Environmental Performance Index 2024

Yale Center for
Environmental Law & Policy,
Yale University

Center for International Earth
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Columbia University

With support from
the McCall MacBain
Foundation

2024 Environmental Performance Index

Corrigendum
7 October 2024

After publishing the 2024 Environmental Performance Index (EPI) on 3 June 2024, the EPI team became aware of three small errors that impacted the results:

1. The weights assigned to the *Wastewater Collected* and *Wastewater Treated* indicators in the Water Resources category should be 1.5% each, not 2%.

2. A coding error affected the identification of performance targets for indicators based on percentiles of raw values. This error impacted the scores of five indicators in the Environmental Health policy objective: *Household solid fuels*, *NO_2 exposure*, *Lead exposure*, *Unsafe sanitation*, and *Unsafe drinking water*.

3. An error in our formula incorrectly calculated the geometric mean of the *Bioclimatic Ecosystem Resilience Index* across a country's territory.

We have now corrected these three mistakes and published updated results.

While there were minor changes in the scores and rankings of some countries in the overall EPI and some of its component categories, these corrections did not affect the main conclusions in the 2024 EPI report.

The Environmental Performance Index

The 2024 Environmental Performance Index (EPI) provides a data-driven summary of the state of sustainability around the world. Using 58 performance indicators across 11 environmental issues, the EPI scores 180 countries on their progress toward mitigating climate change, improving environmental health, and protecting ecosystem vitality. The EPI offers a scorecard to help countries assess how close they are to established environmental policy targets. EPI ranks highlight leaders and laggards in different aspects of environmental performance and provides practical guidance for countries that aspire to move toward a sustainable future.

EPI indicators provide a way to spot problems, set targets, track trends, understand outcomes, and identify best policy practices. By synthesizing environmental data and providing rigorous analyses, the EPI helps government officials refine their policy agendas, facilitates communications with key stakeholders, and maximizes the return on environmental investments. The EPI offers a powerful policy tool in support of efforts to meet the targets of the UN Sustainable Development Goals, the Paris Agreement, and the Kunming-Montreal Global Biodiversity Framework.

Overall EPI rankings indicate which countries are best addressing the worlds' most critical environmental challenges. Going beyond the aggregate scores and drilling down into the data to analyze performance by issue category, policy objective, peer group, and country offers even greater value for policymakers. This granular view and comparative perspective can assist in understanding the determinants of environmental progress and in refining policy choices.

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Cover Art

The cover of the 2024 EPI, by Clarissa Tan, is inspired by the landscapes and ecosystems of Lahemaa National Park, in northern Estonia. Lahemaa National Park was established in 1971 and was the national park of the former Soviet Union. Today it is the largest national park in Estonia and one of the largest in Europe. Its 747 km^2 cover a diverse mosaic of forests, wetlands, and marine ecosystems, and its wildlife includes wolves, bears, and lynxes.

Estonia tops the ranking of the 2024 EPI, and biodiversity conservation is one of the many areas on which it performs strongly. Protected areas already cover close to one fifth of the country's lands and seas, two-thirds of the way toward achieving the target of protecting 30 percent by 2030.

Intellectual Property

Environmental Performance Index

Table of Contents

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Abbreviations

BLL	Blood lead level
CBD	Convention on Biological Diversity
CEDS	Community Emissions Data System
CH_4	Methane
CIESIN	Center for International Earth Science Information Network
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	Carbon monoxide
CO_2	Carbon dioxide
COP	Conference of the Parties (UNFCCC)
COVID-19	Coronavirus disease of 2019
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DALY	Disability-adjusted life-year
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
EPI	Environmental Performance Index
ESA	European Space Agency
EU	European Union
F-gases	Fluorinated gases
FAO	Food and Agriculture Organization (UN)
GBD	Global Burden of Disease
GBF	Kunming-Montreal Global Biodiversity Framework
GDP	Gross domestic product
GFW	Global Forest Watch
GHG	Greenhouse gas
HAP	Household air pollution
HDI	Human Development Index
IEA	International Energy Agency
IHME	Institute for Health Metrics and Evaluation
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
MPA	Marine protected area
MODIS	Moderate-resolution imaging spectroradiometer
MTI	Marine Trophic Index
N	Nitrogen
N_2O	Nitrous oxide
NASA	National Aeronautics and Space Administration (U.S.)
NDC	Nationally Determined Distributions
NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides ($NO + NO_2$)
NOAA	National Oceanic and Atmospheric Administration (U.S.)
NUE	Nitrogen use efficiency
OECD	Organization for Economic Co-operation and Development
OECMs	Other Effective area-based Conservation Measures
PARI	Protected Area Representativeness Index
PIK	Potsdam Institute for Climate Impact Research
$PM_{2.5}$	Particulate matter having a diameter ≤ 2.5 microns
PPP	Purchasing power parity
PRIMAP	Potsdam Realtime Integrated Model for probabilistic Assessment of emission Paths
SAU	Sea Around Us
SHI	Species Habitat Index
SIDS	Small Island Developing Nations
SDG	Sustainable Development Goal
SNMI	Sustainable Nitrogen Management Index
SO_2	Sulfur dioxide
SPI	Species Protection Index

Abbreviations

UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNICEF	United Nations Children's Fund
UNSD	United Nations Statistics Division
USA	United States of America
VOC	Volatile organic compounds
WB	World Bank
WCMC	World Conservation Monitoring Centre
WDPA	World Database on Protected Areas
WGI	Worldwide Governance Indicators
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resources Institute
WWF	World Wildlife Fund
WHO	World Health Organization

Executive Summary

Mounting evidence highlights the degradation of the planet's life-supporting systems on which humanity depends. A world economy that continues to rely heavily on fossil fuels translates into ongoing air and water pollution, acidification of the oceans, and rising concentrations of greenhouse gases in the atmosphere. These changes threaten the survival of species already suffering from widespread habitat loss, pushing them closer to extinction. Recent analyses show that humanity has already transgressed six out of nine critical planetary boundaries that define Earth's safe operating space — and is close to crossing a seventh.

In the face of these compounding crises, an empirical, data-driven approach to environmental policymaking is more important than ever. Carefully constructed metrics allow policymakers and other stakeholders to track trends, identify successful policy interventions, share best practices, and maximize the return on environmental investments.

The 2024 Environmental Performance Index (EPI) harnesses the latest data sets, science, and technology to provide the most comprehensive assessment of the state of sustainability around the world. In total, the EPI incorporates 58 indicators to rank 180 countries on their progress at mitigating climate change, safeguarding ecosystem vitality, and promoting environmental health. This broad set of metrics is a powerful tool to track progress towards the UN Sustainable Development Goals, the climate mitigation targets in the 2015 Paris Climate Change Agreement, and the biodiversity protection goals in the Kunming-Montreal Global Biodiversity Framework.

Overall EPI scores help identify which countries have been most successful at addressing a wide variety of global environmental challenges, spotlighting sustainability leaders, and calling out laggards. Delving into the details beyond overall scores—examining individual issue categories, indicators, and peer comparisons—provides a more nuanced understanding of the trends and drivers of environmental performance.

The World is Failing to Address the Climate Crisis

Last year, the first global assessment of progress toward the goals of the Paris Agreement revealed a grim picture: the world is far off track. Despite record deployment of renewable energy, greenhouse gas (GHG) emissions keep rising. As the world enters uncharted climatic territory, there is a heightened risk of crossing irreversible tipping points in the planet's climate system.

In support of more effective climate action, the 2024 EPI. introduces refined metrics to track countries' progress at curbing their GHG emissions. The new metrics score countries on their emissions reduction (or growth) rates while also considering their proximity to the net-zero target. In addition, new pilot indicators score countries on their climate mitigation efforts in relation to their allocated shares of the remaining global carbon budget — the amount of carbon that society globally can still emit before crossing dangerous warming limits — and thus better reflect the principle of common but differentiated responsibilities.

While GHG emissions are falling in more countries than ever before, the 2024 EPI analysis of emission trends over the last decade shows that only five countries — Estonia, Finland, Greece, Timor-Leste, and the United Kingdom — cut their GHG emissions at the rate needed to reach zero by 2050. And it is unclear whether any of these nations can maintain the pace of reduction that they achieved in recent years.

Emissions in the world's largest economies are either falling too slowly, such as in the United States, or still rising, such as in China, India, and Russia. Moreover, apart from the United Kingdom, all the countries identified in the 2022 EPI report as being on track to reach net zero emissions by 2050 have since fallen off track.

The pace of decarbonization in Denmark, for example, has slowed in recent years, highlighting that early gains from implementing low-hanging-fruit policies, such as switching electricity generation from coal to natural gas and expanding renewable power generation, are by themselves insufficient. Cutting emissions at the pace needed will require significant and ongoing investments in renewable energy, transforming food systems, electrifying buildings and transportation, and redesigning cities.

New and Refined Biodiversity Metrics

After climate change, biodiversity loss has emerged as the most serious and irreversible environmental crisis. Scientists warn that we may have unleashed the sixth mass extinction in the planet's history. Given that biodiversity is fundamental to ecosystem vitality and the life-supporting services ecosystems provide, this crisis endangers the stability and continuity of human prosperity.

Responding to the urgency of halting biodiversity loss, the 2024 EPI introduces new metrics to assess how well countries protect their most important habitats. The 2024 EPI also introduces pilot indicators to measure the effectiveness and stringency of protected areas. These new metrics track key issues related to the expansion of protected areas to meet the Kunming-Montreal Global Biodiversity Framework's goal of safeguarding 30 percent of lands and seas by 2030. These pilot metrics reveal that, while many countries have reached their area protection goals, many protected areas have failed to halt the loss of natural ecosystems. The 2024 EPI's analyses underscore the necessity of providing protected areas with adequate funding and of developing stricter regulations in partnership with local communities.

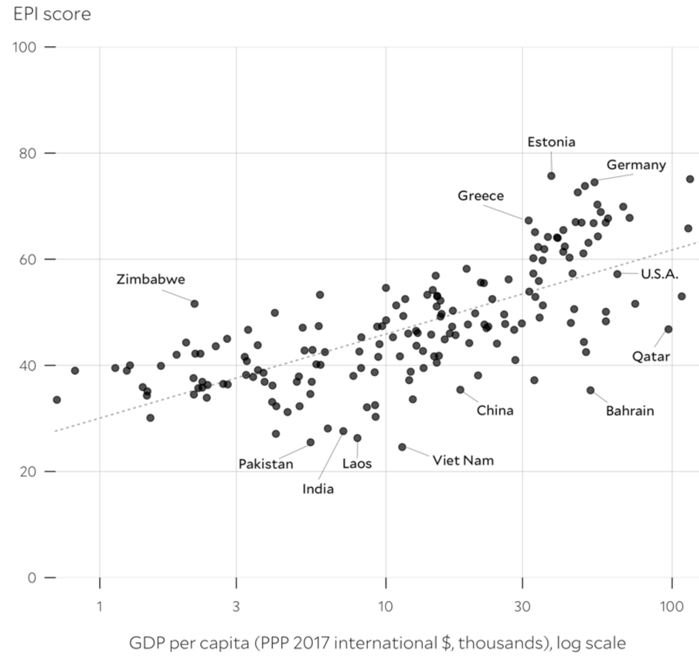

Figure ES-1. Countries' wealth is a strong predictor of their overall environmental performance, but some countries vastly outperform their economic peers, while others lag.

Tradeoffs in Environmental Performance

EPI scores are positively correlated with a country's wealth, although after a point, increasing wealth yields diminishing. returns. At every level of economic development, though, some countries outperform their peers while others lag (Figure ES-1). And indeed, some of the poorest countries in the world outperform some of the richest. In this regard, factors other than wealth, such as investments in human development, rule of law, and regulatory quality, are stronger predictors of environmental performance.

With its broad set of metrics across a wide range of environmental issues, the 2024 EPI reveals fundamental tradeoffs across different aspects of environmental performance, underscoring that no country can claim to be on a fully sustainable trajectory. Wealth allows countries to make investments in the infrastructure required to provide clean drinking water, safely manage waste, and rapidly expand renewable energy. But wealth also leads to higher material consumption and its associated environmental impacts, such as higher rates of waste generation, GHG emissions, and ecosystem degradation. Many countries with high scores in some Ecosystem Vitality metrics — such as those measuring the pollution from pesticides and fertilizers in agriculture, the integrity of forest landscapes, and the use of destructive fishing methods — do so because their economies are stagnant and underdeveloped.

These tradeoffs underscore the urgency of international cooperation and cultural changes in the type of development societies value. Developing countries must be careful not to repeat the mistakes of nations that followed a dirty and unsustainable path to industrialization. On the other hand, rich countries need to decouple their consumption from environmental degradation and use their wealth to help developing countries leapfrog to a path of truly sustainable development, preserving their biodiversity and other global commons for the benefit of all humankind.

Persistent Gaps in a Data-Rich World

An unprecedented availability of environmental data, including exciting recent developments in machine learning and remote sensing, underpin the innovations introduced in the 2024 EPI. Nonetheless, crucial data gaps persist, creating serious challenges for robust, data-driven policymaking. For years, the EPI team has called attention to the dearth of high-quality, standardized data on solid waste, toxic waste, and wastewater management around the world, especially in developing countries. These data gaps hamper the ability of policymakers to tackle the worsening plastic pollution crisis and to advance the world toward a circular economy. The world also continues to lack robust data on the protection of wetlands, grasslands, and other important ecosystems that remain difficult to characterize with remote sensing technologies.

A Comprehensive Environmental Index

In each iteration, the EPI expands the scope of its sustainability scorecard to reflect advances in our scientific understanding of environmental issues. The 2024 EPI distills data on dozens of sustainability issues into a single score. To make the metrics easy to interpret, we transform raw environmental data into indicators that score countries on a 0–100 scale, from worst to best performance.

For a more careful examination of priority topics and their trends, we encourage users to dive into the disaggregated indicators and data underpinning them. All the indicator scores, the underlying data, and further methodological details are available on our website: epi.yale.edu.

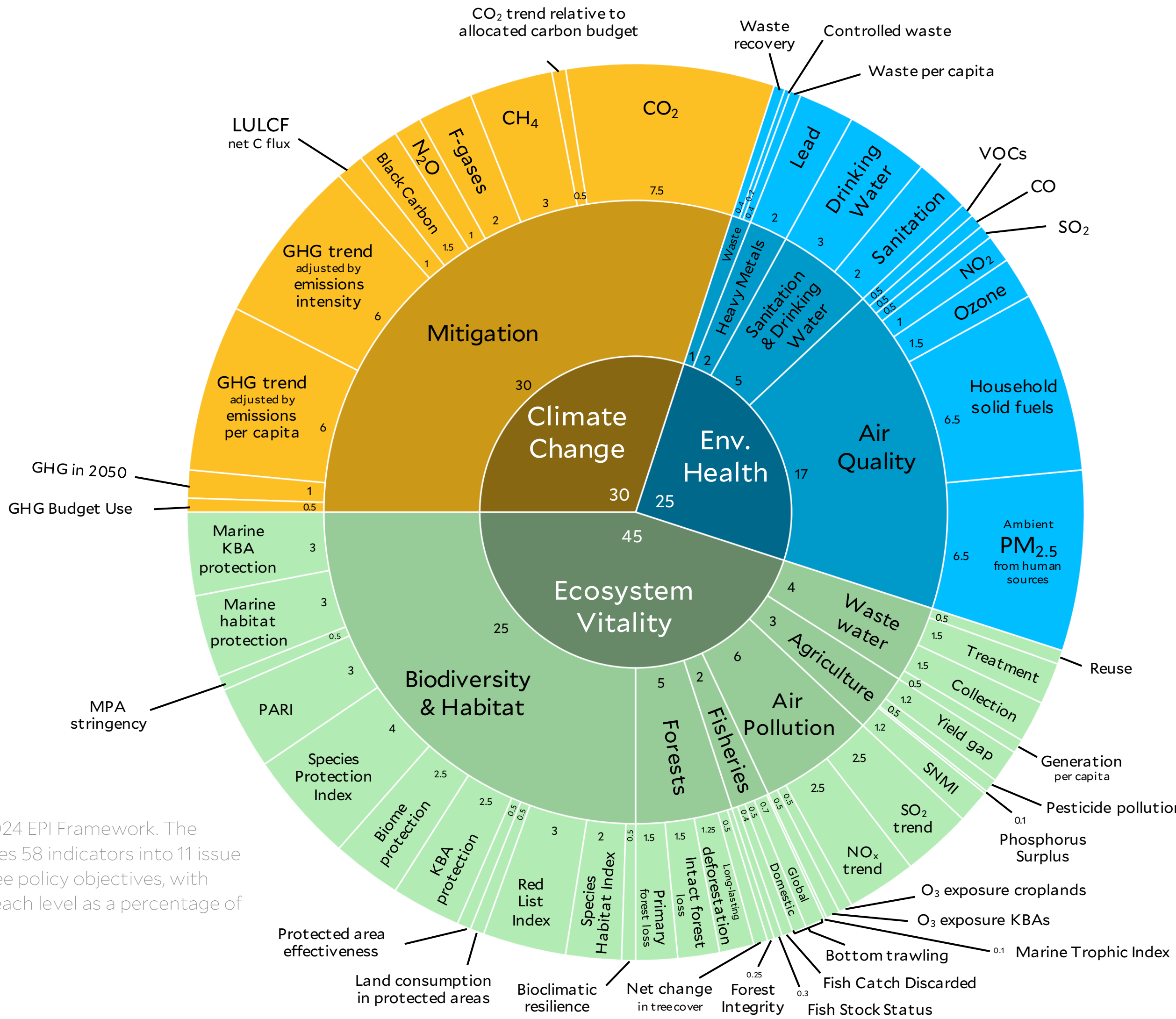

Figure ES-2. The 2024 EPI Framework. The framework organizes 58 indicators into 11 issue categories and three policy objectives, with weights shown at each level as a percentage of the total score.

Table ES-1. 2024 EPI rank, score, and regional rank (REG) for 180 countries.

RANK	COUNTRY	SCORE	REG
1	Estonia	75.7	1
2	Luxembourg	75.1	1
3	Germany	74.5	2
4	Finland	73.8	3
5	United Kingdom	72.6	4
6	Sweden	70.3	5
7	Norway	69.9	6
8	Austria	68.9	7
9	Switzerland	67.8	8
10	Denmark	67.7	9
11	Greece	67.3	2
12	France	67.0	10
13	Malta	66.9	11
13	Netherlands	66.9	11
15	Belgium	66.8	13
16	Ireland	65.8	14
17	Czech Republic	65.5	3
18	Slovakia	65.1	4
19	Iceland	64.3	15
20	Poland	64.2	5
21	Lithuania	64.1	6
22	Spain	64.0	16
23	Australia	63.1	17
24	Slovenia	62.4	7
25	Croatia	62.3	8
26	Portugal	61.9	18
27	Japan	61.4	1
28	Canada	61.1	19
29	Italy	60.3	20
30	Latvia	60.2	9
31	Hungary	59.8	10
32	Belarus	58.2	1
33	New Zealand	57.3	21
33	Romania	57.3	11
35	United States of America	57.2	22
36	Suriname	56.9	1
37	Bulgaria	56.2	12
38	Bahamas	55.9	2
39	Antigua and Barbuda	55.6	3
40	Costa Rica	55.5	4
41	Ukraine*	54.6	2
42	St. Vincent and Grenadines	54.2	5
43	Cyprus	53.9	13
44	Gabon	53.3	1
44	Venezuela	53.3	6
46	Barbados	53.1	7
47	Brazil	53.0	8
47	Singapore	53.0	2
49	Panama	52.9	9
50	Cuba	52.5	10
50	Trinidad and Tobago	52.5	10
52	Albania	52.2	14
53	United Arab Emirates	51.6	1
53	Zimbabwe	51.6	2
55	Ecuador	51.3	12
55	Oman	51.3	2
57	Saint Lucia	51.1	13
58	South Korea	50.6	3
59	North Macedonia	50.3	15
60	Taiwan	50.1	4
61	Timor-Leste	49.9	5
62	Serbia	49.8	16
63	Colombia	49.7	14
64	Chile	49.6	15
65	Dominica	49.3	16
66	Botswana	49.2	3
67	Guyana	49.0	17
68	Jamaica	48.5	18
69	Brunei Darussalam	48.3	6
70	Israel	48.0	3
71	Seychelles	47.9	4
72	Kazakhstan	47.8	3
73	Dominican Republic	47.7	19
73	Montenegro	47.7	17
75	Belize	47.4	20
75	Nicaragua	47.4	20
77	Georgia	47.3	4
77	Jordan	47.3	4
77	Mauritius	47.3	5
80	Samoa	47.1	7
81	Argentina	47.0	22
82	Qatar	46.8	5
83	Russia	46.7	5
83	Zambia	46.7	6
85	Peru	46.5	23
86	Moldova	46.1	6
87	Bosnia and Herzegovina	46.0	18
87	Fiji	46.0	8
89	Grenada	45.8	24
90	Thailand	45.7	9
91	Bolivia	45.3	25
91	Tunisia	45.3	6
93	Vanuatu	45.0	10
94	Armenia	44.9	7
95	Kuwait	44.4	7
96	Kiribati	44.3	11
97	Mexico	44.2	26
98	Uruguay	44.1	27
99	Namibia	44.0	7
100	Senegal	43.8	8
101	Egypt	43.7	8
102	Tanzania	43.6	9
103	Bhutan	43.3	1
104	Côte d'Ivoire	42.9	10
105	Kyrgyzstan	42.8	8
106	South Africa	42.7	11
107	Uzbekistan	42.6	9
108	Marshall Islands	42.5	12
108	Saudi Arabia	42.5	9
110	Burkina Faso	42.2	12
110	Solomon Islands	42.2	13
112	Guinea-Bissau	42.0	13
113	Iran	41.8	10
114	Algeria	41.7	11
114	Equatorial Guinea	41.7	14
116	El Salvador	41.6	28
116	Republic of Congo	41.6	15
118	Malaysia	41.0	14
119	Micronesia	40.8	15
120	Turkmenistan	40.6	10
121	Azerbaijan	40.5	11
122	Tonga	40.4	16
123	Honduras	40.2	29
124	Angola	40.1	16
125	Niger	40.0	17
126	Lebanon	39.9	12
126	Sierra Leone	39.9	18
128	Dem. Rep. Congo	39.5	19
128	Morocco	39.5	13
128	Paraguay	39.5	30
131	Sudan	39.1	14
132	Central African Republic	39.0	20
132	Mozambique	39.0	20
134	Sri Lanka	38.8	2
135	Eswatini	38.7	22
136	Cameroon	38.6	23
137	Comoros	38.2	24
138	Maldives	38.1	3
139	Cabo Verde	38.0	25
140	Nigeria	37.9	26
141	Benin	37.8	27
142	Gambia	37.6	28
143	Mongolia	37.2	17
143	Türkiye	37.2	19
145	Ghana	36.9	29
145	Kenya	36.9	29
145	Lesotho	36.9	29
145	Papua New Guinea	36.9	18
149	Guinea	36.5	32
150	Haiti	36.4	31
151	Ethiopia	36.3	33
152	São Tomé and Príncipe	36.2	34
153	Chad	35.9	35
154	Uganda	35.8	36
155	Togo	35.7	37
156	China	35.4	19
157	Bahrain	35.3	15
158	Malawi	35.1	38
159	Mauritania	34.6	39
160	Mali	34.5	40
161	Liberia	34.3	41
162	Rwanda	33.9	42
163	Indonesia	33.6	20
164	Burundi	33.5	43
165	Nepal	33.1	4
166	Guatemala	32.5	32
167	Djibouti	32.3	44
167	Tajikistan	32.3	12
169	Philippines	32.1	21
170	Cambodia	31.2	22
171	Afghanistan	31.0	5
172	Iraq	30.3	16
173	Madagascar	30.1	45
174	Eritrea	29.0	46
175	Bangladesh	28.1	6
176	India	27.6	7
177	Myanmar	27.1	23
178	Laos	26.3	24
179	Pakistan	25.5	8
180	Viet Nam	24.6	25

* The Russian invasion led to a sharp decline in economic activity, energy use, and associated GHG emissions in the Ukraine in 2022, so this score might not accurately reflect environmental performance.

Asia-Pacific | Eastern Europe | Former Soviet States | Global West

Greater Middle East | Latin America & Caribbean | Southern Asia | Sub-Saharan Africa

Chapter 1. Introduction

1. Power and Limits of Data-driven Ranking

Climate change, biodiversity loss, and other environmental issues pose some of the biggest societal challenges of the 21st century. To tackle these challenges and steer society toward a sustainable future, environmental policies must be grounded on high-quality data and the latest scientific insights. But the rapid pace of scientific and technological advancements creates persistent gaps between research findings and environmental policies. Tools to synthesize and interpret the growing body of scientific literature and environmental data help decisionmakers better understand trends in critical sustainability challenges and support informed policy decisions. Carefully constructed environmental indicators help measure performance, identify leaders and laggards, and promote best practices.

The Environmental Performance Index (EPI) provides a tool to track countries' progress towards meeting UN Sustainable Development Goals and other international policy targets. The EPI's analyses encourage countries to adopt effective policies to maximize the return on their environmental investments. With a comprehensive set of metrics, the EPI assesses country-level performance trends in climate change mitigation, ecosystem vitality, and environmental public health. The 2024 EPI scores 180 countries on 58 indicators across 11 environmental categories. This makes the 2024 EPI the most comprehensive assessment environmental performance to date, based on its geographical scope and number of environmental issues covered. As such, the 2024 EPI supports policymakers, researchers, businesses, the media, and engaged citizens in tracking sustainability trends and making informed environmental decisions.

Despite the usefulness of synthesizing complex environmental data into single performance scores, this approach masks importance nuances. Many assumptions and subjective methodological choices underly the EPI results, so readers should treat the scores and rankings only as the starting point for deeper analyses and examination of disaggregated data. Exploring the results for different issue categories and indicators is essential to understand the overall results, understand tradeoffs, and identify environmental priorities for each country. Rankings promote healthy competition and help celebrate leaders and call out laggards. But being the top-performer in a world amid existential environmental crises should give no reason for countries to rest on their laurels.

2. A Clarion Call for Climate Action

Scientists have been warning the world about the dangers of climate change for decades. Almost ten years ago, in December 2015, 196 countries adopted the Paris Agreement, committing to mitigate climate change to keep global average temperature "well below" 2 ºC above pre-industrial levels, and ideally below 1.5 ºC. Above these warming levels, the impacts of climate change are expected to accelerate and be harder to reverse (Hoegh-Guldberg et al. 2019). This does not mean, however, that all hope is lost after exceeding those levels of warming, as climate impacts can always get worse.

Last year, the first global assessment of progress toward the goals of the Paris Agreement revealed a grim picture: the world is far off track. Despite record deployment of renewable energy, greenhouse gas (GHG) emissions keep rising. While a recent analysis suggests that global GHG emissions might have peaked last year (Fyson et al. 2023), it is imperative that they now start falling fast. At the current rate of emissions, the world with exhaust its remaining carbon budget — the total amount of GHGs that society globally can still emit to have a 50 percent chance of limiting warming to 1.5ºC — before the end of the decade.

Supporting the urgent need for more effective climate action, the 2024 EPI introduces refined metrics to track countries' progress at curbing their GHG emissions. The new metrics score countries on their emissions reduction (or growth) rates while also considering how close they are to targets of net-zero emissions. We also introduce pilot indicators to assess countries' climate mitigation efforts in relation to their allocated shares of the remaining global carbon budget, which better reflects the principle of common but differentiated responsibilities.

3. An Emerging Crisis: Biodiversity Loss

Worsening climate change poses a growing threat to countless species already struggling with widespread habitat loss, exploitation, and pollution. Humans have unleashed the sixth mass extinction event in the planet's history, with species disappearing hundreds of times faster than normal (Ceballos et al. 2015). Since biodiversity is essential for the functioning of ecosystems that support human wellbeing (Díaz et al. 2006), its rapid loss has emerged as the most serious and irreversible environmental crises of our time, just after climate change.

In 2022, 196 countries agreed to redouble their commitments to protect biodiversity with the Kunming-Montreal Global Biodiversity Framework (GBF). The 2024 EPI refined and expanded its component indicators to better support several targets of the Kunming-Montreal Framework, as described in the rest of this section.

We updated the benchmark defining "best" performance of our *Terrestrial Biome Protection* to reflect the world's increased ambition to protect 30 percent of all lands and seas by 2030 (known as the 30x30 target). New indicators measure how well protected areas cover places of high ecological value and important habitats, helping countries maximize the impact of their conservation efforts.

While the world's protected areas already cover approximately 17 percent of land and 8 percent of the ocean, many protected areas have failed to halt the loss of biodiversity. The Kunming-Montreal Framework emphasizes that 30 percent of lands and seas must be *effectively* conserved and managed, and that any sustainable use of those area should be *fully consistent* with biodiversity conservation. For the first time, the EPI includes pilot indicators to assess the effectiveness and stringency of protected areas. The EPI's analyses reveal that in 23 countries, over 10 percent of all the protected land is covered by croplands and buildings and in 35 countries, there is more fishing activity inside marine protected areas than outside.

The EPI's analyses corroborate findings by other researchers, demonstrating that simply establishing protected areas is insufficient to guarantee the long-term persistence of biodiversity. For this reason, it is essential to assess the integrity of countries' ecosystems and the health of wildlife populations both inside and outside protected areas. To this end, the 2024 EPI incorporates the *Red List Index*, a metric of the overall extinction risk of a country's species. Together with the *Species Habitat Index*, which measures the extent of integrity of species' habitats remaining in a country, this indicator helps track progress toward Target 4: halting extinctions and reducing extinction risk.

Assessments of the extent of remaining habitats and coverage of protected areas assume that the spatial distribution of biodiversity is fixed. This assumption is no longer valid, however, as climate change is driving a redistribution of life on Earth (Pecl et al. 2017). The 2024 EPI introduces the *Bioclimatic Ecosystem Resilience Index* to assess countries' capacity to retain biodiversity under climate change as a function of the extent, integrity, and connectivity of their remaining habitats. This indicator informs GBF Target 8: "minimizing the impacts of climate change on biodiversity and building resilience."

For the first time, the EPI incorporates indicators that distinguish between different types of tree cover loss, helping countries prioritize the protection of forests with the highest ecological value, such as tropical humid primary forests and intact forest landscapes. These new indicators help track progress toward one key component of GBF Target 1: "bringing the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, close to zero by 2030."

In the Agriculture issue category, indicators measuring the efficiency of nitrogen and phosphorus fertilizer use, as well as the risk of pesticide pollution, help track progress toward GBF Target 7: "reduce pollution to levels that are not harmful to biodiversity" (Möhring et al. 2023). In the Solid Waste issue category, a new indicator measuring rates of *Waste Generation Per Capita,* also informs this Target. In general, the indicators in the Agriculture and Fisheries issue categories help countries assess their progress toward Target 10, which calls for increasing the sustainability of fisheries and agriculture.

Finally, the EPI project, and its Ecosystem Vitality indicators in particular, contribute to GBF Target 21: "ensure that the best available data, information, and knowledge are accessible to decision makers, practitioners and the public."

4. Overview of the 2024 EPI

The 2024 Environmental Performance Index distills diverse environmental data sets into 58 indicators across 11 issue categories and three main policy objectives. The EPI team sources data from research institutions, international organizations, and academic researchers. Then, we transform data into easy-to-interpret indicators with scores ranging from 0 to 100. Finally, we weight and aggregate indicators into issue categories, policy objectives, and overall EPI scores.

Chapter 2 provides an overview of the results, highlighting key findings and trends in global, regional, and country-level performance. Chapters 3-13 discuss each issue category in detail, describing trends, highlighting leaders and laggards, and document the underlying data sources, methodological assumptions, and limitations of each indicator. Chapter 14 presents an overview of the EPI's methodology, including our criteria to select data, construct indicators, and aggregate scores.

Results for each component indicator, country profiles, and further resources are available on the project's website at *epi.yale.edu*.

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Chapter 2. Results

As a comprehensive composite indicator, the Environmental Performance Index provides insights on national and regional trends on a broad range of critical environmental issues. Overall EPI scores provide a helpful summary of performance, but the disaggregated results at the level of the three policy objectives, 11 issue categories, and 58 performance indicators provide increasingly detailed and nuanced insights. While the 2024 EPI scores and rankings are based on the most recent available data for each indicator, we also apply the current methodology to data from previous years to provide information on performance trends. Analyzing trends is essential to understand on which areas countries are making progress, and on which they are backtracking.

Ranks help compare scores across countries and provide additional insights, highlighting countries that out- or underperform their peers. The EPI reports results for using different peer groupings based on geographic, economic, and social characteristics.

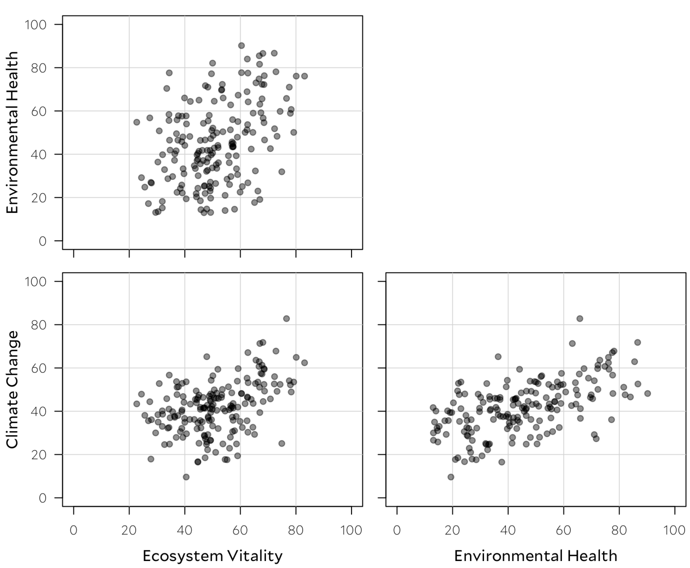
This section gives an overview of the 2024 EPI results, with subsequent chapters diving into the details of specific issue categories. All the EPI results and underlying data are freely available to explore and download at the project website, epi.yale.edu.

1. Insights from the 2024 EPI

Policy Objectives

The EPI's 11 issue categories are grouped into three main policy objectives: Climate Change, Ecosystem Vitality, and Environmental Health. Ecosystem Vitality, which measures how well countries manage their natural resources and conserve their biodiversity and natural ecosystems, has the narrowest range of scores, from Luxembourg at 83.1 to Cabo Verde at 22.7. Ecosystem Vitality scores also show the weakest correlation with scores of the other two policy objectives (Figure 2-1). Ecosystem Vitality covers a broader range of environmental issues than the other two policy objectives and includes indicators that are weakly, and sometimes negatively, correlated with countries' wealth. Strong performance on some issues is offset by poor performance in others, resulting in a compressed range of scores.

Figure 2-1. Sub-scores on the 2024 EPI's three policy objectives are positively correlated with each other.



Environmental Health, which measures how well countries protect public health from exposure to air pollution and other environmental risk factors, has the broadest range of scores, from Iceland at 90.2 to Lesotho at 13.0. Wealthier countries with strong environmental regulations are generally able to invest in the infrastructure required to control pollution and minimize the health impacts of exposure to environmental risk factors. Lacking these resources, low-income nations, concentrated in Sub-Saharan Africa, tend to get the lowest scores on Environmental Health.

This contrast highlights the importance of accounting for socio-economic and geographic differences when comparing EPI scores. The EPI team groups countries into eight regions based on geographic, socioeconomic, and historical characteristics: (1) Asia-Pacific; (2) Eastern Europe; (3) Former Soviet States; (4) Global West (which includes Western European countries, Canada, the United States, Australia, and New Zealand); (5) Greater Middle East; (6) Latin America & the Caribbean; (7) Southern Asia; and (8) Sub-Saharan Africa.

Figure 2-2 shows the relationship between Environmental Health scores and overall EPI scores, with panels highlighting for each of the eight regions. Global West countries cluster on the top-right corner of the plot, with all scoring above 60 on both dimensions (except the United States and New Zealand, which score 57.2 and 57.3 on the overall EPI, respectively). In contrast, most countries in Sub-Saharan Africa and Southern Asia cluster at the other end of the spectrum.

Figure 2-2. The relationship between Environmental Health and overall EPI scores, by region.

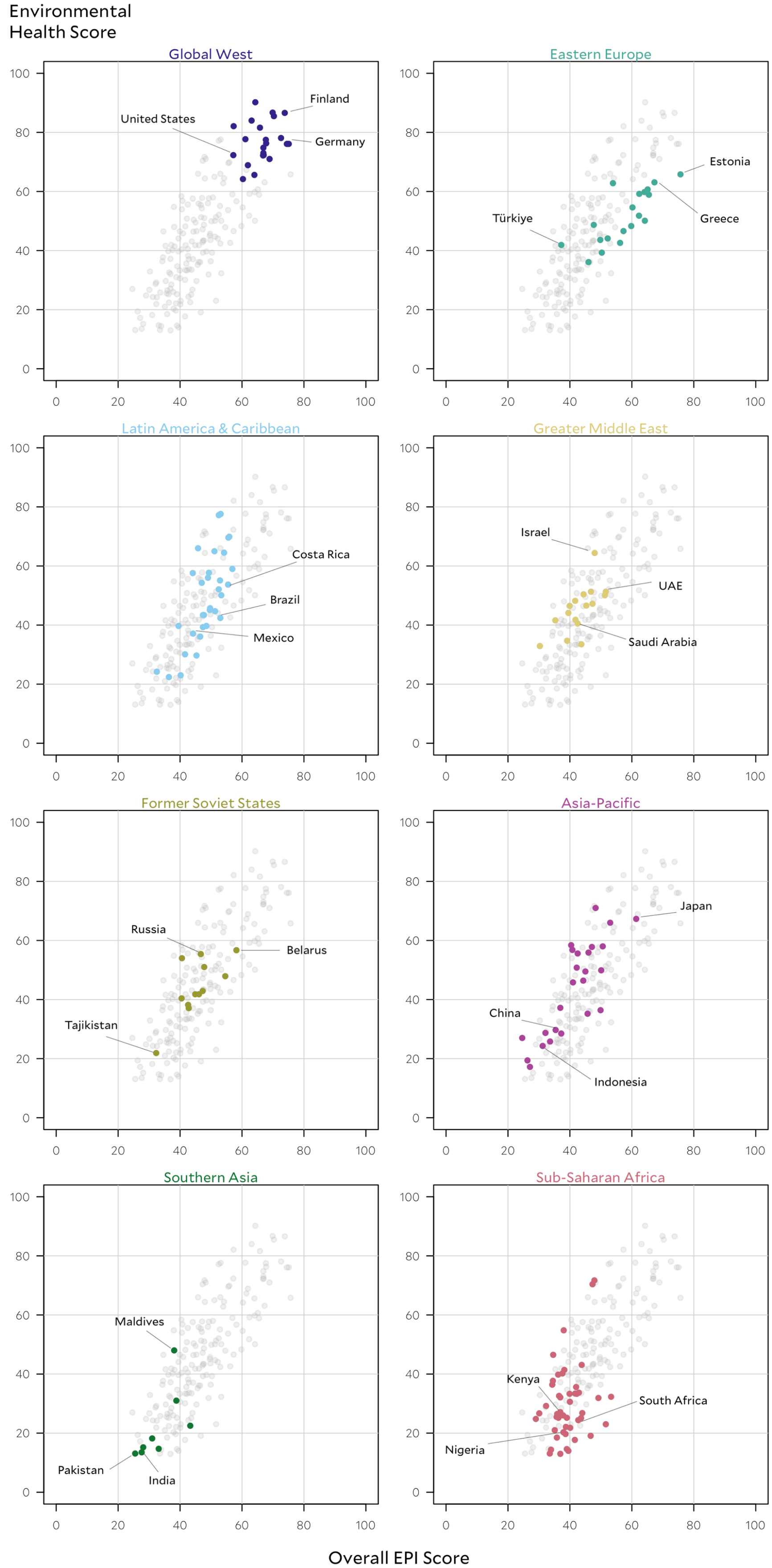


Figure 2-3. The relationship between Ecosystem Vitality and overall EPI scores, by region.

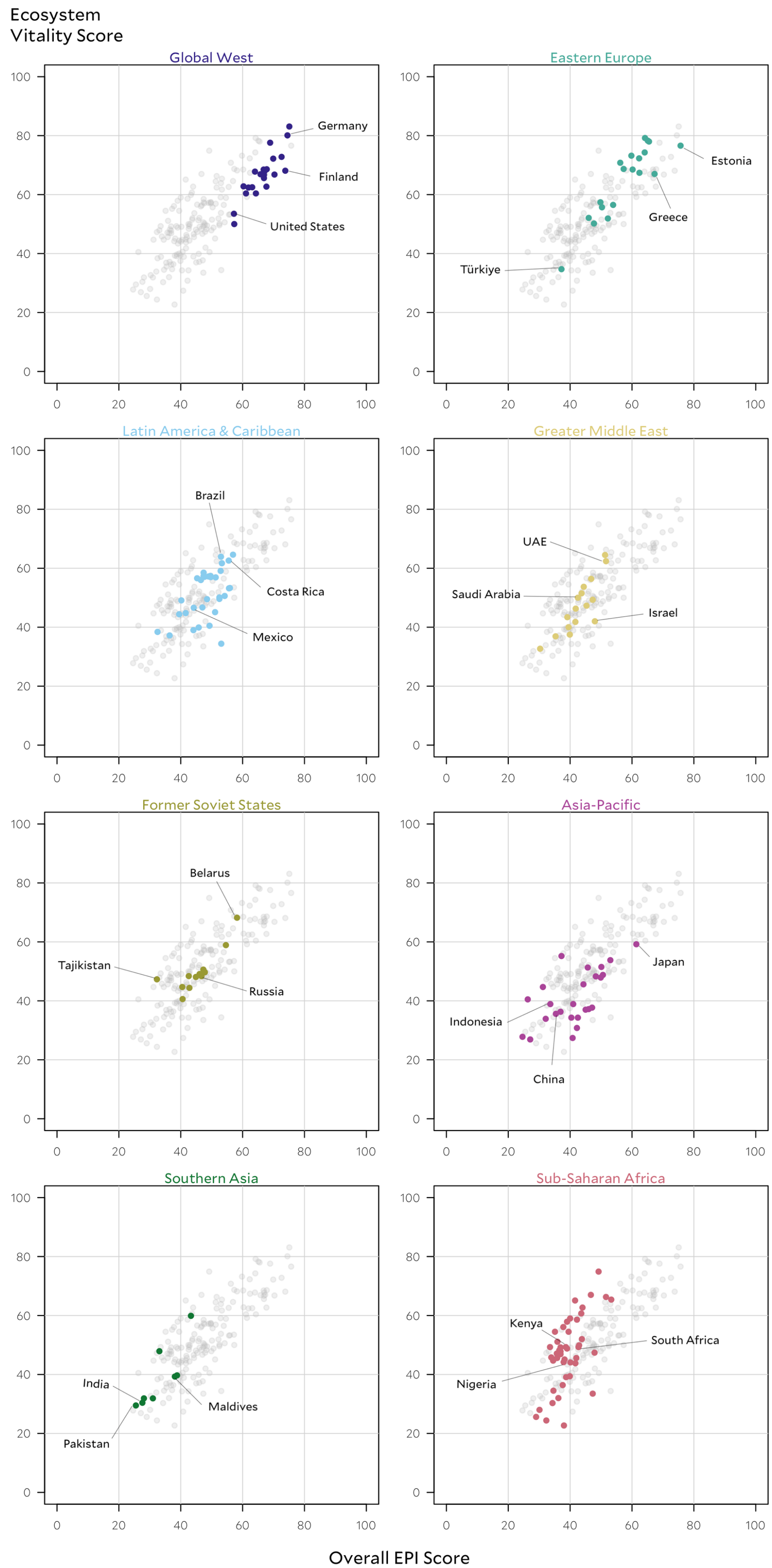
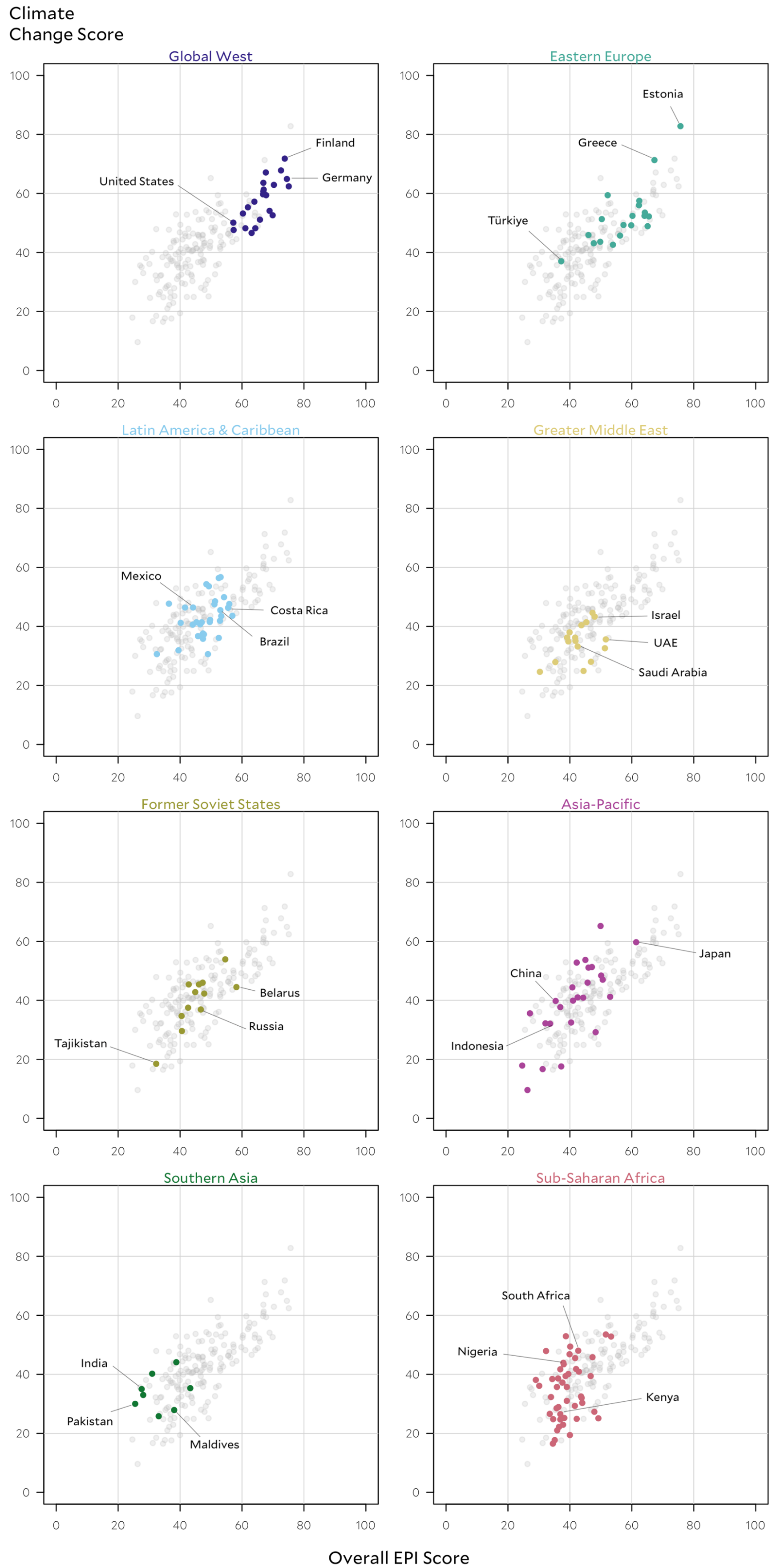


Figure 2-4. The relationship between Climate Change and overall EPI scores, by region.



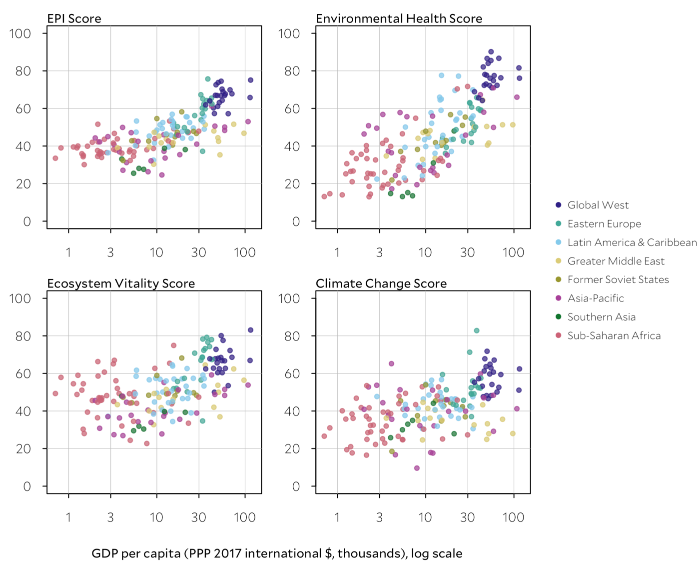
This clustering is not as pronounced for Ecosystem Vitality (Figure 2-3) and Climate Change (Figure 2-4). Eastern European countries tend to perform more strongly in Ecosystem Vitality than in the other two policy objectives. On Climate Change, however, Estonia and Greece vastly outperform other countries in Eastern Europe, earning the first and third highest scores, respectively. On Ecosystem Vitality, Sub-Saharan countries are represented across almost the entire range of scores, with both the bottom overall performers (Eritrea, Djibouti, and Cabo Verde) and several countries with scores above 60 (Namibia, Republic of Congo, Gabon, Zambia, Zimbabwe, and Botswana).

Correlates of Environmental Performance

Countries' wealth is a strong predictor of overall EPI scores and especially of Environmental Health scores (Figure 2-5). Wealth (as measured by GDP per capita) is positively correlated with countries' scores on Ecosystem Vitality and Climate Change, but the relationship is weaker (Spearman correlation, r_S = 0.71 for Environmental Health, compared to 0.52 and 0.41 for Ecosystem Vitality and Climate Change, respectively). At each level of wealth, however, there are countries that outperform their economic peers. Among the countries with a GDP per capita above 30 thousand PPP 2017 international dollars, for example, overall EPI scores range between Estonia's 75.7 and Bahrain's 35.3. Gabon, with a GDP per capita below $14 thousand, outperforms Qatar, which has a GDP per capita almost seven times higher than Gabon.

These examples show that strong environmental performance requires more than wealth. Indeed, the Human Development Index (HDI) — a composite indicator that combines metrics of wealth, health, and education (UNDP 2024) — is more strongly correlated with Environmental Health (r_S = 0.80) and with Climate Change (r_S = 0.54) scores than GDP per capita, although not with Ecosystem Vitality (r_S = 0.51).

Figure 2-5. GDP per capita is positively correlated with scores on the overall EPI and on each of its three policy objectives.



The HDI uses average life expectancy data as a proxy for health, so its stronger correlation with Environmental Health scores is not surprising. It is likely that there is a causal link, with better Environmental Health scores leading to longer life expectancy.

Another potential determinant of countries' environmental performance is the quality of their governance. The World Bank's Worldwide Governance Indicators assess patterns in *perceptions* of governance across countries (Kaufmann and Kraay 2023). For example, the *Rule of Law* indicator measures perceptions of "the extent to which agents have confidence in and abide by the rules of society". *Governess Effectiveness* captures perceptions about the quality of public services, the quality of policy formulations, and the credibility of governments' commitment to those policies. In turn, *Control of Corruption* measures "the extent to which public power is exercised for private gain" (World Bank 2024).

Each of these three governance indicators explains variation in EPI scores *after* accounting for countries' differences in HDI, with *Control of Corruption* explaining the most. Linear models including HDI and *Control of Corruption* as independent variables explained 62.1 percent of the variation in overall EPI scores and 71.0 percent of variation in Environmental Health scores. The same variables predicted only 32.1 and 23.7 percent of the variation in Climate Change and Ecosystem Vitality scores, respectively.

Part of the reason why human development and governance are relatively weak predictors of Climate Change and Ecosystem Vitality scores is that countries across the development and governance spectrum perform poorly on these policy objectives, albeit for different reasons. For example, industrialized countries, many of which score high on the HDI and on governance indicators, tend to emit more greenhouse gases (GHGs), but in developing countries GHG emissions tend to grow at a faster rate.

2. Global Rankings

Reflecting the importance of wealth and good governance for environmental performance, Scandinavian countries consistently rise to the top ranks of the Environmental Performance Index. More broadly, European countries tend to perform well. In the 2024 EPI overall ranking, European countries occupy the top 20 positions (Table 2-1). These countries have broad and ambitious environmental policies, which they support with strong regulations and financial investments. But even the top performers have important gaps. No country scores above 80 in the overall 2024 EPI, highlighting that the world remains far from a truly sustainable path. Many European countries at the top of the overall ranking perform notoriously poorly on the 2024 EPI's indicators of protected area stringency and greenhouse emission reductions relative to allocated shares of the remaining carbon budget. While these pilot indicators receive a low weight in the EPI framework, they highlight that all countries have considerable room for improvement.

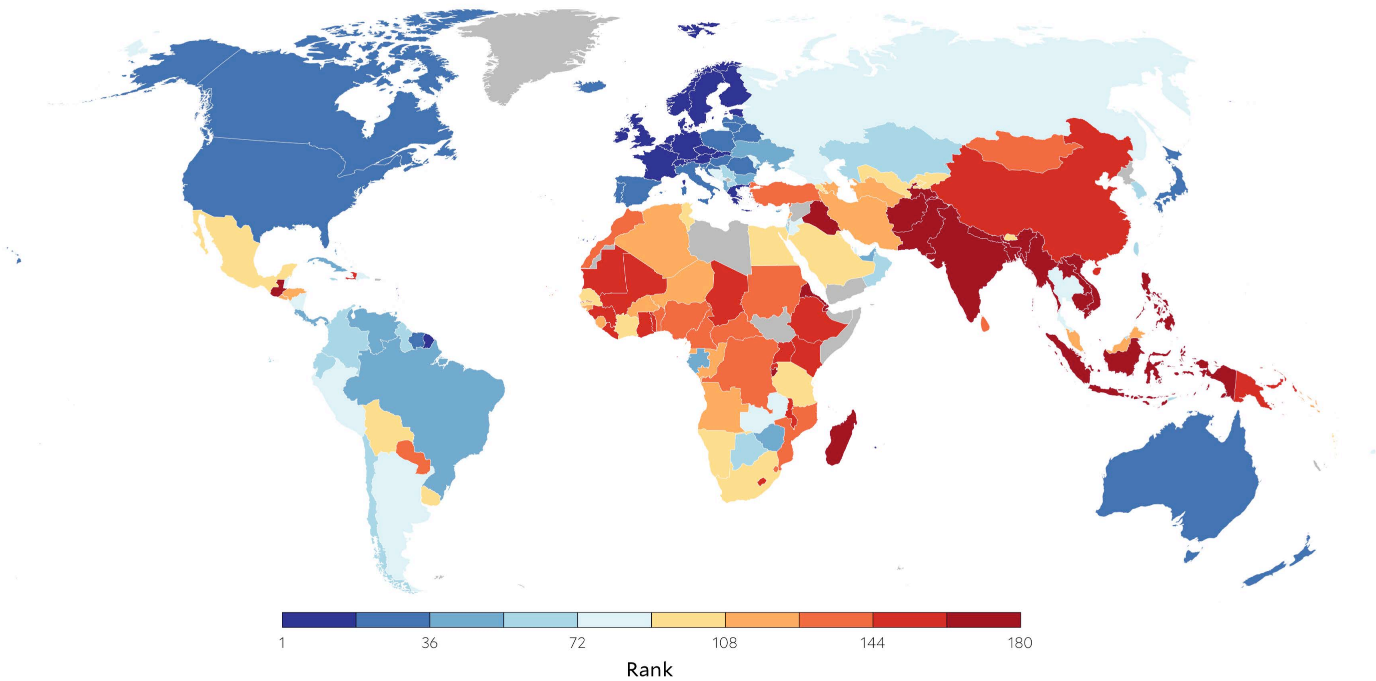
Table 2-1. 2024 EPI global rankings, scores, and regional rankings (REG) for 180 countries.

