

Historical Carbon Debt and Credit 1750-2023

Supplementary Information (SI)

December 19, 2025

Contents

1	Introduction	3
2	Summary tables carbon debts and credits (main article)	4
3	Carbon debts and credits under different scenarios	9
3.1	Carbon debts and credits from fossil fuels	9
3.1.1	Scenario (1): Production-based CO ₂ emissions (1960-2023)	9
3.1.2	Scenario (2): Incorporating consumption-based CO ₂ emissions (1750-2023)	10
3.1.3	Scenario (3): Production-based GHG emissions (1750-2023)	11
3.1.4	Scenario (4): Production-based CO ₂ emissions (1750-2023) (without Monte Carlo)	12
3.2	Carbon debts and credits from fossil fuels and land use change	15
3.2.1	Scenario (5): Production-based CO ₂ emissions (inc. LUC) (1960-2023)	15
3.2.2	Scenario (6): Production-based GHG emissions (inc. LUC) (1850 - 2023)	16
3.2.3	Scenario (7): Production-based CO ₂ emissions (inc. LUC) (1850-2023) (without Monte Carlo)	18
3.2.4	Scenario (8): Land use change CO ₂ emissions (excl. emissions from fossils) (1850-2023)	19
3.3	Summary tables of all alternative scenarios	21
4	Per capita contributions to national debts and credits	26
4.1	Per capita contribution to debts and credits from fossil fuels	26
4.1.1	Person-year contributions to production-based CO ₂ emissions (1960 - 2023)	26
4.1.2	Person-year contributions when incorporating consumption-based CO ₂ emissions (1750 - 2023)	27

4.1.3	Person-year contributions to production-based GHG emissions (1750 - 2023)	29
4.1.4	Person-year contributions to production-based CO ₂ emissions (1750 - 2023) (without Monte Carlo)	30
4.2	Per capita contributions to debts and credits from fossil fuels and land use change	32
4.2.1	Person-year contributions to production-based CO ₂ emissions (inc. LUC) (1960 - 2023)	32
4.2.2	Person-year contributions to GHG emissions (inc. land use change) (1750 - 2023)	33
4.2.3	Person-year contributions to production-based CO ₂ emissions (inc. land use change) (1850 - 2023) (without Monte Carlo)	34
4.2.4	Person-year contributions to land use change CO ₂ emissions, excl. fossils (1750 - 2023)	37
4.3	Summary tables of per capita contributions to debts and credits	38
5	Country-level cumulative emissions	41
5.1	Cumulative production-based CO ₂ emissions from fossil fuels (1960 - 2023) . .	41
5.2	Cumulative CO ₂ emissions from fossil fuels (inc. consumption-based) (1750 - 2023)	42
5.3	Cumulative GHG emissions from fossil fuels (1750 - 2023)	43
5.4	Cumulative production-based CO ₂ emissions from fossil fuels (1750 - 2023) (without Monte Carlo)	44
5.5	Cumulative production-based CO ₂ emissions from fossil fuels and land use change (1960 - 2023)	46
5.6	Cumulative GHG emissions from fossil fuels and land use change (1750 - 2023)	47
5.7	Cumulative production-based CO ₂ emissions from fossil fuels and land use change (1750 - 2023) (without Monte Carlo)	48
5.8	Cumulative land use change CO ₂ emissions (1850 - 2023)	49

1 Introduction

This Supplementary Information provides the full set of numerical results underlying the specifications presented in the main article, together with additional figures and calculations of carbon debts and credits with different data. These alternative scenarios incorporate different greenhouse gases (e.g., CO₂, methane), emission sources (fossil fuels, land-use change), and time frames. By systematically varying these elements, we broaden the scope of our assessment and offer robustness checks for the main findings reported in the article.

Table 1 summarizes the consistency in country rankings for the two largest historical carbon creditors and debtors across all specifications. Their positions remain stable under every scenario with one exception: Russia’s ranking when using consumption-based data where possible. We also report results for Brazil, which typically appears as the 7th or 8th largest creditor. When emissions from land-use change are included, however, Brazil’s position shifts substantially, from a major creditor to the third largest debtor, consistent with the findings presented in our main paper.

Scenario	Main specification				
	Fossil fuels 1750–2023	Fossil fuels 1960–2023	Fossil fuels (cons.-based)	Fossil fuels incl. all GHGs	Fossil fuels incl. LUC 1850–2023
India largest creditor	✓	✓	✓	✓	✓
China second largest creditor	✓	✓	✓	✓	✓
Brazil 8th largest creditor	✓	✗(7th instead)	✓	✓	✗(3rd largest debtor)
Russia second largest debtor	✓	✓	✗ (4th instead)	✓	✓
USA largest debtor	✓	✓	✓	✓	✓

Tab. A1.: Position of main debtors and creditors across scenarios

Section 2 contains summary tables of countries’ carbon debts and credits, as presented in the main paper. Section 3 presents the results of carbon debts and credits calculated across different scenarios, which vary by time frame, emission source (fossil fuels, land use change), and pollutant type (CO₂, methane, etc.). Section 4 shows the per capita contributions to the national carbon debts and credits presented earlier. Finally, Section 5 presents cumulative emissions per country under these eight scenarios, highlighting the importance of incorporating historical population when assessing countries’ contributions to climate change.

2 Summary tables carbon debts and credits (main article)

Here, we present the numerical results underlying the carbon debt and credit estimates shown in Figures 2 and 3 of the main article. Table 2 presents carbon debts and credits calculated based on production-based CO₂ emissions from fossil fuels and industrial processes obtained from the Global Carbon Budget. Table 3 presents carbon debts and credits calculated based on fossil fuel and land use change emissions. Land-use change (LUC) emissions are computed as the average of four bookkeeping models (OSCAR, LUCE, BLUE, and H&C2023)^{1, 2}.

Data uncertainties for carbon debt and credit estimates are quantified using Monte Carlo simulations. For fossil CO₂ emissions, confidence intervals are derived from the +/- 5% observational uncertainty reported by the Global Carbon Budget¹. For land-use change emissions, annual uncertainties are calculated from the range spanned by the four bookkeeping models included in the Global Carbon Atlas; these annual uncertainties are then propagated through Monte Carlo simulation before aggregation¹. For more details, see the Methods section of the main article.

Tab A2.: Carbon Debts and Credits from fossil fuels by 2023 (Monte Carlo)

	country	Debt median	lower bound	upper bound	Debt median (pc)	lower bound	upper bound
1	United States	-356.60	-320.08	-393.13	-13.20	-11.85	-14.55
2	Russia	-65.37	-54.72	-76.02	-3.29	-2.75	-3.82
3	Germany	-57.11	-48.32	-65.89	-4.22	-3.57	-4.87
4	United Kingdom	-52.33	-44.86	-59.80	-5.34	-4.58	-6.11
5	Canada	-27.52	-24.59	-30.46	-10.13	-9.05	-11.21
6	Japan	-22.78	-15.65	-29.90	-1.39	-0.95	-1.82
7	Australia	-15.04	-13.34	-16.75	-9.15	-8.11	-10.18
8	Saudi Arabia	-14.46	-12.92	-16.01	-10.62	-9.48	-11.75
9	South Africa	-12.71	-10.63	-14.78	-3.72	-3.11	-4.32
10	Poland	-12.66	-9.85	-15.48	-2.20	-1.71	-2.68
11	Ukraine	-11.90	-8.73	-15.07	-1.73	-1.27	-2.19
12	Kazakhstan	-9.77	-8.51	-11.03	-5.78	-5.03	-6.52
13	France	-9.03	-4.77	-13.30	-0.82	-0.43	-1.21
14	Belgium	-7.99	-6.90	-9.09	-4.61	-3.98	-5.25
15	Netherlands	-6.96	-5.87	-8.05	-3.72	-3.14	-4.31
16	South Korea	-6.51	-4.39	-8.63	-1.34	-0.90	-1.77
17	Czechia	-6.26	-5.02	-7.50	-2.91	-2.33	-3.49
18	Iran	-5.97	-3.75	-8.19	-1.10	-0.69	-1.51
19	United Arab Emirates	-5.03	-4.56	-5.51	-22.14	-20.05	-24.23
20	Taiwan	-4.68	-3.71	-5.65	-2.51	-1.99	-3.03
21	Kuwait	-3.32	-3.00	-3.63	-21.76	-19.69	-23.83
22	Venezuela	-2.95	-2.20	-3.70	-1.72	-1.28	-2.16
23	Qatar	-2.27	-2.08	-2.45	-39.12	-35.92	-42.33
24	Malaysia	-2.25	-1.58	-2.93	-1.39	-0.97	-1.81
25	Denmark	-2.04	-1.68	-2.41	-2.70	-2.22	-3.19
26	Slovakia	-1.64	-1.25	-2.03	-1.95	-1.48	-2.42
27	Austria	-1.61	-0.99	-2.23	-1.10	-0.68	-1.53
28	Turkmenistan	-1.48	-1.24	-1.72	-3.76	-3.15	-4.38
29	Singapore	-1.43	-1.25	-1.61	-5.30	-4.62	-5.98
30	Israel	-1.37	-1.13	-1.61	-3.23	-2.66	-3.79
31	Libya	-1.36	-1.13	-1.59	-3.52	-2.94	-4.11
32	Trinidad and Tobago	-1.35	-1.21	-1.48	-11.47	-10.33	-12.60
33	Finland	-1.26	-0.92	-1.60	-1.73	-1.26	-2.20
34	Sweden	-1.23	-0.68	-1.78	-0.89	-0.49	-1.28
35	Belarus	-1.14	-0.59	-1.70	-0.81	-0.41	-1.20
36	Estonia	-1.05	-0.92	-1.19	-4.87	-4.23	-5.50
37	Oman	-1.01	-0.87	-1.15	-4.91	-4.24	-5.59
38	New Zealand	-0.99	-0.81	-1.17	-2.79	-2.28	-3.30
39	Norway	-0.99	-0.71	-1.26	-1.56	-1.12	-1.99
40	Uzbekistan	-0.92	-0.16	-1.68	-0.45	-0.08	-0.82
41	Bahrain	-0.90	-0.82	-0.99	-15.36	-13.87	-16.86
42	Argentina	-0.63	0.43	-1.69	-0.21	0.14	-0.57
43	Luxembourg	-0.59	-0.52	-0.65	-8.75	-7.78	-9.73
44	Bulgaria	-0.56	-0.11	-1.02	-0.46	-0.09	-0.84
45	Azerbaijan	-0.39	-0.10	-0.69	-0.50	-0.13	-0.87
46	Brunei	-0.36	-0.32	-0.39	-17.41	-15.77	-19.04
47	Switzerland	-0.31	0.06	-0.67	-0.30	0.06	-0.66
48	Greece	-0.20	0.32	-0.72	-0.14	0.22	-0.50
49	Lithuania	-0.18	0.02	-0.37	-0.34	0.03	-0.72
50	Slovenia	-0.12	-0.02	-0.21	-0.43	-0.08	-0.77
51	Bahamas	-0.10	-0.09	-0.12	-3.91	-3.32	-4.49
52	Hungary	-0.10	0.56	-0.76	-0.05	0.31	-0.42
53	Iceland	-0.08	-0.06	-0.09	-2.30	-1.80	-2.81
54	Mongolia	-0.05	0.05	-0.15	-0.18	0.17	-0.53
55	Mexico	-0.04	2.56	-2.64	-0.01	0.33	-0.34

	country	Debt median	lower bound	upper bound	Debt median (pc)	lower bound	upper bound
56	Cyprus	-0.03	0.01	-0.06	-0.25	0.11	-0.60
57	Serbia	-0.03	0.33	-0.38	-0.02	0.32	-0.37
58	Palau	-0.01	-0.004	-0.01	-2.71	-2.18	-3.25
59	Andorra	-0.005	-0.003	-0.01	-1.21	-0.78	-1.65
60	Nauru	-0.002	-0.002	-0.003	-2.21	-1.71	-2.70
61	World	0	238.40	-238.40	0	0.37	-0.37
62	Liechtenstein	0.001	0.002	-0.001	0.17	0.52	-0.17
63	Tuvalu	0.003	0.003	0.003	2.53	2.79	2.27
64	Antigua and Barbuda	0.01	0.01	0.002	0.50	0.82	0.18
65	Suriname	0.01	0.02	-0.01	0.17	0.50	-0.17
66	Seychelles	0.01	0.01	0.01	1.09	1.38	0.80
67	Marshall Islands	0.02	0.02	0.01	2.23	2.49	1.96
68	Moldova	0.02	0.18	-0.15	0.03	0.37	-0.30
69	Saint Kitts and Nevis	0.02	0.02	0.02	1.97	2.23	1.70
70	Dominica	0.02	0.02	0.02	2.24	2.50	1.98
71	Tonga	0.03	0.03	0.02	2.34	2.60	2.08
72	Kiribati	0.03	0.03	0.02	2.58	2.84	2.32
73	Saint Vincent and the Grenadines	0.03	0.04	0.03	2.26	2.53	2.00
74	Saint Lucia	0.03	0.04	0.03	1.91	2.18	1.64
75	Belize	0.04	0.04	0.03	1.77	2.05	1.50
76	Grenada	0.04	0.04	0.03	2.24	2.50	1.97
77	Sao Tome and Principe	0.04	0.04	0.04	2.54	2.80	2.28
78	Equatorial Guinea	0.05	0.07	0.02	0.63	0.95	0.32
79	Maldives	0.05	0.05	0.04	1.68	1.95	1.40
80	Samoa	0.05	0.05	0.04	2.41	2.67	2.15
81	Vanuatu	0.05	0.05	0.04	2.51	2.77	2.25
82	Iraq	0.05	0.68	-0.58	0.03	0.38	-0.32
83	Malta	0.06	0.08	0.04	0.97	1.27	0.67
84	Barbados	0.06	0.08	0.05	1.40	1.69	1.12
85	Gabon	0.08	0.12	0.03	0.56	0.86	0.25
86	Solomon Islands	0.10	0.11	0.09	2.51	2.77	2.25
87	Djibouti	0.10	0.12	0.09	2.33	2.59	2.07
88	Cape Verde	0.11	0.13	0.10	2.44	2.70	2.18
89	Latvia	0.12	0.25	-0.01	0.31	0.64	-0.02
90	Comoros	0.12	0.14	0.11	2.65	2.91	2.39
91	Guyana	0.15	0.17	0.12	1.58	1.85	1.30
92	Montenegro	0.15	0.18	0.12	1.60	1.88	1.33
93	Eswatini	0.16	0.18	0.14	2.20	2.46	1.93
94	Fiji	0.17	0.19	0.15	2.14	2.41	1.88
95	Botswana	0.17	0.21	0.14	1.39	1.67	1.11
96	North Macedonia	0.17	0.25	0.10	0.69	1.00	0.38
97	Romania	0.20	1.31	-0.92	0.06	0.41	-0.28
98	Mauritius	0.20	0.23	0.17	1.71	1.98	1.44
99	Bhutan	0.21	0.23	0.19	2.45	2.71	2.19
100	Jordan	0.21	0.32	0.10	0.61	0.92	0.29
101	Lebanon	0.23	0.34	0.11	0.62	0.93	0.31
102	Panama	0.26	0.32	0.20	1.18	1.48	0.89
103	Gambia	0.28	0.31	0.25	2.63	2.89	2.37
104	Jamaica	0.29	0.37	0.20	1.05	1.35	0.75
105	East Timor	0.29	0.32	0.26	2.68	2.94	2.42
106	Namibia	0.32	0.35	0.28	2.17	2.44	1.91
107	Guinea-Bissau	0.34	0.37	0.31	2.70	2.96	2.44
108	Lesotho	0.37	0.41	0.33	2.32	2.58	2.06
109	Uruguay	0.44	0.53	0.35	1.35	1.63	1.06
110	Costa Rica	0.45	0.52	0.38	1.72	2.00	1.45
111	Bosnia and Herzegovina	0.45	0.61	0.29	0.85	1.16	0.55
112	Kyrgyzstan	0.47	0.62	0.33	0.98	1.28	0.68
113	Italy	0.53	3.73	-2.68	0.06	0.40	-0.28
114	Armenia	0.54	0.63	0.44	1.60	1.88	1.33
115	Mauritania	0.55	0.61	0.49	2.39	2.65	2.12
116	Albania	0.57	0.65	0.49	1.82	2.09	1.55
117	Palestine	0.57	0.63	0.51	2.48	2.74	2.22
118	Chile	0.58	1.03	0.14	0.43	0.75	0.10
119	Eritrea	0.62	0.68	0.57	2.71	2.97	2.45
120	Congo	0.63	0.71	0.56	2.17	2.43	1.90
121	Liberia	0.71	0.78	0.64	2.60	2.86	2.34
122	Croatia	0.77	0.97	0.57	1.11	1.40	0.82
123	Dominican Republic	0.78	0.95	0.62	1.35	1.63	1.06
124	Nicaragua	0.83	0.93	0.73	2.26	2.53	2.00
125	Paraguay	0.84	0.94	0.74	2.25	2.52	1.99
126	Tajikistan	0.97	1.12	0.83	1.84	2.11	1.57
127	Honduras	0.99	1.11	0.87	2.15	2.42	1.89
128	Central African Republic	1.04	1.14	0.95	2.76	3.02	2.50
129	Cuba	1.05	1.36	0.75	1.03	1.33	0.73
130	El Salvador	1.06	1.18	0.93	2.24	2.51	1.98
131	Laos	1.09	1.22	0.97	2.32	2.58	2.06
132	Georgia	1.14	1.32	0.96	1.74	2.01	1.46
133	Togo	1.15	1.26	1.04	2.62	2.88	2.36
134	Spain	1.18	3.16	-0.81	0.20	0.53	-0.13
135	Ireland	1.22	1.60	0.84	0.96	1.26	0.66
136	Papua New Guinea	1.24	1.38	1.11	2.40	2.66	2.14
137	Sierra Leone	1.27	1.39	1.15	2.70	2.96	2.45
138	Ecuador	1.32	1.59	1.05	1.39	1.67	1.10
139	North Korea	1.39	2.18	0.59	0.57	0.89	0.24
140	Tunisia	1.39	1.63	1.15	1.61	1.88	1.33
141	Syria	1.51	1.86	1.15	1.21	1.50	0.93
142	Zimbabwe	1.61	1.84	1.37	1.85	2.12	1.58
143	Bolivia	1.66	1.88	1.45	2.04	2.31	1.78
144	Portugal	1.67	2.14	1.20	1.06	1.36	0.76
145	Algeria	1.84	2.62	1.06	0.72	1.03	0.42
146	Burundi	1.92	2.10	1.74	2.77	3.03	2.51
147	South Sudan	1.94	2.12	1.75	2.73	2.99	2.47
148	Haiti	1.96	2.16	1.77	2.67	2.93	2.41
149	Guatemala	1.99	2.23	1.76	2.23	2.49	1.97
150	Senegal	2.02	2.23	1.80	2.45	2.71	2.19

	country	Debt median	lower bound	upper bound	Debt median (pc)	lower bound	upper bound
151	Benin	2.02	2.22	1.82	2.63	2.89	2.37
152	Rwanda	2.06	2.26	1.87	2.74	3.00	2.49
153	Guinea	2.13	2.34	1.92	2.66	2.92	2.40
154	Zambia	2.14	2.37	1.92	2.47	2.74	2.21
155	Somalia	2.24	2.45	2.03	2.75	3.01	2.49
156	Chad	2.39	2.62	2.16	2.73	2.99	2.47
157	Niger	2.66	2.91	2.41	2.73	2.99	2.47
158	Malawi	2.70	2.96	2.44	2.73	2.99	2.47
159	Cambodia	3.03	3.33	2.73	2.60	2.86	2.34
160	Cote d'Ivoire	3.07	3.39	2.75	2.48	2.74	2.22
161	Mali	3.21	3.52	2.91	2.71	2.97	2.45
162	Burkina Faso	3.22	3.53	2.91	2.72	2.97	2.46
163	Angola	3.41	3.79	3.02	2.31	2.57	2.05
164	Cameroon	3.66	4.03	3.29	2.58	2.84	2.32
165	Peru	3.72	4.28	3.15	1.80	2.07	1.52
166	Madagascar	3.84	4.21	3.48	2.71	2.97	2.45
167	Yemen	4.15	4.61	3.70	2.39	2.65	2.13
168	Sri Lanka	4.31	4.76	3.85	2.47	2.73	2.21
169	Ghana	4.32	4.76	3.88	2.55	2.81	2.29
170	Colombia	4.42	5.23	3.60	1.51	1.79	1.23
171	Mozambique	4.76	5.22	4.30	2.68	2.94	2.42
172	Morocco	4.83	5.48	4.18	1.99	2.26	1.72
173	Turkey	5.25	7.18	3.33	0.84	1.14	0.53
174	Uganda	5.64	6.18	5.10	2.73	2.99	2.47
175	Thailand	5.74	7.19	4.29	1.16	1.46	0.87
176	Afghanistan	5.87	6.44	5.30	2.68	2.94	2.42
177	Nepal	6.17	6.76	5.58	2.70	2.96	2.44
178	Kenya	6.24	6.88	5.61	2.56	2.82	2.30
179	Sudan	6.76	7.44	6.08	2.59	2.85	2.33
180	Tanzania	7.77	8.52	7.01	2.68	2.94	2.42
181	Egypt	8.82	10.44	7.21	1.53	1.81	1.25
182	Myanmar	10.75	11.81	9.68	2.62	2.88	2.36
183	Philippines	11.82	13.30	10.33	2.11	2.37	1.84
184	Democratic Republic of Congo	12.67	13.87	11.47	2.74	3.00	2.48
185	Vietnam	12.82	14.55	11.09	1.98	2.25	1.71
186	Brazil	17.49	21.10	13.89	1.39	1.67	1.10
187	Ethiopia	18.26	19.99	16.54	2.74	3.00	2.48
188	Nigeria	26.95	29.91	23.98	2.38	2.64	2.12
189	Pakistan	28.63	31.85	25.41	2.33	2.59	2.07
190	Bangladesh	32.73	35.96	29.51	2.64	2.90	2.38
191	Indonesia	34.32	39.24	29.41	1.88	2.15	1.62
192	China	149.28	193.70	104.87	0.99	1.28	0.69
193	India	248.47	277.87	219.08	2.23	2.49	1.96

