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Global cropland expansion enhances cropping potential and reduces its inequality among countries

Xiaoxuan Liu et al.

Correspondence to: Le Yu (leyu@tsinghua.edu.cn)

Supplementary Information

Table S1. Delineation of GCAM regions and their containing countries.

reg32_id	Continent	Region	Country
1	North America	USA	United States
8		Canada	Canada
9		Central America and Caribbean	Aruba, Anguilla, Netherlands Antilles, Antigua & Barbuda, Bahamas, Belize, Bermuda, Barbados, Costa Rica, Cuba, Cayman Islands, Dominica, Dominican Republic, Guadeloupe, Grenada, Guatemala, Honduras, Haiti, Jamaica, Saint Kitts and Nevis, Saint Lucia, Montserrat, Martinique, Nicaragua, Panama, El Salvador, Trinidad and Tobago, Saint Vincent and the Grenadines
20		Mexico	Mexico
7		Brazil	Brazil
25		South America_Northern	French Guiana, Guyana, Suriname, Venezuela
26		South America_Southern	Bolivia, Chile, Ecuador, Peru, Paraguay, Uruguay
30		Argentina	Argentina
31		Colombia	Colombia
12	Europe	EU-12	Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, Slovenia
13		EU-15	Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Greenland, Ireland, Italy, Luxembourg, Monaco, Netherlands, Portugal, Sweden, Spain, United Kingdom
14		Europe_Eastern	Belarus, Moldova, Ukraine
15		Europe_Non_EU	Albania, Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, Serbia, Turkey
16		European Free Trade Association	Iceland, Norway, Switzerland
2	Africa	Africa_Eastern	Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Reunion, Rwanda, Sudan, Somalia, Uganda
3		Africa_Northern	Algeria, Egypt, Western Sahara, Libya, Morocco, Tunisia
4		Africa_Southern	Angola, Botswana, Lesotho, Mozambique, Malawi, Namibia, Swaziland, Tanzania, Zambia, Zimbabwe
5		Africa_Western	Benin, Burkina Faso, Central African Republic, Cote d'Ivoire, Cameroon, Democratic Republic of the Congo, Congo, Cape Verde, Gabon, Ghana, Guinea, Gambia, Guinea-Bissau,

			Equatorial Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Sao Tome and Principe, Chad, Togo
24		South Africa	South Africa
10	Asia	Central Asia	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Turkmenistan, Uzbekistan
11		China	China
17		India	India
18		Indonesia	Indonesia
19		Japan	Japan
21		Middle East	United Arab Emirates, Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Yemen
22		Pakistan	Pakistan
23		Russia	Russia
27		South Asia	Afghanistan, Bangladesh, Bhutan, Sri Lanka, Maldives, Nepal
28		South Korea	South Korea
29		Southeast Asia	American Samoa, Brunei Darussalam, Cocos (Keeling) Islands, Cook Islands, Christmas Island, Fiji, Federated States of Micronesia, Guam, Cambodia, Kiribati, Lao Peoples Democratic Republic, Marshall Islands, Myanmar, Northern Mariana Islands, Malaysia, Mayotte, New Caledonia, Norfolk Island, Niue, Nauru, Pacific Islands Trust Territory, Pitcairn Islands, Philippines, Palau, Papua New Guinea, Democratic People's Republic of Korea, French Polynesia, Singapore, Solomon Islands, Seychelles, Thailand, Tokelau, Timor Leste, Tonga, Tuvalu, Viet Nam, Vanuatu, Samoa
6	Australia	Australia_NZ	Australia, New Zealand

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Table S2. Correspondence between our new categories and legends used in HYDE datasets.

Land Cover Type	legends used in HYDE datasets	
Cropland	21	Village, Rice
	22	Village, Irrigated
	23	Village, Rainfed
	31	Croplands, residential irrigated
	32	Croplands, residential rainfed
	33	Croplands, populated
Woodland	51	Semi-natural woodlands, residential
	52	Semi-natural woodlands, populated
	53	Semi-natural woodlands, remote
	61	Wild, remote - woodlands
Grassland	24	Village, Pastoral
	34	Croplands, pastoral
	41	Rangeland, residential
	42	Rangeland, populated
	43	Rangeland, remote
Ice	63	Wild, remote - ice
Urban	11	Urban
	12	Dense settlements
Bareland	54	Semi-natural treeless & barren lands
	62	Wild, remote - treeless & barren

Table S3. Correspondence between our new categories and legends used in PV datasets.

Land Cover Type	legends used in PV datasets	
Woodland	1	Tropical Evergreen Forest/Woodland
	2	Tropical Deciduous Forest/Woodland
	3	Temperate Broadleaf Evergreen Forest/Woodland
	4	Temperate Needleleaf Evergreen Forest/Woodland
	5	Temperate Deciduous Forest/Woodland
	6	Boreal Evergreen Forest/Woodland
	7	Boreal Deciduous Forest/Woodland
	8	Mixed Forest
	11	Dense Shrubland
	12	Open Shrubland
Grassland	9	Savanna
	10	Grassland/Steppe
	13	Tundra
Ice	63	Polar desert/Rock/Ice
Bareland	54	Desert

Table S4. Delineation of climate cropping potential zones in the tropics.

ZONE	PRE	$LGP_{T=5}$	$LGP_{T=10}$	$TS_{T=0}$	$TS_{T=10}$	LGP	$TSG_{T=5}$	$TSG_{T=10}$
0	＜300	＜120	＜90	＜1600	＜1000	＜45	＜3200	＜2700
1	⩾300	⩾120	⩾90	⩾1600	⩾1000	⩾45	⩾3200	⩾2700
2	⩾600	⩾240	⩾165	⩾6400	⩾3600	⩾210	⩾4000	⩾3200
3	⩾1850	⩾360	⩾360	⩾7200	⩾7000	⩾360	⩾5100	⩾4800

Table S5. Delineation of cropping potential zones in subtropics and temperate zones.

ZONE	PRE	$LGP_{T=5}$	$LGP_{T=10}$	$TS_{T=0}$	$TS_{T=10}$	LGP	$TSG_{T=5}$	$TSG_{T=10}$
0	＜300	＜120	＜90	＜1600	＜1000	＜45	＜3200	＜2900
1	≥300	≥120	≥90	≥1600	≥1000	≥45	≥3200	≥2900
2	≥600	≥240	≥165	≥4500	≥3600	≥210	≥4000	≥3200
3	≥1850	≥330	≥270	≥5700	≥5500	≥330	≥5100	≥4800

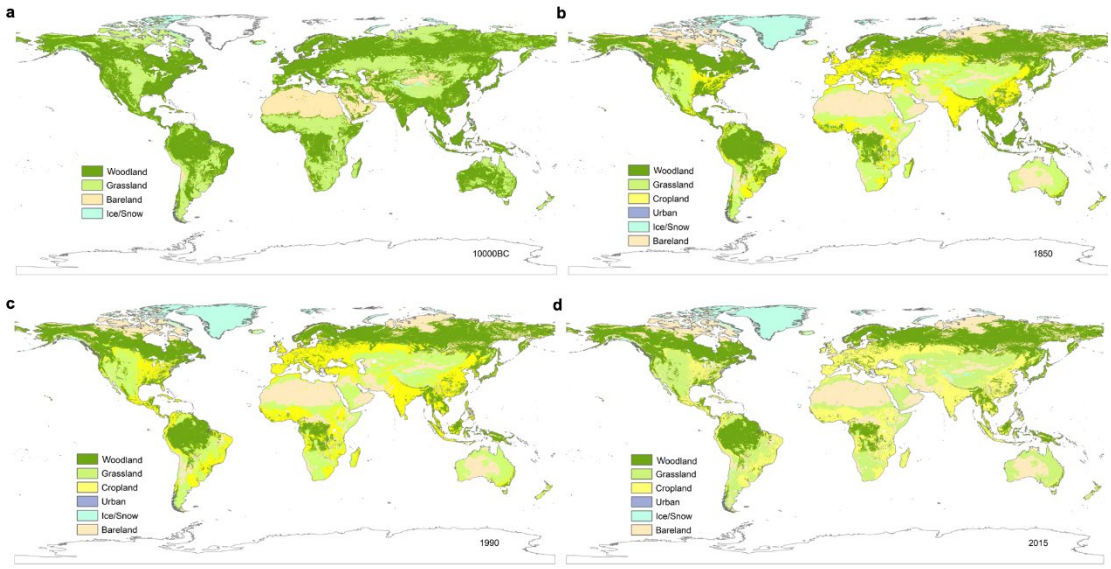

Fig. S1. HYDE data for (a) 10000BC, (b) 1850, (c) 1990 and (d) 2015.

