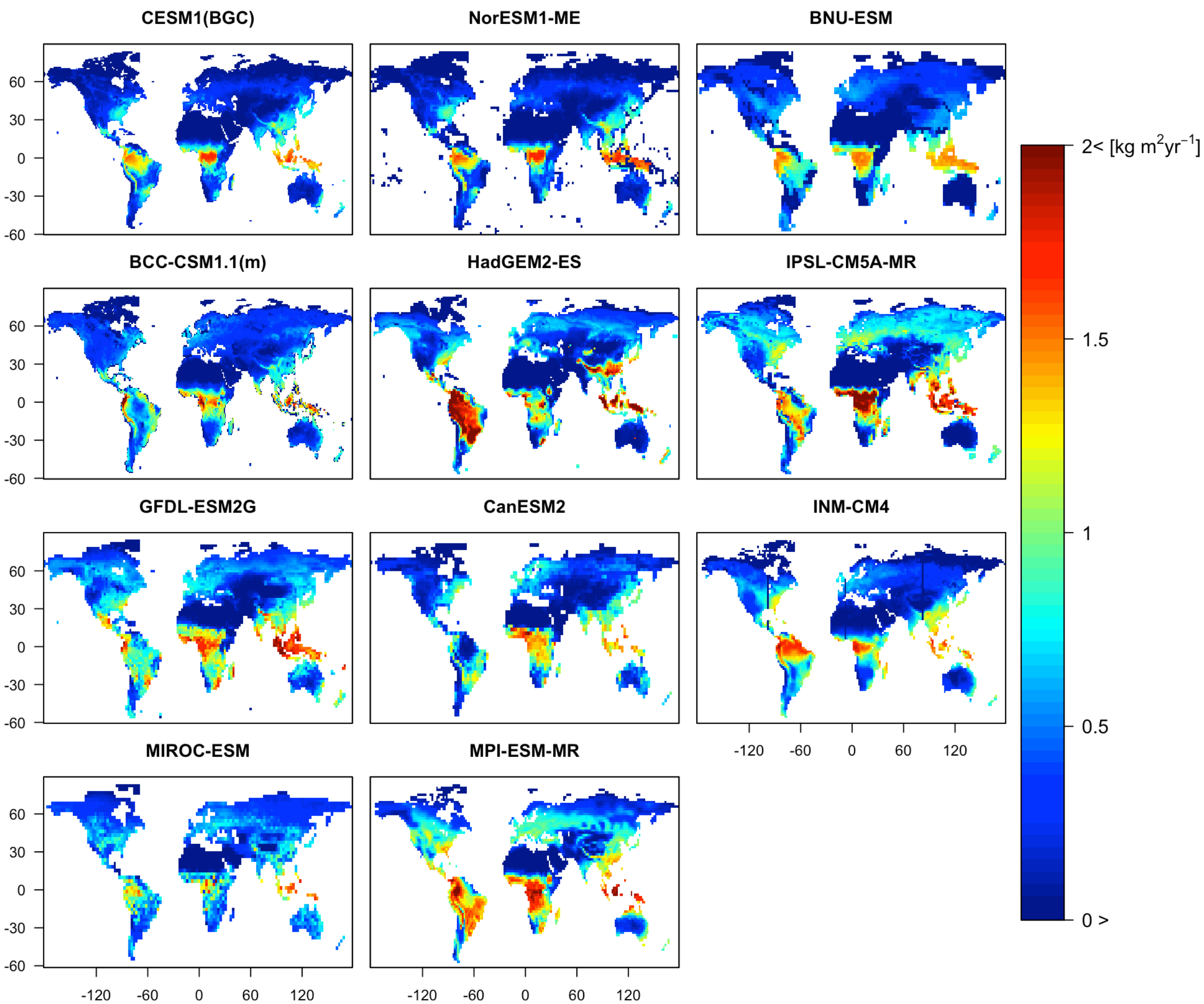

Figure S3: Modern NPP [kg m^{-2} yr^{-1}] for all models (10-year average; 1997-2006).