Tab. A3.: Carbon Debts and Credits from fossil fuels and land use change by 2023 (Monte Carlo)

	country	Debt median	lower bound	upper bound	Debt median (pc)	lower bound	upper bound
1	USA	-410.89	-376.23	-445.56	-15.69	-14.37	-17.01
2	Russia	-116.78	-104.01	-129.54	-6.96	-6.20	-7.72
3	Brazil	-64.29	-57.35	-71.23	-5.23	-4.67	-5.80
4	Canada	-52.04	-48.63	-55.45	-19.78	-18.49	-21.08
5	Germany	-39.66	-31.00	-48.32	-3.53	-2.76	-4.30
6	United Kingdom	-39.37	-32.82	-45.92	-4.77	-3.98	-5.56
7	Australia	-23.87	-21.94	-25.80	-14.81	-13.61	-16.00
8	Kazakhstan	-16.08	-14.26	-17.90	-10.73	-9.52	-11.95
9	Saudi Arabia	-12.78	-11.24	-14.33	-11.07	-9.73	-12.41
10	Indonesia	-11.91	-6.22	-17.60	-0.71	-0.37	-1.05
11	Ukraine	-11.55	-8.35	-14.76	-1.96	-1.42	-2.51
12	Malaysia	-10.97	-10.10	-11.83	-7.00	-6.45	-7.55
13	South Africa	-10.81	-8.66	-12.97	-3.29	-2.64	-3.95
14	Argentina	-9.82	-7.98	-11.66	-3.33	-2.71	-3.96
15	Colombia	-8.59	-7.18	-10.00	-3.09	-2.58	-3.60
16	Japan	-7.85	-1.02	-14.68	-0.58	-0.08	-1.09
17	Poland	-6.60	-3.80	-9.40	-1.37	-0.79	-1.96
18	Belgium	-6.37	-5.22	-7.52	-4.55	-3.73	-5.37
19	Venezuela	-5.87	-4.92	-6.82	-3.59	-3.01	-4.17
20	Netherlands	-5.22	-4.13	-6.31	-3.19	-2.53	-3.86
21	United Arab Emirates	-4.58	-4.12	-5.03	-20.49	-18.45	-22.54
22	New Zealand	-3.93	-3.55	-4.31	-11.54	-10.41	-12.66
23	Côte d'Ivoire	-3.88	-2.83	-4.93	-3.48	-2.54	-4.42
24	Bolivia	-3.71	-3.28	-4.14	-5.21	-4.61	-5.81
25	Czechia	-3.65	-2.50	-4.80	-2.21	-1.51	-2.90
26	Mongolia	-3.47	-3.10	-3.84	-16.08	-14.37	-17.79
27	Belarus	-3.38	-2.80	-3.97	-2.82	-2.33	-3.31
28	Finland	-3.09	-2.67	-3.52	-4.93	-4.25	-5.62
29	Kuwait	-3.06	-2.75	-3.37	-21.52	-19.32	-23.73
30	Democratic Republic of the Congo	-2.98	-1.05	-4.91	-0.75	-0.26	-1.23
31	Paraguay	-2.50	-2.22	-2.77	-7.15	-6.36	-7.95
32	Nicaragua	-2.49	-2.16	-2.81	-7.13	-6.21	-8.05
33	Qatar	-2.15	-1.95	-2.34	-37.60	-34.19	-41.01
34	Ecuador	-1.93	-1.53	-2.34	-2.15	-1.71	-2.60
35	Denmark	-1.91	-1.51	-2.30	-2.95	-2.34	-3.56
36	Turkmenistan	-1.88	-1.54	-2.21	-5.36	-4.40	-6.32
37	Congo	-1.56	-1.23	-1.89	-6.12	-4.83	-7.41
38	Sweden	-1.45	-0.80	-2.09	-1.26	-0.70	-1.83
39	Zambia	-1.25	-0.80	-1.70	-1.59	-1.02	-2.15
40	Trinidad and Tobago	-1.19	-1.04	-1.33	-10.41	-9.15	-11.67
41	Slovakia	-1.19	-0.75	-1.62	-1.82	-1.16	-2.49
42	Estonia	-1.09	-0.94	-1.24	-5.83	-5.03	-6.63
43	Panama	-1.08	-0.96	-1.20	-5.11	-4.55	-5.67
44	Madagascar	-1.04	-0.33	-1.76	-0.83	-0.26	-1.39
45	Singapore	-0.93	-0.73	-1.13	-3.48	-2.72	-4.23

	country	Debt median	lower bound	upper bound	Debt median (pc)	lower bound	upper bound
46	Papua New Guinea	-0.92	-0.65	-1.19	-2.19	-1.55	-2.84
47	Costa Rica	-0.87	-0.70	-1.04	-3.42	-2.75	-4.09
48	Honduras	-0.86	-0.57	-1.14	-1.92	-1.29	-2.56
49	Bahrain	-0.81	-0.73	-0.90	-15.15	-13.53	-16.78
50	Norway	-0.80	-0.51	-1.09	-1.48	-0.94	-2.02
51	Libya	-0.78	-0.55	-1.02	-2.23	-1.56	-2.91
52	Oman	-0.75	-0.61	-0.89	-4.28	-3.48	-5.08
53	Lithuania	-0.73	-0.51	-0.96	-1.64	-1.14	-2.14
54	Israel	-0.71	-0.50	-0.92	-1.82	-1.27	-2.36
55	Guyana	-0.66	-0.60	-0.71	-8.33	-7.62	-9.04
56	Gabon	-0.65	-0.58	-0.73	-5.63	-4.97	-6.28
57	Laos	-0.53	-0.29	-0.77	-1.28	-0.70	-1.85
58	Luxembourg	-0.52	-0.45	-0.59	-9.48	-8.25	-10.71
59	Uruguay	-0.52	-0.33	-0.70	-1.61	-1.02	-2.20
60	Bhutan	-0.50	-0.40	-0.59	-7.81	-6.37	-9.25
61	Guatemala	-0.44	-0.07	-0.82	-0.53	-0.08	-0.98
62	Brunei Darussalam	-0.41	-0.38	-0.44	-20.80	-19.22	-22.38
63	South Korea	-0.40	1.68	-2.48	-0.10	0.42	-0.61
64	Belize	-0.28	-0.24	-0.31	-14.82	-13.10	-16.54
65	Iceland	-0.18	-0.15	-0.20	-6.45	-5.53	-7.37
66	Liberia	-0.17	-0.02	-0.32	-0.72	-0.10	-1.34
67	Suriname	-0.08	-0.06	-0.10	-1.91	-1.46	-2.35
68	Guinea	-0.07	0.39	-0.53	-0.10	0.58	-0.78
69	Bahamas	-0.06	-0.05	-0.08	-2.65	-1.96	-3.33
70	Botswana	-0.05	0.06	-0.15	-0.42	0.49	-1.33
71	Equatorial Guinea	-0.03	0.01	-0.06	-0.43	0.09	-0.96
72	Vanuatu	-0.02	0.0003	-0.04	-1.27	0.02	-2.57
73	Slovenia	-0.02	0.09	-0.12	-0.07	0.37	-0.52
74	Palau	-0.003	-0.002	-0.004	-2.07	-1.47	-2.68
75	Nauru	-0.001	-0.001	-0.002	-1.35	-0.77	-1.94
76	World	0	219.22	-219.22	0	0.40	-0.40
77	Andorra	0.001	0.003	-0.0003	0.38	0.82	-0.07
78	Tuvalu	0.004	0.005	0.004	4.44	4.73	4.16
79	Cuba	0.005	0.49	-0.48	0.01	0.51	-0.50
80	Liechtenstein	0.01	0.01	0.004	1.66	2.05	1.27
81	Latvia	0.01	0.14	-0.13	0.02	0.41	-0.38
82	Antigua and Barbuda	0.02	0.02	0.02	2.14	2.54	1.74
83	Seychelles	0.02	0.02	0.02	2.79	3.12	2.47
84	Marshall Islands	0.03	0.03	0.02	4.15	4.43	3.86
85	Dominica	0.03	0.03	0.03	3.53	3.86	3.20
86	Saint Kitts and Nevis	0.03	0.03	0.03	3.82	4.13	3.51
87	Tonga	0.03	0.03	0.03	3.21	3.55	2.87
88	Kiribati	0.04	0.04	0.04	4.51	4.79	4.23
89	Saint Vincent and the Grenadines	0.05	0.05	0.04	3.93	4.22	3.63
90	Samoa	0.05	0.05	0.04	2.85	3.24	2.46
91	Saint Lucia	0.05	0.06	0.05	3.46	3.77	3.15
92	Grenada	0.05	0.06	0.05	4.11	4.40	3.81
93	Sao Tome and Principe	0.06	0.06	0.06	4.34	4.64	4.03
94	Solomon Islands	0.06	0.09	0.04	1.71	2.35	1.07
95	Chile	0.08	0.59	-0.43	0.06	0.45	-0.33
96	Maldives	0.08	0.09	0.07	3.45	3.75	3.15
97	Cyprus	0.10	0.14	0.06	1.12	1.58	0.65
98	Barbados	0.11	0.12	0.10	2.95	3.26	2.64
99	Sierra Leone	0.11	0.38	-0.16	0.26	0.89	-0.36
100	Malta	0.13	0.14	0.11	2.59	2.93	2.26
101	Montenegro	0.14	0.18	0.11	1.76	2.18	1.33
102	Austria	0.15	0.75	-0.45	0.13	0.66	-0.39
103	Fiji	0.16	0.19	0.14	2.42	2.81	2.03
104	Djibouti	0.18	0.19	0.17	4.23	4.52	3.95
105	Cape Verde	0.18	0.19	0.17	4.32	4.60	4.03
106	Eswatini	0.18	0.21	0.15	2.65	3.13	2.17
107	Timor-Leste	0.18	0.22	0.15	2.01	2.40	1.63
108	Comoros	0.19	0.20	0.18	4.52	4.81	4.24
109	Thailand	0.24	2.09	-1.61	0.05	0.46	-0.35
110	Iran	0.31	2.63	-2.01	0.06	0.55	-0.42
111	Guinea-Bissau	0.31	0.35	0.27	2.86	3.21	2.52
112	North Macedonia	0.35	0.45	0.24	1.60	2.09	1.11
113	Namibia	0.35	0.41	0.30	2.79	3.23	2.35
114	Azerbaijan	0.35	0.64	0.07	0.50	0.91	0.10
115	Gambia	0.37	0.40	0.34	3.66	3.97	3.34
116	Mauritius	0.41	0.44	0.38	3.63	3.93	3.34
117	Jamaica	0.42	0.51	0.33	1.72	2.08	1.36
118	Moldova	0.42	0.59	0.26	1.00	1.39	0.61
119	Angola	0.43	1.13	-0.27	0.33	0.86	-0.21
120	Lesotho	0.46	0.51	0.42	3.29	3.62	2.96
121	Bulgaria	0.48	0.94	0.03	0.48	0.92	0.03
122	Central African Republic	0.58	0.70	0.46	1.76	2.12	1.40
123	Serbia	0.60	0.97	0.23	0.73	1.18	0.28
124	Kyrgyzstan	0.65	0.80	0.50	1.56	1.91	1.20
125	Switzerland	0.71	1.06	0.35	0.85	1.28	0.42
126	Ireland	0.74	1.07	0.42	1.03	1.49	0.58
127	Bosnia and Herzegovina	0.74	0.92	0.57	1.64	2.03	1.25
128	Lebanon	0.76	0.87	0.65	2.31	2.64	1.97
129	Jordan	0.79	0.90	0.68	2.38	2.72	2.04
130	Mauritania	0.80	0.87	0.73	4.10	4.44	3.76
131	Dominican Republic	0.80	1.01	0.59	1.41	1.77	1.04
132	Albania	0.81	0.89	0.72	2.97	3.29	2.65
133	Eritrea	0.86	0.93	0.80	4.19	4.50	3.88
134	Cambodia	0.88	1.36	0.41	0.92	1.41	0.43
135	Armenia	0.90	0.99	0.81	3.08	3.39	2.77
136	State of Palestine	0.95	1.01	0.89	4.43	4.72	4.15
137	Greece	1.10	1.60	0.60	0.90	1.30	0.49
138	Uzbekistan	1.12	1.89	0.36	0.62	1.04	0.20
139	Myanmar	1.13	2.58	-0.31	0.31	0.72	-0.09
140	Croatia	1.15	1.36	0.94	1.99	2.35	1.63

	country	Debt median	lower bound	upper bound	Debt median (pc)	lower bound	upper bound
141	El Salvador	1.19	1.34	1.04	2.64	2.98	2.31
142	Peru	1.29	1.95	0.63	0.67	1.02	0.33
143	France	1.37	5.45	-2.71	0.17	0.68	-0.34
144	Togo	1.40	1.53	1.28	3.63	3.96	3.30
145	Tajikistan	1.53	1.68	1.39	3.23	3.53	2.92
146	South Sudan	1.59	1.81	1.36	2.62	2.99	2.25
147	Hungary	1.63	2.23	1.03	1.11	1.52	0.70
148	Cameroon	1.67	2.09	1.24	1.36	1.71	1.02
149	Benin	1.68	1.88	1.49	2.95	3.29	2.62
150	Zimbabwe	1.70	1.98	1.41	2.14	2.50	1.78
151	Georgia	1.93	2.13	1.73	3.47	3.83	3.11
152	Tunisia	2.21	2.46	1.96	2.86	3.19	2.53
153	Niger	2.22	2.68	1.76	2.56	3.08	2.03
154	Burundi	2.33	2.51	2.15	3.87	4.17	3.57
155	Chad	2.33	2.58	2.09	3.19	3.53	2.86
156	Haiti	2.61	2.81	2.41	3.81	4.10	3.53
157	Rwanda	2.65	2.84	2.45	4.03	4.33	3.73
158	Senegal	2.68	2.91	2.46	3.62	3.92	3.32
159	Iraq	2.77	3.41	2.14	1.64	2.01	1.26
160	Romania	2.78	3.84	1.72	1.04	1.44	0.65
161	Somalia	2.86	3.07	2.64	4.01	4.32	3.71
162	Malawi	2.86	3.13	2.59	3.19	3.50	2.89
163	Syria	2.99	3.36	2.63	2.69	3.02	2.37
164	Portugal	3.08	3.51	2.65	2.42	2.76	2.08
165	Mexico	3.17	5.96	0.39	0.45	0.84	0.05
166	Burkina Faso	3.62	3.91	3.33	3.60	3.89	3.31
167	Mozambique	3.73	4.26	3.20	2.41	2.75	2.07
168	Mali	3.86	4.26	3.46	3.76	4.15	3.37
169	Tanzania	3.98	5.01	2.94	1.54	1.94	1.14
170	North Korea	4.69	5.49	3.90	2.29	2.67	1.90
171	Ghana	4.89	5.42	4.37	3.32	3.68	2.96
172	Algeria	5.10	5.88	4.32	2.23	2.57	1.89
173	Sri Lanka	5.23	5.73	4.74	3.28	3.59	2.97
174	Uganda	6.11	6.66	5.56	3.33	3.63	3.03
175	Yemen	6.36	6.78	5.94	4.29	4.57	4.00
176	Spain	6.67	8.52	4.83	1.39	1.77	1.00
177	Sudan	7.04	7.71	6.37	3.24	3.55	2.93
178	Nepal	7.04	7.59	6.49	3.69	3.98	3.41
179	Morocco	7.28	7.95	6.60	3.34	3.65	3.03
180	Kenya	7.66	8.39	6.94	3.52	3.86	3.19
181	Afghanistan	7.67	8.20	7.14	4.10	4.38	3.82
182	Philippines	9.58	11.25	7.92	1.78	2.09	1.47
183	Italy	10.28	13.22	7.34	1.37	1.76	0.98
184	Türkiye	10.40	12.32	8.48	1.97	2.33	1.60
185	Viet Nam	14.32	16.14	12.51	2.41	2.72	2.11
186	Egypt	17.86	19.49	16.23	3.32	3.63	3.02
187	Ethiopia	20.33	22.21	18.45	3.51	3.84	3.19
188	Nigeria	31.34	34.38	28.31	3.22	3.53	2.91
189	Pakistan	44.02	47.13	40.91	4.06	4.35	3.78
190	Bangladesh	45.79	48.75	42.83	4.37	4.65	4.08
191	China	255.06	296.04	214.07	2.13	2.47	1.79
192	India	350.32	376.57	324.07	3.84	4.13	3.55

3 Carbon debts and credits under different scenarios

We present country-level carbon debts and credits across a range of alternative specifications. First, we consider production-based CO₂ emissions from fossil fuels over a shorter time frame than in the main article (1960–2023)³. We choose 1960 as the starting date because this period marks the emergence of a scientific consensus on anthropogenic climate change^{4,5}.

Second, we incorporate consumption-based emissions where data allow, which is limited to the period 1990–2020⁶. Third, we extend the analysis to all major greenhouse gases, including among others methane and nitrous oxide in CO₂ equivalent emissions, using data from the Global Carbon Budget^{1,3}. Fourth, we report carbon debts and credits derived from non–Monte Carlo simulated data, which are coherent with the estimates presented in the main article.

Finally, we incorporate emissions from land-use change into the scenarios described above (i.e., starting in 1960, all GHGs, and production-based emissions without Monte Carlo simulation). In addition, we report carbon debts and credits from land use change considered separately.

3.1 Carbon debts and credits from fossil fuels

3.1.1 Scenario (1): Production-based CO₂ emissions (1960–2023)

Figure 1 shows results broadly consistent with the main specification (1750–2023), particularly for the largest carbon debtors and creditors. Some changes occur: Spain, Italy, and Romania shift from carbon creditors to carbon debtors, while Argentina and Mexico move from a minor carbon debtors to a carbon creditors.

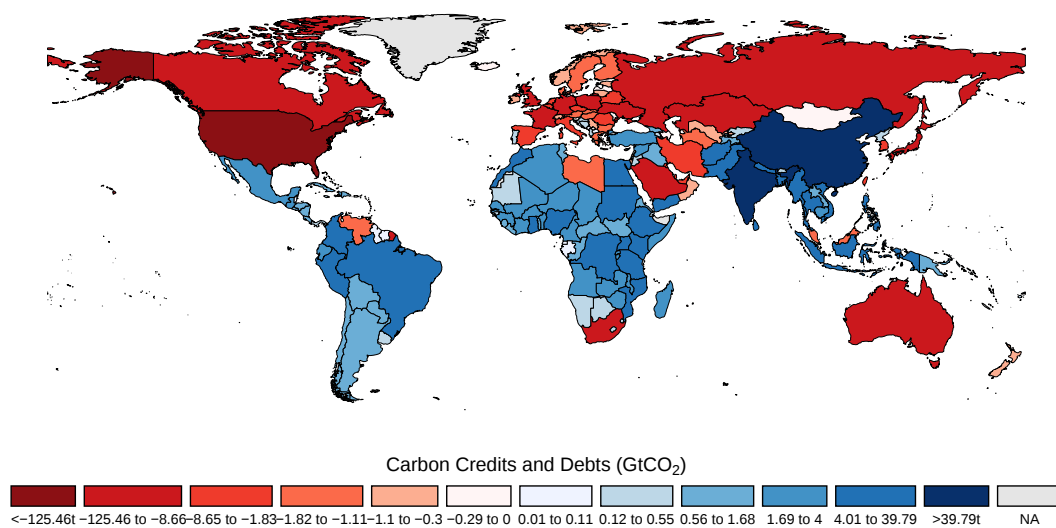


Fig. A1 | Carbon credits and debts from fossil fuels (1960 - 2023). Per capita carbon credits and debts are calculated comparing the average historical per capita emissions by country to the world average. Production-based carbon emissions are measured in tonnes of CO₂

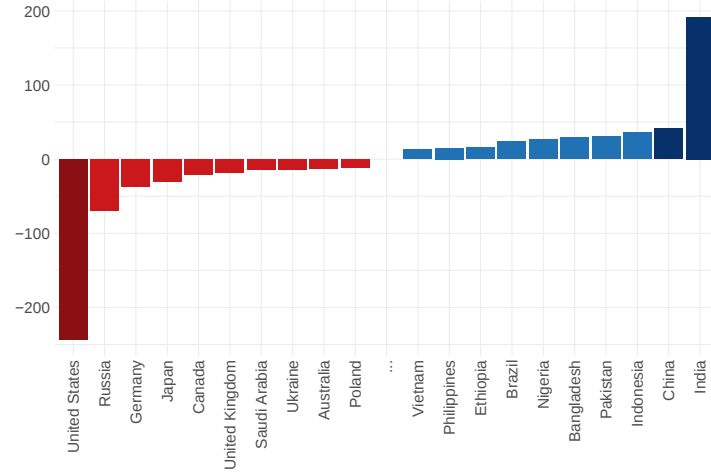


Fig. A2 | Carbon credits and debts of each country from fossil fuels (1960 - 2023). Carbon emissions are measured in tons of CO_2

3.1.2 Scenario (2): Incorporating consumption-based CO_2 emissions (1750-2023)

The results in Figure 3 are broadly consistent with the baseline scenario (main paper) using production-based CO_2 emissions for 1750–2023. When considering consumption-based emissions between 1990 and 2020, Mexico and Italy emerge as larger carbon debtors. Additionally, China further increases its carbon credit, while several oil-exporting countries, such as Qatar, see a reduction in their carbon debt.

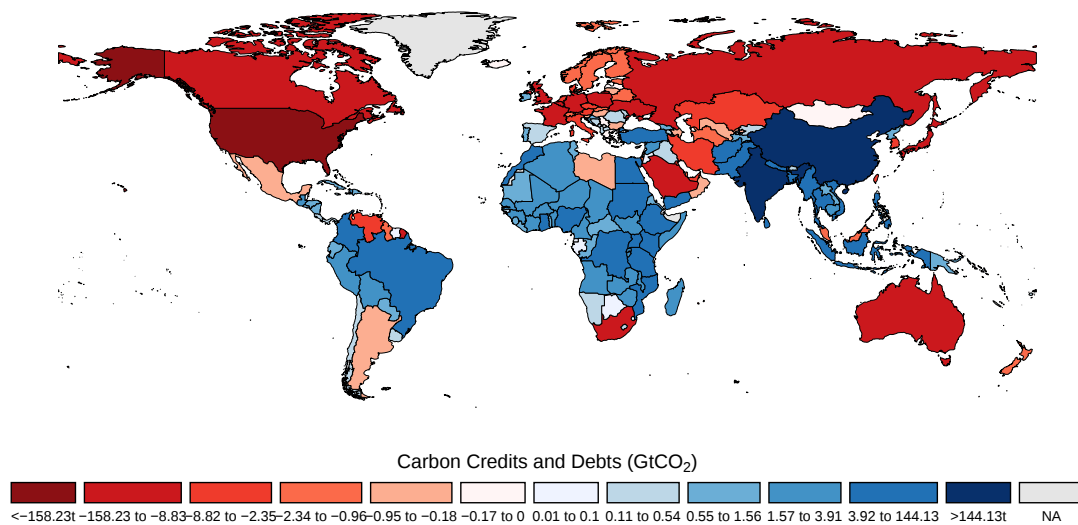


Fig. A3 | Carbon debts and credits from fossil fuels (1750 - 2023). We use consumption-based estimates between 1990-2020, production-based estimates for the rest of the time-frame. Carbon emission are measured in tonnes of CO_2

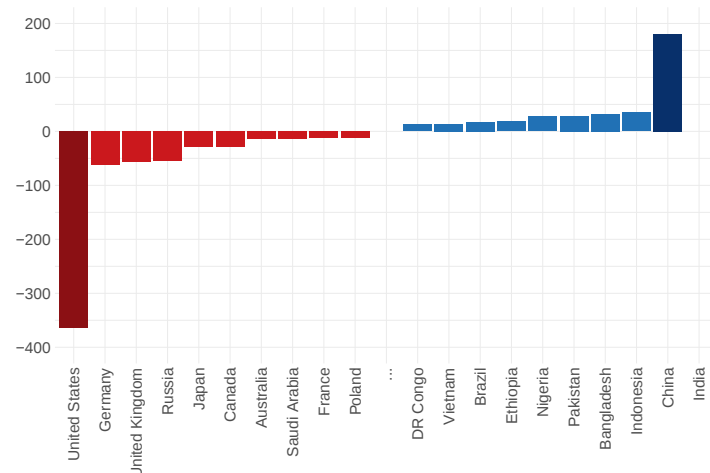


Fig. A4 | Carbon credits and debts of each country from fossil fuels (1750 - 2023). We use consumption-based estimates between 1990-2020, production-based estimates for the rest of the time-frame. Carbon emission are measured in tonnes of CO_2

3.1.3 Scenario (3): Production-based GHG emissions (1750-2023)

The results in Figure 5 are also consistent with Figure 2 in the main paper (production-based CO_2 emissions, 1750–2023). The only noticeable changes concern Mexico and Algeria, which show an increase in their carbon debt. The United States increase their total carbon debt in $GtCO_2$.

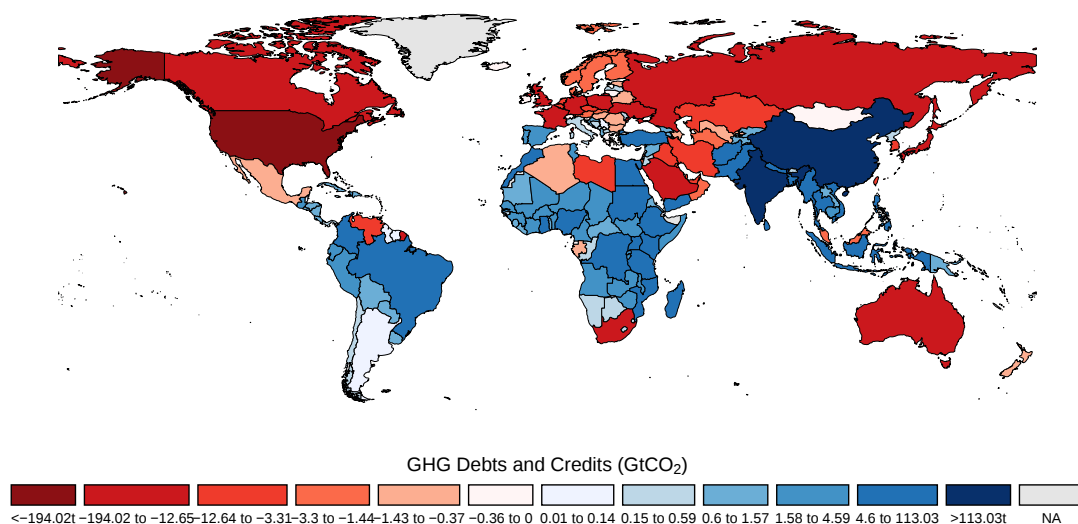


Fig. A5 | Total ghg debts and credits from fossil fuels (1750 - 2023). Ghg emissions are measured equivalent to tonnes of CO_2

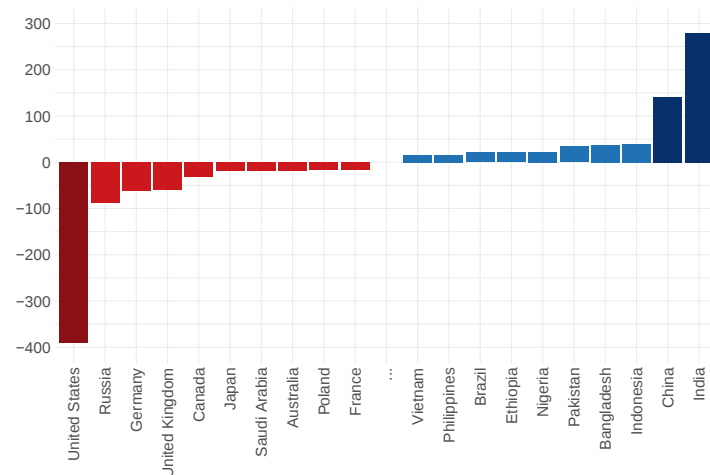


Fig. A6 | Total ghg debts and credits of each country from fossil fuels (1750 - 2023). Ghg emissions are measured equivalent to tonnes of CO_2

3.1.4 Scenario (4): Production-based CO_2 emissions (1750-2023) (without Monte Carlo)

Figure 7 visualizes the carbon debts and credits (1750–2023) based on production-based emissions without the Monte Carlo simulation. Incorporating the Monte Carlo simulation introduces only small changes in the median values of carbon debts and credits when calculating confidence bands. These differences, however, are negligible and do not affect the relative position of any country. Further details can be seen by comparing Table 1 with Table 4.