RANK	COUNTRY	SCORE	REG
1	Estonia	75.7	1
2	Luxembourg	75.1	1
3	Germany	74.5	2
4	Finland	73.8	3
5	United Kingdom	72.6	4
6	Sweden	70.3	5
7	Norway	69.9	6
8	Austria	68.9	7
9	Switzerland	67.8	8
10	Denmark	67.7	9
11	Greece	67.3	2
12	France	67.0	10
13	Malta	66.9	11
13	Netherlands	66.9	11
15	Belgium	66.8	13
16	Ireland	65.8	14
17	Czech Republic	65.5	3
18	Slovakia	65.1	4
19	Iceland	64.3	15
20	Poland	64.2	5
21	Lithuania	64.1	6
22	Spain	64.0	16
23	Australia	63.1	17
24	Slovenia	62.4	7
25	Croatia	62.3	8
26	Portugal	61.9	18
27	Japan	61.4	1
28	Canada	61.1	19
29	Italy	60.3	20
30	Latvia	60.2	9
31	Hungary	59.8	10
32	Belarus	58.2	1
33	New Zealand	57.3	21
33	Romania	57.3	11
35	United States of America	57.2	22
36	Suriname	56.9	1
37	Bulgaria	56.2	12
38	Bahamas	55.9	2
39	Antigua and Barbuda	55.6	3
40	Costa Rica	55.5	4
41	Ukraine*	54.6	2
42	St. Vincent and Grenadines	54.2	5
43	Cyprus	53.9	13
44	Gabon	53.3	1
44	Venezuela	53.3	6
46	Barbados	53.1	7
47	Brazil	53.0	8
47	Singapore	53.0	2
49	Panama	52.9	9
50	Cuba	52.5	10
50	Trinidad and Tobago	52.5	10
52	Albania	52.2	14
53	United Arab Emirates	51.6	1
53	Zimbabwe	51.6	2
55	Ecuador	51.3	12
55	Oman	51.3	2
57	Saint Lucia	51.1	13
58	South Korea	50.6	3
59	North Macedonia	50.3	15
60	Taiwan	50.1	4
61	Timor-Leste	49.9	5
62	Serbia	49.8	16
63	Colombia	49.7	14
64	Chile	49.6	15
65	Dominica	49.3	16
66	Botswana	49.2	3
67	Guyana	49.0	17
68	Jamaica	48.5	18
69	Brunei Darussalam	48.3	6
70	Israel	48.0	3
71	Seychelles	47.9	4
72	Kazakhstan	47.8	3
73	Dominican Republic	47.7	19
73	Montenegro	47.7	17
75	Belize	47.4	20
75	Nicaragua	47.4	20
77	Georgia	47.3	4
77	Jordan	47.3	4
77	Mauritius	47.3	5
80	Samoa	47.1	7
81	Argentina	47.0	22
82	Qatar	46.8	5
83	Russia	46.7	5
83	Zambia	46.7	6
85	Peru	46.5	23
86	Moldova	46.1	6
87	Bosnia and Herzegovina	46.0	18
87	Fiji	46.0	8
89	Grenada	45.8	24
90	Thailand	45.7	9
91	Bolivia	45.3	25
91	Tunisia	45.3	6
93	Vanuatu	45.0	10
94	Armenia	44.9	7
95	Kuwait	44.4	7
96	Kiribati	44.3	11
97	Mexico	44.2	26
98	Uruguay	44.1	27
99	Namibia	44.0	7
100	Senegal	43.8	8
101	Egypt	43.7	8
102	Tanzania	43.6	9
103	Bhutan	43.3	1
104	Côte d'Ivoire	42.9	10
105	Kyrgyzstan	42.8	8
106	South Africa	42.7	11
107	Uzbekistan	42.6	9
108	Marshall Islands	42.5	12
108	Saudi Arabia	42.5	9
110	Burkina Faso	42.2	12
110	Solomon Islands	42.2	13
112	Guinea-Bissau	42.0	13
113	Iran	41.8	10
114	Algeria	41.7	11
114	Equatorial Guinea	41.7	14
116	El Salvador	41.6	28
116	Republic of Congo	41.6	15
118	Malaysia	41.0	14
119	Micronesia	40.8	15
120	Turkmenistan	40.6	10
121	Azerbaijan	40.5	11
122	Tonga	40.4	16
123	Honduras	40.2	29
124	Angola	40.1	16
125	Niger	40.0	17
126	Lebanon	39.9	12
126	Sierra Leone	39.9	18
128	Dem. Rep. Congo	39.5	19
128	Morocco	39.5	13
128	Paraguay	39.5	30
131	Sudan	39.1	14
132	Central African Republic	39.0	20
132	Mozambique	39.0	20
134	Sri Lanka	38.8	2
135	Eswatini	38.7	22
136	Cameroon	38.6	23
137	Comoros	38.2	24
138	Maldives	38.1	3
139	Cabo Verde	38.0	25
140	Nigeria	37.9	26
141	Benin	37.8	27
142	Gambia	37.6	28
143	Mongolia	37.2	17
143	Türkiye	37.2	19
145	Ghana	36.9	29
145	Kenya	36.9	29
145	Lesotho	36.9	29
145	Papua New Guinea	36.9	18
149	Guinea	36.5	32
150	Haiti	36.4	31
151	Ethiopia	36.3	33
152	São Tomé and Príncipe	36.2	34
153	Chad	35.9	35
154	Uganda	35.8	36
155	Togo	35.7	37
156	China	35.4	19
157	Bahrain	35.3	15
158	Malawi	35.1	38
159	Mauritania	34.6	39
160	Mali	34.5	40
161	Liberia	34.3	41
162	Rwanda	33.9	42
163	Indonesia	33.6	20
164	Burundi	33.5	43
165	Nepal	33.1	4
166	Guatemala	32.5	32
167	Djibouti	32.3	44
167	Tajikistan	32.3	12
169	Philippines	32.1	21
170	Cambodia	31.2	22
171	Afghanistan	31.0	5
172	Iraq	30.3	16
173	Madagascar	30.1	45
174	Eritrea	29.0	46
175	Bangladesh	28.1	6
176	India	27.6	7
177	Myanmar	27.1	23
178	Laos	26.3	24
179	Pakistan	25.5	8
180	Viet Nam	24.6	25

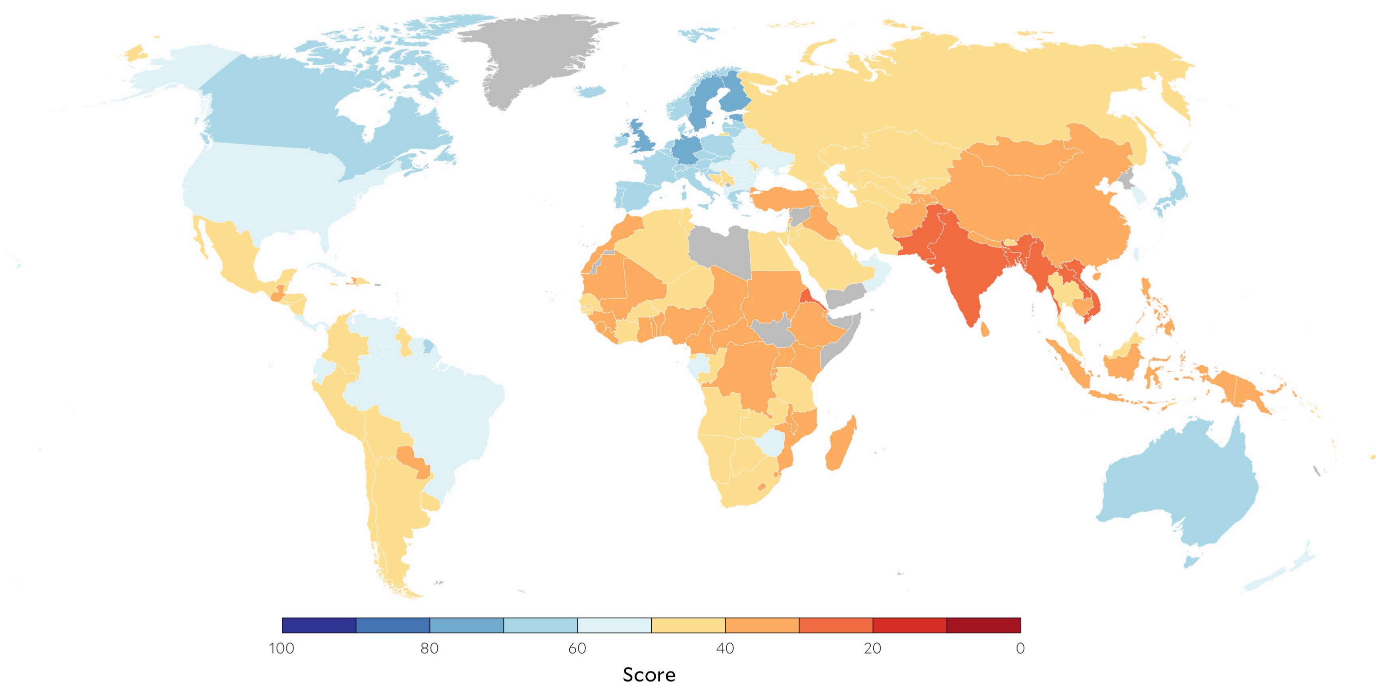
* The Russian invasion led to a sharp decline in economic activity, energy use, and associated GHG emissions in the Ukraine in 2022, so this score might not accurately reflect environmental performance.

- Asia-Pacific
- Eastern Europe
- Former Soviet States
- Global West
- Greater Middle East
- Latin America & Caribbean
- Southern Asia
- Sub-Saharan Africa

Map 2-1. Rankings in the 2024 Environmental Performance Index for 180 countries.



Map 2-2. 2024 Environmental Performance Index scores for 180 countries.



Estonia rises to the top position of the 2024 EPI overall ranking, a first for an Eastern European country. Estonia achieved a remarkable 40 percent reduction in greenhouse gas (GHG) emissions over the last decade, which also earned the country the top score on the Climate Change policy objective. If Estonia maintained its recent fast pace of decarbonization, it would not only be on track to reach zero emissions by 2050, but it would do so without exceeding its allocated share of the remaining carbon budget. No other country outside the Global South is on track to achieve that. The main driver of Estonia's GHG emission reduction has been a shift away from oil shale power generation and an expansion of wind, solar, and biomass energy (IEA 2023). Estonia is leveraging its high level of digitalization and 100 percent coverage of smart electric meters to accelerate its energy transition by facilitating access to information about buildings energy performance (IEA 2023).

Estonia is also a leader in biodiversity conservation, ranking 7th worldwide in the Ecosystem Vitality policy objective and the Biodiversity & Habitat issue category. Not only does Estonia have a large coverage of protected areas, but also these are strategically located to represent a large fraction of the country's ecosystems and biodiversity. Estonia's Lahemaa National Park is one of the largest protected areas in Europe and the first in the former Soviet Union, demonstrating the country's long commitment to nature conservation. Overall, Estonia performs well across a broad range of environmental issues, ranking among the top third of countries in all but one of the EPI's issue categories. The notable exception is the Forests issue category. In its efforts to move away from dirty oil shale power generation, Estonia has increasingly relied on forest biomass as an energy source. This has contributed to increased logging of forests, leading to poor scores in indicators of tree cover loss. Estonia's rising deforestation rate is also reflected in the indicator measuring net carbon fluxes from land cover change, which shows that the country's land recently switched from a net sink of carbon to a source. This highlights the tensions among different dimensions of sustainability which make simultaneously tackling the climate and biodiversity crises a daunting task.

Luxembourg and Germany are less than two points below Estonia in the overall 2024 EPI ranking. Luxembourg ranks 1st in the Ecosystem Vitality ranking — with over 55 percent of its land covered by protected areas — and is also a world leader in wastewater management. Germany (ranked 3rd) outperforms other large economies thanks to its fast deployment of renewable energy (slashing its GHG emissions by almost a fifth in the last 10 years), its vast network of protected areas (which exceed 30 percent coverage of Germany's land and seas), and its leadership in solid waste management. The United Kingdom (ranked 5th) also has a large network of terrestrial and marine protected areas. In fact, when including its overseas territories, the United Kingdom is the only country included in the EPI that has already established marine protected areas with full or high levels of protection covering more than 30 percent of the ocean under its jurisdiction (Marine Conservation Institute 2024). The United Kingdom has also cut its GHG emissions by almost 30 percent over the last decade, although the recent backtracking of its climate goals make it unclear if the country will be able to maintain its recent pace of decarbonization (Climate Action Tracker 2023).

At rank 35 globally, the United States lags all its peers in the Global West. As the world's largest economy and largest historical contributor to climate change, the 6.4 percent GHG emission reduction the country achieved over the last decade is woefully insufficient. The 2024 EPI's climate change indicators are based on GHG emissions data up to 2022, and thus they still do not reflect the impacts of the landmark Inflation Reduction Act and other climate policies of the Biden administration.

While the highest overall EPI scores are concentrated in Europe, the lowest scores go to Southern and Southeast Asian countries, with Viet Nam (24.6), Pakistan (25.5), Laos (26.3), Myanmar (27.1), and India (27.6) at the bottom of the ranking. These countries have increasingly relied on coal — the dirtiest fossil fuel — to power their rapidly growing economies, resulting in skyrocketing GHG emissions and some of the highest air pollution levels in the world, which harm public health and degrade ecosystems. Viet Nam has implemented policies to accelerate the deployment of solar and wind energy, but its electric distribution grid has struggled to adapt to these intermittent energy sources (Le 2022). Severe droughts and heat waves in recent years have also impacted hydropower generation in the region, forcing Laos and Viet Nam to rely more heavily on coal (Guarascio and Vu 2024). This has created serious environmental challenges for Laos, a country that aims to increase its electricity exports and become the "battery of Southeast Asia" (Chin and Wan 2022). The poor performance of Southern and Southeast Asian countries underscores the challenges of achieving fast economic growth while minimizing environmental degradation. With international help, these countries must redouble their sustainability efforts to protect the health of their populations, the vitality of their ecosystems, and the stability of the planet's climate.

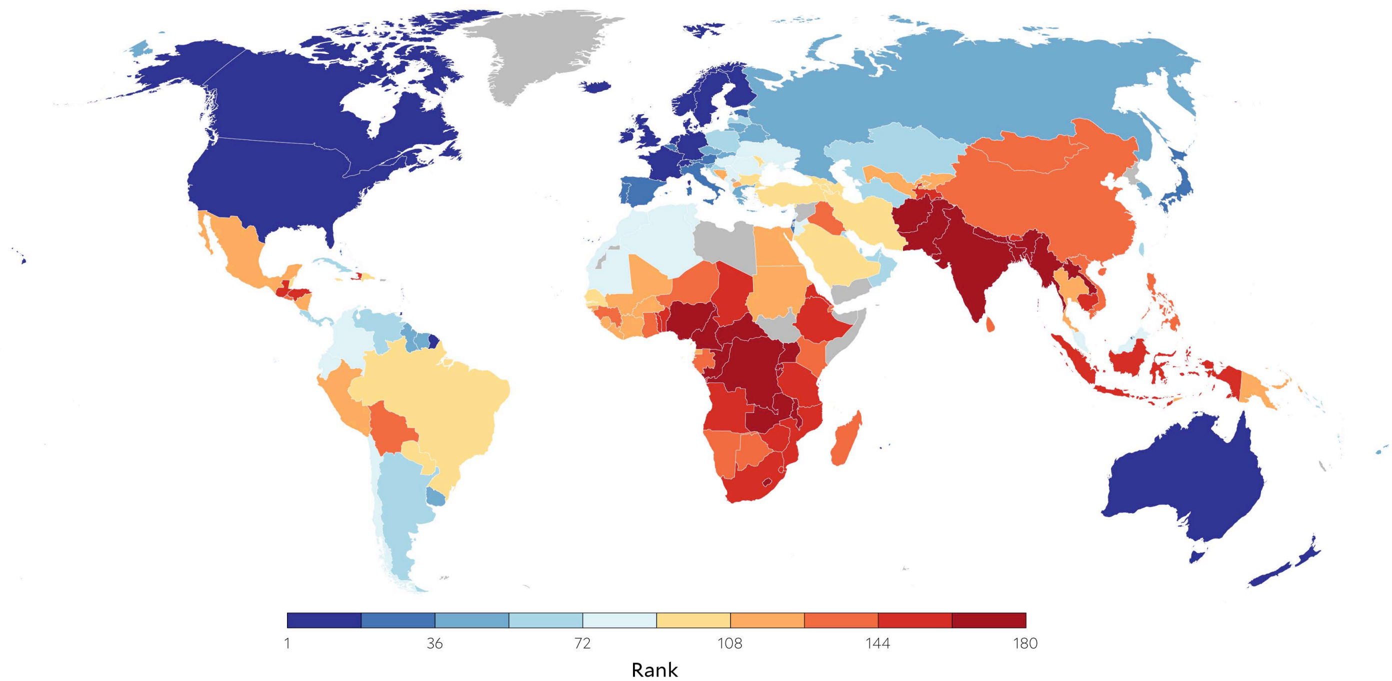
Looking at changes in performance through time shows which countries are making progress toward sustainability targets and which are moving backwards. Over the last decade, Estonia achieved the largest increase in overall EPI scores (+14.9 points), thanks to its fast drop in GHG emissions. Kyrgyzstan rose 13.0 points, thanks to large reductions in the growth rate of its emissions of greenhouse gases and air pollutants. Oman's overall EPI score rose 12.9 points over the last decade, mostly due to a recent expansion of its protected areas, although the country has also made progress in improving agricultural sustainability, banning wasteful and destructive fishing practices, and reducing the growth rate of its GHG emissions. Meanwhile, Tonga (-7.3), Malawi (-6.7), and Comoros (-5.9) had the biggest drops in performance, mostly due to accelerating growth of emissions of greenhouse gases and air pollutants in these countries.

Table 2-2. Environmental Health global rankings, scores, and regional rankings (REG) for 180 countries.

RANK	COUNTRY	SCORE	REG	RANK	COUNTRY	SCORE	REG	RANK	COUNTRY	SCORE	REG
1	Iceland	90.2	1	61	Cuba	52.1	15	121	Thailand	35.2	17
2	Norway	86.7	2	62	Croatia	51.8	9	122	Sudan	34.7	14
3	Finland	86.6	3	63	Qatar	51.3	2	123	Côte d'Ivoire	33.7	12
4	Sweden	85.5	4	63	United Arab Emirates	51.3	2	124	Egypt	33.5	15
5	Australia	84.0	5	65	Kazakhstan	51.0	4	125	Equatorial Guinea	33.4	13
6	New Zealand	82.1	6	66	Solomon Islands	50.8	10	126	Burkina Faso	33.3	14
7	Ireland	81.6	7	67	Kuwait	50.4	4	126	Sierra Leone	33.3	14
8	United Kingdom	78.1	8	68	Oman	50.1	5	128	Iraq	32.9	16
9	Canada	77.7	9	68	Poland	50.1	10	129	Guinea	32.6	16
10	Barbados	77.6	1	68	Venezuela	50.1	16	130	Gabon	32.3	17
11	Denmark	77.5	10	71	Taiwan	49.9	11	131	Ghana	32.1	18
12	Trinidad and Tobago	77.2	2	72	Vanuatu	49.5	12	132	Botswana	31.9	19
13	Switzerland	76.3	11	73	Montenegro	48.7	11	133	Sri Lanka	31.0	2
14	Germany	76.1	12	74	Hungary	48.3	12	134	Niger	30.6	20
14	Luxembourg	76.1	12	75	Algeria	48.2	6	135	El Salvador	30.1	28
16	Netherlands	74.8	14	76	Maldives	48.0	1	136	Bolivia	29.7	29
17	Malta	73.0	15	77	Ukraine	47.9	5	136	China	29.7	18
18	France	72.3	16	78	Jordan	47.2	7	138	Djibouti	29.2	21
18	United States of America	72.3	16	79	Romania	46.6	13	139	Philippines	28.7	19
20	Belgium	72.2	18	79	Tunisia	46.6	8	140	Mongolia	28.5	20
21	Seychelles	71.7	1	81	Lebanon	46.5	9	141	Kenya	27.1	22
22	Austria	71.0	19	81	Mauritania	46.5	4	142	Viet Nam	27.0	21
22	Brunei Darussalam	71.0	1	83	Kiribati	46.4	13	143	Namibia	26.8	23
24	Mauritius	70.4	2	84	Malaysia	45.8	14	144	Madagascar	26.7	24
25	Bahamas	69.9	3	85	Colombia	45.7	17	145	Chad	26.5	25
26	Antigua and Barbuda	69.6	4	86	Chile	45.1	18	146	Benin	26.0	26
27	Portugal	68.9	20	87	Ecuador	44.7	19	147	Indonesia	25.8	22
28	Japan	67.3	2	88	Albania	44.1	14	148	Togo	25.5	27
29	Grenada	66.0	5	88	Morocco	44.1	10	149	Ethiopia	25.2	28
29	Singapore	66.0	3	90	Serbia	43.6	15	149	Mozambique	25.2	28
31	Estonia	65.8	1	91	Belize	43.4	20	151	Tanzania	25.1	30
32	Spain	65.6	21	91	Dominican Republic	43.4	20	152	Eritrea	24.8	31
33	Saint Lucia	65.0	6	93	Senegal	43.1	5	153	South Africa	24.4	32
34	St. Vincent and Grenadines	64.5	7	94	Georgia	42.9	6	154	Cambodia	24.3	23
35	Israel	64.4	1	95	Bulgaria	42.6	16	155	Guatemala	24.2	30
36	Italy	64.2	22	96	Brazil	42.4	22	156	Honduras	23.0	31
37	Greece	63.1	2	97	Türkiye	41.9	17	156	Zimbabwe	23.0	33
38	Cyprus	62.8	3	98	Armenia	41.8	7	158	Bhutan	22.5	3
39	Slovakia	60.7	4	98	Iran	41.8	11	159	Haiti	22.4	32
40	Lithuania	59.8	5	98	Moldova	41.8	7	160	Eswatini	22.1	34
41	Slovenia	59.2	6	101	Bahrain	41.6	12	161	Tajikistan	21.9	12
42	Suriname	59.0	8	102	Comoros	41.4	6	162	Angola	21.8	35
43	Czech Republic	58.9	7	103	Saudi Arabia	40.5	13	163	Malawi	21.0	36
44	Tonga	58.4	4	104	Azerbaijan	40.4	9	164	Nigeria	20.3	37
45	South Korea	58.0	5	105	Gambia	40.2	7	165	Cameroon	19.7	38
46	Samoa	57.8	6	106	São Tomé and Príncipe	39.8	8	166	Laos	19.4	24
47	Dominica	57.7	9	107	Jamaica	39.7	23	167	Zambia	19.1	39
48	Uruguay	57.6	10	107	Paraguay	39.7	23	168	Uganda	18.5	40
49	Micronesia	56.8	7	109	Nicaragua	39.3	25	169	Afghanistan	18.2	4
50	Belarus	56.7	1	109	North Macedonia	39.3	18	170	Republic of Congo	17.7	41
51	Guyana	56.0	11	111	Uzbekistan	38.2	10	171	Myanmar	17.2	25
52	Fiji	55.9	8	112	Mali	37.7	9	172	Bangladesh	15.2	5
53	Marshall Islands	55.6	9	113	Papua New Guinea	37.2	15	173	Nepal	14.7	6
54	Russia	55.4	2	114	Kyrgyzstan	37.1	11	174	Central African Republic	14.6	42
55	Panama	55.1	12	114	Mexico	37.1	26	175	Rwanda	14.4	43
56	Cabo Verde	54.8	3	116	Liberia	36.4	10	176	Dem. Rep. Congo	14.0	44
57	Latvia	54.6	8	116	Timor-Leste	36.4	16	177	India	13.5	7
58	Argentina	54.3	13	118	Bosnia and Herzegovina	36.1	19	178	Burundi	13.1	45
59	Turkmenistan	54.0	3	118	Peru	36.1	27	178	Pakistan	13.1	8
60	Costa Rica	53.7	14	120	Guinea-Bissau	35.6	11	180	Lesotho	13.0	46

Asia-Pacific
Eastern Europe
Former Soviet States
Global West
Greater Middle East
Latin America & Caribbean
Southern Asia
Sub-Saharan Africa

Map 2-3. Rankings in Environmental Health for 180 countries.



Map 2-4. Environmental Health scores for 180 countries.

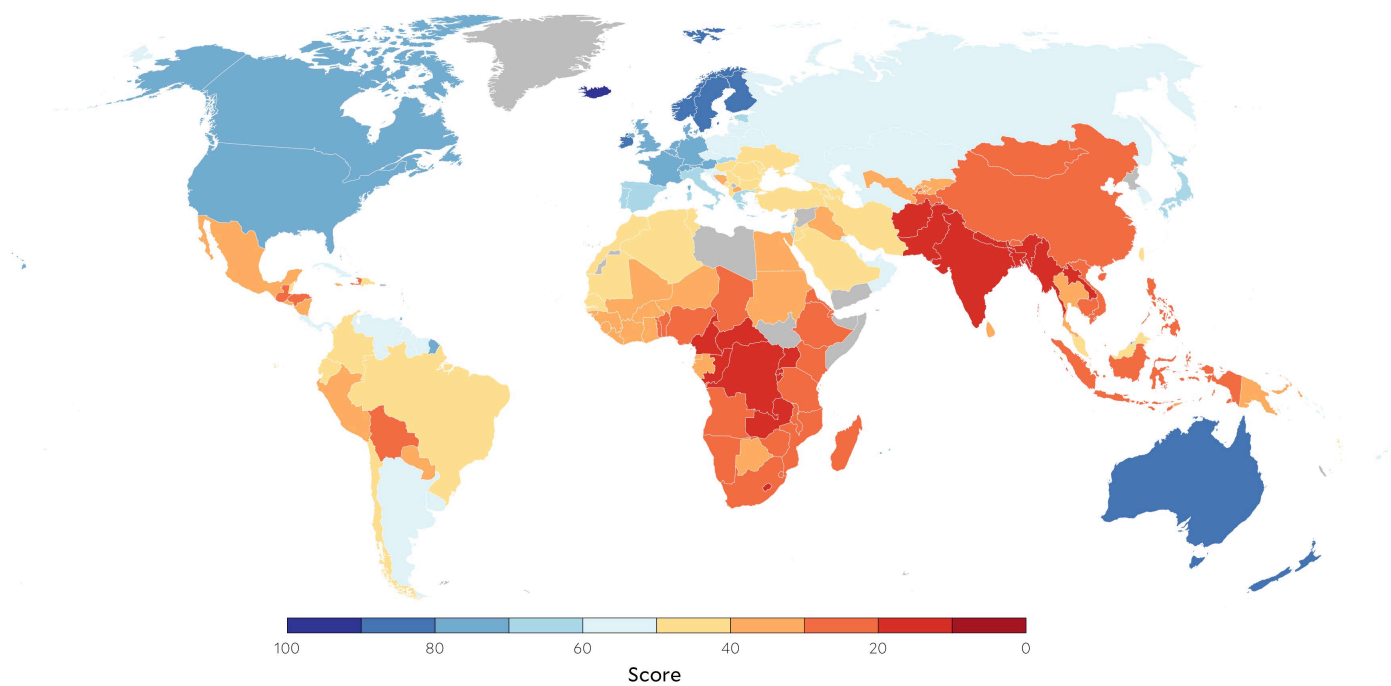


Table 2-3. Ecosystem Vitality global rankings, scores, and regional rankings (REG) for 180 countries.

RANK	COUNTRY	SCORE	REG
1	Luxembourg	83.1	1
2	Germany	80.1	2
3	Poland	79.2	1
4	Slovakia	78.3	2
5	Czech Republic	78.0	3
6	Austria	77.6	3
7	Estonia	76.6	4
8	Botswana	74.9	1
9	Lithuania	74.3	5
10	Hungary	73.2	6
11	United Kingdom	72.8	4
12	Croatia	72.3	7
13	Norway	72.2	5
14	Bulgaria	70.8	8
15	Romania	68.7	9
16	Switzerland	68.6	6
17	Belgium	68.5	7
17	Latvia	68.5	10
19	Belarus	68.2	1
20	Finland	68.1	8
21	France	67.8	9
21	Spain	67.8	9
23	Slovenia	67.4	11
24	Greece	67.0	12
24	Zambia	67.0	2
26	Ireland	66.9	11
27	Sweden	66.8	12
28	Netherlands	66.7	13
29	Zimbabwe	66.3	3
30	Malta	65.6	14
31	Gabon	65.4	4
32	Republic of Congo	65.1	5
33	Suriname	64.6	1
34	Oman	64.5	1
35	Brazil	63.9	2
36	Italy	62.8	15
37	Denmark	62.7	16
37	Namibia	62.7	6
39	Costa Rica	62.6	3
40	Australia	62.5	17
41	Portugal	62.4	18
41	United Arab Emirates	62.4	2
43	Venezuela	61.7	4
44	Tanzania	60.7	7
45	Canada	60.4	19
45	Iceland	60.4	19
47	Bhutan	59.9	1
48	Japan	59.2	1
49	Panama	59.1	5
50	Niger	59.0	8
51	Ukraine	58.9	2
52	Burkina Faso	58.6	9
53	Nicaragua	58.5	6
54	Central African Republic	57.9	10
55	Belize	57.4	7
55	Chile	57.4	7
55	Serbia	57.4	13
58	Guyana	57.2	9
59	Dominican Republic	57.1	10
60	Colombia	57.0	11
61	Ecuador	56.9	12
62	Bolivia	56.6	13
63	Cyprus	56.5	14
64	Qatar	56.4	3
65	Benin	56.1	11
66	Peru	56.0	14
67	North Macedonia	55.7	15
68	Mongolia	55.2	2
69	Dem. Rep. Congo	54.5	12
69	Malawi	54.5	12
71	Singapore	53.8	3
72	Kuwait	53.7	4
73	United States of America	53.5	21
74	Bahamas	53.3	15
75	Antigua and Barbuda	53.2	16
76	Bosnia and Herzegovina	52.1	16
77	Senegal	52.0	14
78	Albania	51.9	17
79	Egypt	51.5	5
79	Taiwan	51.5	4
81	Thailand	51.3	5
82	Chad	51.1	15
83	Georgia	50.6	3
83	St. Vincent and Grenadines	50.6	17
85	Montenegro	50.2	18
86	Cuba	50.1	18
87	New Zealand	50.0	22
87	Saudi Arabia	50.0	6
89	Côte d'Ivoire	49.9	16
90	Kazakhstan	49.7	4
91	Trinidad and Tobago	49.6	19
92	Jamaica	49.5	20
93	Burundi	49.3	17
93	Cameroon	49.3	17
93	Jordan	49.3	7
93	South Africa	49.3	17
97	Kenya	49.2	20
98	Honduras	49.1	21
98	Moldova	49.1	5
100	Mozambique	48.8	21
100	South Korea	48.8	6
102	Russia	48.4	6
102	Uzbekistan	48.4	6
104	Brunei Darussalam	48.3	7
105	Guinea	48.2	22
106	Armenia	48.1	8
107	Nepal	47.9	2
107	Timor-Leste	47.9	8
109	Ghana	47.8	23
110	Seychelles	47.4	24
111	Tajikistan	47.3	9
111	Tunisia	47.3	8
113	Togo	47.1	25
114	Ethiopia	47.0	26
115	Lesotho	46.9	27
116	Argentina	46.7	22
117	Mexico	46.6	23
118	Iran	46.3	9
119	Rwanda	45.8	28
120	Guinea-Bissau	45.6	29
120	Kiribati	45.6	9
120	Uganda	45.6	30
123	Comoros	45.1	31
123	Saint Lucia	45.1	24
125	El Salvador	44.8	25
126	Azerbaijan	44.7	10
126	Cambodia	44.7	10
126	Mali	44.7	32
129	Kyrgyzstan	44.4	11
129	Paraguay	44.4	26
131	Nigeria	44.2	33
132	Angola	44.1	34
133	Equatorial Guinea	43.8	35
134	Sudan	43.4	10
135	Israel	42.0	11
136	Algeria	41.8	12
137	Turkmenistan	40.6	12
138	Dominica	40.5	27
138	Laos	40.5	11
140	Morocco	40.0	13
141	Grenada	39.9	28
142	Sri Lanka	39.7	3
143	Sierra Leone	39.4	36
144	Maldives	39.3	4
145	Eswatini	39.1	37
146	Uruguay	39.0	29
147	Indonesia	38.9	12
147	Malaysia	38.9	12
149	Guatemala	38.4	30
150	Samoa	37.7	14
151	Lebanon	37.5	14
152	Fiji	37.2	15
152	Haiti	37.2	31
154	Vanuatu	37.0	16
155	Bahrain	36.9	15
156	Gambia	36.4	38
157	Papua New Guinea	36.3	17
158	China	35.6	18
159	Türkiye	34.7	19
160	Mauritania	34.5	39
161	Barbados	34.4	32
162	Marshall Islands	34.3	19
162	Tonga	34.3	19
164	Philippines	33.9	21
165	Mauritius	33.5	40
166	Iraq	32.7	16
167	São Tomé and Príncipe	32.0	41
168	Afghanistan	31.9	5
168	Bangladesh	31.9	5
170	Solomon Islands	30.8	22
171	India	30.4	7
172	Liberia	30.3	42
173	Pakistan	29.5	8
174	Madagascar	28.0	43
175	Viet Nam	27.8	23
176	Micronesia	27.4	24
177	Myanmar	26.9	25
178	Eritrea	25.6	44
179	Djibouti	24.4	45
180	Cabo Verde	22.7	46

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Former Soviet States
Global West
Greater Middle East
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Southern Asia
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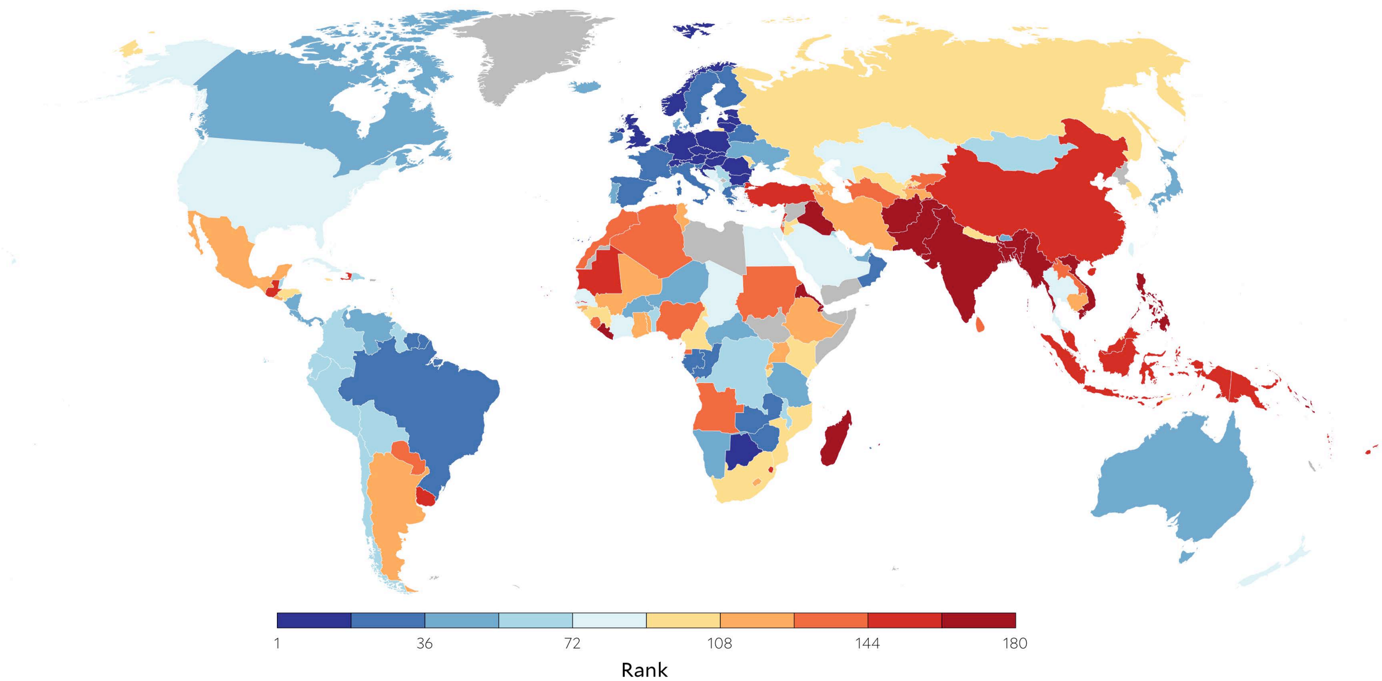
Map 2-5. Rankings in Ecosystem Vitality for 180 countries.



Map 2-6. Ecosystem Vitality scores for 180 countries.

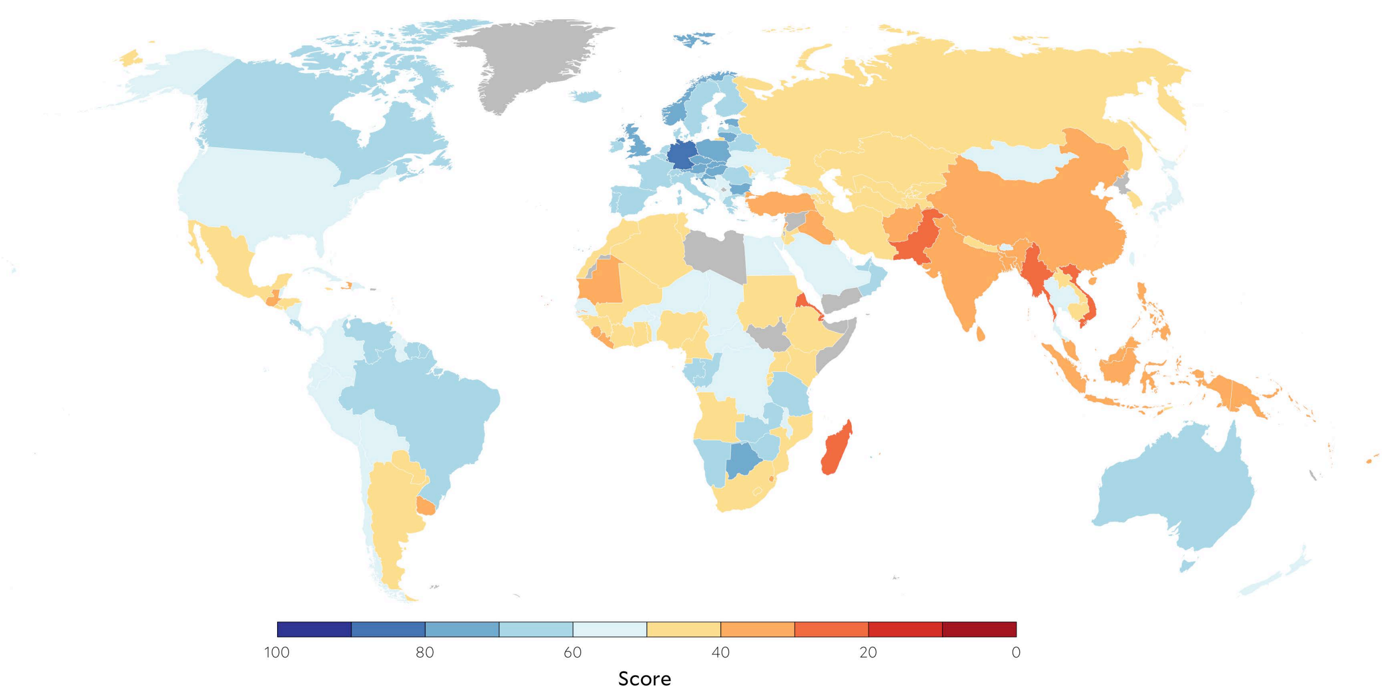


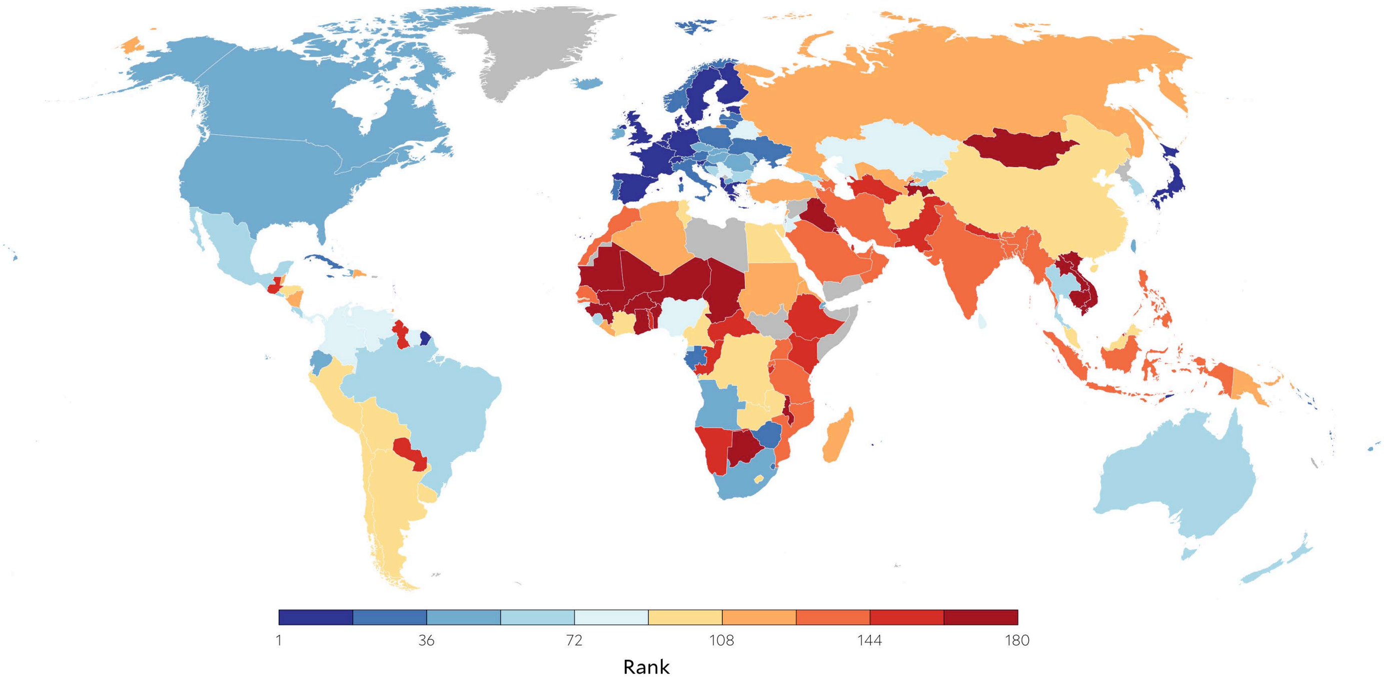
Table 2-4. Climate Change global rankings, scores, and regional rankings (REG) for 180 countries.

RANK	COUNTRY	SCORE	REG
1	Estonia	82.8	1
2	Finland	71.8	1
3	Greece	71.3	2
4	United Kingdom	67.8	2
5	Denmark	67.1	3
6	Timor-Leste	65.2	1
7	Germany	64.9	4
8	Malta	63.6	5
9	Sweden	62.9	6
10	Luxembourg	62.4	7
11	France	61.3	8
12	Netherlands	60.7	9
13	Belgium	59.7	10
13	Japan	59.7	2
15	Albania	59.4	3
15	Switzerland	59.4	11
17	Slovenia	57.5	4
18	Spain	57.2	12
19	Barbados	56.7	1
20	Cuba	56.4	2
21	Croatia	56.0	5
22	Portugal	55.3	13
23	Jamaica	54.3	3
24	Austria	54.1	14
25	Ukraine*	53.9	1
26	Vanuatu	53.7	3
27	Dominica	53.6	4
28	Poland	53.5	6
28	Zimbabwe	53.5	1
30	Italy	53.2	15
31	Eswatini	52.9	2
32	Gabon	52.8	3
32	Solomon Islands	52.8	4
34	Norway	52.6	16
35	Latvia	52.4	7
35	Lithuania	52.4	7
37	Czech Republic	52.2	9
38	North Macedonia	51.3	10
38	Samoa	51.3	5
40	Fiji	51.1	6
40	Ireland	51.1	17
42	United States of America	50.1	18
43	St. Vincent and Grenadines	49.9	5
44	Angola	49.4	4
45	Romania	49.3	11
46	Hungary	49.2	12
47	Slovakia	48.9	13
48	Ecuador	48.5	6
49	Taiwan	48.4	7
50	Canada	48.2	19
50	Iceland	48.2	19
52	South Africa	48.0	5
53	Djibouti	47.9	6
54	Haiti	47.7	7
55	Bahamas	47.6	8
55	New Zealand	47.6	21
57	Saint Lucia	47.5	9
58	South Korea	47.0	8
59	Sierra Leone	46.8	7
60	Australia	46.6	22
61	Antigua and Barbuda	46.4	10
61	El Salvador	46.4	10
61	Mexico	46.4	10
64	Costa Rica	46.3	13
65	Georgia	46.0	2
65	Thailand	46.0	9
67	Bosnia and Herzegovina	45.9	14
68	Mauritius	45.8	8
69	Bulgaria	45.7	15
70	Brazil	45.5	14
70	Equatorial Guinea	45.5	9
72	Kyrgyzstan	45.4	3
72	Moldova	45.4	3
74	Jordan	44.6	1
75	Belarus	44.5	5
76	Micronesia	44.4	10
77	Sri Lanka	44.1	1
78	Nigeria	43.9	10
79	Serbia	43.6	16
79	Suriname	43.6	15
81	Venezuela	43.5	16
82	Cabo Verde	43.4	11
83	Israel	43.3	2
84	Montenegro	43.1	17
85	Armenia	42.8	6
86	Cyprus	42.6	18
87	Kazakhstan	42.3	7
88	Colombia	42.2	17
89	Panama	41.9	18
90	Guinea-Bissau	41.8	12
91	Lesotho	41.7	13
92	Chile	41.5	19
93	Argentina	41.4	20
93	Bolivia	41.4	20
93	Tunisia	41.4	3
96	Honduras	41.2	22
96	Singapore	41.2	11
98	Marshall Islands	41.0	12
99	Côte d'Ivoire	40.9	14
99	Kiribati	40.9	13
101	Peru	40.7	23
102	Uruguay	40.6	24
103	Egypt	40.4	4
104	Afghanistan	40.2	2
105	Dem. Rep. Congo	40.1	15
106	Malaysia	39.9	14
107	China	39.8	15
108	Cameroon	39.4	16
108	Zambia	39.4	16
110	São Tomé and Príncipe	38.6	18
111	Liberia	38.4	19
112	Eritrea	38.1	20
113	Lebanon	38.0	5
114	Papua New Guinea	37.7	16
115	Nicaragua	37.6	25
116	Uzbekistan	37.5	8
117	Dominican Republic	37.3	26
118	Gambia	37.2	21
119	Türkiye	37.0	19
120	Russia	36.9	9
121	Grenada	36.7	27
122	Algeria	36.2	6
122	Sudan	36.2	6
124	Madagascar	36.1	22
124	Trinidad and Tobago	36.1	28
126	Belize	35.8	29
127	Mozambique	35.7	23
127	Uganda	35.7	23
129	Myanmar	35.6	17
129	United Arab Emirates	35.6	8
131	Bhutan	35.3	3
132	Iran	35.1	9
133	India	35.0	4
134	Morocco	34.9	10
135	Azerbaijan	34.7	10
136	Saudi Arabia	33.2	11
137	Bangladesh	33.0	5
138	Oman	32.6	12
139	Tanzania	32.5	25
139	Tonga	32.5	18
141	Rwanda	32.3	26
142	Philippines	32.2	19
143	Indonesia	32.1	20
144	Senegal	32.0	27
145	Paraguay	31.9	30
146	Central African Republic	31.0	28
147	Guatemala	30.6	31
147	Guyana	30.6	31
149	Namibia	30.3	29
150	Pakistan	30.0	6
151	Turkmenistan	29.6	11
152	Republic of Congo	29.3	30
153	Brunei Darussalam	29.2	21
154	Ethiopia	28.9	31
155	Togo	28.5	32
156	Qatar	28.0	13
157	Bahrain	27.9	14
157	Maldives	27.9	7
159	Seychelles	27.3	33
160	Burundi	26.6	34
161	Kenya	26.5	35
162	Nepal	25.8	8
163	Comoros	25.2	36
164	Botswana	25.1	37
165	Burkina Faso	24.9	38
165	Kuwait	24.9	15
167	Mauritania	24.8	39
168	Ghana	24.7	40
169	Iraq	24.6	16
170	Benin	22.9	41
171	Guinea	22.2	42
172	Chad	21.0	43
173	Niger	19.4	44
174	Tajikistan	18.5	12
175	Viet Nam	17.9	22
176	Malawi	17.7	45
177	Mongolia	17.6	23
178	Cambodia	16.7	24
179	Mali	16.5	46
180	Laos	9.6	25

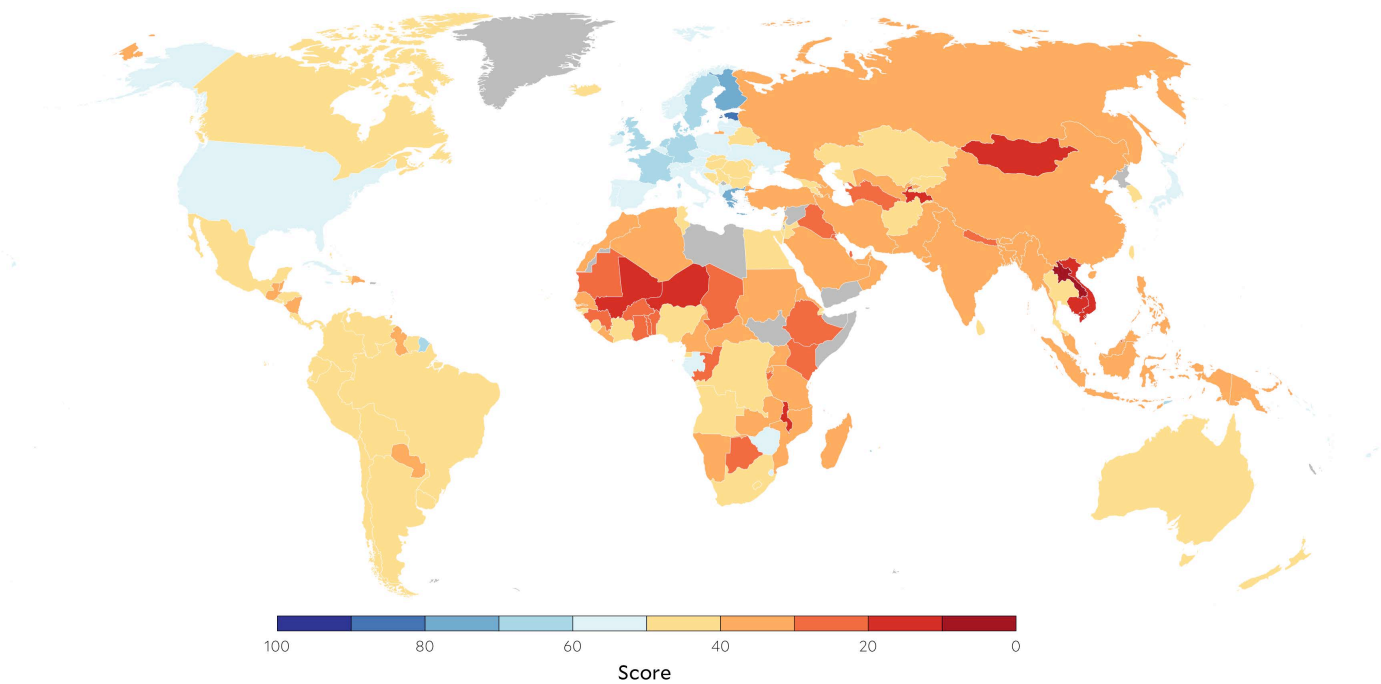
* The Russian invasion led to a sharp decline in economic activity, energy use, and associated GHG emissions in the Ukraine in 2022, so this score might not accurately reflect performance.

Asia-Pacific | Eastern Europe | Former Soviet States | Global West
Greater Middle East | Latin America & Caribbean | Southern Asia | Sub-Saharan Africa

Map 2-7. Rankings on Climate Change for 180 countries.



Map 2-8. Climate Change scores for 180 countries.



3. Regional Rankings

Global rankings compare countries with contrasting stages of socioeconomic development, geography, and ecological characteristics. Analyzing performance within "peer groups" can yield more useful comparisons and help identify policies that have proven successful in a particular context. The 2024 EPI reports rankings for eight regions defined by geographical, historical, and socioeconomic factors (Map 2-9).

Global West

The Global West is the region with the highest median score (66.9). Out of the top 20 positions in the 2024 EPI ranking, countries in the Global West occupy 15. These countries score particularly well on Environmental Health, occupying 18 of the top 20 ranks. Luxembourg, Germany, and Finland earn the top three positions within the Global West. But even these countries have big room for improvement in some areas. While Luxembourg has one of the largest percentages of protected area coverage in the world, it earns among the lowest scores in the pilot indicators of protected area effectiveness. Nearly 30 percent of all the land under protection in Luxembourg is covered by croplands and buildings, and in 94.2 percent of the country's protected areas, croplands and buildings are expanding. Germany also scores poorly on these pilot indicators, has high rates of waste generation *per capita,* and has worse air quality than most other Global West countries. In turn, Finland has lower coverage of protected areas, although it scores higher on the pilot indicators of protected area effectiveness and stringency.

Italy, New Zealand and the United States are at the bottom of the regional ranking. Italy has the worst air quality among Global West countries. New Zealand performs poorly on Biodiversity & Habitat metrics, despite having protected areas covering more than 30 percent of its land and seas. Since New Zealand's protected areas are concentrated on the eastern, mountainous half of *Te Waipounamu* (South Island), they do not cover the full range of the country's varied biomes and species. New Zealand is rich in endemic species, many of which are threatened by habitat loss and invasive species (Holdaway, Wiser, and Williams 2012), and these threats are being exacerbated by climate change (Macinnis-Ng et al. 2021). The United States also performs poorly on biodiversity metrics (mostly due to the relatively low coverage of its terrestrial protected areas), has one of the highest rates of waste generation per capita, and lags most Global West countries on air quality and climate change mitigation.

Eastern Europe

Eastern Europe, which includes the top-performing country in the 2024 EPI — Estonia — has the second highest median regional score (59.8). Among the top 20 ranks of the overall EPI, all the countries that are not from the Global West are from Eastern Europe, including Greece (11th), the Czech Republic (17th), Slovakia (18th), and Poland (20th). The region also earns the highest median score on the Biodiversity & Habitat issue category, just ahead of the Global West.

We already mentioned Estonia's climate mitigation and biodiversity protection achievements in the "Global Rankings" section. Greece has also made great progress slashing its GHG emissions by moving away from coal electricity generation and expanding renewable energy, earning the third highest score on Climate Change Mitigation, just behind Estonia and Finland.

Map 2-9. EPI-defined world regions.

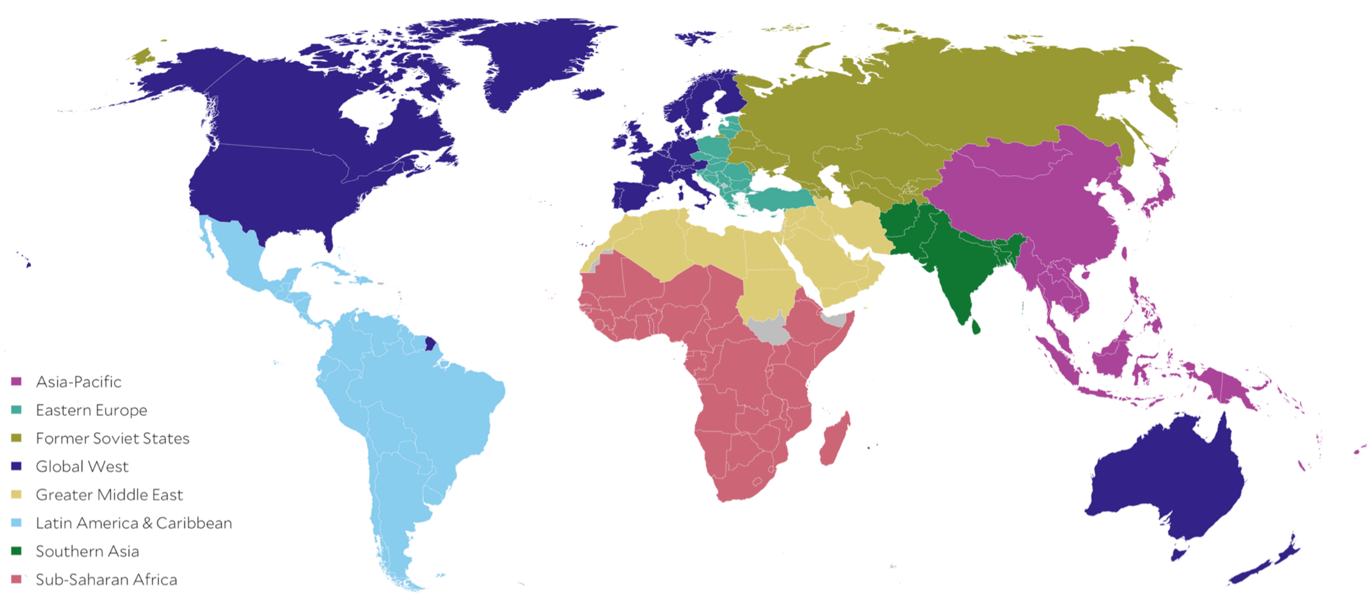


Table 2-5. EPI scores and regional rankings.

Latin America & Caribbean		
Country	Score	Rank
Suriname	56.9	1
Bahamas	55.9	2
Antigua and Barbuda	55.6	3
Costa Rica	55.5	4
St. Vincent and Grenadines	54.2	5
Venezuela	53.3	6
Barbados	53.1	7
Brazil	53.0	8
Panama	52.9	9
Cuba	52.5	10
Trinidad and Tobago	52.5	10
Ecuador	51.3	12
Saint Lucia	51.1	13
Colombia	49.7	14
Chile	49.6	15
Dominica	49.3	16
Guyana	49.0	17
Jamaica	48.5	18
Dominican Republic	47.7	19
Belize	47.4	20
Nicaragua	47.4	20
Argentina	47.0	22
Peru	46.5	23
Grenada	45.8	24
Bolivia	45.3	25
Mexico	44.2	26
Uruguay	44.1	27
El Salvador	41.6	28
Honduras	40.2	29
Paraguay	39.5	30
Haiti	36.4	31
Guatemala	32.5	32

Eastern Europe		
Country	Score	Rank
Estonia	75.7	1
Greece	67.3	2
Czech Republic	65.5	3
Slovakia	65.1	4
Poland	64.2	5
Lithuania	64.1	6
Slovenia	62.4	7
Croatia	62.3	8
Latvia	60.2	9
Hungary	59.8	10
Romania	57.3	11
Bulgaria	56.2	12
Cyprus	53.9	13
Albania	52.2	14
North Macedonia	50.3	15
Serbia	49.8	16
Montenegro	47.7	17
Bosnia and Herzegovina	46.0	18
Türkiye	37.2	19

Southern Asia		
Country	Score	Rank
Bhutan	43.3	1
Sri Lanka	38.8	2
Maldives	38.1	3
Nepal	33.1	4
Afghanistan	31.0	5
Bangladesh	28.1	6
India	27.6	7
Pakistan	25.5	8

Global West		
Country	Score	Rank
Luxembourg	75.1	1
Germany	74.5	2
Finland	73.8	3
United Kingdom	72.6	4
Sweden	70.3	5
Norway	69.9	6
Austria	68.9	7
Switzerland	67.8	8
Denmark	67.7	9
France	67.0	10
Malta	66.9	11
Netherlands	66.9	11
Belgium	66.8	13
Ireland	65.8	14
Iceland	64.3	15
Spain	64.0	16
Australia	63.1	17
Portugal	61.9	18
Canada	61.1	19
Italy	60.3	20
New Zealand	57.3	21
United States of America	57.2	22

Former Soviet States		
Country	Score	Rank
Belarus	58.2	1
Ukraine	54.6	2
Kazakhstan	47.8	3
Georgia	47.3	4
Russia	46.7	5
Moldova	46.1	6
Armenia	44.9	7
Kyrgyzstan	42.8	8
Uzbekistan	42.6	9
Turkmenistan	40.6	10
Azerbaijan	40.5	11
Tajikistan	32.3	12

Asia-Pacific		
Country	Score	Rank
Japan	61.4	1
Singapore	53.0	2
South Korea	50.6	3
Taiwan	50.1	4
Timor-Leste	49.9	5
Brunei Darussalam	48.3	6
Samoa	47.1	7
Fiji	46.0	8
Thailand	45.7	9
Vanuatu	45.0	10
Kiribati	44.3	11
Marshall Islands	42.5	12
Solomon Islands	42.2	13
Malaysia	41.0	14
Micronesia	40.8	15
Tonga	40.4	16
Mongolia	37.2	17
Papua New Guinea	36.9	18
China	35.4	19
Indonesia	33.6	20
Philippines	32.1	21
Cambodia	31.2	22
Myanmar	27.1	23
Laos	26.3	24
Viet Nam	24.6	25

Sub-Saharan Africa		
Country	Score	Rank
Gabon	53.3	1
Zimbabwe	51.6	2
Botswana	49.2	3
Seychelles	47.9	4
Mauritius	47.3	5
Zambia	46.7	6
Namibia	44.0	7
Senegal	43.8	8
Tanzania	43.6	9
Côte d'Ivoire	42.9	10
South Africa	42.7	11
Burkina Faso	42.2	12
Guinea-Bissau	42.0	13
Equatorial Guinea	41.7	14
Republic of Congo	41.6	15
Angola	40.1	16
Niger	40.0	17
Sierra Leone	39.9	18
Dem. Rep. Congo	39.5	19
Central African Republic	39.0	20
Mozambique	39.0	20
Eswatini	38.7	22
Cameroon	38.6	23
Comoros	38.2	24
Cabo Verde	38.0	25
Nigeria	37.9	26
Benin	37.8	27
Gambia	37.6	28
Ghana	36.9	29
Kenya	36.9	29
Lesotho	36.9	29
Guinea	36.5	32
Ethiopia	36.3	33
São Tomé and Príncipe	36.2	34
Chad	35.9	35
Uganda	35.8	36
Togo	35.7	37
Malawi	35.1	38
Mauritania	34.6	39
Mali	34.5	40
Liberia	34.3	41
Rwanda	33.9	42
Burundi	33.5	43
Djibouti	32.3	44
Madagascar	30.1	45
Eritrea	29.0	46

Greater Middle East		
Country	Score	Rank
United Arab Emirates	51.6	1
Oman	51.3	2
Israel	48.0	3
Jordan	47.3	4
Qatar	46.8	5
Tunisia	45.3	6
Kuwait	44.4	7
Egypt	43.8	8
Saudi Arabia	42.5	9
Iran	41.8	10
Algeria	41.7	11
Lebanon	39.9	12
Morocco	39.5	13
Sudan	39.1	14
Bahrain	35.3	15
Iraq	30.3	16

Table 2-6. Environmental Health scores and regional rankings.