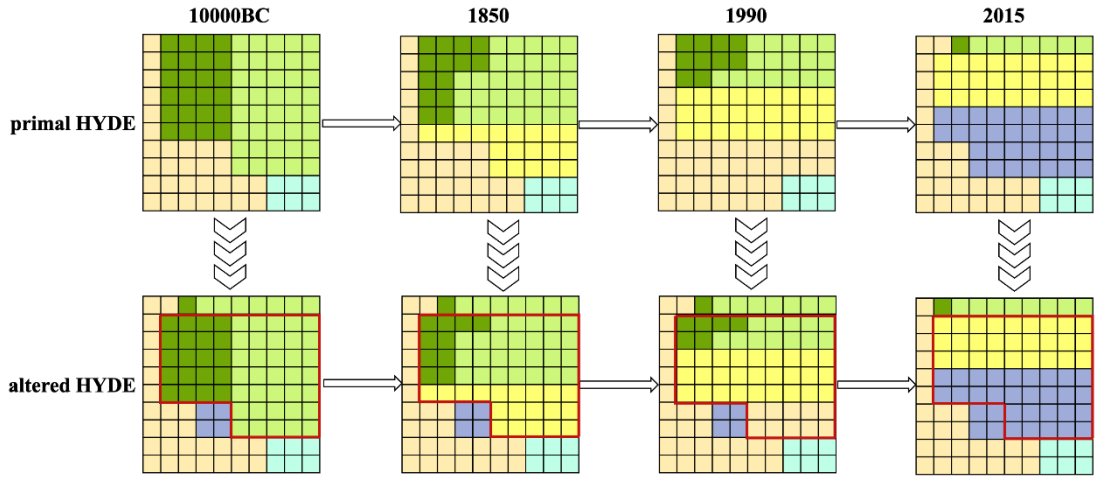

Fig. S2. The primal HYDE data and the altered HYDE data, which only keep areas (the red frame) with land cover changes in cropland and other areas of variation are set the same as the base year of 2015.

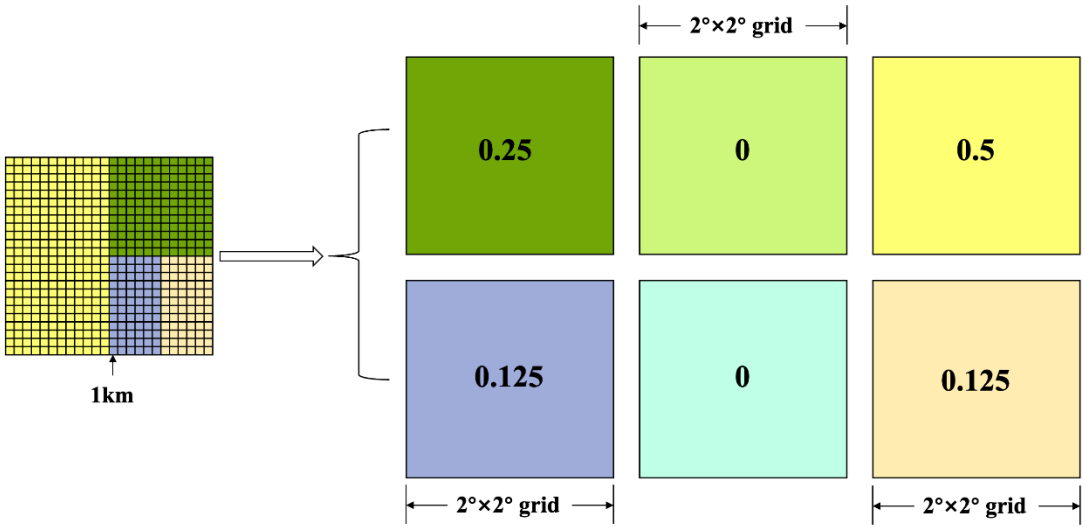

Fig. S3. The aggregate example from 1km to 2° grid cell.

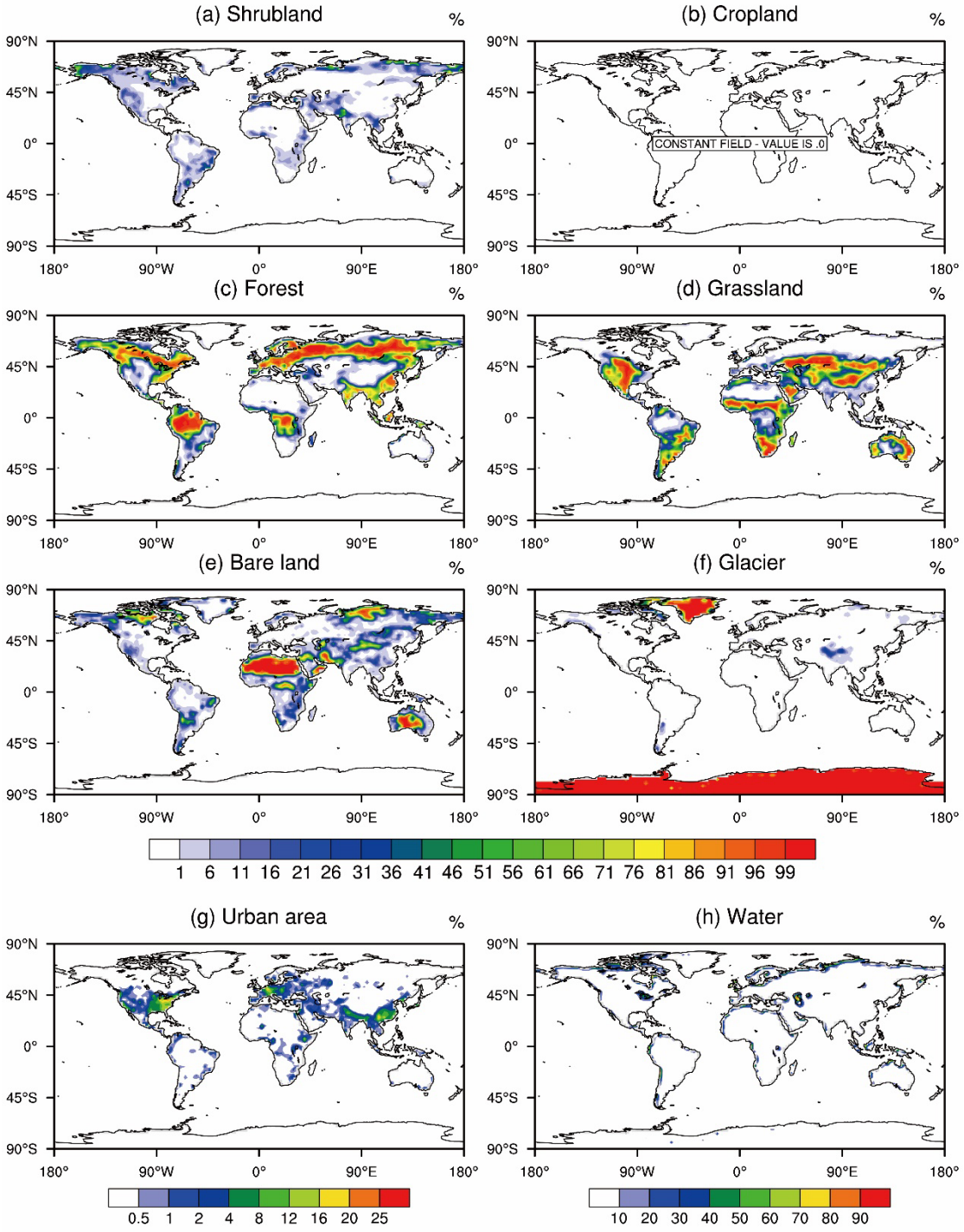

Fig. S4. Land cover used in CESM for 10000BC.