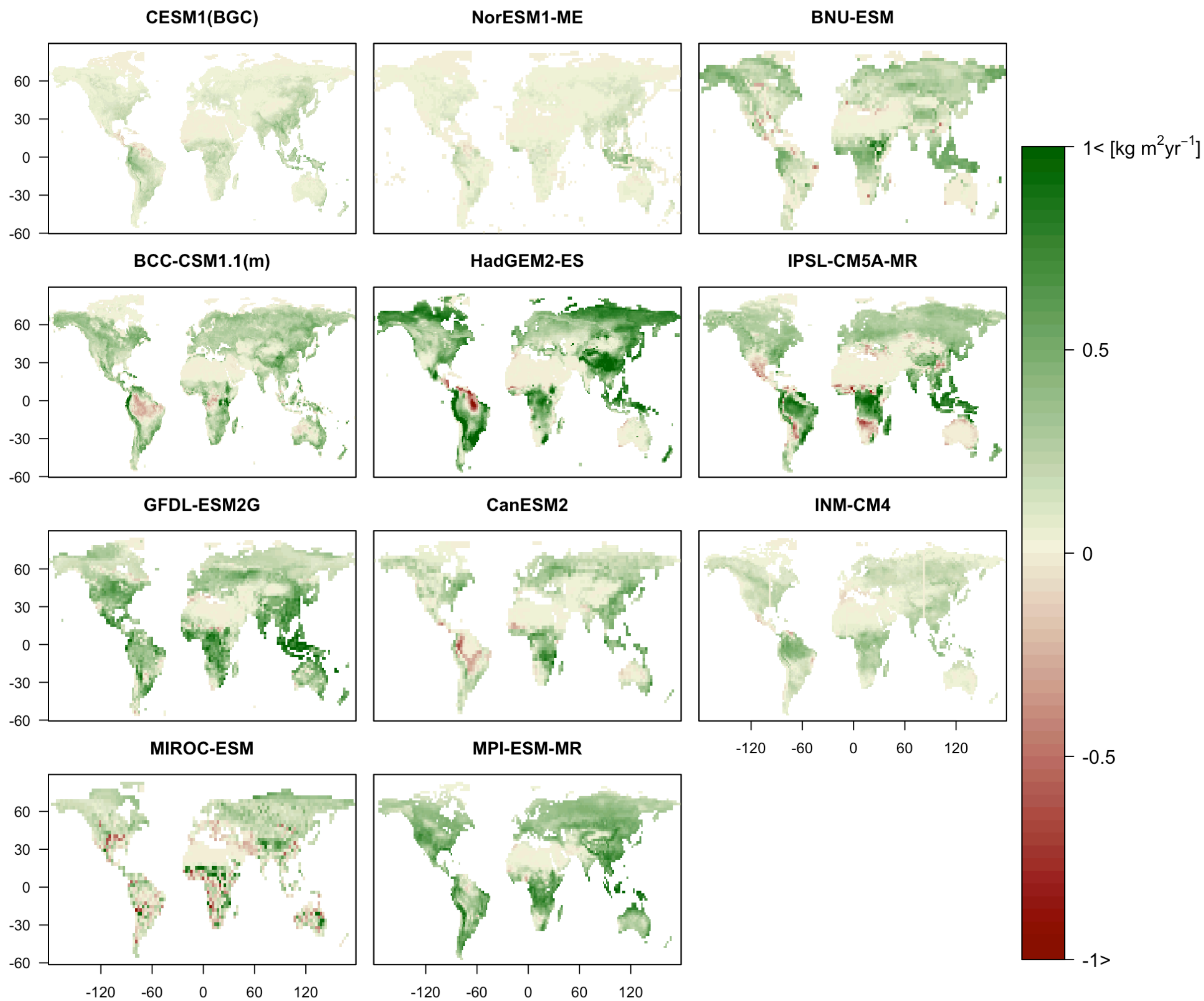

Figure S4: Absolute change in NPP [kg m^{-2} yr^{-1}] over the 21st century for all models (difference in 10-year means; 2090-2099 minus 1997-2006).