Latin America & Caribbean		
Country	Score	Rank
Barbados	77.6	1
Trinidad and Tobago	77.2	2
Bahamas	69.9	3
Antigua and Barbuda	69.6	4
Grenada	66.0	5
Saint Lucia	65.0	6
St. Vincent and Grenadines	64.5	7
Suriname	59.0	8
Dominica	57.7	9
Uruguay	57.6	10
Guyana	56.0	11
Panama	55.1	12
Argentina	54.3	13
Costa Rica	53.7	14
Cuba	52.1	15
Venezuela	50.1	16
Colombia	45.7	17
Chile	45.1	18
Ecuador	44.7	19
Belize	43.4	20
Dominican Republic	43.4	20
Brazil	42.4	22
Jamaica	39.7	23
Paraguay	39.7	23
Nicaragua	39.3	25
Mexico	37.1	26
Peru	36.1	27
El Salvador	30.1	28
Bolivia	29.7	29
Guatemala	24.2	30
Honduras	23.0	31
Haiti	22.4	32

Eastern Europe		
Country	Score	Rank
Estonia	65.8	1
Greece	63.1	2
Cyprus	62.8	3
Slovakia	60.7	4
Lithuania	59.8	5
Slovenia	59.2	6
Czech Republic	58.9	7
Latvia	54.6	8
Croatia	51.8	9
Poland	50.1	10
Montenegro	48.7	11
Hungary	48.3	12
Romania	46.6	13
Albania	44.1	14
Serbia	43.6	15
Bulgaria	42.6	16
Türkiye	41.9	17
North Macedonia	39.3	18
Bosnia and Herzegovina	36.1	19

Southern Asia		
Country	Score	Rank
Maldives	48.0	1
Sri Lanka	31.0	2
Bhutan	22.5	3
Afghanistan	18.2	4
Bangladesh	15.2	5
Nepal	14.7	6
India	13.5	7
Pakistan	13.1	8

Global West		
Country	Score	Rank
Iceland	90.2	1
Norway	86.7	2
Finland	86.6	3
Sweden	85.5	4
Australia	84.0	5
New Zealand	82.1	6
Ireland	81.6	7
United Kingdom	78.1	8
Canada	77.7	9
Denmark	77.5	10
Switzerland	76.3	11
Germany	76.1	12
Luxembourg	76.1	12
Netherlands	74.8	14
Malta	73.0	15
France	72.3	16
United States of America	72.3	16
Belgium	72.2	18
Austria	71.0	19
Portugal	68.9	20
Spain	65.6	21
Italy	64.2	22

Former Soviet States		
Country	Score	Rank
Belarus	56.7	1
Russia	55.4	2
Turkmenistan	54.0	3
Kazakhstan	51.0	4
Ukraine	47.9	5
Georgia	42.9	6
Armenia	41.8	7
Moldova	41.8	7
Azerbaijan	40.4	9
Uzbekistan	38.2	10
Kyrgyzstan	37.1	11
Tajikistan	21.9	12

Asia-Pacific		
Country	Score	Rank
Brunei Darussalam	71.0	1
Japan	67.3	2
Singapore	66.0	3
Tonga	58.4	4
South Korea	58.0	5
Samoa	57.8	6
Micronesia	56.8	7
Fiji	55.9	8
Marshall Islands	55.6	9
Solomon Islands	50.8	10
Taiwan	49.9	11
Vanuatu	49.5	12
Kiribati	46.4	13
Malaysia	45.8	14
Papua New Guinea	37.2	15
Timor-Leste	36.4	16
Thailand	35.2	17
China	29.7	18
Philippines	28.7	19
Mongolia	28.5	20
Viet Nam	27.0	21
Indonesia	25.8	22
Cambodia	24.3	23
Laos	19.4	24
Myanmar	17.2	25

Sub-Saharan Africa		
Country	Score	Rank
Seychelles	71.7	1
Mauritius	70.4	2
Cabo Verde	54.8	3
Mauritania	46.5	4
Senegal	43.1	5
Comoros	41.4	6
Gambia	40.2	7
São Tomé and Príncipe	39.8	8
Mali	37.7	9
Liberia	36.4	10
Guinea-Bissau	35.6	11
Côte d'Ivoire	33.7	12
Equatorial Guinea	33.4	13
Burkina Faso	33.3	14
Sierra Leone	33.3	14
Guinea	32.6	16
Gabon	32.3	17
Ghana	32.1	18
Botswana	31.9	19
Niger	30.6	20
Djibouti	29.2	21
Kenya	27.1	22
Namibia	26.8	23
Madagascar	26.7	24
Chad	26.5	25
Benin	26.0	26
Togo	25.5	27
Ethiopia	25.2	28
Mozambique	25.2	28
Tanzania	25.1	30
Eritrea	24.8	31
South Africa	24.4	32
Zimbabwe	23.0	33
Eswatini	22.1	34
Angola	21.8	35
Malawi	21.0	36
Nigeria	20.3	37
Cameroon	19.7	38
Zambia	19.1	39
Uganda	18.5	40
Republic of Congo	17.7	41
Central African Republic	14.6	42
Rwanda	14.4	43
Dem. Rep. Congo	14.0	44
Burundi	13.1	45
Lesotho	13.0	46

Greater Middle East		
Country	Score	Rank
Israel	64.4	1
Qatar	51.3	2
United Arab Emirates	51.3	2
Kuwait	50.4	4
Oman	50.1	5
Algeria	48.2	6
Jordan	47.2	7
Tunisia	46.6	8
Lebanon	46.5	9
Morocco	44.1	10
Iran	41.8	11
Bahrain	41.6	12
Saudi Arabia	40.5	13
Sudan	34.7	14
Egypt	33.5	15
Iraq	32.9	16

Table 2-7. Ecosystem Vitality scores and regional rankings.

Latin America & Caribbean		
Country	Score	Rank
Suriname	64.6	1
Brazil	63.9	2
Costa Rica	62.6	3
Venezuela	61.7	4
Panama	59.1	5
Nicaragua	58.5	6
Belize	57.4	7
Chile	57.4	7
Guyana	57.2	9
Dominican Republic	57.1	10
Colombia	57.0	11
Ecuador	56.9	11
Bolivia	56.6	13
Peru	56.0	14
Bahamas	53.3	15
Antigua and Barbuda	53.2	16
St. Vincent and Grenadines	50.6	17
Cuba	50.1	18
Trinidad and Tobago	49.6	19
Jamaica	49.5	20
Honduras	49.1	21
Argentina	46.7	22
Mexico	46.6	23
Saint Lucia	45.1	24
El Salvador	44.8	25
Paraguay	44.4	26
Dominica	40.5	27
Grenada	39.9	28
Uruguay	39.0	29
Guatemala	38.4	30
Haiti	37.2	31
Barbados	34.4	32

Eastern Europe		
Country	Score	Rank
Poland	79.2	1
Slovakia	78.3	2
Czech Republic	78.0	3
Estonia	76.6	4
Lithuania	74.3	5
Hungary	73.2	6
Croatia	72.3	7
Bulgaria	70.8	8
Romania	68.7	9
Latvia	68.5	10
Slovenia	67.4	11
Greece	67.0	12
Serbia	57.4	13
Cyprus	56.5	14
North Macedonia	55.7	15
Bosnia and Herzegovina	52.1	16
Albania	51.9	17
Montenegro	50.2	18
Türkiye	34.7	19

Southern Asia		
Country	Score	Rank
Bhutan	59.9	1
Nepal	47.9	2
Sri Lanka	39.7	3
Maldives	39.3	4
Afghanistan	31.9	5
Bangladesh	31.9	5
India	30.4	7
Pakistan	29.5	8

Global West		
Country	Score	Rank
Luxembourg	83.1	1
Germany	80.1	2
Austria	77.6	3
United Kingdom	72.8	4
Norway	72.2	5
Switzerland	68.6	6
Belgium	68.5	7
Finland	68.1	8
France	67.8	9
Spain	67.8	9
Ireland	66.9	11
Sweden	66.8	12
Netherlands	66.7	13
Malta	65.6	14
Italy	62.8	15
Denmark	62.7	16
Australia	62.5	17
Portugal	62.4	18
Canada	60.4	19
Iceland	60.4	19
United States of America	53.5	21
New Zealand	50.0	22

Former Soviet States		
Country	Score	Rank
Belarus	68.2	1
Ukraine	58.9	2
Georgia	50.6	3
Kazakhstan	49.7	4
Moldova	49.1	5
Russia	48.4	6
Uzbekistan	48.4	6
Armenia	48.1	8
Tajikistan	47.3	9
Azerbaijan	44.7	10
Kyrgyzstan	44.4	11
Turkmenistan	40.6	12

Asia-Pacific		
Country	Score	Rank
Japan	59.2	1
Mongolia	55.2	2
Singapore	53.8	3
Taiwan	51.5	4
Thailand	51.3	5
South Korea	48.8	6
Brunei Darussalam	48.3	7
Timor-Leste	47.9	8
Kiribati	45.6	9
Cambodia	44.7	10
Laos	40.5	11
Indonesia	38.9	12
Malaysia	38.9	12
Samoa	37.7	14
Fiji	37.2	15
Vanuatu	37.0	16
Papua New Guinea	36.3	17
China	35.6	18
Marshall Islands	34.3	19
Tonga	34.3	19
Philippines	33.9	21
Solomon Islands	30.8	22
Viet Nam	27.8	23
Micronesia	27.4	24
Myanmar	26.9	25

Sub-Saharan Africa		
Country	Score	Rank
Botswana	74.9	1
Zambia	67.0	2
Zimbabwe	66.3	3
Gabon	65.4	4
Republic of Congo	65.1	5
Namibia	62.7	6
Tanzania	60.7	7
Niger	59.0	8
Burkina Faso	58.6	9
Central African Republic	57.9	10
Benin	56.1	11
Dem. Rep. Congo	54.5	12
Malawi	54.5	12
Senegal	52.0	14
Chad	51.1	15
Côte d'Ivoire	49.9	16
Burundi	49.3	17
Cameroon	49.3	17
South Africa	49.3	17
Kenya	49.2	20
Mozambique	48.8	21
Guinea	48.2	22
Ghana	47.8	23
Seychelles	47.4	24
Togo	47.1	25
Ethiopia	47.0	26
Lesotho	46.9	27
Rwanda	45.8	28
Guinea-Bissau	45.6	29
Uganda	45.6	29
Comoros	45.1	31
Mali	44.7	32
Nigeria	44.2	33
Angola	44.1	34
Equatorial Guinea	43.8	35
Sierra Leone	39.4	36
Eswatini	39.1	37
Gambia	36.4	38
Mauritania	34.5	39
Mauritius	33.5	40
São Tomé and Príncipe	32.0	41
Liberia	30.3	42
Madagascar	28.0	43
Eritrea	25.6	44
Djibouti	24.4	45
Cabo Verde	22.7	46

Greater Middle East		
Country	Score	Rank
Oman	64.5	1
United Arab Emirates	62.4	2
Qatar	56.4	3
Kuwait	53.7	4
Egypt	51.5	5
Saudi Arabia	50.0	6
Jordan	49.3	7
Tunisia	47.3	8
Iran	46.3	9
Sudan	43.4	10
Israel	42.0	11
Algeria	41.8	12
Morocco	40.0	13
Lebanon	37.5	14
Bahrain	36.9	15
Iraq	32.7	16

Table 2-8. Climate Change scores and regional rankings.

Latin America & Caribbean		
Country	Score	Rank
Barbados	56.7	1
Cuba	56.4	2
Jamaica	54.3	3
Dominica	53.6	4
St. Vincent and Grenadines	49.9	5
Ecuador	48.5	6
Haiti	47.7	7
Bahamas	47.6	8
Saint Lucia	47.5	9
Antigua and Barbuda	46.4	10
El Salvador	46.4	10
Mexico	46.4	10
Costa Rica	46.3	13
Brazil	45.5	14
Suriname	43.6	15
Venezuela	43.5	16
Colombia	42.2	17
Panama	41.9	18
Chile	41.5	19
Argentina	41.4	20
Bolivia	41.4	20
Honduras	41.2	22
Peru	40.7	23
Uruguay	40.6	24
Nicaragua	37.6	25
Dominican Republic	37.3	26
Grenada	36.7	27
Trinidad and Tobago	36.1	28
Belize	35.8	29
Paraguay	31.9	30
Guatemala	30.6	31
Guyana	30.6	31

Eastern Europe		
Country	Score	Rank
Estonia	82.8	1
Greece	71.3	2
Albania	59.4	3
Slovenia	57.5	4
Croatia	56.0	5
Poland	53.5	6
Latvia	52.4	7
Lithuania	52.4	7
Czech Republic	52.2	9
North Macedonia	51.3	10
Romania	49.3	11
Hungary	49.2	12
Slovakia	48.9	13
Bosnia and Herzegovina	45.9	14
Bulgaria	45.7	15
Serbia	43.6	16
Montenegro	43.1	17
Cyprus	42.6	18
Türkiye	37.0	19

Southern Asia		
Country	Score	Rank
Sri Lanka	44.1	1
Afghanistan	40.2	2
Bhutan	35.3	3
India	35.0	4
Bangladesh	33.0	5
Pakistan	30.0	6
Maldives	27.9	7
Nepal	25.8	8

Global West		
Country	Score	Rank
Finland	71.8	1
United Kingdom	67.8	2
Denmark	67.1	3
Germany	64.9	4
Malta	63.6	5
Sweden	62.9	6
Luxembourg	62.4	7
France	61.3	8
Netherlands	60.7	9
Belgium	59.7	10
Switzerland	59.4	11
Spain	57.2	12
Portugal	55.3	13
Austria	54.1	14
Italy	53.2	15
Norway	52.6	16
Ireland	51.1	17
United States of America	50.1	18
Canada	48.2	19
Iceland	48.2	19
New Zealand	47.6	21
Australia	46.6	22

Former Soviet States		
Country	Score	Rank
Ukraine*	53.9	1
Georgia	46.0	2
Kyrgyzstan	45.4	3
Moldova	45.4	3
Belarus	44.5	5
Armenia	42.8	6
Kazakhstan	42.3	7
Uzbekistan	37.5	8
Russia	36.9	9
Azerbaijan	34.7	10
Turkmenistan	29.6	11
Tajikistan	18.5	12

Asia-Pacific		
Country	Score	Rank
Timor-Leste	65.2	1
Japan	59.7	2
Vanuatu	53.7	3
Solomon Islands	52.8	4
Samoa	51.3	5
Fiji	51.1	6
Taiwan	48.4	7
South Korea	47.0	8
Thailand	46.0	9
Micronesia	44.4	10
Singapore	41.2	11
Marshall Islands	41.0	12
Kiribati	40.9	13
Malaysia	39.9	14
China	39.8	15
Papua New Guinea	37.7	16
Myanmar	35.6	17
Tonga	32.5	18
Philippines	32.2	19
Indonesia	32.1	20
Brunei Darussalam	29.2	21
Viet Nam	17.9	22
Mongolia	17.6	23
Cambodia	16.7	24
Laos	9.6	25

Sub-Saharan Africa		
Country	Score	Rank
Zimbabwe	53.5	1
Eswatini	52.9	2
Gabon	52.8	3
Angola	49.4	4
South Africa	48.0	5
Djibouti	47.9	6
Sierra Leone	46.8	7
Mauritius	45.8	8
Equatorial Guinea	45.5	9
Nigeria	43.9	10
Cabo Verde	43.4	11
Guinea-Bissau	41.8	12
Lesotho	41.7	13
Côte d'Ivoire	40.9	14
Dem. Rep. Congo	40.1	15
Cameroon	39.4	16
Zambia	39.4	16
São Tomé and Príncipe	38.6	18
Liberia	38.4	19
Eritrea	38.1	20
Gambia	37.2	21
Madagascar	36.1	22
Mozambique	35.7	23
Uganda	35.7	23
Tanzania	32.5	25
Rwanda	32.3	26
Senegal	32.0	27
Central African Republic	31.0	28
Namibia	30.3	29
Republic of Congo	29.3	30
Ethiopia	28.9	31
Togo	28.5	32
Seychelles	27.3	33
Burundi	26.6	34
Kenya	26.5	35
Comoros	25.2	36
Botswana	25.1	37
Burkina Faso	24.9	38
Mauritania	24.8	39
Ghana	24.7	40
Benin	22.9	41
Guinea	22.2	42
Chad	21.0	43
Niger	19.4	44
Malawi	17.7	45
Mali	16.5	46

Greater Middle East		
Country	Score	Rank
Jordan	44.6	1
Israel	43.3	2
Tunisia	41.4	3
Egypt	40.4	4
Lebanon	38.0	5
Algeria	36.2	6
Sudan	36.2	6
United Arab Emirates	35.6	8
Iran	35.1	9
Morocco	34.9	10
Saudi Arabia	33.2	11
Oman	32.6	12
Qatar	28.0	13
Bahrain	27.9	14
Kuwait	24.9	15
Iraq	24.6	16

Serbia, Montenegro, and Bosnia and Herzegovina are regional laggards, with poor scores on biodiversity protection, waste management, and some of the worst air quality in Europe. Türkiye gets the lowest score in the region (37.2) due to its poor air quality, rising GHG emissions, and low biodiversity protection scores (largely a result of Türkiye restricting public access to its data in the World Database of Protected Areas).

Latin America & the Caribbean

Latin America & the Caribbean earns the third highest median regional score on the overall EPI (49.2). The region has mixed performance across issue categories, however, earning the second highest median regional score on Air Quality but the lowest median score on Waste Management. On several issues, such as Forests, Fisheries, Agriculture, Air Quality, and Heavy Metals, there is wide variation in performance within the region, with countries close to the top and the bottom of the global ranking.

Suriname is the highest scoring country in Latin America & the Caribbean, ranking 36th globally. After several island states in the Caribbean, Suriname has the highest air quality score in the Americas, with particularly low levels of ozone and anthropogenic fine particulate matter pollution. The country also has some of the most pristine forests in the world, with the second highest score on the *Forest Landscape Integrity Index*. These pristine forests translate into a low overall extinction risk for the country's species, earning Suriname the highest score on the *Red List Index*, despite a relatively low coverage of protected areas.

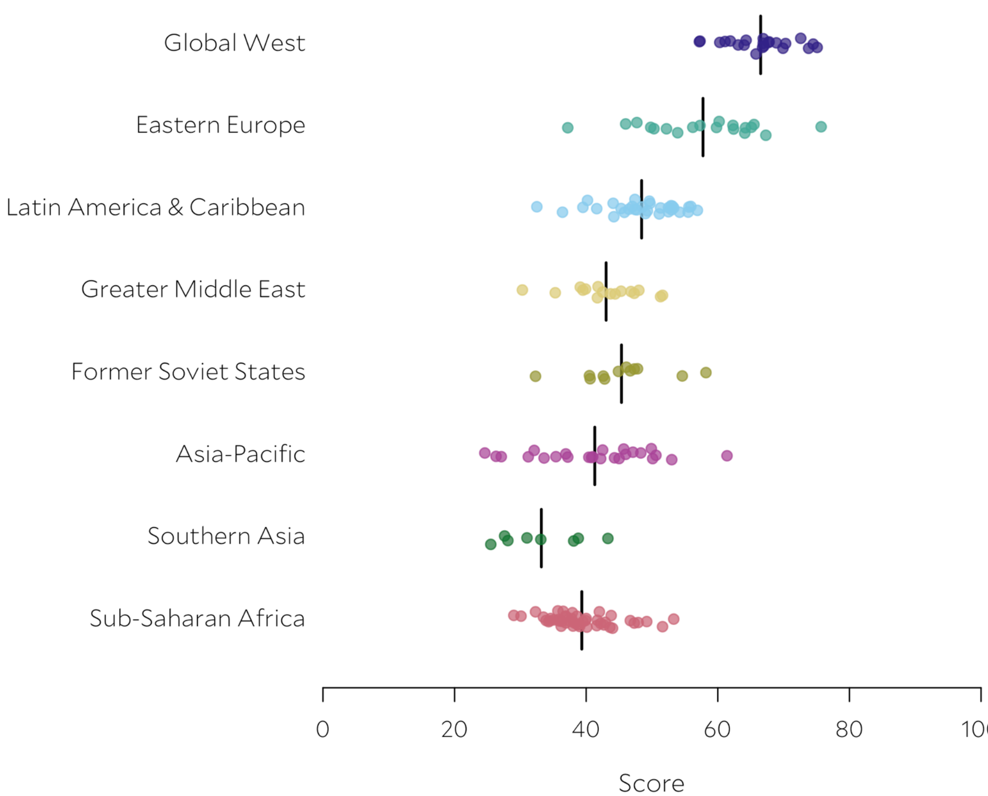
Guatemala earns the lowest EPI score in the region, with poor performance across all issue categories. While protected areas cover one fifth of Guatemala's land, they do not represent the full range of biodiversity in the country and have high rates of land use change. Marine protected areas cover less than 1 percent of Guatemala's exclusive economic zone and score low on stringency. The country is rapidly losing its forests, relies heavily on destructive fishing methods, has low air quality, poor waste management, and rapidly rising GHG emissions.

Former Soviet States

The Former Soviet States have the next highest median EPI score (45.5). Belarus, followed by Ukraine, are the two highest scoring countries in this region, generally outperforming other Former Soviet States by a wide margin. Over the last two decades, Belarus' forest cover has substantially expanded and the overall extinction risk of its species — captured by the *Red List Index* — has decreased faster than in any other country. Ukraine's score on Agriculture (76.4) is more than 13 points higher than the next best in the region, which goes to Azerbaijan (63.0). Ukraine also leads the region in climate change mitigation, although a sharp drop in its GHG emissions in 2022 is related to Russia's attacks on its energy infrastructure (Vatman and Hart 2024).

Tajikistan receives the lowest score among Former Soviet States (32.3), lagging far behind its peers across a broad range

Figure 2-6. Distribution of regional scores on the overall 2024 EPI. Vertical bars show regional averages.



of issues. The country's strategy to improve energy security has relied heavily on increasing coal power generation (IEA 2022) leading to an 80 percent increase in GHG emissions over the last decade and rising levels of air pollution. Tajikistan also scores poorly on solid waste and wastewater management, drinking water and sanitation and lead exposure.

Greater Middle East

The Greater Middle East region has a median EPI score of 43.1. Reflecting the wide range of income levels within the region, the performance of countries in the Greater Middle East varies substantially on some issue categories. For example, in Heavy Metals, Israel is ranked 1st globally, while Egypt ranks second to last. In wastewater management, wealthy countries in the Persian Gulf perform well — with high rates of wastewater collection, treatment, and reuse — but Sudan ranks in the bottom five.

The United Arab Emirates (UAE) gets the highest overall EPI score in the region (51.6), with Oman only 0.3 points behind. Both countries have large networks of protected areas that already cover more than 17 percent of their land and 10 percent of their exclusive economic zones. The UAE is the regional leader in wastewater treatment and reuse, while Oman is one of the few countries that have successfully banned bottom trawling in their exclusive economic zone and fishing fleet.

With appalling performance across most issue categories, Iraq gets the lowest EPI score in the region (30.3). Iraq's protected areas cover less than 2 percent of its land, its ecosystems are degraded, and its species face a relatively high extinction risk, all leading to a low score in Biodiversity & Habitat. Iraq is a major oil producer and its energy supply relies almost entirely on oil and gas (IEA 2021a). As a result, the country's GHG emissions have increased nearly 35 percent over the last decade. The country's heavy reliance on fossil fuels also leads to the worst levels of anthropogenic air pollution in the region, with serious consequences for public health and ecosystem vitality.

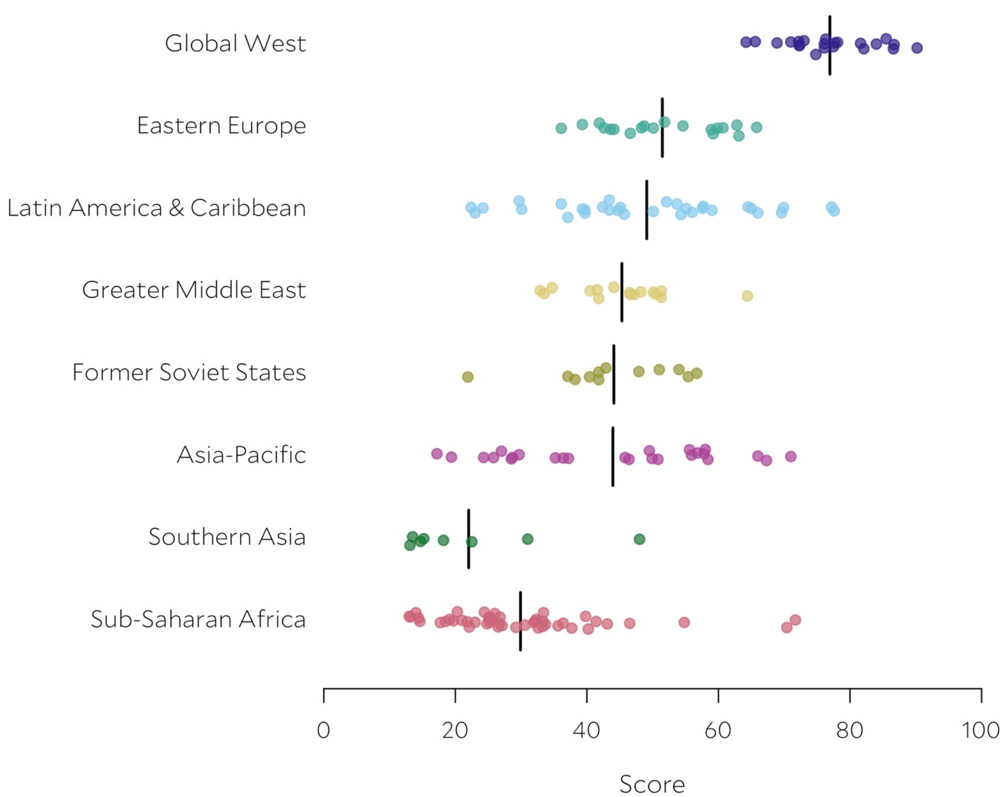
Asia-Pacific

Asia-Pacific is the third-lowest performing region, with median EPI score of 42.2. This is also the region with the highest variability in EPI scores, including countries in the top-third of the ranking, such as Japan (27th), Singapore (47th), and South Korea (58th), and in the very bottom, such as Myanmar (177th), Laos (178th), and Viet Nam (180th).

Japan receives the highest score in the region (61.4), with leadership in all three policy objectives. With protected areas covering almost 30 percent of its land, Japan has the lowest rate of loss of intact forest landscapes in the world. Japan earns top scores on Waste Management and Heavy Metals and has the best air quality in the region after Brunei and several Pacific Island nations. Japan is also a regional leader in climate change mitigation, with a 19 percent reduction in GHG emissions over the last decade.

At the bottom of the overall EPI ranking, Viet Nam faces a broad range of environmental challenges. Its increasing reliance on coal power generation has led to rapidly growing

Figure 2-7. Distribution of regional scores on Environmental Health. Vertical bars show regional averages.



emissions of air pollutants and greenhouse gases. Severe air pollution harms not only public health (Nhung et al. 2022), but also Vietnamese biodiversity already threatened by high rates of habitat loss.

Sub-Saharan Africa

Sub-Saharan Africa is the region with the second lowest median EPI score (38.4), with particularly poor performance on Environmental Health. In every policy objective, however, there is a wide variation in scores within Sub-Saharan Africa.

On Environmental Health, Seychelles gets a score of 71.7, ranking 21st out of 180 countries, with the best air quality in the region and second-highest score on Sanitation and Drinking Water. In contrast, Lesotho gets the lowest score on Environmental Health out of all countries assessed in the EPI, with some of the worst air quality, access to safe sanitation and drinking water, and lead exposure in the world.

On Ecosystem Vitality, Botswana ranks 8th globally thanks to its vast network of protected areas and pristine ecosystems, while Cabo Verde ranks 180th due to minimal coverage of protected areas, unsustainable agriculture, and severe air pollution.

On Climate Change, Zimbabwe ranks 28th globally thanks to a reduction in coal power generation over the last decade that led to a 12.4 percent drop in GHG emissions. In contrast, Mali ranks 179th due to a 50 percent increase in GHG emissions from 2013 to 2022. Despite this low score, the EPI team emphasizes that in a country where nearly half of the population does not have access to electricity, rising GHG emissions are expected. In the pilot indicator assessing projected GHG emission to 2050 relative to countries' allocated share of the remaining carbon budget, Mali ranks 89th out of 180 countries, above 10 countries in the Global West, including the Netherlands, Austria, Norway, and the United States.

Southern Asia

Southern Asia has the lowest regional EPI score (32.1), with several of the world's worst performers but also some notable outliers.

Bhutan is the highest-scoring country in Southern Asia, performing particularly well on Ecosystem Vitality. Bhutan's protected areas cover more than half of its land and is the world's top performer on the Forests issue category. On Environmental Health, however, Maldives outperforms all other countries in the region by at least 17 points. While Maldives has relatively good air quality, the rest of Southern Asia is the global hotspot of air pollution (Greenstone and Hasenkopf 2023). Maldives' remote location helps, as transboundary air pollution from coal-fired power generation is a serious problem in South Asia, with India being the main emitter of transboundary pollution, mostly affecting the residents of Bangladesh (Du et al. 2020).

Figure 2-8. Distribution of regional scores on Ecosystem Vitality. Vertical bars show regional averages.

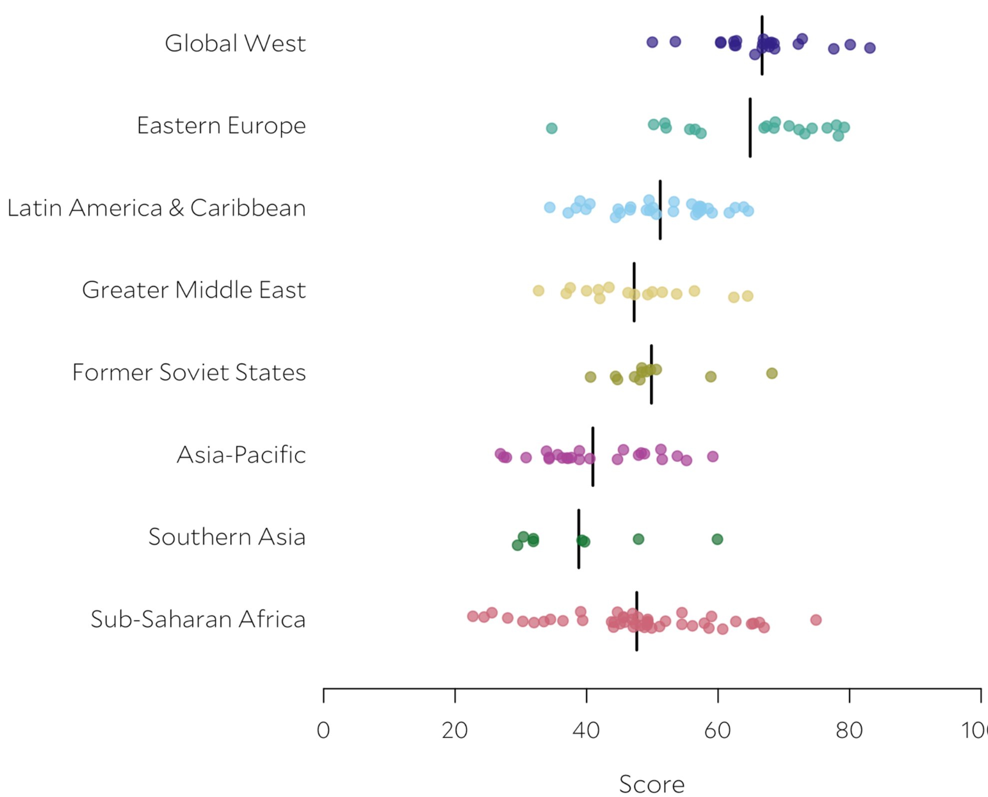
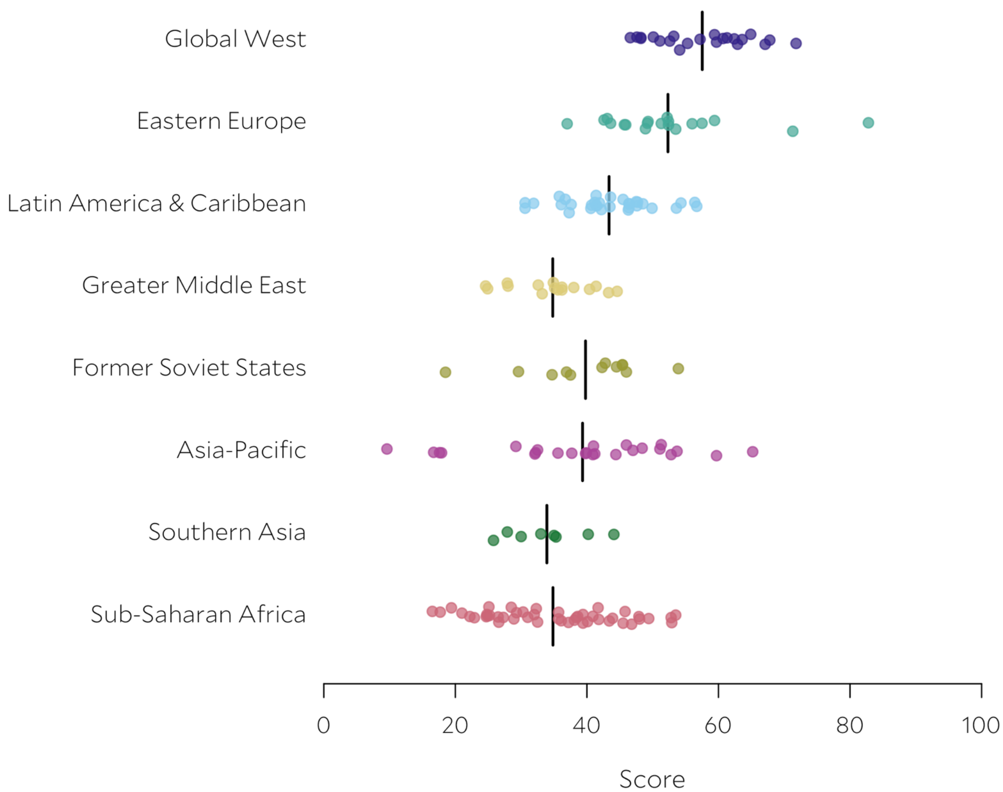


Figure 2-9. Distribution of regional scores on Climate Change. Vertical bars show regional averages.



Pakistan gets the lowest overall EPI score in Southern Asia, ranking 179th out of 180 countries. Coal-powered electricity generation has increased almost fivefold over the last decade (IEA 2021b), leading to a nearly 30 percent increase in GHG emissions and severe levels of air pollution. Pakistan is already suffering severe consequences from climate change, such as the extreme flooding that impacted 33 million people in 2022 (Otto et al. 2023). By prioritizing the expansion of renewable energy to decrease dependence on coal and other fossil fuels, Pakistan can make big improvements in public health and mitigate further climate disasters.

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Chapter 3. Climate Change Mitigation

1. Introduction

Society faces a climate emergency, marked by rapid warming, extreme weather events, and ecosystem collapse. World surface temperatures are already 1.1ºC warmer than pre-industrial levels, perhaps as much as 1.7 ºC according to the latest evidence (UNFCCC 2023b; McCulloch et al. 2024), and they keep rising. Current rates of warming are the highest in the past 24,000 years (Osman et al. 2021). The 10 warmest years on record have all occurred after 2010, and 2023 was the warmest of all (NOAA 2023a). Wildfires, heatwaves, and droughts have steadily increased. Ocean acidification and marine heatwaves are putting precious ecosystems such as coral reefs through enormous stress, seriously threatening their irreplaceable biodiversity. In 2024, the world experienced its fourth global coral bleaching event in record, and the second in the last decade (NOAA 2024b).

Climate change inflicts enormous economic and social costs. Climate disasters have already caused US$2.8 trillion worth of damage over the past 20 years (Newman and Noy 2023). Due to climate change, the world economy is already committed to an income reduction of 19 percent by 2050 (Kotz, Levermann, and Wenz 2024). Sea level rise threatens coastal and low-lying communities, while worsening droughts expose millions to water and food insecurity (IPCC 2023). Nearly half of the world population lives in regions highly vulnerable to climate change, and an estimated 1.2 billion people could become climate refugees by the middle of the century (IPCC 2023; IEP 2023).

Human activities, particularly the emission of greenhouse gases (GHGs), are the primary drivers of climate change (IPCC 2023). Atmospheric concentrations of carbon dioxide are the highest they have been in at least two million years, ensuring that, even absent any further emissions, global temperatures will continue to rise (IPCC 2023). As of 2023, climatic models estimate that to have a 50 percent chance of limiting warming to 1.5 ºC, global society can emit at most another 250 billion tonnes of carbon dioxide, equivalent to only six more years at the current pace of emissions (Lamboll et al. 2023). This means that global emissions should be dropping rapidly. Yet nearly a decade after the signing of the 2015 Paris Climate Change Agreement, GHG emissions are still rising.

Immediate action to reverse this trend is imperative given that the world may be nearing a series of dangerous tipping points in the climate system (Lenton et al. 2023). For instance, global warming drives thawing of permafrost, which releases vast volumes of buried carbon, further exacerbating warming (Natali et al. 2021). Freshwater from melting glaciers in Greenland is reducing the salinity of the Atlantic Ocean, which weakens the North Atlantic meridional overturning circulation and could eventually cause its entire collapse, leading to a plummeting of temperatures in Western Europe and rapid local climate change around the planet (Ditlevsen and Ditlevsen 2023).

Since the release of the last EPI in 2022, the world has made important progress in climate change mitigation. At COP27 in 2022, nations took the pivotal step to establish a “loss and damage” fund to aid the most vulnerable countries in facing climate disasters (UNFCCC 2022). And at COP28 in 2023, parties took the historic — though much delayed — step of agreeing to transition away from fossil fuels (UNFCCC 2023a). Investments in solar energy surpassed oil production for the first time in 2023, and renewable energy sources across the board are becoming more competitive (IEA 2023d). Electric vehicle sales achieved a 35 percent year-on-year increase in 2023, and green construction and agricultural innovations are being experimented with all over the world (IEA 2023d). Perhaps most importantly, global awareness of climate change and willingness to reduce emissions has never been higher. According to a recent survey across 125 countries, more than two thirds of people are willing to contribute 1 percent of their personal income to support climate action, 86 percent endorse pro-climate social norms, and 89 percent demand intensified political action (Andre et al. 2024). If these trends continue, global GHG emissions could start falling in 2024 (Fyson et al. 2023).

The Environmental Performance Index assesses the effectiveness of 180 countries in mitigating climate change, relying on historical greenhouse gas emissions data rather than stated goals or plans. The Climate Change Mitigation scores offer a holistic view of each country’s climate efforts, with component indicators shedding light on areas ripe for improvement and illustrating how factors like geography and economy impact climate outcomes. The findings are stark, revealing that—out of the countries in which policy has led to emission reductions over the last decade—only Estonia cut its emissions at the pace required to reach net-zero by 2050 while staying close to its allocated share of the global carbon budget. The data also uncover significant disparities in climate performance across countries, even within similar geographic regions, suggesting ample room for improvement among climate laggards. By packaging climate performance data in an accessible way, the EPI provides insights on the effectiveness of national policies, highlighting major contributors to climate change and motivating more aggressive action from policymakers, activists, and every global citizen.

2. Indicators

GHG trend adjusted by proximity to targets
(40% of issue category)
Average annual growth rate in greenhouse gas emissions over the last decade, adjusted to account for declines in GDP and for how close countries are to a target of zero absolute emissions. We use two equally weighted variants of this indicator. In one, the absolute target is based on per capita emissions (20% of issue category). In the other, the absolute target is based on emissions intensity of GDP (20% of issue category).

Adjusted emission growth rates
(52% of issue category)
Average annual growth rate of emissions of major greenhouse gases and black carbon over the last decade, adjusted to account for economic trends, rewarding decoupling and penalizing recessions.

- Carbon dioxide (CO_2)
    - Global target (25% of issue category)
    - Country-specific targets based on allocated shares of remaining carbon budget (2% of issue category)
- Methane (CH_4) (10% of issue category)
- Nitrous oxide (N_2O) (3% of issue category)
- Fluorinated gases (7% of issue category)
- Black carbon (5% of issue category)

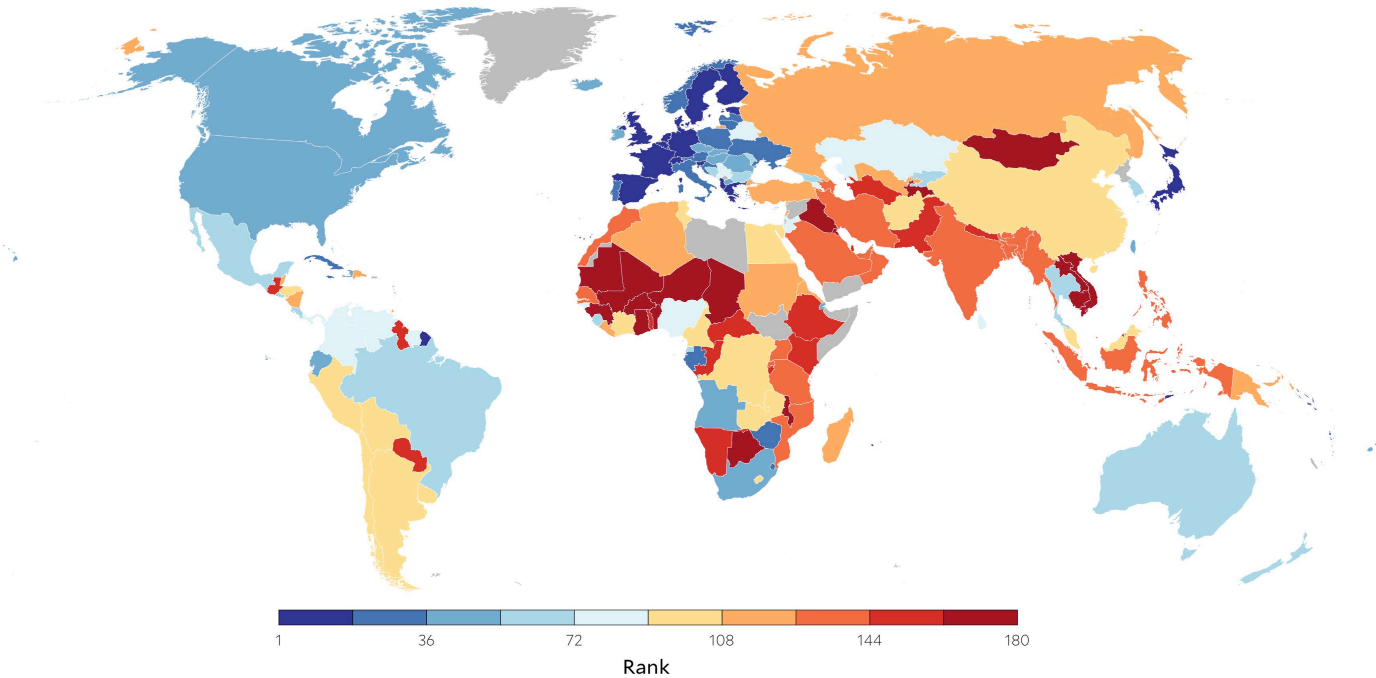
Projected emissions
(5% of issue category)
Emissions of major greenhouse gases (CO_2, CH_4, N_2O, and fluorinated gases) projected linearly to 2050 based on their average annual growth rate over the last decade. We derive two indicators from this projection.

- Projected GHG emissions in 2050: Scores are based on countries' projected GHG emission levels in 2050, showing whether the pace of emission reductions over the last decade is sufficient for countries to achieve their net-zero targets. (3% of issue category)

- Projected cumulative GHG emissions to 2050 relative to carbon budget: Scores are based on the cumulative GHG emissions between 2023 and 2050 relative to countries' allocated share of the remaining carbon budget. This pilot indicator underscores that the amount of GHG countries emit in their journey to net-zero is as — or more — important than *when* they reach net-zero. (2% of issue category)

Net carbon fluxes from land use, land cover change and forestry
(3% of issue category)
Sum of carbon fluxes (both emissions and sinks) from land use, land cover change, and forestry over the last decade, relative to countries' forested area.

Map 3-1. Global rankings on Climate Change Mitigation.



Map 3-2. Climate Change Mitigation scores.

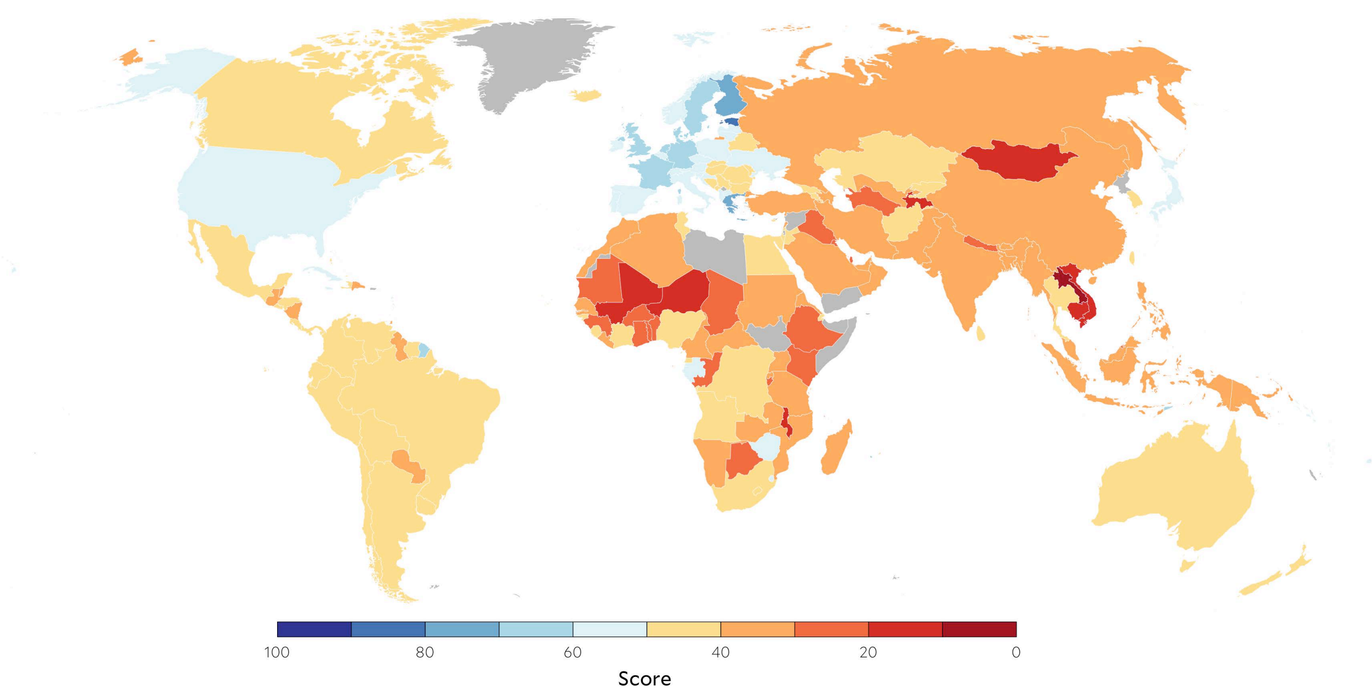


Table 3-1. Global rankings, scores, and regional rankings (REG) on Climate Change Mitigation issue category.

RANK	COUNTRY	SCORE	REG
1	Estonia	82.8	1
2	Finland	71.8	1
3	Greece	71.3	2
4	United Kingdom	67.8	2
5	Denmark	67.1	3
6	Timor-Leste	65.2	1
7	Germany	64.9	4
8	Malta	63.6	5
9	Sweden	62.9	6
10	Luxembourg	62.4	7
11	France	61.3	8
12	Netherlands	60.7	9
13	Belgium	59.7	10
13	Japan	59.7	2
15	Albania	59.4	3
15	Switzerland	59.4	11
17	Slovenia	57.5	4
18	Spain	57.2	12
19	Barbados	56.7	1
20	Cuba	56.4	2
21	Croatia	56.0	5
22	Portugal	55.3	13
23	Jamaica	54.3	3
24	Austria	54.1	14
25	Ukraine*	53.9	1
26	Vanuatu	53.7	3
27	Dominica	53.6	4
28	Poland	53.5	6
28	Zimbabwe	53.5	1
30	Italy	53.2	15
31	Eswatini	52.9	2
32	Gabon	52.8	3
32	Solomon Islands	52.8	4
34	Norway	52.6	16
35	Latvia	52.4	7
35	Lithuania	52.4	7
37	Czech Republic	52.2	9
38	North Macedonia	51.3	10
38	Samoa	51.3	5
40	Fiji	51.1	6
40	Ireland	51.1	17
42	United States of America	50.1	18
43	St. Vincent and Grenadines	49.9	5
44	Angola	49.4	4
45	Romania	49.3	11
46	Hungary	49.2	12
47	Slovakia	48.9	13
48	Ecuador	48.5	6
49	Taiwan	48.4	7
50	Canada	48.2	19
50	Iceland	48.2	19
52	South Africa	48.0	5
53	Djibouti	47.9	6
54	Haiti	47.7	7
55	Bahamas	47.6	8
55	New Zealand	47.6	21
57	Saint Lucia	47.5	9
58	South Korea	47.0	8
59	Sierra Leone	46.8	7
60	Australia	46.6	22
61	Antigua and Barbuda	46.4	10
61	El Salvador	46.4	10
61	Mexico	46.4	10
64	Costa Rica	46.3	13
65	Georgia	46.0	2
65	Thailand	46.0	9
67	Bosnia and Herzegovina	45.9	14
68	Mauritius	45.8	8
69	Bulgaria	45.7	15
70	Brazil	45.5	14
70	Equatorial Guinea	45.5	9
72	Kyrgyzstan	45.4	3
72	Moldova	45.4	3
74	Jordan	44.6	1
75	Belarus	44.5	5
76	Micronesia	44.4	10
77	Sri Lanka	44.1	1
78	Nigeria	43.9	10
79	Serbia	43.6	16
79	Suriname	43.6	15
81	Venezuela	43.5	16
82	Cabo Verde	43.4	11
83	Israel	43.3	2
84	Montenegro	43.1	17
85	Armenia	42.8	6
86	Cyprus	42.6	18
87	Kazakhstan	42.3	7
88	Colombia	42.2	17
89	Panama	41.9	18
90	Guinea-Bissau	41.8	12
91	Lesotho	41.7	13
92	Chile	41.5	19
93	Argentina	41.4	20
93	Bolivia	41.4	20
93	Tunisia	41.4	3
96	Honduras	41.2	22
96	Singapore	41.2	11
98	Marshall Islands	41.0	12
99	Côte d'Ivoire	40.9	14
99	Kiribati	40.9	13
101	Peru	40.7	23
102	Uruguay	40.6	24
103	Egypt	40.4	4
104	Afghanistan	40.2	2
105	Dem. Rep. Congo	40.1	15
106	Malaysia	39.9	14
107	China	39.8	15
108	Cameroon	39.4	16
108	Zambia	39.4	16
110	São Tomé and Príncipe	38.6	18
111	Liberia	38.4	19
112	Eritrea	38.1	20
113	Lebanon	38.0	5
114	Papua New Guinea	37.7	16
115	Nicaragua	37.6	25
116	Uzbekistan	37.5	8
117	Dominican Republic	37.3	26
118	Gambia	37.2	21
119	Türkiye	37.0	19
120	Russia	36.9	9
121	Grenada	36.7	27
122	Algeria	36.2	6
122	Sudan	36.2	6
124	Madagascar	36.1	22
124	Trinidad and Tobago	36.1	28
126	Belize	35.8	29
127	Mozambique	35.7	23
127	Uganda	35.7	23
129	Myanmar	35.6	17
129	United Arab Emirates	35.6	8
131	Bhutan	35.3	3
132	Iran	35.1	9
133	India	35.0	4
134	Morocco	34.9	10
135	Azerbaijan	34.7	10
136	Saudi Arabia	33.2	11
137	Bangladesh	33.0	5
138	Oman	32.6	12
139	Tanzania	32.5	25
139	Tonga	32.5	18
141	Rwanda	32.3	26
142	Philippines	32.2	19
143	Indonesia	32.1	20
144	Senegal	32.0	27
145	Paraguay	31.9	30
146	Central African Republic	31.0	28
147	Guatemala	30.6	31
147	Guyana	30.6	31
149	Namibia	30.3	29
150	Pakistan	30.0	6
151	Turkmenistan	29.6	11
152	Republic of Congo	29.3	30
153	Brunei Darussalam	29.2	21
154	Ethiopia	28.9	31
155	Togo	28.5	32
156	Qatar	28.0	13
157	Bahrain	27.9	14
157	Maldives	27.9	7
159	Seychelles	27.3	33
160	Burundi	26.6	34
161	Kenya	26.5	35
162	Nepal	25.8	8
163	Comoros	25.2	36
164	Botswana	25.1	37
165	Burkina Faso	24.9	38
165	Kuwait	24.9	15
167	Mauritania	24.8	39
168	Ghana	24.7	40
169	Iraq	24.6	16
170	Benin	22.9	41
171	Guinea	22.2	42
172	Chad	21.0	43
173	Niger	19.4	44
174	Tajikistan	18.5	12
175	Viet Nam	17.9	22
176	Malawi	17.7	45
177	Mongolia	17.6	23
178	Cambodia	16.7	24
179	Mali	16.5	46
180	Laos	9.6	25

* The Russian invasion led to a sharp decline in economic activity, energy use, and associated GHG emissions in the Ukraine in 2022, so this score might not accurately reflect performance.

Asia-Pacific | Eastern Europe | Former Soviet States | Global West | Greater Middle East | Latin America & Caribbean | Southern Asia | Sub-Saharan Africa

Table 3-2. Regional rankings and scores on Climate Change Mitigation.

Latin America & Caribbean		
Country	Score	Rank
Barbados	56.7	1
Cuba	56.4	2
Jamaica	54.3	3
Dominica	53.6	4
St. Vincent and Grenadines	49.9	5
Ecuador	48.5	6
Haiti	47.7	7
Bahamas	47.6	8
Saint Lucia	47.5	9
Antigua and Barbuda	46.4	10
El Salvador	46.4	10
Mexico	46.4	10
Costa Rica	46.3	13
Brazil	45.5	14
Suriname	43.6	15
Venezuela	43.5	16
Colombia	42.2	17
Panama	41.9	18
Chile	41.5	19
Argentina	41.4	20
Bolivia	41.4	20
Honduras	41.2	22
Peru	40.7	23
Uruguay	40.6	24
Nicaragua	37.6	25
Dominican Republic	37.3	26
Grenada	36.7	27
Trinidad and Tobago	36.1	28
Belize	35.8	29
Paraguay	31.9	30
Guatemala	30.6	31
Guyana	30.6	31

Eastern Europe		
Country	Score	Rank
Estonia	82.8	1
Greece	71.3	2
Albania	59.4	3
Slovenia	57.5	4
Croatia	56.0	5
Poland	53.5	6
Latvia	52.4	7
Lithuania	52.4	7
Czech Republic	52.2	9
North Macedonia	51.3	10
Romania	49.3	11
Hungary	49.2	12
Slovakia	48.9	13
Bosnia and Herzegovina	45.9	14
Bulgaria	45.7	15
Serbia	43.6	16
Montenegro	43.1	17
Cyprus	42.6	18
Türkiye	37.0	19

Southern Asia		
Country	Score	Rank
Sri Lanka	44.1	1
Afghanistan	40.2	2
Bhutan	35.3	3
India	35.0	4
Bangladesh	33.0	5
Pakistan	30.0	6
Maldives	27.9	7
Nepal	25.8	8

Global West		
Country	Score	Rank
Finland	71.8	1
United Kingdom	67.8	2
Denmark	67.1	3
Germany	64.9	4
Malta	63.6	5
Sweden	62.9	6
Luxembourg	62.4	7
France	61.3	8
Netherlands	60.7	9
Belgium	59.7	10
Switzerland	59.4	11
Spain	57.2	12
Portugal	55.3	13
Austria	54.1	14
Italy	53.2	15
Norway	52.6	16
Ireland	51.1	17
United States of America	50.1	18
Canada	48.2	19
Iceland	48.2	19
New Zealand	47.6	21
Australia	46.6	22

Former Soviet States		
Country	Score	Rank
Ukraine*	53.9	1
Georgia	46.0	2
Kyrgyzstan	45.4	3
Moldova	45.4	3
Belarus	44.5	5
Armenia	42.8	6
Kazakhstan	42.3	7
Uzbekistan	37.5	8
Russia	36.9	9
Azerbaijan	34.7	10
Turkmenistan	29.6	11
Tajikistan	18.5	12

Asia-Pacific		
Country	Score	Rank
Timor-Leste	65.2	1
Japan	59.7	2
Vanuatu	53.7	3
Solomon Islands	52.8	4
Samoa	51.3	5
Fiji	51.1	6
Taiwan	48.4	7
South Korea	47.0	8
Thailand	46.0	9
Micronesia	44.4	10
Singapore	41.2	11
Marshall Islands	41.0	12
Kiribati	40.9	13
Malaysia	39.9	14
China	39.8	15
Papua New Guinea	37.7	16
Myanmar	35.6	17
Tonga	32.5	18
Philippines	32.2	19
Indonesia	32.1	20
Brunei Darussalam	29.2	21
Viet Nam	17.9	22
Mongolia	17.6	23
Cambodia	16.7	24
Laos	9.6	25

Sub-Saharan Africa		
Country	Score	Rank
Zimbabwe	53.5	1
Eswatini	52.9	2
Gabon	52.8	3
Angola	49.4	4
South Africa	48.0	5
Djibouti	47.9	6
Sierra Leone	46.8	7
Mauritius	45.8	8
Equatorial Guinea	45.5	9
Nigeria	43.9	10
Cabo Verde	43.4	11
Guinea-Bissau	41.8	12
Lesotho	41.7	13
Côte d'Ivoire	40.9	14
Dem. Rep. Congo	40.1	15
Cameroon	39.4	16
Zambia	39.4	16
São Tomé and Príncipe	38.6	18
Liberia	38.4	19
Eritrea	38.1	20
Gambia	37.2	21
Madagascar	36.1	22
Mozambique	35.7	23
Uganda	35.7	23
Tanzania	32.5	25
Rwanda	32.3	26
Senegal	32.0	27
Central African Republic	31.0	28
Namibia	30.3	29
Republic of Congo	29.3	30
Ethiopia	28.9	31
Togo	28.5	32
Seychelles	27.3	33
Burundi	26.6	34
Kenya	26.5	35
Comoros	25.2	36
Botswana	25.1	37
Burkina Faso	24.9	38
Mauritania	24.8	39
Ghana	24.7	40
Benin	22.9	41
Guinea	22.2	42
Chad	21.0	43
Niger	19.4	44
Malawi	17.7	45
Mali	16.5	46

Greater Middle East		
Country	Score	Rank
Jordan	44.6	1
Israel	43.3	2
Tunisia	41.4	3
Egypt	40.4	4
Lebanon	38.0	5
Algeria	36.2	6
Sudan	36.2	6
United Arab Emirates	35.6	8
Iran	35.1	9
Morocco	34.9	10
Saudi Arabia	33.2	11
Oman	32.6	12
Qatar	28.0	13
Bahrain	27.9	14
Kuwait	24.9	15
Iraq	24.6	16

* The Russian invasion led to a sharp decline in economic activity, energy use, and associated GHG emissions in the Ukraine in 2022, so this score might not accurately reflect performance.

3. Global Trends

Concerted global climate action since the Paris Climate Change Agreement has slowed the rate of growth of GHG emissions. Indeed, GHG emissions may have peaked in 2023 (Fyson et al. 2023). Yet at the current rate of emissions, the probability of limiting warming to 1.5 ºC will fall below 50 per-cent before 2030 (Lamboll et al. 2023). As of 2022, aggregated GHG emissions were falling in 60 countries but still rising in 128. This is a modest improvement from 2015, the year the Paris Agreement was signed, when 136 nations had GHG rising emissions, but it is still woefully inadequate considering our rapidly shrinking carbon budget (Friedlingstein et al. 2023). Global GHG missions must drop quickly.

In the 2024 EPI, the Global West and Eastern Europe lead the world in average regional climate change mitigation scores, while the Greater Middle East and Southern Asia have the low-est average scores (Figure 3-1). The EPI scores reflect only countries' recent climate mitigation performance and do not measure countries' historic responsibility for climate change, which can be measured by the cumulative sum of countries' historical CO_2 emissions (Figure 3-2). Though regions such as the Global West lead the world in current performance, it is critical to underscore that their greater historical emissions and current capabilities give them a bigger responsibility to address climate change. Furthermore, while developed nations have promised to assist developing nations financially in their climate change mitigation efforts, these promises have fallen short by tens of billions of dollars (Timperley 2021). The Global West must focus not just on curbing its own emissions but also on helping the entire world shift to a greener future.

Figure 3-2. A few countries are responsible for most of current climate change.