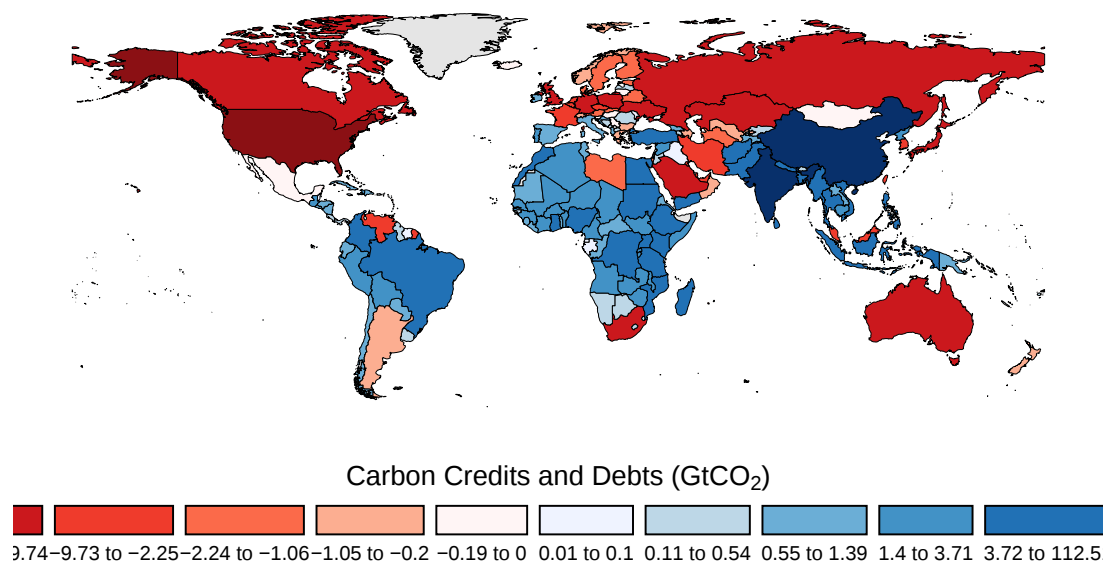


Fig. A7 | Carbon credits and debts from fossil fuels (1750 - 2023). Average per capita carbon credits and debts multiplied by cumulative population.

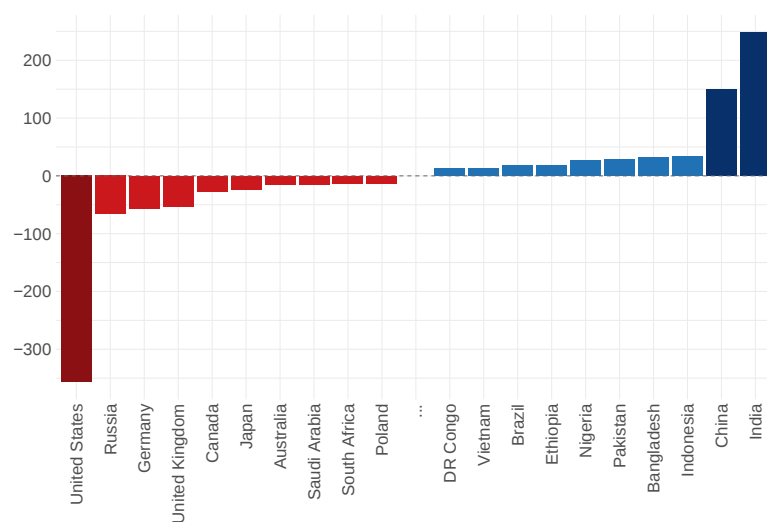


Fig. A8 | Carbon debts and credits from fossil fuels for each country (1750 - 2023). Average per capita carbon credits and debts multiplied by cumulative population.

3.2 Carbon debts and credits from fossil fuels and land use change

In this section, we incorporate land use change emissions into national fossil fuel CO₂ emissions. The earliest possible starting date is 1850 due to limitations in land use change emissions data availability. In the main paper, country-level land use change emissions are constructed as the average of four bookkeeping models included in the Global Carbon Budget, namely BLUE, H&C2023, OSCAR, and LUCE¹. The dispersion across these four models is used to derive a standard deviation, which serves as the basis for the Monte Carlo uncertainty analysis.

For the supplementary analysis presented here, we rely exclusively on land use change data from the BLUE bookkeeping model⁷. BLUE provides spatially explicit estimates and is among the most widely used and thoroughly documented bookkeeping models. This contrasts with models such as H&C2023 and OSCAR, which do not provide spatially explicit outputs, and with LUCE⁸, which is more recently developed and less comprehensively documented. While the main paper incorporates the full range of available land use change estimates, here we adopt the BLUE dataset as our best-informed estimate.

3.2.1 Scenario (5): Production-based CO₂ emissions (inc. LUC) (1960-2023)

In contrast to the main scenario, which considers production-based CO₂ emissions from fossil fuels, the inclusion of land use change emissions changes countries' shares in carbon debts. The United States reduces its share of global carbon debt from 48% to 37% when including land use change and shortening the time frame. Yet, it clearly remains the world's largest carbon debtor. Brazil becomes a carbon debtor once land use change emissions are included. Its position worsens even in comparison to Figure 13, where we include land use change emission from 1850-2023: its share of global carbon debt increases from 7% (1850 - 2023, including land use change) to 9% (1960 - 2023, including land use change). This reflects Brazil's relatively recent surge in land use change emissions, whereas the United States experienced its peak around 1900. As in Scenario (1), late-developing countries such as China see a reduction in their carbon credit under this scenario.

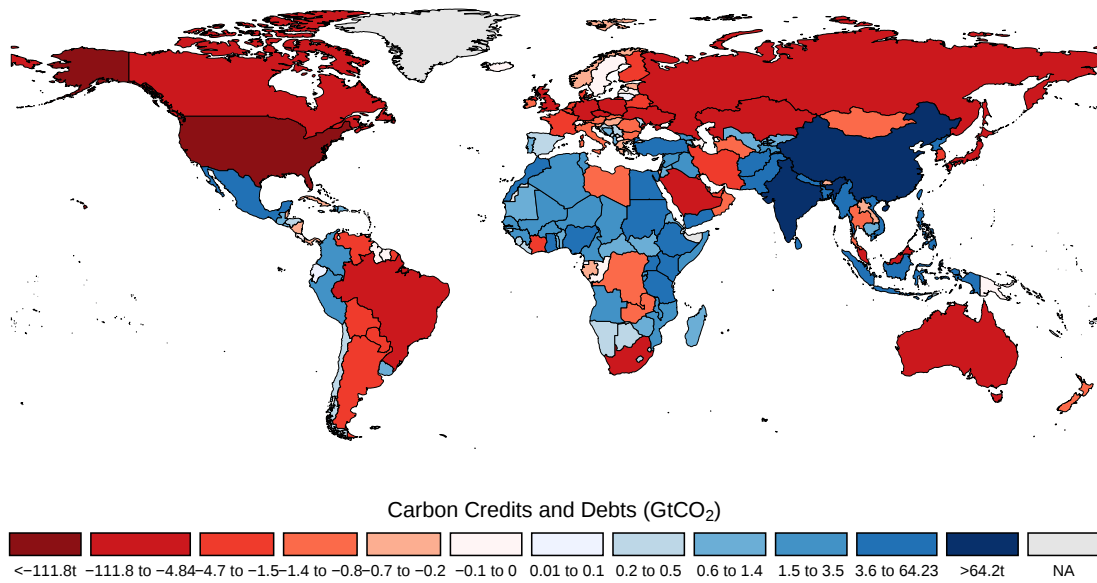


Fig. A9 | Carbon credits and debts from fossil fuels and land-use change (1960 - 2023). Carbon credits and debts are calculated comparing the average historical per capita emissions by country to the world average. Production-based carbon emissions are measured in tons of CO₂

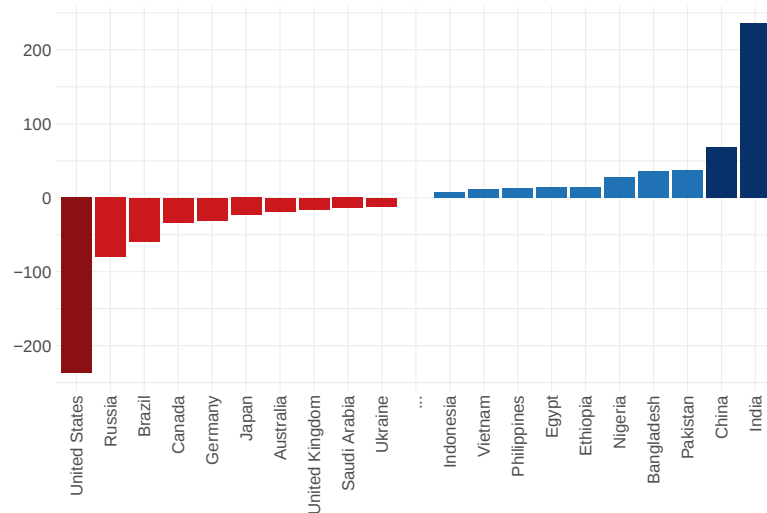


Fig. A10 | Carbon credits and debts of each country from fossil fuels and land-use change (1960 - 2023). Carbon emissions are measured in gigatons of CO₂

3.2.2 Scenario (6): Production-based GHG emissions (inc. LUC) (1850 - 2023)

Figure 11 illustrates the aforementioned changes in carbon debts and credits when including land use change emissions. In contrast to scenarios considering only CO₂ emissions from fossil fuels and land use change (Figure 13), accounting for all greenhouse gases worsens the position

of countries with substantial livestock production, such as Argentina and Brazil. This effect is most likely driven by methane emissions. The Democratic Republic of the Congo shifts from a debtor to a creditor position. Land use change there is not associated with the emission of greenhouse gases other than CO₂.

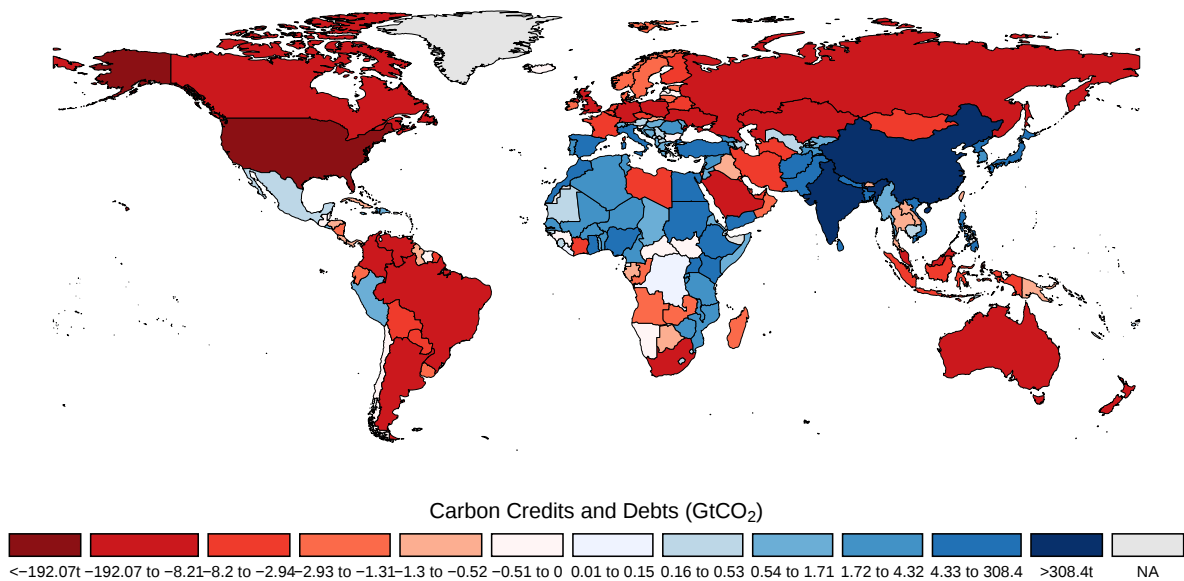


Fig. A11 | Total ghg debts and credits from fossil fuels and land-use change (1850 - 2023). Ghg emissions are measured equivalent to tonnes of CO₂

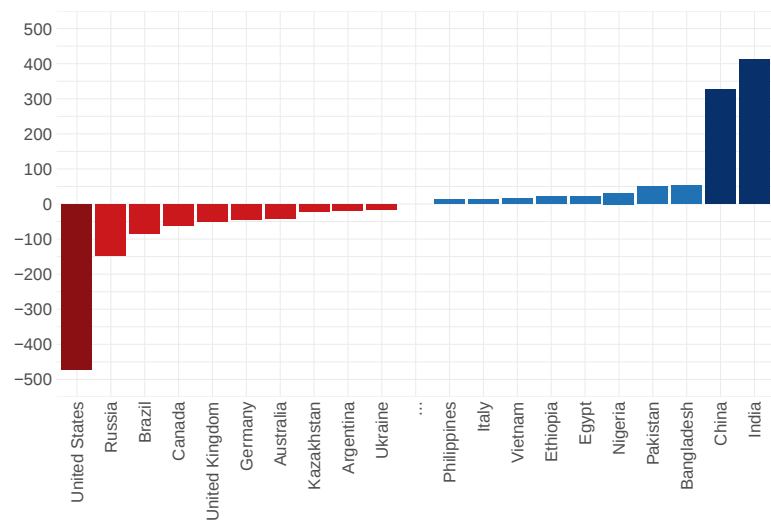


Fig. A12 | Total ghg debts and credits of each country from fossil fuels and land-use change (1850 - 2023). Ghg emissions are measured equivalent to tonnes of CO₂

3.2.3 Scenario (7): Production-based CO₂ emissions (inc. LUC) (1850-2023) (without Monte Carlo)

Figure 13 does not display major changes compared to the scenario shown in the main article (Figure 3). Here, we rely exclusively on the BLUE model rather than the average of the four bookkeeping models from the Global Carbon Budget (BLUE, LUCE, H&C2023, OSCAR). As a result, land use change estimates are generally slightly higher here than in the main paper, where the average across models is used. BLUE provides above-average estimates of land use change emissions, which worsens Brazil's carbon debt position and reduces the credit of India and China (in contrast to Figure 3, main article).

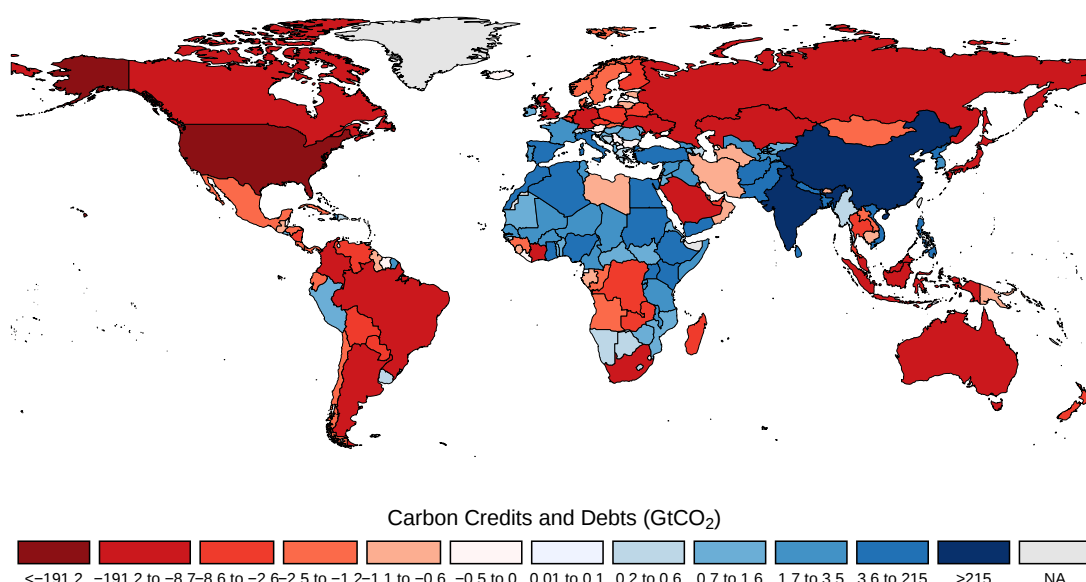


Fig. A13 | Carbon credits and debts from fossil fuels and land-use change (1850 - 2023). Average per capita carbon credits and debts multiplied by cumulative population.

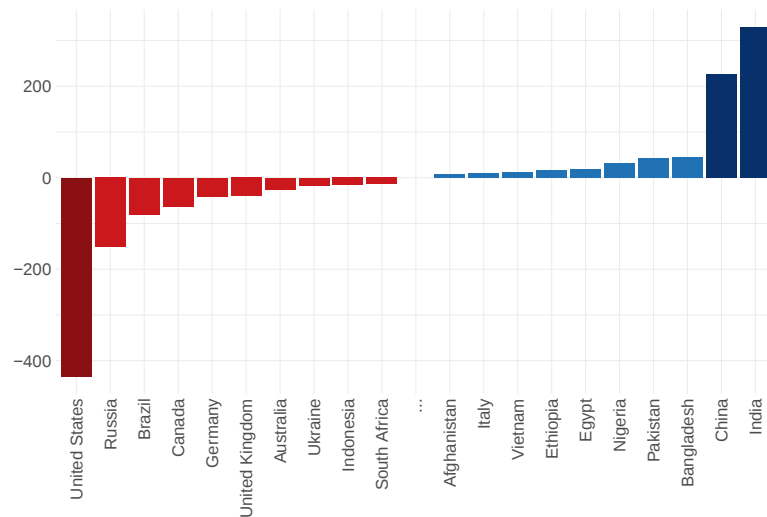


Fig. A14 | Carbon credits and debts from fossil fuels and land-use change for each country (1850-2023). Average per capita carbon credits and debts multiplied by cumulative population.

3.2.4 Scenario (8): Land use change CO₂ emissions (excl. emissions from fossils) (1850-2023)

Figure 15 depicts carbon debts and credits based solely on CO₂ emissions. While this scenario is not realistic, since it ignores the roughly 80% of global emissions that come from fossil fuel combustion, it reveals several interesting patterns. Brazil has generated the largest carbon debt from land use change emissions since 1850, followed by the United States and Russia, which are also among the top debtors in terms of fossil fuel emissions. China and India consistently generate the highest carbon credit across all scenarios. Here, they are followed by several high-income countries that deforested prior to the start of this time frame and have reforested in recent years. These countries are also typically importers of agricultural products.

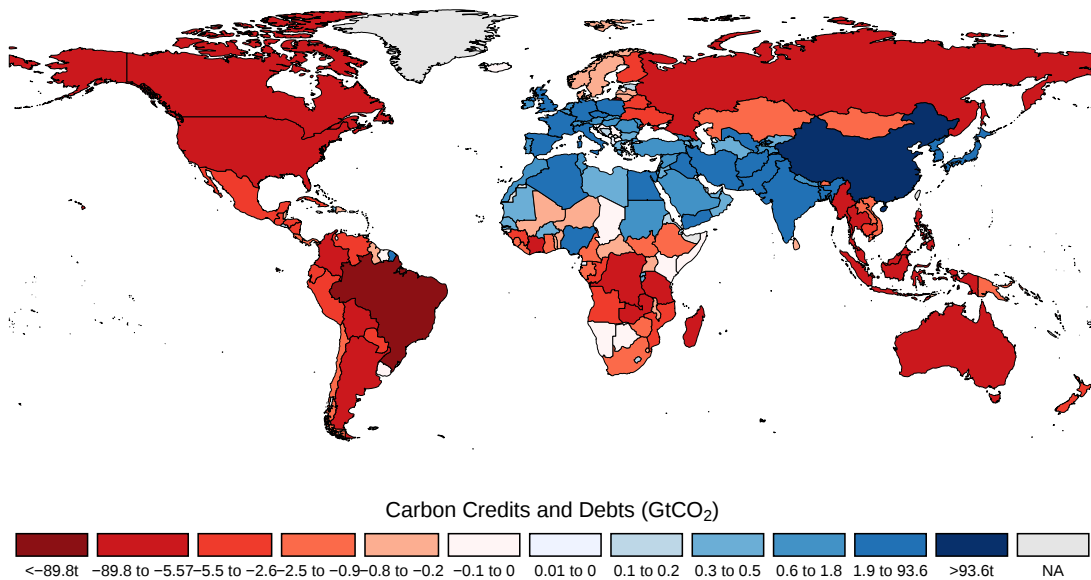


Fig. A15 | Carbon credits and debts from land-use change (1850 - 2023). Average per capita carbon credits and debts multiplied by cumulative population.

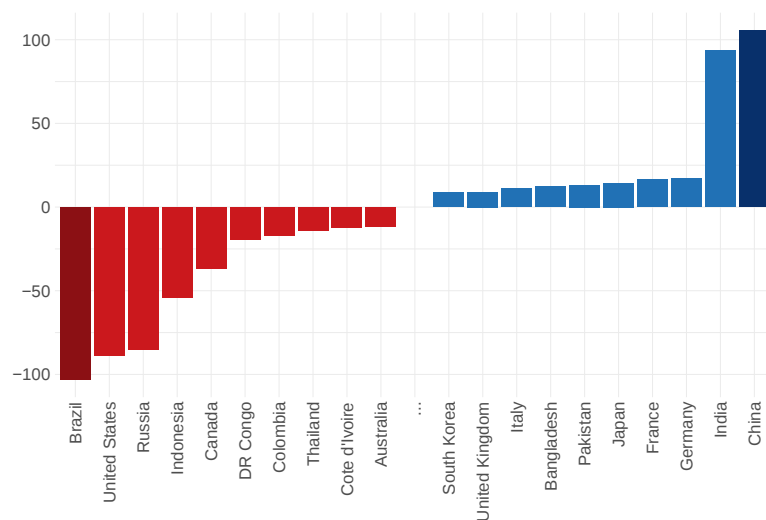


Fig. A16 | Carbon credits and debts from land-use change fro each country (1850-2023). Average per capita carbon credits and debts multiplied by cumulative population.

3.3 Summary tables of all alternative scenarios

Table 4 summarizes carbon debt and credit estimates across all the scenarios presented in Section 3.1, excluding land use change emissions. Column (1) reports results based solely on production-based CO₂ emissions from fossil fuels. The median values differ slightly from those obtained through the Monte Carlo simulations. Column (2) shows carbon debts and credits when consumption-based emissions are included, where available (1990–2020). Column (3) presents the production-based scenario from Column (1), but with a shorter time frame, starting 1960. The results remain broadly consistent with the main specification, as most cumulative emissions occurred after 1960; however, earlier starting dates affect the ranking of countries that industrialized later but had large populations in the 19th century (e.g., Italy, Spain). Finally, Column (4) extends the analysis to all production-based greenhouse gases.