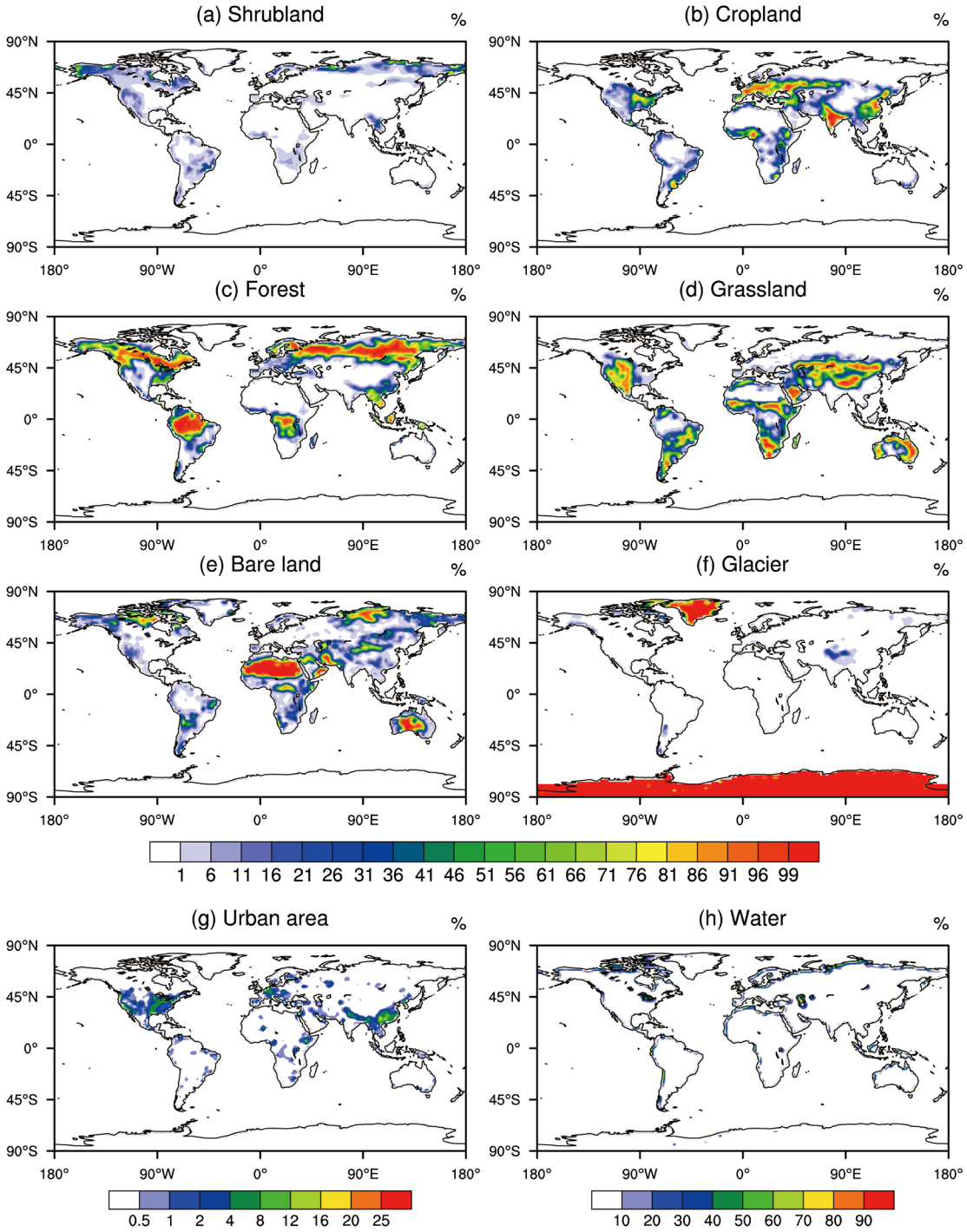

Fig. S5. Land cover used in CESM for 1850.

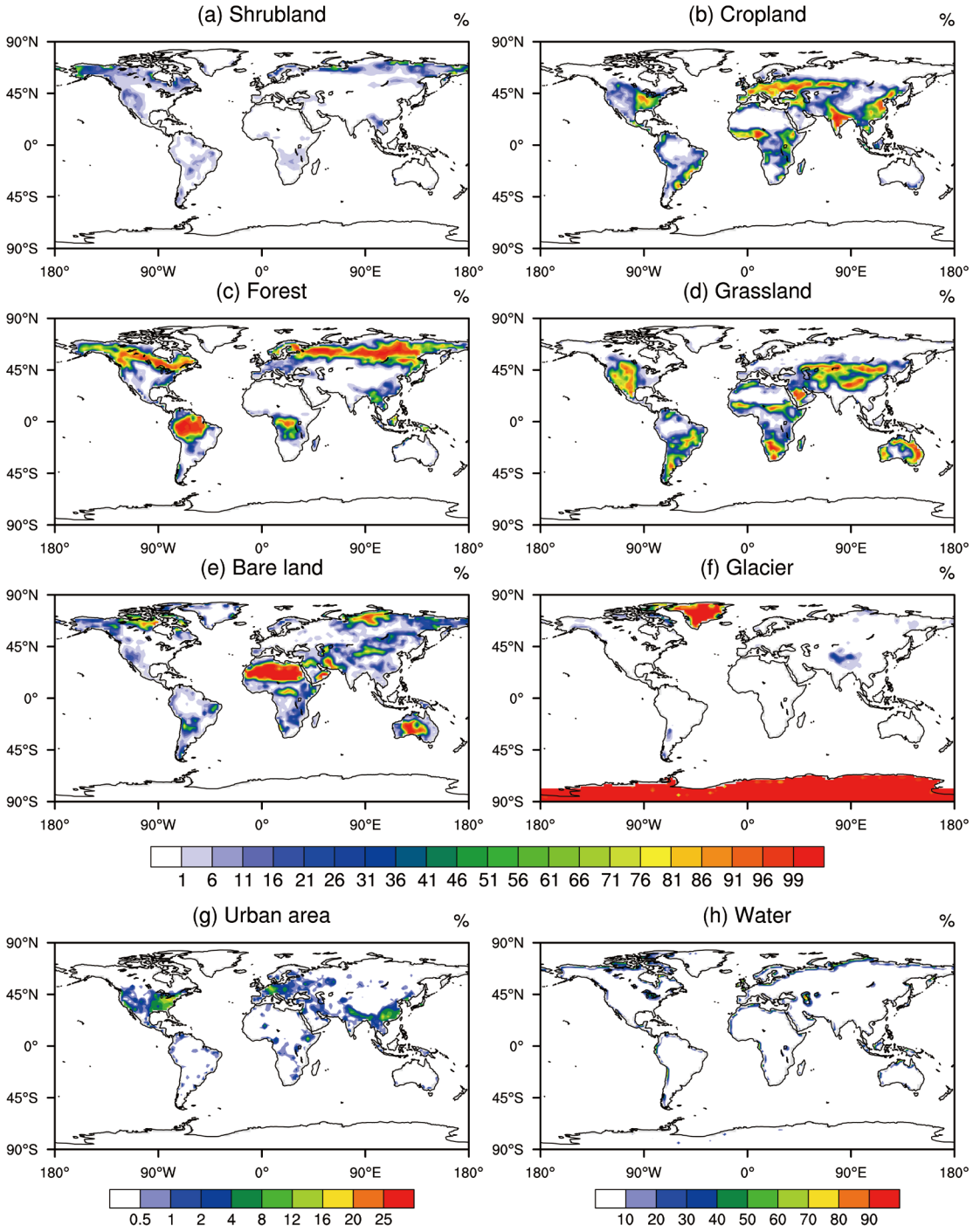

Fig. S6. Land cover used in CESM for 1990.

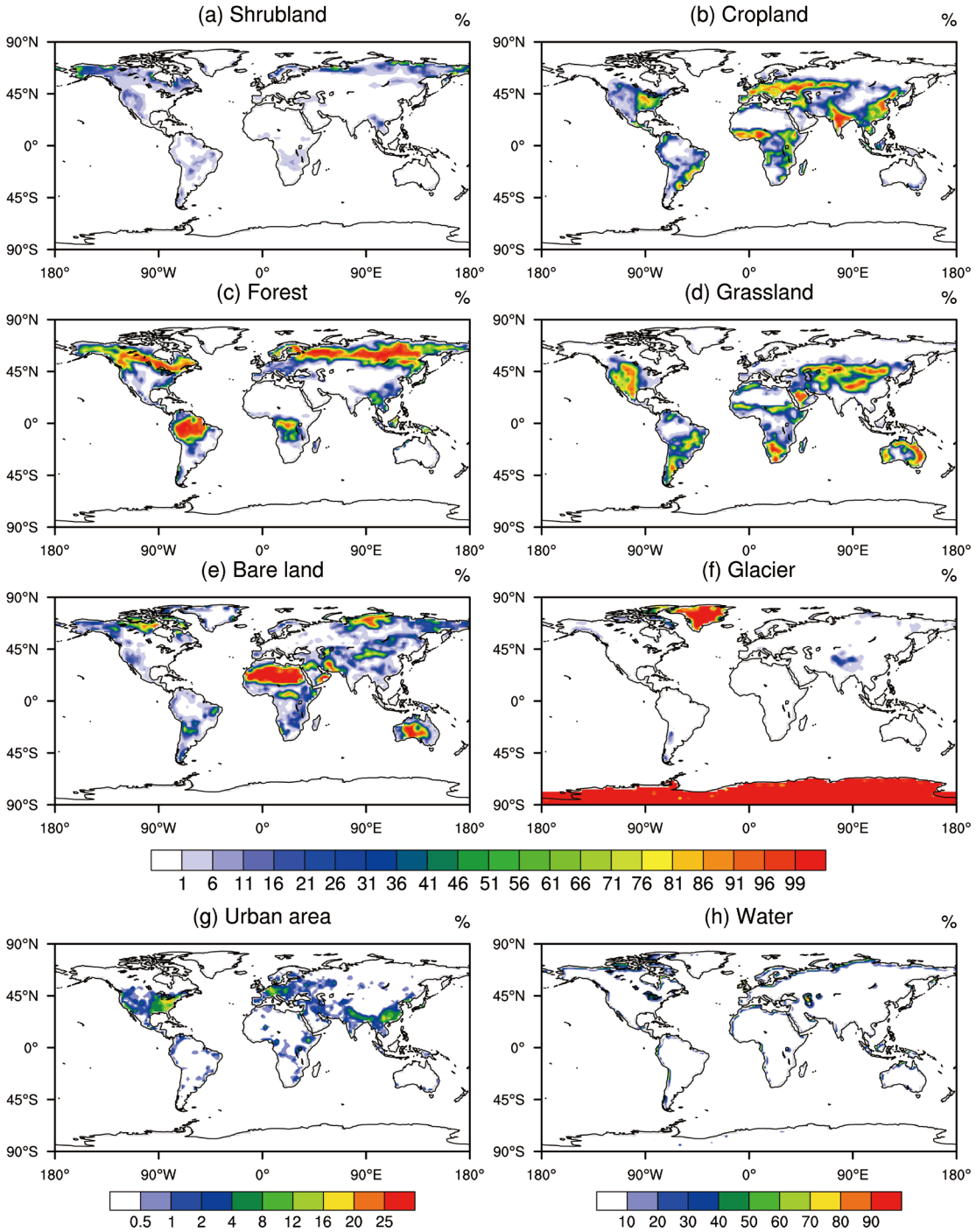

Fig. S7. Land cover used in CESM for 2015.