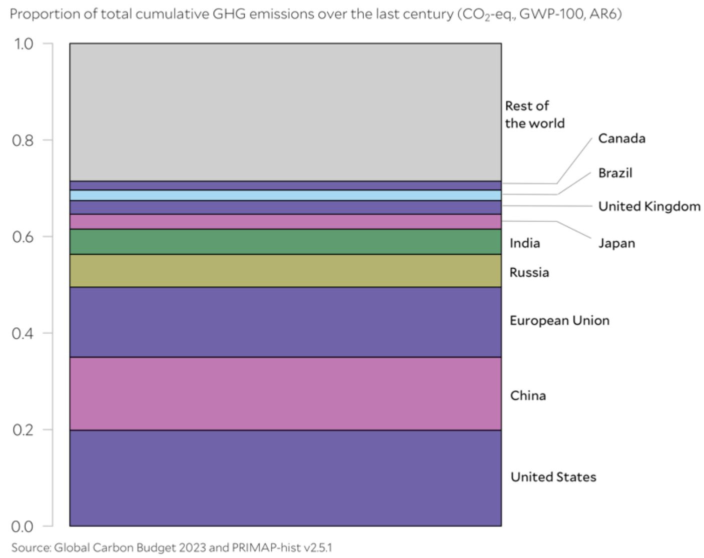
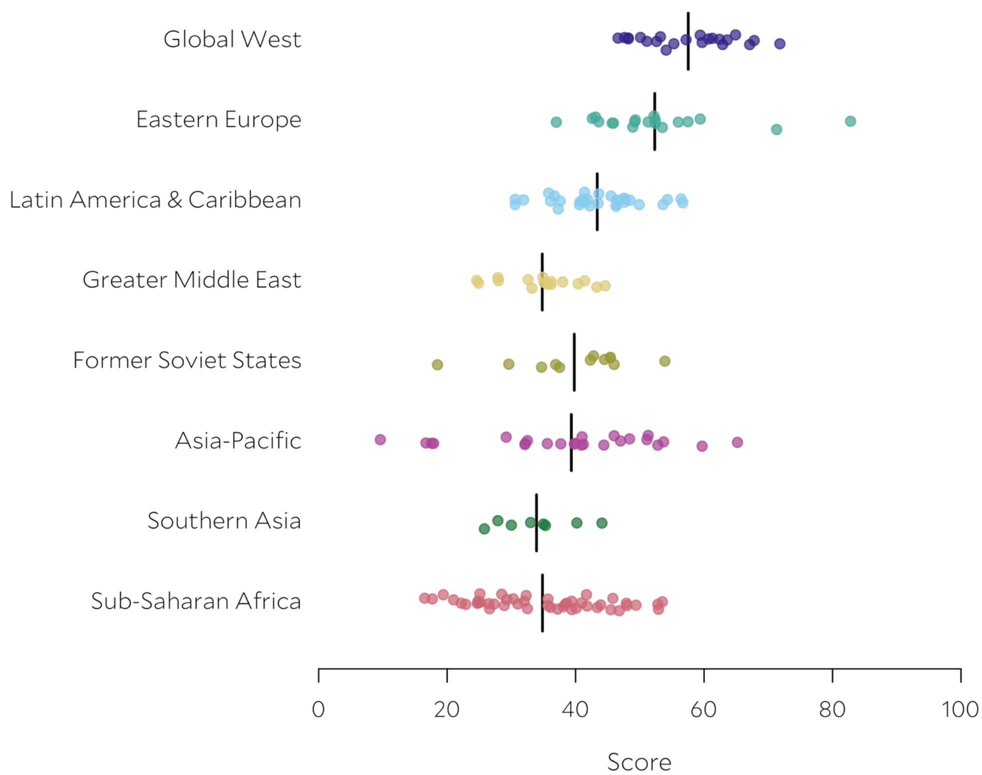


Figure 3-1. Distribution of regional scores on Climate Change Mitigation. Vertical bars show regional averages.



Climate change mitigation performance varies more within than between regions. Zimbabwe, for example, not only outperforms all its Sub-Saharan peers but also several countries in the Global West, such as the United States, Norway, and Italy. Zimbabwe's strong performance is due in part to a surge in biofuel utilization that helped the country reduce its coal energy consumption, and its energy-related per capita CO_2 emissions by half between 2000 and 2021 (IEA 2021e). This shift towards a greener energy portfolio was facilitated by Zimbabwe's proactive biofuels policy, which also spurred economic development and enhanced energy security (FAO 2020). Zimbabwe, along with other regional leaders, demonstrates that countries in diverse geographic and socioeconomic circumstances can contribute toward a safer climate future.

Climate Pollutant Trends

Climate change is fueled by key greenhouse gases, such as CO_2, CH_4, N_2O, and fluorinated gases, and aerosols, such as black carbon, each posing unique challenges for mitigation requiring targeted strategies.

While each molecule of CO_2 has a lower warming potential than other greenhouse gases, the scale of CO_2 emissions — 20 times greater than all other major greenhouse gases combined — and its long lifetime in the atmosphere — spanning centuries — make it a key driver of climate change. Human activities, namely the combustion of fossil fuels, of which CO_2 is an inevitable byproduct, have caused a nearly 50 percent of the increase in CO_2 levels in the atmosphere since the industrial revolution, with atmospheric concentration surpassing 426 parts per million in April 2024 — a level higher than at any point in human history (NOAA 2024a).

Besides its atmospheric warming effects, CO_2 is also the main driver of ocean acidification, posing a double threat to marine ecosystems (Doney et al. 2009). Rapidly reducing CO_2 emissions is a priority for climate change mitigation efforts. So far, progress in this area is vastly insufficient. Only in the Global West region have CO_2 emissions declined over the last decades —albeit much too slowly — but this progress has been more than offset by increasing emissions elsewhere, especially in Asia (Figure 3-3). Efforts to decarbonize the economy can also provide the impetus for growth and savings. For example, electrification of homes can lead to significant savings in energy and appliance maintenance (Billimoria et al., n.d.), and in 2022, approximately 86 percent of newly commissioned renewable energy capacity had lower costs than fossil fuel alternatives (IRENA 2023). There is clearly huge potential, and desperate need, for rapid CO_2 emission reductions.

Methane, a potent greenhouse gas, has been responsible for approximately one third of global temperature rises since the industrial revolution, ranking just behind CO_2 (IEA 2023b). Over the past decade, global methane emissions rose 7.6 percent, with especially pronounced growth in the Asia-Pacific region (Figure 3-4). Faulty fossil fuel exploration, production, and transportation equipment led to 1000 super-emitting methane leaks in 2022 alone (Carrington 2023a). Other important human sources of methane include agriculture, especially enteric fermentation in ruminant livestock such as cattle, sheep and goats, and decomposition of waste in landfills (Saunois et al. 2020). Methane's global warming potential exceeds that of CO_2 by 28 times over a 100-year time horizon, though it resides in the atmosphere for a much shorter period (ERCE 2023). Due to methane's strong, short-term warming effects, reducing methane emissions can be especially helpful in mitigating warming within the next few decades, buying society time to reduce other sources of GHGs (Wood et al. 2023). The international community underscored the significance of methane in combating climate change through the 2021 Global Methane Pledge, committing to a reduction of methane emissions by at least 30 percent from 2020 levels by 2030 (GMP 2021). However, our analysis shows that only seven countries are on track to meet the goals of the Global Methane Pledge.

Figure 3-3. CO_2 emissions by region since 1980.

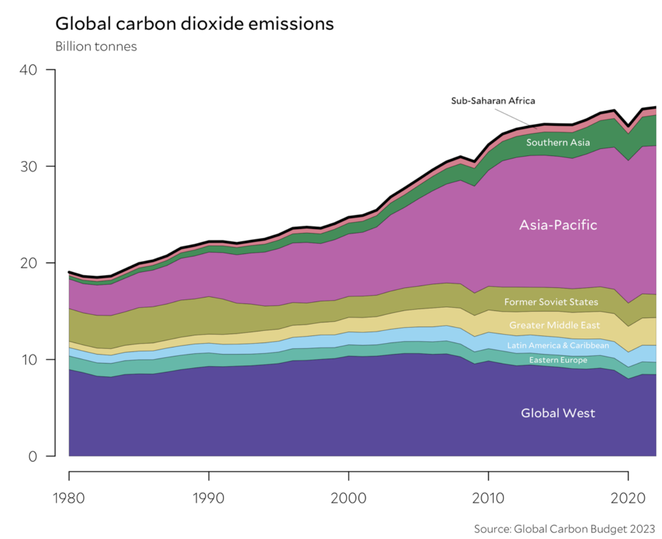


Figure 3-4. CH_4 emissions by region since 1980.

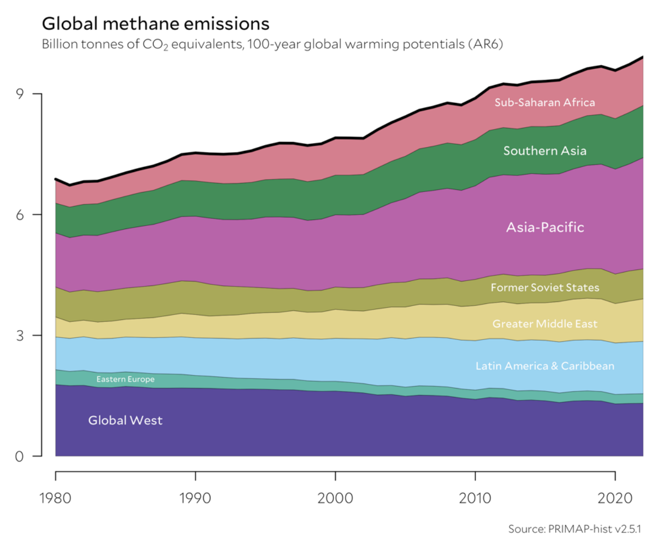


Figure 3-5. N_2O emissions by region since 1980.

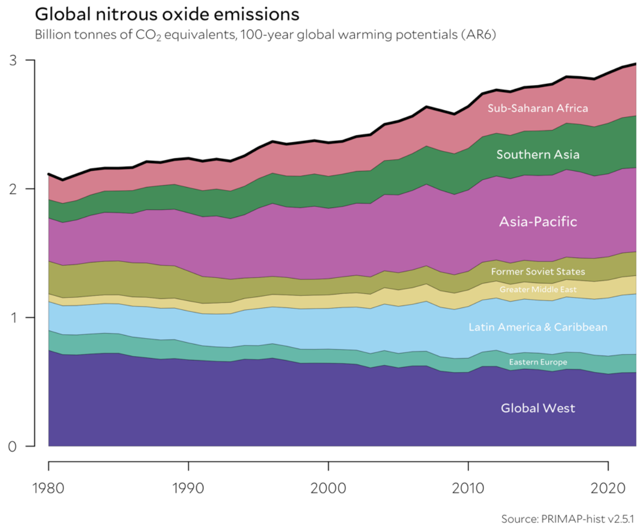
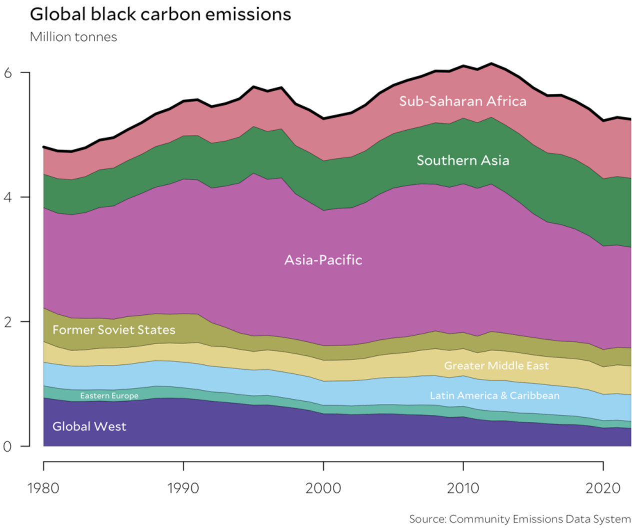


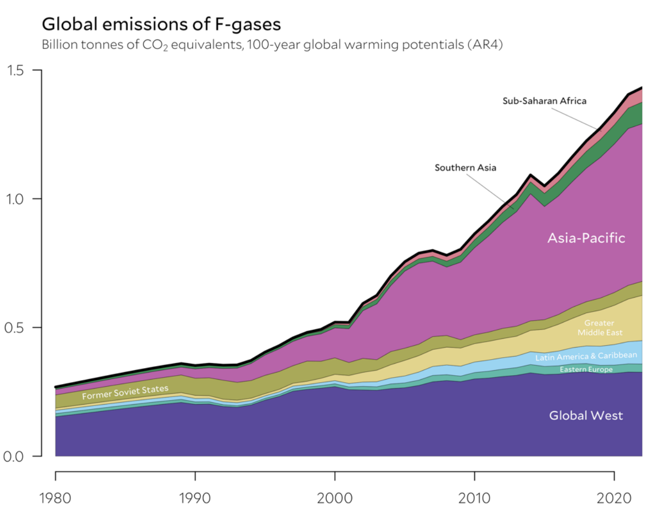
Figure 3-7. Black carbon emissions by region since 1980.



And the methane reductions in at least one of them, Timor-Leste, seem to stem from natural resource constraints rather than a strong climate agenda (EITI 2014; Timor-Leste's State Secretariat for Environment 2014). Aggressive action on methane, including fixing methane leaks, adopting more sustainable agricultural practices, and transitioning away from fossil fuels, are urgently needed to fulfill commitments to the Global Methane Pledge.

Nitrous oxide, despite making up a smaller fraction of overall GHG emissions, has a global warming potential approximately 273 times greater than that of CO_2 over a 100-year period (ERCE 2023). Around half of anthropogenic N_2O emissions come from the use of chemical fertilizers and manure management in agriculture (Tian et al. 2020). Rapid growth in global agriculture has resulted in a 7.8 percent growth in N_2O emissions over the past decade (Figure 3-5). Atmospheric N_2O concentrations are now 24 percent higher than pre-industrial levels (NOAA 2023b). Improving the efficiency of nitrogen fertilizer use in agriculture (Gao and Cabrera Serrenho 2023) and investing in better, more accurate N_2O inventories are essential to feed a growing population without exacerbating climate change (Del Grosso et al. 2022).

Figure 3-6. F-gas emissions by region since 1980.



Fluorinated gases (F-gases), including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3), are potent greenhouse gases with global warming potentials that are 140 to many thousands of times more powerful than CO_2 (Sovacool et al. 2021). Used in refrigeration, air conditioning, and various industrial processes due to their stability and non-flammability, their extreme warming potential and longevity in the atmosphere pose serious climate risks. Among the greenhouse gases analyzed in the EPI, emissions of F-gases have increased the fastest in recent years, with a 40.8 percent increase over the last decade (Figure 3-6). F-gas emissions have risen so rapidly for two reasons. First, even as countries phase out the use of ozone-depleting substances under the Montreal Protocol, F-gases are the preferred substitutes in industrial applications. Second, demand for cooling and refrigeration has risen sharply, particularly in the Asia-Pacific region (Sovacool et al. 2021). While the global community has set goals to phase down HFCs in the Kigali Amendment to the Montreal Protocol, the lack of regulations regarding other F-gases represents a glaring loophole in climate change mitigation efforts and may have contributed to the rise in emissions (UNEP 2018; Sovacool et al. 2021). Reducing F-gas emissions involves transitioning to low-global warming potential alternatives in refrigeration and air conditioning, adopting good practices for leak prevention and equipment maintenance, and utilizing non-HFC substances, such as ammonia and carbon dioxide, in cooling systems (Purohit and Höglund-Isaksson 2017).

Black carbon, a component of soot, is primarily produced from incomplete combustion from engines, industrial sources, and heating and cooking (Rönkkö et al. 2023). It is a short-lived climate pollutant, and its global warming potential is uncertain but potentially hundreds of times stronger than carbon dioxide (Bond et al. 2013). Aside from its climate change effects, black carbon is also a major source of air pollution (Schmidt 2011). Fortunately, global black carbon emissions have decreased by more than 13 percent between 2013 and 2022 (Figure 3-7), largely driven by a sharp downward trend in China, which has seen emissions fall by around a third over this period (Kanaya et al. 2020; Hoesly and Smith 2024). Reducing black carbon emissions further would translate into immediate improvements in global warming and air quality.

As black carbon illustrates, besides releasing greenhouse gases into the atmosphere, the extraction and burning of fossil fuels is also a major source or air pollution that results in over five million annual excess deaths worldwide (Lelieveld et al. 2023; see also Chapter 4 of this report). Thus, one major co-benefit of phasing out fossil fuels and transitioning to cleaner energy sources will be improved air quality (Shi et al. 2021). In contrast to black carbon, however, some air pollutants released during the burning of fossil fuels, such as sulfate aerosols, *reflect* incoming solar radiation and have a *cooling* effect in the atmosphere (Wang et al. 2023). As levels of these cooling air pollutants go down, they will unmask the warming effect of greenhouse gases, worsening climate change (Wang et al. 2023). Indeed, the International Maritime Organization introduced regulations in 2020 that limit sulfur content in shipping fuels and are already improving air quality while intensifying warming trends (Diamond 2023).

4. Leaders and Laggards

New Global Leaders Emerge in Eastern Europe

Estonia stands out for its reduction in GHG emissions over the last decade. Estonia is the only country in which policy interventions achieved emission reductions that, *if* maintained, put the country on track to reach net-zero by 2050 without exceeding its allocated share of the remaining carbon budget. From 2013 to 2022, Estonia slashed its GHG emissions by 40 percent while simultaneously growing its economy and population, illustrating that countries can pursue decarbonization alongside economic growth. A key factor behind Estonia's environmental achievements has been the shift away from oil shale energy, despite it being a significant domestic resource and the largest energy source for the country (IEA 2021b). A pivotal moment in this journey was the decommissioning of major oil shale power plants in 2019, removing over 600 MW of capacity (ICIS 2018). The drive toward a greener economy in Estonia has been primarily influenced by high emissions allowance prices in the European Union and, to a lesser extent, by low electricity prices in the late 2010s, which made fossil fuels less economically competitive (Estonian Environmental Research Center 2022). The Estonian government has also promoted renewable energy sources like solar, wind, and, especially, forest biomass, aiming for a renewable energy supply that meets 100 percent of its electricity needs by 2030 (IEA 2021b). This ambition has led to renewables growing from 16.1 percent of the energy mix in 2006 to 30.2 percent in 2020 (Estonian Environmental Research Center 2022).

Despite a minor increase in emissions in 2022 and 2023, due to rising electricity prices and economic recovery post-COVID-19, Estonia has not wavered in its commitment to climate change mitigation, setting even more ambitious targets (IEA 2021b). In 2023, Estonia consolidated various government bodies into the new Ministry of Climate, granting it extensive powers to support the energy transition (Euronews 2023). Additionally, Estonia is preparing to enact a comprehensive climate law in January 2025, which will establish legally binding climate mitigation goals (Euronews 2023). To ensure a just transition, particularly for communities dependent on oil shale, Estonia has developed a Territorial Just Transition Plan, ensuring widespread support for its climate initiatives (IEA 2023a). Estonia's approach highlights how stringent measures against high-emission industries, coupled with focused encouragement of renewable energy, can lead to a successful and sustainable energy transformation.

Greece is another Eastern European country with a substantial drop in greenhouse gas emissions over the last decade. A major factor behind this drop in emissions is the phasing out of brown coal—or lignite—in electricity production. From 2005 to 2021, the share of coal-generated electricity in Greece fell from 60 to 10 percent (IEA 2023c). This phase out is bound to continue, as Greece's National Climate Law, adopted in 2022, sets targets to completely end lignite's use by 2028 (Reuters 2022). Lignite electricity generation has been replaced primarily with natural gas, as well as growth in wind energy and photovoltaics (IEA 2023c). In 2022, Greece also adopted its Offshore Wind Law, which aims to generate 2 gigawatts of electricity by 2030 (Tang 2022). This law may help Greece make progress toward the targets in its National Climate Law of reducing total GHG emissions 55 percent by 2030, 80 percent by 2040, and achieving net-zero by 2050. According to the International Energy Agency's 2023 review of Greece's energy policy (IEA 2023c), to accelerate its energy transition, Greece aims to reduce the time needed for licensing and permitting of renewable energy projects.

Greece also aims to modernize its building and vehicle stock, among the oldest in the European Union, with stricter building codes, incentives for thermal renovations, and the replacement of appliances with more efficient ones. From 2025, the installation of oil boilers in buildings will no longer be allowed. Greece is already a leader in the use of solar thermal energy to cover building hot water demand (Argiriou and Mirasgedis 2003). Greece will also introduce subsidies and fiscal measures to promote the adoption of electric vehicles, and local authorities are obliged to promote the use of public transit, cycling, and walking. Despite its remarkable progress, however, there is still room for major improvements in Greece's climate policy. Greece has relied heavily on natural gas to replace coal-generated electricity and invested heavily in gas infrastructure. Moreover, while Greece's subsidies for fossil fuels are going down, it still spends 1.9 billion Euro—over one quarter of energy tax revenue—among the highest in the OECD.

Greece's success in reducing emissions during times of economic recovery offers important lessons to other countries. Reeling from the consequences of the 2008–2009 debt crisis, Greece's economic recovery is, in part, driven by substantial climate investment (Alderman and Vourloumis 2021). Denmark and Finland, two European countries with effective climate policy and strong emission declines, have restructured their already-strong economies to combat climate change. If Greece can continue to do the same with a smaller—though rapidly growing—economy, its decarbonization path can be an important model for others.

Global Laggards in Rapidly Developing Southeast Asia

Laos ranks last in the 2024 EPI Climate Change Mitigation issue category, primarily due to a staggering 444 percent increase in carbon dioxide emissions over the last decade (Friedlingstein et al. 2023). Historically, Laos has relied on hydroelectric power for its energy needs, which continues to contribute about one-third to its energy supply (IEA 2021c). Between 2015 and 2021, however, coal-generated electricity in the country increased by 426 percent (IEA 2021c). Aiming to be the "battery of Southeast Asia," Laos has focused on electricity exports as a central element of its economic developmental strategy, coinciding with strong energy demand growth across Southeast Asia over the last decade (Chin and Wan 2022). Yet the increasing frequency and severity of droughts in Laos, partly attributed to climate change, have compromised its hydroelectric potential, prompting for the switch to alternative, dirtier energy sources (Ha 2020).

Laos' current energy path is unsustainable. Coal production has led to increased pollution, and international investors, including those from China and Singapore who backed the inaugural coal power projects in Laos, now shunning projects with high carbon footprints (Ha 2020). This situation exemplifies the broader challenge faced by emerging economies in juggling the objectives of sustainability and economic expansion. Although renewable energy can be more cost-effective than fossil fuels over time, the immediate lack of capital and technical know-how can push these nations toward readily available but environmentally harmful energy sources like coal. Developed countries urgently need to actualize their Paris Climate Change Agreement commitments to extend both technical and financial support to foster sustainable economic development (Kyophilavong 2023).

Laos' neighbor, Vietnam, is another notable climate change laggard in the 2024 EPI, also mainly driven by its rapid increase in coal usage, which nearly tripled over the last decade (IEA 2021d). During this period, Vietnam's economy — especially its industrial sector — expanded rapidly, causing its total energy consumption to double between 2010 and 2020 (Enerdata 2024), largely supplied by coal. The government has recognized the need to place its growth on a more sustainable footing, announcing in 2021 that it planned to achieve carbon neutrality by 2050 (Petty and Miglani 2021). One example of Vietnam's renewable energy ambitions is its solar feed-in-tariff, which offers heavy financial subsidies for photovoltaic electricity and has prompted a rapid growth in solar panel installations (Le 2022). However, the national electric grid has struggled to adapt to the boom in renewables, and many solar panels need to be disconnected during peak sunshine hours (Le 2022). Similarly, heatwaves in 2023 hampered the production of hydroelectricity, leading to increased reliance on coal (Lee, Iskandar, and Islam 2023; Guarascio and Vu 2024). More generally, the investment in renewables has not kept up with rapid economic expansion, so while Vietnam's carbon intensity—tonnes of CO_2 emissions per unit of GDP— has dropped, its total emissions have grown significantly (IEA 2021d). Despite the challenges Vietnam faces in its energy transition, it is critical that the country—with help from the international community—continues investing in energy storage solutions and a robust transmission and distribution grid to manage the fluctuations intrinsic in solar and wind electricity generation. Vietnam's Just Energy Transition Partnerships, announced together with international partners last year, is an important step in this direction and could become a successful case study of the power of multilateral collaboration for decarbonization (Nguyen 2024).

Global Largest Emitters Need to Do More

Although all nations must play a role in mitigating climate change, China, the United States, and India are pivotal, accounting for over half of global GHG emissions. Each of these emission giants lags its regional peers: India ranks 4th out of eight countries in Southern Asia, China is 15th among 25 in the Asia-Pacific, and the United States is 18th out of 22 in the Global West.

China emitted approximately 28 percent of global GHG emissions in 2022, more than any other country by a wide margin. China burns a quarter of total world coal use to generate electricity, covering over 60 percent of the country's energy supply (IEA 2021a). Beyond electricity generation, rapidly growing Chinese cities have also resulted in large GHG emissions: China used more cement in two years (2020 and 2021) than the United States did in the entire twentieth century (Ritchie 2023). And China's car fleet, mostly composed of gasoline vehicles, grew almost 10-fold between 2004 and 2018 (Maizland 2021).

In the early 2000s, the Chinese government began to shift from a narrow focus on GDP growth to building an "ecological civilization" (Prytherch, Lieberthal, and Hass 2023). China aims to reach peak emissions by 2030 and carbon neutrality by 2060 (Maizland 2021). To limit coal pollution, China rolled out the largest national emissions trading scheme in the world in 2020 (IEA 2020). China has also invested heavily in technologies critical to the energy transition and is now a global leader in solar energy deployment and electric vehicle production

(Hilton 2024). As a result of these efforts, China's carbon intensity halved between 2005 and 2021 (MEE 2022). Overall, while China has made tremendous progress in its energy transition, it must continue to rapidly reduce its dependence on fossil fuels if the world is to achieve the Paris Agreement target of limiting warming to 1.5 ºC (Maizland 2021).

The United States is the largest historical GHG emitter and the world's largest economy. Out of the three largest emitters, the United States is the only one which has already reached peak emissions, though on a *per capita* basis its emissions are 80 percent higher than China's and more than six times higher than India's (Friedlingstein et al. 2023; Gütschow, Pflüger, and Busch 2024). The United States has announced official goals of reaching carbon neutrality by 2050 and halving net emissions relative to 2005 by 2030 (United States Department of State 2021). Under the Biden Administration, the United States rejoined the Paris Agreement and lead negotiations of the Global Methane Pledge. The United States has no national carbon tax or emissions trading scheme, focusing instead on providing tax credits and other financial incentives to accelerate electrification and deployment of clean energy (Lashof 2024). Worryingly, the increased politicization of climate change raises concerns that climate policies may be rolled back depending on the outcome of the next presidential election (Tyson, Funk, and Kennedy 2023). As the world's largest economy and historic contributor to climate change, the United States has the opportunity and the moral responsibility to be more aggressive in its climate change policy.

India is currently the world's third-largest GHG emitter, with total emissions growing 32 percent over the past decade. This increase results from the country's rapid economic growth and industrialization, which has spurred an escalating demand for energy. The Indian government aspires to generate half of its electricity from renewable sources and reduce carbon intensity by 45 percent from 2005 levels by 2030, on its way to reach net zero emissions by 2070 (MoEFCC 2023). India has made strides toward these objectives by investing in renewable energy and expanding its forest cover (Singh 2023). With a rapidly growing and urbanizing population, however, India will require an additional $160 billion per year in climate change mitigation investments to achieve its goals (Birol and Kant 2022). Balancing economic development with environmental sustainability in the face of such demographic and financial challenges will be a critical task for India in the years to come.

While China, America, and India have all significantly ramped up their climate change ambitions over the past decade, they need to do much more for the world to avoid the worst consequences of climate change. As leading economic and political powers, these countries have a critical responsibility to spearhead urgent action and set an example for others as climate leaders, not laggards.

5. Methods

Adjusted Emission Growth Rates

To help countries identify climate policy gaps and priorities, the EPI's *adjusted emission growth rate* indicators track progress toward reducing emissions of four major greenhouse gases and black carbon.

Indicator Background

For each greenhouse gas and black carbon, the EPI team calculates the average annual percentage rate of increase or decrease in raw emissions over the most recent ten years of data, 2013–2022. To partially disentangle emission trends from economic fluctuations, the EPI team calculates the correlation between annual emissions and GDP over the last decade, and emission growth rates are adjusted according to the following formula:

Adjusted growth rate = Raw growth rate × (1 – r)

Where *r* is the Spearman's correlation coefficient between ten years of GDP and emissions data. When *r* is close to 1, indicating a tight link between emissions and economic activity, negative emission growth rates are adjusted toward zero. This approach gives less credit to countries that achieved emission reductions through economic contraction. In contrast, countries who have decoupled their economic growth from GHG emissions could have a theoretical maximum *r* of -1, and negative emission reductions result in a higher indicator score.

For all gases and black carbon, scores above 50 indicate a reduction in emissions, while scores below 50 indicate growing emissions. For CO_2, a score of 100 indicates that emissions are falling at the rate that *global* emissions should fall for the world to reach 2050 staying within the remaining carbon budget for a 50 percent chance of limiting warming to 1.5 ºC, i.e., 275 billion tonnes of CO_2 (Friedlingstein et al. 2023). While this estimate of the remaining carbon budget is from the start of 2024, the EPI team opted to err on the side of caution and assumed instead that it was from the year 2021. We think this decision is justifiable because (1) the indicator only includes emissions of fossil CO_2, (2) not all CO_2 emissions are accounted for in the data, and (3) a 50 percent chance of limiting warming to 1.5 ºC—or a flip of a coin—is low when what is at stake is avoiding dangerous climate impacts.

For CH_4, a score of 100 corresponds to the rate of reductions needed for countries to achieve the goal of the Global Methane Pledge, i.e., reducing emissions 30 percent from 2020 levels by 2030. For other gases and black carbon, since countries have not agreed on clear emission reduction targets, a score of 100 simply reflects the fastest reduction rates in the world.

While mitigating climate change requires the whole world to reduce its GHG emissions as fast as possible, the Paris Agreement recognizes that countries should act according to their, "common but differentiated responsibilities and respective capabilities." Given the wide variation in stages of economic development, GHG emission levels, and financial and technological capacity to reduce emissions across countries, indicators of climate mitigation performance that requires the same rate of emission reduction from every country are arguably unfair. The 2024 EPI introduces an associated pilot indicator of *CO_2 emission growth rates with country-specific targets* to address this concern. This new indicator scores countries' CO_2 emission trends relative to each country's allocated share of the remaining carbon budget. We allocate the remaining carbon budget following the blended approach proposed by Raupach et al. (2014). This approach allocates the budget in proportion to countries' current share of the global population (known as "equal-per-capita" approach) and of global emissions (known as "inertia" approach), giving equal weight to each. This blended approach balances fairness, by allocating more of the budget to countries with larger populations, and feasibility, by not demanding unrealistic rates of emission reductions from industrialized countries (Raupach et al. 2014). Countries earn a top score (100) if, at the current rate of CO_2 emission reductions, the country could reach 2050 staying within its allocated share of the remaining carbon budget.

Data Sources

Carbon dioxide emissions data come from the Global Carbon Budget 2023, and data for other greenhouse gases come from PRIMAP-hist. These sources are described in the previous section.

Data for black carbon emissions span from 1750 to 2022 and come from the Community Emissions Data System (CEDS) of Historical Emissions, a research program of the Pacific Northwest National Laboratory. Emissions data are derived using fuel consumption, technology, and emissions control policy as inputs (Hoesly et al. 2018; McDuffie et al. 2020; Hoesly and Smith 2024). The data set is freely available at: *https://zenodo.org/records/10904361*

Limitations

The 2024 EPI's climate change mitigation indicators are based on data from existing GHG inventories, which are calculated using several assumptions. The Global Carbon Budget, PRIMAP-hist, and CEDS inventories (or the sources on which they are based) estimate emissions by multiplying fossil fuel use or other human activities by corresponding emission factors that account for the GHG released per unit of fuel use or activity. This method results in a rough estimation of GHG emissions, since emission factors do not account for variation across different sites, factories, and operations. For example, the emission factors associated with the use agricultural fertilizer vary across space and time as a function of soil and climatic conditions (Walling and Vaneeckhaute 2020), but this variability is not represented in the GHG inventories on which the EPI indicators are based.

By using global performance targets, most adjusted emission growth rate indicators do not account for countries' different stages of development and abilities to mitigate emissions. The 2024 EPI's pilot indicator of *CO_2 growth rates with country-specific targets* is a first attempt to address this limitation by scoring countries' decarbonization efforts relative to their allocated share of the remaining carbon budget. There is no consensus on the optimal way to allocate the remaining carbon budget to different countries, and several approaches have been proposed that account for equity, fairness, and feasibility aspects if the allocation (Raupach et al. 2014; Pan et al. 2022; Williges et al. 2022). The 2024 EPI team used a relatively simple approach, originally proposed by Raupach et al. (2014), that aims at balancing equity and feasibility considerations. This allocation method does not, however, consider historical emissions, future population projections, or the right of developing nations to provide basic needs to their citizens (Williges et al. 2022). Future versions of this pilot indicator could easily incorporate alternative, more sophisticated allocation methods.

Weighting Rationale

The indicators of adjusted emission growth rates have been the core of the EPI's Climate Change Mitigation issue category since 2020 and thus receive 52 percent of its overall weight. The weight of the indicator for each climate pollutant is roughly proportional to its 2022 Global Radiative Forcing (NOAA 2023c). The pilot indicator of *CO_2 growth rates with country-specific targets* receives only 2 percent of the issue category's weight because it is based on a new approach to assess performance, which the EPI team presents here for review and commentary by the global scientific and policymaking communities.

GHG trend adjusted by proximity to targets

To avoid the worst effects of climate change, the world needs to get to net-zero, or even to net-negative, emissions as soon as possible (Ricke, Millar, and MacMartin 2017; Drouet et al. 2021). To gauge recent policy efforts, the EPI previously focused on measuring the growth rate in emissions over the last ten years of available data. Our approach, however, continues to evolve, further refining our metrics to account for more nuanced understandings of climate change mitigation.

Countries should also be measured by their proximity to achieving net-zero emissions. Focusing exclusively on emission growth rates allows high-emitting countries with stable or slowly decreasing emissions to score better than low-emitting countries in which growing emissions are often the result of basic development and rising living standards. Ignoring the relative emission levels of countries relies on an incomplete perspective, which is unfairly indifferent to countries' stages of economic development.

Accounting for absolute emission levels allows indicators to recognize the increasing difficulty of decarbonization as countries' approach net-zero targets. Countries with exceptionally high emissions can usually achieve big reductions by improving energy efficiency, replacing the dirtiest fossil fuels with natural gas, and investing in clean energy. But achieving further reductions requires deeper changes, such as electrifying buildings and transport, building smart electric grids, improving urban design, and reforming the food system. Progress is expected to slow down as nations approach net zero in the next few decades, as a few industries, such as aviation, will likely remain hard to fully decarbonize and will continue to emit greenhouse gases (Kumar, Tiwari, and Milani 2024). Scores based on growth rates of emissions, by themselves, can over-reward countries experiencing the easier, earlier reductions in emissions from a high baseline while under-rewarding countries who, after past success, struggle with the later reductions closer to the net-zero target.

Indicator Background

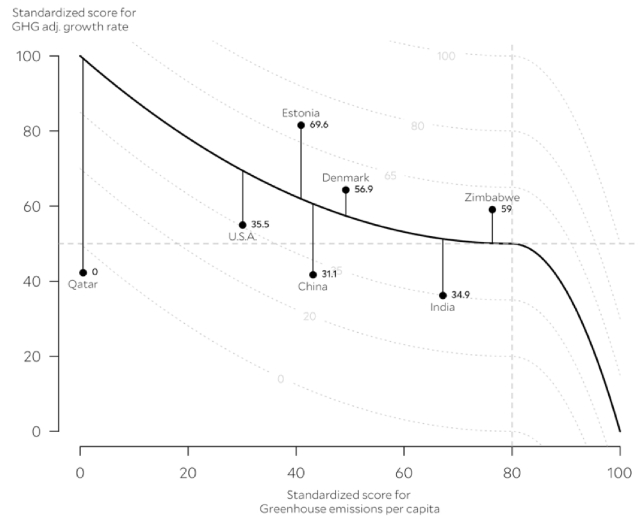
The 2024 EPI introduces two new indicators that adjust GHG growth rate scores based on countries' proximity to zero-emission targets. We start by aggregating GHG emissions (CO_2, CH_4, N_2O, and F-gases) based on their 100-year global warming potentials and measuring the growth rate of these combined gases. We adjust the raw emission growth rates to account for fluctuations in economic activity (see Technical Appendix for details). Then, we transform the adjusted GHG growth rates into an indicator with scores from 0 to 100, in which a growth rate of zero — meaning constant emission levels — corresponds to a score of 50. A score of 100 means that a country's emissions are going down at or faster than the rate consistent with the global carbon budget for the year 2050. We use an estimate of the remaining carbon budget for a 50 percent chance of limiting warming to 1.5 ºC: 275 billion tonnes of CO_2 after 2023 (Friedlingstein et al. 2023).

Our new indicators measure how close countries are to the goal of zero absolute emissions. Given the tight link between GHG emissions and economic activity — and the wide variation in the size of countries' populations and economies — we build metrics that normalize absolute emissions in two ways: by population and by GDP. Each of these normalization approaches has complementary strengths and limitations, and in presenting both together we offer a more complete and nuanced analysis of climate change mitigation performance.

Normalizing by population is a key perspective as, everything else being equal, countries with larger populations will also have larger emissions. But because of sharp differences in countries' levels of economic development, the lowest levels of *per capita* emissions are currently found in low-income countries, where only a small fraction of the population has access to electricity. Even though reductions in material consumption and energy use might be required to tackle the climate and biodiversity crises (Slameršak et al. 2024), low per capita emissions are rarely the result of leadership in climate and sustainability policy.

The ratio of GHG emissions to GDP, known as the *emission intensity* of the economy, can be a proxy for the deployment of

Figure 3-8. Curve to adjust GHG trend scores (vertical axis) by countries' proximity to a net-zero emissions target (horizontal axis). Adjusted scores are determined by countries' vertical distance from the solid black line.



renewable energy and energy efficiency. On its own, however, declining emission intensity can still reward countries with rising GHG emissions so long as GDP grows at a higher rate. Meeting climate change mitigation goals requires declining GHG emissions regardless of economic performance.

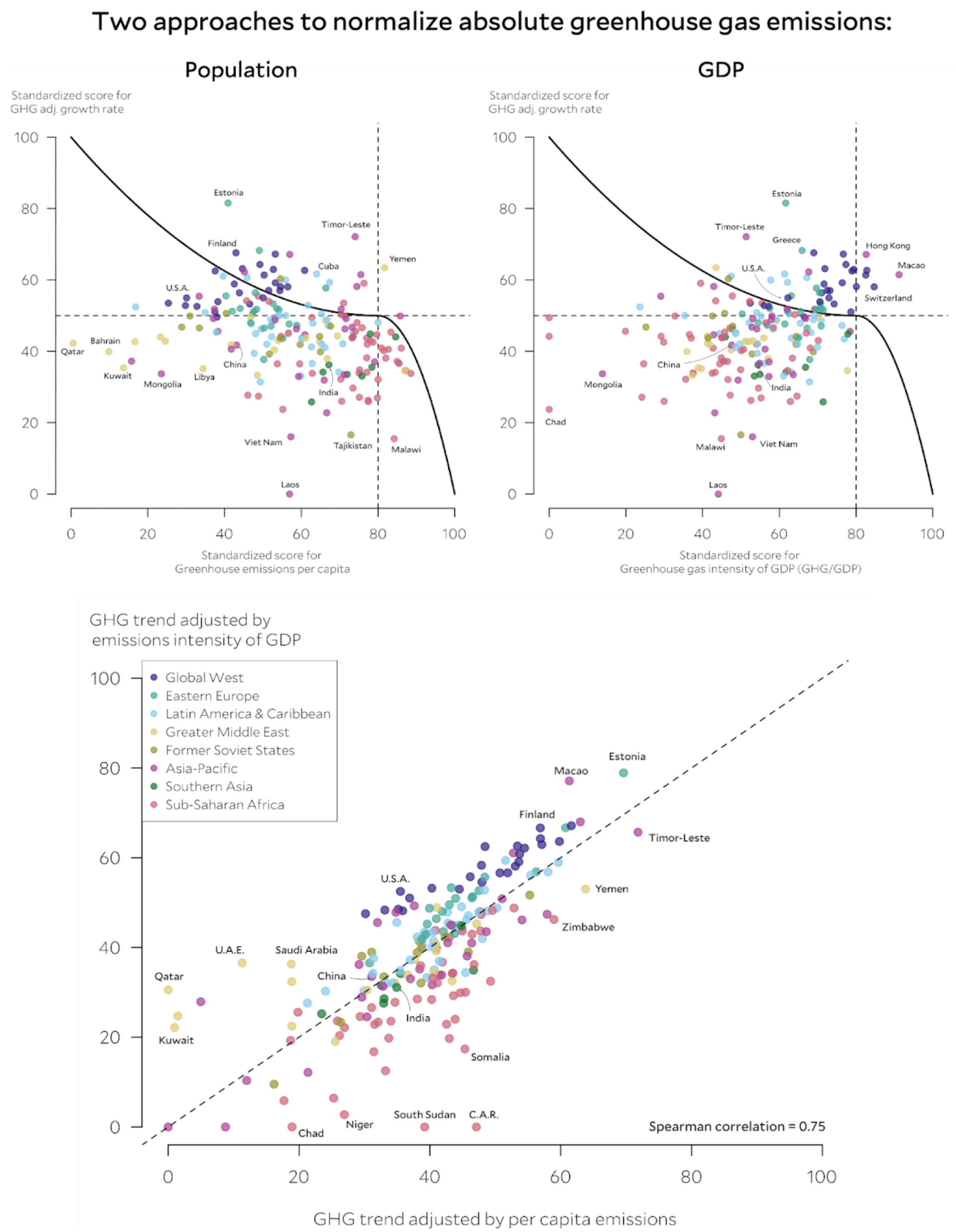
We rescaled each country's normalized GHG emissions, by population or GDP, so that 100 corresponds to zero emissions and 0 corresponds to the 99th percentile of all normalized emission values in the data set.

The ultimate score for each country's emissions growth rate indicator reflects an adjustment according to their score in the indicators of proximity to zero normalized emissions, as shown in Figure 3-8. First, countries with neutral growth rates (unadjusted growth rate score = 50) should get a perfect score if their absolute emissions reach zero (score of 100 in proximity to the net-zero target) but score worse as absolute emissions move away from zero. Second, countries with very high absolute emission levels (score of 0 in proximity to the net-zero target) but also with rapid reductions (score of 100 in the growth rate indicator) should get the same score as countries with very low emission levels (score of 80 in proximity to the net-zero target) but with neutral growth rates.

Countries' adjusted scores are determined by their vertical distance from the solid black curve in Figure 3-8. Falling on the curve corresponds to a score of 50. Being above the curve corresponds to scores higher than 50, and vice versa. For example, when using a *per capita* normalization to measure proximity to a zero emissions target, both India and the United States obtain a very similar score, close to 35. *Per capita* emissions in the United States are much higher than in India, but emissions are slowly going down in the U.S.A., while in India they are rising rapidly. This new indicator considers these two situations equivalent in terms of climate change mitigation performance. On the other hand, while emissions are falling faster in Denmark than in Zimbabwe, Denmark gets a lower adjusted score owing to its higher *per capita* emission levels.

Figure 3-9 shows how the two approaches to normalize absolute emissions — by population or by GDP — yield similar but complementary results in these new indicators. Normalizing by GDP tends to benefit wealthier countries in the Global West and the Persian Gulf, while normalizing by population tends to benefit countries in Sub-Saharan Africa.

Figure 3-9. Normalizing absolute GHG emissions by population or by GDP yields similar but complementary results in the indicators of GHG trend adjusted by proximity to net-zero target.



Data Sources

Carbon dioxide emissions data come from the Global Carbon Budget 2023 (Friedlingstein et al. 2023). These data span the period from 1850 up to 2022 and include emissions from the use of fossil fuels and cement production. The Global Carbon Project obtains data from a variety of sources, primarily from the CDIAC-FF dataset (Gilfillan and Marland 2021). Due to large uncertainties around estimates of CO_2 emissions from land use, land-use change, and forestry, we did not include them in these indicators. The latest Global Carbon Budget data is freely available at:
https://globalcarbonbudgetdata.org/latest-data.html

Data for other greenhouse gases (CH_4, N_2O, and F-gases) come from the Potsdam Realtime Integrated Model for probabilistic Assessment of emission Paths (PRIMAP-hist) dataset v2.5.1 (Gütschow, Pflüger, and Busch 2024). This data set covers the period from 1750 to 2022, and integrates information from various sources (Gütschow et al. 2016). There are two versions of the PRIMAP-hist data set: one that prioritizes data from government reports to the United Nations Framework Convention on Climate Change (UNFCCC), and one that prioritizes data from third-party sources, such as the Emissions Database for Global Atmospheric Research (EDGAR) (Crippa et al. 2023). For many countries, data in their reports to the UNFCCC are based on country-specific activity data and emission factors, resulting in more accurate estimations of GHG emissions than in data sets from third parties. However, since the primary goal of the EPI is to compare relative performance across countries rather than provide accurate estimates of emission levels, we used the third-party version of the PRIMAP-hist data set because it is based on a consistent GHG accounting methodology for all countries. The PRIMAP-hist dataset is freely available at:
https://zenodo.org/records/10705513

Limitations

These two pilot indicators are an attempt to better assess countries' climate change mitigation performance by simultaneously accounting for the trend in their emissions and their proximity to net-zero targets. However, due data limitations, the indicators do not yet include information on countries' efforts to remove carbon dioxide from the atmosphere, and thus they do not really assess proximity to *net* zero emissions. The data on carbon sinks from land use change and forestry included in the Global Carbon Budget 2023 are still highly uncertain, and the data on CO_2 removal via enhanced rock weathering and direct air capture is of poor quality, suffering from fragmented, inconsistent reporting standards, and limited geographical coverage (Friedlingstein et al. 2023). As data on carbon sinks improves, a priority of the EPI will be to incorporate them into these indicators to properly assess proximity to net-zero targets.

A second, more fundamental limitation of the indicators is the arbitrary shape of the curve used to adjust GHG emission trends according to countries' absolute emission levels. The EPI team emphasizes that this is simply an initial, proof-of-concept proposal, and we encourage other researchers to provide feedback and experiment with other shapes of the curve.

Weighting Rationale

Each of the two versions of this indicator receives 20 percent of the weight of the issue category, as they provide a complementary overview of countries' climate mitigation performance by measuring emissions of all greenhouse gases while accounting for both emission trends and proximity to net-zero targets.

Projected GHG Emissions

Indicator Background

To explicitly assess whether countries' recent rates of GHG emission reductions put them on track to reach close to zero emissions by 2050, the EPI uses indicators of projected emission levels. We first sum emissions of carbon dioxide, methane, nitrous oxide, and F-gases using 100-year global warming potentials. Next, we use the slope of a line fitted to GHG emissions data from 2013 to 2022 to linearly extrapolate emissions from 2022 to 2050.

The 2024 EPI derives two indicators from this linear extrapolation. One indicator, originally introduced in the 2022 EPI, scores countries on their *projected GHG emissions in 2050*, and thereby serves as a metric to assess countries' contribution to climate change in 2050 if they continue their current track.

The shape of the path countries follow to net-zero, and not only when they get there, is critically important as it determines how many tonnes of GHG will still be emitted (Sun et al. 2021; Fankhauser et al. 2022). To account for this, the 2024 EPI introduces a pilot indicator that measures the *cumulative sum of projected GHG emissions to 2050*. This indicator compares the sum of projected GHG emissions between 2023 and 2050 to countries' allocated share of the remaining carbon budget. Countries in which projected GHG emissions do not exceeding their allocated share of the budget receive a score of 100. A score of 0 indicates that a country's projected emissions exceed its share of the budget by 10 times or more.

Data Sources

Carbon dioxide emissions data come from the Global Carbon Budget 2023 (Friedlingstein et al. 2023) and other gases from the PRIMAP-hist dataset (Gütschow, Pflüger, and Busch 2024). Both sources are described in more detail above.

Limitations

In addition to the limitations for other indicators above, these indicators are also limited by methods the EPI uses to project GHG emissions. Recent trends in GHG emissions are unlikely to continue in a linear path. Emission trends can improve or worsen depending on the implementation of new climate policies, as well as economic and demographic trends and technological developments. Hence, the indicators should not be interpreted as estimates of future emissions, but rather as a gauge of whether current emission trajectories, if maintained, are sufficient to reach net-zero goals.

Weighting Rationale

The *projected GHG emissions in 2050* indicator receives only 3 percent of the weight in the issue category because the EPI projects absolute emissions without normalizing by population or GDP. As a result, countries with small populations or economies may receive high scores even when their emissions are rising. The indicator measures countries' projected contribution to climate change in 2050, and thus emphasizes that countries with large populations and economies have a greater responsibility to rapidly reduce their emissions.

The *projected cumulative GHG emissions to 2050* indicator receives only 2 percent of the weight in the issue category because it is a pilot indicator presented here for review and commentary by the global scientific and policymaking community.

Net carbon fluxes from land use change

Land use, land-use change, and forestry (LULUCF) are responsible for approximately 14 percent of carbon dioxide emissions over the last decade, although estimates are highly uncertain (Friedlingstein et al. 2023). Land use change can be both a source and a sink of carbon dioxide, as ecosystems store carbon in soils and plant tissues through growth and release carbon during decomposition and burning. Accounting for the fluxes of carbon due to LULUCF completes our understanding of climate change mitigation efforts and countries' proximity to net-zero goals.

Indicator Background

The 2024 EPI introduces a pilot indicator of *net carbon fluxes from land use, land-use change, and forestry* to assess whether countries' terrestrial ecosystems have been a net source or a net sink of carbon dioxide over the last decade. The indicator sums carbon fluxes (both emissions and sinks) related to LULUCF over ten years (2013–2022). Since these fluxes are predominantly related to forest dynamics, countries with larger forest area are expected to have larger fluxes. Thus, the EPI standardizes this indicator by dividing the cumulative sum of carbon fluxes by countries' forest area in 2000.

Data Sources

Estimates of country-level net carbon fluxes from land use, land-use change, and forestry come from the Global Carbon Budget 2023 (Friedlingstein et al. 2023). These estimates are based primarily on forest dynamics, including fluxes from deforestation, afforestation, logging, forest degradation, shifting

Focus 3.1

Fix methane leaks: Low-hanging fruit of climate change mitigation

While much of the global discourse on climate change mitigation has focused on CO_2, cutting methane emissions is one of the most cost-effective strategies to reduce the rate of warming over the next few decades (United Nations Environment Programme and Climate and Clean Air Coalition 2021). The production, transportation, and use of fossil fuels accounts for 35 percent of anthropogenic methane emissions. More than 70 percent of those emissions could be avoided with available technologies, and as much as 45 percent can be abated with either zero net cost or even with a profit (IEA 2022). Effective strategies include frequent maintenance of fossil fuel infrastructure to prevent leaks, as well as banning routine flaring and venting (IEA 2022). These remedies avoid wasteful losses of natural gas, which can instead be sold to cover the cost of leak repairs. Independently of climate concerns, there is a compelling economic case to implement greener methane policies.

Without concerted action, however, methane leaks pose a serious and growing concern to global efforts of climate change mitigation. According to the International Energy Agency, there were twice as many large methane leaks detected by satellites in 2023 compared to 2022 (IEA 2024). In 2022, leaks from two fossil fuel fields in Turkmenistan, likely caused by aging Soviet equipment, released 4.4 million tonnes of methane, equivalent to more than the entire carbon dioxide emissions of the United Kingdom in 2022 (Carrington 2023). The United States also had more than 600 super-emitter events, defined as a leak from a single source that released methane at the rate of multiple tonnes an hour (Carrington 2023). Given methane's strong short term warming effects, the growing number of super-emitter methane leaks jeopardize climate goals and risk pushing the planet across dangerous climate tipping points.

Greater transparency can help address methane leaks by pinpointing areas of concern and attracting pressure on polluters. Turkmenistan recently announced a roadmap to curtail methane emissions and plug its largest leaks, partially due to international pressure after its super-emitters were exposed (Carrington 2023b). The recent establishment of the International Methane Emissions Observatory is a step in the right direction (UNEP 2023). The launch of MethaneSAT, a new satellite that can measure methane from space with high precision and accuracy, and whose data will be automatically analyzed by artificial intelligence, is another exciting development (Khurana and Tabuchi 2024).

cultivation, peat burning, and drainage. The EPI uses the average of LULUCF fluxes derived from three different bookkeeping approaches included in the Global Carbon Budget dataset (Hansis, Davis, and Pongratz 2015; Gasser et al. 2020; Houghton and Castanho 2023). The three approaches define LULUCF carbon fluxes in the context of models of the global carbon cycle and do not include certain types of managed land that are included in LULUCF estimates from the IPCC and the FAO. As a result, the Global Carbon Budget's estimates of LULUCF carbon fluxes are typically lower than the LULUCF fluxes included in national GHG inventories.

Limitations
Estimates of carbon fluxes from LULUCF are highly uncertain due to incomplete knowledge about the amount of carbon stored in vegetation and soils before and after land use changes (Friedlingstein et al. 2023). The three bookkeeping approaches included in the Global Carbon Budget use different computational units, incorporate different processes, and assign different carbon densities to different soils and vegetation types, which yields widely variable estimates of carbon fluxes. For example, only one of the approaches considers enhanced vegetation growth due to CO_2-fertilization and other environmental changes (Gasser et al. 2020).

For all three bookkeeping methods, the quality of the underlying land use maps is poor, and the representation of land management processes in the underlying models is rudimentary. Estimates of current and historical carbon stocks in soils and vegetation are also highly uncertain. Resolving these issues is a research priority given the importance of land-based carbon fluxes for climate mitigation strategies and outcomes.

Weighting Rationale
The low weight of this pilot indicator (3 percent of the issue category) reflects the uncertainties in the underlying data rather than the importance of the issue.

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Chapter 4. Air Quality

1. Introduction

Air pollution remains the most serious environmental threat to public health. Long-term exposure to fine particulate matter less than 2.5 μm in diameter ($PM_{2.5}$) caused 7.8 million premature deaths in 2021, close to 12 percent of global deaths (Brauer et al. 2024). Air pollution is linked to severe health complications, including pulmonary and cardiovascular diseases (Lee et al. 2020). Ground-level ozone pollution induces inflammation of the airways, which can aggravate lung diseases such as asthma (Zhang, Wei, and Fang 2019). Maternal exposure to high levels of ozone, fine particulate matter, and nitrogen dioxide can all lead to low birth weights (Zhou et al. 2023).

Despite the importance of air pollution for public health, it is challenging to accurately quantify the full scale of its effects and its response to countries' environmental policies. The wind blows air pollutants across political boundaries, so the air quality in one country may depend on the activities of its upwind neighbors. Furthermore, interactions between different air pollutants can yield complex trade-offs. For example, reducing concentrations of $PM_{2.5}$ can lead to rising ozone levels, as $PM_{2.5}$ interacts with chemical compounds responsible for ozone formation (Zhang, Wei, and Fang 2019).

The 2024 EPI aims to provide holistic insights into the latest global air quality trends and countries' performance on air quality management. This information can help policymakers make informed decisions and create effective air pollution control policies.

2. Indicators

Anthropogenic PM2.5
(38% of issue category)
We measure the exposure to fine particulate matter ($PM_{2.5}$) from satellite-derived ground-level measurements, weighted by population density. We exclude the population-weighted fraction of exposure to $PM_{2.5}$ from windblown dust, sea spray, and other natural sources of air pollution.

Household Solid Fuels
(38% of issue category)
Household solid fuel combustion is the primary cause of poor indoor air quality in many parts of the world. We measure the health impacts from the combustion of household solid fuels using the number of age-standardized disability-adjusted life-years (DALY rate) lost per 100,000 persons.

Ozone
(9% of issue category)
Ground-level ozone is produced via reactions of other air pollutants. We measure the public health impacts of exposure to ground-level ozone using the number of age-standardized disability-adjusted life-years (DALY rate) lost per 100,000 persons.

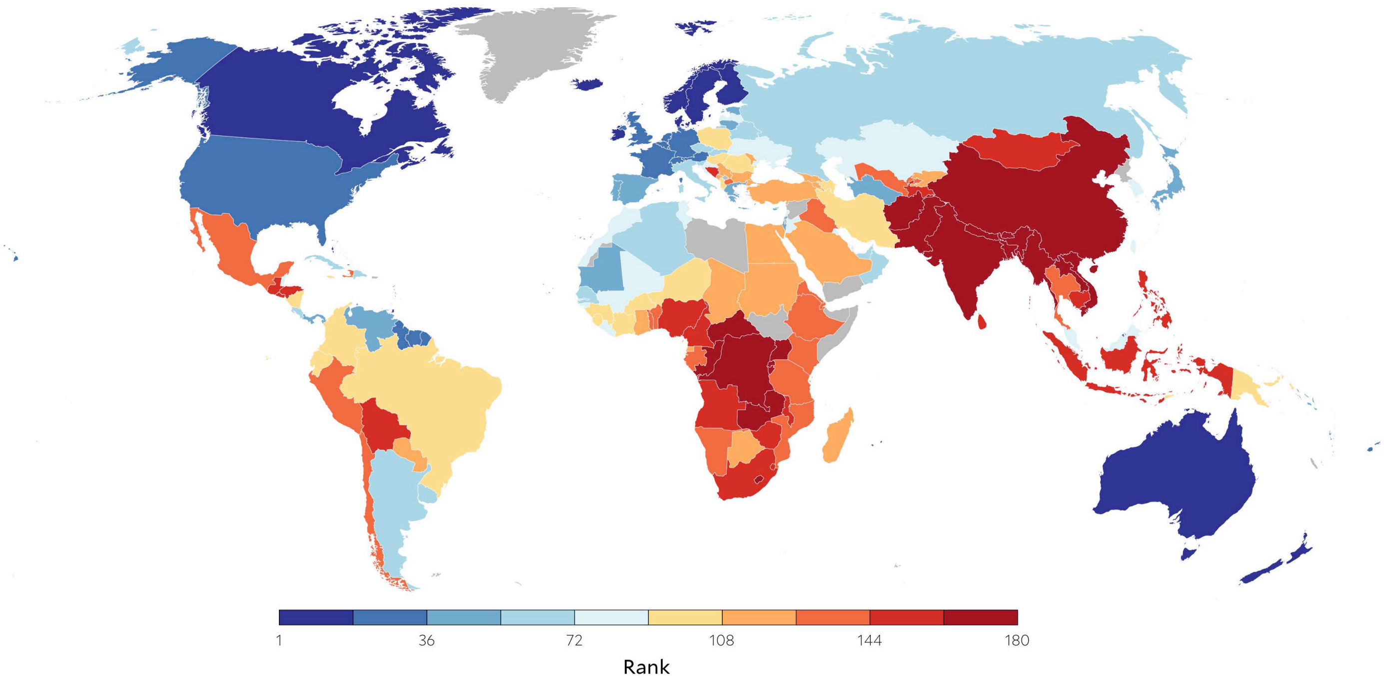
Nitrogen Dioxide
(6% of issue category)
We measure the public health impacts of exposure to ground-level nitrogen dioxide using the number of age-standardized disability-adjusted life-years (DALY rate) lost per 100,000 persons.

Sulfur Dioxide
(3% of issue category)
We measure the exposure to sulfur dioxide pollution using a country's ambient ground-level concentration. The pollutant concentration is population-weighted to better capture the exposure levels in geographic areas with a higher human population density.

Carbon Monoxide
(3% of issue category)
We measure the exposure to carbon monoxide using a country's ambient ground-level concentration. The pollutant concentration is population-weighted to better capture the exposure levels in geographic areas with a higher human population density.

Volatile Organic Compounds
(3% of issue category)
We measure exposure to ground-level volatile organic compounds using a country's ambient ground-level concentration. The pollutant concentration is population-weighted to better capture the exposure levels in geographic areas with a higher human population density.

Map 4-1. Global rankings on Air Quality.



Map 4-2. Air Quality scores.