Tab. A4 | Carbon Debts and Credits under different scenarios.

	country	CO ₂	(%)	CO ₂ / CB	(%)	CO ₂ / 1960	(%)	GHG	(%)
1	United States	-356.48	47.68	-363.98	47.66	-243.30	41.30	-390.02	44.63
2	Russia	-65.79	8.80	-54.27	7.11	-70.01	11.88	-88.48	10.13
3	Germany	-56.85	7.60	-61.41	8.04	-37.07	6.29	-61.28	7.01
4	United Kingdom	-52.45	7.02	-56.59	7.41	-18.66	3.17	-59.15	6.77
5	Canada	-27.57	3.69	-27.94	3.66	-21.27	3.61	-32.14	3.68
6	Japan	-22.99	3.08	-29.51	3.86	-30.23	5.13	-19.38	2.22
7	Australia	-15.08	2.02	-14.04	1.84	-12.60	2.14	-17.54	2.01
8	Saudi Arabia	-14.51	1.94	-13.41	1.76	-14.29	2.42	-18.48	2.11
9	South Africa	-12.71	1.70	-9.14	1.20	-9.11	1.55	-13.34	1.53
10	Poland	-12.69	1.70	-11.78	1.54	-11.81	2.00	-17.11	1.96
11	Ukraine	-11.92	1.59	-9.69	1.27	-13.90	2.36	-13.05	1.49
12	Kazakhstan	-9.74	1.30	-8.36	1.10	-8.83	1.50	-12.55	1.44
13	France	-9.07	1.21	-12.86	1.68	-9.75	1.66	-17.02	1.95
14	Belgium	-7.98	1.07	-10.07	1.32	-4.49	0.76	-8.86	1.01
15	Netherlands	-6.93	0.93	-7.24	0.95	-5.55	0.94	-8.16	0.93
16	South Korea	-6.54	0.87	-7.68	1.01	-8.40	1.43	-6.64	0.76
17	Czechia	-6.26	0.84	-5.40	0.71	-5.99	1.02	-7.62	0.87
18	Iran	-5.95	0.80	-5.05	0.66	-4.73	0.80	-10.30	1.18
19	United Arab Emirates	-5.03	0.67	-5.58	0.73	-4.72	0.80	-6.49	0.74
20	Taiwan	-4.68	0.63	-4.88	0.64	-4.23	0.72	-4.04	0.46
21	Kuwait	-3.31	0.44	-2.56	0.33	-3.15	0.54	-5.25	0.60
22	Venezuela	-2.93	0.39	-2.63	0.34	-1.34	0.23	-6.98	0.80
23	Qatar	-2.27	0.30	-1.61	0.21	-2.19	0.37	-4.24	0.48
24	Malaysia	-2.25	0.30	-1.93	0.25	-1.22	0.21	-2.47	0.28
25	Denmark	-2.06	0.28	-2.40	0.31	-1.80	0.31	-1.98	0.23
26	Slovakia	-1.66	0.22	-1.86	0.24	-1.49	0.25	-1.97	0.23
27	Austria	-1.61	0.22	-2.47	0.32	-1.59	0.27	-1.78	0.20
28	Turkmenistan	-1.47	0.20	-1.08	0.14	-1.29	0.22	-2.92	0.33
29	Singapore	-1.44	0.19	-3.36	0.44	-1.20	0.20	-1.50	0.17
30	Israel	-1.37	0.18	-1.84	0.24	-1.08	0.18	-2.24	0.26
31	Libya	-1.36	0.18	-0.54	0.07	-1.21	0.21	-3.99	0.46
32	Trinidad and Tobago	-1.35	0.18	-0.97	0.13	-1.12	0.19	-1.95	0.22
33	Finland	-1.27	0.17	-1.88	0.25	-1.69	0.29	-2.19	0.25
34	Sweden	-1.22	0.16	-2.13	0.28	-1.40	0.24	-1.60	0.18
35	Belarus	-1.16	0.16	-0.98	0.13	-1.93	0.33	-1.34	0.15
36	Estonia	-1.06	0.14	-1.09	0.14	-1.07	0.18	-1.07	0.12
37	Oman	-1.01	0.13	-0.90	0.12	-1.02	0.17	-2.10	0.24
38	New Zealand	-0.99	0.13	-1.06	0.14	-0.63	0.11	-1.09	0.12
39	Norway	-0.98	0.13	-1.04	0.14	-1.02	0.17	-1.75	0.20
40	Uzbekistan	-0.93	0.12	-0.34	0.04	-0.31	0.05	-1.31	0.15
41	Bahrain	-0.90	0.12	-0.62	0.08	-0.82	0.14	-2.13	0.24
42	Argentina	-0.67	0.09	-0.52	0.07	1.09	0.17	0.14	0.02
43	Luxembourg	-0.59	0.08	-0.77	0.10	-0.56	0.10	-0.58	0.07
44	Bulgaria	-0.57	0.08	-0.36	0.05	-1.49	0.25	-0.96	0.11
45	Azerbaijan	-0.40	0.05	-0.30	0.04	-0.30	0.05	-0.39	0.04
46	Brunei	-0.36	0.05	-0.31	0.04	-0.30	0.05	-0.62	0.07
47	Switzerland	-0.31	0.04	-2.34	0.31	-0.60	0.10	-0.02	0.003
48	Greece	-0.20	0.03	-0.15	0.02	-1.36	0.23	-0.10	0.01
49	Lithuania	-0.17	0.02	-0.44	0.06	-0.49	0.08	-0.13	0.02
50	Slovenia	-0.12	0.02	-0.22	0.03	-0.30	0.05	-0.12	0.01
51	Bahamas	-0.10	0.01	-0.15	0.02	-0.10	0.02	-0.10	0.01
52	Hungary	-0.09	0.01	-0.60	0.08	-1.26	0.21	-0.53	0.06
53	Iceland	-0.08	0.01	-0.11	0.01	-0.08	0.01	-0.08	0.01
54	Mexico	-0.07	0.01	-0.84	0.11	3.52	0.56	-0.61	0.07
55	Mongolia	-0.05	0.01	-0.06	0.01	-0.23	0.04	-0.27	0.03

	country	CO ₂	(%)	CO ₂ / CB	(%)	CO ₂ / 1960	(%)	GHG	(%)
56	Serbia	-0.04	0.01	-0.16	0.02	-0.66	0.11	0.04	0.005
57	Cyprus	-0.03	0.003	-0.08	0.01	-0.07	0.01	-0.01	0.001
58	Palau	-0.01	0.001	-0.01	0.001	-0.01	0.001	-0.01	0.001
59	Andorra	-0.005	0.001	-0.005	0.001	-0.002	0.0004	-0.01	0.001
60	Nauru	-0.002	0.0003	-0.002	0.0003	-0.003	0.0004	-0.002	0.0002
61	World	0	0	0	0	0	0	0	0
62	Liechtenstein	0.001	0.0001	-0.004	0.0005	-0.002	0.0003	0.002	0.0002
63	Tuvalu	0.003	0.0004	0.003	0.0004	0.002	0.0003	0.003	0.0004
64	Antigua and Barbuda	0.01	0.001	-0.005	0.001	-0.01	0.001	0.003	0.0004
65	Suriname	0.01	0.001	0.01	0.001	0.001	0.0002	0.01	0.002
66	Seychelles	0.01	0.001	-0.002	0.0003	0.01	0.001	0.01	0.001
67	Marshall Islands	0.02	0.002	0.02	0.002	0.01	0.001	0.02	0.003
68	Saint Kitts and Nevis	0.02	0.002	0.02	0.002	0.005	0.001	0.01	0.001
69	Moldova	0.02	0.002	0.23	0.03	-0.09	0.02	0.21	0.02
70	Dominica	0.02	0.003	0.02	0.003	0.01	0.002	0.02	0.003
71	Micronesia (country)	0.02	0.003	0.02	0.003	0.02	0.003	0.03	0.003
72	Tonga	0.03	0.003	0.03	0.003	0.02	0.003	0.03	0.003
73	Kiribati	0.03	0.003	0.03	0.003	0.02	0.003	0.03	0.004
74	Saint Vincent and the Grenadines	0.03	0.004	0.03	0.004	0.02	0.003	0.03	0.004
75	Saint Lucia	0.03	0.004	0.03	0.004	0.02	0.004	0.04	0.005
76	Belize	0.04	0.005	0.03	0.004	0.04	0.01	0.03	0.003
77	Grenada	0.04	0.005	0.04	0.005	0.02	0.003	0.04	0.005
78	Sao Tome and Principe	0.04	0.01	0.04	0.004	0.03	0.01	0.05	0.01
79	Equatorial Guinea	0.05	0.01	0.05	0.01	0.04	0.01	-0.19	0.02
80	Maldives	0.05	0.01	0.04	0.005	0.04	0.01	0.06	0.01
81	Samoa	0.05	0.01	0.04	0.01	0.04	0.01	0.05	0.01
82	Vanuatu	0.05	0.01	0.04	0.01	0.04	0.01	0.06	0.01
83	Malta	0.06	0.01	-0.01	0.001	-0.0001	0.0000	0.08	0.01
84	Barbados	0.06	0.01	0.04	0.01	0.01	0.002	0.06	0.01
85	Iraq	0.07	0.01	0.25	0.03	1.12	0.18	-3.90	0.45
86	Gabon	0.07	0.01	0.10	0.01	0.02	0.003	-0.59	0.07
87	Solomon Islands	0.10	0.01	0.10	0.01	0.09	0.01	0.13	0.02
88	Djibouti	0.10	0.01	0.10	0.01	0.14	0.02	0.12	0.01
89	Cape Verde	0.11	0.01	0.11	0.01	0.09	0.01	0.14	0.02
90	Latvia	0.12	0.02	-0.03	0.004	-0.20	0.03	0.23	0.03
91	Comoros	0.12	0.02	0.12	0.02	0.12	0.02	0.15	0.02
92	Guyana	0.15	0.02	-1.06	0.14	0.10	0.02	0.13	0.02
93	Montenegro	0.15	0.02	0.12	0.01	0.06	0.01	0.18	0.02
94	Eswatini	0.16	0.02	0.09	0.01	0.18	0.03	0.28	0.03
95	Fiji	0.17	0.02	0.15	0.02	0.15	0.02	0.19	0.02
96	Botswana	0.17	0.02	0.04	0.01	0.21	0.03	0.21	0.02
97	North Macedonia	0.17	0.02	0.15	0.02	0.03	0.01	0.26	0.03
98	Mauritius	0.20	0.03	0.16	0.02	0.17	0.03	0.27	0.03
99	Bhutan	0.21	0.03	0.21	0.03	0.12	0.02	0.16	0.02
100	Jordan	0.21	0.03	0.03	0.003	0.54	0.09	0.38	0.04
101	Romania	0.21	0.03	0.41	0.05	-1.95	0.33	-0.45	0.05
102	Lebanon	0.23	0.03	0.08	0.01	0.29	0.05	0.36	0.04
103	Panama	0.26	0.03	0.21	0.03	0.38	0.06	0.40	0.05
104	Gambia	0.28	0.04	0.28	0.03	0.33	0.05	0.37	0.04
105	Jamaica	0.29	0.04	0.27	0.03	0.19	0.03	0.34	0.04
106	East Timor	0.29	0.04	0.29	0.04	0.22	0.03	0.30	0.04
107	Namibia	0.32	0.04	0.26	0.03	0.33	0.05	0.37	0.04
108	Guinea-Bissau	0.34	0.04	0.34	0.04	0.30	0.05	0.38	0.04
109	Lesotho	0.37	0.05	0.35	0.04	0.38	0.06	0.43	0.05
110	Uruguay	0.44	0.06	0.35	0.04	0.49	0.08	0.65	0.08
111	Costa Rica	0.45	0.06	0.31	0.04	0.63	0.10	0.61	0.07
112	Bosnia and Herzegovina	0.45	0.06	0.44	0.05	0.12	0.02	0.54	0.06
113	Kyrgyzstan	0.47	0.06	0.35	0.04	0.48	0.08	0.62	0.07
114	Armenia	0.54	0.07	0.52	0.06	0.45	0.07	0.69	0.08
115	Mauritania	0.55	0.07	0.54	0.07	0.55	0.09	0.62	0.07
116	Italy	0.57	0.07	-2.98	0.39	-7.70	1.31	0.57	0.07
117	Albania	0.57	0.07	0.54	0.07	0.47	0.08	0.65	0.08
118	Palestine	0.57	0.07	0.57	0.07	0.65	0.10	0.86	0.10
119	Chile	0.59	0.08	0.50	0.06	0.97	0.15	0.56	0.07
120	Eritrea	0.62	0.08	0.61	0.08	0.56	0.09	0.72	0.08
121	Congo	0.63	0.08	0.71	0.09	0.63	0.10	0.24	0.03
122	Liberia	0.71	0.09	0.71	0.09	0.71	0.11	0.77	0.09
123	Croatia	0.76	0.10	0.66	0.08	0.14	0.02	0.89	0.10
124	Dominican Republic	0.78	0.10	0.72	0.09	1.19	0.19	1.14	0.13
125	Nicaragua	0.83	0.11	0.80	0.10	0.99	0.16	1.07	0.12
126	Paraguay	0.84	0.11	0.77	0.09	0.97	0.15	1.02	0.12
127	Tajikistan	0.97	0.12	0.94	0.12	1.11	0.18	1.28	0.15
128	Honduras	0.99	0.13	0.93	0.11	1.27	0.20	1.30	0.15
129	Central African Republic	1.04	0.13	1.03	0.13	0.90	0.14	1.13	0.13
130	Cuba	1.06	0.13	0.76	0.09	1.23	0.19	0.74	0.09
131	El Salvador	1.06	0.13	0.99	0.12	1.15	0.18	1.38	0.16
132	Laos	1.09	0.14	1.04	0.13	1.05	0.17	1.26	0.15
133	Georgia	1.14	0.15	1.10	0.13	0.64	0.10	1.23	0.14
134	Togo	1.15	0.15	1.08	0.13	1.19	0.19	1.30	0.15
135	Spain	1.20	0.15	0.19	0.02	-2.91	0.49	1.76	0.21
136	Ireland	1.22	0.15	0.92	0.11	-0.97	0.16	-0.15	0.02
137	Papua New Guinea	1.24	0.16	1.23	0.15	1.19	0.19	1.31	0.15
138	Sierra Leone	1.27	0.16	1.25	0.15	1.21	0.19	1.51	0.18
139	Ecuador	1.32	0.17	1.20	0.15	1.71	0.27	1.61	0.19
140	Tunisia	1.39	0.18	1.40	0.17	1.29	0.20	1.60	0.19
141	North Korea	1.39	0.18	1.46	0.18	0.51	0.08	0.56	0.06
142	Syria	1.50	0.19	1.62	0.20	1.78	0.28	1.40	0.16
143	Zimbabwe	1.61	0.20	1.59	0.19	2.05	0.32	1.99	0.23
144	Bolivia	1.66	0.21	1.70	0.21	1.49	0.24	1.39	0.16
145	Portugal	1.67	0.21	1.39	0.17	0.26	0.04	1.68	0.20
146	Algeria	1.83	0.23	3.35	0.41	2.07	0.33	-0.48	0.06
147	Burundi	1.92	0.24	1.91	0.23	1.77	0.28	2.23	0.26
148	South Sudan	1.94	0.25	1.94	0.24	1.66	0.26	2.17	0.25
149	Haiti	1.96	0.25	1.95	0.24	1.94	0.31	2.30	0.27
150	Guatemala	1.99	0.25	1.87	0.23	2.30	0.36	2.36	0.27

	country	CO ₂ (%)		CO ₂ / CB (%)		CO ₂ / 1960 (%)		GHG (%)	
151	Senegal	2.02	0.26	1.99	0.24	2.17	0.34	2.42	0.28
152	Benin	2.02	0.26	1.96	0.24	1.68	0.27	1.96	0.23
153	Rwanda	2.06	0.26	2.06	0.25	2.02	0.32	2.34	0.27
154	Guinea	2.13	0.27	2.13	0.26	1.97	0.31	2.33	0.27
155	Zambia	2.14	0.27	2.08	0.26	2.34	0.37	2.46	0.29
156	Somalia	2.24	0.29	2.24	0.28	2.24	0.36	2.55	0.30
157	Chad	2.39	0.30	2.40	0.29	2.17	0.34	2.65	0.31
158	Niger	2.66	0.34	2.61	0.32	2.93	0.46	3.22	0.37
159	Malawi	2.70	0.34	2.66	0.33	2.75	0.44	3.31	0.38
160	Cambodia	3.03	0.39	2.95	0.36	2.53	0.40	3.29	0.38
161	Cote d'Ivoire	3.07	0.39	3.01	0.37	3.62	0.57	3.59	0.42
162	Mali	3.21	0.41	3.18	0.39	3.01	0.48	3.79	0.44
163	Burkina Faso	3.22	0.41	3.20	0.39	2.96	0.47	3.62	0.42
164	Angola	3.40	0.43	3.46	0.43	3.45	0.55	2.84	0.33
165	Cameroon	3.66	0.47	3.67	0.45	3.41	0.54	3.79	0.44
166	Peru	3.71	0.47	3.49	0.43	4.33	0.69	4.57	0.53
167	Madagascar	3.84	0.49	3.81	0.47	3.94	0.62	4.60	0.53
168	Yemen	4.15	0.53	4.07	0.50	4.09	0.65	4.63	0.54
169	Sri Lanka	4.30	0.55	4.08	0.50	4.13	0.65	5.32	0.62
170	Ghana	4.32	0.55	4.18	0.51	4.46	0.71	4.97	0.58
171	Colombia	4.40	0.56	4.15	0.51	5.73	0.91	5.35	0.62
172	Mozambique	4.76	0.61	4.59	0.56	4.30	0.68	5.28	0.61
173	Morocco	4.83	0.61	4.61	0.57	4.90	0.78	5.79	0.67
174	Turkey	5.29	0.67	4.27	0.52	3.89	0.62	5.92	0.69
175	Uganda	5.64	0.72	5.59	0.69	5.89	0.93	6.46	0.75
176	Thailand	5.74	0.73	5.63	0.69	6.84	1.08	7.47	0.87
177	Afghanistan	5.87	0.75	5.78	0.71	5.09	0.81	6.91	0.80
178	Nepal	6.17	0.78	6.08	0.75	5.39	0.85	6.92	0.80
179	Kenya	6.24	0.79	6.11	0.75	6.86	1.09	7.15	0.83
180	Sudan	6.76	0.86	7.00	0.86	6.32	1.00	6.98	0.81
181	Tanzania	7.77	0.99	7.65	0.94	8.11	1.28	9.14	1.06
182	Egypt	8.82	1.12	8.93	1.10	10.48	1.66	10.86	1.26
183	Myanmar	10.74	1.37	10.74	1.32	10.25	1.62	12.59	1.46
184	Philippines	11.82	1.50	11.18	1.37	15.04	2.38	16.00	1.86
185	Democratic Republic of Congo	12.67	1.61	12.58	1.55	12.43	1.97	14.20	1.65
186	Vietnam	12.81	1.63	13.03	1.60	13.29	2.11	15.94	1.85
187	Brazil	17.46	2.22	17.41	2.14	23.98	3.80	20.72	2.41
188	Ethiopia	18.26	2.32	18.17	2.23	16.16	2.56	21.15	2.46
189	Nigeria	26.94	3.43	27.47	3.38	26.79	4.25	22.04	2.56
190	Pakistan	28.60	3.64	28.24	3.47	30.50	4.83	34.32	3.99
191	Bangladesh	32.72	4.16	32.35	3.98	29.45	4.67	37.50	4.36
192	Indonesia	34.34	4.37	34.93	4.29	35.85	5.68	39.88	4.64
193	China	149.30	18.99	180.53	22.19	41.11	6.51	141.47	16.45
194	India	248.28	31.58	250.45	30.78	191.92	30.41	279.42	32.48

Table 5 presents the carbon debt and credit scenario's from Section 3.2, incorporating both fossil fuel CO₂ emissions and land use change emissions. We also report results for land use change considered separately. Here, land use change emissions are taken from the BLUE book-keeping model⁷, which provides spatially explicit estimates and is widely used and extensively documented. This contrasts with models such as H&C2023 and OSCAR, which are not spatially explicit, and with LUCE⁸, which is more recently developed and less comprehensively documented. Those country that change the most after incorporating land use change are Brazil and Indonesia, which turn from major creditors to major debtors.

Tab. A5 | Carbon Debts and Credits including land use change under different scenarios.

	country	CO ₂ (%)		CO ₂ 1960 (%)		GHG (%)		LUC (%)	
1	United States	-434.45	39.94	-237.29	37.20	-473.17	40.49	-88.69	14.54
2	Russia	-151.55	13.93	-80.47	12.61	-146.31	12.52	-85.35	14.00
3	Brazil	-80.58	7.41	-58.93	9.24	-83.02	7.10	-103.15	16.91
4	Canada	-63.16	5.81	-33.63	5.27	-60.63	5.19	-36.63	6.01
5	Germany	-40.65	3.74	-30.59	4.80	-43.00	3.68	16.85	4.49
6	United Kingdom	-40.07	3.68	-15.63	2.45	-49.44	4.23	9.04	2.41
7	Australia	-26.16	2.40	-18.92	2.97	-41.90	3.59	-11.78	1.93
8	Ukraine	-16.78	1.54	-12.05	1.89	-16.30	1.40	-5.00	0.82
9	Indonesia	-15.45	1.42	7.20	1.17	-5.99	0.51	-53.85	8.83
10	South Africa	-13.92	1.28	-10.09	1.58	-12.61	1.08	-2.44	0.40
11	Malaysia	-13.10	1.20	-9.13	1.43	-11.19	0.96	-11.47	1.88
12	Saudi Arabia	-12.96	1.19	-13.61	2.13	-16.02	1.37	1.57	0.42
13	Kazakhstan	-11.57	1.06	-8.24	1.29	-20.74	1.78	-2.03	0.33
14	Colombia	-11.45	1.05	2.43	0.40	-11.00	0.94	-16.84	2.76
15	Japan	-10.25	0.94	-23.65	3.71	6.12	0.53	14.40	3.83
16	Argentina	-8.81	0.81	-3.25	0.51	-19.20	1.64	-9.46	1.55
17	Cote d'Ivoire	-8.73	0.80	-1.86	0.29	-2.94	0.25	-12.01	1.97
18	Thailand	-7.34	0.67	-0.89	0.14	-1.01	0.09	-14.31	2.35
19	Venezuela	-6.54	0.60	-1.92	0.30	-11.57	0.99	-4.19	0.69
20	Democratic Republic of Congo	-6.40	0.59	-1.53	0.24	0.15	0.01	-19.25	3.16

	country	CO ₂	(%)	CO ₂ 1960	(%)	GHG	(%)	LUC	(%)
21	Belgium	-6.38	0.59	-3.86	0.60	-7.18	0.61	1.70	0.45
22	Poland	-6.22	0.57	-8.20	1.29	-11.66	1.00	6.74	1.79
23	Netherlands	-5.38	0.49	-4.84	0.76	-7.20	0.62	1.38	0.37
24	Bolivia	-5.12	0.47	-2.28	0.36	-5.09	0.44	-6.85	1.12
25	Belarus	-4.61	0.42	-2.17	0.34	-5.96	0.51	-3.42	0.56
26	United Arab Emirates	-4.60	0.42	-4.52	0.71	-6.01	0.51	0.33	0.09
27	Zambia	-4.50	0.41	-1.09	0.17	-1.85	0.16	-6.81	1.12
28	Czechia	-4.12	0.38	-4.85	0.76	-4.33	0.37	2.70	0.72
29	Finland	-3.81	0.35	-2.16	0.34	-4.45	0.38	-2.57	0.42
30	New Zealand	-3.53	0.32	-1.54	0.24	-8.21	0.70	-2.67	0.44
31	Kuwait	-3.06	0.28	-3.03	0.47	-4.93	0.42	0.21	0.06
32	Madagascar	-2.94	0.27	1.30	0.21	-1.56	0.13	-6.98	1.14
33	Nicaragua	-2.89	0.27	-0.67	0.10	-2.65	0.23	-3.84	0.63
34	Paraguay	-2.61	0.24	-1.70	0.27	-3.68	0.32	-3.55	0.58
35	Denmark	-2.47	0.23	-1.55	0.24	-2.69	0.23	-0.43	0.07
36	Congo	-2.40	0.22	-0.22	0.03	-1.93	0.16	-3.05	0.50
37	Mongolia	-2.29	0.21	-1.10	0.17	-5.36	0.46	-2.17	0.36
38	Qatar	-2.16	0.20	-2.13	0.33	-4.11	0.35	0.08	0.02
39	Mexico	-2.12	0.20	3.83	0.62	0.37	0.03	-3.76	0.62
40	Sweden	-2.05	0.19	-0.18	0.03	-1.70	0.15	-0.71	0.12
41	Ecuador	-1.84	0.17	0.08	0.01	-2.03	0.17	-3.46	0.57
42	Angola	-1.75	0.16	1.40	0.23	-1.32	0.11	-5.36	0.88
43	Panama	-1.69	0.16	-0.41	0.06	-1.11	0.10	-2.03	0.33
44	Chile	-1.57	0.14	0.34	0.06	-0.19	0.02	-2.56	0.42
45	Honduras	-1.52	0.14	0.43	0.07	-0.77	0.07	-2.69	0.44
46	Guinea	-1.46	0.13	1.62	0.26	-0.04	0.004	-3.58	0.59
47	Slovakia	-1.38	0.13	-1.30	0.20	-1.22	0.10	0.48	0.13
48	Costa Rica	-1.35	0.12	-0.22	0.03	-0.91	0.08	-1.91	0.31
49	Cuba	-1.31	0.12	-0.34	0.05	-1.08	0.09	-2.69	0.44
50	Laos	-1.30	0.12	-0.58	0.09	-0.67	0.06	-2.43	0.40
51	Norway	-1.21	0.11	-0.68	0.11	-1.75	0.15	-0.24	0.04
52	Trinidad and Tobago	-1.20	0.11	-1.00	0.16	-1.75	0.15	0.10	0.03
53	Turkmenistan	-1.08	0.10	-1.11	0.17	-3.66	0.31	0.34	0.09
54	Estonia	-0.99	0.09	-0.74	0.12	-1.31	0.11	0.06	0.02
55	Papua New Guinea	-0.96	0.09	-0.06	0.01	-0.60	0.05	-2.14	0.35
56	Gabon	-0.94	0.09	-0.62	0.10	-1.24	0.11	-1.02	0.17
57	Singapore	-0.94	0.09	-0.99	0.15	-0.89	0.08	0.38	0.10
58	Lithuania	-0.88	0.08	0.07	0.01	-1.39	0.12	-0.75	0.12
59	Libya	-0.88	0.08	-0.97	0.15	-3.35	0.29	0.40	0.11
60	Sierra Leone	-0.83	0.08	0.31	0.05	0.44	0.04	-2.19	0.36
61	Bahrain	-0.81	0.07	-0.78	0.12	-2.01	0.17	0.08	0.02
62	Bhutan	-0.80	0.07	-0.46	0.07	-0.53	0.05	-0.97	0.16
63	Oman	-0.74	0.07	-0.90	0.14	-1.74	0.15	0.26	0.07
64	Israel	-0.73	0.07	-0.78	0.12	-1.46	0.12	0.54	0.14
65	Cambodia	-0.69	0.06	0.52	0.08	0.32	0.03	-3.62	0.59
66	Iran	-0.61	0.06	-1.99	0.31	-3.31	0.28	4.74	1.26
67	Guyana	-0.60	0.06	-0.17	0.03	-0.93	0.08	-0.75	0.12
68	Guatemala	-0.58	0.05	0.64	0.10	-0.07	0.01	-2.81	0.46
69	Luxembourg	-0.52	0.05	-0.53	0.08	-0.53	0.05	0.08	0.02
70	Liberia	-0.47	0.04	0.13	0.02	0.04	0.004	-1.20	0.20
71	Brunei	-0.42	0.04	-0.35	0.06	-0.67	0.06	-0.07	0.01
72	Austria	-0.41	0.04	-0.96	0.15	0.18	0.02	1.50	0.40
73	Belize	-0.37	0.03	-0.24	0.04	-0.29	0.02	-0.41	0.07
74	Bulgaria	-0.32	0.03	-1.03	0.16	-0.06	0.01	0.31	0.08
75	Serbia	-0.30	0.03	0.28	0.05	0.45	0.04	-0.08	0.01
76	Latvia	-0.28	0.03	-0.08	0.01	-0.19	0.02	-0.43	0.07
77	Iceland	-0.25	0.02	-0.10	0.02	-0.22	0.02	-0.17	0.03
78	Slovenia	-0.16	0.01	-0.26	0.04	-0.06	0.01	-0.04	0.01
79	Vanuatu	-0.10	0.01	-0.03	0.01	-0.03	0.003	-0.15	0.02
80	Suriname	-0.09	0.01	-0.09	0.01	-0.09	0.01	-0.10	0.02
81	Bahamas	-0.07	0.01	-0.08	0.01	-0.05	0.004	0.03	0.01
82	Solomon Islands	-0.04	0.004	-0.05	0.01	0.11	0.01	-0.15	0.02
83	Eswatini	-0.01	0.001	0.15	0.02	0.18	0.02	-0.19	0.03
84	Palau	-0.003	0.0003	-0.01	0.001	-0.01	0.001	0.002	0.001
85	Nauru	-0.001	0.0001	-0.002	0.0003	0.0001	0.0000	0.001	0.0003
86	World	0	0	0	0	0	0	0	0
87	Andorra	0.001	0.0001	0.001	0.0001	-0.003	0.0003	0.005	0.001
88	Tuvalu	0.004	0.0005	0.003	0.0004	0.01	0.0005	0.001	0.0004
89	Liechtenstein	0.005	0.001	0.001	0.0001	0.01	0.001	0.005	0.001
90	North Macedonia	0.01	0.001	-0.09	0.01	0.39	0.03	-0.17	0.03
91	Seychelles	0.02	0.002	0.01	0.002	0.03	0.003	0.01	0.003
92	Marshall Islands	0.03	0.003	0.01	0.001	0.04	0.003	0.01	0.002
93	Antigua and Barbuda	0.03	0.003	0.01	0.001	0.02	0.002	0.02	0.01
94	Saint Kitts and Nevis	0.03	0.003	0.01	0.002	0.03	0.002	0.01	0.003
95	Dominica	0.03	0.003	0.02	0.003	0.04	0.003	0.01	0.003
96	Tonga	0.04	0.004	0.03	0.004	0.04	0.003	0.01	0.003
97	Micronesia (country)	0.04	0.004	0.03	0.004	0.05	0.004	0.01	0.003
98	Kiribati	0.04	0.004	0.03	0.004	0.05	0.004	0.01	0.003
99	Cyprus	0.04	0.005	0.07	0.01	0.15	0.01	0.07	0.02
100	East Timor	0.05	0.01	0.18	0.03	0.20	0.02	-0.24	0.04
101	Saint Vincent and the Grenadines	0.05	0.01	0.03	0.004	0.06	0.005	0.02	0.004
102	Equatorial Guinea	0.05	0.01	0.05	0.01	-0.21	0.02	0.004	0.001
103	Saint Lucia	0.05	0.01	0.03	0.01	0.07	0.01	0.02	0.01
104	Grenada	0.06	0.01	0.03	0.01	0.07	0.01	0.02	0.01
105	Samoa	0.06	0.01	0.05	0.01	0.06	0.01	0.01	0.002