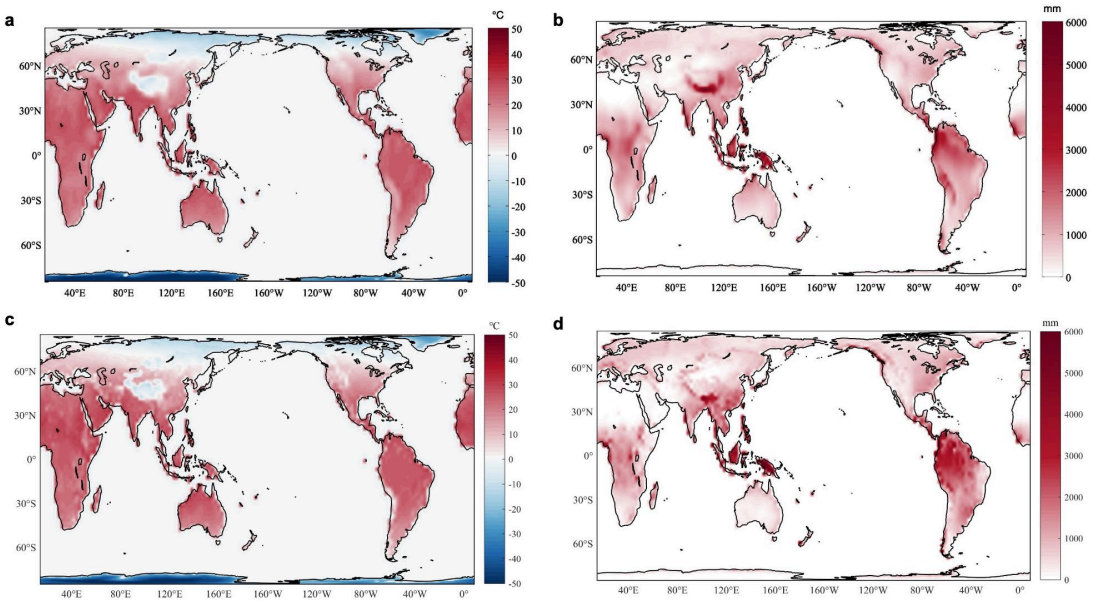

Fig. S8. Bias-corrected T and P in 10000BC based on ERA5. (a) uncorrected temperature (b) uncorrect precipitation (c) corrected temperature (d) corrected precipitation.

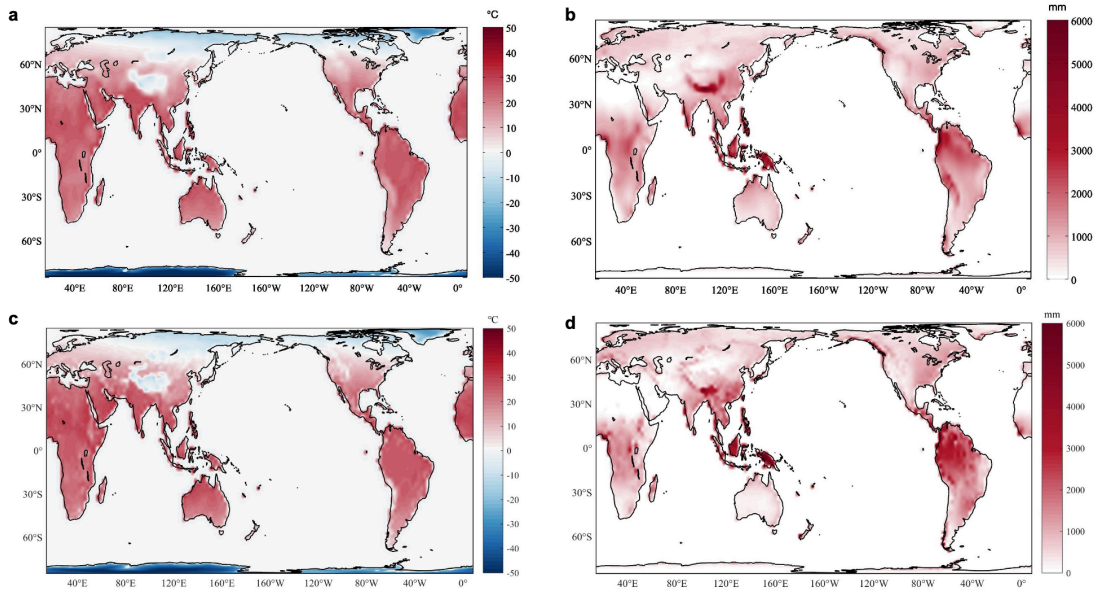

Fig. S9. Bias-corrected T and P in 1850 based on ERA5. (a) uncorrected temperature (b) uncorrect precipitation (c) corrected temperature (d) corrected precipitation.

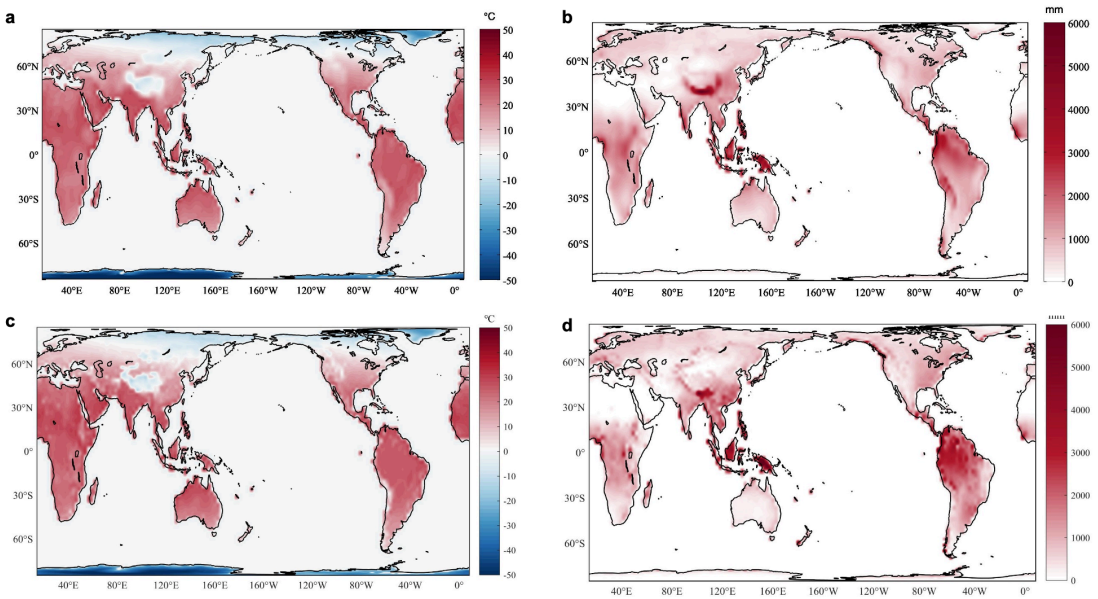

Fig. S10. Bias-corrected T and P in 1990 based on ERA5. (a) uncorrected temperature (b) uncorrect precipitation (c) corrected temperature (d) corrected precipitation.