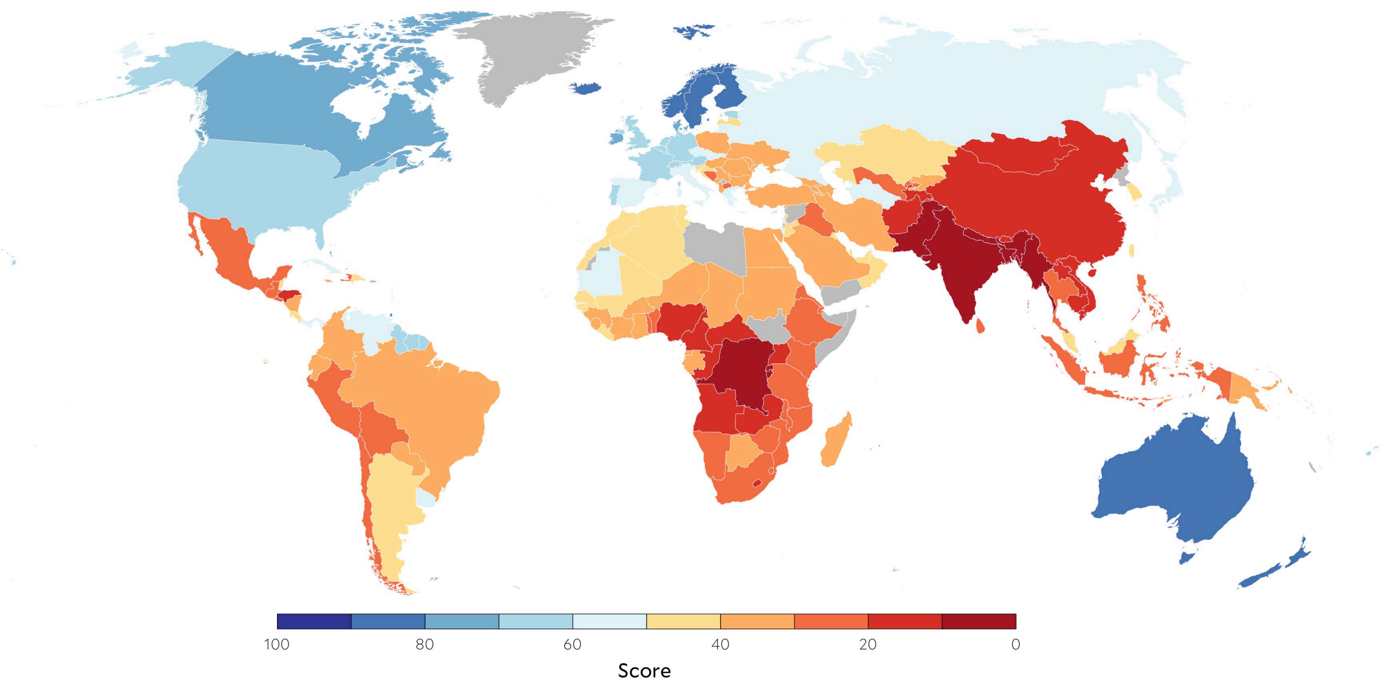


Table 4-1. Global rankings, scores, and regional rankings (REG) on the Air Quality issue category.

RANK	COUNTRY	SCORE	REG
1	Iceland	89.7	1
2	Trinidad and Tobago	87.1	1
3	Barbados	85.8	2
4	New Zealand	83.0	2
5	Norway	82.9	3
6	Finland	82.2	4
7	Sweden	81.1	5
8	Australia	80.9	6
9	Seychelles	80.0	1
10	Antigua and Barbuda	77.8	3
11	Ireland	76.8	7
12	Bahamas	76.4	4
13	Mauritius	75.7	2
14	Grenada	74.3	5
15	St. Vincent and Grenadines	73.9	6
16	Saint Lucia	73.6	7
17	Canada	72.4	8
18	Denmark	70.9	9
19	United Kingdom	69.9	10
20	Malta	69.8	11
21	Brunei Darussalam	68.6	1
22	Suriname	68.3	8
23	Switzerland	67.5	12
24	Netherlands	67.4	13
25	Luxembourg	67.1	14
26	Germany	66.9	15
27	United States of America	65.8	16
28	Guyana	65.4	9
29	France	65.2	17
30	Belgium	64.8	18
30	Micronesia	64.8	2
32	Marshall Islands	63.2	3
33	Cabo Verde	63.0	3
34	Dominica	61.9	10
35	Austria	61.5	19
35	Fiji	61.5	4
37	Portugal	61.1	20
38	Estonia	60.9	1
39	Tonga	60.2	5
40	Japan	59.9	6
40	Solomon Islands	59.9	6
42	Samoa	57.8	8
43	Vanuatu	57.5	9
44	Panama	57.4	11
45	Spain	56.2	21
46	Cyprus	55.9	2
47	Kiribati	54.4	10
48	Venezuela	54.1	12
49	Turkmenistan	54.0	1
50	Greece	53.7	3
50	Singapore	53.7	11
52	Israel	53.6	1
53	Mauritania	53.5	4
54	Lithuania	53.2	4
55	Cuba	52.5	13
56	Uruguay	52.3	14
57	Italy	52.2	22
58	Belarus	51.3	2
59	Russia	50.5	3
59	Slovakia	50.5	5
61	Czech Republic	50.4	6
62	Costa Rica	49.6	15
63	Senegal	49.4	5
64	Argentina	47.6	16
65	Maldives	47.5	1
65	Oman	47.5	2
67	Gambia	46.8	6
68	Comoros	46.6	7
69	Dominican Republic	46.3	17
70	United Arab Emirates	46.2	3
71	Algeria	46.0	4
72	Slovenia	45.8	7
73	Latvia	45.1	8
74	Morocco	44.7	5
75	Mali	44.6	8
76	South Korea	44.5	12
77	Kazakhstan	44.4	4
78	Tunisia	44.3	6
79	Malaysia	43.2	13
80	Liberia	43.0	9
81	Jordan	42.9	7
82	Guinea-Bissau	42.8	10
83	Qatar	42.4	8
84	Kuwait	41.5	9
85	Belize	41.2	18
86	São Tomé and Príncipe	40.9	11
87	Croatia	40.5	9
88	Taiwan	40.1	14
89	Lebanon	40.0	10
90	Ukraine	39.9	5
91	Burkina Faso	39.8	12
91	Papua New Guinea	39.8	15
93	Colombia	39.6	19
94	Romania	39.3	10
95	Hungary	38.6	11
96	Poland	38.5	12
97	Azerbaijan	38.2	6
97	Timor-Leste	38.2	16
99	Sierra Leone	38.1	13
100	Ecuador	37.2	20
101	Côte d'Ivoire	37.0	14
102	Iran	36.9	11
103	Guinea	36.6	15
103	Nicaragua	36.6	21
105	Albania	36.4	13
105	Niger	36.4	16
107	Brazil	36.2	22
108	Jamaica	35.7	23
109	Montenegro	35.2	14
109	Sudan	35.2	12
111	Türkiye	34.8	15
112	Saudi Arabia	34.6	13
113	Georgia	34.5	7
113	Moldova	34.5	7
115	Botswana	34.3	17
116	Paraguay	33.6	24
117	Chad	33.5	18
118	Bahrain	32.7	14
119	Ghana	32.3	19
120	Equatorial Guinea	32.2	20
121	Bulgaria	31.9	16
122	Egypt	31.7	15
123	Serbia	31.6	17
124	Armenia	30.9	9
125	Madagascar	30.7	21
126	Kyrgyzstan	30.6	10
127	Gabon	30.5	22
128	North Macedonia	29.8	18
129	Mexico	29.7	25
130	Chile	29.2	26
131	Djibouti	29.1	23
132	Iraq	27.6	16
133	Uzbekistan	27.5	11
134	Namibia	27.3	24
135	Eritrea	26.8	25
135	Mozambique	26.8	25
137	Togo	26.7	27
138	Peru	26.6	27
139	Thailand	25.4	17
140	Ethiopia	25.3	28
141	Haiti	25.0	28
142	Benin	24.9	29
142	Kenya	24.9	29
144	Tanzania	23.8	31
145	Bolivia	23.0	29
146	Bosnia and Herzegovina	22.9	19
147	El Salvador	22.8	30
148	Indonesia	22.7	18
148	Philippines	22.7	18
148	Zimbabwe	22.7	32
151	Eswatini	22.4	33
152	South Africa	20.3	34
153	Guatemala	20.1	31
154	Malawi	20.0	35
154	Sri Lanka	20.0	2
156	Angola	19.9	36
157	Honduras	18.6	32
158	Cambodia	18.1	20
159	Nigeria	17.9	37
160	Mongolia	17.7	21
161	Tajikistan	17.3	12
162	Cameroon	16.9	38
163	Bhutan	16.6	3
163	Zambia	16.6	39
165	Afghanistan	15.8	4
166	Central African Republic	15.4	40
166	Viet Nam	15.4	22
168	China	14.3	23
169	Uganda	13.8	41
170	Laos	13.6	24
171	Republic of Congo	12.1	42
172	Lesotho	11.6	43
173	Burundi	9.0	44
173	Myanmar	9.0	25
175	Rwanda	8.4	45
176	Dem. Rep. Congo	8.1	46
177	India	6.8	5
178	Bangladesh	6.3	6
178	Pakistan	6.3	6
180	Nepal	6.1	8

Asia-Pacific | **Eastern Europe** | **Former Soviet States** | **Global West**

Greater Middle East | **Latin America & Caribbean** | **Southern Asia** | **Sub-Saharan Africa**

Table 4-2. Regional rankings and scores on Air Quality.

Latin America & Caribbean

Country	Score	Rank
Trinidad and Tobago	87.1	1
Barbados	85.8	2
Antigua and Barbuda	77.8	3
Bahamas	76.4	4
Grenada	74.3	5
St. Vincent and Grenadines	73.9	6
Saint Lucia	73.6	7
Suriname	68.3	8
Guyana	65.4	9
Dominica	61.9	10
Panama	57.4	11
Venezuela	54.1	12
Cuba	52.5	13
Uruguay	52.3	14
Costa Rica	49.6	15
Argentina	47.6	16
Dominican Republic	46.3	17
Belize	41.2	18
Colombia	39.6	19
Ecuador	37.2	20
Nicaragua	36.6	21
Brazil	36.2	22
Jamaica	35.7	23
Paraguay	33.6	24
Mexico	29.7	25
Chile	29.2	26
Peru	26.6	27
Haiti	25.0	28
Bolivia	23.0	29
El Salvador	22.8	30
Guatemala	20.1	31
Honduras	18.7	32

Eastern Europe

Country	Score	Rank
Estonia	60.9	1
Cyprus	55.9	2
Greece	53.7	3
Lithuania	53.2	4
Slovakia	50.5	5
Czech Republic	50.4	6
Slovenia	45.8	7
Latvia	45.1	8
Croatia	40.5	9
Romania	39.3	10
Hungary	38.6	11
Poland	38.5	12
Albania	36.4	13
Montenegro	35.2	14
Türkiye	34.8	15
Bulgaria	31.9	16
Serbia	31.6	17
North Macedonia	29.8	18
Bosnia and Herzegovina	22.9	19

Southern Asia

Country	Score	Rank
Maldives	47.5	1
Sri Lanka	20.0	2
Bhutan	16.6	3
Afghanistan	15.8	4
India	6.8	5
Bangladesh	6.3	6
Pakistan	6.3	6
Nepal	6.2	8

Global West

Country	Score	Rank
Iceland	89.7	1
New Zealand	83.0	2
Norway	82.9	3
Finland	82.2	4
Sweden	81.1	5
Australia	80.9	6
Ireland	76.8	7
Canada	72.4	8
Denmark	70.9	9
Malta	69.9	10
United Kingdom	69.8	11
Switzerland	67.5	12
Netherlands	67.4	13
Luxembourg	67.1	14
Germany	66.9	15
United States of America	65.8	16
France	65.2	17
Belgium	64.8	18
Austria	61.5	19
Portugal	61.1	20
Spain	56.2	21
Italy	52.2	22

Former Soviet States

Country	Score	Rank
Turkmenistan	54.0	1
Belarus	51.3	2
Russia	50.5	3
Kazakhstan	44.4	4
Ukraine	39.9	5
Azerbaijan	38.2	6
Georgia	34.5	7
Moldova	34.5	7
Armenia	30.9	9
Kyrgyzstan	30.6	10
Uzbekistan	27.5	11
Tajikistan	17.3	12

Asia-Pacific

Country	Score	Rank
Brunei Darussalam	68.6	1
Micronesia	64.8	2
Marshall Islands	63.2	3
Fiji	61.5	4
Tonga	60.2	5
Japan	59.9	6
Solomon Islands	59.9	6
Samoa	57.8	8
Vanuatu	57.5	9
Kiribati	54.4	10
Singapore	53.7	11
South Korea	44.5	12
Malaysia	43.2	13
Taiwan	40.1	14
Papua New Guinea	39.8	15
Timor-Leste	38.2	16
Thailand	25.4	17
Indonesia	22.7	18
Philippines	22.7	18
Cambodia	18.1	20
Mongolia	17.7	21
Viet Nam	15.4	22
China	14.3	23
Laos	13.6	24
Myanmar	9.0	25

Sub-Saharan Africa

Country	Score	Rank
Seychelles	80.0	1
Mauritius	75.7	2
Cabo Verde	63.0	3
Mauritania	53.5	4
Senegal	49.4	5
Gambia	46.8	6
Comoros	46.6	7
Mali	44.6	8
Liberia	43.0	9
Guinea-Bissau	42.8	10
São Tomé and Príncipe	40.9	11
Burkina Faso	39.8	12
Sierra Leone	38.1	13
Côte d'Ivoire	37.0	14
Guinea	36.6	15
Niger	36.4	16
Botswana	34.3	17
Chad	33.5	18
Ghana	32.3	19
Equatorial Guinea	32.2	20
Madagascar	30.7	21
Gabon	30.5	22
Djibouti	29.1	23
Namibia	27.3	24
Eritrea	26.8	25
Mozambique	26.8	25
Togo	26.7	27
Ethiopia	25.3	28
Benin	24.9	29
Kenya	24.9	29
Tanzania	23.8	31
Zimbabwe	22.7	32
Eswatini	22.4	33
South Africa	20.3	34
Malawi	20.0	35
Angola	19.9	36
Nigeria	17.9	37
Cameroon	16.9	38
Zambia	16.6	39
Central African Republic	15.4	40
Uganda	13.8	41
Republic of Congo	12.1	42
Lesotho	11.6	43
Burundi	9.0	44
Rwanda	8.4	45
Dem. Rep. Congo	8.1	46

Greater Middle East

Country	Score	Rank
Israel	53.6	1
Oman	47.5	2
United Arab Emirates	46.2	3
Algeria	46.0	4
Morocco	44.7	5
Tunisia	44.3	6
Jordan	42.9	7
Qatar	42.4	8
Kuwait	41.5	9
Lebanon	40.0	10
Iran	36.9	11
Sudan	35.2	12
Saudi Arabia	34.7	13
Bahrain	32.7	14
Egypt	31.7	15
Iraq	27.6	16

3. Global Trends

Despite progress over the last two decades — partly resulting from tightening regulations to control pollutant emissions — air pollution is the leading environmental factor behind the world's burden of disease (Brauer et al. 2024). If the world succeeded at permanently reducing air pollution to meet the World Health Organization's 2021-revised guideline of 5 µg/m^3 $PM_{2.5}$ annual average, human life expectancy could increase by 2.3 years on average (Greenstone and Hasenkopf 2023). Unfortunately, the world is far away from that goal. A recent study found that only seven out of 134 monitored countries and territories achieved the revised guideline in 2023: Australia, Estonia, Finland, Grenada, Iceland, Mauritius, and New Zealand (IQAir 2023). And in 2019, only 0.001 percent of the global population breathed air that met the guideline (Yu et al. 2023). Moreover, pollution at levels lower than the new guideline from the World Health Organization (WHO) can still be harmful to health (Dominici et al. 2022). Prolonged exposure to even low levels of air pollution, below the norms imposed by the United States' Environmental Protection Agency, can result in premature deaths among vulnerable groups (Yazdi et al. 2021). Air pollution's health burden results in huge economic losses. Globally, the cost of air pollution's health impacts amounts to 8.1 trillion US dollars, equivalent to 6.1 percent of global GDP (World Bank 2022).

Figure 4-2. Global health burden of fine particulate matter. Data from the 2021 Global Burden of Disease study.

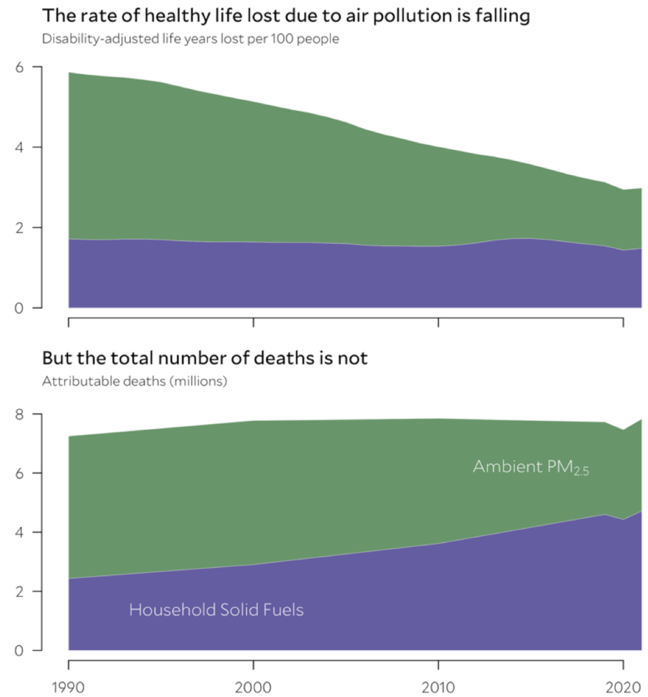


Figure 4-1. Distribution of regional scores on Air Quality. Vertical bars show regional averages.

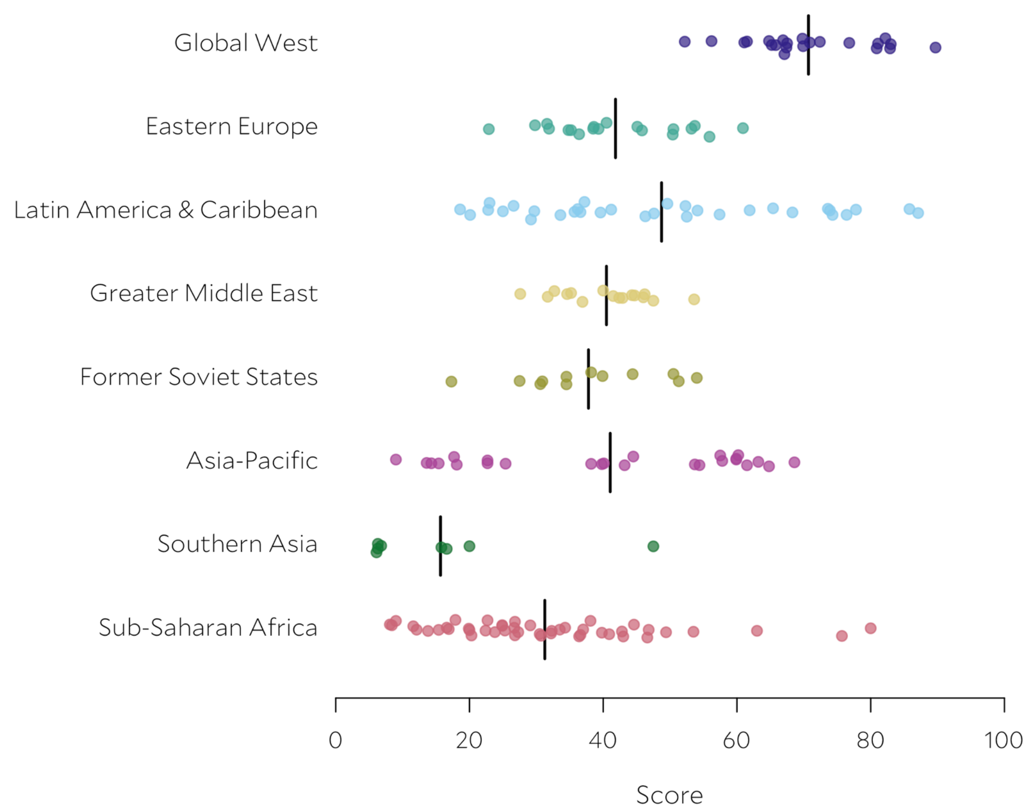
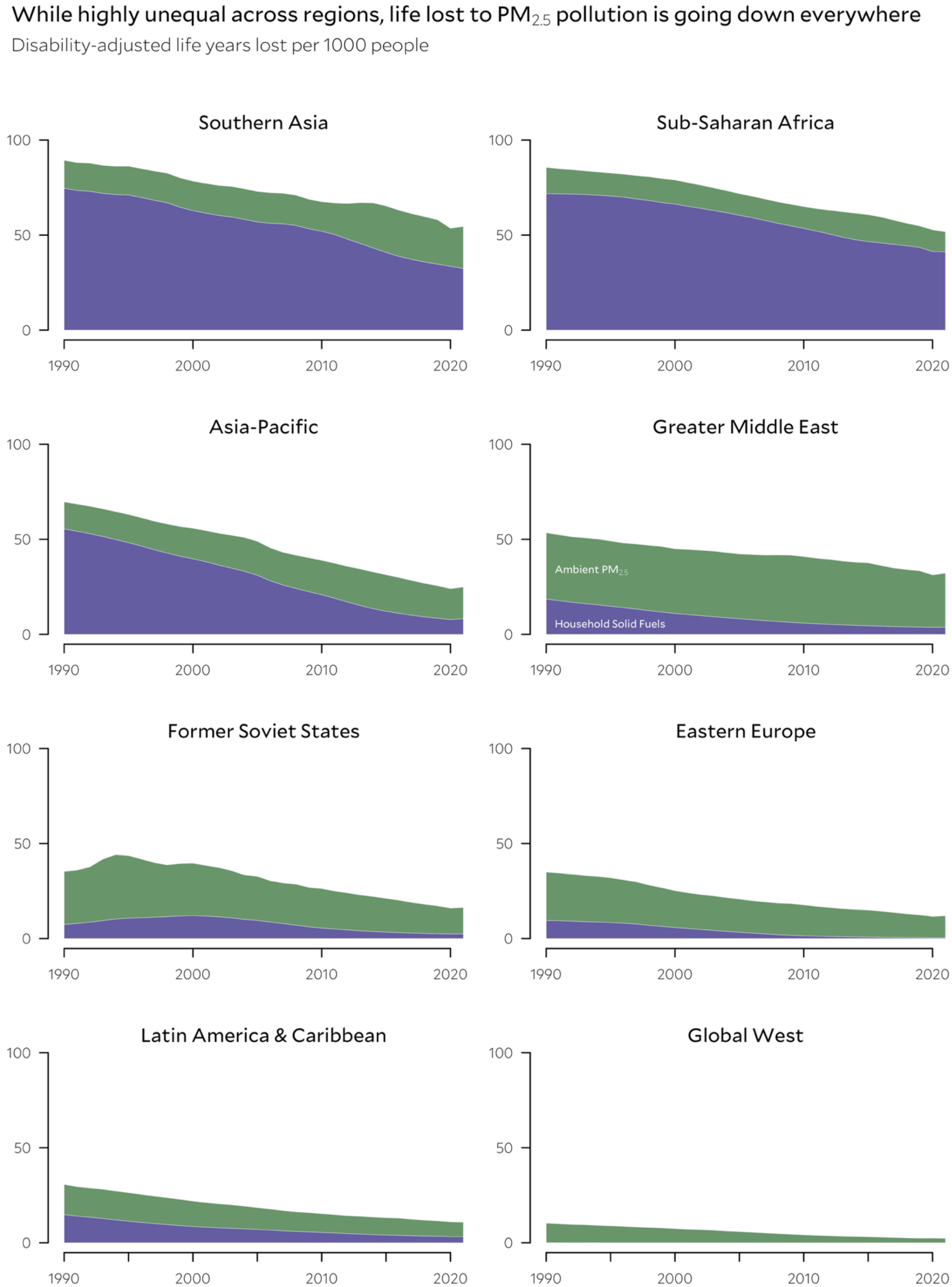


Figure 4-3. Health burden of fine particulate matter since 1990 in each EPI-defined region. Data from the 2021 Global Burden of Disease.



Fortunately, the global disability-adjusted life years lost per 100,000 people (DALY rates) due to air pollution are decreasing (Figure 4-2). Global deaths due to pollution have stayed relatively constant, however, since more people are exposed to pollution and ageing populations are more vulnerable to it (Brauer et al. 2024). Reductions in deaths from ambient $PM_{2.5}$ have been offset by increases in deaths from household solid fuel combustion.

The Global West leads the world in air quality, with negligible life lost due to pollution from household solid fuels (Figure 4-3). The burden of fine particulate matter pollution falls disproportionately on lower-middle-income countries, given that their economies tend to be highly dependent on energy-intensive industries and heavily polluting technologies (Rentschler and Leonova 2023). Out of the 7.3 billion people facing direct exposure to unsafe average annual $PM_{2.5}$ levels, 80 percent reside in low- and middle-income countries (Rentschler and Leonova 2023). Southern Asia and Sub-Saharan Africa bear the greatest health burden from air pollution but lack basic infrastructure to address the issue, from open air quality data to air quality standards (Greenstone and Hasenkopf 2023). Southern Asia accounts for over half of the total life years lost globally due to air pollution (Greenstone and Hasenkopf 2023). In Africa, air pollution stems from crude oil exploitation, power generation, coal mining, and biomass burning (Mead et al. 2023) — killing more people than AIDS and malaria combined (Greenstone and Hasenkopf 2023). Nearly 970 million people on the continent rely on biomass burning for cooking, heating, and lighting, making biomass a leading source of indoor and outdoor air pollution (Mead et al. 2023).

Mirroring the relationship between wealth and air pollution exposure across regions and countries, *within* rich countries, exposure to air pollution is particularly severe among lower-income groups (Jbaily et al. 2022). However, this pattern reverses in many developing countries, where wealthier people in urban centers are often exposed to higher levels of air pollution (Behrer and Heft-Neal 2024). Meanwhile, in contrast to exposure to fine particulate matter, exposure to other pollutants such as ozone and nitrogen dioxide remains nearly as bad in wealthy countries as in developing ones.

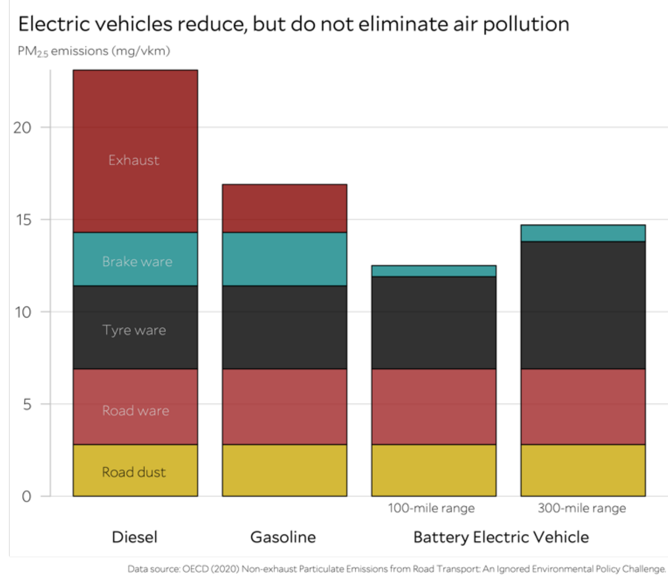
Countries in the Greater Middle East, especially in the Persian Gulf, offer a notable exception to the relationship between countries' wealth and air pollution from particulate matter. Due to its natural aridity, windblown dust accounts for a large fraction of ambient fine particulate matter in the Arabian Peninsula (McDuffie et al. 2021). However, recent ship-borne measurements in the region have shown that over 90 percent of hazardous fine particulate matter pollution is of human origin, primarily from fossil energy production, the petrochemical industry, and intense maritime shipping (Osipov et al. 2022).

Human activities are by far the main driver of current global air pollution trends. Key sources of air pollutant emissions worldwide include coal power generation, fossil-fuel-powered transportation, and indoor and outdoor biomass burning (Oberschelp, Pfister, and Hellweg 2023). To effectively reduce the global health impacts of air pollution, it is imperative that countries phase out fossil fuels and transition to clean energy sources, as well as electrify their buildings and transportation.

Free of exhaust emissions typical of diesel and gasoline vehicles, battery electric vehicles (EVs) help reduce exposure to carbon monoxide, nitrogen oxides, sulfur dioxide, and other air pollutants (Sydbom et al. 2001; Kagawa 2002). However, non-exhaust air pollutant emissions from the wearing of brakes, tires, and roads are an increasingly important source of fine particulate matter from road traffic (Piscitello et al. 2021).

EVs' large batteries tend to make them heavier than their gasoline counterparts, resulting in higher $PM_{2.5}$ emissions from tire and road wear (OECD 2020). However, because of regenerative braking, electric vehicles typically have less brake wear (OECD 2020). The net effect is a minimal difference in the non-exhaust emissions of $PM_{2.5}$ between internal combustion cars (petrol and diesel) and electric vehicles (Figure 4-4). The weight of the electric vehicle matters a lot. EVs with longer range tend to have bigger batteries and be heavier, resulting in higher non-exhaust emissions. However, accounting for exhaust pollutants, switching to electric vehicles does result in a 21 percent reduction in $PM_{2.5}$ emissions (OECD 2020).

Figure 4-4. Emissions of $PM_{2.5}$ pollution of vehicles powered by diesel, gasoline, and electric batteries.



Of course, the particulate matter emissions from generating electricity to power electric vehicles also matter. While a few countries such as Norway, Sweden, and Iceland produce nearly all their electricity from renewable sources with near-zero emissions, around the world, fossil fuels still contribute 60.6 percent of electricity generation, and coal (the dirtiest fossil fuel) 35.4 percent (Wiatros-Motyka et al. 2024). Thus, continuing to decarbonize electricity grids is key to reducing air pollution and its health impacts.

In sum, two main factors determine the impact of electric vehicles in reducing air pollution: (1) the vehicles' weight and (2) the energy mix of the electric grid. Future improvements in battery technologies and increased market access to smaller and more affordable electric vehicles would result in lighter, cleaner vehicles with fewer $PM_{2.5}$ emissions from tire and road wear.

Maritime shipping is a large source of air pollutants. The International Maritime Organization introduced new regulations in 2020 that strongly limited the sulfur content of maritime fuels from a maximum of 3.5 percent to 0.5 percent. As a result, air quality has improved at sea, in coastal areas, and even in cities dozens of kilometers inland (Jang et al. 2023). But there is still progress to be made. Compliance rates are higher near ports than in open waters, and while regulations have successfully reduced sulfur pollution, nitrogen oxides have increased in the North and Baltic seas (Van Roy et al. 2023). Moreover, since sulfur aerosols reflect sunlight and thus have a cooling effect, gains in air quality have been accompanied by worsening global warming trends (Hausfather and Forster 2023). This makes decarbonizing maritime shipping more urgent than ever (Wang et al. 2021).

4. Leaders and Laggards

Iceland continues to be the global leader in the EPI's Air Quality issue category, benefiting from its location far away from polluting neighbors and an electric grid 100 percent powered by renewables. But new leaders emerged as well. Small island countries in the Caribbean, such as Trinidad and Tobago and Barbados, outperform rich nations of the Global West to become the top-ranking countries on air quality in the world. Meanwhile, Brunei Darussalam leads its Asia-Pacific peers, outperforming Japan, Singapore, and South Korea. The emergence of these new leaders in the 2024 EPI is partly a result of the new $PM_{2.5}$ indicator excluding natural sources of pollution -— such as windblown dust and sea spray — which are the predominant source of air pollution in the Caribbean. The Global West has been successful at maintaining low levels of particulate matter exposure, especially Nordic countries such as Iceland and Finland, due to tight air pollution control in the industrial sector as well as resilient and expanding electric vehicle markets. However, the Global West is not free from air pollution's health impacts. Residential fuel combustion and transportation are the two main sources of air-pollution-induced mortality in Europe, which lead to about 72,000 and 35,000 excess deaths annually, respectively (Paisi et al. 2024). Countries

Focus 4.1

Wildfires: a growing source of air pollution

From June 6 to 8 in 2023, New York City was shrouded in a mysterious, smoky haze. Under the gloomy sky, the city became almost unrecognizable. Wildfire smoke from Quebec, Canada, made levels of $PM_{2.5}$ pollution in New York City spike up to 11 times its background daily average of 9.0 $\mu g/m^3$. For a few days, New York City had one of the worst air qualities of any city in the world (Newburger 2023). During those days, asthma syndrome emergency department visits increased by 44 percent (Chen et al. 2023). Globally, brief periods of exposure to high concentrations of $PM_{2.5}$, such as those often resulting from wildfires, result in more than one million premature deaths each year (Yu et al. 2024).

Wildfires are a natural source of air pollution, emitting large amounts of carbon monoxide, methane, and fine particulate matter. As the world transitions toward cleaner energy sources and climate change makes vegetation easier to burn, wildfires are likely to become a dominant source of air pollution (Knorr et al. 2016; 2017). In regions with strict air quality control targeting anthropogenic pollutants, wildfires are already a dominant source of fine particulate matter.

Climate change is strengthening this trend. Since the 1980s, the total area burned by wildfires has roughly quadrupled in the United States, partly because of a warming climate (Burke et al. 2021). In some regions of the Western United States, wildfires have contributed up to half of particulate matter exposure in recent years (Burke et al. 2021), and wildfire pollution is likely to continue worsening (Franke 2023). The 2023 Canadian wildfires engulfed 18 million hectares of land and generated roughly 480 million tonnes of carbon emissions, 23 percent of global wildfire carbon emissions that year (Copernicus 2023).

While humans start most wildfires in some regions, especially in the tropics, in others they are a natural part of the ecosystem and can be difficult to control through policy (Janssen et al. 2023). Some policy interventions can backfire. For example, fire suppressions may lead to the build-up of flammable dead biomass, resulting in less frequent but more severe wildfires (Steel, Safford, and Viers 2015). Prescribed burns — the intentional application of a low-intensity controlled fire, with roots in indigenous practices of "cultural burning" — help reduce the amount of fuel in the landscape and thereby the risk of future high-intensity fires (Fernandes and Botelho 2003). This can help reduce fire damage to infrastructure and the intensity of wildfire smoke exposure. However, prescribed burns may increase the public health burden from exposure to fine particulate matter if they result in more people being exposed to smoke more often (Rosenberg et al. 2024). Thus, strategies to mitigate the public health burden of wildfire smoke need to consider both the level and frequency of exposure.

in the Balkan peninsula, such as North Macedonia and especially Bosnia and Herzegovina, suffer the most severe air pollution in Europe and can make significant strides toward improving air quality by targeting emissions from the residential energy use sector (World Bank 2019; Juginović et al. 2021; Human Rights Watch 2022).

Countries in Southern Asia and Africa suffer from the worst air pollution in the world. At the bottom of the 2024 EPI Air Quality ranking, India, Pakistan, Bangladesh, and Nepal are the epicenter of the global air pollution crisis. India suffers predominantly from dirty residential energy use, which contributes 20 to 50 percent of $PM_{2.5}$ pollution in the country (Rao et al. 2021). Exposure to household air pollution caused over one million premature deaths in India in 2021 (Brauer et al. 2024). However, household air pollution is particularly severe in rural areas, with almost 57 percent of rural households relying on solid fuel (Parchure et al. 2024). Rural households' adoption of cleaner alternatives, such as liquid petroleum gas, has been hindered by a lack of capital, education, and empowerment for women (Timilsina et al. 2023). Thus, more policies to help rural households get access to cleaner energy sources can make significant strides in alleviating household air pollution in India (Timilsina et al. 2023).

In addition to household solid fuels, other pollution sources in India include industrial processes, coal-fired power generation, and burning agricultural residue (Jiang 2023b). While India has regulations on heavy-polluting industrial plants, their enforcement is often weak and uneven (Greenstone et al. 2023). India shifted its $PM_{2.5}$ pollution policy focus from national to regional in 2022, declaring a new set of goals for 131 cities to reduce fine particulate matter levels by 40 percent by 2026, relative to their 2017 levels (Greenstone and Hasenkopf 2023). The motivation behind this switch from national to city-level policy was five years of consecutive failures from 132 cities under the National Clean Air Program to meet the prescribed national ambient air quality standard. Updating the reduction target to 40 percent by 2026 seeks to encourage cities to commit to more tangible actions. More optimism about effectively abating particulate matter emissions surfaced with the experimental success of the world's first market for particulate matter emissions in Gujarat, India (Greenstone et al. 2023). The market-based, cap-and-trade regulation resulted in up to a 30 percent decline in particulate matter emissions while reducing abatement costs by 11 percent relative to the old command-and-control regime (Greenstone et al. 2023). These results in Gujarat suggest that market mechanisms have great potential as a policy tool to improve air quality across India and elsewhere.

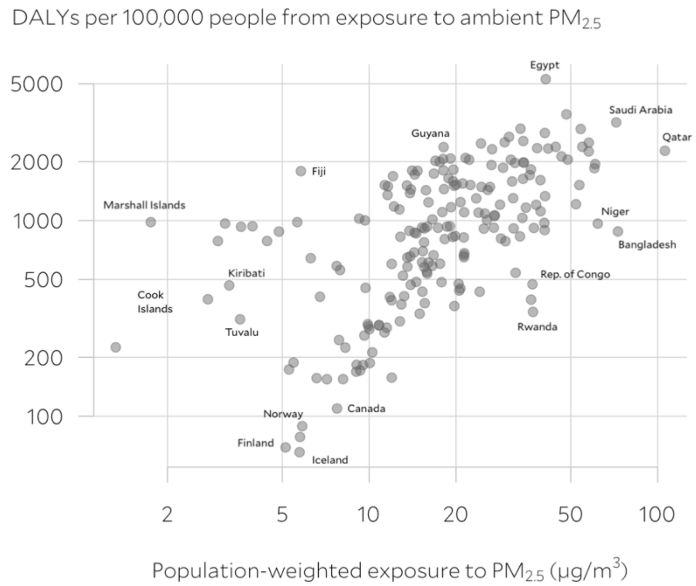
Sources of air pollution in Pakistan include residential biomass burning for cooking and heating, a transport sector with inadequate fuel and pollution standards, mass slashing and burning of agricultural fields, and large-scale open burning of waste (Government of Pakistan 2023). Acknowledging the severity of air pollution as a national threat to public health, the country declared the National Clean Air Plan (NCAP) in 2021, pushing forth interventions to reduce air pollutant emissions in five sectors — transport, industry, agriculture, waste, and residential energy use (Government of Pakistan 2023). In response to NCAP, the government has made plans to convert 30 percent of vehicles to electric, implement Euro-5 standard fuel, decarbonize brick kiln technology, enforce emission standards for heavy industries, and prevent the burning of agricultural residues and municipal solid waste.

Several countries have made progress in recent years in containing and regulating their air pollution (Li et al. 2023). The best example is China, which — according to EPI analysis — curtailed its population-weighted exposure to anthropogenic $PM_{2.5}$ pollution by 38.3 percent between 2013 and 2022. This sharp improvement in air quality was largely due to the implementation of the Air Pollution Prevention and Control Action Plan between 2013 and 2017 (Yue et al. 2020). However, over the last decade, DALY rates due to ambient $PM_{2.5}$ pollution in China declined only 17 percent between 2012 and 2021 (Brauer et al. 2024), highlighting the need for stronger policies to control pollution (Yue et al. 2020). China's $PM_{2.5}$ level is still six times higher than the World Health Organization's guidelines, which shortens Chinese life expectancy by 2.5 years (Greenstone and Hasenkopf 2023). Moreover, Beijing experienced a 14 percent increase in $PM_{2.5}$ pollution in 2023, partly reversing previous air quality gains (Greenstone and Hasenkopf 2023). Like India, rural regions of China remain heavily dependent on solid fuel combustion despite a rapid transition towards clean energy (Shen et al. 2019). While China reduced its $PM_{2.5}$ and nitrogen dioxide concentrations by 19 percent and 30 percent, respectively, during the COVID-19 pandemic, the country's ozone concentration rose by nearly 20 percent from its level in 2019, demonstrating the complex tradeoffs in air pollutants' interactions (Zhao, Wang, and Zhang 2023). Despite China's remarkable success in reducing $PM_{2.5}$ pollution over the last decade, further reductions from coal-burning plants will be challenging, as highly efficient pollution control technologies are already widely deployed (Jiang 2023a). Additionally, China's population, like that of other industrialized countries, is gradually growing older and more vulnerable to the health harms of air pollution (Yin et al. 2021). This population aging is driving an increase in $PM_{2.5}$-induced mortality and countering the gains made by improvements in national healthcare and air quality regulation policies (Xu et al. 2023).

This trend highlights a crucial point: the health consequences of air pollution depend on more than the levels of pollution exposure. As Figure 4-5 shows, two countries can have similar levels of exposure to air pollution, but widely different associated DALY rates due to differences in population age structure and the baseline mortality rates from different diseases (Xu et al. 2023; Brauer et al. 2024). While the EPI indicators use age-standardized DALY rates to account for differences in age structure, differences in countries' quality of healthcare and in the prevalence of co-morbidities can result in contrasting baseline mortalities that obscure the relationship between pollution exposure level and DALY rates. For example, while

PM2.5 pollution exposure in the Marshall Islands and other island nations in the Pacific Ocean is very low, these countries have disproportionately high DALY rates due to inadequate health care and a high prevalence of obesity, which increases the risk of cardiovascular diseases (Hawley and McGarvey 2015).

Figure 4-5. Relationship between country-level exposure to fine particulate matter and the associated health consequences. Data from the 2021 Global Burden of Disease.



5. Methods

The Air Quality indicators in the 2024 EPI can help countries track progress toward target 3.9.1 of the Sustainable Development Goals (SDGs), which aims to reduce the mortality rate attributed to household and ambient air pollution, as well as and SDG 11.6.2, which aims at reducing annual mean levels of fine particulate matter. Quantifying both air pollution exposure and the resulting health consequences helps inform effective air quality policies. While the goal of air quality policies is to improve public health, tracking exposure allows policymakers to directly assess the impact of different interventions to control pollutant emissions. Health burden metrics, such as attributable DALYs or mortality, do not always match trends in pollution exposure, as they depend on other factors, such as the prevalence of comorbidities and baseline mortality rates (Murray et al. 2020).

To provide a holistic picture of air quality and its health impacts, the 2024 EPI incorporates metrics to track major air pollutants, sometimes focusing on exposure levels and others focusing on the health consequences of exposure. However, the EPI team believes that exposure metrics are more directly related to the effectiveness of environmental policy, and thus, future iterations of the EPI will increasingly rely on exposure metrics to score countries' performance while continuing to report the associated health burden of air pollution.

Indicator Background

The EPI's exposure-based indicators — anthropogenic $PM_{2.5}$, sulfur dioxide, carbon monoxide, and volatile organic compounds — measure the average ground-level concentration of pollutants to which the population of a country is exposed. To measure this, EPI researchers combine maps of ground-level pollutant concentration with maps of population density to calculate population-weighted levels of exposure, following the approach described in Wolf et al. (2022).

The relative contribution of different sources of $PM_{2.5}$ pollution, such as forest fires, agricultural waste burning, windblown mineral dust, and inefficient fuel combustion, varies across regions (McDuffie et al. 2021). Windblown dust dominates air pollution in arid regions and is the second single largest source of $PM_{2.5}$ at the global scale after residential fossil fuel combustion for heating and cooling (McDuffie et al. 2021). While human activities that drive desertification can worsen pollution from wind-blown dust, in naturally arid regions, this source of pollution is largely outside policymakers' control. For this reason, the 2024 EPI indicator of exposure to $PM_{2.5}$ pollution harnesses recent research about the regional variation in $PM_{2.5}$ sources to score countries based only on exposure to anthropogenic pollution that is more easily influenced by environmental policy. Specifically, after calculating the population-weighted exposure to $PM_{2.5}$, we multiply it by the population-weighted fraction of exposure to $PM_{2.5}$ originating from anthropogenic sources in each country. For this indicator, pollution from wildfires was considered anthropogenic, given that most fires are ignited by humans, and forest management practices can mitigate wildfire risk. Pollution from windblown dust, sea spray, and natural sources of chemical precursors of $PM_{2.5}$ — such as volcanic SO_2, lightning NO_x, and biogenic soil NO — were excluded.

The health-impact-based indicators — household solid fuels, ozone, and nitrogen dioxide — are based on estimates of the number of years of healthy life lost due to exposure to different pollutants. These estimates are derived from the Comprehensive Risk Assessment framework established by the Global Burden of Disease (GBD) initiative (Brauer et al. 2024). The GBD uses estimates of exposure to model the risk of various diseases and ultimately estimate attributable mortality and disability-adjusted life years lost (DALYs).

Data Sources

Ambient fine particulate matter ($PM_{2.5}$) data come from a global dataset of satellite-derived pollution measurements published and maintained by the Atmospheric Composition Analysis Group of Washington University in Saint Louis (van Donkelaar et al. 2021). Specifically, we used a version of the dataset with annual average values of ground-level $PM_{2.5}$ concentrations (μg/m^3) at a 0.01° × 0.01° spatial resolution, covering the period from 1998 to 2022. Country-level estimates of the fraction of population-weighted exposure to $PM_{2.5}$ from different sources come from the Global Burden of Disease Major Air Pollution Sources project (McDuffie et al. 2021).

Sulfur dioxide, carbon monoxide, and volatile organic compound (ethane, formaldehyde, isoprene, and propane) concentrations come from the European Center for Medium-Range Weather Forecast's Atmospheric Composition Reanalysis 4 (EAC4) datasets, which are freely available from the Copernicus Atmospheric Data Store (ads.atmosphere.copernicus.eu). These global datasets are available at a 0.75º × 0.75º spatial resolution, and the 2024 EPI indicators cover the period from 2003 to 2022 (data from 2023 became available recently but not in time to be included in this edition of the EPI). Population density data come from the Gridded Population of the World v4.11 dataset, published by the Socioeconomic Data and Applications Center (CIESIN 2018).

Estimates of disability-adjusted life years (DALY) lost per 100,000 people due to exposure to $PM_{2.5}$ from household solid fuels, ozone, and nitrogen dioxide come from the Global Burden of Disease 2021 study (Brauer et al. 2024), published by the Institute of Health Metrics and Evaluation of the University of British Columbia. The GBD models DALYs as a function of exposure derived from satellite data (for ozone and nitrogen dioxide) and from surveys (for pollution from household solid fuels).

Limitations

EPI users must consider several limitations when interpreting the results of the Air Quality indicators. The Global Burden of Disease study estimates health risks from air pollution exposure based on the latest understanding of the links between exposure and a broad range of diseases, but statistical uncertainties persist due to ongoing research about exposure-health relationships and limitations in monitoring networks. For example, a recent study showed that gaps in satellite-derived measurements of PM2.5 pollution in India between 2017 and 2022 can lead to an overestimation of exposure and attributable mortality (Katoch et al. 2023). Similarly, the uncertainty in Copernicus air quality data is higher in areas lacking robust monitoring and emissions data.

While DALY rates are a standardized metric that facilitates comparisons of the public health burden of air pollution across countries, country-level averages can mask important regional variations in the impacts of different pollutants. In urban areas, ambient $PM_{2.5}$ and ozone are key health concerns, while pollution from household solid fuels is typically more important in rural environments. However, an exclusive focus on household pollution from the use of solid fuels ignores the substantial contribution of gas stoves to indoor concentrations of nitrogen dioxide, carbon monoxide, formaldehyde, and other air pollutants (Nicole 2014). This indoor pollution is particularly harmful to children and is of great concern given that, as opposed to solid fuels, gas stoves are prevalent in most countries (Gruenwald et al. 2023). Electric stoves are a superior option for improving air quality, but in 2020, they were used only in approximately 8 percent of households worldwide (Stoner et al. 2021). Future editions of the EPI will incorporate metrics of the proportion of households using electric stoves, given the importance of phasing out natural gas stoves (and solid fuels) for both air quality and climate change mitigation.

Weighting Rationale

The weight of different issue categories within the Environmental Health policy objective (Air Quality, Drinking Water & Sanitation, and Heavy Metals), as well as of the different indicators within the Air Quality issue category, are roughly proportional to the fraction of global DALYs attributable to each environmental risk factor.

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Chapter 5. Sanitation & Drinking Water

1. Introduction

Access to adequate sanitation facilities and clean drinking water is essential to our health and quality of life. Water and sanitation infrastructure impact not only human physical and mental health (Hutton and Chase 2017), but also school attendance (Adukia 2017) and the prevalence of sexual violence (Kayser et al. 2021).

Sanitation facilities enable households to dispose of human waste and fecal matter. The World Health Organization defines adequate sanitation as each family unit having access to a private latrine or restroom that hygienically separates fecal matter from human contact (WHO 2024). Flush toilets connected to a piped sewer system, septic tank pit latrines, pit latrines with improved ventilation or slabs, and composting toilets are all examples of adequate sanitation facilities.

Clean drinking water refers to the accessibility, availability, and quality of the water used by a given family for daily health and household needs (JMP 2023). An adequate water source must be easily accessible and unlikely to be contaminated, particularly by fecal matter. Examples of adequate water sources include household water connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection (WHO 2023).

In 2022, 27 percent of the world's population lacked access to a safely managed water source, while 43 percent did not use a safely managed sanitation system (UN Water 2023). This lack of clean drinking water is a leading cause of death for children under five, while microbiologically tainted drinking sources cause over half a million deaths per year from illnesses including diarrhea, cholera, dysentery, typhoid, and polio (WHO 2023). Further, lack of access to sanitation facilities increases the risk of water-borne illness, sexual assault, and early-education drop-out (WHO 2024; Andrés, Joseph, and Rana 2021).

Lack of safe drinking water and sanitation limits social progress and economic development, exacerbating existing gender, race, and class inequities. Women and girls generally bear the brunt of providing water for their families, which results in increased female school dropout rates and lessening women's economic and social engagement (WHO/UNICEF JMP 2023). Further, lack of adequate sanitation usually results in sewage and sludge being directed towards marginalized areas of cities and towns, increasing inequalities in health and living conditions (Ghosh, Hossain, and Sarkar 2023; Saroj et al. 2020; Wells et al. 2022).

Inadequate water and sanitation access gives rise to a myriad of health, social, and economic problems that will only worsen with ongoing climate change. Currently, two billion people live in water-stressed countries, and this number is rising along with global temperatures (He et al. 2021; Munia et al. 2020). As weather patterns become more erratic and countries deplete their supply of groundwater, investments in renewable water sources will be vital in meeting population needs (Scanlon et al. 2023; Jasechko and Perrone 2021).

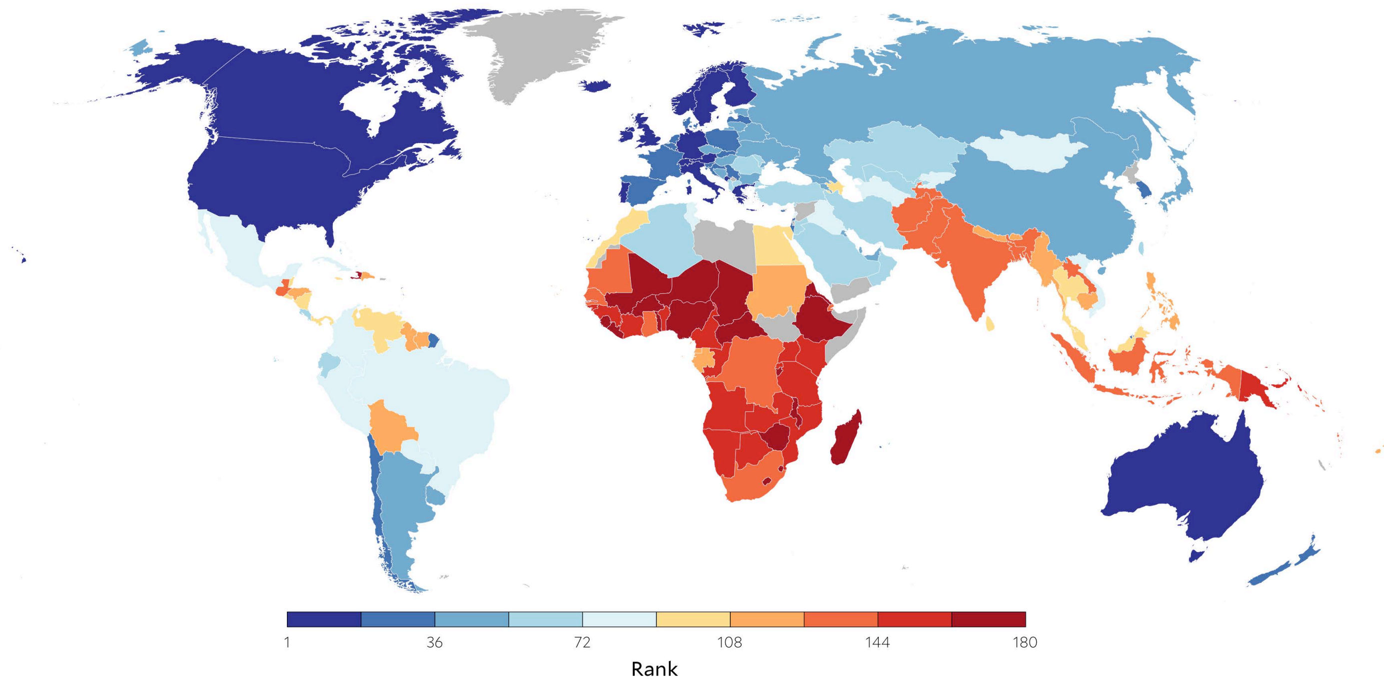
Through tracking the public health consequences of lack of access to safe drinking water and sanitation facilities, the 2024 EPI indicators provide countries with information to better understand if their sanitation and water infrastructure is adequately protecting the health of their citizens.

2. Indicators

Unsafe Sanitation
(40% of issue category)
We measure unsafe sanitation using the number of age-standardized disability-adjusted life-years lost per 100,000 persons (DALY rate) due to lack of improved sanitation facilities, such as flush toilets and composting toilets.

Unsafe Drinking Water
(60% of issue category)
We measure unsafe drinking water using the number of age-standardized disability- adjusted life-years lost per 100,000 persons (DALY rate) due to exposure to unsafe drinking water.

Map 5-1. Global rankings on Sanitation & Drinking Water.



Map 5-2. Sanitation & Drinking Water scores.

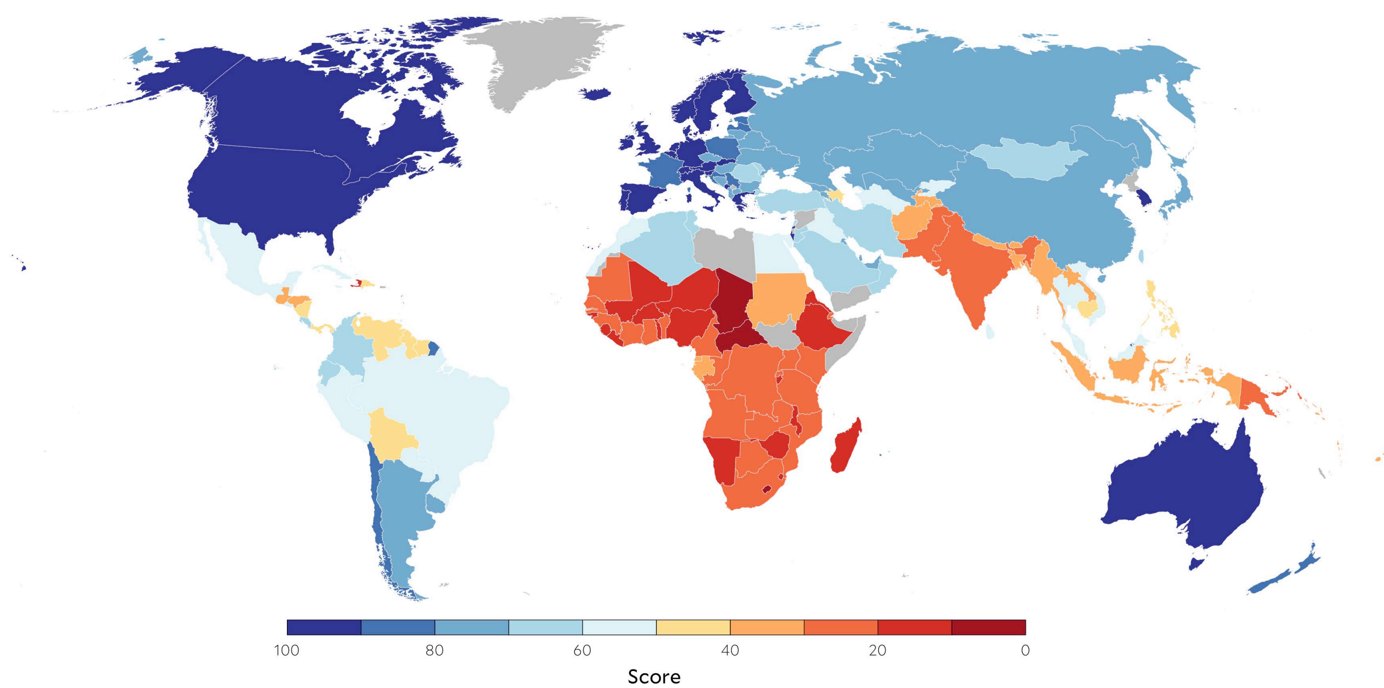


Table 5-1. Global rankings, scores, and regional rankings (REG) on the Sanitation & Drinking Water issue category.

RANK	COUNTRY	SCORE	REG
1	Finland	100.0	1
1	Germany	100.0	1
1	Switzerland	100.0	1
1	United Kingdom	100.0	1
5	Luxembourg	99.8	5
5	Norway	99.8	5
7	Australia	99.5	7
8	Singapore	99.2	1
9	Italy	98.6	8
10	Iceland	98.5	9
11	Montenegro	97.1	1
12	Sweden	96.9	10
13	Greece	96.6	2
14	Portugal	96.4	11
15	United States of America	96.2	12
16	Austria	96.0	13
17	Ireland	95.6	14
18	Canada	95.5	15
19	Malta	95.3	16
20	Spain	93.8	17
21	Denmark	93.6	18
22	Belgium	93.3	19
23	Slovakia	92.6	3
24	Israel	92.0	1
25	Slovenia	91.2	4
26	Netherlands	91.1	20
27	South Korea	90.1	2
28	Cyprus	89.4	5
29	France	88.2	21
30	Brunei Darussalam	87.2	3
31	New Zealand	86.3	22
32	Croatia	84.8	6
33	Latvia	82.4	7
34	Serbia	82.0	8
35	Chile	80.8	1
36	Poland	80.1	9
37	Estonia	80.0	10
38	Czech Republic	79.3	11
39	Bulgaria	79.0	12
40	Bosnia and Herzegovina	78.3	13
41	Japan	78.1	4
42	Belarus	77.5	1
43	Kuwait	77.1	2
44	Qatar	76.6	3
45	Uruguay	76.5	2
46	Russia	76.0	2
47	Armenia	75.8	3
47	Lithuania	75.8	14
49	China	73.9	5
50	Ukraine	73.7	4
51	United Arab Emirates	73.6	4
52	Georgia	73.5	5
52	Hungary	73.5	15
54	Argentina	73.4	3
55	Kazakhstan	72.9	6
56	Uzbekistan	72.8	7
57	Albania	71.0	16
58	North Macedonia	70.0	17
59	Bahrain	69.0	5
59	Taiwan	69.0	6
61	Oman	68.5	6
62	Romania	68.0	18
63	Moldova	66.6	8
64	Costa Rica	66.4	4
64	Jordan	66.4	7
66	Saudi Arabia	65.4	8
67	Bahamas	65.3	5
68	Iran	64.9	9
69	Algeria	64.1	10
69	Ecuador	64.1	6
71	Mauritius	63.3	1
72	Türkiye	63.0	19
73	Lebanon	62.6	11
74	Tunisia	61.5	12
75	Mongolia	61.4	7
76	Colombia	60.6	7
77	Trinidad and Tobago	59.8	8
78	Kyrgyzstan	59.7	9
79	Barbados	59.1	9
79	Brazil	59.1	9
81	Mexico	58.2	11
81	Turkmenistan	58.2	10
83	Cuba	57.8	12
83	Iraq	57.8	13
85	Paraguay	57.3	13
86	Samoa	56.7	8
87	Peru	56.3	14
88	Antigua and Barbuda	55.8	15
89	Seychelles	54.6	2
90	Viet Nam	54.3	9
91	Grenada	53.5	16
91	Malaysia	53.5	10
93	Jamaica	53.3	17
94	Saint Lucia	52.9	18
95	Sri Lanka	52.8	1
96	Egypt	52.6	14
97	Maldives	51.5	2
98	St. Vincent and Grenadines	51.3	19
98	Thailand	51.3	11
100	Morocco	50.9	15
101	Dominica	50.7	20
102	Belize	50.1	21
102	El Salvador	50.1	21
104	Tonga	49.7	12
105	Panama	48.9	23
106	Azerbaijan	47.9	11
107	Venezuela	47.8	24
108	Nicaragua	47.3	25
109	Bolivia	46.6	26
110	Suriname	43.2	27
111	Dominican Republic	42.5	28
112	Philippines	42.4	13
113	Guyana	42.2	29
114	Cambodia	40.0	14
115	Micronesia	39.4	15
116	Sudan	39.1	16
117	Honduras	37.7	30
117	São Tomé and Príncipe	37.7	3
119	Marshall Islands	36.6	16
120	Cabo Verde	36.1	4
120	Fiji	36.1	17
122	Myanmar	35.4	18
123	Equatorial Guinea	35.1	5
124	Bhutan	35.0	3
125	Nepal	34.3	4
126	Gabon	33.9	6
127	Solomon Islands	33.6	19
128	Indonesia	33.2	20
129	Timor-Leste	33.1	21
130	Vanuatu	32.4	22
131	Afghanistan	32.3	5
132	Laos	32.2	23
133	Bangladesh	32.0	6
134	Guatemala	31.3	31
135	Tajikistan	31.1	12
136	Pakistan	28.0	7
137	Ghana	27.4	7
138	Senegal	27.3	8
139	Mauritania	26.9	9
140	Comoros	25.7	10
140	Djibouti	25.7	11
142	Dem. Rep. Congo	25.6	12
143	India	25.4	8
144	South Africa	25.0	13
145	Gambia	24.9	14
146	Rwanda	24.7	15
147	Republic of Congo	24.4	16
148	Côte d'Ivoire	24.3	17
149	Uganda	23.6	18
150	Cameroon	23.0	19
151	Angola	22.9	20
152	Kiribati	21.6	24
153	Zambia	21.5	21
154	Papua New Guinea	21.2	25
155	Kenya	21.0	22
156	Tanzania	20.6	23
157	Mozambique	20.5	24
158	Botswana	20.1	25
158	Guinea	20.1	25
160	Benin	20.0	27
161	Guinea-Bissau	19.8	28
161	Namibia	19.8	28
163	Zimbabwe	19.5	30
164	Liberia	18.7	31
165	Ethiopia	18.4	32
165	Mali	18.4	32
167	Eswatini	18.2	34
168	Haiti	18.1	32
169	Togo	17.8	35
170	Sierra Leone	17.7	36
171	Malawi	17.1	37
172	Burundi	16.9	38
173	Eritrea	16.0	39
174	Burkina Faso	15.7	40
175	Nigeria	14.3	41
176	Madagascar	12.9	42
177	Niger	12.3	43
178	Lesotho	9.5	44
179	Central African Republic	8.9	45
180	Chad	4.4	46

Asia-Pacific
Eastern Europe
Former Soviet States
Global West
Greater Middle East
Latin America & Caribbean
Southern Asia
Sub-Saharan Africa

Table 5-2. Regional rankings and scores on Sanitation & Drinking Water.