	country	CO ₂	(%)	CO ₂ 1960	(%)	GHG	(%)	LUC	(%)
106	Sao Tome and Principe	0.06	0.01	0.05	0.01	0.08	0.01	0.02	0.005
107	Montenegro	0.06	0.01	0.16	0.03	0.15	0.01	-0.09	0.01
108	Maldives	0.08	0.01	0.05	0.01	0.11	0.01	0.03	0.01
109	Botswana	0.09	0.01	0.19	0.03	-0.59	0.05	-0.10	0.02
110	Greece	0.10	0.01	-0.62	0.10	1.24	0.11	0.33	0.09
111	Barbados	0.11	0.01	0.03	0.005	0.14	0.01	0.05	0.01
112	Malta	0.13	0.01	0.03	0.005	0.19	0.02	0.08	0.02
113	Azerbaijan	0.13	0.01	-0.01	0.001	0.39	0.03	0.42	0.11
114	Djibouti	0.17	0.02	0.17	0.03	0.18	0.02	0.05	0.01
115	Cape Verde	0.17	0.02	0.11	0.02	0.23	0.02	0.05	0.01
116	Comoros	0.18	0.02	0.15	0.02	0.22	0.02	0.05	0.01
117	Fiji	0.19	0.02	0.16	0.03	0.18	0.02	0.02	0.005
118	Dominican Republic	0.20	0.02	1.09	0.18	0.93	0.08	-0.83	0.14
119	Namibia	0.23	0.03	0.30	0.05	-0.19	0.02	-0.10	0.02
120	Guinea-Bissau	0.24	0.03	0.22	0.04	0.33	0.03	-0.11	0.02
121	Myanmar	0.25	0.03	6.08	0.99	0.60	0.05	-10.89	1.79
122	Gambia	0.31	0.03	0.36	0.06	0.43	0.04	-0.01	0.001
123	Jamaica	0.32	0.04	0.20	0.03	0.57	0.05	-0.003	0.001
124	Mauritius	0.41	0.05	0.23	0.04	0.53	0.05	0.17	0.04
125	Lesotho	0.42	0.05	0.41	0.07	0.50	0.04	0.03	0.01
126	Uruguay	0.49	0.05	0.67	0.11	-2.66	0.23	-0.10	0.02
127	Bosnia and Herzegovina	0.51	0.06	0.70	0.11	0.91	0.08	0.05	0.01
128	Switzerland	0.56	0.06	-0.20	0.03	1.05	0.09	0.96	0.25
129	Moldova	0.57	0.06	0.32	0.05	0.61	0.05	0.53	0.14
130	Albania	0.59	0.07	0.51	0.08	0.82	0.07	0.01	0.002
131	Croatia	0.64	0.07	0.45	0.07	1.39	0.12	-0.10	0.02
132	Romania	0.68	0.08	-1.06	0.17	1.98	0.17	0.74	0.20
133	Central African Republic	0.70	0.08	0.73	0.12	-0.22	0.02	-0.37	0.06
134	Zimbabwe	0.73	0.08	1.27	0.21	1.71	0.15	-1.06	0.17
135	Jordan	0.74	0.08	0.78	0.13	1.08	0.09	0.41	0.11
136	Eritrea	0.74	0.08	0.61	0.10	0.84	0.07	0.09	0.02
137	Kyrgyzstan	0.75	0.08	0.65	0.11	0.68	0.06	0.24	0.06
138	Lebanon	0.76	0.08	0.53	0.09	1.07	0.09	0.47	0.12
139	Mauritania	0.78	0.09	0.65	0.11	0.34	0.03	0.23	0.06
140	Armenia	0.88	0.10	0.61	0.10	1.16	0.10	0.32	0.09
141	South Sudan	0.89	0.10	0.73	0.12	-0.29	0.02	-1.06	0.17
142	Ireland	0.92	0.10	-1.09	0.17	-2.59	0.22	0.90	0.24
143	Palestine	0.95	0.11	0.82	0.13	1.36	0.12	0.32	0.08
144	Togo	1.01	0.11	1.21	0.20	1.71	0.15	-0.19	0.03
145	Peru	1.16	0.13	1.83	0.30	1.24	0.11	-3.07	0.50
146	Hungary	1.24	0.14	-0.26	0.04	1.28	0.11	1.58	0.42
147	El Salvador	1.25	0.14	1.31	0.21	1.48	0.13	0.03	0.01
148	Mozambique	1.41	0.16	2.77	0.45	4.32	0.38	-3.47	0.57
149	Benin	1.55	0.17	0.97	0.16	2.13	0.19	-0.20	0.03
150	Tajikistan	1.63	0.18	1.42	0.23	1.77	0.15	0.57	0.15
151	Uzbekistan	1.63	0.18	0.97	0.16	0.16	0.01	2.29	0.61
152	South Korea	1.64	0.18	-3.35	0.52	2.23	0.19	8.49	2.26
153	Cameroon	1.81	0.20	2.14	0.35	2.03	0.18	-1.90	0.31
154	Tunisia	2.08	0.23	1.61	0.26	2.63	0.23	0.57	0.15
155	Chad	2.20	0.25	2.06	0.34	0.95	0.08	-0.14	0.02
156	Somalia	2.23	0.25	1.86	0.30	1.69	0.15	-0.07	0.01
157	Georgia	2.33	0.26	1.68	0.27	2.24	0.20	1.20	0.32
158	Burundi	2.33	0.26	1.90	0.31	2.99	0.26	0.38	0.10
159	Niger	2.33	0.26	2.67	0.43	2.01	0.18	-0.46	0.08
160	Senegal	2.39	0.27	2.43	0.40	2.83	0.25	0.25	0.07
161	Haiti	2.40	0.27	2.15	0.35	3.01	0.26	0.25	0.07
162	Malawi	2.45	0.27	2.36	0.38	3.84	0.34	-0.44	0.07
163	Iraq	2.47	0.28	2.25	0.37	-0.94	0.08	1.87	0.50
164	Tanzania	2.51	0.28	3.82	0.62	4.23	0.37	-5.62	0.92
165	Rwanda	2.59	0.29	2.17	0.35	3.30	0.29	0.46	0.12
166	Syria	2.80	0.31	2.60	0.42	3.29	0.29	1.12	0.30
167	Mali	2.84	0.32	2.18	0.35	3.46	0.30	-0.44	0.07
168	Portugal	2.86	0.32	0.94	0.15	3.56	0.31	1.42	0.38
169	France	3.39	0.38	-4.36	0.68	-6.18	0.53	16.41	4.37
170	Burkina Faso	3.44	0.39	2.66	0.43	3.89	0.34	0.23	0.06
171	Ghana	3.55	0.40	4.18	0.68	6.19	0.54	-0.88	0.14
172	Sri Lanka	4.26	0.48	3.81	0.62	6.64	0.58	-0.41	0.07
173	Algeria	4.44	0.50	3.18	0.52	3.72	0.32	2.19	0.58
174	Spain	5.24	0.59	0.16	0.03	8.78	0.77	4.97	1.32
175	Uganda	5.57	0.62	5.39	0.88	7.13	0.62	-0.32	0.05
176	North Korea	5.76	0.65	3.56	0.58	5.00	0.44	4.46	1.19
177	Yemen	6.40	0.72	5.11	0.83	7.62	0.67	2.23	0.59
178	Kenya	6.42	0.72	6.47	1.05	7.89	0.69	-0.16	0.03
179	Nepal	6.59	0.74	5.40	0.88	7.61	0.66	0.55	0.15
180	Morocco	6.66	0.75	5.54	0.90	8.53	0.74	1.46	0.39
181	Turkey	6.89	0.77	5.80	0.94	11.43	1.00	1.76	0.47
182	Sudan	7.20	0.81	5.79	0.94	5.09	0.44	0.57	0.15
183	Philippines	7.36	0.82	13.35	2.17	11.82	1.03	-6.49	1.06
184	Afghanistan	7.80	0.87	6.02	0.98	8.99	0.79	1.90	0.51
185	Italy	10.17	1.14	-1.20	0.19	14.08	1.23	11.29	3.00
186	Vietnam	12.81	1.44	11.38	1.85	16.41	1.43	-1.40	0.23
187	Ethiopia	17.16	1.92	14.53	2.37	21.27	1.86	-1.52	0.25
188	Egypt	17.96	2.01	14.18	2.31	21.30	1.86	7.62	2.03
189	Nigeria	31.18	3.50	28.31	4.61	31.38	2.74	3.87	1.03
190	Pakistan	43.01	4.82	37.44	6.09	49.31	4.31	13.19	3.51
191	Bangladesh	44.61	5.00	35.31	5.75	52.59	4.59	12.12	3.23
192	China	225.83	25.32	68.24	11.10	327.65	28.62	105.71	28.13
193	India	329.85	36.98	235.47	38.32	410.55	35.86	93.60	24.91

4 Per capita contributions to national debts and credits

In this section, we present person-year contributions to national carbon debts. These values are obtained by dividing total carbon debts by cumulative population over the period. They can be interpreted as a measure of how much a country has polluted relative to the size of its population.

4.1 Per capita contribution to debts and credits from fossil fuels

We begin with Scenario (1), which considers production-based CO₂ emissions from 1960 - 2023. Figure 17 shows that, on a historical per-capita basis, China has contributed more to climate change per person than, for example, Brazil. However, due to its large population, China has generated the second-largest total carbon credit, following India (Figure 7). The top per-capita debtors are predominantly oil-producing countries. Luxembourg and the United States also appear among the top ten.

4.1.1 Person-year contributions to production-based CO₂ emissions (1960 - 2023)

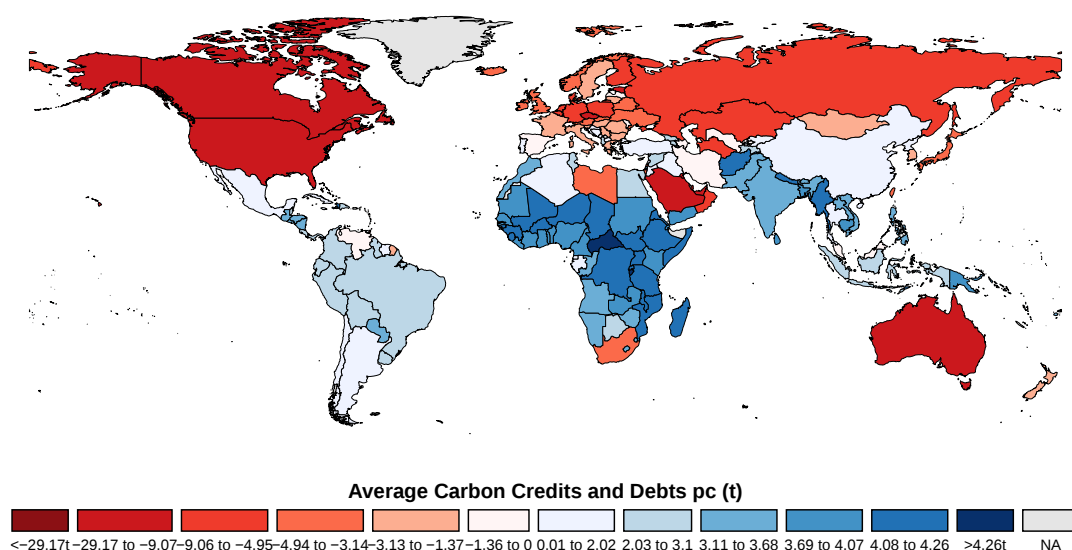


Fig. A17 | Person-year carbon credits and debts from fossil fuels (1960 - 2023). Per capita carbon credits and debts are calculated comparing the person-year emissions by country to the world average. Carbon emission are measured in tonnes of CO₂

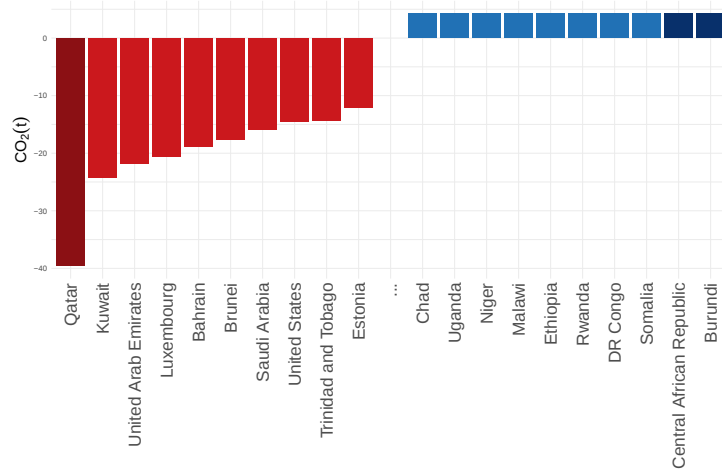


Fig. A18 | Person-year carbon credits and debts of each country from fossil fuels (1960 - 2023). Carbon emission are measured in tonnes of CO_2

4.1.2 Person-year contributions when incorporating consumption-based CO_2 emissions (1750 - 2023)

In Figure 19, we incorporate consumption-based emissions over the 30-year period from 1990 to 2023. Considering only these three decades increases the per capita credit generated by China, raises the per-capita debt of the United States, and reduces Qatar's per-capita debt by approximately 40% compared to Figure 24.

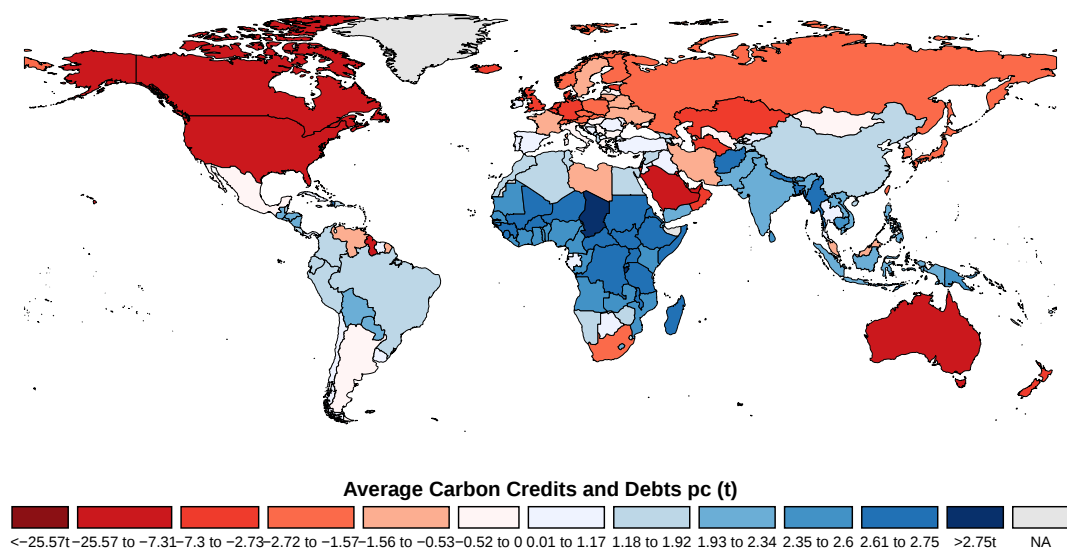


Fig. A19 | Person-year carbon credits and debts from fossil fuels (1750 - 2023). Per capita carbon credits and debts are calculated comparing the average historical per capita emissions by country to the world average. We use consumption-based estimates between 1990-2020, production-based estimates for the rest of the time-frame. Carbon emission are measured in tonnes of CO_2

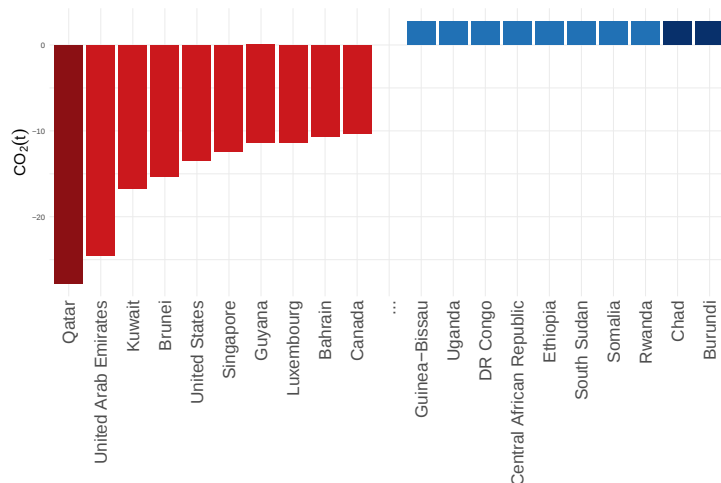


Fig. A20 | Person-year carbon credits and debts of each country from fossil fuels (1750 - 2023). We use consumption-based estimates between 1990-2020, production-based estimates for the rest of the time-frame. Carbon emission are measured in tonnes of CO_2

4.1.3 Person-year contributions to production-based GHG emissions (1750 - 2023)

Figure 21 further shows that per capita, some countries, such as China, are relatively close to becoming carbon debtors. However, their large populations allow them to generate substantial total carbon credits.

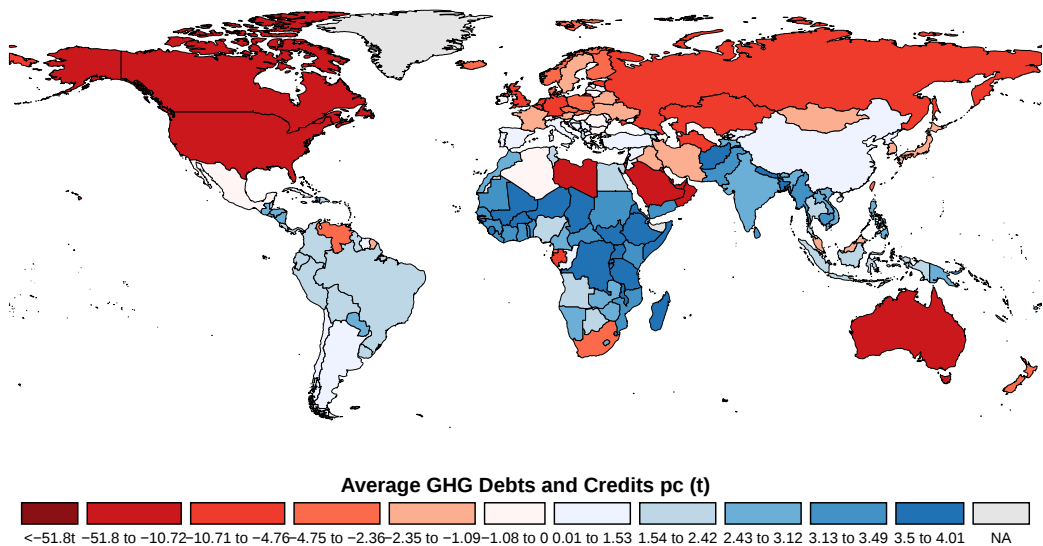


Fig. A21 | Person-year ghg debts and credits from fossil fuels (1750 - 2023). Per capita estimates are compared to the world average. Ghg emissions are measured equivalent to tonnes of CO_2

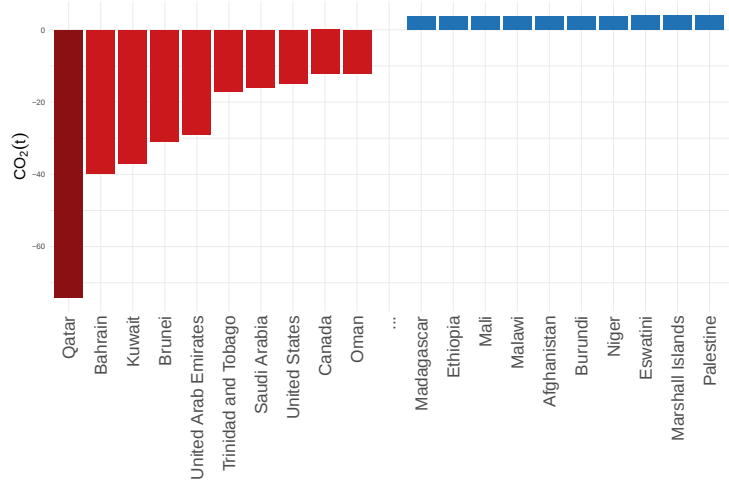


Fig. A22 | Person-year ghg debts and credits of each country from fossil fuels (1750 - 2023). Ghg emissions are measured equivalent to tonnes of CO_2

4.1.4 Person-year contributions to production-based CO₂ emissions (1750 - 2023) (without Monte Carlo)

This baseline scenario, which does not include Monte Carlo simulation, shows a pattern similar to previous results. China generates relatively little per-capita carbon credit.

Figure 25 illustrates the development of carbon debts and credits for selected countries. Qatar became a carbon debtor in 1960, with its debt rising sharply until the early 2000s; since then, its per capita carbon debt has begun to decline. China is gradually approaching the zero threshold, indicating that if current emission patterns continue, it will soon exhaust its carbon credit. Great Britain has also started to moderately reduce its carbon debt since the 1970s.