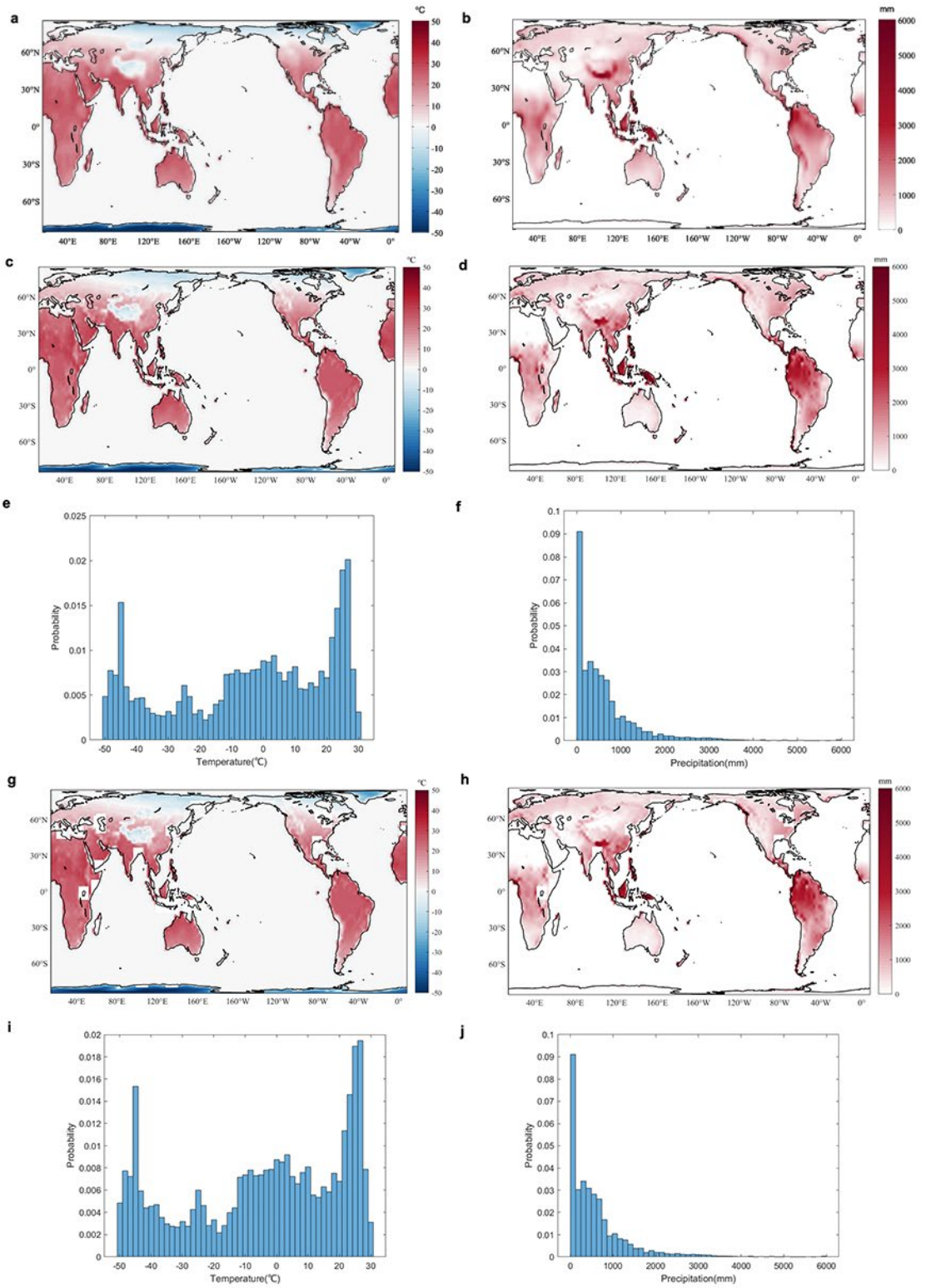

Fig. S11. Bias-corrected T and P in 2015 based on ERA5. (a) uncorrected temperature (b) uncorrect precipitation (c) corrected temperature (d) corrected precipitation (e) PDF of corrected temperature (f) PDF of corrected precipitation (g) ERA5 temperature (h) ERA5 precipitation (i) PDF of ERA5 temperature (j) PDF of ERA5 precipitation.

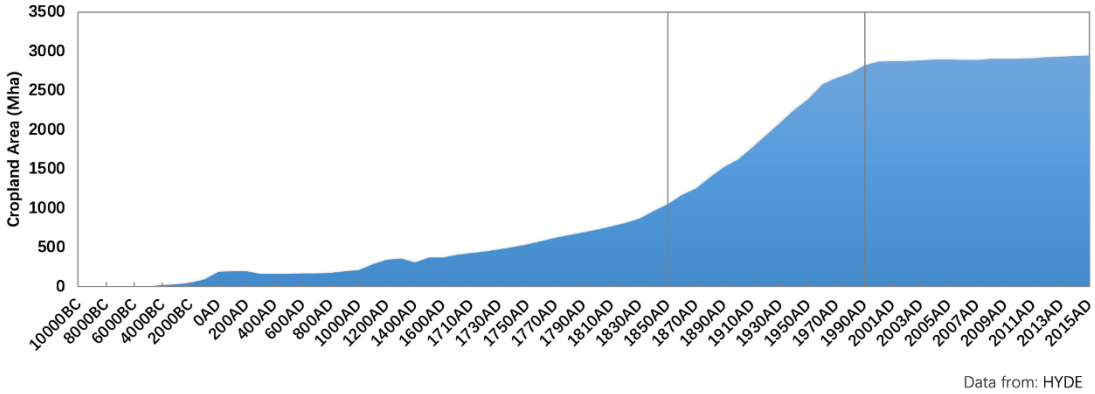

Fig. S12. Cropland areas from 10000BC to 2015.

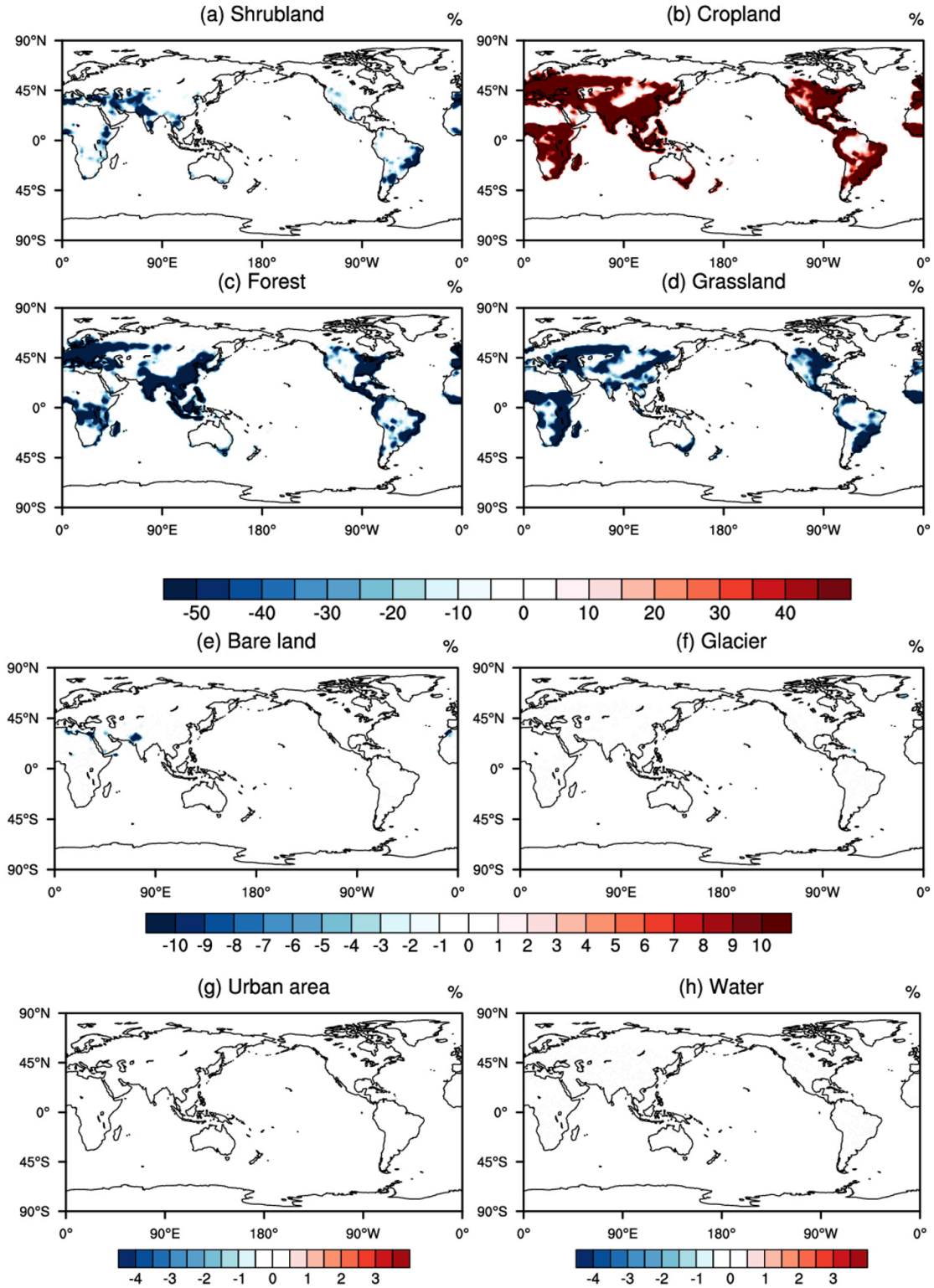

Fig. S13. Land cover changes caused by cropland expansion/contraction from 10000BC to 2015.