Latin America & Caribbean		
Country	Score	Rank
Chile	80.8	1
Uruguay	76.5	2
Argentina	73.4	3
Costa Rica	66.4	4
Bahamas	65.3	5
Ecuador	64.1	6
Colombia	60.6	7
Trinidad and Tobago	59.8	8
Barbados	59.1	9
Brazil	59.1	9
Mexico	58.2	11
Cuba	57.8	12
Paraguay	57.3	13
Peru	56.3	14
Antigua and Barbuda	55.8	15
Grenada	53.5	16
Jamaica	53.3	17
Saint Lucia	52.9	18
St. Vincent and Grenadines	51.3	19
Dominica	50.7	20
Belize	50.1	21
El Salvador	50.1	21
Panama	48.9	23
Venezuela	47.8	24
Nicaragua	47.3	25
Bolivia	46.6	26
Suriname	43.2	27
Dominican Republic	42.5	28
Guyana	42.2	29
Honduras	37.7	30
Guatemala	31.3	31
Haiti	18.1	32

Eastern Europe		
Country	Score	Rank
Montenegro	97.1	1
Greece	96.6	2
Slovakia	92.6	3
Slovenia	91.2	4
Cyprus	89.4	5
Croatia	84.8	6
Latvia	82.4	7
Serbia	82.0	8
Poland	80.1	9
Estonia	80.0	10
Czech Republic	79.3	11
Bulgaria	79.0	12
Bosnia and Herzegovina	78.3	13
Lithuania	75.8	14
Hungary	73.5	15
Albania	71.0	16
North Macedonia	70.0	17
Romania	68.0	18
Türkiye	63.0	19

Southern Asia		
Country	Score	Rank
Sri Lanka	52.8	1
Maldives	51.5	2
Bhutan	35.0	3
Nepal	34.3	4
Afghanistan	32.3	5
Bangladesh	32.0	6
Pakistan	28.0	7
India	25.4	8

Global West		
Country	Score	Rank
Finland	100.0	1
Germany	100.0	1
Switzerland	100.0	1
United Kingdom	100.0	1
Luxembourg	99.8	5
Norway	99.8	5
Australia	99.5	7
Italy	98.6	8
Iceland	98.5	8
Sweden	96.9	10
Portugal	96.4	11
United States of America	96.2	12
Austria	96.0	13
Ireland	95.6	14
Canada	95.5	15
Malta	95.3	16
Spain	93.8	17
Denmark	93.6	18
Belgium	93.3	19
Netherlands	91.1	19
France	88.2	21
New Zealand	86.3	22

Former Soviet States		
Country	Score	Rank
Belarus	77.5	1
Russia	76.0	2
Armenia	75.8	3
Ukraine	73.7	4
Georgia	73.5	5
Kazakhstan	72.9	6
Uzbekistan	72.8	7
Moldova	66.6	8
Kyrgyzstan	59.7	9
Turkmenistan	58.2	10
Azerbaijan	47.9	11
Tajikistan	31.1	12

Asia-Pacific		
Country	Score	Rank
Singapore	99.2	1
South Korea	90.1	2
Brunei Darussalam	87.2	3
Japan	78.1	4
China	73.9	5
Taiwan	69.0	6
Mongolia	61.4	7
Samoa	56.7	8
Viet Nam	54.3	9
Malaysia	53.5	10
Thailand	51.3	11
Tonga	49.7	12
Philippines	42.4	13
Cambodia	40.0	14
Micronesia	39.4	15
Marshall Islands	36.6	16
Fiji	36.1	17
Myanmar	35.4	18
Solomon Islands	33.6	19
Indonesia	33.2	20
Timor-Leste	33.1	21
Vanuatu	32.4	22
Laos	32.2	23
Kiribati	21.6	24
Papua New Guinea	21.2	25

Sub-Saharan Africa		
Country	Score	Rank
Mauritius	63.3	1
Seychelles	54.6	2
São Tomé and Príncipe	37.7	3
Cabo Verde	36.1	4
Equatorial Guinea	35.1	5
Gabon	33.9	6
Ghana	27.4	7
Senegal	27.3	8
Mauritania	26.9	9
Comoros	25.7	10
Djibouti	25.7	10
Dem. Rep. Congo	25.6	12
South Africa	25.0	13
Gambia	24.9	14
Rwanda	24.7	15
Republic of Congo	24.4	16
Côte d'Ivoire	24.3	17
Uganda	23.6	18
Cameroon	23.0	19
Angola	22.9	20
Zambia	21.5	21
Kenya	21.0	22
Tanzania	20.6	23
Mozambique	20.5	24
Botswana	20.1	25
Guinea	20.1	25
Benin	20.0	27
Guinea-Bissau	19.8	28
Namibia	19.8	28
Zimbabwe	19.5	30
Liberia	18.7	31
Ethiopia	18.4	32
Mali	18.4	32
Eswatini	18.2	34
Togo	17.8	35
Sierra Leone	17.7	36
Malawi	17.1	37
Burundi	16.9	38
Eritrea	16.0	39
Burkina Faso	15.7	40
Nigeria	14.3	41
Madagascar	12.9	42
Niger	12.3	43
Lesotho	9.5	44
Central African Republic	8.9	45
Chad	4.4	46

Greater Middle East		
Country	Score	Rank
Israel	92.0	1
Kuwait	77.1	2
Qatar	76.6	3
United Arab Emirates	73.6	4
Bahrain	69.0	5
Oman	68.5	6
Jordan	66.4	7
Saudi Arabia	65.4	8
Iran	64.9	9
Algeria	64.1	10
Lebanon	62.6	11
Tunisia	61.5	12
Iraq	57.8	13
Egypt	52.6	14
Morocco	50.9	15
Sudan	39.1	16

3. Global Trends

Despite recent progress, the world must redouble its efforts to meet the UN Sustainable Development Goal of universal water and sanitation access by 2030. Between 2000 and 2022, the proportion of the global population with access to safely managed water rose from 61 to 73 percent (JMP 2023), and 2.5 billion people gained access to safely managed sanitation services (UNICEF 2023). Despite this expansion of water and sanitation infrastructure over the past two decades, more than 2 billion people still lack access to safe drinking water, while 3.5 billion do not have access to safely managed sanitation.

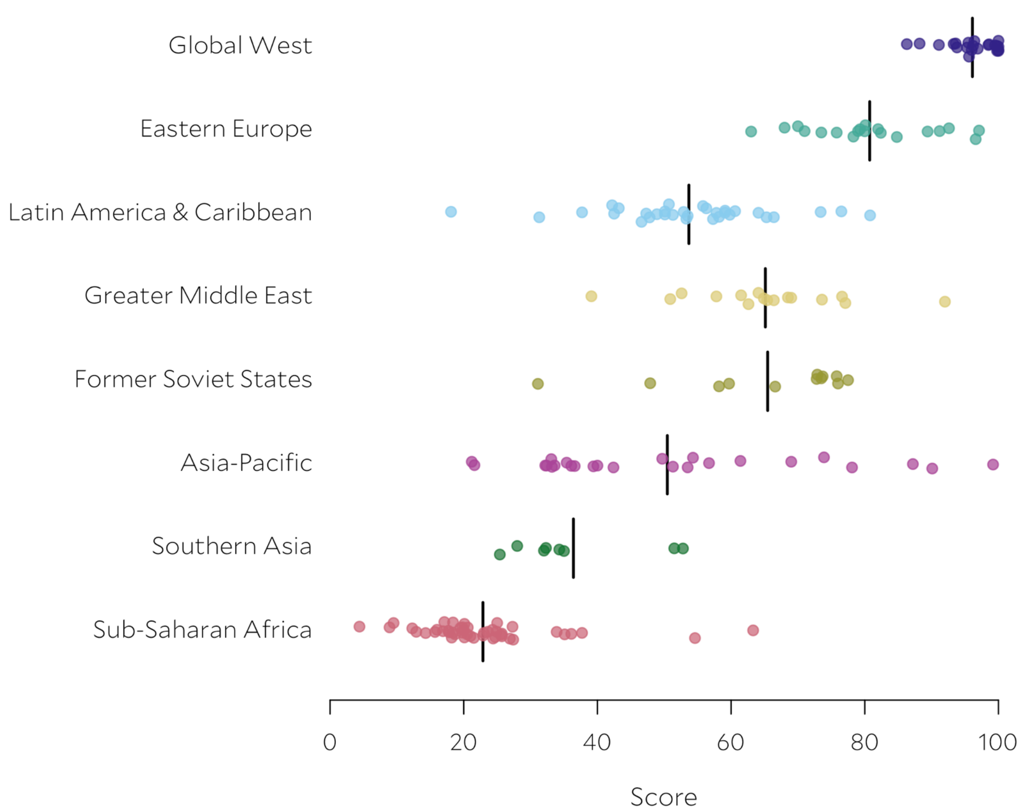
The expansion of access to safe drinking water and sanitation has already improved public health outcomes (Figure 5-2). According to the Global Burden of Disease data, the proportion of deaths attributable to unsafe drinking water fell from 3 to 1.3 percent between 2000 and 2021. During the same period, the percentage of global deaths attributable to unsafe sanitation fell from 2.6 to 0.95 percent.

Global trends mask substantial variation in access to safe sanitation and drinking water and its public health consequences between and within geographic regions (Figure 5-1). By 2022, 59 countries, mainly in the Global West, had achieved universal access to basic sanitation services. However, in 55 countries, mostly in Sub-Saharan Africa, less than half of the population had access (UNICEF 2023). As a result, over two percent of deaths in Southern Asia and Sub-Saharan Africa can be attributed to unsafe sanitation, while in Western Europe that percentage is zero.

Despite its already high performance, the European Union continues to pass legislation promoting the protection and improvement of water access. In January 2022, the European Union adopted the first drinking water watch list to closely monitor drinking water for beta-estradiol and nonylphenol – two endocrine-disrupting compounds (European Commission 2022). This and other policies represent the European Union's continued dedication to drinking water and sanitation, highlighting why its member nations consistently top the EPI rankings in this issue category. Nonetheless, even in countries with high access to safely managed water the burden of disease from contaminated water can be significant (Lee et al. 2023), especially when considering not only bacterial diseases but also exposure to chemical pollutants, such as per- and polyfluroalkyl substances (PFAS) and other emerging contaminants (Wee and Aris 2023; Cserbik et al. 2023; Ackerman Grunfeld et al. 2024).

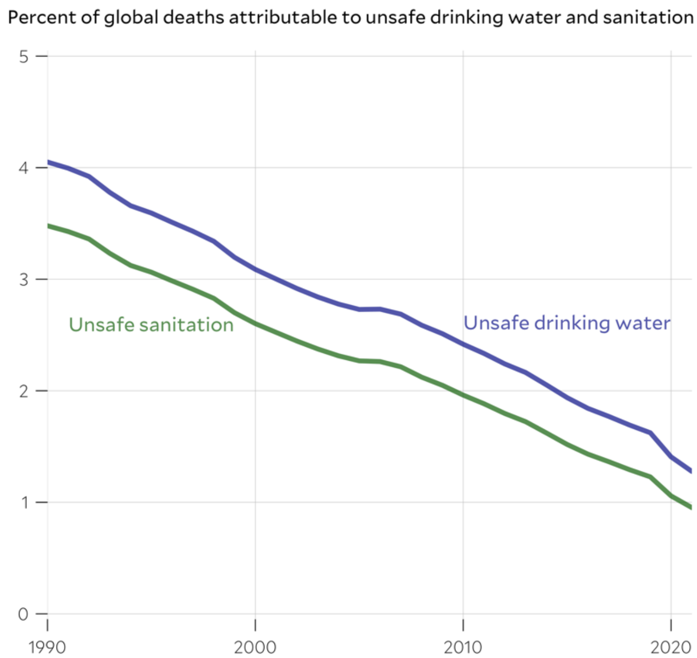
Low access to safe water is indicative of a lack of both drinking water infrastructure and general water availability. Many developing countries are located in regions with inadequate water supplies. For example, India contains 18 percent of the world's population, but has just 4 percent of the global freshwater supply (SIWI 2018). This mismatch results in high

Figure 5-1. Distribution of regional scores on Sanitation & Drinking Water. Vertical bars show regional averages.



levels of water stress, particularly for individuals living in poverty. Unfortunately, as the global population continues to rise and climate change worsens, water scarcity is likely to become more prevalent across all regions. In this context, new technologies to provide safe drinking water hold great potential. For example, using solar energy to harvest water directly from the air could provide drinking water for a billion people worlwide, especially in the tropics, where two thirds of people without safely managed water live (Lord et al. 2021).

Figure 5-2. Trends in the percentage of global deaths attributed to exposure to unsafe drinking water and sanitation. Data from the 2021 Global Burden of Disease study.



4. Leaders and Laggards

Outside the Global West, Singapore's strong performance in Sanitation and Drinking Water stands out among its Asian peers, reflecting decades of strong institutions prioritizing safe water management (Tortajada and Joshi 2014). Singapore's National Water Agency pioneered the automation of drinking water monitoring and early warning systems (Storey, van der Gaag, and Burns 2011). The country now benefits a robust monitoring system to test drinking water for potential chemical, microbiological, and radiological contaminants (PUB 2023). Yet, despite the top quality of their tap water, many Singaporeans boil tap water before drinking (Li, Araral, and Jeuland 2019), further removing potential bacterial and chemical contamination (Yu et al. 2024). Singapore not only has universal access to safe sanitation, but it is also a global leader in the treatment and reuse of wastewater. The Singaporean government has integrated wastewater reuse into its socioeconomic development and water security (Tortajada 2024).

While most countries in Central America still struggle with poor access to safe sanitation and drinking water, Costa Rica has made significant progress thanks to thoughtful and comprehensive national policymaking. In 2022, thanks to a coordinated effort involving several Costa Rican governmental divisions, including the Ministry of Health and the National Water Laboratory, over 80 percent of the population had access to safely managed drinking water, while more than 98 percent had access to at least basic sanitation (WHO/UNICEF JMP 2024). Much of this progress was due to policies improving water infrastructure in rural parts of the country. As a result, Costa Rica has one of the lowest levels of inequality in access to water and sanitation in Latin America (Queiroz, Carvalho, and Heller 2020).

Despite being one of Asia's largest economies, India still lags its peers in providing water access to its citizens. With a growing population and limited water resources, India is one of the most water stressed countries in the world (SIWI 2018; He et al. 2021). India's *Swachh Bharat* (Clean India) Mission, launched in 2014, has significantly improved access to toilets and reduced open defecation (Curtis 2019), leading to more than a 50 percent reduction in the rate disability-adjusted life years lost due to unsafe sanitation over the last decade of available data. Additionally, the burden of disease from unsafe water exposure halved between 2012 and 2021. The *Jal Jeevan* Mission, launched in 2019, aims to provide clean drinking water to all Indian households by 2024. Despite these achievements, 3.25 percent of all deaths in India in 2021 were still linked to unsafe drinking water. Moreover, access to safe sanitation and drinking water in India reflects deep social and economic inequalities (Ghosh, Hossain, and Sarkar 2023). To sustain its recent progress, India will need not only to enforce its policies more strictly, but also to address these fundamental inequalities (Sarkar and Bharat 2021).

Sub-Saharan Africa lags far behind most other regions in access to safe sanitation and drinking water. In 2022, less than a third of its population had access to a safely managed drinking water, and less than a quarter had access to safely managed sanitation (UN Water 2022). While these fractions are rising, population growth means the actual number of people lacking access to sanitation and drinking water is increasing. For instance, the number of people in the region without access to basic drinking water services grew from 350 million in 2000 to 387 million in 2020 (WHO/UNICEF JMP 2021). Mauritius is a notable outlier in the region, with near universal access to safe water and sanitation. The island nation uses a network of canals, dams, and dikes to protect and transport its water, which is largely sourced from aquifers. Mauritius' National Water Policy, introduced in 2014, aimed at providing universal access to safe and reliable drinking water by 2020, and built on years of investments in water management infrastructure (Proag 2006).

Countries around the world demonstrate that bold investments water and sanitation infrastructure are key to improving public health. Policy efforts that proactively plan for urbanization and climate change, and work to extend water systems to rural areas, are essential to guarantee universal access to safe water and sanitation.

5. Methods

Safe and clean drinking water and sanitation is an essential human right, and its access for all was recognized as a global priority in 2015 as the Sustainable Development Goal target 6.1 (Sadoff, Borgomeo, and Uhlenbrook 2020). However, measuring global progress towards this basic human right has remained challenging due to the diversity of sanitation facilities, water sources and water treatments around the world, and the difficulty in assessing their relative safety. Moreover, while initial benchmarks focused on simple access and availability, recent water quality monitoring emphasizes the importance of tracking health outcomes. The most comprehensive data on health outcomes associated with exposure to environmental risks comes from the Global Burden of Disease Study (GBD) from the Institute for Health Metrics and Evaluation (IHME), enabling health risk assessments related to water and sanitation for almost every country and territory. Based on the latest GBD data, the 2024 EPI uses two indicators to gauge health impacts from unsafe drinking water and sanitation.

Indicator Background

Estimates of the health impacts of exposure to unsafe sanitation and unsafe drinking water are based on the GBD's Comprehensive Risk Assessment framework, and measured by age-standardized disability-adjusted life years (DALYs) lost per 100,000 persons (Brauer et al. 2024). To estimate DALYs, the GBD authors first assess the exposure to health risks in each country and then use statistical models to estimate the fraction of deaths and DALYs lost attributable to those risks.

Exposure to unsafe drinking water in a household is based on two factors: the primary water source and the treatment of drinking water at the household to improve its quality before consumption. Water sources are categorized as "improved" or "unimproved" as defined in the WHO/UNICEF Joint Monitoring Program for Water Supply, Sanitation and Hygiene. "Improved" sources of drinking water are those likely to be protected from outside contamination, especially from fecal matter. Boreholes, tube wells, protected wells, and packaged or delivered water are all examples of improved sources. Piped water is also considered "improved", but the GBD places it into its own category. Unimproved sources include unprotected springs, unprotected wells, and surface water. The risk from both improved and unimproved water sources can be reduce by treating water in before drinking it. GBD considers four household water treatments: solar treatment, chlorine treatment, boiling, and filtering.

Exposure to unsafe sanitation is determined by the type of toilet used by households. The GBD considers three categories of sanitation facilities, as defined in the WHO/UNICEF Joint Monitoring Program for Water Supply, Sanitation and Hygiene: unimproved, improved, and toilets with a sewer connection or septic tank. Open pit latrines, open defecation, and toilets that flush into creeks or open fields are all examples of "unimproved" facilities. "Improved" facilities include ventilated improved pit latrines, composting toilets, and pit latrines with slabs. Finally, sewer connection toilets include flush toilets or any toilet with connection to the sewer or septic tank.

Data Sources

Data come from the Global Burden of Disease Study 2021, available from 1990 to 2021 for 204 countries and territories. The GBD compiles data on household water sources and sanitation facilities from household surveys and censuses, such as the Demographic and Health Survey, the Multiple Indicator Cluster Surveys, the World Health Survey, and the DHS AIDS Indicator Survey (Murray et al. 2020). Survey and census data were then pooled, corrected for bias, and further adjusted with other covariates. Data are freely available from the GBD results tool: *https://vizhub.healthdata.org/gbd-results/*

Limitations

While the GBD offers valuable insights, tracking all health problems caused by unsafe water and sanitation remains a challenge. The GBD focuses on assessing risk of bacterial contamination leading to diarrheal diseases. While unsafe drinking water and sanitation are also linked to risk of other serious bacterial diseases, such as typhoid (Hu et al. 2022), cholera (Challa et al. 2022), and shigellosis (Nisa et al. 2021), data on how the prevalence of these diseases varies as a function of access to safe water and sanitation is too scarce for robust modelling of risk exposure.

Moreover, a sole focus on health hazards from biological contamination ignores the emerging threat of chemical contaminants, such as as heavy metals, pesticides, and per- and polyfluroalkyl substances – commonly known as "forever chemicals" (Villanueva et al. 2014). Chemical contaminants of drinking water are widespread across both developed and developing countries (Voutchkova et al. 2021; El-Nahhal and El-Nahhal 2021; Wee and Aris 2023), and can cause serious health consequences including cancer, hormonal disregulation, and lowered fertility (Alavanja, Hoppin, and Kamel 2004; Kahn et al. 2020).

Furthermore, assuming that "improved" water sources are free of contamination, or entail a lower risk of disease, may sometimes be inaccurate (Clasen et al. 2014). Piped water and even well water, not just open sources, can be contaminated by soil pollutants or leakage from nearby latrines (Back et al. 2018), and millions of people are potentially exposed to high concentrations of arsenic in groundwater (Podgorski and Berg 2020). Access to improved water sources and safe sanitation facilities does not guarantee good health outcomes.

Weighting Rationale

The weight of the issue category and its component indicators is roughly proportional to their global DALY rates in relation to each other and other environmental risk factors included in the EPI.

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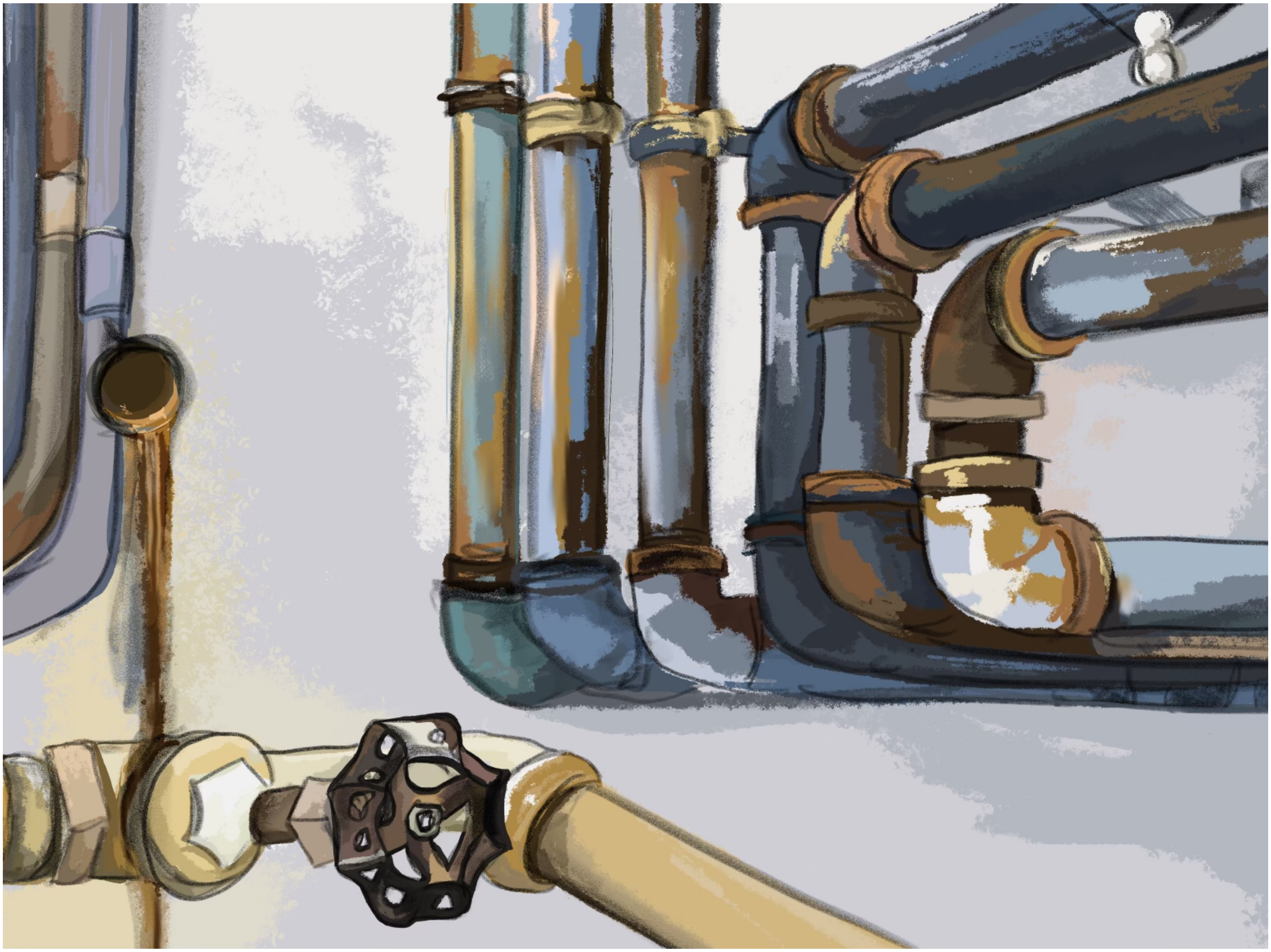


Chapter 6. Heavy Metals

1. Introduction

Heavy metals—such as arsenic, cadmium, chromium, lead, and mercury—are toxic to virtually every organ system in the human body (Tchounwou et al. 2012). In 2019, exposure to lead alone was responsible for approximately one percent of the global burden of disease, measured in disability-adjusted life years lost (Murray et al. 2020; Zhou et al. 2022). There is no safe level of exposure to lead, which is particularly harmful to children (WHO 2023). Lead exposure during childhood harms the brain and central nervous system irreversibly, delaying development, reducing cognitive ability, and increasing antisocial behavior (WHO 2023). Lead exposure is also linked to anemia, renal failure, hypertension, and other serious health problems (Larsen and Sánchez-Triana 2023).

Lead exposure is prevalent in every area of the world, especially in low-income and middle-income countries (Ericson et al. 2021). Due to the long-lasting health and cognitive effects of lead exposure, even countries where policies have successfully reduced lead exposure still suffer the consequences of exposure that happened decades ago. In the United States, half of the population was exposed to harmful levels of lead in early childhood, which caused an average loss of 2.6 IQ points as of 2015 (McFarland, Hauer, and Reuben 2022). Losses of cognitive ability due to lead exposure hinder individuals' educational attainment and professional productivity, which translate into significant economic losses for society. In Africa, for example, these losses amount to over four percent of GDP (Attina and Trasande 2013).

Exposure to other heavy metals also has serious health consequences (Rahaman et al. 2021; Zhang et al. 2021), but due to limited available data, the EPI focuses on the public health consequences of lead exposure as a representative measure of heavy metal pollution.

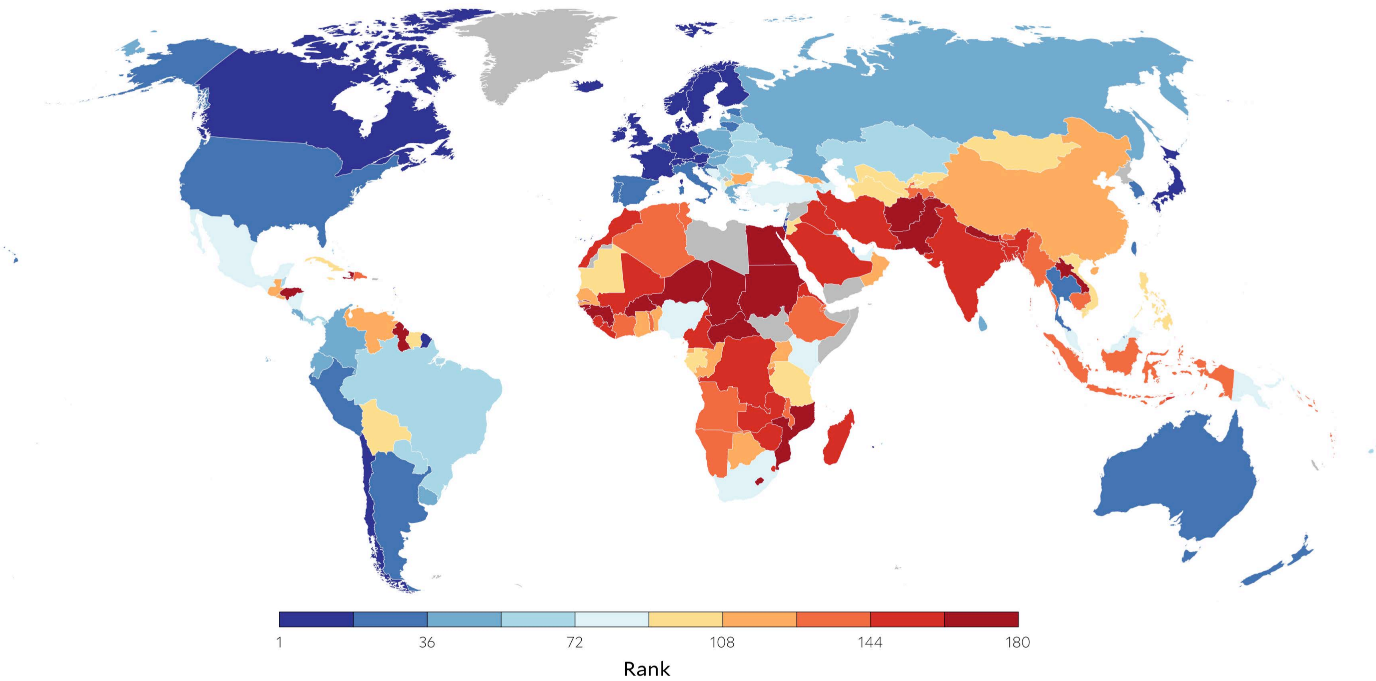
2. Indicators

Lead Exposure

(100% of issue category)

We measure lead exposure using the number of age-standardized disability-adjusted life-years lost per 100,000 persons (DALY rate) due to this environmental risk.

Map 6-1. Global rankings on Heavy Metals.



Map 6-2. Heavy Metals scores.

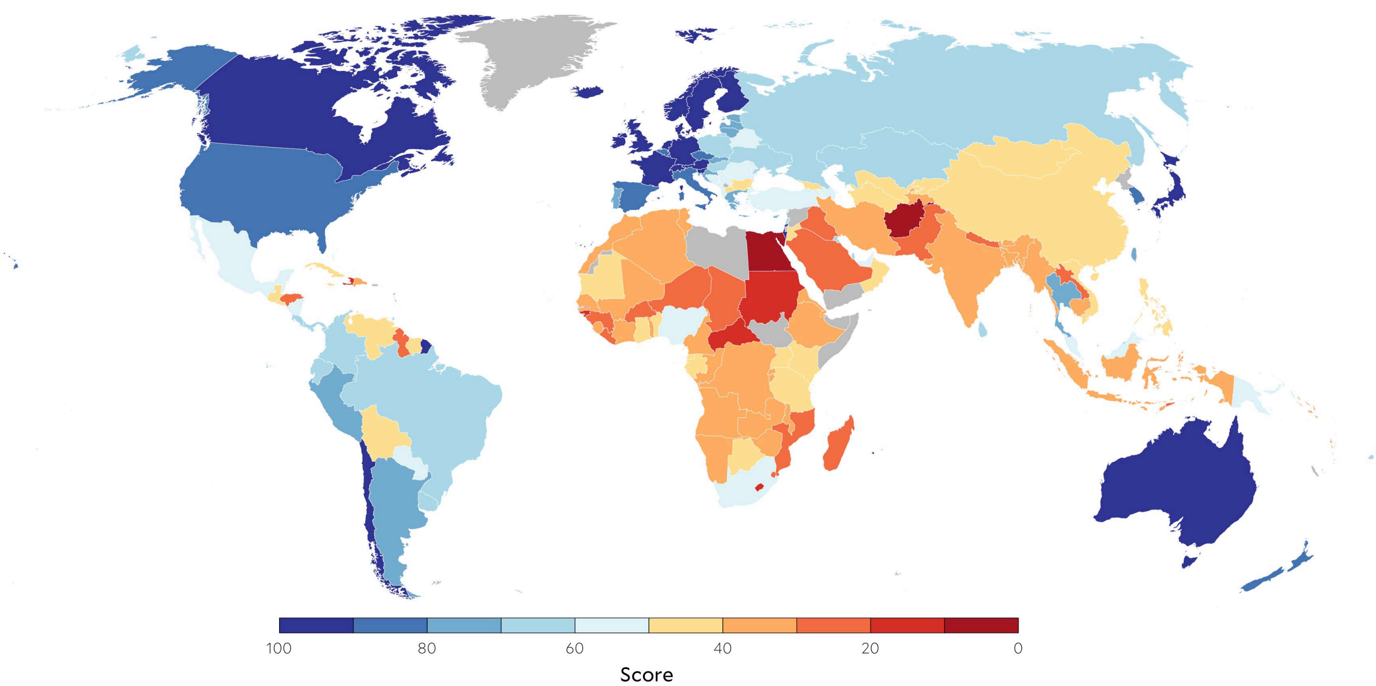


Table 6-1. Global rankings, scores, and regional rankings (REG) on the Heavy Metals issue category.

RANK	COUNTRY	SCORE	REG
1	Canada	100.0	1
1	Denmark	100.0	1
1	Finland	100.0	1
1	Israel	100.0	1
1	Japan	100.0	1
1	Luxembourg	100.0	1
1	Netherlands	100.0	1
1	Norway	100.0	1
1	Sweden	100.0	1
10	Iceland	99.8	8
10	United Kingdom	99.8	8
12	France	98.9	10
13	Germany	98.7	11
14	Chile	98.1	1
15	Ireland	97.3	12
16	Slovenia	96.6	1
17	Switzerland	96.2	13
18	Austria	92.3	14
19	Australia	90.3	15
20	South Korea	89.4	2
21	Belgium	85.2	16
22	Czech Republic	84.8	2
22	New Zealand	84.8	17
24	Italy	83.6	18
25	Singapore	82.5	3
25	United States of America	82.5	19
27	Spain	81.7	20
28	Thailand	79.3	4
29	Tonga	77.9	5
30	Argentina	76.7	2
31	Taiwan	75.7	6
32	Lithuania	75.4	3
32	Portugal	75.4	21
34	Estonia	72.6	4
35	Peru	72.1	3
36	Croatia	72.0	5
37	Latvia	71.9	6
38	Greece	71.1	7
39	Cyprus	70.9	8
39	Slovakia	70.9	8
41	Barbados	69.5	4
42	Colombia	69.1	5
42	Poland	69.1	10
44	Sri Lanka	69.0	1
44	Trinidad and Tobago	69.0	6
46	Brunei Darussalam	68.8	7
47	Qatar	68.6	2
48	Uruguay	68.5	7
49	Costa Rica	68.2	8
50	Malta	67.4	22
51	Lebanon	66.2	3
52	Ecuador	66.0	9
53	Hungary	65.7	11
54	Russia	65.5	1
55	Panama	65.3	10
56	Ukraine	64.5	2
57	Kuwait	64.0	4
58	Fiji	63.3	8
58	Seychelles	63.3	1
60	Kazakhstan	62.4	3
61	Samoa	61.9	9
62	Mauritius	61.3	2
63	Brazil	61.2	11
64	Maldives	61.0	2
65	Montenegro	59.8	12
66	Armenia	58.4	4
67	Belize	57.9	12
68	Serbia	57.8	13
69	Bahamas	57.6	13
70	Romania	57.1	14
71	Belarus	56.6	5
72	Paraguay	56.2	14
73	Türkiye	55.8	15
74	Papua New Guinea	55.4	10
75	Albania	55.2	16
76	Malaysia	54.9	11
76	Moldova	54.9	6
78	Kiribati	54.0	12
79	United Arab Emirates	53.5	5
80	Mexico	52.8	15
81	Bosnia and Herzegovina	52.4	17
82	South Africa	52.2	3
83	Antigua and Barbuda	52.1	16
84	Bahrain	51.6	6
85	Nicaragua	51.2	17
86	Nigeria	50.6	4
87	Azerbaijan	50.4	7
88	Micronesia	49.4	13
89	Kenya	49.3	5
90	Cabo Verde	48.8	6
91	Cuba	48.6	18
92	Dominica	48.4	19
93	Saint Lucia	47.8	20
93	Uzbekistan	47.8	8
95	Marshall Islands	47.7	14
95	Tanzania	47.7	7
97	Bolivia	46.9	21
97	Viet Nam	46.9	15
99	Kyrgyzstan	46.7	9
100	North Macedonia	46.6	18
101	Jordan	46.4	7
102	Jamaica	46.2	22
103	Mongolia	45.4	16
103	Turkmenistan	45.4	10
105	Philippines	45.2	17
106	Gabon	44.9	8
107	Mauritania	44.3	9
108	Suriname	43.2	23
109	El Salvador	43.1	24
109	Equatorial Guinea	43.1	10
111	Ghana	43.0	11
112	China	42.9	18
113	Comoros	42.5	12
114	Uganda	41.8	13
115	Guatemala	41.7	25
115	Venezuela	41.7	25
117	Benin	41.6	14
117	São Tomé and Príncipe	41.6	14
119	Botswana	40.8	16
119	Bulgaria	40.8	19
121	Georgia	40.5	11
122	Grenada	40.4	27
123	Oman	40.2	8
124	Rwanda	39.7	17
125	Senegal	39.0	18
126	Republic of Congo	38.9	19
127	Djibouti	38.0	20
127	Vanuatu	38.0	19
129	Namibia	37.7	21
130	Tajikistan	37.2	12
131	Tunisia	36.7	9
132	Ethiopia	36.5	22
133	Côte d'Ivoire	34.3	23
134	Bhutan	33.9	3
134	Dominican Republic	33.9	28
134	Togo	33.9	24
137	Angola	33.8	25
138	Indonesia	33.4	20
139	Malawi	33.3	26
140	Burundi	33.0	27
141	Myanmar	32.7	21
142	Algeria	32.6	10
143	Cambodia	32.3	22
144	Solomon Islands	32.0	23
145	Cameroon	31.7	28
145	St. Vincent and Grenadines	31.7	29
147	India	31.6	4
147	Sierra Leone	31.6	29
147	Zambia	31.6	29
150	Dem. Rep. Congo	31.1	31
150	Eritrea	31.1	31
152	Mali	30.7	33
153	Morocco	30.5	11
154	Bangladesh	30.4	5
154	Zimbabwe	30.4	34
156	Iran	30.2	12
157	Saudi Arabia	29.6	13
158	Eswatini	29.0	35
159	Liberia	28.9	36
160	Iraq	27.7	14
161	Madagascar	27.3	37
162	Timor-Leste	27.2	24
163	Gambia	26.8	38
164	Niger	26.6	39
165	Guinea	26.5	40
166	Pakistan	25.8	6
167	Burkina Faso	25.7	41
168	Laos	25.2	25
169	Nepal	24.7	7
170	Guyana	23.6	30
171	Honduras	22.0	31
172	Chad	20.8	42
173	Mozambique	20.0	43
174	Lesotho	19.4	44
175	Guinea-Bissau	19.3	45
176	Central African Republic	18.5	46
177	Sudan	15.2	15
178	Haiti	11.6	32
179	Egypt	5.0	16
180	Afghanistan	0.0	8

Asia-Pacific | Eastern Europe | Former Soviet States | Global West

Greater Middle East | Latin America & Caribbean | Southern Asia | Sub-Saharan Africa

Table 5-2. Regional rankings and scores on Sanitation & Drinking Water.

Latin America & Caribbean

Country	Score	Rank
Chile	98.1	1
Argentina	76.7	2
Peru	72.1	3
Barbados	69.5	4
Colombia	69.1	5
Trinidad and Tobago	69.0	6
Uruguay	68.5	7
Costa Rica	68.2	8
Ecuador	66.0	9
Panama	65.3	10
Brazil	61.2	11
Belize	57.9	12
Bahamas	57.6	13
Paraguay	56.2	14
Mexico	52.8	15
Antigua and Barbuda	52.1	16
Nicaragua	51.2	17
Cuba	48.6	18
Dominica	48.4	19
Saint Lucia	47.8	20
Bolivia	46.9	21
Jamaica	46.2	22
Suriname	43.2	23
El Salvador	43.1	24
Guatemala	41.7	25
Venezuela	41.7	25
Grenada	40.4	27
Dominican Republic	33.9	28
St. Vincent and Grenadines	31.7	29
Guyana	23.6	30
Honduras	22.0	31
Haiti	11.6	32

Eastern Europe

Country	Score	Rank
Slovenia	96.6	1
Czech Republic	84.8	2
Lithuania	75.4	3
Estonia	72.6	4
Croatia	72.0	5
Latvia	71.9	6
Greece	71.1	7
Cyprus	70.9	8
Slovakia	70.9	8
Poland	69.1	10
Hungary	65.7	11
Montenegro	59.8	12
Serbia	57.8	13
Romania	57.1	14
Türkiye	55.8	15
Albania	55.2	16
Bosnia and Herzegovina	52.4	17
North Macedonia	46.6	18
Bulgaria	40.8	19

Southern Asia

Country	Score	Rank
Sri Lanka	69.0	1
Maldives	61.0	2
Bhutan	33.9	3
India	31.6	4
Bangladesh	30.4	5
Pakistan	25.8	6
Nepal	24.7	7
Afghanistan	0.0	8

Global West

Country	Score	Rank
Canada	100.0	1
Denmark	100.0	1
Finland	100.0	1
Luxembourg	100.0	1
Netherlands	100.0	1
Norway	100.0	1
Sweden	100.0	1
Iceland	99.8	8
United Kingdom	99.8	8
France	98.9	10
Germany	98.7	11
Ireland	97.3	12
Switzerland	96.2	13
Austria	92.3	14
Australia	90.3	15
Belgium	85.2	16
New Zealand	84.8	17
Italy	83.6	18
United States of America	82.5	19
Spain	81.7	20
Portugal	75.4	21
Malta	67.4	22

Former Soviet States

Country	Score	Rank
Russia	65.5	1
Ukraine	64.5	2
Kazakhstan	62.4	3
Armenia	58.4	4
Belarus	56.6	5
Moldova	54.9	6
Azerbaijan	50.4	7
Uzbekistan	47.8	8
Kyrgyzstan	46.7	9
Turkmenistan	45.4	10
Georgia	40.5	11
Tajikistan	37.2	12

Asia-Pacific

Country	Score	Rank
Japan	100.0	1
South Korea	89.4	2
Singapore	82.5	3
Thailand	79.3	4
Tonga	77.9	5
Taiwan	75.7	6
Brunei Darussalam	68.8	7
Fiji	63.3	8
Samoa	61.9	9
Papua New Guinea	55.4	10
Malaysia	54.9	11
Kiribati	54.0	12
Micronesia	49.4	13
Marshall Islands	47.7	14
Viet Nam	46.9	15
Mongolia	45.4	16
Philippines	45.2	17
China	42.9	18
Vanuatu	38.0	19
Indonesia	33.4	20
Myanmar	32.7	21
Cambodia	32.3	22
Solomon Islands	32.0	23
Timor-Leste	27.2	24
Laos	25.2	25

Sub-Saharan Africa

Country	Score	Rank
Seychelles	63.3	1
Mauritius	61.3	2
South Africa	52.2	3
Nigeria	50.6	4
Kenya	49.3	5
Cabo Verde	48.8	6
Tanzania	47.7	7
Gabon	44.9	8
Mauritania	44.3	9
Equatorial Guinea	43.1	10
Ghana	43.0	11
Comoros	42.5	12
Uganda	41.8	13
Benin	41.6	14
São Tomé and Príncipe	41.6	14
Botswana	40.8	16
Rwanda	39.7	17
Senegal	39.0	18
Republic of Congo	38.9	19
Djibouti	38.0	20
Namibia	37.7	21
Ethiopia	36.5	22
Côte d'Ivoire	34.3	23
Togo	33.9	24
Angola	33.8	25
Malawi	33.3	26
Burundi	33.0	27
Cameroon	31.7	28
Sierra Leone	31.6	29
Zambia	31.6	29
Dem. Rep. Congo	31.1	31
Eritrea	31.1	31
Mali	30.7	33
Zimbabwe	30.4	34
Eswatini	29.0	35
Liberia	28.9	36
Madagascar	27.3	37
Gambia	26.8	38
Niger	26.6	39
Guinea	26.5	40
Burkina Faso	25.7	41
Chad	20.8	42
Mozambique	20.0	43
Lesotho	19.4	44
Guinea-Bissau	19.3	45
Central African Republic	18.5	46

Greater Middle East

Country	Score	Rank
Israel	100.0	1
Qatar	68.6	2
Lebanon	66.2	3
Kuwait	64.0	4
United Arab Emirates	53.5	5
Bahrain	51.6	6
Jordan	46.4	7
Oman	40.2	8
Tunisia	36.7	9
Algeria	32.6	10
Morocco	30.5	11
Iran	30.2	12
Saudi Arabia	29.6	13
Iraq	27.7	14
Sudan	15.2	15
Egypt	5.0	16

3. Global Trends

In contrast to other environmental risk factors that the EPI tracks, such as unsafe water, unsafe sanitation, and air pollution, the world has made little progress at mitigating the public health impacts of lead exposure. By some measures, the public health impact of lead exposure is worsening (Figure 5-2). For example, from 1990 to 2019, the total number of deaths attributable to lead exposure increased by 70 percent, while the number of disability-adjusted life years (DALYs) lost increased 35 percent (Xu et al. 2023). According to the 2021 Global Burden of Disease data, lead exposure was responsible for over 1.5 million deaths in 2021, over 2 percent of global mortality.

Rising trends in mortality and overall DALYs also reflect population growth. Global DALY *rates* from lead exposure have decreased by a quarter between 1990 and 2021. This decrease reflects the success of some policies to reduce exposure to lead, such as ending the use leaded gasoline worldwide (Domonoske 2021). However, the world has not been as successful at phasing out other sources of lead exposure. For example, lead paint continues to be widely used in regions including Eastern Europe, the Caucasus, and Central Asia (IPEN 2017). Other source can be important in specific countries and regions. These include electronic waste in Nigeria and China; glazed ceramics and polluted water in Mexico; and cosmetics, spices, and traditional medicines in India and other countries in Southern and Eastern Asia (Obeng-Gyasi 2019; Newby 2023).

High-income countries in the Global West and elsewhere earn the highest scores in the EPI's lead exposure indicator. Most high-income countries banned leaded gasoline in the 1980s, two decades earlier than the rest of the world (UN News 2021). Low- and middle-income countries tend to have weaker regulations around lead mining and smelting, as well as the recycling of electronic waste and lead-acid batteries, which result in higher levels of lead pollution (UNICEF and Pure Earth 2020). At the same time, better health care systems in high-income countries also help mitigate the impacts of lead exposure (Xu et al. 2023). The combination of different sources of exposure, strictness of regulations, and quality of health care results in a wide variation of scores both between and within regions (Figure 5-1).

Slow global progress at tackling lead exposure reflects international neglect of the issue. While the World Bank estimates that lead exposure drives a loss of income worth US$1.4 trillion, philanthropy funds only $11 million annually to reduce lead exposure in low- and middle- income countries (CGD 2023). Increased funding will be key in reversing trends of rising mortality due to lead exposure.

Figure 5-1. Distribution of regional scores on Heavy Metals. Vertical bars show regional averages.

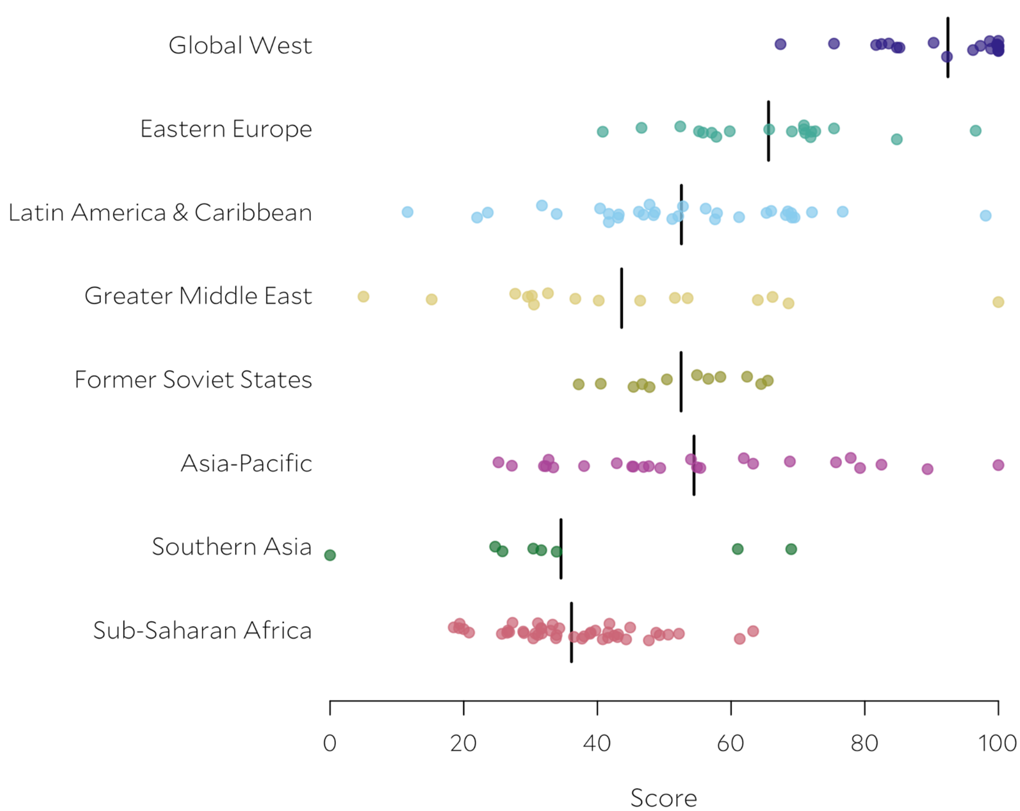
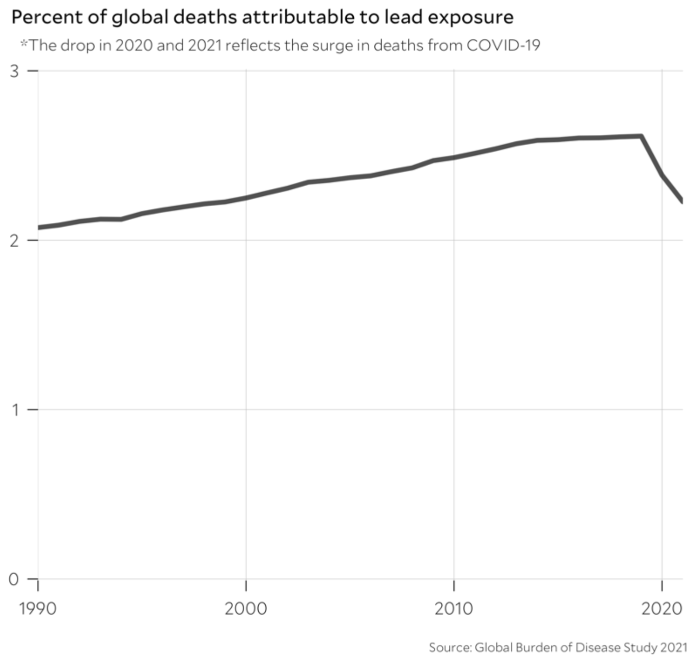


Figure 5-2. Percentage of global deaths attributable to lead exposure since 1990.



4. Leaders and Laggards

Israel, Japan, and several countries from the Global West earn top scores in the 2024 EPI's lead exposure indicator. Israel has made impressive progress in the last three decades, with DALY rates due to lead exposure in 2021 almost 70 percent lower than in 1990. Israel set a 90 ppm lead limit for all paints in 2019 (IISD 2019) and has generally been quick to adopt stringent international standards in response to scientific studies showing gaps in lead-related regulations (Negev et al. 2022).

Japan's performance is remarkable given that is one of few industrialized countries without a legally binding regulation limiting lead content in paint (IPEN 2017). However, in 2015 the Japan Paint Manufacturers Association called on its members to voluntarily eliminate lead in paints for "general usages" by March 2019 (IPEN 2017). Japan's early phase-out of leaded gasoline, replacement of lead water pipes, and strict food regulations have resulted in some of the lowest levels of lead exposure in the world (Yoshinaga 2012; Ohtsu et al. 2019).

Chile is another non-Western country that has achieved low levels of lead exposure. It ranks 14th globally and outperforms all other countries in Latin American and the Caribbean by more than 20 points. Chile regulated lead content in paints in 1997 and banned leaded gasoline in 2001 (Tchernitchin et al. 2006), resulting in a rapid drop in infant blood lead concentrations (Pino et al. 2004) and a 50 percent reduction in DALY rates from lead exposure in 2021 relative to 1990.

Malta severely lags other countries in the Global West in mitigating lead exposure. Malta has banned leaded paint, batteries, and gasoline (Times of Malta 2004), which resulted in an impressive 65 percent reduction in DALY rates in 2021 relative to 1990. However, lead exposure levels remain high. Lead bullets widely used for hunting in Malta until recently could be a source of remaining lead exposure (Mateo and Kanstrup 2019; Balzan 2023).

Countries in Southern Asia suffer from some of the worst levels of lead exposure in the world, with India, Bangladesh, and Pakistan ranked 147th, 155th, and 166th, respectively. Nearly half of the 800 million children worldwide with blood lead levels above five micrograms per deciliter live in Southern Asia (UNICEF and Pure Earth 2020). Besides sources of exposure common in other low- and middle-income countries, such as paint and lead-acid battery recycling, contaminated spices are particularly problematic in Southern Asia (Brown et al. 2022).

Turmeric, a common spice in the region, may be an important reason behind the high lead levels in South Asian populations (Gleason et al. 2014). Studies have shown that much of the turmeric in Bangladesh contains high levels of lead and cadmium, as manufacturers use these compounds to brighten the spice's famous yellow color (Forsyth et al. 2019). In response to this evidence, the Bangladeshi government designated turmeric adulteration a prosecutable offense and provided educational materials regarding the dangers of lead to local businesses and vendors via television and radio stations, pamphlets, and informational meetings (Newby 2023). This prompt and assertive governmental response cut the incidence of adulterated turmeric at Bangladeshi markets from 47 percent in September of 2019 to 5 percent in early 2020 and finally to 0 percent in 2021 (Newby 2023).

5. Methods

Indicator Background

Public health researchers consider the consequences of acute and chronic lead exposure separately. Acute exposure, measured by blood lead concentrations, is associated with children's cognitive impairment. (Jusko et al. 2008) Lead accumulated in bones and teeth (WHO 2023), and thus lead bone concentrations are typically used to measure chronic exposure, which is more pervasive in adults due to long-term occupational exposure. Chronic lead exposure increases systolic pressure and the risk of cardiovascular disease (Glenn et al. 2006; Navas-Acien et al. 2007). Measurements of lead concentrations in human blood and bone samples indicate the prevalence and acuteness of lead exposure in a population, from which epidemiologists estimate the risks of death and disease (Xu et al. 2023).

Data Sources

Data on lead exposure come from the Institute for Health Metrics and Evaluation's 2021 Global Burden of Disease Study (GBD) (Brauer et al. 2024), which provides estimates of the public health consequences of lead exposure for 204 countries and 811 subnational locations from 1990 to 2021. The GBD derives these estimates from epidemiological models based on data from 553 studies measuring blood lead concentrations in

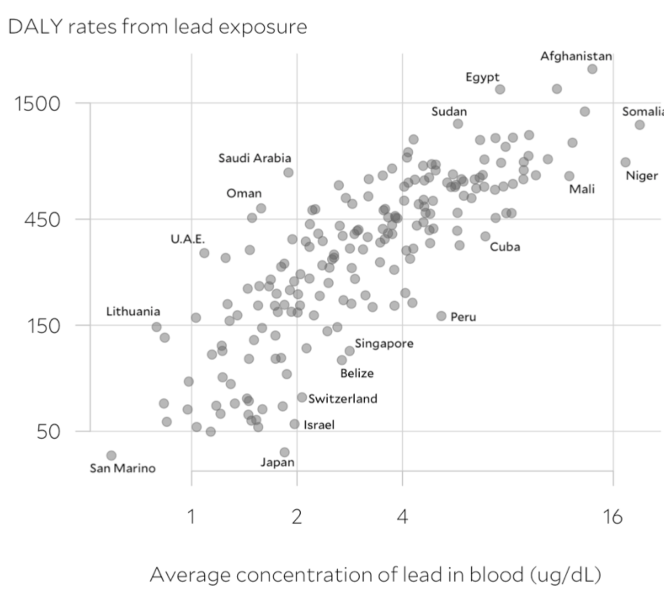
85 countries. The 2024 EPI uses GBD estimates on disability-adjusted life years lost per 100,000 people (DALYs rates).

Limitations

The lead exposure indicator is limited by the incompleteness of the underlying data and uncertainties in the modelling of DALY rates. Measuring lead exposure requires intense effort to collect and analyze samples. The GBD exposure data was based in studies from only 85 countries, and exposure in other countries had to be modelled as a function of variables such as a socio-demographic index, urbanicity, the time of leaded gasoline phaseout, and the number of motor vehicles per capita (Brauer et al. 2024). After measuring or estimating lead exposure levels, epidemiologists must further model their link to diverse health complications and eventually calculate attributable mortality and morbidity. Each modelling step introduces additional uncertainty to the estimates.

Importantly, DALY rates from lead exposure depend on factors such as the baseline mortality in a country and the prevalence of different diseases and risk factors. As a result, similar levels of lead exposure may translate into different DALY rates in different countries (Figure 5-3). While it is important to understand the impact of lead exposure on public health, the covariates that determine DALY rates are often not associated with the quality of environmental policy and therefore are beyond the scope of the EPI. For this reason, future editions of the EPI may shift toward directly measuring levels of exposure to heavy metals and other environmental risk factors, in addition to or instead of measuring the public health consequences of that exposure.

Figure 5-3. Relationship between country-level lead exposure and the associated burden of disease. Data from the 2021 Global Burden of Disease.



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Chapter 7. Solid Waste

1. Introduction

Every year, the world generates 2.1 billion tonnes of municipal solid waste, and without drastic action, that number is projected to rise to 3.8 billion tonnes in 2050 (UNEP 2024). As much as one third of that waste is disposed of in open dumps, and one quarter is placed in rudimentary landfills without adequate isolation and compacting measures (Kaza et al. 2018). These mountains of untreated waste facilitate the spread of deadly diseases such as cholera, malaria, and diarrhea (Omang et al., 2021). Managing all this waste is also expensive – with annual costs in the hundreds of billions of dollars (UNEP, 2024). Moreover, solid waste – and its mismanagement – contributes to several of our most serious environmental problems. For instance, anaerobic decay of waste in landfills results in almost a quarter of anthropogenic methane emissions in the United States and close to 10 percent worldwide (Saunois et al. 2020). Open burning of waste is also a leading cause of air pollution, contributing approximately 11 percent of global $PM_{2.5}$ emissions and 7 percent of black carbon emissions (Klimont et al. 2017; Hoesly et al. 2018).