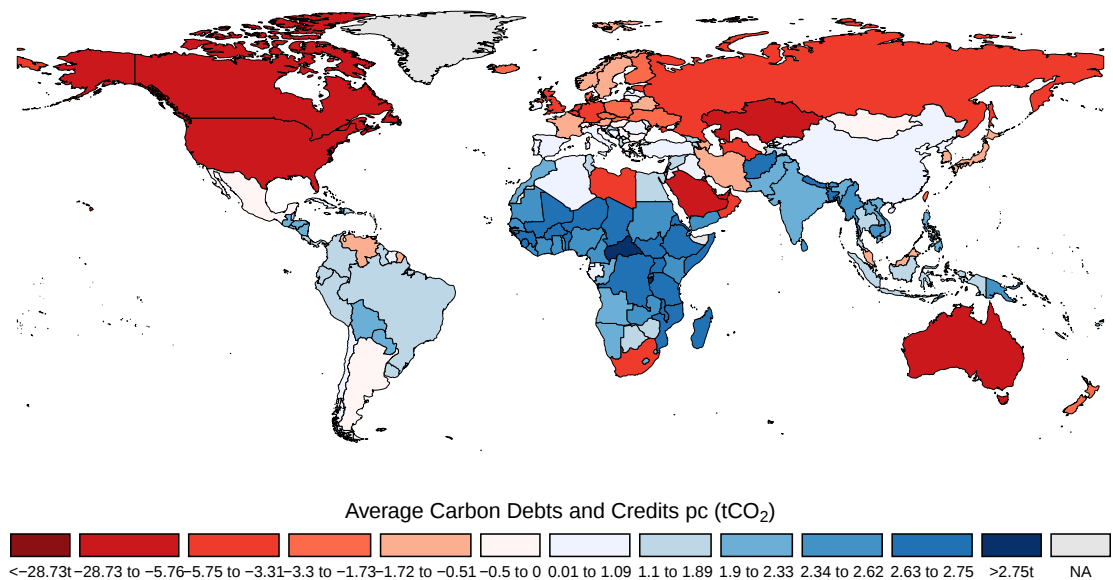


Fig. A23 | Person-year carbon credits and debts from fossil fuels (1750 - 2023). Per capita carbon credits and debts are calculated comparing the average historical per capita emissions by country to the world average. Production-based carbon emissions are measured in tons of CO₂

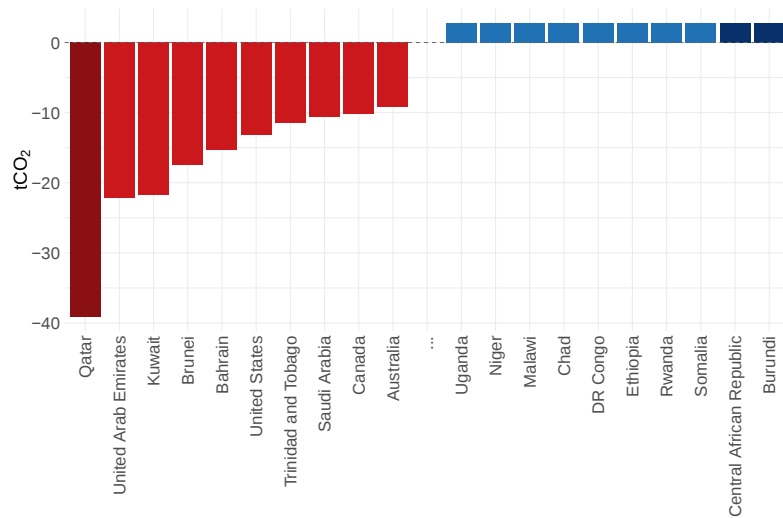


Fig. A24 | Person-year carbon credits and debts of each country from fossil fuels (1750 - 2023).
Carbon emissions are measured in tons of CO_2

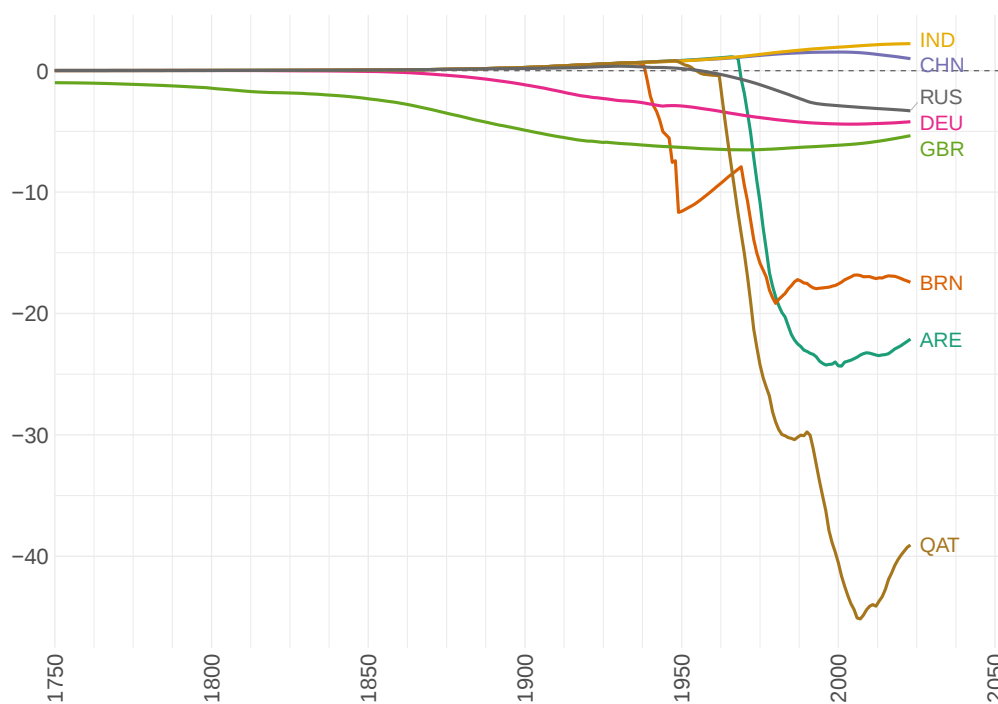


Fig. A25 | Development of person-year carbon credits and debts from fossil fuels (1750 - 2023).
Selected countries.

4.2 Per capita contributions to debts and credits from fossil fuels and land use change

In this subsection, we present the per person-year contributions to national carbon debts and credits for the scenarios that include land use change emissions.

4.2.1 Person-year contributions to production-based CO₂ emissions (inc. LUC) (1960 - 2023)

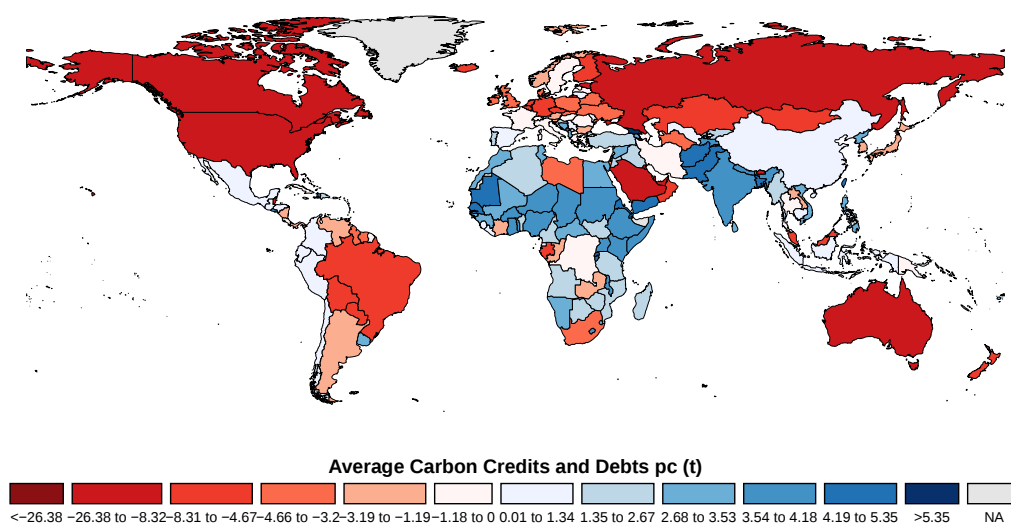


Fig. A26 | Person-year carbon credits and debts from fossil fuels and land use change (1960 - 2023). Per capita carbon credits and debts are calculated comparing the person-year emissions by country to the world average. Carbon emission are measured in tonnes of CO₂

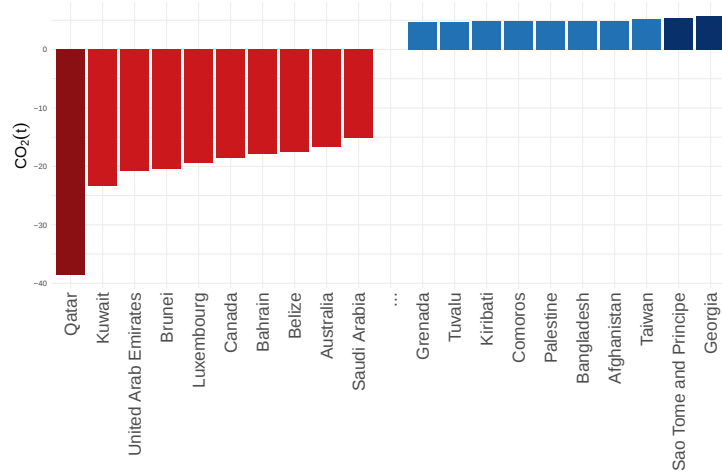


Fig. A27 | Person-year carbon credits and debts of each country from fossil fuels and land use change (1960 - 2023). Carbon emission are measured in tonnes of CO_2

4.2.2 Person-year contributions to GHG emissions (inc. land use change) (1750 - 2023)

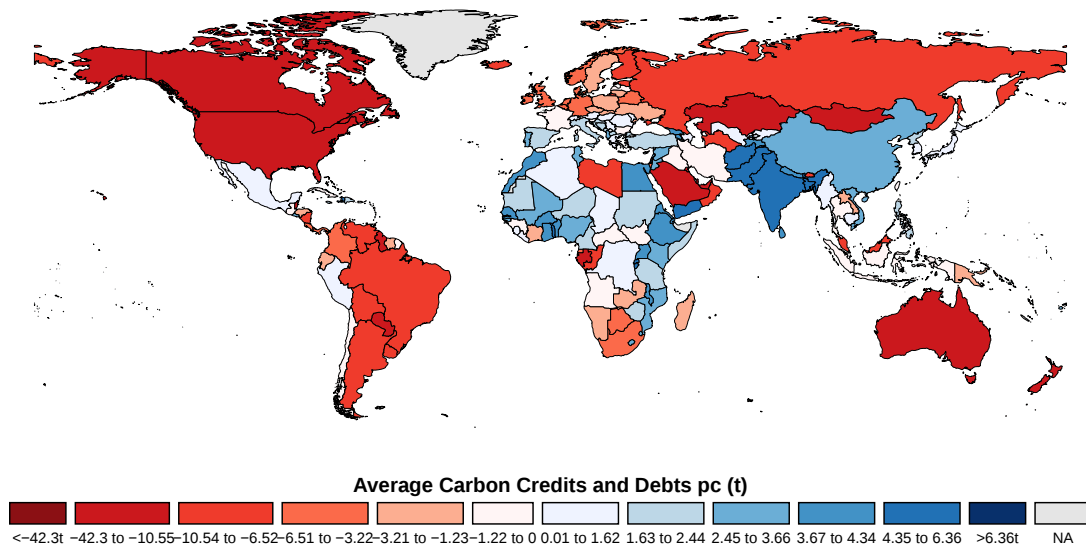


Fig. A28 | Person-year ghg debts and credits from fossil fuels and land-use change (1850 - 2023). Per capita estimates are compared to the world average. Ghg emissions are measured equivalent to tonnes of CO_2

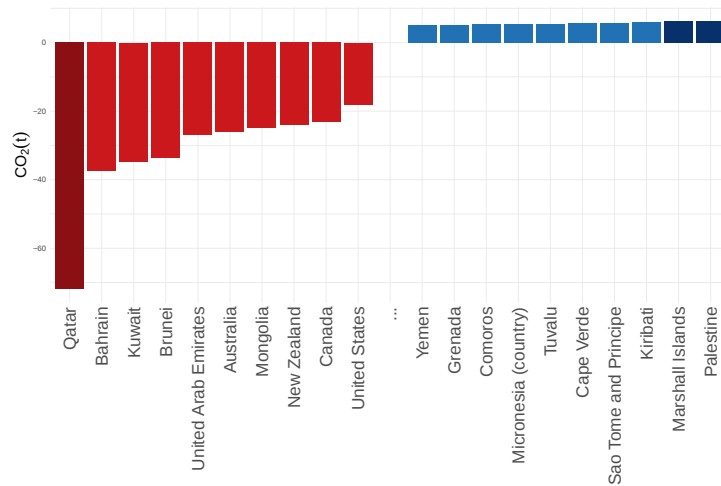


Fig. A29 | Person-year ghg debts and credits of each country from fossil fuels and land-use change (1850 - 2023). Ghg emissions are measured equivalent to tonnes of CO_2

4.2.3 Person-year contributions to production-based CO_2 emissions (inc. land use change) (1850 - 2023) (without Monte Carlo)

This is the baseline scenario using the BLUE model for land use change data and without Monte Carlo simulation. Figure 32 again depicts the per person-year development of carbon debts and credits for selected countries. Qatar shows little change compared to Figure 25. Canada has the second largest per person-year contribution to its carbon debt. Both Canada and the United States exhibit very high per person-year emissions before 1900, primarily due to the combination of small populations and high levels of land use change.

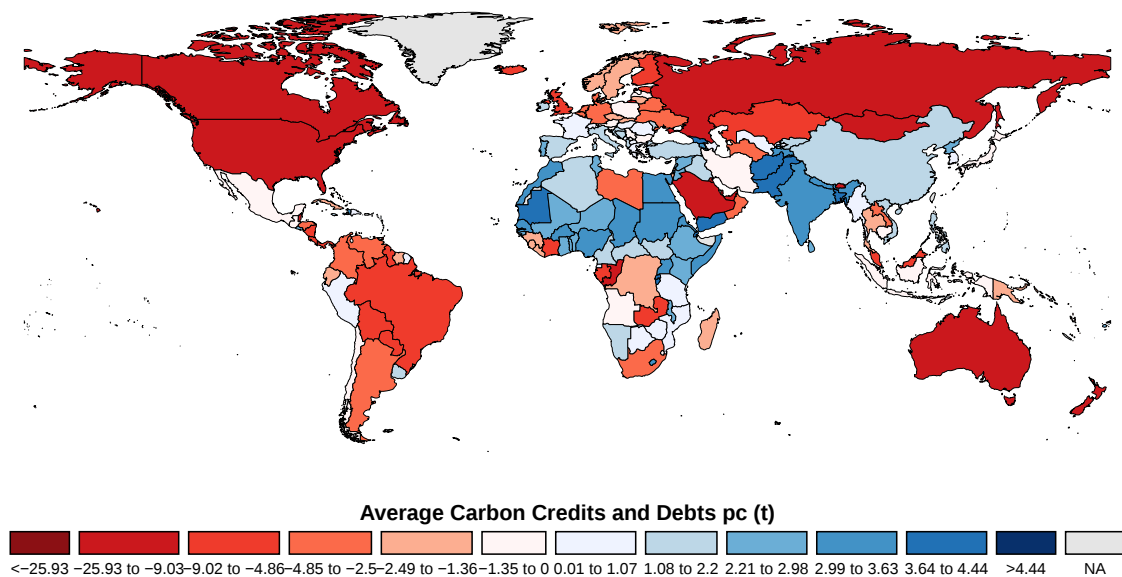


Fig. A30 | Person-year carbon credits and debts from fossil fuels and land-use change (1850 - 2023). Per capita carbon credits and debts are calculated comparing the average historical per capita emissions by country to the world average. Production-based carbon emissions are measured in tons of CO_2

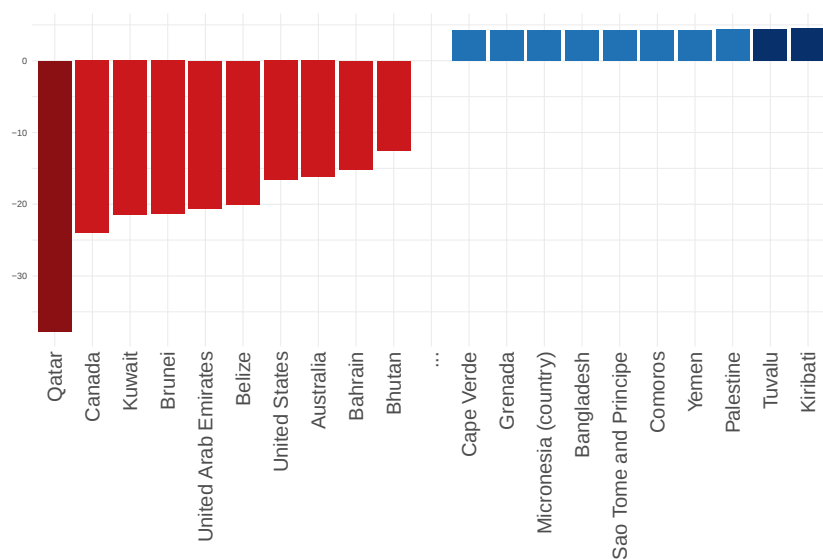


Fig. A31 | Person-year carbon credits and debts of each country from fossil fuels and land-use change (1850 - 2023). Carbon emissions are measured in tons of CO_2

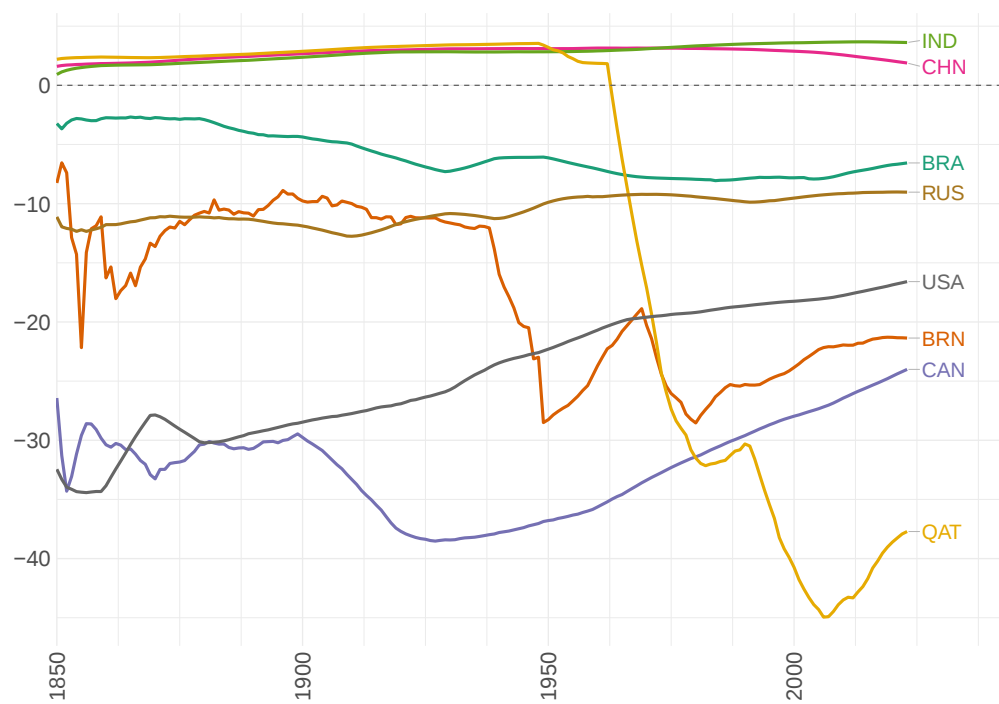


Fig. A32 | Development of average per capita carbon credits and debts of each country from fossil fuels and land-use change (1850 - 2023). Selected countries.

4.2.4 Person-year contributions to land use change CO₂ emissions, excl. fossils (1750 - 2023)

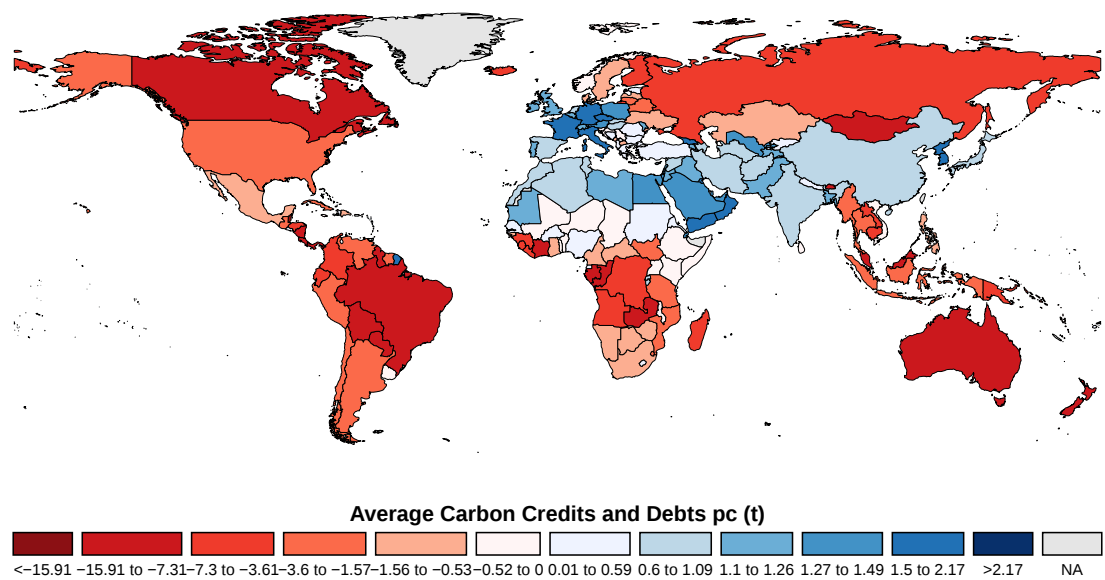


Fig. A33 | Person-year carbon credits and debts from land-use change (1850 - 2023). Per capita carbon credits and debts are calculated comparing the average historical per capita emissions by country to the world average. Carbon emissions are measured in tons of CO₂

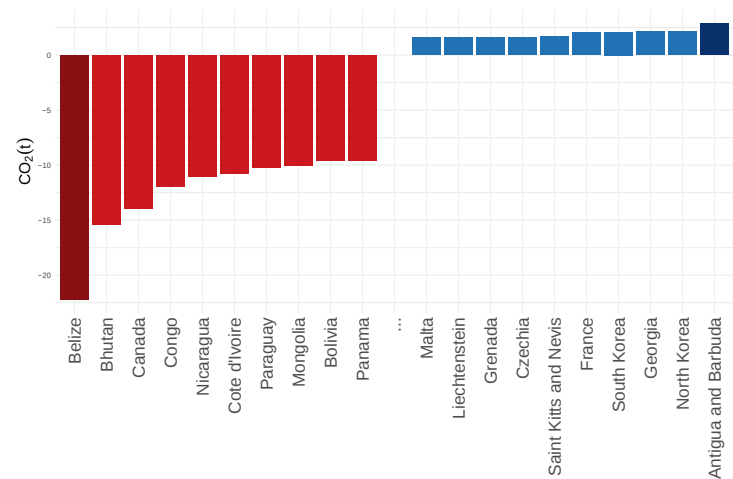


Fig. A34 | Person-year carbon credits and debts of each country from land-use change (1850 - 2023). Carbon emissions are measured in tons of CO₂

4.3 Summary tables of per capita contributions to debts and credits

Table 6 reports average per capita carbon debts and credits over the relevant time frames. For example, Column (1) covers the period 1750–2023. Qatar exhibits the highest per capita carbon debt in Column (1), which is reduced by approximately 40% when consumption-based emissions are considered between 1750 and 2023 (Column 3). In contrast, Canada’s per capita carbon debt increases by 137% when land use change emissions are included (1750–2024, Column 5), generating the second largest per capita carbon debt worldwide.