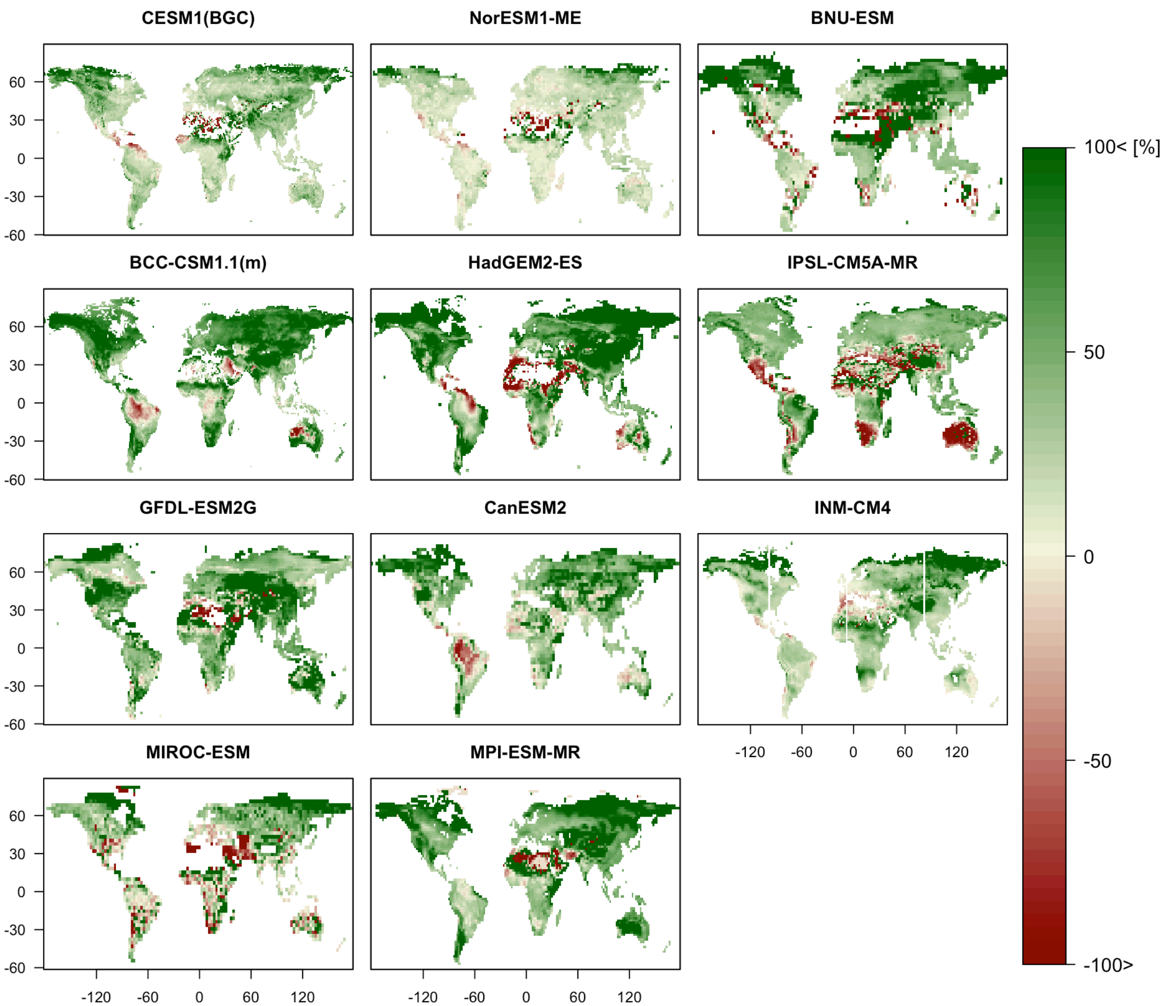

Figure S5: Relative change in NPP [%] over the 21st century for all models (difference in 10-year means; 2090-2099 minus 1997-2006).