Roughly 12 percent of global municipal solid waste is plastic, which has an outsized influence on environmental health and ecosystem vitality (Kaza et al. 2018). Each year, around 22 million tonnes of mismanaged plastic leak into the environment (OECD 2022), where it accumulates in lakes (Murray et al. 2020) or ends up flowing into the ocean and harming marine species and ecosystems (Roman et al. 2021; MacLeod et al. 2021; Pinheiro et al. 2023). Hundreds of fish species (Savoca, McInturf, and Hazen 2021), seabirds (Avery-Gomm et al. 2012), marine mammals (Baulch and Perry 2014), and all species of sea turtles (Duncan et al. 2019) ingest or get entangled in plastic debris. Microplastics also end up inside human bodies when we consume fish and other contaminated foods (Danopoulos et al. 2020; Jin et al. 2021; Makhdoumi, Hossini, and Pirsaheb

2023), drink from plastic containers (Gambino et al. 2022), or even when we breath (Prata 2018). While the health effects of microplastics in humans are still poorly understood (Blackburn and Green 2022), microplastics have been linked to elevated risk of heart attacks, strokes, and other diseases (Marfella Raffaele et al. 2024).

Improving waste management practices, while necessary, is not sufficient to tackle the environmental problems associated with solid waste and plastic pollution. All waste management methods have associated environmental impacts (Laurent et al. 2014). Plastic waste collected and deposited in landfills can leak into the environment and reach sensitive habitats, sometimes carried by animals (Martín-Vélez et al. 2024), and plastic mechanical recycling can be a large source of microplastic pollution (Suzuki et al. 2022). Recent analyses have shown that even if all waste was recycled, the plastics industry will transgress its allocated share of planetary boundaries under current projections of rapidly rising plastic consumption (Bachmann et al. 2023). To achieve true sustainability, the world needs both to improve waste management and to reduce the amount of waste generated. Hence, the 2024 EPI complements its indicators of sustainable waste management with a new indicator measuring countries' average waste generation per capita.

For years, severe limitations in the coverage, quality, and standardization of solid waste generation and management data have hindered the EPI's ability to inform waste management policy. Even wealthy countries lack a standardized system of waste classification and data reporting to international organizations, which impedes robust comparative analyses of waste management policy. While the 2024 EPI team attempted to standardize data from multiple sources using the best information available, the results must be interpreted with caution. We urge the global community to invest in better systems of waste data collection and standardization.

While acknowledging these data limitations, the 2024 EPI still provides the most comprehensive overview of countries' progress towards a circular economy based on publicly available data. The EPI's waste indicators assess countries' performance across the entire waste cycle, from generation to the recovery of energy and materials from managed waste.

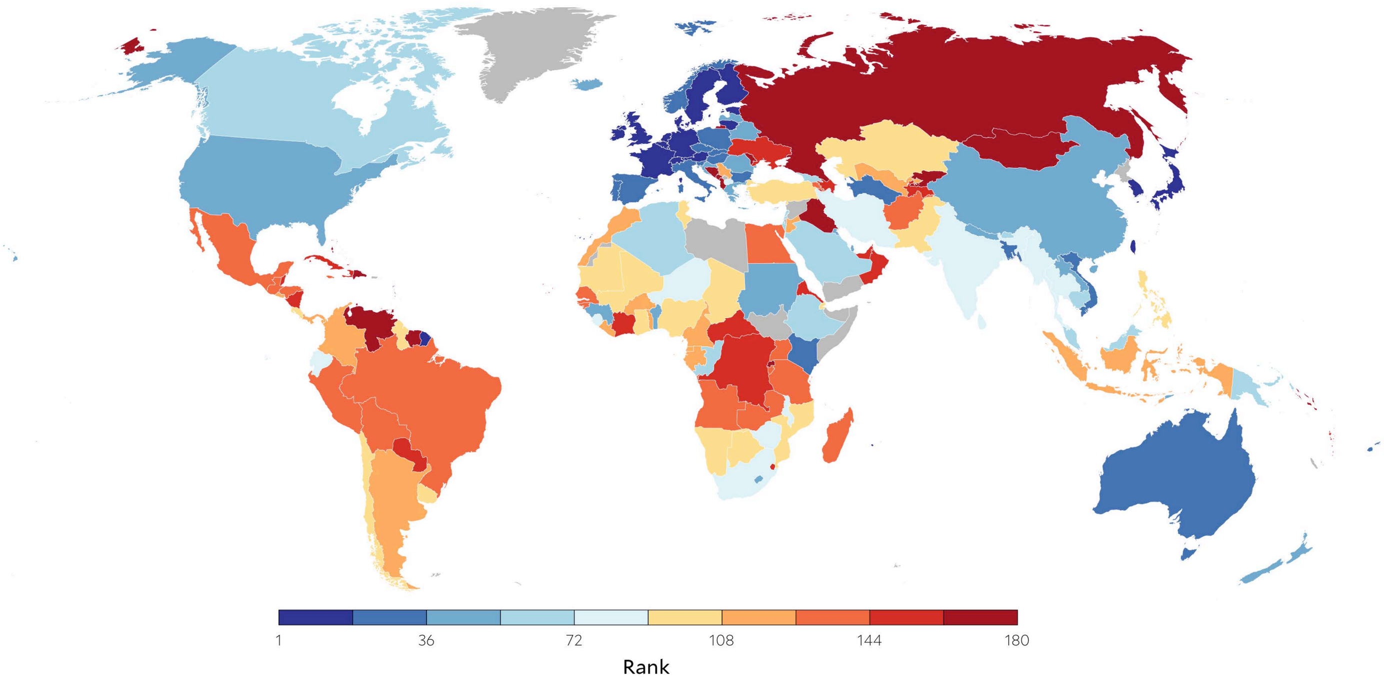
2. Indicators

Waste Generation *per capita*
(40% of issue category)
The total mass of municipal solid waste produced, measured in tonnes per person per year. .

Controlled Municipal Solid Waste
(20% of issue category)
Controlled solid waste refers to the percentage of municipal solid waste generated in a country that is collected and treated in a manner that controls environmental risks. This metric counts waste as "controlled" if it is treated through recycling, composting, anaerobic digestion, incineration, or disposed of in a sanitary landfill.

Recovery of Energy and Materials from Waste
(40% of issue category)
As a higher bar for sustainable waste management, this indicator measures the proportion of waste that is treated in a way that not only controls for environmental risks, but also recovers energy and/or materials (i.e., recycling, composting, anaerobic digestion, or incineration with energy recovery) and thus contributes to a circular economy.

Map 7-1. Global rankings on Solid Waste.



Map 7-2. Solid Waste scores.

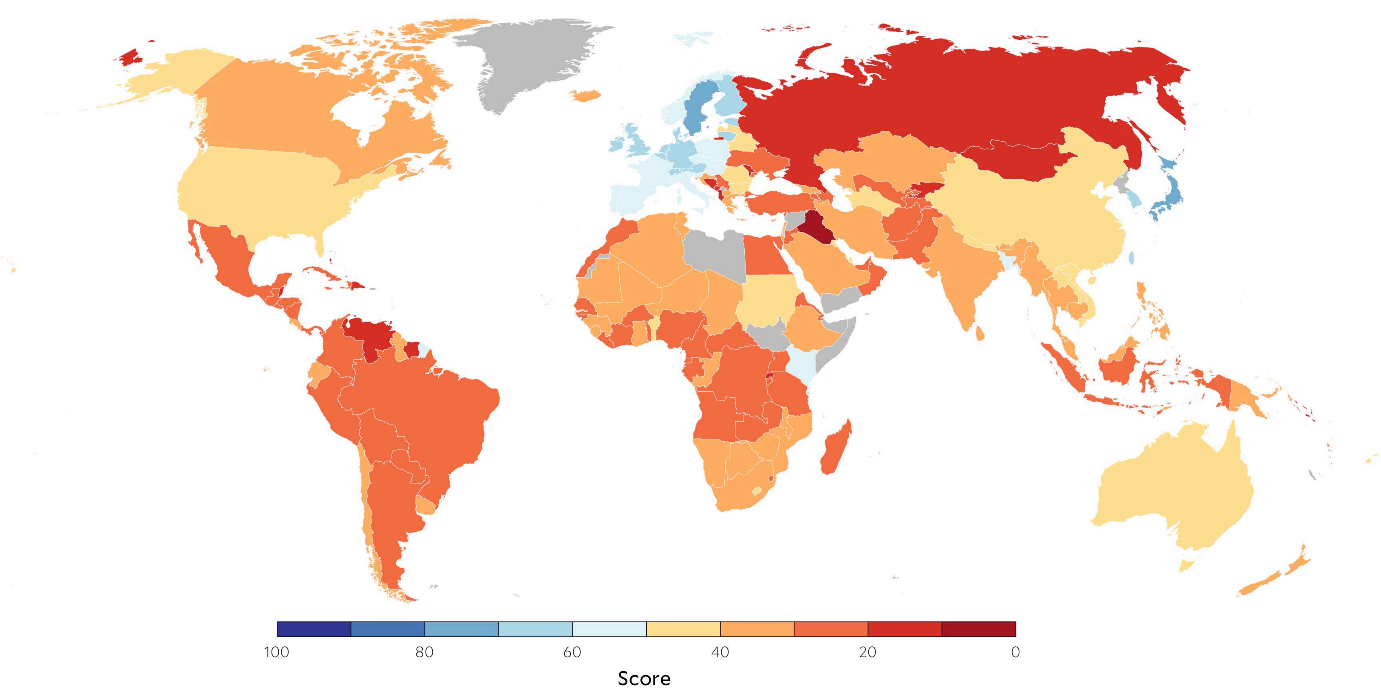


Table 7-1. Global rankings, scores, and regional rankings (REG) on the Solid Waste issue category.

RANK	COUNTRY	SCORE	REG
1	Singapore	75.5	1
2	Japan	73.6	2
3	Sweden	72.7	1
4	Taiwan	69.7	3
5	Netherlands	69.6	2
6	Finland	68.4	3
7	Germany	67.4	4
8	Switzerland	66.8	5
9	Denmark	65.5	6
10	United Kingdom	65.4	7
11	Belgium	65.1	8
11	Estonia	65.1	1
13	South Korea	64.7	4
14	Austria	63.8	9
14	Luxembourg	63.8	9
16	Lithuania	61.3	2
17	Ireland	60.7	11
18	France	59.6	12
19	Poland	58.8	3
20	Norway	58.3	13
21	Italy	57.5	14
22	Samoa	55.7	5
23	Slovenia	53.6	4
24	Slovakia	53.4	5
25	Bangladesh	52.9	1
26	Kenya	51.8	1
27	Hungary	51.7	6
28	Czech Republic	51.2	7
29	Portugal	50.8	15
29	Spain	50.8	15
31	Turkmenistan	48.7	1
32	Bulgaria	47.3	8
33	Viet Nam	46.1	6
34	Barbados	46.0	1
35	Australia	45.7	17
36	Fiji	44.7	7
37	Sudan	44.5	1
38	Belarus	44.3	2
39	China	43.3	8
40	Latvia	42.8	9
41	Nepal	42.7	2
42	Kuwait	42.6	2
42	Laos	42.6	9
44	Romania	42.3	10
45	Qatar	42.0	3
46	Benin	41.9	2
47	United States of America	41.7	18
48	Lesotho	40.4	3
49	Timor-Leste	39.7	10
50	New Zealand	39.5	19
51	Greece	39.4	11
52	Guinea	39.3	4
52	Iceland	39.3	20
54	Croatia	39.1	12
55	Grenada	38.8	2
56	Dominica	38.4	3
57	Republic of Congo	37.8	5
58	Algeria	37.6	4
59	Saudi Arabia	37.4	5
60	Israel	37.1	6
60	St. Vincent and Grenadines	37.1	4
62	Papua New Guinea	36.8	11
63	Georgia	36.6	3
63	Lebanon	36.6	7
65	Marshall Islands	36.4	12
66	Cambodia	36.3	13
67	Ethiopia	36.1	6
68	Canada	36.0	21
69	Bhutan	35.8	3
70	Antigua and Barbuda	35.6	5
71	Malaysia	35.4	14
72	Brunei Darussalam	35.0	15
73	Mauritius	34.8	7
74	Myanmar	34.7	16
75	Bahrain	34.6	8
76	South Africa	34.5	8
77	Malawi	33.9	9
78	Thailand	33.6	17
79	Sierra Leone	32.8	10
80	Gambia	32.6	11
80	Sri Lanka	32.6	4
82	Ecuador	32.4	6
83	Seychelles	32.0	12
83	Tonga	32.0	18
85	Niger	31.9	13
86	India	31.8	5
86	Zimbabwe	31.8	14
88	Cyprus	31.7	13
88	Iran	31.7	9
90	North Macedonia	31.6	14
91	Mozambique	31.5	15
92	Botswana	31.4	16
93	Ghana	31.3	17
94	Chad	31.2	18
94	Costa Rica	31.2	7
96	Guyana	31.1	8
97	Chile	31.0	9
98	Uruguay	30.9	10
99	Kazakhstan	30.8	4
99	Tunisia	30.8	10
101	Namibia	30.5	19
102	Mauritania	30.1	20
103	Mali	30.0	21
103	Philippines	30.0	19
105	Nigeria	29.7	22
105	Türkiye	29.7	15
107	Pakistan	29.3	5
108	Djibouti	29.1	23
109	Gabon	29.0	24
110	Uzbekistan	28.7	5
111	Morocco	28.4	11
112	Liberia	28.2	25
113	Comoros	28.0	26
114	São Tomé and Príncipe	27.8	27
115	Panama	27.5	11
116	Burkina Faso	27.4	28
116	El Salvador	27.4	12
118	Jordan	27.3	12
119	Malta	27.1	22
120	Colombia	27.0	13
121	Cameroon	26.8	29
122	Indonesia	26.7	20
123	Argentina	26.6	14
124	Equatorial Guinea	26.4	30
124	Serbia	26.4	16
124	Togo	26.4	30
127	Mexico	26.3	15
128	Brazil	26.2	16
129	Angola	26.1	32
130	Peru	25.9	17
131	Honduras	25.7	18
131	Madagascar	25.7	33
133	Jamaica	25.5	19
134	Afghanistan	25.2	6
134	Egypt	25.2	13
134	Zambia	25.2	34
137	Guinea-Bissau	25.0	35
138	Armenia	24.8	6
139	Bolivia	24.5	20
139	Senegal	24.5	36
141	Guatemala	24.3	21
141	Uganda	24.3	37
143	Tanzania	24.1	38
144	Burundi	24.0	39
145	Dem. Rep. Congo	23.9	40
146	Côte d'Ivoire	23.7	41
147	Cuba	23.5	22
148	Paraguay	23.4	23
149	Eswatini	22.8	42
149	Tajikistan	22.8	7
151	Oman	22.7	14
152	Ukraine	22.2	8
153	Vanuatu	21.9	21
154	Micronesia	21.8	22
155	Azerbaijan	21.6	9
155	Haiti	21.6	24
155	Nicaragua	21.6	24
158	Eritrea	21.3	43
159	Central African Republic	20.7	44
160	Cabo Verde	20.2	45
161	United Arab Emirates	20.0	15
162	Belize	19.6	26
163	Solomon Islands	19.4	23
164	Kiribati	18.8	24
165	Dominican Republic	18.3	27
166	Bosnia and Herzegovina	17.7	17
167	Albania	16.4	18
168	Moldova	16.2	10
169	Russia	15.5	11
170	Rwanda	15.0	46
171	Kyrgyzstan	14.8	12
172	Maldives	13.4	7
173	Suriname	13.1	28
174	Montenegro	12.7	19
175	Saint Lucia	12.5	29
176	Mongolia	12.3	25
177	Trinidad and Tobago	11.8	30
178	Venezuela	10.3	31
179	Bahamas	8.7	32
180	Iraq	8.6	16

Asia-Pacific · Eastern Europe · Former Soviet States · Global West · Greater Middle East · Latin America & Caribbean · Southern Asia · Sub-Saharan Africa

Table 7-2. Regional rankings and scores on Solid Waste.

Latin America & Caribbean		
Country	Score	Rank
Barbados	46.0	1
Grenada	38.8	2
Dominica	38.4	3
St. Vincent and Grenadines	37.1	4
Antigua and Barbuda	35.6	5
Ecuador	32.4	6
Costa Rica	31.2	7
Guyana	31.1	8
Chile	31.0	9
Uruguay	30.9	10
Panama	27.5	11
El Salvador	27.4	12
Colombia	27.0	13
Argentina	26.6	14
Mexico	26.3	15
Brazil	26.2	16
Peru	25.9	17
Honduras	25.7	18
Jamaica	25.5	19
Bolivia	24.5	20
Guatemala	24.3	21
Cuba	23.5	22
Paraguay	23.4	23
Haiti	21.6	24
Nicaragua	21.6	24
Belize	19.6	26
Dominican Republic	18.3	27
Suriname	13.1	28
Saint Lucia	12.5	29
Trinidad and Tobago	11.8	30
Venezuela	10.3	31
Bahamas	8.7	32

Eastern Europe		
Country	Score	Rank
Estonia	65.1	1
Lithuania	61.3	2
Poland	58.8	3
Slovenia	53.6	4
Slovakia	53.4	5
Hungary	51.7	6
Czech Republic	51.2	7
Bulgaria	47.3	8
Latvia	42.8	9
Romania	42.3	10
Greece	39.4	11
Croatia	39.1	12
Cyprus	31.7	13
North Macedonia	31.6	14
Turkiye	29.7	15
Serbia	26.4	16
Bosnia and Herzegovina	17.7	17
Albania	16.4	18
Montenegro	12.7	19

Southern Asia		
Country	Score	Rank
Bangladesh	52.9	1
Nepal	42.7	2
Bhutan	35.8	3
Sri Lanka	32.6	4
India	31.8	5
Pakistan	29.3	6
Afghanistan	25.2	7
Maldives	13.4	8

Global West		
Country	Score	Rank
Sweden	72.7	1
Netherlands	69.6	2
Finland	68.4	3
Germany	67.4	4
Switzerland	66.8	5
Denmark	65.5	6
United Kingdom	65.4	7
Belgium	65.1	8
Austria	63.8	9
Luxembourg	63.8	9
Ireland	60.7	11
France	59.6	12
Norway	58.3	13
Italy	57.5	14
Portugal	50.8	15
Spain	50.8	15
Australia	45.7	17
United States of America	41.7	18
New Zealand	39.5	19
Iceland	39.3	19
Canada	36.0	21
Malta	27.1	22

Former Soviet States		
Country	Score	Rank
Turkmenistan	48.7	1
Belarus	44.3	2
Georgia	36.6	3
Kazakhstan	30.8	4
Uzbekistan	28.7	5
Armenia	24.8	6
Tajikistan	22.8	7
Ukraine	22.2	8
Azerbaijan	21.6	9
Moldova	16.2	10
Russia	15.5	11
Kyrgyzstan	14.8	12

Asia-Pacific		
Country	Score	Rank
Singapore	75.5	1
Japan	73.6	2
Taiwan	69.7	3
South Korea	64.7	4
Samoa	55.7	5
Viet Nam	46.1	6
Fiji	44.7	7
China	43.3	8
Laos	42.6	9
Timor-Leste	39.7	10
Papua New Guinea	36.8	11
Marshall Islands	36.4	12
Cambodia	36.3	13
Malaysia	35.4	14
Brunei Darussalam	35.0	15
Myanmar	34.7	16
Thailand	33.6	17
Tonga	32.0	18
Philippines	30.0	19
Indonesia	26.7	20
Vanuatu	21.9	21
Micronesia	21.8	22
Solomon Islands	19.4	23
Kiribati	18.8	24
Mongolia	12.3	25

Sub-Saharan Africa		
Country	Score	Rank
Kenya	51.8	1
Benin	41.9	2
Lesotho	40.4	3
Guinea	39.3	4
Republic of Congo	37.8	5
Ethiopia	36.1	6
Mauritius	34.8	7
South Africa	34.5	8
Malawi	33.9	9
Sierra Leone	32.8	10
Gambia	32.6	11
Seychelles	32.0	12
Niger	31.9	13
Zimbabwe	31.8	14
Mozambique	31.5	15
Botswana	31.4	16
Ghana	31.3	17
Chad	31.2	18
Namibia	30.5	19
Mauritania	30.1	20
Mali	30.0	21
Nigeria	29.7	22
Djibouti	29.1	23
Gabon	29.0	24
Liberia	28.2	25
Comoros	28.0	26
São Tomé and Príncipe	27.8	27
Burkina Faso	27.4	28
Cameroon	26.8	29
Equatorial Guinea	26.4	30
Togo	26.4	30
Angola	26.1	32
Madagascar	25.7	33
Zambia	25.2	34
Guinea-Bissau	25.0	35
Senegal	24.5	36
Uganda	24.3	37
Tanzania	24.1	38
Burundi	24.0	39
Dem. Rep. Congo	23.9	40
Côte d'Ivoire	23.7	41
Eswatini	22.8	42
Eritrea	21.3	43
Central African Republic	20.7	44
Cabo Verde	20.2	45
Rwanda	15.0	46

Greater Middle East		
Country	Score	Rank
Sudan	44.5	1
Kuwait	42.6	2
Qatar	42.0	3
Algeria	37.6	4
Saudi Arabia	37.4	5
Israel	37.1	6
Lebanon	36.6	7
Bahrain	34.6	8
Iran	31.7	9
Tunisia	30.8	10
Morocco	28.4	11
Jordan	27.3	12
Egypt	25.2	13
Oman	22.7	14
United Arab Emirates	20.0	15
Iraq	8.6	16

3. Global Trends

Municipal solid waste generation has risen rapidly over the last half-century, from an estimated 0.6 billion tonnes in 1965 to 2 billion tonnes in 2015 (D. M.-C. Chen et al. 2020). Waste generation is associated with wealth, so global waste generation will likely continue to grow along with countries' economies (UNEP 2024). However, economic development also allows countries to invest in the infrastructure required to collect and manage waste. In 2016, high-income countries collected roughly 96 percent of their waste, compared to 39 percent in low-income countries (Kaza et al. 2018).

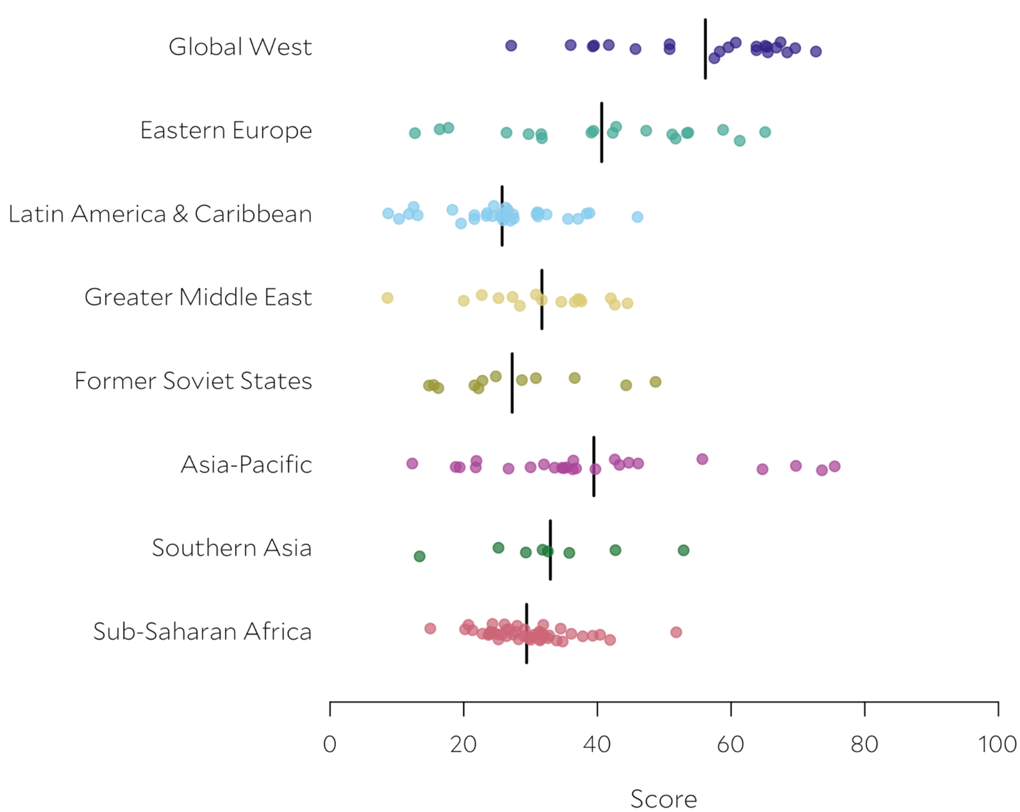
Reflecting the importance of countries' wealth for waste management infrastructure, the Global West has the highest average score in this issue category. However, countries in the Global West also have some of the highest rates of waste generation per capita in the world. In their transition toward a sustainable future, countries in the Global West must prioritize policies to reduce the amount of waste they generate. While the European Union's Waste Framework Directive from 2008 emphasizes the importance of reducing waste generation, most countries in the European Union have so far failed to decouple waste generation from economic activity (EEA 2023).

Wide variation in countries' wealth in the Asia-Pacific region is also reflected in highly variable performance in the EPI's waste management indicators. This region includes the two top global performers – Singapore and Japan – as well as countries with both high waste generation rates and poor waste management practices, such as Mongolia. Wealth is not always correlated with leadership in waste management. Wealthy countries in the Persian Gulf underperform their economic peers, combining high waste generation rates and poor waste management infrastructure (Zafar 2018; Thabit, Nassour, and Nelles 2023).

The COVID-19 pandemic, particularly the lockdown-induced changes to economic and social activities, changed the composition of waste generation. Industries that require large-scale plastic use, including transportation and construction, generally declined, while demand for medical equipment and consumer packaging surged (OECD 2022). The latter trend placed great stress on waste management infrastructure. For instance, an estimated 25.9 thousand tonnes of pandemic-associated plastic waste reached the oceans in 2020 and 2021 (Peng et al. 2021). While the long-term effects on waste generation are unclear, it appears that COVID-19 slightly decreased total plastic *use* overall in 2020 but increased the plastic *intensity* of the economy—the tonnes of plastic waste generated per unit of GDP (OECD 2022).

Global attention to the importance of waste management has increased in the past few years. In 2022, the United Nations Environment Assembly adopted a historic resolution to develop

Figure 7-1. Distribution of regional scores on Solid Waste. Vertical bars show regional averages.



a global legally binding treaty for better management of plastic production, use, and disposal. Nearly 70 percent of countries had public institutions responsible for waste management in 2018, and more countries have developed institutional infrastructure in this area since then (Kaza et al. 2018). From 2017 to 2022, the number of national and voluntary initiatives to tackle plastic pollution increased by 60 percent (WWF 2022). However, these efforts are not enough. Ongoing negotiations for the Global Plastics Treaty have been thwarted by opposition from oil-producing nations—such as Russia, Saudi Arabia, China, and the United States—to measures that curb plastic production. Announced commitments to improve plastic management are projected to decrease plastic leakage to oceans by only 7 percent compared to business-as-usual scenarios (SYSTEMIQ 2020). More aggressive policies are required to turn the tide of waste proliferation.

4. Leaders and Laggards

Singapore ranks first in 2024 EPI's Solid Waste indicators, with relatively low rates of waste generation per capita and high rates of recovery of energy and materials from waste. Singapore's rapid economic development since independence led to a six-fold increase in the amount of waste generated between 1970 and 2000 (Yep 2015). As a densely populated city state, Singapore had to take decisive action to limit the ecological footprint of its waste. In 1973, Singapore built the first waste-to-energy plant in Asia outside of Japan (MEWR 2019). Beginning in 2001, the government also launched a city-wide campaign to boost recycling rates and introduce more waste collection infrastructure in households (Yep 2015). Singapore also invested heavily in its only landfill, Semakau Island, which, thanks to excellent isolation and treatment infrastructures, now boasts lush vegetation and diverse wildlife despite holding all the country's landfill trash (Begum 2023). In 2021, 55 percent of Singapore's waste was recycled, while 42 percent was incinerated to generate electricity (MSE 2022). Looking forward, Singapore has announced a Zero-Waste Masterplan that aims to increase recycling rates to 70 percent and reduce the amount of waste sent to landfills per capita by 30 percent from 2020 to 2030 (MEWR 2019). Singaporean researchers are also experimenting with new waste utilization methods, such as using the ash left over from incineration as fillings for port construction (Begum 2023).

Taiwan is another global leader in waste management, a remarkable feat considering that, just three decades ago, Taiwan was nicknamed "garbage island" (K. Chen 2016). In the 1990s, Taiwan collected only 70 percent of its municipal solid waste, and two thirds of its landfills were at or near capacity (Rossi 2018). Poor trash management angered many affected communities and sparked a grassroots movement demanding government action (Taiwan Today 1996). In response, Taiwan's government implemented a robust recycling system, which involved waste separation and garbage collection by trucks playing classical music and other popular tunes (Qin and Chien 2022). By 2015, Taiwan's recycling rates had reached 55 percent, among the highest in the world (K. Chen 2016). Strong community support has been critical for this effort. While the garbage collection system is complicated, many citizens have incorporated it into their daily routines and see it as a chance to relax and socialize (Qin and Chien 2022).

Several countries at the bottom of the Solid Waste ranking are fragile states, such as Iraq and Venezuela, where economic hardship and political instability have led to a breakdown of public services, including waste management. For instance, many Venezuelan communities only collect garbage once per month, leading to accumulation of waste and forcing citizens to resort to private disposal means (Radwin 2023). However, several wealthy nations also score near the bottom of the list. Russia, for instance, produces 50 percent more waste per capita than the global average and disposes 90 percent of its waste in open dumps as of 2019 (Martus, Shiklomanov, and Plantan 2020). These open dumps became so obnoxious that Russians who lived near them organized a series of "rubbish riots" from 2017 to 2019, which were some of the largest movements of civil action in recent Russian history (Martus, Shiklomanov, and Plantan 2020; Bennetts 2019). Fortunately, in response to the protests, the Russian government has implemented "rubbish reforms" that centralized municipal waste authority and increased government oversight (Martus, Shiklomanov, and Plantan 2020; REO 2021). The Russian experience underlines the importance of proactive investment in waste management as a critical component of public services.

Some countries with relatively high positions in the overall ranking are notable laggards in terms of waste generation per capita. The United States, for instance, is home to only 4 percent of the world's population but generates 12 percent of global solid waste (Environment America 2021). Furthermore, while the United States has a robust waste management infrastructure, it lags its peers in the recovery of materials and energy from waste. The Recycling Partnership, an NGO committed to advancing a circular economy, estimated that three quarters of all residential recyclables are thrown out as trash at the household level (Appel et al. 2024) and only 6.2 percent of plastics are recycled (Di et al. 2021). Therefore, all communities and stakeholders need to continue investing in more sustainable waste management infrastructures and practices.

5. Methods

Most countries lack accurate and recent data about the generation, composition, and management of municipal solid waste. Even in the wealthiest regions of the world, data reporting has not been standardized. These heterogeneous and incomplete data severely hinder efforts to compare countries' progress toward waste reduction and sustainable management (Pires and Martinho 2019). The 2024 EPI compiles and synthesizes information from a variety of sources—such as country reports to international organizations and the scientific literature—to offer a broad picture of countries' relative performance in safely and sustainably managing their municipal solid waste.

In general, the best approach to minimize the environmental impacts of waste management is to reduce the amount of waste generated in the first place (Van Ewijk and Stegemann 2016). All waste management methods have negative environmental impacts, and the optimal treatment method depends on several factors ranging from the type of waste being treated to the local energy mix (Laurent et al. 2014). The three indicators in the 2024 EPI—waste generation per capita, controlled solid waste, and recovery of energy and materials from waste—attempt to provide a comprehensive overview. However, the EPI team acknowledges that this set of indicators provides an incomplete view of waste management sustainability and emphasizes the urgent need for improved data to quantify solid waste's impacts on ecosystems and public health.

Indicator Background

Since reducing waste is better than managing it, the 2024 EPI introduces an indicator measuring *Waste Generation per capita* – the total mass of municipal solid waste generated in a country each year divided by that country's population. The exact definition of municipal solid waste varies in different countries, but it usually includes non-hazardous waste collected by municipalities and originating from households, small businesses, schools, hospitals, and government buildings. It includes bulky waste, such as old furniture, and waste from parks and gardens. Sewage, construction, and demolition waste are not considered municipal solid waste.

We measure *Controlled Solid Waste* as the proportion of municipal solid waste generated in a country that is collected and treated to mitigate its environmental impacts. This metric includes disposal in sanitary landfills, recycling, composting, anaerobic digestion, and incineration with or without energy recovery. Uncontrolled waste, in contrast, includes all waste that is not collected or that is dumped or burned in the open.

Landfills may have smaller environmental impacts than open dumps, and waste incineration may be better than burning waste in the open. However, these waste management methods still have substantial environmental impacts and have no place in a circular economy (Pires and Martinho 2019). Hence, to impose a higher bar to waste management practices, the 2024 EPI introduces an indicator to track the rate of *Material and Energy Recovery from Waste*. This new indicator measures the proportion of waste generated that is composted, anaerobically digested, recycled, or incinerated *with* energy recovery. While landfill methane recovery is an important method of energy recovery from waste (Bolan et al. 2013), it is not included in the indicator due to a lack of data on the prevalence of this practice in different countries. The EPI team decided to introduce this indicator to replace the Recycling Rates indicator included in the 2022 EPI for two reasons. First, the new indicator is more general in that it includes methods to treat organic wastes that are not recyclable but from which valuable energy and materials can be recovered through composting and anaerobic digestion. Second, recycling is not always the optimal method to treat solid waste

Focus 7-1

Why does the 2024 EPI drop the pilot indicator of Ocean Plastics Pollution?

Every year, millions of tons of plastic enter the ocean. Plastic pollutes the global ocean from the Arctic (Bergmann et al. 2022) to the Antarctic (Lacerda et al. 2019) and down to its deepest trenches (Abel et al. 2023). Hundreds of marine species are known to ingest and get entangled in plastic waste, but the full magnitude of the ecological impacts of marine plastic pollution remains poorly understood.

In 2022, the EPI introduced a pilot indicator scoring countries on their estimated contributions to ocean plastic pollution (D. M.-C. Chen et al. 2020; Meijer et al. 2021). These estimates were a function of (1) how much plastic waste countries produce, (2) what fraction of that plastic waste is mismanaged, (3) the size of countries' population living near the coast, and (4) how windy and rainy countries are. Of these four factors, only the first two can be realistically influenced through environmental policy, and since they are already captured in the other waste management indicators in the EPI, the 2024 EPI team decided to drop the *oceans plastics* indicator. This does not mean, of course, that countries' efforts to mitigate their contribution to ocean plastic pollution is any less critical. We emphasize, however, that plastic pollution also poses a severe threat to freshwater and terrestrial ecosystems (MacLeod et al. 2021), so policy efforts to mitigate plastic pollution should not focus too narrowly on ocean-bound plastics.

Estimates of how much plastic enters the ocean, and from where, remain uncertain (Jambeck et al. 2015; L. C. M. Lebreton et al. 2017; Meijer et al. 2021; Weiss et al. 2021; Kaandorp et al. 2023; Zhang et al. 2023). Recent studies have shown that nearly half of all ocean-bound plastic pollution comes not from rivers or coastlines but from fishing activities (L. Lebreton et al. 2022; Kaandorp et al. 2023). Hence, efforts to tackle ocean plastic pollution should include improving regulations to prevent the loss of fishing gear and banning the types of gear most likely to degrade and pollute the ocean, such as Danish seine ropes and trawls (Syversen et al. 2022). As remote observation of global fishing activity and data about the rates of fishing gear loss and discards improve (Kuczenski et al. 2022), the EPI team may be able to develop metrics to track this important environmental issue.

(Laurent et al. 2014; van Ewijk, Stegemann, and Ekins 2021; Tan et al. 2024).

Data Sources

The World Bank's *What a Waste 2.0* report (Kaza et al. 2018) is the most comprehensive assessment of municipal solid waste generation and treatment in countries around the world. However, all the data included in the report are from 2016 or earlier. Hence, we used data from the OECD, Eurostat, and UNEP/UNSD Environmental Questionnaires to update data from *What a Waste 2.0*, whenever they were available. Note that Eurostat data (used for Cyprus, Kosovo, Malta, Montenegro, and Serbia) included only waste from households, while the other two sources generally include waste from both households and certain commercial activities.

The data compilation process was challenging since countries report different types of data and use different definitions of solid municipal waste and waste treatments. When the EPI team noticed a critical incompatibility in the data countries reported to the UNSD, we reverted to data from the *What a Waste 2.0* report. We refer the reader to our Technical Appendix for further details about the data compilation process.

Limitations

Measuring waste generation and management remains challenging. The insights that can be derived from the EPI's waste management indicators are severely limited by coarse, incomplete, heterogeneous, and outdated data. The decentralized nature of waste generation and management hampers comprehensive data collection, particularly in low-income countries but even in countries with high levels of development.

A big challenge for making meaningful international comparisons of waste management systems is that definitions of municipal waste vary both between countries and over time. Definitions of waste treatment methods are also variable, which makes it difficult to score and rank countries using available datasets. Lack of standardized definitions hinders comparability both between databases (UN, Eurostat, OECD) and between countries in a single database. Moreover, since some municipal waste is traded internationally (Shi, Zhang, and Chen 2021), the volume of waste generated in a country will not necessarily correspond to the volume of waste treated in that country.

Finally, a key limitation of the available databases of solid waste management is that they do not include data on informal waste collection and sorting. Informal waste collectors are particularly important in developing countries, where they account for large fractions of the recovery of recyclable and reusable materials from waste (Linzner and Salhofer 2014; Botello-Álvarez et al. 2018). As a result, the EPI indicators may seriously underestimate the rate of recovery of materials from waste in developing countries.

Weighting Rationale

The low weight of the Waste Management issue category reflects the low quality, recency, and accuracy of the underlying data, rather than the importance of waste generation and management for human health and ecosystem vitality. Since the indicator of *Controlled Solid Waste* represents a low bar for waste management, it received a lower weight than the other two indicators in this category.

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Chapter 8. Water Resources

1. Introduction

Water is essential for sustaining life and ecosystem vitality. Aquatic ecosystems support one fifth of the world's species (Grosberg, Vermeij, and Wainwright 2012) and provide essential services such as coastal storm protection (Temmerman et al. 2023) and carbon storage (Macreadie et al. 2021). Humans need water for drinking, washing, and sanitation, to irrigate crops, produce energy, and to support a wide range of industrial processes (Flörke et al. 2013).

Agriculture is the main driver of water demand, and a key driver of water pollution. Agricultural irrigation accounts for 70 percent of global freshwater withdrawals and 90 percent of water consumption (Siebert et al. 2010). Groundwater levels are declining across most of the world, especially in arid regions with extensive agriculture, such as northern Saudi Arabia, Iran, and the southwest of the United States (Jasechko et al. 2024). Runoff of excess fertilizer and other agrochemicals from croplands are a leading driver of surface water pollution (Evans et al. 2019; Ma et al. 2024). When considering both water quantity and quality, over half of the world's population is exposed to water scarcity at least one month per year (Jones, Bierkens, and van Vliet 2024). Under climate change and projected growth in human populations and agricultural production, water scarcity will likely worsen in coming decades (Wang et al. 2024; Jones, Bierkens, and van Vliet 2024). Worsening clean water scarcity underscores the urgency of expanding infrastructure to treat and reuse wastewater (Van Vliet et al. 2021).

Besides alleviating water scarcity, improved wastewater management systems can help mitigate a range of environmental impacts. For example, cities that treat all their wastewater emit on average 33 kg of methane per person per year, compared to 138 kg in cities without wastewater treatment (Foy et al. 2023). Discharges of untreated wastewater harm ecosystem vitality. Nutrients in wastewater contribute to eutrophication (Preisner, Neverova-Dziopak, and Kowalewski 2021), while microplastics and other chemical contaminants are toxic to both humans and wildlife (Edokpayi et al. 2017; Jiang and Li 2020; Woodward et al. 2021). Even treated wastewater discharges can profoundly alter the composition of freshwater invertebrate communities (Enns et al. 2023). These impacts are pervasive. At least 10 percent of the volume in 31,000 km of rivers worldwide consists of wastewater, and 874 million people live within 10 km of these waterways (Ehalt Macedo et al. 2022).

Despite the diverse environmental issues related to the sustainable use of Water Resources, due to limited data availability, the 2024 EPI indicators focus on wastewater production and management. Harnessing the latest data-synthesis efforts around global wastewater management, the 2024 EPI complements its indicators of wastewater treatment and collection rates with new indicators of wastewater production and reuse.

2. Indicators

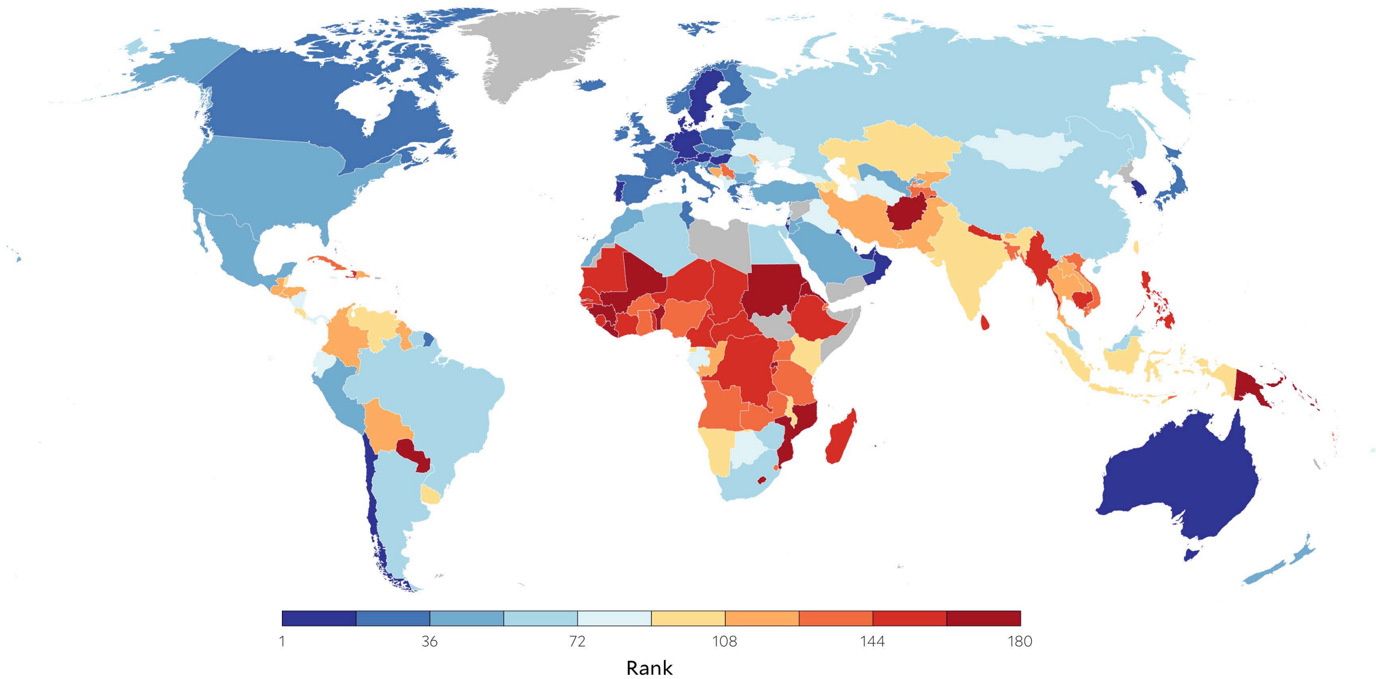
Wastewater Generation *per capita*
(12.5% of issue category)
Total volume of municipal wastewater generated (m^3) per person each year.

Wastewater Collection
(37.5% of issue category)
Percentage of wastewater collected for treatment. Sometimes measured as the percentage of the population connected to urban or independent wastewater treatment facilities.

Wastewater Treatment
(37.5% of issue category)
Percentage of wastewater that undergoes at least primary treatment.

Wastewater Reuse
(12.5% of issue category)
Percentage of wastewater reused after treatment, either for irrigation in agriculture or, when clean enough, in industry or as drinking water.

Map 8-1. Global rankings on Water Resources.



Map 8-2. Water Resources scores.

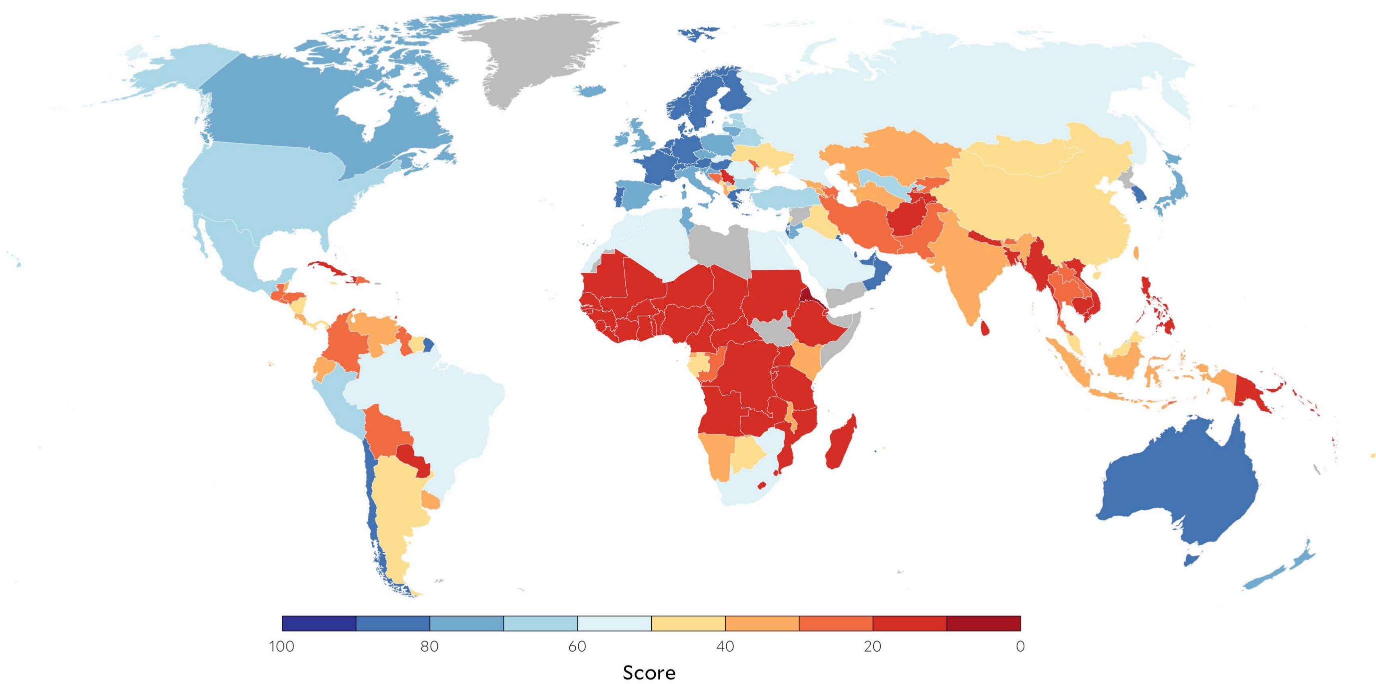


Table 8-1. Global rankings, scores, and regional rankings (REG) on the Water Resources issue category.

RANK	COUNTRY	SCORE	REG
1	Luxembourg	90.6	1
2	Singapore	90.5	1
3	United Arab Emirates	89.8	1
4	Netherlands	89.2	2
5	Germany	89.1	3
6	Israel	88.7	2
7	Austria	87.3	4
8	Australia	87.2	5
9	Hungary	86.2	1
10	Kuwait	85.7	3
10	Oman	85.7	4
12	Chile	85.5	1
12	Portugal	85.5	6
14	Qatar	84.7	5
15	Sweden	84.5	7
16	South Korea	84.3	2
17	Switzerland	83.4	8
18	Denmark	83.3	9
19	Greece	83.1	2
20	Finland	82.5	10
20	France	82.5	10
22	Belgium	81.7	12
23	Norway	80.8	13
24	Czech Republic	79.1	3
25	Spain	78.7	14
26	Bahrain	78.5	6
27	United Kingdom	78.3	15
28	Canada	77.7	16
29	Poland	77.5	4
30	Japan	76.5	3
31	Iceland	75.0	17
32	Tunisia	74.5	7
33	Croatia	74.1	5
34	Italy	72.7	18
34	Lithuania	72.7	6
36	Ireland	72.5	19
37	Jordan	72.4	8
38	New Zealand	70.7	20
38	Slovenia	70.7	7
40	Cyprus	70.2	8
41	Estonia	69.6	9
42	Mexico	69.5	2
43	Latvia	68.0	10
44	Türkiye	67.9	11
45	Bulgaria	66.1	12
46	Brunei Darussalam	66.0	4
47	United States of America	63.9	21
48	Peru	63.3	3
49	Belarus	61.7	1
50	Bahamas	60.9	4
51	Uzbekistan	60.7	2
52	Slovakia	58.3	13
53	Morocco	57.1	9
54	Saudi Arabia	56.9	10
55	Egypt	55.9	11
56	Algeria	55.7	12
57	Zimbabwe	55.5	1
58	Brazil	53.6	5
59	Russia	52.5	3
60	Malta	52.3	22
61	South Africa	51.5	2
62	Romania	51.4	14
63	Seychelles	50.9	3
64	Barbados	49.0	6
65	Antigua and Barbuda	48.3	7
66	China	48.2	5
67	Argentina	46.8	8
67	Lebanon	46.8	13
67	Malaysia	46.8	6
70	Grenada	46.0	9
71	Dominica	44.5	10
72	Suriname	44.2	11
73	Iraq	43.9	14
74	Mongolia	43.8	7
75	Montenegro	43.6	15
76	Gabon	42.9	4
77	Fiji	42.4	8
78	Botswana	42.2	5
78	North Macedonia	42.2	16
80	Panama	42.0	12
81	St. Vincent and Grenadines	41.5	13
82	Ukraine	40.8	4
83	Nicaragua	40.7	14
84	Jamaica	40.5	15
85	Maldives	40.4	1
86	Marshall Islands	40.0	9
87	Albania	39.6	17
88	Turkmenistan	39.2	5
89	Ecuador	38.5	16
89	Georgia	38.5	6
89	Saint Lucia	38.5	16
92	Taiwan	38.2	10
93	Belize	38.1	18
94	Kenya	37.8	6
95	Mauritius	37.4	7
96	Costa Rica	37.3	19
97	Indonesia	36.7	11
98	Equatorial Guinea	35.2	8
99	Tonga	35.1	12
100	Uruguay	34.7	20
101	Armenia	34.0	7
102	Kazakhstan	32.1	8
103	Venezuela	32.0	21
104	India	30.8	2
105	Malawi	30.7	9
106	Cabo Verde	30.3	10
107	Namibia	30.0	11
108	Azerbaijan	29.7	9
109	Iran	29.2	15
110	Honduras	28.7	22
111	Colombia	28.6	23
112	Guatemala	28.4	24
113	Guyana	27.9	25
114	Micronesia	25.5	13
115	Bolivia	25.2	26
116	Bhutan	24.9	3
117	Dominican Republic	24.8	27
118	Bosnia and Herzegovina	23.9	18
118	Kyrgyzstan	23.9	10
120	Republic of Congo	23.0	12
121	Moldova	22.4	11
122	Pakistan	21.8	4
123	Thailand	21.7	14
124	Laos	21.6	15
125	El Salvador	21.5	28
126	São Tomé and Príncipe	21.3	13
127	Kiribati	21.0	16
128	Timor-Leste	20.2	17
129	Cuba	19.7	29
130	Tajikistan	19.6	12
131	Vanuatu	19.1	18
132	Samoa	18.9	19
133	Tanzania	18.2	14
134	Zambia	17.3	15
135	Djibouti	16.3	16
136	Viet Nam	16.1	20
137	Serbia	16.0	19
138	Eswatini	15.9	17
138	Ghana	15.9	17
140	Angola	15.8	19
141	Nigeria	15.0	20
141	Uganda	15.0	20
143	Burkina Faso	14.8	22
144	Bangladesh	14.7	5
145	Senegal	14.4	23
146	Mauritania	14.0	24
147	Burundi	13.8	25
148	Côte d'Ivoire	13.6	26
148	Myanmar	13.6	21
150	Cambodia	13.4	22
151	Ethiopia	13.2	27
151	Nepal	13.2	6
153	Sri Lanka	13.0	7
154	Haiti	12.8	30
154	Trinidad and Tobago	12.8	30
156	Cameroon	12.7	28
157	Philippines	12.6	23
158	Central African Republic	12.5	29
158	Chad	12.5	29
158	Dem. Rep. Congo	12.5	29
158	Guinea-Bissau	12.5	29
158	Madagascar	12.5	29
158	Niger	12.5	29
158	Sierra Leone	12.5	29
158	Togo	12.5	29
166	Benin	12.4	37
166	Liberia	12.4	37
166	Paraguay	12.4	32
169	Guinea	12.0	39
169	Mozambique	12.0	39
171	Gambia	11.8	41
172	Lesotho	11.7	42
172	Solomon Islands	11.7	24
174	Comoros	11.5	43
175	Afghanistan	11.2	8
175	Mali	11.2	44
175	Sudan	11.2	16
178	Papua New Guinea	11.1	25
179	Rwanda	10.5	45
180	Eritrea	9.5	46

Asia-Pacific | Eastern Europe | Former Soviet States | Global West | Greater Middle East | Latin America & Caribbean | Southern Asia | Sub-Saharan Africa

Table 8-2. Regional rankings and scores on Water Resources.

Latin America & Caribbean		
Country	Score	Rank
Chile	85.5	1
Mexico	69.5	2
Peru	63.3	3
Bahamas	60.9	4
Brazil	53.6	5
Barbados	49.0	6
Antigua and Barbuda	48.3	7
Argentina	46.8	8
Grenada	46.0	9
Dominica	44.5	10
Suriname	44.2	11
Panama	42.0	12
St. Vincent and Grenadines	41.5	13
Nicaragua	40.7	14
Jamaica	40.5	15
Ecuador	38.5	16
Saint Lucia	38.5	16
Belize	38.1	18
Costa Rica	37.3	19
Uruguay	34.7	20
Venezuela	32.0	21
Honduras	28.7	22
Colombia	28.6	23
Guatemala	28.4	24
Guyana	27.9	25
Bolivia	25.2	26
Dominican Republic	24.8	27
El Salvador	21.5	28
Cuba	19.7	29
Haiti	12.8	30
Trinidad and Tobago	12.8	30
Paraguay	12.4	32

Eastern Europe		
Country	Score	Rank
Hungary	86.2	1
Greece	83.1	2
Czech Republic	79.1	3
Poland	77.5	4
Croatia	74.1	5
Lithuania	72.7	6
Slovenia	70.7	7
Cyprus	70.2	8
Estonia	69.6	9
Latvia	68.0	10
Türkiye	67.9	11
Bulgaria	66.1	12
Slovakia	58.3	13
Romania	51.4	14
Montenegro	43.6	15
North Macedonia	42.2	16
Albania	39.6	17
Bosnia and Herzegovina	23.9	18
Serbia	16.0	19

Southern Asia		
Country	Score	Rank
Maldives	40.4	1
India	30.8	2
Bhutan	24.9	3
Pakistan	21.8	4
Bangladesh	14.7	5
Nepal	13.2	6
Sri Lanka	13.0	7
Afghanistan	11.2	8

Global West		
Country	Score	Rank
Luxembourg	90.6	1
Netherlands	89.2	2
Germany	89.1	3
Austria	87.3	4
Australia	87.2	5
Portugal	85.5	6
Sweden	84.5	7
Switzerland	83.4	8
Denmark	83.3	9
Finland	82.5	10
France	82.5	10
Belgium	81.7	12
Norway	80.8	13
Spain	78.7	14
United Kingdom	78.3	15
Canada	77.7	16
Iceland	75.0	17
Italy	72.7	18
Ireland	72.5	19
New Zealand	70.7	20
United States of America	63.9	21
Malta	52.3	22

Former Soviet States		
Country	Score	Rank
Belarus	61.7	1
Uzbekistan	60.7	2
Russia	52.5	3
Ukraine	40.8	4
Turkmenistan	39.2	5
Georgia	38.5	6
Armenia	34.0	7
Kazakhstan	32.1	8
Azerbaijan	29.7	9
Kyrgyzstan	23.9	10
Moldova	22.4	11
Tajikistan	19.6	12

Asia-Pacific		
Country	Score	Rank
Singapore	90.5	1
South Korea	84.3	2
Japan	76.5	3
Brunei Darussalam	66.0	4
China	48.2	5
Malaysia	46.8	6
Mongolia	43.8	7
Fiji	42.4	8
Marshall Islands	40.0	9
Taiwan	38.2	10
Indonesia	36.7	11
Tonga	35.1	12
Micronesia	25.5	13
Thailand	21.7	14
Laos	21.6	15
Kiribati	21.0	16
Timor-Leste	20.2	17
Vanuatu	19.1	18
Samoa	18.9	18
Viet Nam	16.1	20
Myanmar	13.6	21
Cambodia	13.4	22
Philippines	12.6	23
Solomon Islands	11.7	24
Papua New Guinea	11.1	25

Sub-Saharan Africa		
Country	Score	Rank
Zimbabwe	55.5	1
South Africa	51.5	2
Seychelles	50.9	3
Gabon	42.9	4
Botswana	42.2	5
Kenya	37.8	6
Mauritius	37.4	7
Equatorial Guinea	35.2	8
Malawi	30.7	9
Cabo Verde	30.3	10
Namibia	30.0	11
Republic of Congo	23.0	12
São Tomé and Príncipe	21.3	13
Tanzania	18.2	14
Zambia	17.3	15
Djibouti	16.3	16
Eswatini	15.9	17
Ghana	15.9	17
Angola	15.8	19
Nigeria	15.0	20
Uganda	15.0	20
Burkina Faso	14.8	22
Senegal	14.4	23
Mauritania	14.0	24
Burundi	13.8	25
Côte d'Ivoire	13.6	26
Ethiopia	13.2	27
Cameroon	12.7	28
Central African Republic	12.5	29
Chad	12.5	29
Dem. Rep. Congo	12.5	29
Guinea-Bissau	12.5	29
Madagascar	12.5	29
Niger	12.5	29
Sierra Leone	12.5	29
Togo	12.5	29
Benin	12.4	37
Liberia	12.4	37
Guinea	12.0	39
Mozambique	12.0	39
Gambia	11.8	41
Lesotho	11.7	42
Comoros	11.5	43
Mali	11.2	44
Rwanda	10.5	45
Eritrea	9.5	46

Greater Middle East		
Country	Score	Rank
United Arab Emirates	89.8	1
Israel	88.7	2
Kuwait	85.7	3
Oman	85.7	3
Qatar	84.7	5
Bahrain	78.5	6
Tunisia	74.5	7
Jordan	72.4	8
Morocco	57.1	9
Saudi Arabia	56.9	10
Egypt	55.9	11
Algeria	55.7	12
Lebanon	46.8	13
Iraq	43.9	14
Iran	29.2	15
Sudan	11.2	16

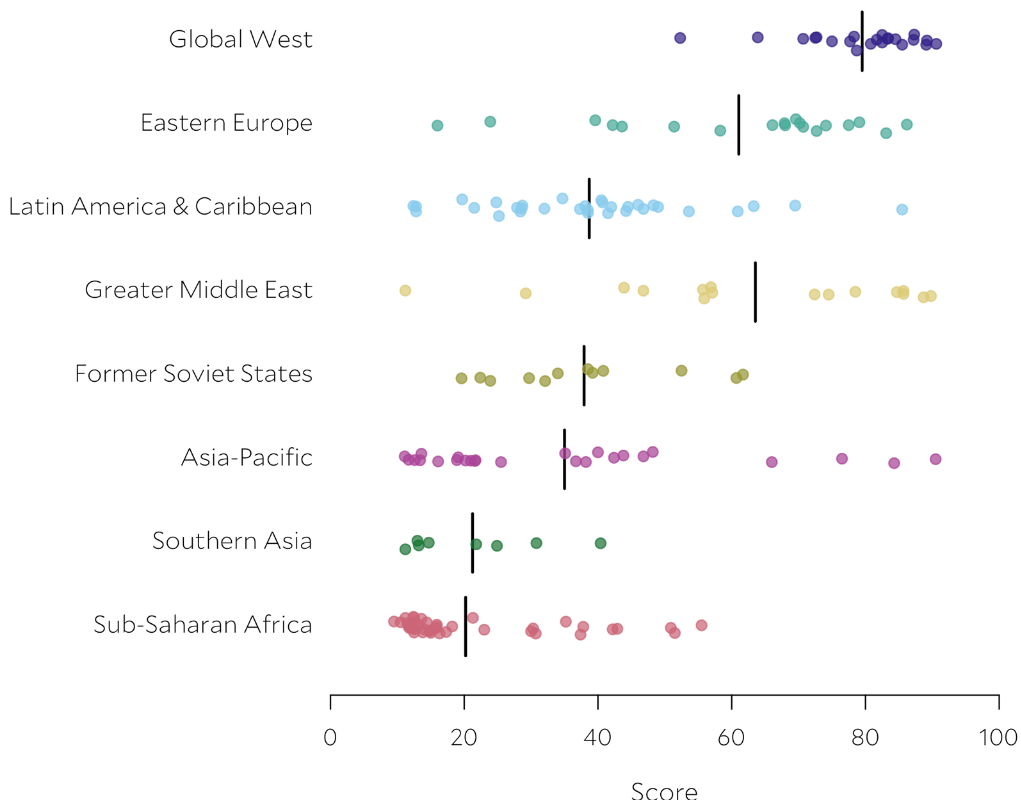
3. Global Trends

Wastewater is not used to its full potential anywhere in the world. On average, each person generates 49 thousand liters of wastewater each year (Jones et al. 2021). This amounts to a total of nearly 360 trillion cubic meters of wastewater generated each year, which is approximately five times the volume flowing through the Niagara Falls. Of that total volume, approximately two-thirds is collected, of which only three-quarters undergo treatment. Only one fifth of the treated water is reused for any purpose, a mere 10 percent of the total wastewater generated (Jones et al. 2021). This is a tremendous waste. Recovering nutrients in wastewater could offset 13.4 of agriculture's fertilizer demand, and the energy embedded in wastewater could provide electricity to 158 million households (Qadir et al. 2020).