Tab. A6| Per person carbon Debts and Credits under different scenarios.

	country	CO ₂	CO ₂ /CB	CO ₂ 1960	GHG	CO ₂ (+LUC)	CO ₂ + LUC 1960	GHG (+LUC)	LUC
1	Qatar	-39.07	-27.74	-39.59	-74.07	-37.71	-38.65	-71.93	1.46
2	United Arab Emirates	-22.11	-24.55	-21.75	-29.06	-20.59	-20.80	-26.89	1.48
3	Kuwait	-21.73	-16.77	-24.26	-36.94	-21.51	-23.31	-34.68	1.50
4	Brunei	-17.43	-15.27	-17.63	-31.00	-21.36	-20.51	-33.70	-3.77
5	Bahrain	-15.36	-10.60	-18.90	-39.81	-15.15	-17.95	-37.48	1.49
6	United States	-13.19	-13.47	-14.53	-14.89	-16.59	-14.18	-18.07	-3.39
7	Trinidad and Tobago	-11.48	-8.30	-14.34	-17.08	-10.54	-12.83	-15.34	0.87
8	Saudi Arabia	-10.65	-9.84	-15.85	-16.00	-11.22	-15.10	-13.88	1.36
9	Canada	-10.15	-10.28	-11.74	-12.22	-24.01	-18.56	-23.05	-13.92
10	Australia	-9.17	-8.54	-11.13	-10.88	-16.23	-16.70	-26.00	-7.31
11	Luxembourg	-8.75	-11.41	-20.54	-10.68	-9.51	-19.47	-9.76	1.41
12	Kazakhstan	-5.76	-4.95	-8.92	-8.38	-7.72	-8.32	-13.84	-1.35
13	United Kingdom	-5.36	-5.78	-4.94	-7.17	-4.86	-4.14	-5.99	1.10
14	Singapore	-5.33	-12.45	-5.35	-5.60	-3.50	-4.42	-3.34	1.41
15	Oman	-4.90	-4.37	-7.81	-12.02	-4.27	-6.89	-9.99	1.51
16	Estonia	-4.88	-5.03	-12.00	-5.74	-5.29	-8.35	-7.03	0.33
17	Belgium	-4.61	-5.81	-6.86	-6.32	-4.55	-5.89	-5.13	1.22
18	Germany	-4.20	-4.54	-7.26	-5.46	-3.62	-5.99	-3.83	1.50
19	Bahamas	-3.91	-5.81	-5.47	-4.00	-2.76	-4.49	-1.91	1.20
20	Turkmenistan	-3.75	-2.76	-5.00	-8.33	-3.07	-4.29	-10.45	0.98
21	South Africa	-3.72	-2.67	-3.60	-4.06	-4.24	-3.99	-3.84	-0.74
22	Netherlands	-3.70	-3.88	-5.75	-4.99	-3.29	-5.01	-4.41	0.85
23	Libya	-3.51	-1.39	-4.27	-11.37	-2.50	-3.43	-9.57	1.15
24	Russia	-3.31	-2.73	-7.78	-5.27	-9.03	-8.95	-8.72	-5.09
25	Israel	-3.22	-4.33	-3.26	-5.72	-1.87	-2.37	-3.71	1.38
26	Czechia	-2.91	-2.51	-9.17	-4.60	-2.49	-7.42	-2.62	1.63
27	New Zealand	-2.78	-2.99	-2.72	-3.21	-10.37	-6.63	-24.09	-7.85
28	Palau	-2.73	-2.73	-7.12	-5.86	-2.09	-6.16	-3.64	1.49
29	Denmark	-2.73	-3.18	-5.36	-3.06	-3.81	-4.63	-4.15	-0.66
30	Taiwan	-2.51	-2.62	-3.37	-2.40		5.27	-0.31	
31	Iceland	-2.30	-3.43	-4.76	-3.01	-9.02	-6.11	-8.19	-6.12
32	Poland	-2.20	-2.04	-5.09	-3.56	-1.29	-3.54	-2.43	1.40
33	Nauru	-2.20	-2.21	-4.56	-2.14	-1.35	-3.60	0.12	1.49
34	Slovakia	-1.97	-2.22	-4.58	-3.03	-2.13	-3.99	-1.88	0.74
35	Finland	-1.74	-2.58	-5.26	-3.49	-6.07	-6.71	-7.09	-4.10
36	Ukraine	-1.73	-1.41	-4.53	-2.22	-2.85	-3.93	-2.77	-0.85
37	Venezuela	-1.71	-1.54	-1.03	-4.27	-4.00	-1.48	-7.07	-2.56
38	Norway	-1.55	-1.64	-3.62	-3.23	-2.24	-2.41	-3.22	-0.44
39	Japan	-1.40	-1.80	-3.96	-1.44	-0.76	-3.09	0.46	1.07
40	Malaysia	-1.39	-1.19	-0.97	-1.57	-8.35	-7.25	-7.14	-7.32
41	South Korea	-1.35	-1.58	-3.12	-1.64	0.41	-1.24	0.55	2.10
42	Andorra	-1.21	-1.21	-0.64	-1.55	0.24	0.18	-0.83	1.25
43	Austria	-1.10	-1.69	-3.14	-1.55	-0.36	-1.90	0.16	1.31
44	Iran	-1.09	-0.93	-1.32	-2.14	-0.13	-0.56	-0.69	0.99
45	Sweden	-0.88	-1.53	-2.50	-1.39	-1.79	-0.31	-1.48	-0.62
46	France	-0.83	-1.17	-2.66	-2.12	0.42	-1.19	-0.77	2.04
47	Belarus	-0.82	-0.69	-3.18	-1.12	-3.85	-3.56	-4.98	-2.85
48	Azerbaijan	-0.51	-0.37	-0.64	-0.55	0.18	-0.01	0.55	0.59
49	Bulgaria	-0.46	-0.29	-2.87	-0.95	-0.32	-1.99	-0.06	0.31
50	Uzbekistan	-0.46	-0.17	-0.23	-0.72	0.90	0.72	0.09	1.26
51	Slovenia	-0.44	-0.81	-2.46	-0.52	-0.69	-2.08	-0.27	-0.15
52	Lithuania	-0.33	-0.86	-2.36	-0.30	-1.96	0.33	-3.11	-1.67
53	Switzerland	-0.30	-2.32	-1.34	-0.03	0.67	-0.44	1.26	1.15
54	Cyprus	-0.25	-0.77	-1.19	-0.11	0.46	1.20	1.68	0.74
55	Argentina	-0.22	-0.17	0.51	0.05	-2.99	-1.53	-6.52	-3.21
56	Mongolia	-0.18	-0.23	-1.66	-1.26	-10.61	-8.07	-24.86	-10.08
57	Greece	-0.13	-0.10	-2.12	-0.08	0.08	-0.96	1.01	0.27
58	Hungary	-0.05	-0.33	-1.92	-0.36	0.85	-0.40	0.87	1.08
59	Serbia	-0.04	-0.15	-1.39	0.05	-0.37	0.59	0.55	-0.09
60	Mexico	-0.01	-0.11	0.65	-0.09	-0.30	0.71	0.05	-0.53
61	World	0	0	0	0	0	0	0	0
62	Iraq	0.04	0.14	0.82	-2.30	1.46	1.64	-0.55	1.10
63	Moldova	0.04	0.47	-0.38	0.50	1.33	1.30	1.44	1.24
64	Italy	0.06	-0.32	-2.12	0.08	1.36	-0.33	1.88	1.51
65	Romania	0.07	0.13	-1.45	-0.17	0.26	-0.79	0.74	0.28

	country	CO ₂	CO ₂ /CB	CO ₂ 1960	GHG	CO ₂ (+LUC)	CO ₂ + LUC 1960	GHG (+LUC)	LUC
66	Suriname	0.17	0.12	0.05	0.36	-2.20	-3.28	-2.20	-2.48
67	Liechtenstein	0.17	-0.99	-0.98	0.49	1.64	0.28	2.16	1.61
68	Spain	0.20	0.03	-1.14	0.37	1.09	0.06	1.83	1.03
69	Latvia	0.31	-0.08	-1.35	0.66	-0.81	-0.51	-0.55	-1.25
70	Chile	0.43	0.36	1.09	0.44	-1.22	0.39	-0.15	-1.99
71	Antigua and Barbuda	0.50	-0.42	-1.34	0.39	3.10	1.54	2.80	2.86
72	Gabon	0.55	0.74	0.28	-5.06	-8.10	-8.16	-10.65	-8.75
73	North Korea	0.57	0.60	0.38	0.27	2.81	2.70	2.44	2.17
74	Jordan	0.60	0.07	1.80	1.15	2.24	2.61	3.25	1.25
75	Lebanon	0.62	0.22	1.19	1.08	2.31	2.15	3.26	1.43
76	Equatorial Guinea	0.64	0.64	0.94	-3.09	0.82	1.16	-3.44	0.06
77	North Macedonia	0.69	0.59	0.27	1.20	0.03	-0.71	1.77	-0.80
78	Algeria	0.72	1.32	1.23	-0.21	1.94	1.89	1.62	0.95
79	Turkey	0.84	0.68	1.06	1.12	1.30	1.58	2.16	0.33
80	Bosnia and Herzegovina	0.85	0.83	0.48	1.19	1.13	2.83	2.01	0.11
81	Ireland	0.96	0.72	-4.03	-0.21	1.28	-4.53	-3.61	1.25
82	Malta	0.97	-0.15	-0.003	1.58	2.62	1.13	3.85	1.60
83	Kyrgyzstan	0.98	0.73	1.69	1.49	1.79	2.27	1.62	0.58
84	China	0.99	1.19	0.57	1.18	1.89	0.95	2.74	0.88
85	Cuba	1.04	0.75	1.88	0.76	-1.36	-0.52	-1.12	-2.79
86	Jamaica	1.05	0.98	1.23	1.41	1.31	1.33	2.35	-0.01
87	Portugal	1.06	0.88	0.41	1.32	2.25	1.50	2.79	1.12
88	Seychelles	1.09	-0.27	1.26	1.51	2.78	2.21	3.81	1.49
89	Croatia	1.10	0.95	0.48	1.53	1.10	1.61	2.40	-0.17
90	Thailand	1.16	1.14	1.99	1.63	-1.60	-0.26	-0.22	-3.13
91	Panama	1.18	0.97	2.27	1.88	-8.00	-2.45	-5.24	-9.60
92	Syria	1.21	1.30	2.05	1.26	2.52	3.00	2.96	1.01
93	Dominican Republic	1.34	1.23	2.54	2.00	0.34	2.33	1.64	-1.46
94	Uruguay	1.35	1.06	2.51	2.02	1.52	3.38	-8.33	-0.30
95	Ecuador	1.38	1.26	2.45	1.79	-2.05	0.11	-2.25	-3.84
96	Brazil	1.38	1.38	2.52	1.69	-6.56	-6.19	-6.76	-8.40
97	Botswana	1.39	0.34	2.36	1.83	0.84	2.14	-5.22	-0.90
98	Barbados	1.41	0.93	0.66	1.74	2.94	1.67	3.76	1.38
99	Colombia	1.51	1.42	2.67	1.92	-4.11	1.13	-3.95	-6.05
100	Egypt	1.53	1.55	2.57	2.02	3.34	3.48	3.96	1.42
101	Guyana	1.57	-11.41	2.03	1.72	-7.68	-3.65	-11.83	-9.52
102	Armenia	1.60	1.54	2.42	2.37	3.01	3.25	4.00	1.10
103	Montenegro	1.60	1.25	1.56	2.30	0.79	4.20	1.92	-1.10
104	Tunisia	1.61	1.62	2.43	2.08	2.69	3.03	3.41	0.73
105	Maldives	1.67	1.34	2.41	2.42	3.45	3.36	4.80	1.49
106	Mauritius	1.71	1.33	2.48	2.43	3.64	3.38	4.67	1.49
107	Costa Rica	1.73	1.20	3.02	2.40	-5.29	-1.06	-3.58	-7.48
108	Georgia	1.73	1.67	2.21	2.21	4.19	5.77	4.03	2.16
109	Belize	1.77	1.39	2.83	1.54	-20.03	-17.56	-15.33	-22.18
110	Peru	1.79	1.69	3.05	2.38	0.60	1.29	0.65	-1.60
111	Albania	1.82	1.73	2.68	2.38	2.18	2.88	3.02	0.02
112	Tajikistan	1.84	1.77	3.10	2.69	3.43	3.97	3.74	1.20
113	Zimbabwe	1.85	1.83	3.25	2.50	0.92	2.01	2.15	-1.33
114	Indonesia	1.89	1.92	3.00	2.39	-0.92	0.60	-0.36	-3.22
115	Saint Lucia	1.92	1.92	2.55	2.66	3.63	3.60	4.61	1.42
116	Saint Kitts and Nevis	1.97	1.97	1.69	1.53	3.98	4.09	3.66	1.71
117	Vietnam	1.98	2.01	3.12	2.69	2.16	2.67	2.76	-0.24
118	Morocco	1.99	1.90	3.11	2.66	3.06	3.52	3.92	0.67
119	Bolivia	2.04	2.08	3.08	1.96	-7.19	-4.72	-7.15	-9.62
120	Philippines	2.11	2.00	3.46	2.97	1.37	3.07	2.20	-1.21
121	Fiji	2.14	1.88	3.27	2.90	2.80	3.49	2.65	0.28
122	Honduras	2.15	2.03	3.52	2.91	-3.41	1.18	-1.73	-6.03
123	Congo	2.17	2.42	3.36	0.94	-9.41	-1.19	-7.55	-11.98
124	Namibia	2.17	1.80	3.39	2.93	1.79	3.11	-1.47	-0.78
125	Eswatini	2.20	1.22	3.48	4.01	-0.14	2.90	2.69	-2.78
126	India	2.23	2.25	3.29	3.06	3.62	4.03	4.50	1.03
127	Marshall Islands	2.23	2.23	2.74	4.01	4.14	3.70	6.39	1.49
128	Guatemala	2.23	2.09	3.56	2.84	-0.70	0.99	-0.09	-3.38
129	Grenada	2.24	2.24	2.95	3.01	4.19	4.63	5.23	1.61
130	Dominica	2.24	2.24	3.12	3.00	3.79	4.48	4.48	1.16

	country	CO ₂	CO ₂ / CB	CO ₂ 1960	GHG	CO ₂ (+LUC)	CO ₂ + LUC 1960	GHG (+LUC)	LUC
131	El Salvador	2.25	2.11	3.54	3.06	2.77	4.03	3.28	0.06
132	Paraguay	2.25	2.05	3.58	2.94	-7.48	-6.29	-10.55	-10.18
133	Saint Vincent and the Grenadines	2.26	2.26	3.19	2.92	3.94	4.02	4.89	1.32
134	Nicaragua	2.26	2.18	3.62	3.07	-8.30	-2.46	-7.61	-11.02
135	Angola	2.31	2.34	3.58	2.15	-1.32	1.45	-1.00	-4.06
136	Laos	2.32	2.21	3.56	3.04	-3.14	-1.96	-1.61	-5.88
137	Lesotho	2.32	2.18	3.61	3.04	3.00	3.88	3.57	0.25
138	Pakistan	2.33	2.30	3.65	3.17	3.97	4.48	4.55	1.22
139	Djibouti	2.33	2.14	3.77	2.94	4.11	4.58	4.34	1.31
140	Micronesia (country)	2.33	2.33	3.50	3.42	4.22	4.45	5.38	1.49
141	Tonga	2.34	2.34	3.52	3.14	3.83	4.16	3.88	1.08
142	Nigeria	2.38	2.43	3.69	2.26	3.20	3.90	3.22	0.40
143	Mauritania	2.39	2.35	3.69	3.17	3.98	4.37	1.77	1.17
144	Yemen	2.39	2.34	3.70	3.12	4.32	4.62	5.14	1.50
145	Papua New Guinea	2.40	2.37	3.69	3.12	-2.30	-0.18	-1.44	-5.10
146	Samoa	2.41	2.22	3.63	3.30	3.37	4.19	3.56	0.54
147	Cape Verde	2.44	2.26	3.69	3.42	4.19	4.51	5.57	1.30
148	Senegal	2.45	2.41	3.82	3.26	3.23	4.28	3.83	0.34
149	Bhutan	2.45	2.42	3.46	2.48	-12.54	-13.67	-8.36	-15.36
150	Sri Lanka	2.47	2.34	3.82	3.33	2.67	3.52	4.16	-0.26
151	Zambia	2.47	2.40	3.92	3.12	-5.69	-1.82	-2.34	-8.63
152	Cote d'Ivoire	2.48	2.43	3.91	3.22	-7.84	-2.02	-2.64	-10.77
153	Palestine	2.48	2.48	3.90	4.01	4.43	4.86	6.39	1.48
154	Vanuatu	2.51	2.26	3.81	3.37	-6.12	-3.28	-1.83	-9.07
155	Solomon Islands	2.51	2.51	3.86	3.53	-1.06	-2.24	2.99	-4.03
156	Tuvalu	2.53	2.53	3.73	3.50	4.44	4.69	5.40	1.49
157	Sao Tome and Principe	2.54	2.35	3.86	3.46	4.25	5.36	5.62	1.26
158	Ghana	2.55	2.47	3.97	3.37	2.41	3.72	4.20	-0.60
159	Kenya	2.56	2.51	4.01	3.29	2.95	3.78	3.63	-0.07
160	Kiribati	2.58	2.58	3.90	3.62	4.51	4.85	5.92	1.49
161	Cameroon	2.58	2.59	3.97	3.10	1.48	2.49	1.66	-1.55
162	Sudan	2.59	2.69	4.00	3.21	3.31	3.67	2.34	0.26
163	Cambodia	2.60	2.52	3.97	3.42	-0.72	0.81	0.33	-3.76
164	Liberia	2.60	2.59	4.03	3.23	-2.00	0.72	0.18	-5.06
165	Myanmar	2.62	2.62	4.07	3.49	0.07	2.41	0.17	-3.02
166	Togo	2.62	2.46	4.07	3.36	2.61	4.15	4.41	-0.48
167	Benin	2.63	2.55	4.03	3.45	2.72	2.32	3.74	-0.35
168	Gambia	2.63	2.57	4.11	3.61	3.06	4.48	4.25	-0.05
169	Bangladesh	2.64	2.60	4.06	3.58	4.25	4.86	5.01	1.16
170	Comoros	2.65	2.65	4.09	3.52	4.29	4.85	5.30	1.18
171	Guinea	2.66	2.67	4.11	3.44	-2.15	3.38	-0.06	-5.29
172	Haiti	2.67	2.65	4.14	3.36	3.51	4.59	4.40	0.36
173	Mozambique	2.68	2.58	4.14	3.41	0.91	2.67	2.79	-2.24
174	Tanzania	2.68	2.64	4.16	3.55	0.98	1.96	1.64	-2.18
175	Afghanistan	2.68	2.64	4.13	3.70	4.17	4.89	4.81	1.02
176	East Timor	2.68	2.68	4.10	3.34	0.50	3.32	2.25	-2.66
177	Nepal	2.70	2.66	4.16	3.63	3.46	4.17	3.99	0.29
178	Guinea-Bissau	2.70	2.70	4.17	3.49	2.21	3.10	3.03	-0.97
179	Sierra Leone	2.70	2.67	4.19	3.55	-1.96	1.07	1.03	-5.14
180	Eritrea	2.71	2.67	4.18	3.50	3.61	4.61	4.10	0.42
181	Mali	2.71	2.68	4.19	3.69	2.76	3.03	3.37	-0.43
182	Madagascar	2.71	2.69	4.20	3.64	-2.33	1.39	-1.23	-5.52
183	Burkina Faso	2.72	2.70	4.19	3.60	3.43	3.76	3.86	0.23
184	South Sudan	2.73	2.73	4.21	3.58	1.46	1.85	-0.47	-1.74
185	Uganda	2.73	2.70	4.23	3.52	3.04	3.87	3.89	-0.18
186	Niger	2.73	2.68	4.24	3.71	2.69	3.86	2.32	-0.53
187	Malawi	2.73	2.69	4.24	3.69	2.73	3.63	4.29	-0.49
188	Chad	2.73	2.75	4.22	3.63	3.02	4.01	1.30	-0.19
189	Democratic Republic of Congo	2.74	2.72	4.25	3.56	-1.61	-0.52	0.04	-4.83
190	Ethiopia	2.74	2.73	4.24	3.66	2.97	3.81	3.68	-0.26
191	Rwanda	2.74	2.75	4.25	3.56	3.94	4.56	5.02	0.71
192	Somalia	2.75	2.74	4.25	3.58	3.13	3.54	2.37	-0.10
193	Central African Republic	2.76	2.73	4.26	3.41	2.12	3.47	-0.66	-1.13
194	Burundi	2.77	2.75	4.28	3.70	3.88	4.58	4.97	0.62

5 Country-level cumulative emissions

In this section, we present cumulative CO₂ emissions for each country, without accounting for population. This serves as a comparison to the calculated carbon debts and credits and highlights the importance of a framework that incorporates historical population to assess countries' contributions to climate change. We show cumulative emissions per country for all our scenarios.

5.1 Cumulative production-based CO₂ emissions from fossil fuels (1960 - 2023)

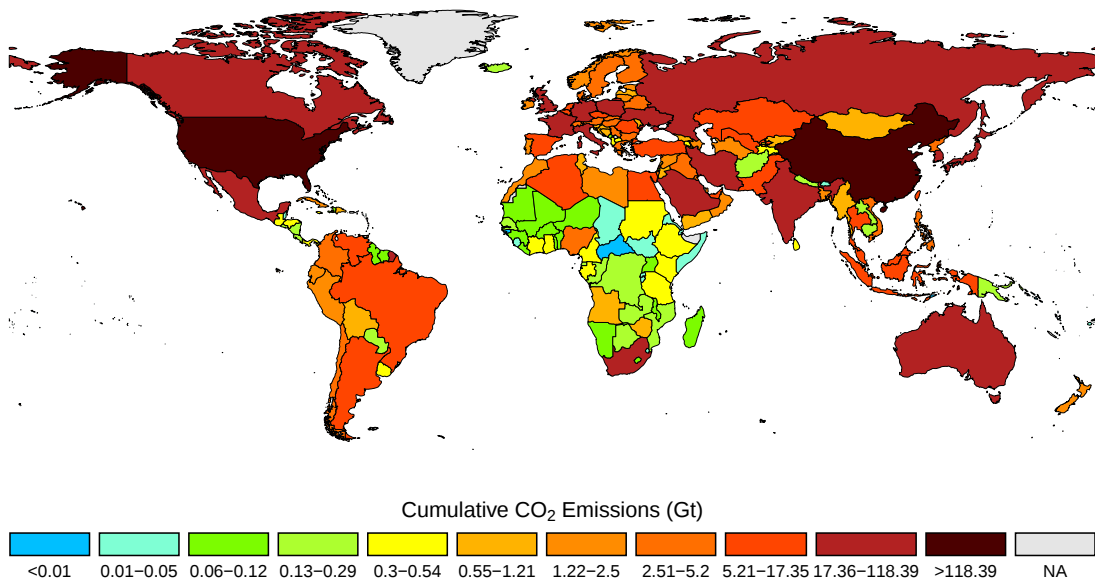


Fig. A35 | Cumulative carbon emissions from fossil fuel combustion per country (1960 - 2023). Production-based carbon emissions are measured in gigatons of CO₂

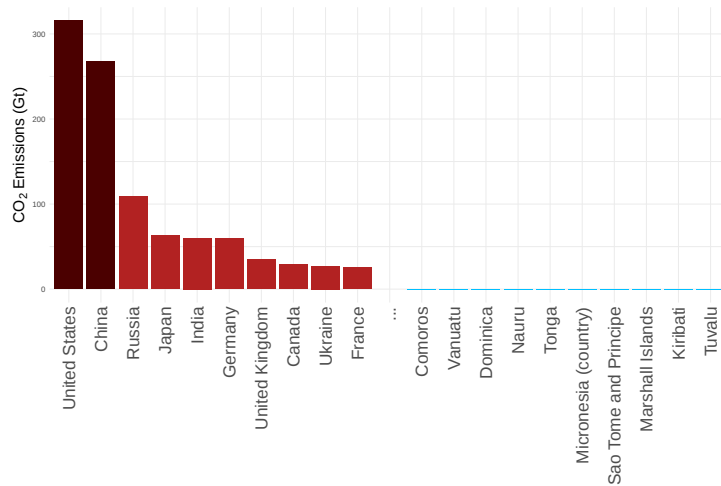


Fig. A36 | Cumulative carbon emission of the top and bottom polluters from fossil fuel combustion (1960 - 2023). Carbon emissions measured in gigatons of CO_2

5.2 Cumulative CO₂ emissions from fossil fuels (inc. consumption-based) (1750 - 2023)

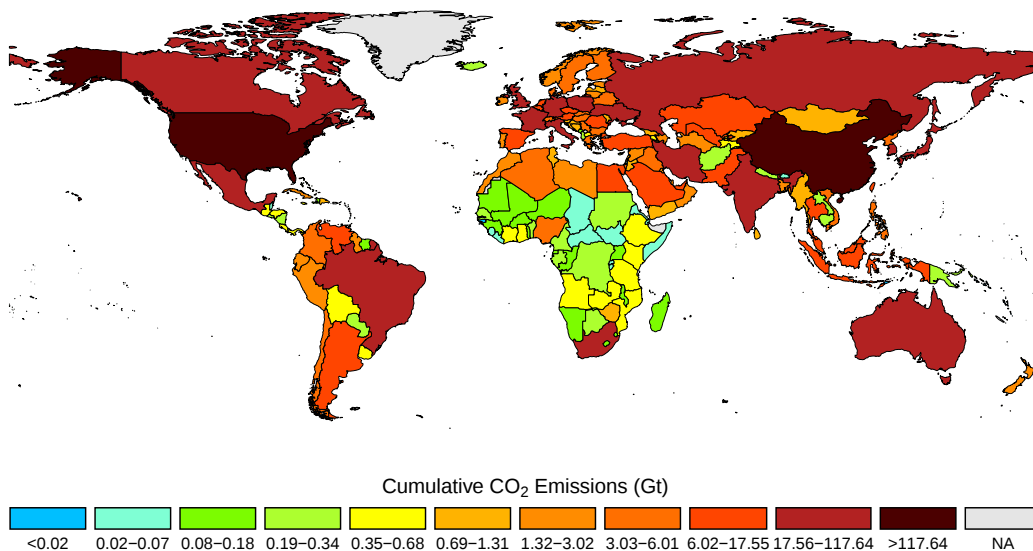


Fig. A37 | Cumulative carbon emission from fossil fuels (1750 - 2023). We use consumption-based estimates between 1990-2020, production-based estimates for the rest of the time-frame. Carbon emission are measured in tonnes of CO_2

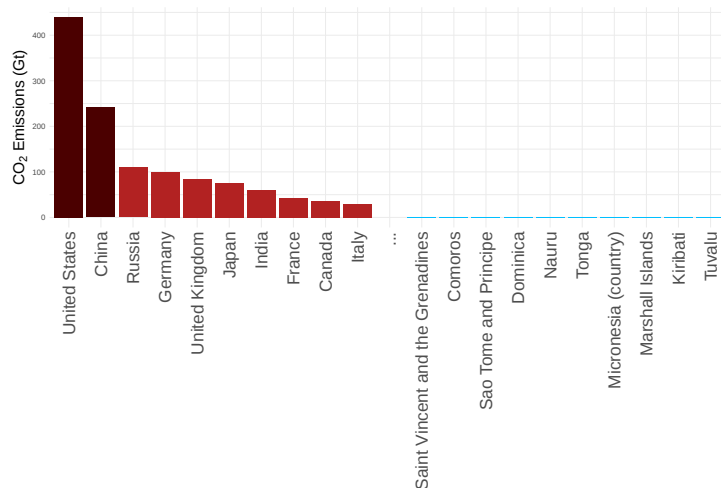


Fig. A38 | Cumulative carbon emission of the top and bottom polluters from fossil fuel combustion (1750 - 2023). We use consumption-based estimates between 1990-2020, production-based estimates for the rest of the time-frame. Carbon emission are measured in tonnes of CO_2

5.3 Cumulative GHG emissions from fossil fuels (1750 - 2023)

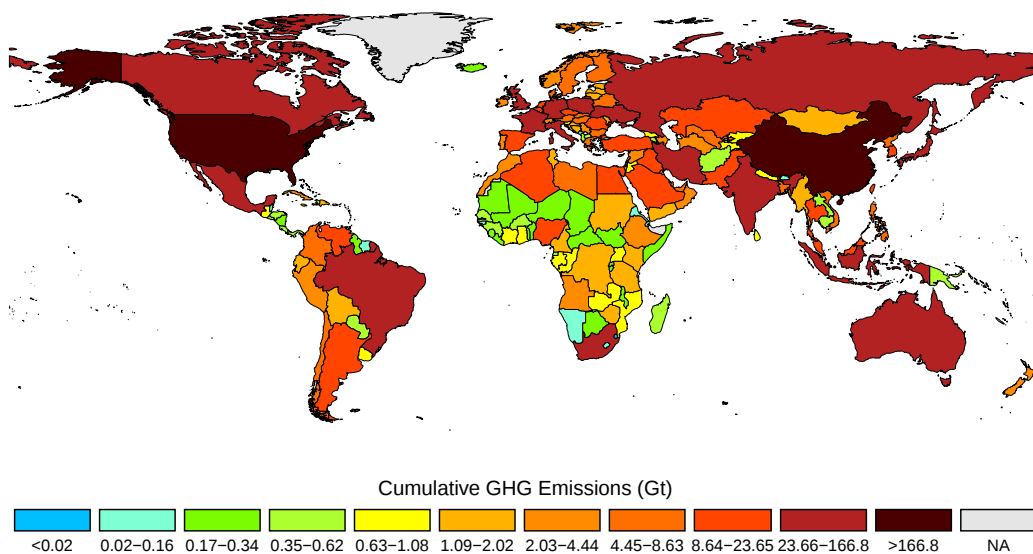


Fig. A39 | Cumulative greenhouse gas emissions (1750 - 2023).