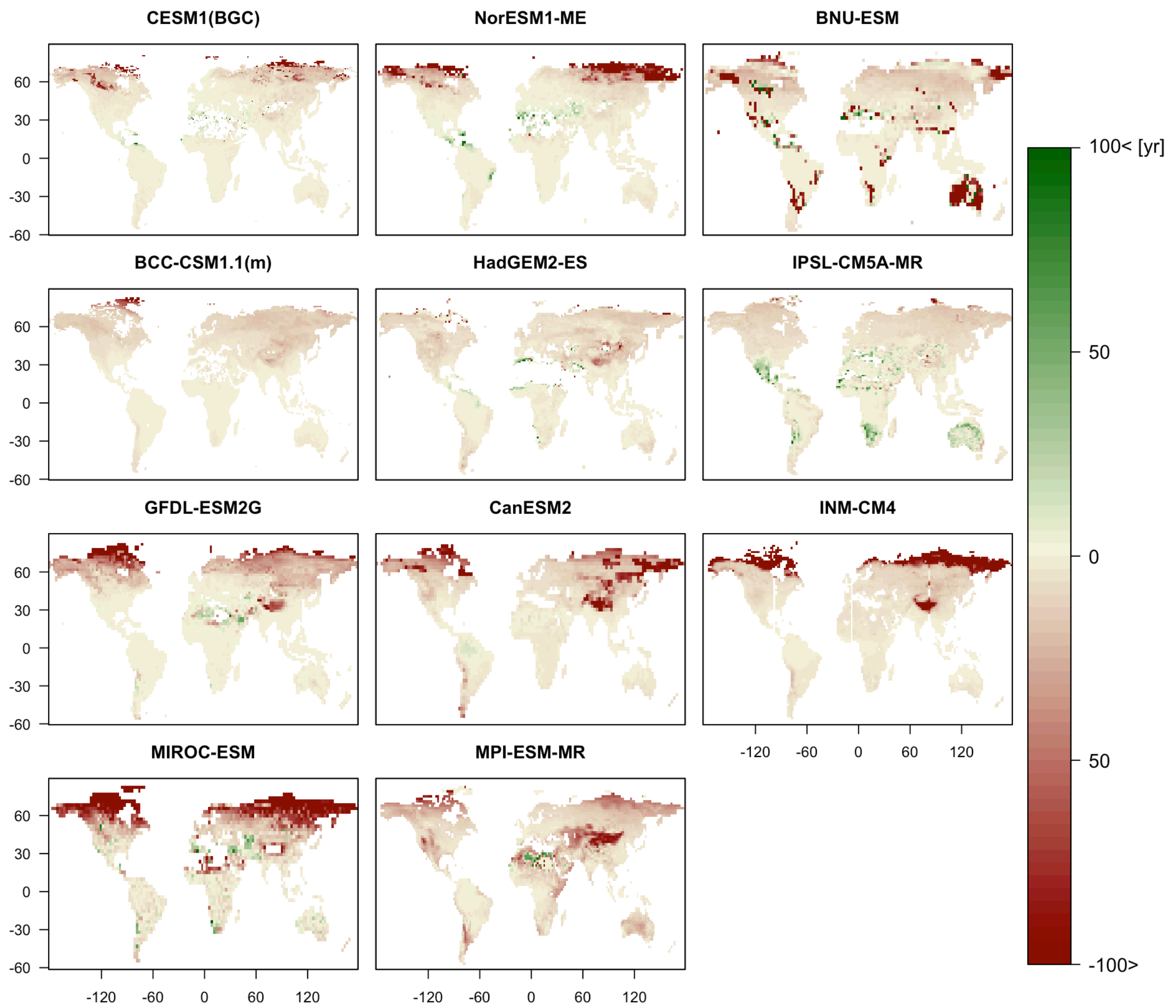

Figure S6: Absolute change in soil carbon turnover time [yr] over the 21st century for all models (difference in 10-year means; 2090-2099 minus 1997-2006).

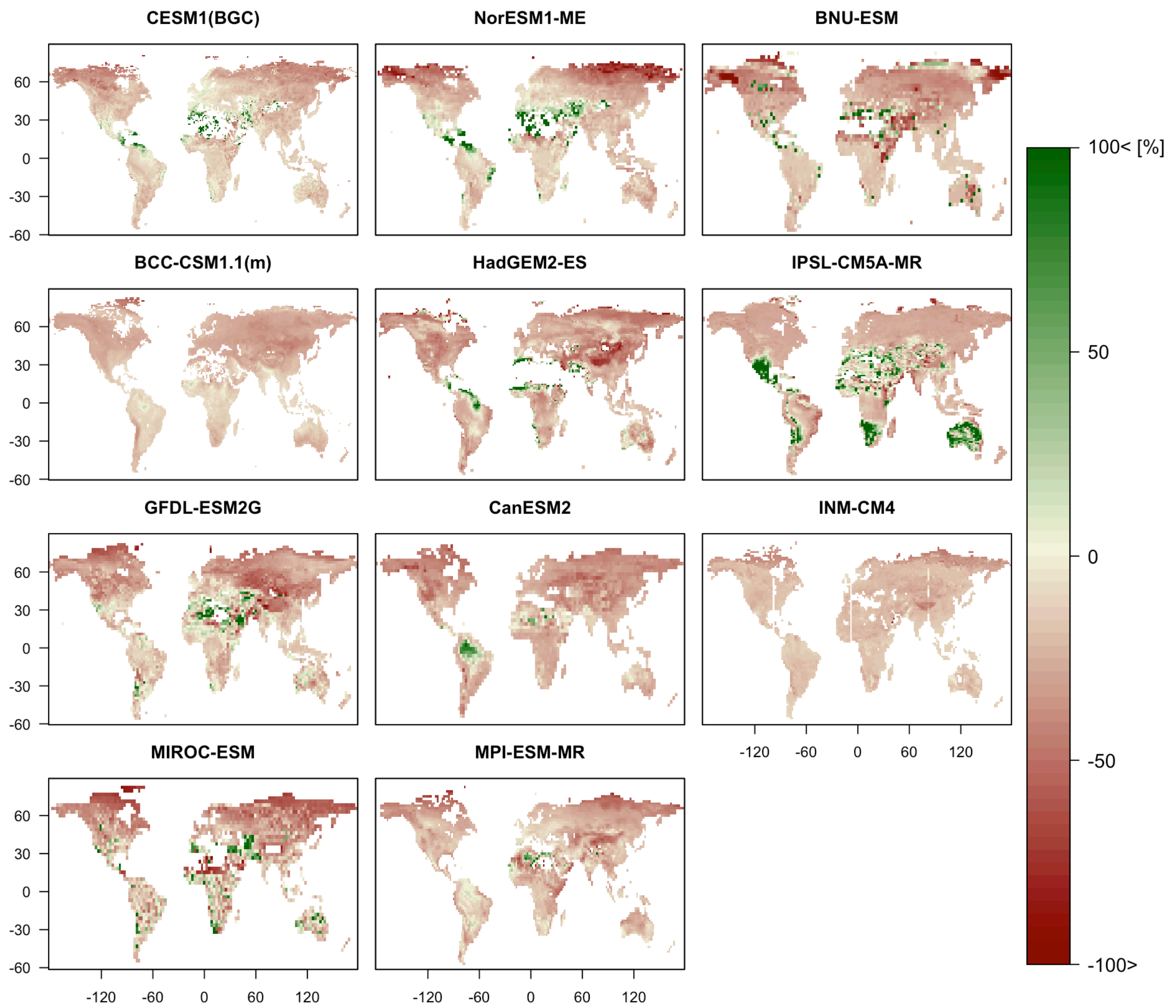

Figure S7: Relative change in soil carbon turnover time [%] over the 21st century for all models (difference in 10-year means; 2090-2099 minus 1997-2006).