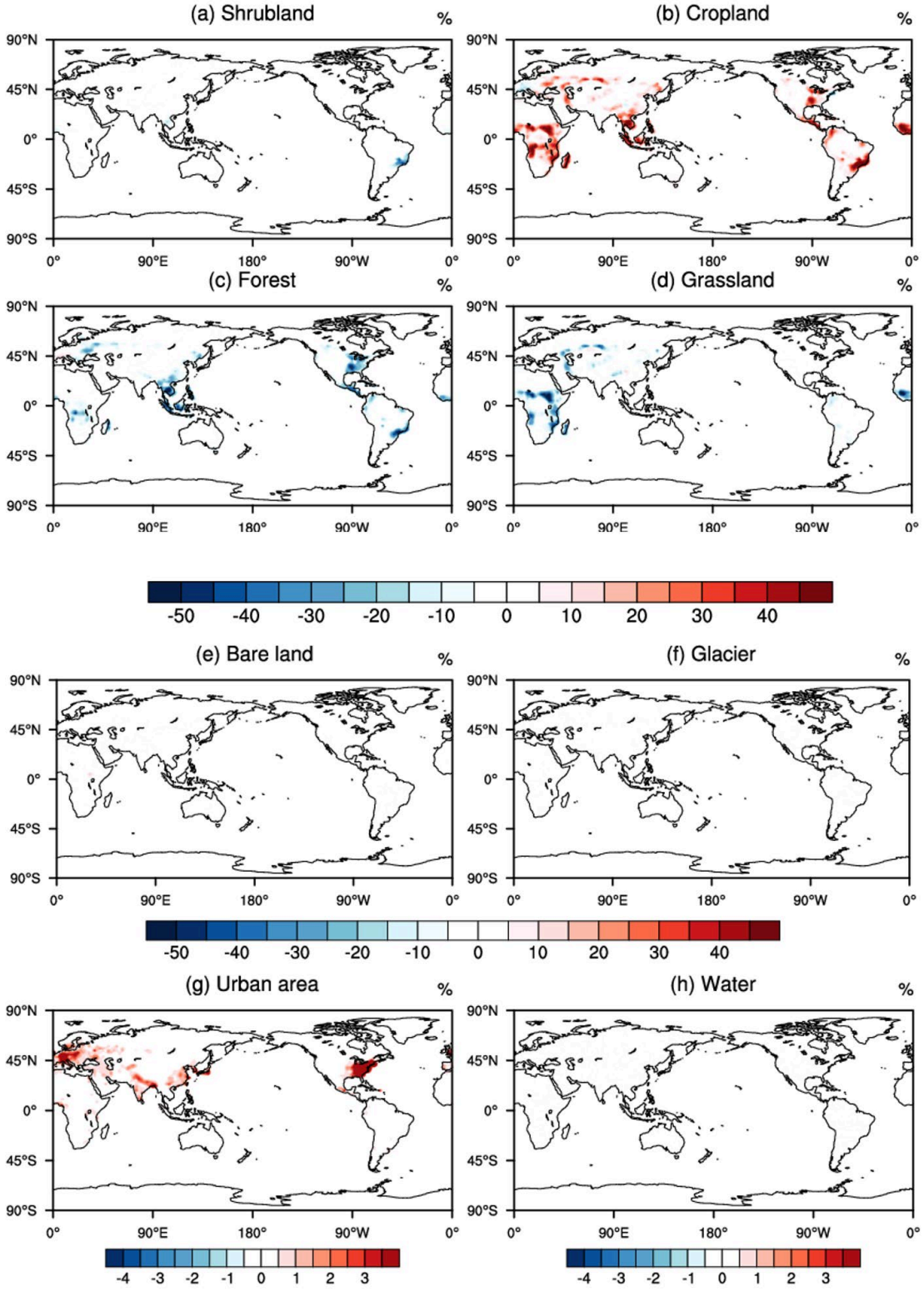

Fig. S14. Same as Fig. S2 but for from 1850 to 2015.

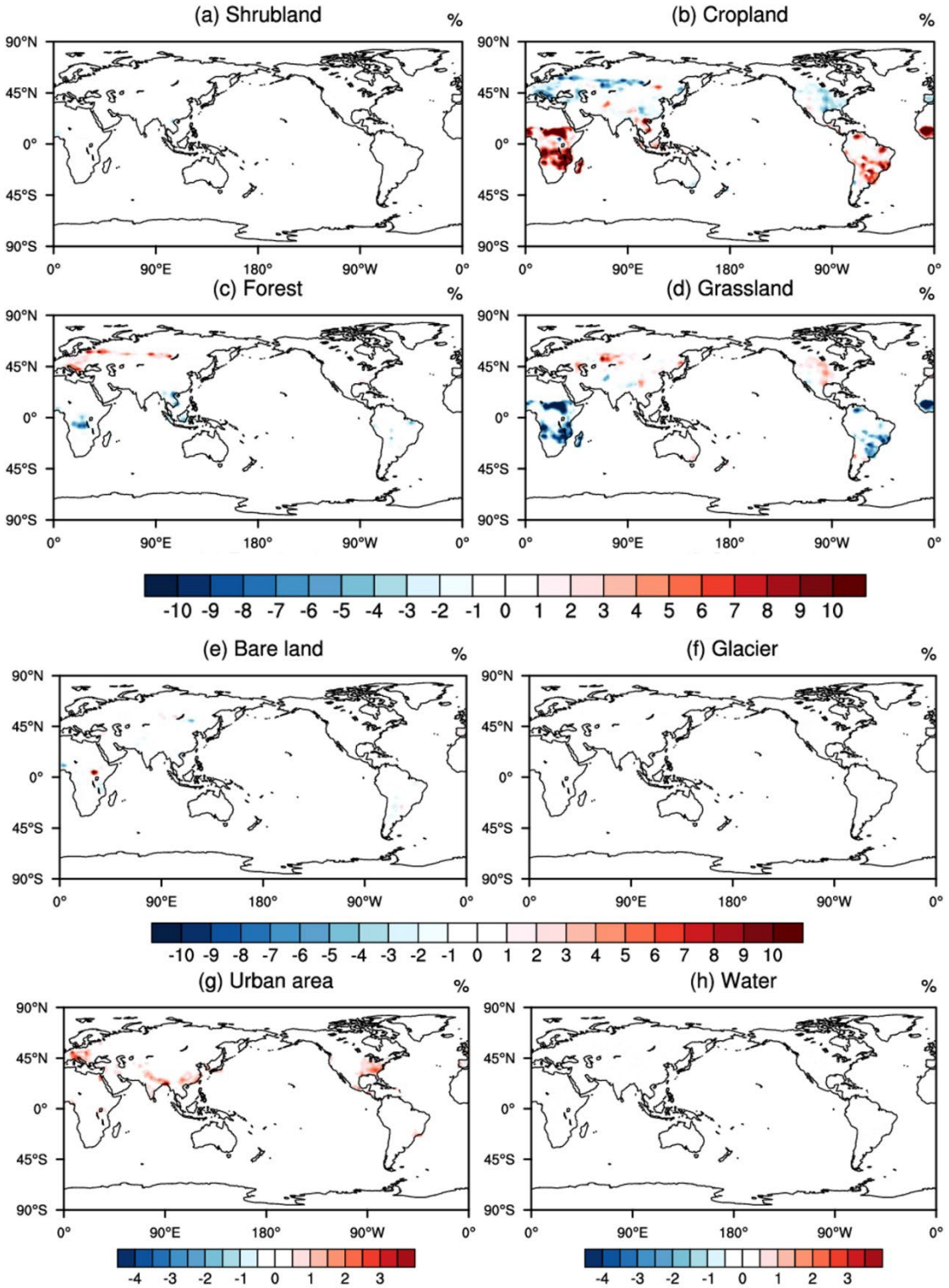

Fig. S15. Same as Fig. S2 but for from 1990 to 2015.

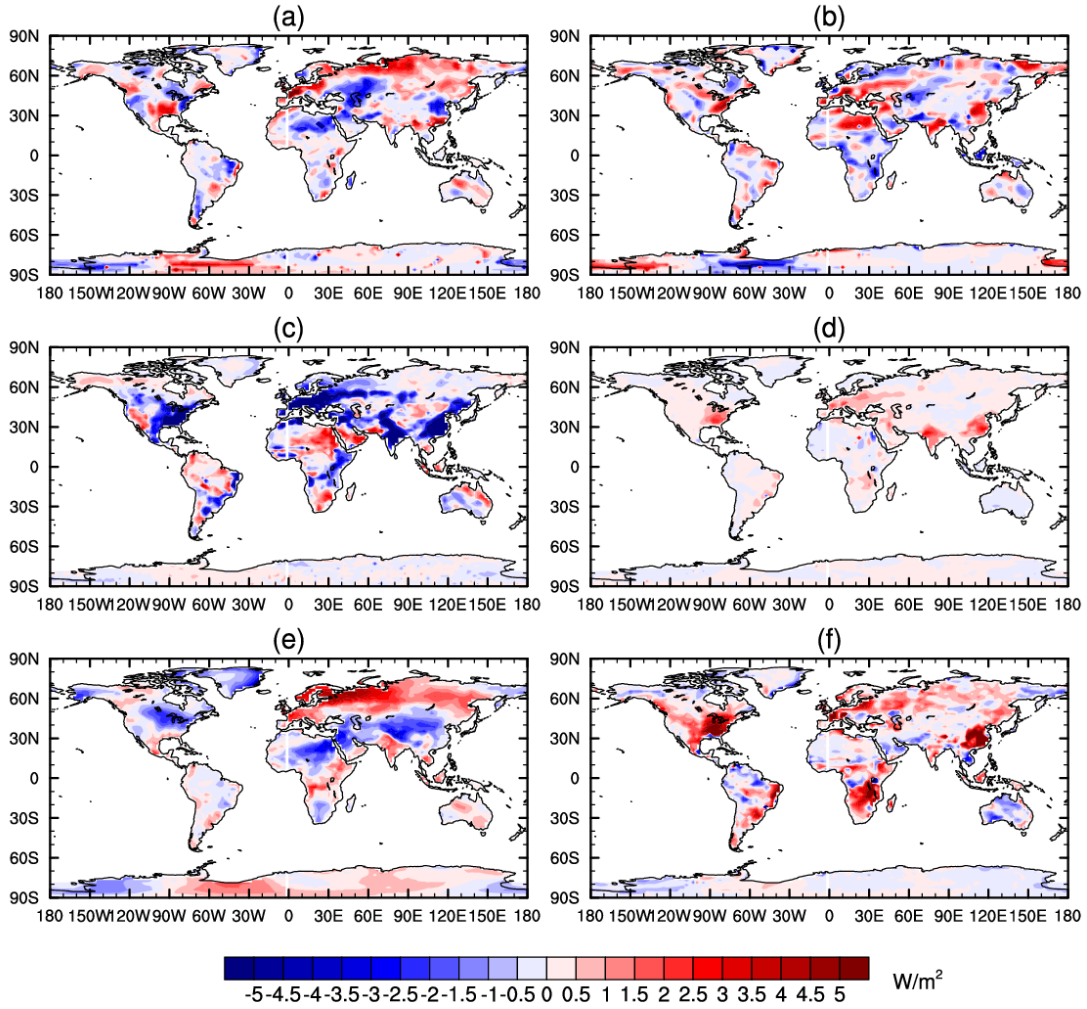

Fig. S16. Differences between crop2015 and crop10000BC in (a) horizontal temperature advection, (b) adiabatic heating/cooling, (c) surface sensible heat flux, (d) shortwave radiative heating, (e) longwave downwelling flux, and (f) latent heat release plus vertical diffusion. Unit is unified to W/m^2 by multiplying atmospheric mass at the near-surface and specific heat of air.