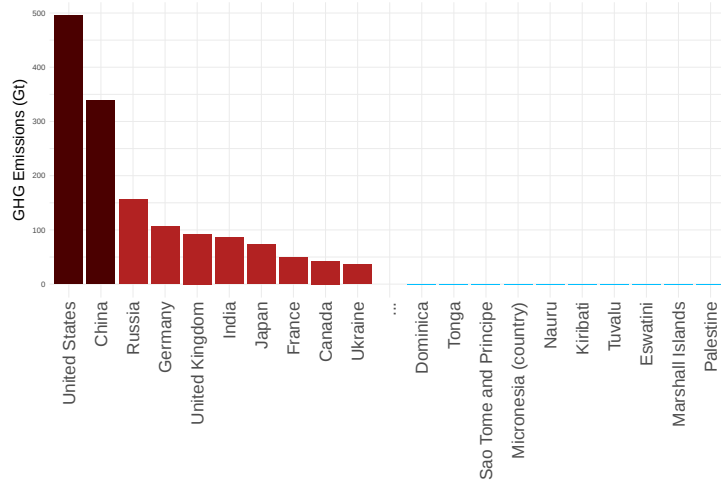


Fig. A40 | Cumulative greenhouse gas emissions of the top and bottom polluters (1750–2023).

5.4 Cumulative production-based CO₂ emissions from fossil fuels (1750 - 2023) (without Monte Carlo)

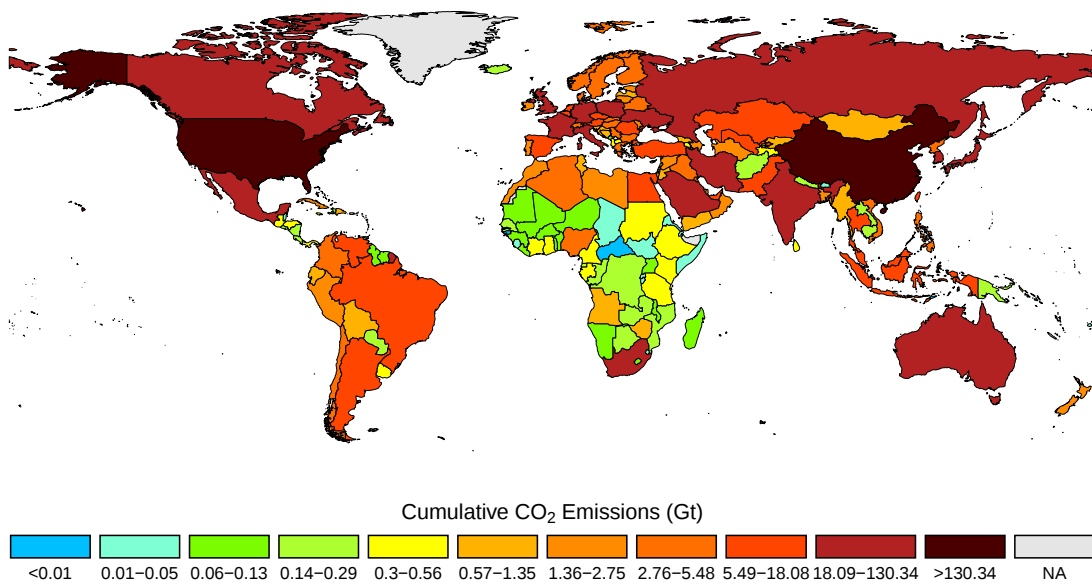


Fig. A41 | Cumulative carbon emissions from fossil fuel combustion per country (1750 - 2023). Production-based carbon emissions are measured in gigatonnes of CO₂

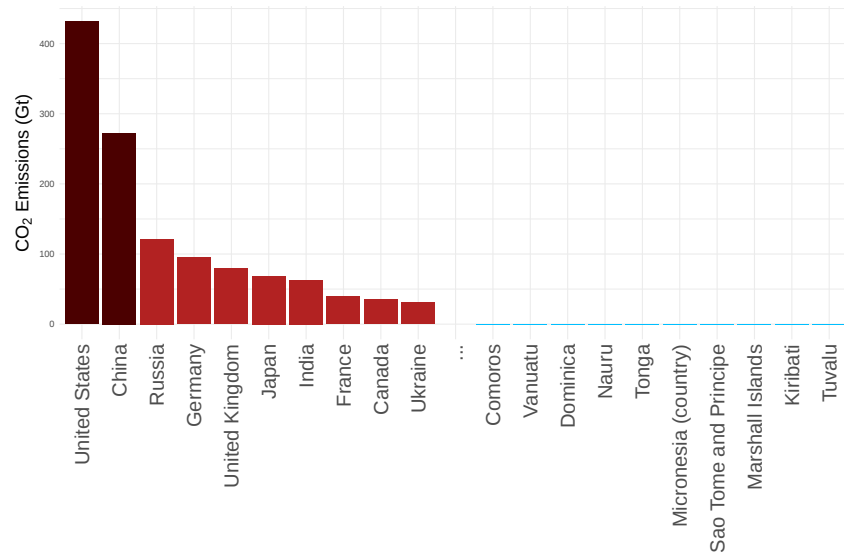


Fig. A42 | Cumulative carbon emission of the top and bottom polluters from fossil fuel combustion (1750 - 2023). Carbon emissions measured in gigatons of CO_2

5.5 Cumulative production-based CO₂ emissions from fossil fuels and land use change (1960 - 2023)

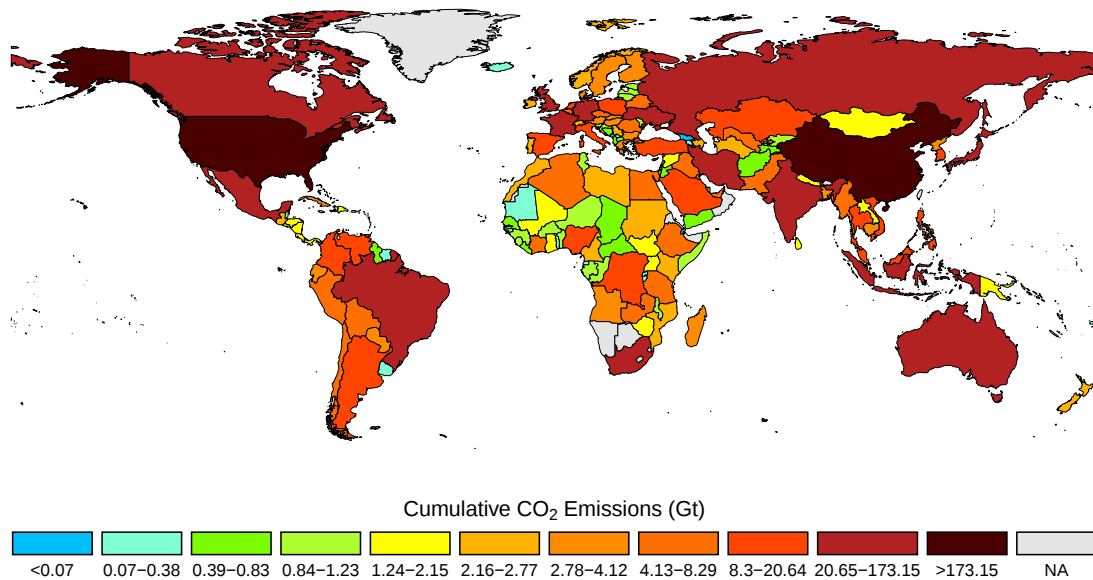


Fig. A43 | Cumulative carbon emission from fossil fuels and land-use change per country (1960 - 2023). Carbon emissions measured in gigatons of CO₂

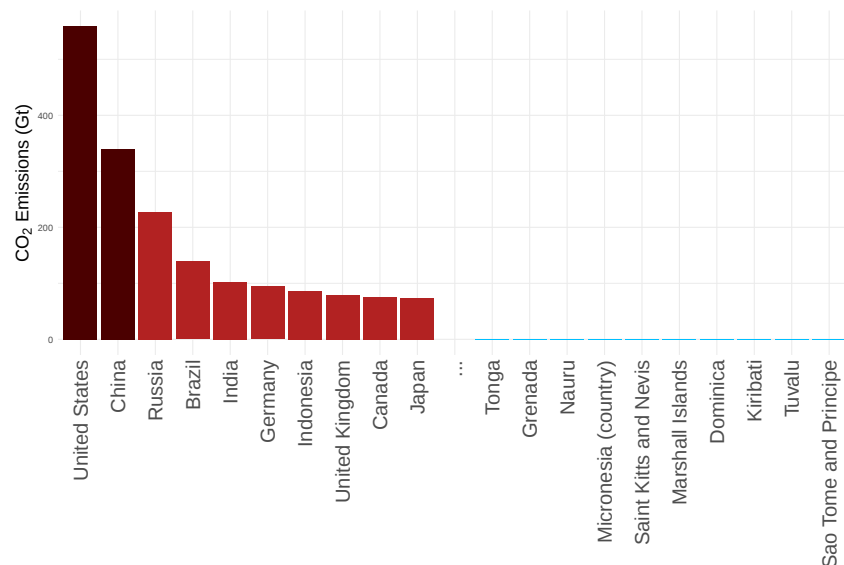


Fig. A44 | Cumulative carbon emission of the top and bottom polluters from fossil fuels and land-use change (1960 - 2023). Carbon emissions are measured in gigatons of CO_2

5.6 Cumulative GHG emissions from fossil fuels and land use change (1750 - 2023)

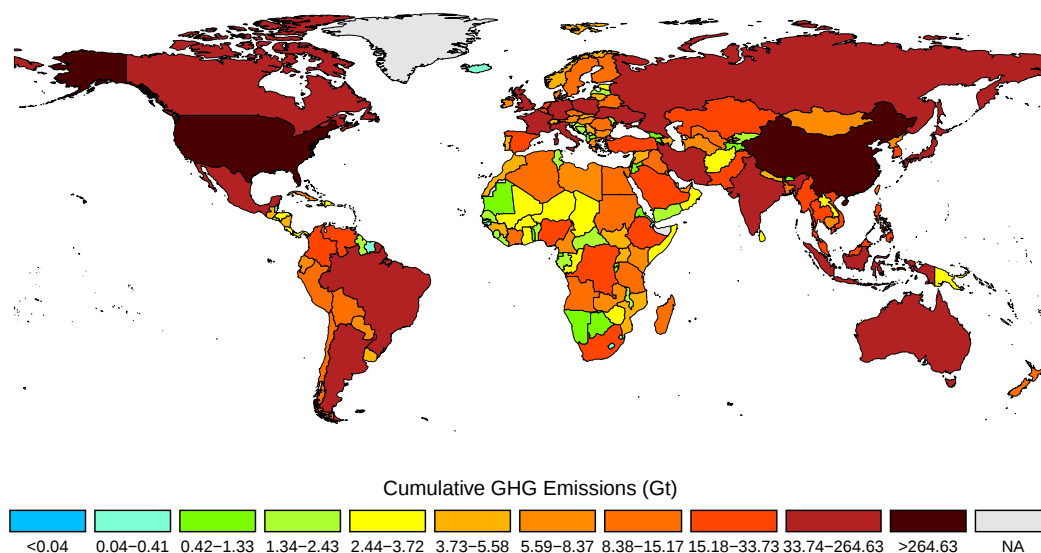


Fig. D2 | Total greenhouse gas emissions including land-use change (1850 - 2023).

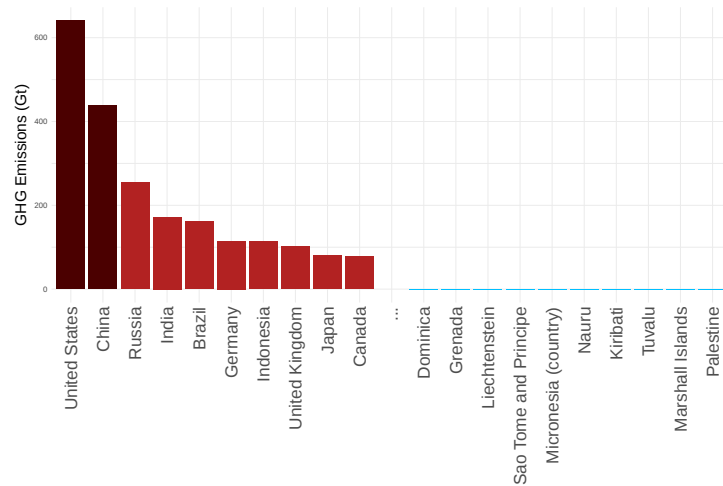


Fig. D2.1 | Total greenhouse gas emissions including land-use change of the top and bottom polluters (1850 - 2023).

5.7 Cumulative production-based CO₂ emissions from fossil fuels and land use change (1750 - 2023) (without Monte Carlo)

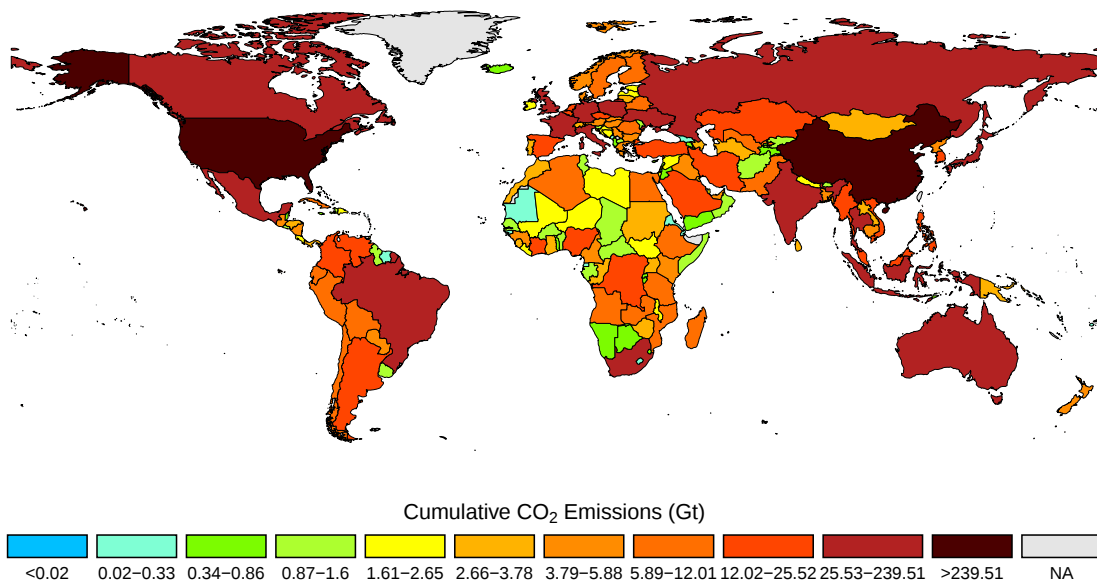


Fig. A3 | Cumulative carbon emission from fossil fuels and land-use change per country (1850 - 2023). Carbon emissions measured in gigatons of CO₂

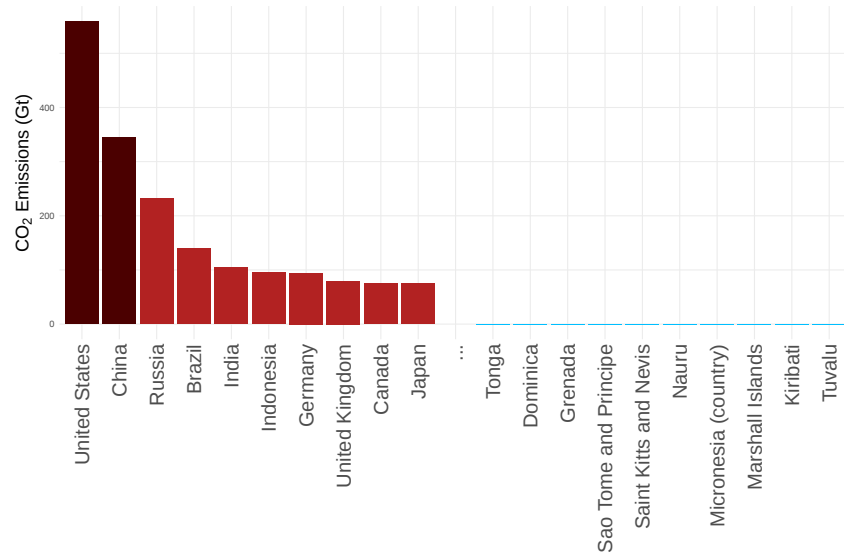


Fig. A3.1 | Cumulative carbon emission of the top and bottom polluters from fossil fuels and land-use change (1850 - 2023). Carbon emissions are measured in gigatons of CO_2

5.8 Cumulative land use change CO_2 emissions (1850 - 2023)

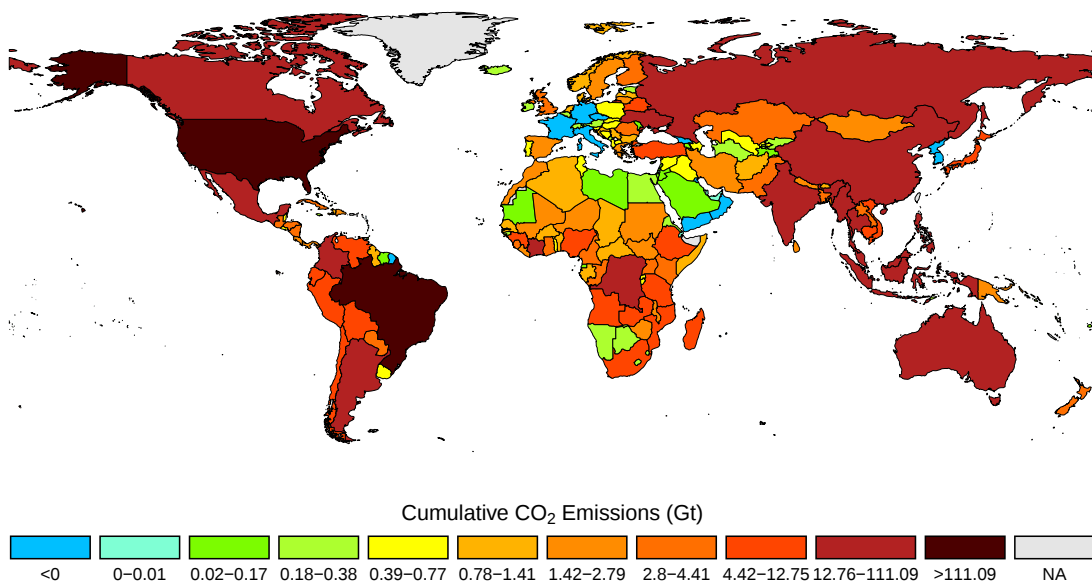


Fig. B2 | Cumulative carbon emissions from land-use change per country (1850 - 2023). Carbon emissions measured in gigatons of CO_2

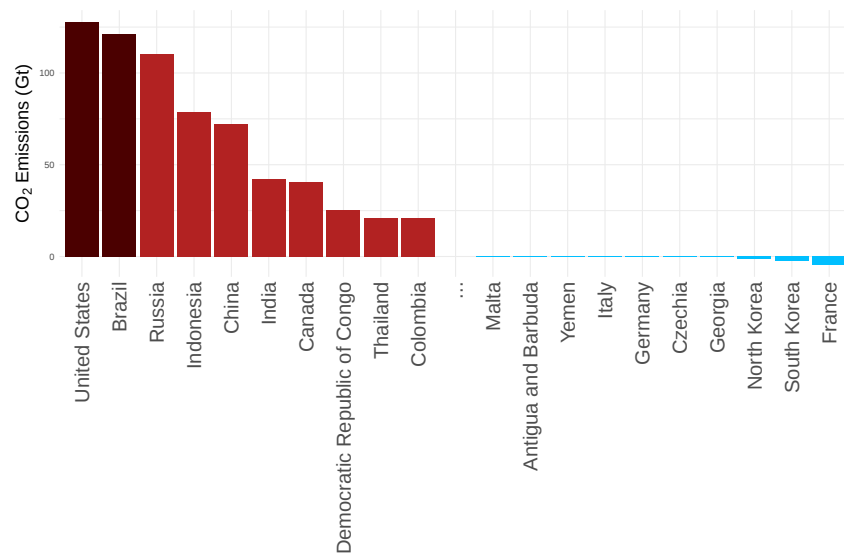


Fig. B2.1 | Cumulative carbon emission of the top and bottom polluters from land-use change (1850 - 2023). Carbon emissions stemming from fossil fuel combustion are measured in gigatons of CO_2

References

1. Friedlingstein, P. *et al.* Global Carbon Budget 2024. *Earth System Science Data* **17**, 965–1039. doi:[10.5194/essd-17-965-2025](https://doi.org/10.5194/essd-17-965-2025) (2025).
2. Friedlingstein, P. *et al.* Emerging climate impact on carbon sinks in a consolidated carbon budget. *Nature*. doi:[10.1038/s41586-025-09802-5](https://doi.org/10.1038/s41586-025-09802-5) (Nov. 2025).
3. Global Carbon Budget. *The Data Hub 2025* en. 2025.
4. Revelle, R. & Suess, H. E. Carbon dioxide exchange between atmosphere and ocean and the question of an increase of atmospheric CO₂ during the past decades. *Tellus* **9**, 18–27 (1957).
5. Keeling, C. D. The concentration and isotopic abundances of carbon dioxide in the atmosphere. *Tellus* **12**, 200–203 (1960).
6. Burq, F. & Chancel, L. Aggregate carbon footprints on WID.world. en (2021).
7. Hansis, E., Davis, S. J. & Pongratz, J. Relevance of methodological choices for accounting of land use change carbon fluxes. *Global Biogeochemical Cycles* **29**, 1230–1246. doi:<https://doi.org/10.1002/2014GB004997>. eprint: <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2014GB004997> (2015).
8. Qin, Z. *et al.* Global spatially explicit carbon emissions from land-use change over the past six decades (1961–2020). *One Earth* **7**, 835–847. doi:<https://doi.org/10.1016/j.oneear.2024.04.002> (2024).