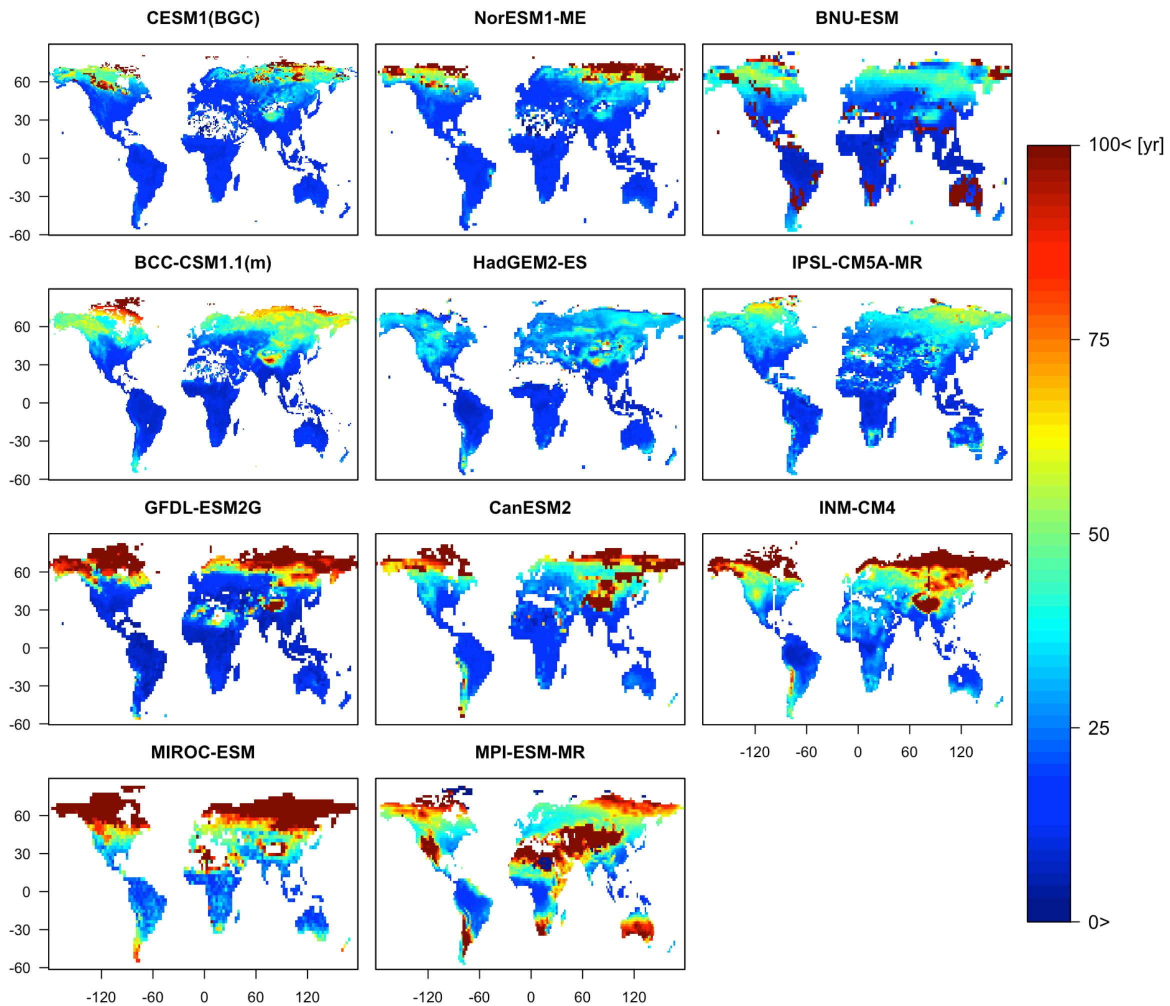

Figure S8: Modern soil carbon turnover time [yr] for all models (10-year average; 1997-2006).