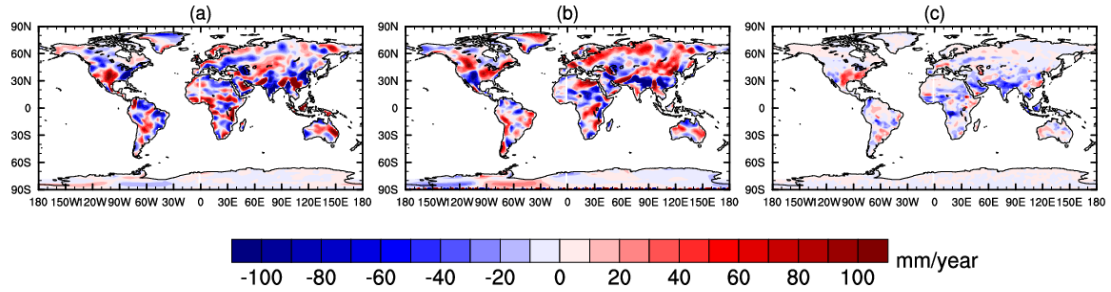

Fig. S17. Differences between crop2015 and crop10000BC in (a) moisture convergence, (b) moisture advection, and (c) evaporation.

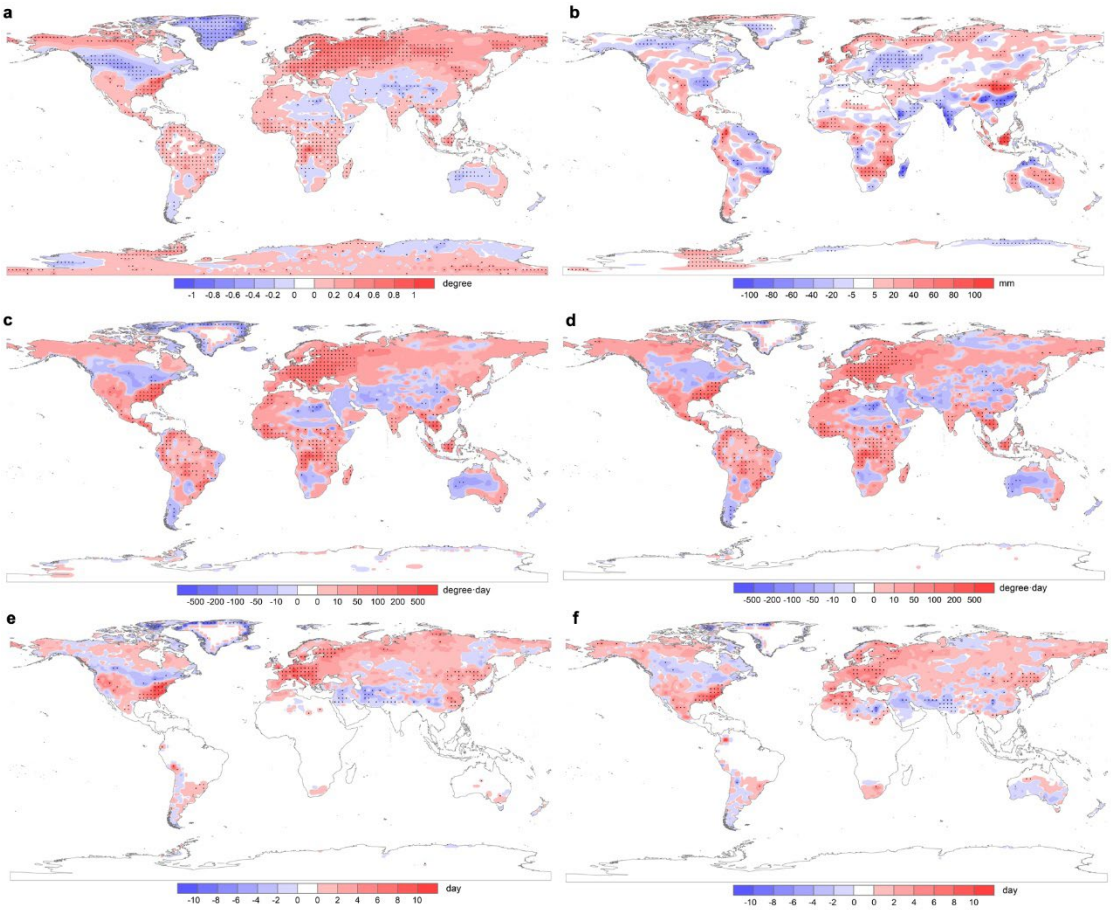

Fig. S18. Temperature and precipitation changes from 1850 to 2015. a, Annual mean temperature. b, Annual mean precipitation. c, $TS_{t=0}$. d, $TS_{t=10}$. e, $LGP_{t=5}$. f, $LGP_{t=10}$.

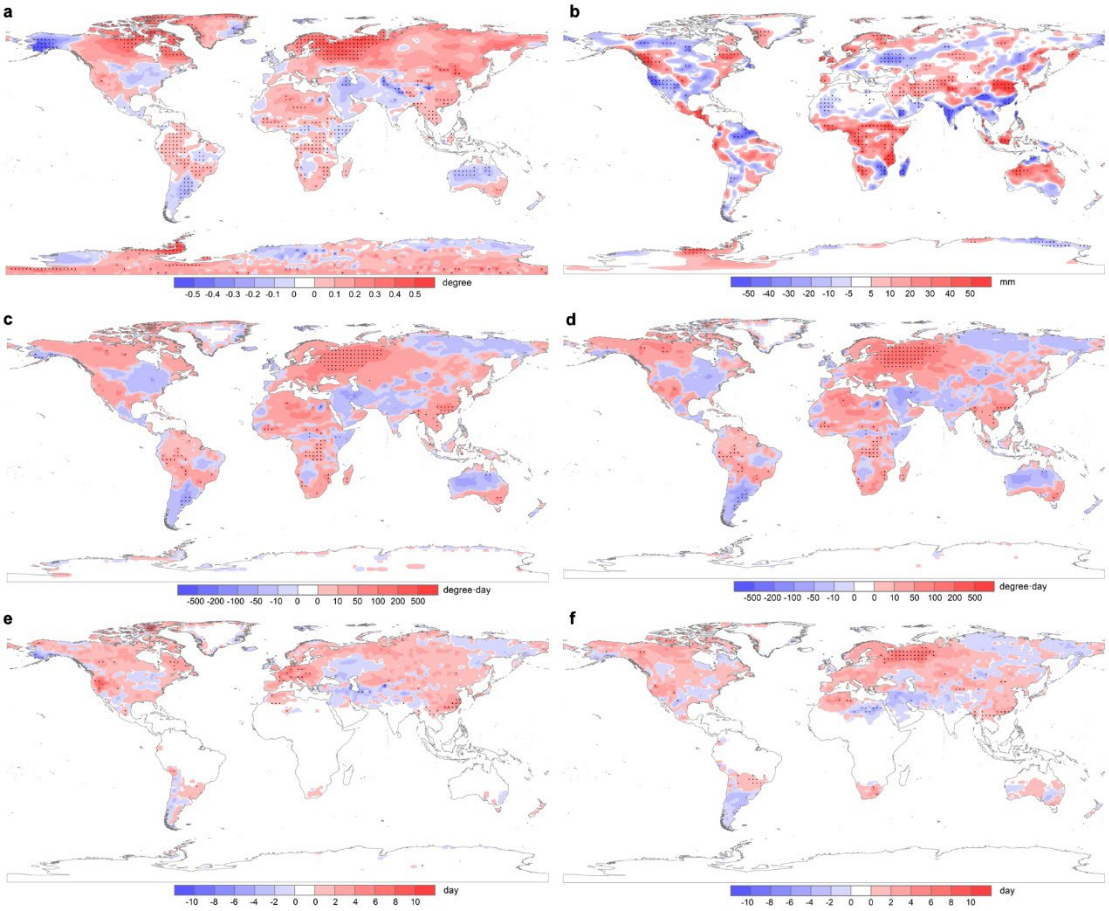

Fig. S19. Same as Fig. S7 but for from 1990 to 2015.