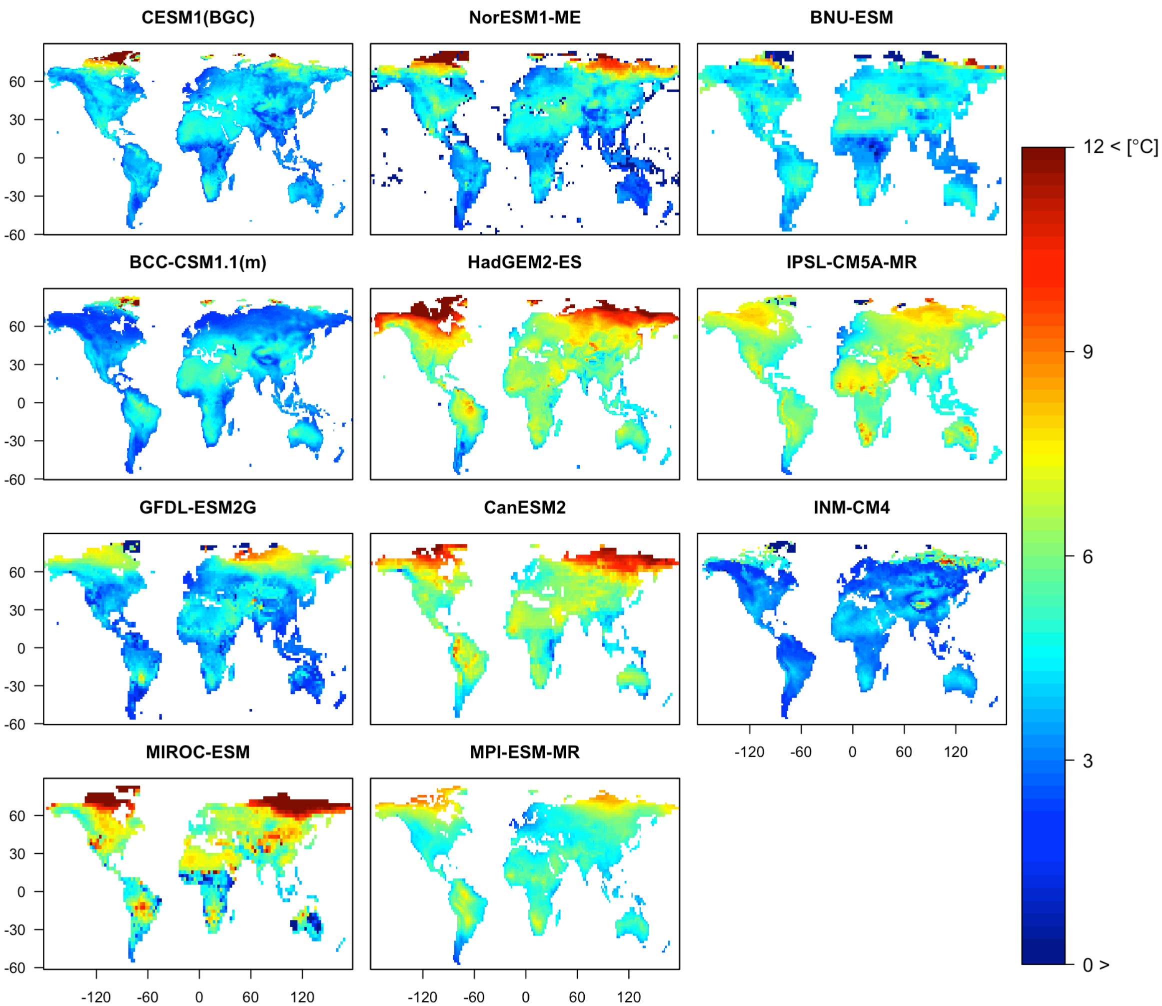

Figure S9: Absolute change in soil temperature [°C] over the 21st century for all models (difference in 10-year means; 2090-2099 minus 1997-2006).

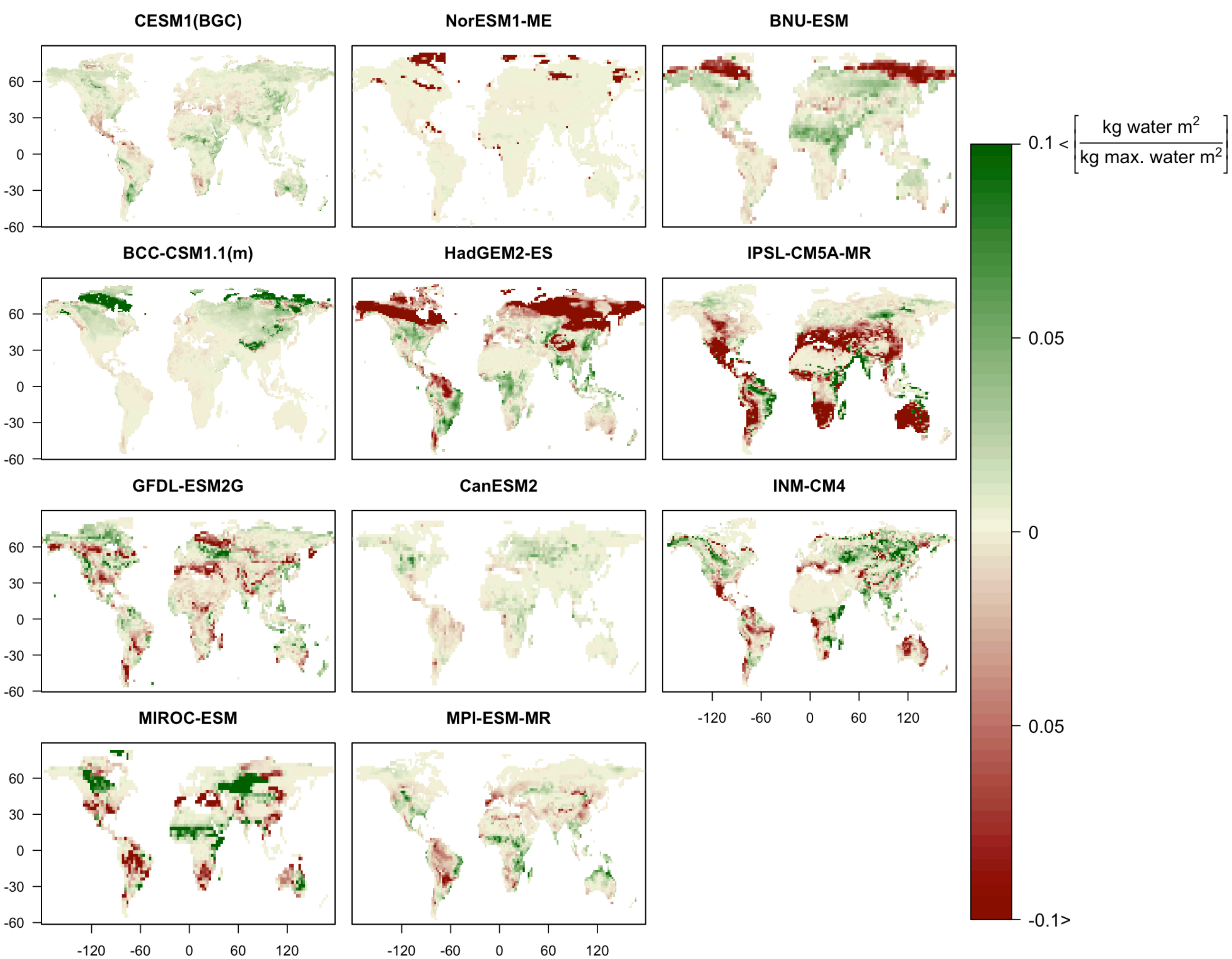

Figure S10: Absolute change in soil water [kg water m^{-2} kg^{-1} max. water m^{2}] over the 21st century for all models (difference in 10-year means; 2090-2099 minus 1997-2006).