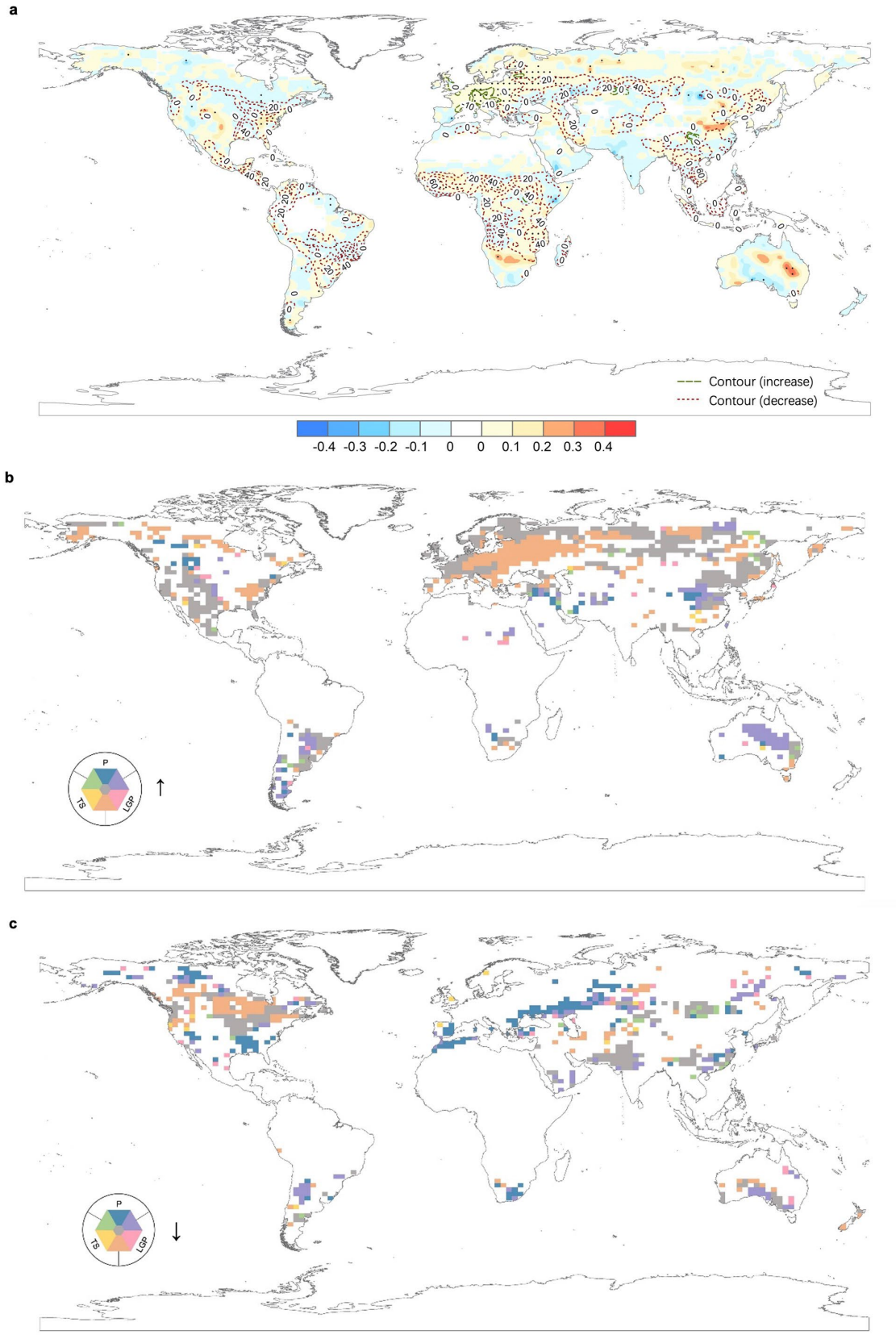

Fig. S20. Cropping potential changes and causes from 1850 to 2015.

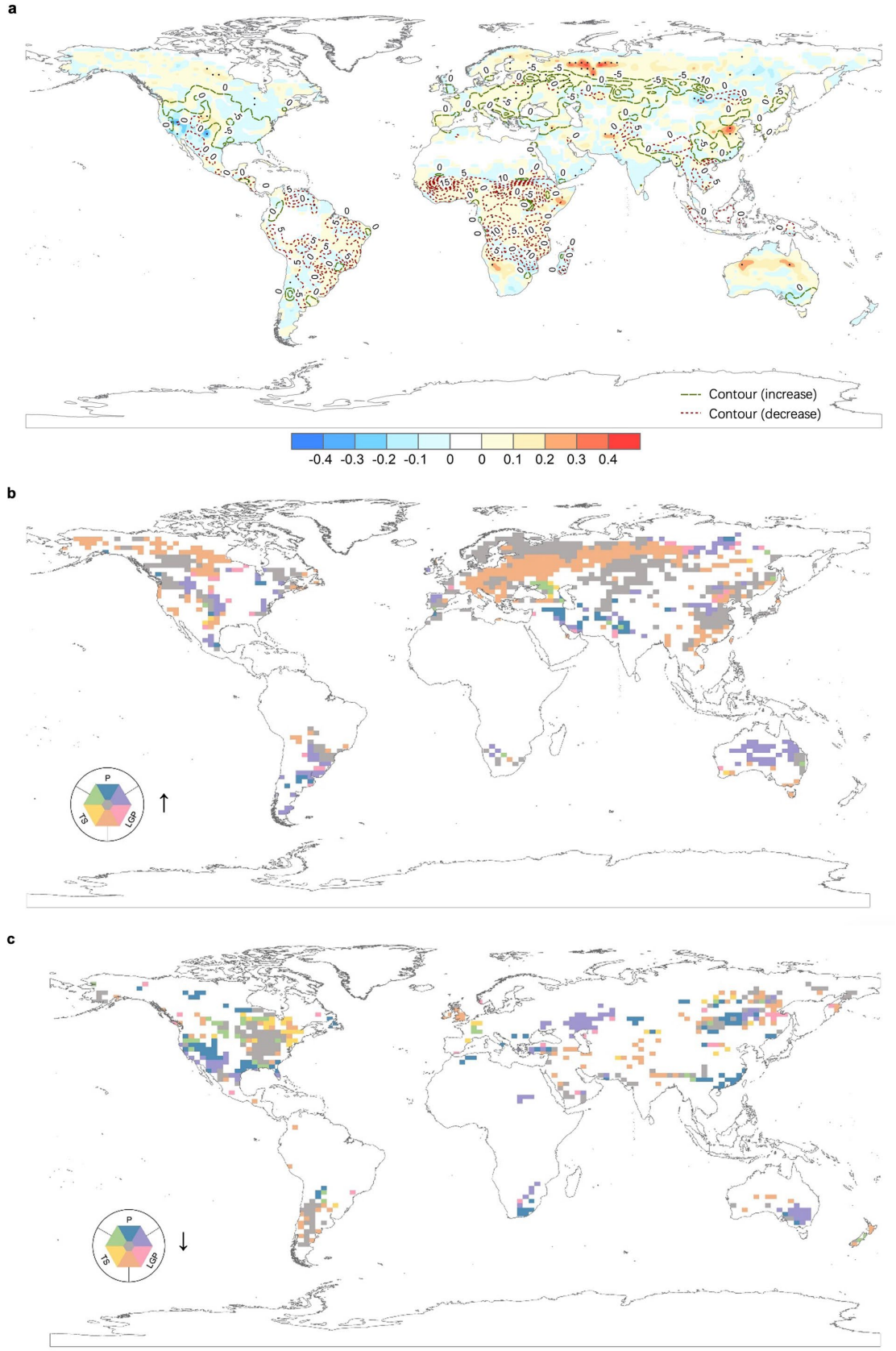

Fig. S21. Cropping potential changes and causes from 1990 to 2015.

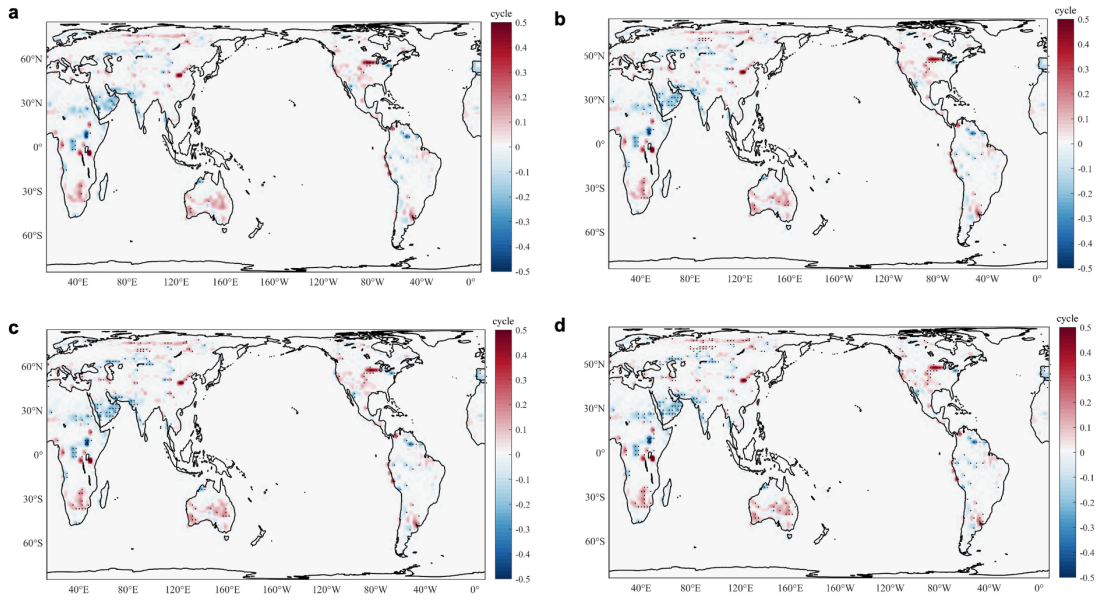

Fig. S22. Cropping potential changes with (a)95%, (b)90%, (c)85%, (d)80%confidence level from 10000BC to 2015.