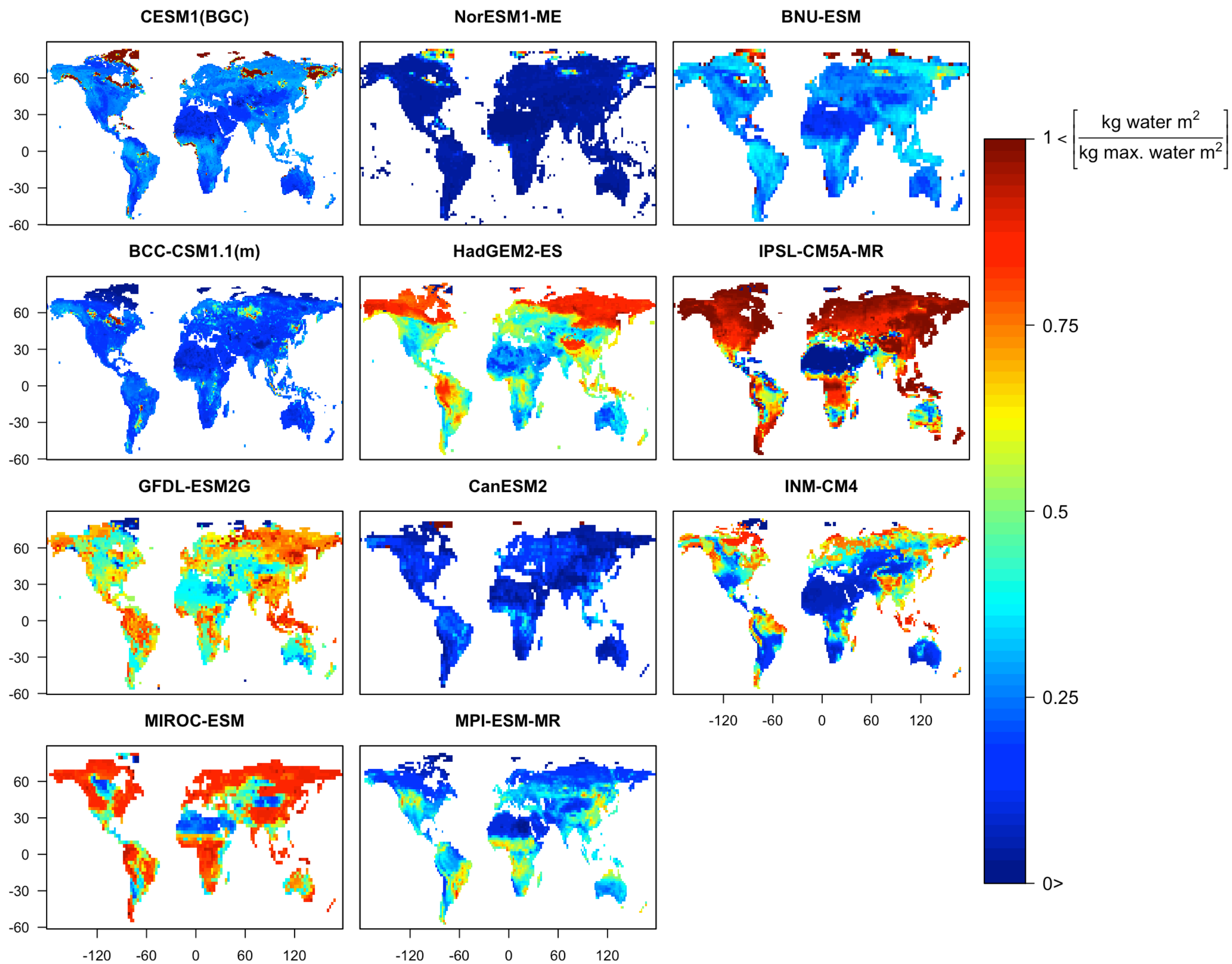

Figure S11: Modern normalized soil water [kg water m^{-2} kg^{-1} max. water m^2] for all models (10-year average; 1997-2006).

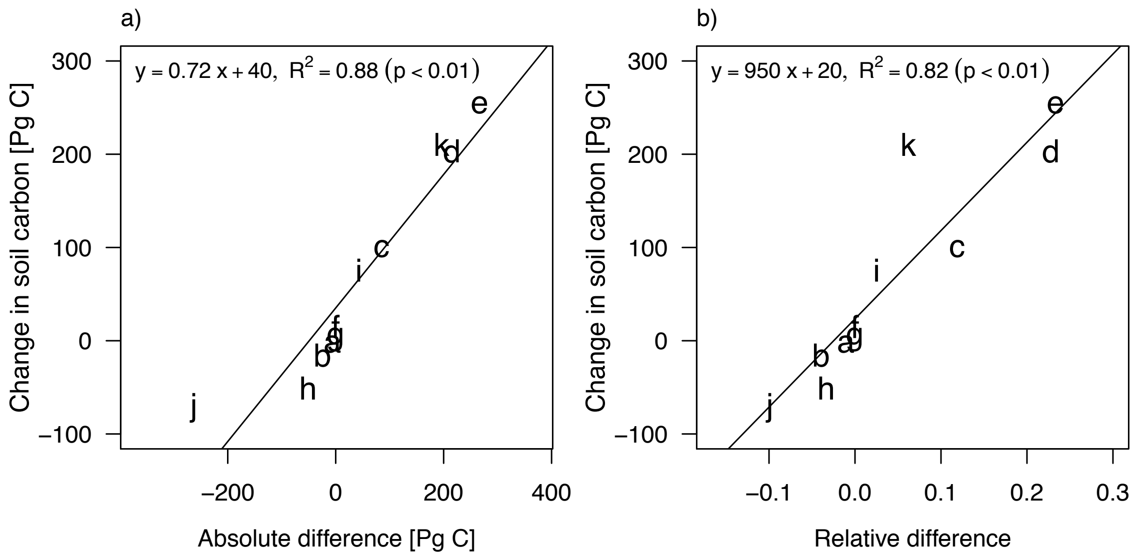

Figure S12: The change in soil carbon over the 21st century as a function of the a) change in soil carbon steady state $\left(\frac{I_{end}}{k_{end}} - \frac{I_{start}}{k_{start}}\right)$ and b) change in soil carbon explained by relative inputs and decomposition $\left(\frac{1+{}^{\Delta I}/_{I_{start}}}{1+{}^{\Delta k}/_{k_{start}}} - 1\right)$. The models are represented as follows; a: CESM1(BGC), b: NorESM1-ME, c: BNU-ESM, d: BCC-CSM1.1(m), e: HadGEM2-ES, f: IPSL-CM5A-MR, g: GFDL-ESM2G, h: CanESM2, i: INM-CM4, j: MIROC-ESM, and k: MPI-ESM-MR.

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