The Global West is by far the region with the highest average score (79.5) in overall wastewater management, while Southern Asia and Sub-Saharan Africa fall behind with regional averages of 21.3 and 20.2, respectively. Current trends suggest that these contrasts will intensify in the coming decades, with Sub-Saharan Africa becoming the global hotspot of surface water pollution (Jones et al. 2023). However, there is substantial score variation within regions. Some countries in all regions except South Asia outperform Malta, the lowest scoring country in the Global West. Four regions are represented in the top ten highest-scoring countries: the Global West, Asia-Pacific, Greater Middle East, and Latin America & Caribbean. The spread of scores in the Greater Middle East, a water-scarce region including wealthy countries from the Persian Gulf and low-income countries in Northern Africa, suggests that the ability to fund the infrastructure required for the collection and treatment of wastewater is an important predictor of performance.

Regional score variability reflects profound differences in the quality of countries' infrastructure, which is in turn correlated with their development status (Sheriff, Kachalla, and Odeyemi 2019). Adequate wastewater infrastructure is costly. And even when infrastructure is available, governments need to deal with lack of policy directives, limited technical expertise, and lack of compliance with existing regulations (Vaidya et al. 2023). Despite being expensive, wastewater infrastructure is a smart sustainability investment, given that the costs of inadequate wastewater management are even higher. Areas without adequate wastewater collection and treatment must deal with polluted water streams that harm the health of people, ecosystems, and the economy (Jones et al. 2022). In contrast, improved water infrastructure can boost economic activity and job creation. In the United States, restoring water infrastructure could result in over US$220 billion in annual economic activity and the creation of 1.3 million jobs (Value of Water Campaign 2024).

Figure 8-1. Distribution of regional scores on Water Resources. Vertical bars show regional averages.



4. Leaders and Laggards

Singapore and Luxembourg top the global ranks in the Water Resources issue category. Both are small, high-income countries with highly urbanized populations. This setting allows for the effective operation of centralized wastewater collection and treatment systems. Luxembourg is one of only four European countries that treat 100 percent of their urban wastewater in accordance with the EU Urban Waste Water Treatment Directive — the other three are Austria, Germany, and the Netherlands (EEA 2023). In 2020, Luxembourg invested about 129 euros per citizen per year in wastewater management, three times the European Union's average of €41 per citizen (WISE 2020a). Much of this spending goes towards improving already existing infrastructure. For example, Luxembourg will spend €10-20 million on each of its 13 biggest wastewater treatment plants to increase their capacity to filter out micro-pollutants (Camposeo and Pauly 2022). The improvements of the wastewater system contribute Luxembourg's circular economy strategy, which includes the recovery of nutrients, minerals, and energy from waste (Schosseler, Tock, and Rasqué 2021).

As one of the most water-stressed countries in the world, Singapore has turned to wastewater reuse as a solution (WEF 2022). In Singapore, the Changi Water Reclamation Plant is one of five facilities producing "NEWater," a term that refers to high-grade reclaimed water. This single plant has the capacity to treat up to 900 million liters of wastewater each day, turning it into clean, drinkable water. Primarily utilized in the microchip manufacturing industry, for cooling buildings, and augmenting drinking water reservoirs, NEWater is a cornerstone of Singapore's water strategy. It accounts for up to 40 percent of the country's water supply and can be used for both potable and non-potable purposes.

As Singapore, the United Arab Emirates (UAE) and other small affluent countries in the Persian Gulf have turned to wastewater reuse as a solution to water scarcity. Rapid population growth and agricultural development have driven fast decline in groundwater levels in the UAE, leading the country to rely more heavily on seawater desalination (Gonzalez et al. 2016). However, desalination has several drawbacks, including high energy consumption and environmentally harmful byproducts such as brine (Jones et al. 2019). These challenges have led the UAE to increasingly reuse wastewater in agriculture, industry, and groundwater aquifer recharge (Keerthana 2023), though the country can still improve its rate of wastewater reuse. The Jones et al. (2021) dataset — on which the 2024 EPI's *Wastewater Reuse* indicator is based — reports a 100 percent rate of treated wastewater reuse in the UAE, but other sources report lower rates. For instance, Abu Dhabi's Department of Energy reported achieving only about a 61 percent reuse in 2019, with most reused for landscape irrigation (Emirates News Agency-WAM 2020). There are two main barriers to increasing reuse rates in the UAE. First, some wastewater plants are below sea level, leading to seepage of seawater into the collection network (Dawoud 2022). The resulting high salinity of the treated water limits its potential uses. Second, the UAE public remains skeptical about the safety of reusing treated wastewater for growing crops directly consumed by humans (Chfadi, Gheblawi, and Thaha 2021).

Chile, which outperforms other countries in the Latin American & Caribbean region by a wide margin, offers a story of rapid policy success. Two decades ago, Chile's capital — Santiago — treated less than four percent of its wastewater. Vast volumes of untreated wastewater and sewer sludge used to flow freely into the Mapocho river, turning it into a dead zone (UNFCCC 2023). Since then, progress has been swift. Between 2004 and 2010, Chile reached its goal of treating 100 percent of urban wastewater with a mix of public and private investments (We Build Value Digital Magazine 2018). More recently, efforts have focused on incorporating wastewater management into a circular economy. Three of Santiago's wastewater treatment plants have been turned into biofactories that convert wastewater and sewer sludge into clean energy and repurposed sand for construction projects (UNFCCC 2023). Wastewater is also being reused in drought-prone, rural areas for small-scale agriculture. In 2018, rural localities in Coquimbo were able to reuse 9.5 liters of wastewater per second (Milesi 2023).

The United States and Malta severely underperform other countries in the Global West. The United States' performance can be explained by a long history of underinvestment in its wastewater infrastructure, with many wastewater treatment facilities approaching or having surpassed their intended lifespan (Infrastructure Report Card 2021). The gap between annual spending and the funding needed to fix the infrastructure of the United States is now more US$80 billion (Qureshi 2022). Another problem is the fragmentation of the United States' water and wastewater systems. The country has more water systems than it has schools (Harris, Hershbein, and Kearney 2014), but over 70 percent of its wastewater systems serve less than 10,000 people (Haarmeyer 2011). Small providers are more likely to lack funding and technical know-how, resulting in lower environmental performance (Haarmeyer 2011; Weirich, Silverstein, and Rajagopalan 2011).

Malta lacks appropriate facilities for wastewater treatment. None of the sewage treated in Malta complies with the European Union's regulations (WISE 2020b). In 2022, the European Commission referred Malta to the Court of Justice of the European Union for failing to comply with the Urban Waste Water Treatment Directive (European Commission 2022). Malta has failed to comply with regulations despite receiving over €60 million in European funds to build and improve wastewater treatment plants (Tihn 2023). In part, the low quality of treated wastewater in Malta is caused by discharges of animal manure into the municipal wastewater system, which hampers the performance of treatment plants (European Commission 2022).

Focus 18.1

Recovering biogas from wastewater

Biogas is a renewable energy source composed primarily of methane and carbon dioxide. Between 2010 and 2019, global biogas electricity generation capacity almost doubled (Kabeyi and Olanrewaju 2022). Wastewater treatment plants that use anaerobic digestion can become a major source of biogas (Uddin and Wright 2023). Besides producing energy resources, wastewater treatment with anaerobic digestion also avoids the release of vast amounts of greenhouse gases into the atmosphere (Musa et al. 2018).

The Netherlands has reframed wastewater treatment plants as water production facilities, pioneering the idea of Nutrient, Energy, Water (NEW) Factories (Roeleveld, Roorda, and Schaafsma 2010; van Leeuwen et al. 2018). The Amersfoort plant is an example of this approach. It creates enough energy to be self-sufficient, while also powering 600 city dwellings and producing around 900 tonnes of fertilizer per year (EEA 2019).

Currently, the biogas generation is led by European countries due to a combination of strong environmental policies and significant research efforts (Pablo-Romero et al. 2017; Lora Grando et al. 2017). However, with technological advancements making the anaerobic processes more efficient, there is significant potential for uptake in developing countries. In Brazil, for instance, methane recovery systems are economically viable in most cities with over 50,000 inhabitants, and in all cities with a population over 250,000 (Campello et al. 2021). The payback period is also relatively short, ranging between 1.25 to 8 years depending on the city's size. Recovering biogas from wastewater will likely play an important role in the world's transition towards cleaner energy and a circular economy.

5. Methods

High-quality data still limits the scope and accuracy of the Water Resource indicators in the EPI. Data on the spatial distribution of water quality, as well as the disruption of natural water flows in ecosystems are key for sustainable water resource management, but currently unavailable. Of the few topics for which data is available, methodological inconsistencies in data collection and reporting severely limit the EPI indicators' ability to gauge policy. The EPI repeats and emphasizes previous calls for the adoption of internationally standardized data collection processes and reporting mechanisms, overseen by independent third-party organizations.

Despite the persistent data limitations, the 2024 EPI introduces new datasets and indicators to the Water Resources issue category to provide a more granular overview of wastewater management gaps and policy priorities. First, we disaggregate our previous Wastewater Treatment indicator (Malik et al. 2015) into its two components: the fraction of wastewater collected, and the fraction treated. We also add two new pilot indicators. One measures the total amount of wastewater generated per person, per year in each country. The other measures the fraction of wastewater reused, a key metric to track progress toward a circular economy. Together, these four indicators offer a more complete view of the sustainability of countries' wastewater production and management.

Indicator Background

The *Wastewater Generated* indicator measures the total volume of wastewater generated per person, per year in each country. Water is considered "waste" when, because of its quality, quantity or mere timing, it is no longer fit for its original purpose. The data include wastewater generated both by households and by economic activities (such as agriculture and manufacturing) but exclude water used for cooling.

The *Wastewater Collected* indicator measures the percentage of wastewater collected for treatment. For many countries, this is measured as the percentage of population connected to urban, and sometimes also to independent, treatment facilities. Urban facilities are typically centralized wastewater treatment plants, while independent treatment facilities include septic tanks, which are common (and cost-effective) in rural areas with low population density (Gill et al. 2009).

The *Wastewater Treatment* indicator measures the percent of all wastewater generated that receives at least primary treatment. Primary treatment removes large solids from raw wastewater through screening and other basic methods. It is an admittedly low bar for treatment level. After undergoing primary treatment, most wastewater is still not safe for discharge into the environment (EPA 1998). Unfortunately, we currently lack the global data required to account for more advanced treatment methods in our indicator.

The *Wastewater Reuse* indicator measures the percent of all wastewater generated that is reused after treatment. Reused wastewater (also known as "reclaimed" or "recycled"), it is typically used for irrigation in agriculture, or, when clean enough, in industry or even for drinking (Jones et al. 2021).

Data Sources

We use a variety of data sources to construct the Water Resources indicators in the 2024 EPI. The bedrock of our indicators are the country-level estimates of wastewater production, collection, treatment, and reuse from a study by Jones et al. (2021). These estimates are primarily based on data from the *Aquastat database* of the Food and Agriculture Organization and the *Global Water Intelligence* report. Jones et al. (2021) standardized data to 2015 estimates based on relationships with GDP and corrected implausible values. The Jones et al. (2021) dataset is the only source for the *Wastewater Reuse* indicator. For the other three indicators, we updated the 2015 estimates by Jones et al. (2021) with data from two public databases of country-level water management statistics: one from the Organization for Economic Co-operation and Development (OECD) and the other from the United Nations Statistics Division (UNSD). Finally, we use data from Eurostat for Kosovo's wastewater collection rates.

To improve the recency, accuracy, and coverage of our indicators, we encourage all countries to report their latest water management data to either the United Nations Environment Programme (UNEP) in their biennial Questionnaire on Environment Statistics, or to the OECD and Eurostat in their own joint questionnaire.

Limitations

Despite the importance of sustainable water management, our ability to measure progress in this key area is limited by the quality, recency, and completeness of the available data. The data available for many countries is over a decade old. Most countries do not regularly report their data for international bodies, if at all (Sato et al. 2013). Furthermore, the scattered data sources make it challenging to ensure methodological consistency across the dataset. Even within a single source, the lack of standardized measurements and definitions means that countries use inconsistent definitions for wastewater treatments, collection, or for wastewater itself. Other times, data is reported on different units or from different geographic scales, further hindering comparability. For example, Chile's OECD metadata states that wastewater data is recorded from only urban populations served by sanitary companies and thus data are "not comparable to other countries." Many other countries in the OECD and UNSD datasets report only urban data. These issues severely limit the usefulness of our indicators for cross-country comparisons and highlight the urgent need for improvements in standardization and automation of data collection systems.

Besides being inconsistent and incomplete, the available data also lacks key information about the quality of wastewater treatment. Many reports of wastewater treatment rates do not even distinguish between filtration and primary treatment, especially in developing countries. Knowing the level of treatment is important to understand the impacts of discharging treated wastewater into the environment. Primary treatment removes only one third of biochemical oxygen demand, while secondary treatment removes up to 90 percent, and tertiary treatment even more (Malik et al. 2015). Developed countries more often report the fraction of wastewater undergoing primary, secondary, and tertiary treatment, but the issues with lack of standardization discussed above also affect these data. Moreover, data about the recovery of energy (such as heat and biogas) and materials (such as fertilizers) from wastewater are scarce, despite the critical importance of these issues to a circular economy.

That the data is so limited about such an important global sustainability issue is a serious problem. Countries and international organizations must redouble their efforts to build standardized and automated wastewater management reporting frameworks. Recent advancements in deep learning and artificial intelligence present opportunities to automate data collection and analysis and fill-in temporal and spatial data gaps (Zhi et al. 2024).

Weighting Rationale

Despite water resources being a key sustainability issue with deep connections to biodiversity, ecosystem services, agriculture, climate change, and environmental health, the relative weight of this category in overall EPI scores is only 5 percent due to the serious data limitations discussed above. Within the category, the indicators of wastewater production and reuse, which are conceptually novel in the EPI and thus introduced as pilot indicators, count for 10 percent each in the aggregated Water Resources scores. The indicators of wastewater collection and treatment account for equal parts of the remaining 80 percent of the aggregated scores.

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Chapter 9. Agriculture

1. Introduction

With a growing global population and rising incomes, the demand for food, feed, and biofuel is expected to increase by almost 50 percent by 2050 (FAO 2017). Nearly half of ice-free land is already used for agriculture (Ellis et al. 2010), and croplands keep expanding (Potapov et al. 2022). Given the climate and biodiversity crises, however, the world cannot afford to convert more natural ecosystems into croplands and pastures. Meeting the growing demand for agricultural produce will therefore require maximizing the productivity of current agricultural land without further degrading the environment (Pretty 2018). Indeed, with appropriate practices, agriculture can even help regenerate ecosystems and store carbon (Rehberger et al. 2023).

Increasing agricultural productivity can help spare land for other uses and for natural ecosystems (Folberth et al. 2020). Our tools to maximize crop yields, such as the use of pesticides, fertilizers, and water for irrigation, are also major drivers of ecosystem degradation. Excessive fertilizer use, for example, is the main source of global nitrogen and phosphorus pollution (Bodirsky et al. 2014; X. Cui et al. 2024). These two nutrients have already surpassed their respective planetary boundaries and threaten human and environmental health on the local and global level (Richardson et al. 2023). When nitrogen fertilizer exceeds plants' requirements, the surplus nitrogen leaches into the environment. In surface water, nitrogen drives eutrophication and biodiversity loss (Erisman et al. 2013). Volatized, it pollutes the air (Gu et al. 2014; Guo et al. 2020; Wang et al. 2021), depletes the ozone layer (Ravishankara, Daniel, and Portmann 2009), and worsens the climate crisis (Erisman et al. 2013). Improved agricultural practices that match fertilizer application to plant needs in time and space can reduce nitrogen loss to air and water by up to 70 percent (Gu et al. 2023). Excess use of phosphorus fertilizer, which also leaches into surface water, similarly threatens ecosystem and human health (Zou, Zhang, and Davidson 2022).

Pesticides can prevent crop losses and economically benefit producers and consumers (Popp, Pető, and Nagy 2013), but their overuse can be devastating. These harmful chemicals can persist in the environment for years, affecting human health (Alavanja, Hoppin, and Kamel 2004; Larsen, Gaines, and Deschênes 2017) and contributing to the global decline in insect pollinators (Potts et al. 2010; Wagner et al. 2021) and other sensitive organisms (Beketov et al. 2013; Brühl et al. 2013). Our reliance on pesticides for crop protection has hindered the success of policies aimed at reducing pesticide pollution (Möhring et al. 2020).

To measure our progress towards the sustainable intensification of agriculture, the 2024 EPI scores countries on both their agricultural productivity and their excessive use of pesticides and fertilizers, both of which contribute to the pollution and degradation of ecosystems. These indicators can help countries track progress towards Target 7 of the Kunming-Montreal Global Biodiversity Framework, which aims at reducing pollution from all sources (including pesticides and fertilizers) to levels not harmful to biodiversity by 2030 (Möhring et al. 2023). Agriculture's contribution to climate change and habitat loss are accounted for in the Climate Change, Forests, and Biodiversity & Habitat categories of the EPI.

2. Indicators

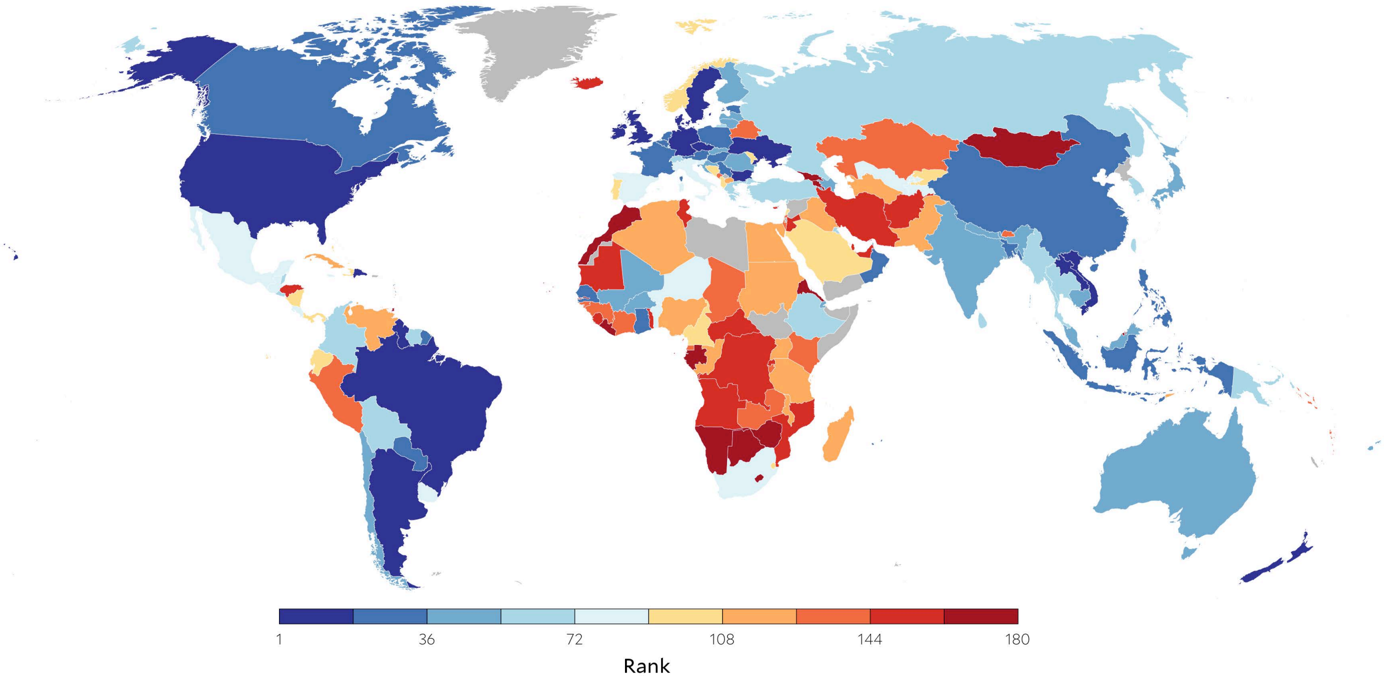
Relative Crop Yield
(40% of issue category)
Land use is behind most of the greenhouse emissions and biodiversity impacts of agriculture. By maximizing crop yields, countries can potentially reduce agricultural land requirements. This indicator measures the average yield of 17 major crops relative to their maximum historical attainable yield, accounting for regional climatic differences.

Sustainable Nitrogen Management Index
(40% of issue category)
Excessive and inefficient use of nitrogen fertilizers results in water pollution and greenhouse gas emissions. This index balances the efficient use of nitrogen fertilizers with the imperative to produce sufficient crop yields.

Phosphorus Surplus
(5% of issue category)
Excessive use of phosphorus fertilizers contributes to eutrophication of water bodies. This indicator measures the difference between the phosphorus added as fertilizer and extracted in crop harvests. Unrecovered phosphorus can potentially leach into water bodies, and thus this indicator serves as a proxy for phosphorus pollution.

Pesticide Pollution Risk
(15% of issue category)
Chemical compounds used to manage pests in agriculture accumulate in the environment and pose a health hazard to humans and other organisms. This indicator measures the accumulation of pesticides in the environment relative to safe levels.

Map 9-1. Global rankings on Agriculture.



Map 9-2. Agriculture scores.

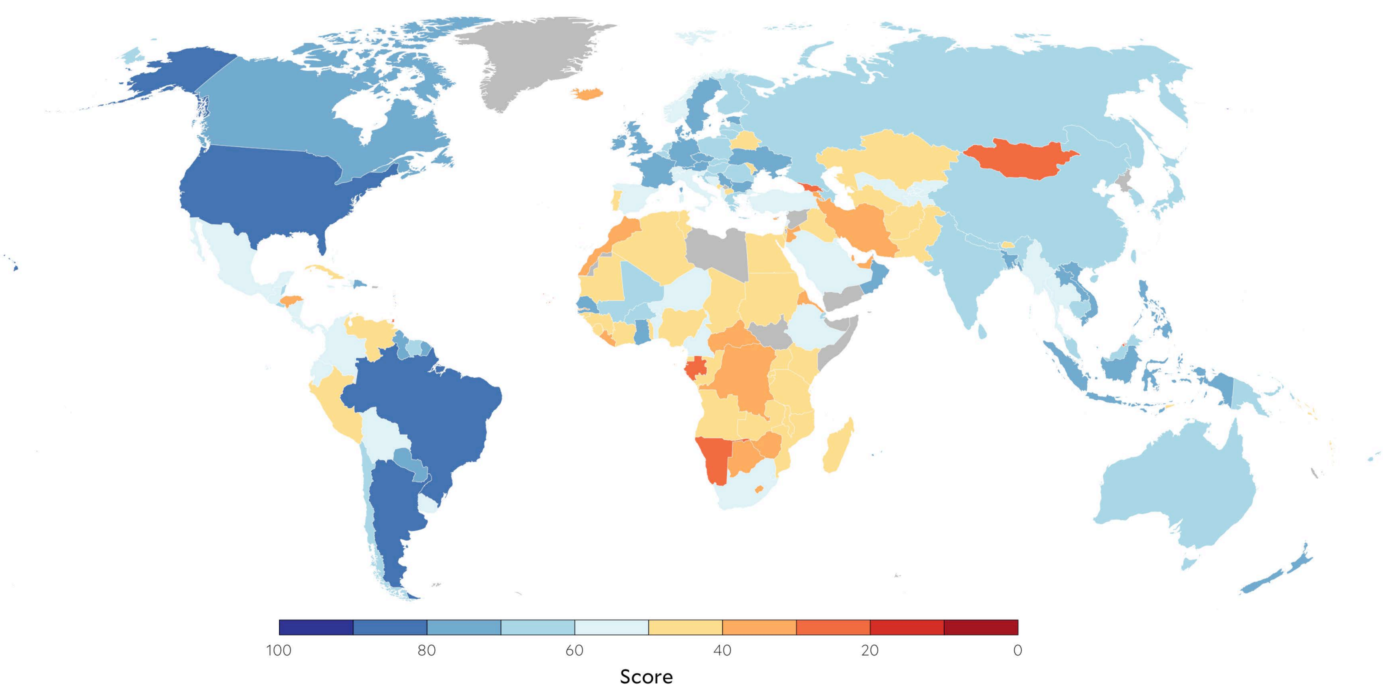


Table 9-1. Global rankings, scores, and regional rankings (REG) on the Agriculture issue category.

RANK	COUNTRY	SCORE	REG
1	United States of America	83.0	1
2	Argentina	81.4	1
3	Brazil	81.0	2
4	Germany	78.8	2
5	Dominican Republic	78.7	3
6	Laos	78.5	1
7	Denmark	77.8	3
7	Marshall Islands	77.8	2
9	St. Vincent and Grenadines	76.9	4
9	United Kingdom	76.9	4
11	Ukraine	76.4	1
12	Bulgaria	74.2	1
13	Czech Republic	74.0	2
13	Guyana	74.0	5
15	Sweden	73.2	5
16	Viet Nam	73.0	3
17	Ireland	72.9	6
17	New Zealand	72.9	6
19	France	72.8	8
20	Austria	72.5	9
21	Canada	72.3	10
21	Philippines	72.3	4
23	Bangladesh	72.2	1
23	Indonesia	72.2	5
25	Paraguay	71.6	6
26	Serbia	71.4	3
27	Senegal	71.1	1
28	Estonia	71.0	4
29	Ghana	70.7	2
29	Oman	70.7	1
31	Hungary	69.2	5
32	China	69.0	6
33	Mauritius	68.6	3
34	Belgium	68.5	11
35	Poland	68.3	6
36	Netherlands	68.0	12
37	Croatia	67.9	7
38	Romania	67.8	8
39	Slovakia	67.4	9
40	Lithuania	67.0	10
41	Finland	66.6	13
42	Mali	66.4	4
43	Chile	66.3	7
44	Nepal	65.6	2
45	Australia	65.3	14
46	India	65.1	3
47	Djibouti	65.0	5
48	Cambodia	64.6	7
49	Latvia	64.4	11
50	Burkina Faso	64.0	6
51	Malaysia	63.6	8
52	Japan	63.3	9
53	Azerbaijan	63.0	2
53	Fiji	63.0	10
55	Russia	62.9	3
56	Luxembourg	62.8	15
56	Suriname	62.8	8
58	Sri Lanka	62.5	4
59	El Salvador	62.3	9
60	Papua New Guinea	61.8	11
60	South Korea	61.8	12
62	Greece	61.4	12
63	Singapore	61.3	13
64	Belize	60.9	10
65	Taiwan	60.3	14
66	Bolivia	59.6	11
66	Myanmar	59.6	15
66	Switzerland	59.6	16
69	Colombia	59.3	12
70	Türkiye	59.2	13
71	Kuwait	59.0	2
72	Ethiopia	58.8	7
72	Thailand	58.8	16
74	Kiribati	58.6	17
75	Uruguay	58.2	13
76	Seychelles	58.0	8
77	Uzbekistan	57.4	4
78	South Africa	57.2	9
79	Samoa	57.1	18
80	Costa Rica	57.0	14
80	Tajikistan	57.0	5
82	Guatemala	56.8	15
82	Mexico	56.8	15
84	Slovenia	56.7	14
85	Italy	56.4	17
86	Niger	55.9	10
87	Maldives	55.8	5
88	Jamaica	55.1	17
89	Spain	54.1	18
90	Benin	54.0	11
91	Saudi Arabia	53.8	3
92	Bosnia and Herzegovina	52.3	15
92	Norway	52.3	19
94	Kyrgyzstan	51.9	6
95	Eswatini	51.7	12
96	Nicaragua	51.6	18
97	Grenada	51.0	19
98	Comoros	50.6	13
98	Haiti	50.6	20
98	Lebanon	50.6	4
101	Albania	50.4	16
101	Cameroon	50.4	14
103	Bahamas	50.2	21
104	Ecuador	50.1	22
105	Panama	50.0	23
106	Moldova	49.9	7
106	Tonga	49.9	19
108	Portugal	49.7	20
109	Iraq	49.6	5
110	Egypt	48.9	6
111	Timor-Leste	48.8	20
112	Sudan	48.5	7
112	Tanzania	48.5	15
114	Uganda	48.3	16
115	Madagascar	48.2	17
116	Republic of Congo	48.1	18
116	Turkmenistan	48.1	8
118	Barbados	47.9	24
118	Nigeria	47.9	19
120	Cuba	47.0	25
120	Micronesia	47.0	21
122	Pakistan	46.8	6
123	Algeria	46.7	8
123	North Macedonia	46.7	17
125	Malawi	46.6	20
126	Venezuela	46.1	26
127	Guinea	45.9	21
128	Dominica	45.7	27
129	Burundi	45.4	22
130	Israel	45.3	9
130	Peru	45.3	28
132	Belarus	45.2	9
133	Bhutan	44.7	7
133	Kazakhstan	44.7	10
135	Solomon Islands	44.6	22
136	Kenya	44.2	23
137	Zambia	44.1	24
138	Equatorial Guinea	43.7	25
139	Malta	43.5	21
140	Montenegro	43.0	18
141	Chad	42.7	26
141	Vanuatu	42.7	23
143	Bahrain	42.5	10
144	Côte d'Ivoire	42.2	27
144	Guinea-Bissau	42.2	27
146	Mauritania	42.1	29
147	Rwanda	41.6	30
148	Afghanistan	41.1	8
149	Angola	41.0	31
150	Togo	40.3	32
151	Tunisia	40.2	11
152	Mozambique	40.1	33
152	Sierra Leone	40.1	33
154	Saint Lucia	39.3	29
155	Dem. Rep. Congo	39.0	35
156	Honduras	38.6	30
157	Central African Republic	38.3	36
158	Jordan	38.1	12
159	Iran	37.8	13
160	United Arab Emirates	37.5	14
161	Iceland	36.5	22
162	Cyprus	35.7	19
162	Qatar	35.7	15
164	Morocco	35.6	16
165	Armenia	35.5	11
165	Zimbabwe	35.5	37
167	Botswana	35.3	38
168	Lesotho	34.3	39
169	Liberia	34.0	40
170	Gambia	33.7	41
171	Eritrea	31.9	42
172	São Tomé and Príncipe	31.7	43
173	Antigua and Barbuda	31.4	31
174	Mongolia	29.0	24
175	Gabon	28.2	44
176	Cabo Verde	28.0	45
177	Georgia	26.0	12
178	Namibia	25.5	46
179	Brunei Darussalam	24.1	25
180	Trinidad and Tobago	22.5	32

Asia-Pacific **Eastern Europe** **Former Soviet States** **Global West**

Greater Middle East **Latin America & Caribbean** **Southern Asia** **Sub-Saharan Africa**

Table 9-2. Regional rankings and scores on Agriculture.

Latin America & Caribbean		
Country	Score	Rank
Argentina	81.4	1
Brazil	81.0	2
Dominican Republic	78.7	3
St. Vincent and Grenadines	76.9	4
Guyana	74.0	5
Paraguay	71.6	6
Chile	66.3	7
Suriname	62.8	8
El Salvador	62.3	9
Belize	60.9	10
Bolivia	59.6	11
Colombia	59.3	12
Uruguay	58.2	13
Costa Rica	57.0	14
Guatemala	56.8	15
Mexico	56.8	15
Jamaica	55.1	17
Nicaragua	51.6	18
Grenada	51.0	19
Haiti	50.6	20
Bahamas	50.2	21
Ecuador	50.1	22
Panama	50.0	23
Barbados	47.9	24
Cuba	47.0	25
Venezuela	46.1	26
Dominica	45.7	27
Peru	45.3	28
Saint Lucia	39.3	29
Honduras	38.6	30
Antigua and Barbuda	31.4	31
Trinidad and Tobago	22.5	32

Eastern Europe		
Country	Score	Rank
Bulgaria	74.2	1
Czech Republic	74.0	2
Serbia	71.4	3
Estonia	71.0	4
Hungary	69.2	5
Poland	68.3	6
Croatia	67.9	7
Romania	67.8	8
Slovakia	67.4	9
Lithuania	67.0	10
Latvia	64.4	11
Greece	61.4	12
Türkiye	59.2	13
Slovenia	56.7	14
Bosnia and Herzegovina	52.3	15
Albania	50.4	16
North Macedonia	46.7	17
Montenegro	43.0	18
Cyprus	35.7	19

Southern Asia		
Country	Score	Rank
Bangladesh	72.2	1
Nepal	65.6	2
India	65.1	3
Sri Lanka	62.5	4
Maldives	55.8	5
Pakistan	46.8	6
Bhutan	44.7	7
Afghanistan	41.1	8

Global West		
Country	Score	Rank
United States of America	83.0	1
Germany	78.8	2
Denmark	77.8	3
United Kingdom	76.9	4
Sweden	73.2	5
Ireland	72.9	6
New Zealand	72.9	6
France	72.8	8
Austria	72.5	9
Canada	72.3	10
Belgium	68.5	11
Netherlands	68.0	12
Finland	66.6	13
Australia	65.3	14
Luxembourg	62.8	15
Switzerland	59.6	16
Italy	56.4	17
Spain	54.1	18
Norway	52.3	19
Portugal	49.7	20
Malta	43.5	21
Iceland	36.5	22

Former Soviet States		
Country	Score	Rank
Ukraine	76.4	1
Azerbaijan	63.0	2
Russia	62.9	3
Uzbekistan	57.4	4
Tajikistan	57.0	5
Kyrgyzstan	51.9	6
Moldova	49.9	7
Turkmenistan	48.1	8
Belarus	45.2	9
Kazakhstan	44.7	10
Armenia	35.5	11
Georgia	26.0	12

Asia-Pacific		
Country	Score	Rank
Laos	78.5	1
Marshall Islands	77.8	2
Viet Nam	73.0	3
Philippines	72.3	4
Indonesia	72.2	5
China	69.0	6
Cambodia	64.6	7
Malaysia	63.6	8
Japan	63.3	9
Fiji	63.0	10
Papua New Guinea	61.8	11
South Korea	61.8	12
Singapore	61.3	13
Taiwan	60.3	14
Myanmar	59.6	15
Thailand	58.8	16
Kiribati	58.6	17
Samoa	57.1	18
Tonga	49.9	19
Timor-Leste	48.8	20
Micronesia	47.0	21
Solomon Islands	44.6	22
Vanuatu	42.7	23
Mongolia	29.0	24
Brunei Darussalam	24.1	25

Sub-Saharan Africa		
Country	Score	Rank
Senegal	71.1	1
Ghana	70.7	2
Mauritius	68.6	3
Mali	66.4	4
Djibouti	65.0	5
Burkina Faso	64.0	5
Ethiopia	58.8	7
Seychelles	58.0	8
South Africa	57.2	9
Niger	55.9	10
Benin	54.0	11
Eswatini	51.7	12
Comoros	50.6	13
Cameroon	50.4	14
Tanzania	48.5	15
Uganda	48.3	16
Madagascar	48.2	17
Republic of Congo	48.1	18
Nigeria	47.9	19
Malawi	46.6	20
Guinea	45.9	21
Burundi	45.4	22
Kenya	44.2	23
Zambia	44.1	24
Equatorial Guinea	43.7	25
Chad	42.7	26
Côte d'Ivoire	42.2	27
Guinea-Bissau	42.2	27
Mauritania	42.1	29
Rwanda	41.6	30
Angola	41.0	31
Togo	40.3	32
Mozambique	40.1	33
Sierra Leone	40.1	33
Dem. Rep. Congo	39.0	35
Central African Republic	38.3	36
Zimbabwe	35.5	37
Botswana	35.3	38
Lesotho	34.3	39
Liberia	34.0	40
Gambia	33.7	41
Eritrea	31.9	42
São Tomé and Príncipe	31.7	43
Gabon	28.2	44
Cabo Verde	28.0	45
Namibia	25.5	46

Greater Middle East		
Country	Score	Rank
Oman	70.7	1
Kuwait	59.0	2
Saudi Arabia	53.8	3
Lebanon	50.6	4
Iraq	49.6	5
Egypt	48.9	6
Sudan	48.5	7
Algeria	46.7	8
Israel	45.3	9
Bahrain	42.5	10
Tunisia	40.2	11
Jordan	38.1	12
Iran	37.8	13
United Arab Emirates	37.5	14
Qatar	35.7	15
Morocco	35.6	16

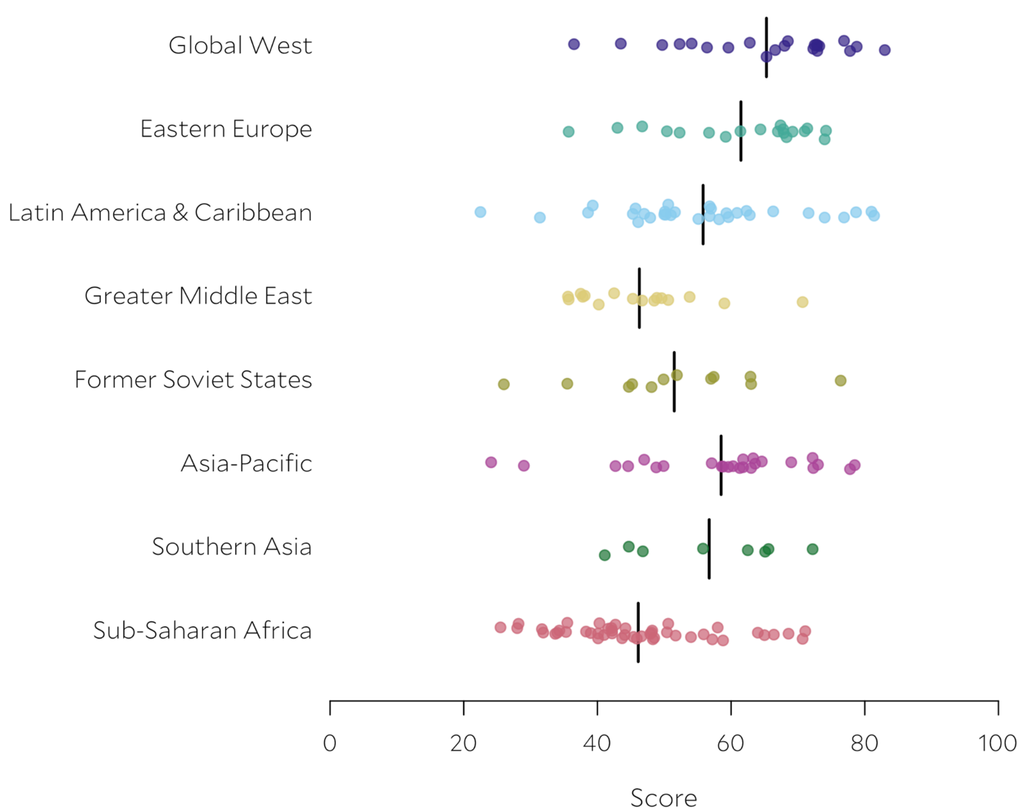
3. Global Trends

Over the last decades, crop yields have steadily increased in every region of the world except Sub-Saharan Africa. However, there is wide variation in crop yields within every region. Average regional crop yields are still below 80 percent of maximum attainable yields in every region except the Global West. This underperformance highlights the urgency of technology diffusion and agricultural support mechanisms between countries (Tian and Yu 2019), especially as climate change threatens agricultural productivity. For example, in 2024, a severe drought in Southern Africa, intensified by El Niño, killed livestock and caused catastrophic crop failures, prompting the governments of Malawi, Zambia, and Zimbabwe to declare national emergencies.

Historical crop yield increases reflect, in part, a sharp increase in the rate of fertilizer use. Between 1963 and 2013, nitrogen fertilizer use per unit of cropland area increased eight-fold, while that of phosphorus tripled (Lu and Tian 2017). However, the efficiency of nitrogen fertilizer use has remained relatively constant through time (He, Liu, and Cui 2021; Xin Zhang et al. 2022), with persistent differences between countries at different stages of development. For example, from the 1960s through 2007, nitrogen inputs in OECD countries were 54 percent greater than in non-OECD countries, translating into 70 percent higher yields (Conant, Berdanier, and Grace 2013). Some research suggests that nitrogen use efficiency in developed countries is approaching its maximum potential, and further increases may require technological innovations such as genetic improvements and precision applications of fertilizers (He, Liu, and Cui 2021). In rapidly developing countries that still have large nitrogen surpluses, low-tech tech approaches to match fertilizer application to plant requirements, or the use of nitrogen-fixing plants in rotation plans, can lead to big improvements in crop yields and nitrogen use efficiency (Chen et al. 2011; Z. Cui et al. 2018; He, Liu, and Cui 2021).

In much of the world, phosphorus fertilizer is also used inefficiently. Between 2002 and 2010, half of total phosphorus inputs to agriculture were lost to freshwaters, while another third accumulated in soils (Lun et al. 2018). This inefficient use, besides leading to eutrophication of water bodies, also threatens long-term food security because phosphorus fertilizer is primarily obtained from phosphate rocks, a finite, non-renewable resource. Annually, the equivalent of 5.2 million tonnes of phosphorus are embodied in internationally traded commodities, primarily from developing to developed countries (Yang et al. 2019). This unbalanced flow of phosphorus exacerbates the risk to food security posed by higher rates of soil phosphorus depletion in Africa and South America (Lun et al. 2018; Zou, Zhang, and Davidson 2022). Other issues, such as soil erosion, further aggravate the risk of future phosphorus shortages (Alewell et al. 2020).

Figure 9-1. Distribution of regional scores on Agriculture. Vertical bars show regional averages.



Agriculture uses approximately two million tonnes of pesticides annually, seriously threatening human health and ecosystem vitality (Sharma et al. 2020). Insecticide concentrations in more than half of global surface waters exceed regulatory thresholds (Stehle and Schulz 2015). Over 30 percent of agricultural areas have high-risk concentrations of pesticide pollution, of which one third is located in high-biodiversity regions, and one fifth in low- and lower-middle-income countries (Tang et al. 2021).The intensity of pesticide use is growing especially fast across a range of middle-income countries, in which hazardous pesticides tend to be more weakly regulated than in higher income countries (Schreinemachers and Tipraqsa 2012). But implementing policies to reduce pesticide pollution can be challenging even in developed, food-secure countries (Möhring et al. 2020). In 2020, the European Commission proposed the Sustainable Use of Pesticides regulation as part of its Green Deal, aiming to reduce the risk of pesticide pollution by half by 2030, in line with Target 7 of the Kunming-Montreal Global Biodiversity Framework. However, the proposal sparked strong opposition from farmers' lobbies, forcing the European Commission to scrap the bill in 2024 (Wax and Brzeziński 2024).

4. Leaders and Laggards

Top performers in agriculture are geographically diverse, including countries from the Americas, Europe, and the Asia-Pacific region. But no country is close to achieving a perfect score. Indeed, the 2024 EPI indicators reveal an important trade-off in agricultural sustainability. Less developed countries using few agricultural inputs have minimal phosphorus surplus and pesticide pollution — but at the expense of low crop yields. In contrast, more affluent countries achieving high yields tend to be highly polluted with pesticides and excessive fertilizer use. Finding ways to achieve high productivity and low environmental impacts is the key to sustainable agriculture.

The United States of America, the top-performing country, has made progress toward balancing agricultural productivity and the minimization of environmental harm. The United States has reached maximum attainable crop yields while scoring high in the phosphorus surplus indicator and in the Sustainable Nitrogen Management Index, which combines metrics of yield and nitrogen use efficiency (Xin Zhang et al. 2022). However, the United States scores only 57.8 in pesticide pollution risk, ranking 99th worldwide and demonstrating that no country has managed to achieve high agricultural productivity with minimum pollution and environmental degradation. The United States' agricultural system historically favored systems based on high fertilizer and pesticide use (Young 1989). Recent agricultural policies, however, increasingly reflect the principles of sustainable intensification (Pretty 2018). For example, the 1994 reform of Federal Crop Insurance led to an 18.5 percent decrease in commercial nitrogen use in the Corn Belt (Xiaojie Zhang 2016), though there is still a lot of room for improvement. The renewal of the 2024 Farm Bill — the United States' most important set of agricultural policies — presents an opportunity to reinforce policies in support of human and ecosystem health (Patel and Rudolph 2023). The United States lags other big agricultural producers, such as Brazil, China, and the European Union, in banning harmful pesticides (Donley 2019). Germany, the 4th top-performing country, has pioneered pesticide-free, non-organic agricultural systems that are easier for farmers to adopt than fully organic agriculture and have smaller associated yield losses (Finger and Möhring 2024).

Laos, which ranks 6th worldwide and 1st in the Asia-Pacific region, achieved high scores across all the indicators except phosphorus surplus. Laos' transition from subsistence to commercial farming has been propelled by the introduction of improved rice varieties and an increase in use of fertilizers (Manivong and Cramb 2020). The Laotian government played an active role in this transition, introducing land reforms to improve tenure security and policies to discourage slash-and-burn agriculture, aiming to redirect farmers to more efficient forms of production (Ducourtieux, Laffort, and Sacklokham 2005). Not all the policies achieved their full potential. For example, the success of contract farming, encouraged by the government to connect individual households to local and international markets, was limited by the country's lack of institutional capacity to enforce contracts, which disincentivized buyers from providing farmers with necessary inputs (Goto and Douangngeune 2017). This failure illustrates the importance of the rule of law for effective environmental policymaking.

The worst performers in this issue category are countries with resource-intensive and inefficient agricultural practices, often due to local climates and environmental conditions. Examples include Mongolia, Qatar, the United Arab Emirates, Iceland, and Norway. These countries score poorly on sustainable nitrogen use, phosphorus surplus, and pesticide pollution risk while also failing to achieve high crop yields.

Qatar's performance illustrates the role of international trade in agricultural sustainability. Limited by both natural and structural constraints — scarce water resources, poor soils, and obsolete farming methods (Ben Hassen and El Bilali 2022) — Qatar imported 90 percent of its food through 2017, as its agricultural sector that was small and environmentally sub-optimal. Threats to food supply during the 2007–8 financial crisis and the 2017 Gulf Rift made food self-sufficiency a government priority (Miniaoui, Irungu, and Kaitibie 2018; Koch 2021). Sustainably achieving this goal, however, will be a formidable challenge considering the land and water scarcity in Qatar. First, the country needs to adopt water-efficient agricultural practices, as the current rate of groundwater extraction is nearly five times greater the sustainable limit (Ahmad and Al-Ghouti 2020). To expand food production in poor soils, Qatar relies heavily on fertilizers. As a result, its score on the Sustainable Nitrogen Management Index fell from 16.1 in 2002 to 6.7 in 2021 and from 49.7 to 30.8 on the phosphorus surplus indicator. Growing crops in locations with unsuitable soils and climates requires high and environmentally costly inputs to obtain low yields. Trade, on the other hand, allows countries with such conditions to source their food from countries where agriculture is intrinsically more efficient. In fact, if all croplands were relocated to optimal locations, allowing abandoned areas to regenerate, the environmental impacts of agriculture could be substantially reduced (Beyer et al. 2022).

5. Methods

Relative Crop Yield

Agricultural intensification is necessary to meet the rising demand for food, fiber, and biofuels while sparing land for natural habitat conservation and other emerging uses, such as renewable energy (Gasparatos et al. 2017). Thus, maximizing crop yields in current agricultural land is key to meeting the Kunming-Montreal Global Biodiversity Framework's goal of protecting 30 percent of all lands by 2030 while feeding a growing population and transitioning away from fossil fuels.

Indicator Background

The 2024 EPI's *Relative Crop Yield* pilot indicator measures countries' agricultural productivity and serves as a proxy for land use efficiency. The scores reflect how close countries are to achieving region-specific maximum attainable yields of 17 major agricultural crops: barley, cassava, cotton, maize, millet, groundnuts, potatoes, rapeseed, rice, rye, sorghum, soybeans, sugar beet, sunflower seed, wheat, sugar cane, and oil palm. We calculated the relative yield of each of these crops in each country as the ratio of average yield to maximum attainable yield. The indicator scores are based on the weighted average of the relative yield values the 17 crops, with weights proportional to the area of harvested land occupied by each crop in each country. To ensure that the indicator is representative of the agricultural productivity of a country, we only scored countries in which the 17 crops for which we had attainable yield estimates represented at least five percent of the agricultural land.

Data Sources

Crop yield estimates come from the Food and Agriculture Organization of the United Nations (FAO), which compiles official statistics from its member countries. Estimates of attainable yields of the 17 major crops in each country come from Mueller et al. (2012), based on historical yield and climate data. Mueller et al. (2012) categorized agricultural regions from annual rainfall and growing degree days. The 95th-percentile of yield values of each crop in each climate bin constitutes its maximum attainable yield.

Limitations

When interpreting the results of the *Relative Crop Yield* pilot indicator, users must consider several important limitations. First, the indicator relies on uncertain estimates of maximum attainable yields. Different methods of estimating attainable yields can produce quite different results (Ollenburger, Kyle, and Zhang 2022). Mueller et al.'s (2012) estimates are based on analyses of timeseries of historical yields in different climate zones. They define a crop's attainable yield in each climate zone as the 95th-percentile of its historical yield values. This method, based on observed historical yields, tends to predict lower values than methods that simulate potential yields based on biophysical conditions, especially in tropical climates (Ollenburger, Kyle, and Zhang 2022). This limitation means that our indicator might overestimate how close countries are to achieving maximum attainable yields for the set of 17 crops. To our knowledge, however, Mueller et al.'s (2012) dataset of crop- and region-specific attainable yields is the most comprehensive available and is thus a good starting point to measure this important aspect of agricultural sustainability.

Second, the percentage of harvested area represented by the 17 crops included in the analyses varies across countries. In countries where these 17 crops make up a greater proportion of total harvested area, the indicator is likely to be more representative of that country's performance. Of the countries scored, the 17 crops represented a minimum of 6.0% (Trinidad and Tobago) and maximum of 92.7% (Bulgaria) of total harvested land in 2022, with a mean value of 48.4%.

Finally, increased agricultural productivity could also result in a rebound effect, whereby productivity increases agricultural profitability, driving more land conversion, and thus undermining the logic of intensification sparing natural habitats. The likelihood of this rebound depends on many factors (Byerlee, Stevenson, and Villoria 2014; García et al. 2020). For example, weaker constraints on cropland expansion and higher price-elasticity of demand result in a stronger rebound effect (García et al. 2020). The timescale considered also matters. In the short term, evidence for the rebound effect is strong across most commodities and regions, with the notable exception of staple cereals, such as wheat, corn, and rice. The short-term rebound effect is especially strong in many countries that are key agricultural producers of high-elasticity commodities, such as sugarcane and soybeans. Over the long run, rebound effects tend to decrease, perhaps due to saturation of demand or stronger constraints on cropland expansion (García et al. 2020). Even if this rebound effect eventually fades, it could have serious consequences for biodiversity and carbon storage tipping points.

Sustainable Nitrogen Management Index

Around half of the world's population relies on food grown thanks to the use of nitrogen fertilizers (Erisman et al. 2008). Merely producing nitrogen fertilizer, however, emits substantial amounts of greenhouse gases (Menegat, Ledo, and Tirado 2022), resulting in harms even before its excessive use, which also pollutes water and air (Erisman et al. 2013). To maximize yields and minimize environmental impacts, sustainable agriculture must therefore use nitrogen fertilizers efficiently, applying just the amount that crops need, where and when they need it (Xin Zhang et al. 2015; You et al. 2023).

Indicator Background

The *Sustainable Nitrogen Management Index* (SNMI) balances the dual need of maximizing crop yields while minimizing the environmental impacts of excessive nitrogen fertilizer use by combining metrics of nitrogen use efficiency and nitrogen yield (Xin Zhang et al. 2022).

Nitrogen use efficiency (NUE) is the ratio of the amount of nitrogen absorbed by harvested crops during growth to the amount of nitrogen inputs—primarily fertilizer. The ideal NUE level is 1, indicating that all nitrogen inputs are absorbed by harvested crops. Values below 1 indicate that more nitrogen is harvested in crops than is added as fertilizer, leading to the depletion of nitrogen from soil over time. Values above 1 indicate that more nitrogen fertilizer is added to croplands than is harvested in crops, indicating that the excess nitrogen can runoff to pollute water bodies, or volatize to pollute the air, destroy the ozone layer, and drive climate change.

Nitrogen yield is the amount of nitrogen bound up in harvested crops every year. The SNMI measures nitrogen yield relative to a reference value of 90 kg N/ha/yr, which is the estimated average global nitrogen yield required to meet 2050 crop production targets without expanding current cropland (Xin Zhang et al. 2022).

Sustainable Nitrogen Management Index scores are based on the Euclidean distance of from an ideal point of NUE = 1, and nitrogen yield ≥ 90 kg N ha^{-1} yr^{-1}.

Data Sources

The SNMI values were calculated using country estimates of average nitrogen inputs and harvested nitrogen per unit area from the Food and Agriculture Organization (FAO) of the United Nations' Cropland Nutrient Balance database (December 2023 release). The data cover the period from 1961 to 2021.

Limitations

The SNMI is a powerful metric that balances the tradeoffs intrinsic in nitrogen fertilizer management. However, as any composite indicator, it obscures the underlying drivers of performance. That is, a country with a medium SNMI score could have high nitrogen yields but low NUE, or *vice versa*.

Furthermore, the SNMI assumes that a NUE = 1 is optimal. However, since at least some nitrogen is likely to runoff or volatize under most circumstances, soil nitrogen depletion could occur at NUE values below 1. Indeed, the maximum NUE is currently estimated at 0.9, since around 10 percent of nitrogen inputs are usually lost even under optimal management (Xin Zhang et al. 2022). Moreover, the fraction of nitrogen inputs lost under ideal management is likely to vary across space as a function of climate and soil conditions (You et al. 2023).

Similarly, the maximum potential nitrogen yield also varies according to soil and climatic conditions. Therefore, using the same reference value of maximum nitrogen yield (90 kg N/ha/yr) for every country disadvantages countries in which physical conditions constrain yields to lower values. As discussed for the *Relative Crop Yield* indicator, estimating region-specific attainable yields is challenging. As a robustness check of the indicator, Xin Zhang et al. (2022) estimated SNMI values using region-specific reference values of maximum nitrogen yield and found that the performance of many countries in Africa and West Asia improved, while the performance many countries in South America and Europe worsened.

Phosphorus Surplus

Indicator Background

Unlike nitrogen, phosphorus can accumulate in soils. As a result, phosphorus use efficiency (PUE)—the ratio of phosphorus harvested in crops to phosphorus inputs—is not always a useful metrics of sustainable phosphorus fertilizer management (Zou, Zhang, and Davidson 2022). France is an illustrative example. Excessive use of phosphorus fertilizer (PUE << 1) over previous decades led to an accumulation of phosphorus in French agricultural soils. Thanks to that accumulation, France can currently afford to use little phosphorus fertilizer (PUE > 1) and maintain high crop yields (Zou, Zhang, and Davidson 2022). Relying on PUE as an indicator, therefore, would ignore or discount previous inefficient applications. Measuring the phosphorus fertilizer surplus, i.e., the difference between P inputs and P harvested in crops, can be a more straightforward indicator of the potential phosphorus pollution from excessive fertilizer use (Xin Zhang et al. 2021).

Data Sources

Country estimates of average phosphorus inputs and harvested phosphorus per unit area come from the December 2023 release of FAO's Cropland Nutrient Balance database, covering the period from 1961 to 2021.

Limitations

Phosphorus surplus serves as a proxy for the potential of phosphorus pollution from excessive fertilizer use. The impact of that pollution, however, depends also on the proximity of croplands to lakes and other sensitive freshwater ecosystems (Fink et al. 2018), which varies across countries. Moreover, lack of phosphorus surplus may sometimes indicate depletion of soil phosphorus and potentially low crop yields. Thus, in isolation, this indicator does not fully capture the sustainability of fertilizer management in a country.

Pesticide Pollution Risk

Indicator Background

The *Pesticide Pollution Risk* indicator is based on pesticide risk score estimates developed by Tang et al. (2021). Pesticide risk scores suppose a "safe" concentration for any given pesticide in any given location. These safe benchmarks account for local characteristics particular to the environmental medium (surface water, ground water, air, and soil) and the pesticide. Estimates of pesticide concentrations can be compared to this benchmark to measure the threat to biodiversity, ecosystem vitality, and human health of pesticide accumulation. The pesticide risk score value for a particular location is the maximum ratio of estimated to benchmark concentrations across the environmental media present, on a logarithmic scale. Hence, a risk score greater than 0 indicates that the predicted concentration of pesticides in the environment is higher than the "safe" benchmark. For more details about the calculation of pesticide risk scores, please refer to Tang et al. (2021).

The 2024 EPI's *pesticide pollution risk* indicator is calculated from a gridded dataset of pesticide risk scores at a 0.05º-resolution across global agricultural land, averaged within a country's borders.

Data sources

Pesticide risk scores were calculated by Tang at Monash University (Australia) using an updated version of the PEST-CHEMGRIDS dataset, a global dataset of pesticide application rates (Maggi et al. 2019). The PEST-CHEMGRIDS v.2 dataset has a spatial resolution of 0.05º, includes 115 pesticide active ingredients, and uses data from 2018.

Limitations

Due to limited data availability, the calculation of pesticide risk scores relies on several assumptions: all agricultural fields are adjacent to water bodies, all pesticides reach the soil (that is, there is no loss to drift or interception by crops), and, to capture the worst-possible scenario, non-target organisms face maximum exposure to pesticide applications. However, the *pesticide pollution risk* indicator may also underestimate risk by not accounting for pesticide pollution that lingers in the environment from previous years of application, the environmental harm of pesticide degradation products, and potential interactions between multiple pesticides acting together. Data of pesticide application rates around the world are sparse and fragmented, and many low-income countries do not have a record of pesticide use at all.

6. References

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Chapter 10. Fisheries

1. Introduction

Fisheries are important for food security, especially in developing countries (Cheung et al. 2023). From 1961 to 2019, global consumption of aquatic foods increased at an average annual rate of 3 percent, double the population growth rate in that same period (FAO 2022). However, the fishing industry is currently not sustainable, and the exploitation of wild fisheries has caused widespread ecological degradation, pushed species to the brink of extinction, and polluted the global oceans. Over one third of fish stocks are exploited above their biologically sustainable level (FAO 2022), and destructive fishing methods with high rates of bycatch, such as bottom trawling, account for over one-quarter of the global catch (Steadman et al. 2021). Bottom trawling not only contributes to overfishing but also destroys sensitive seafloor habitats, releases carbon stored in seabed sediments, and disrupts seabed biogeochemical processes (Epstein et al. 2022; Paradis et al. 2021; Bradshaw et al. 2021).

Possible solutions to mitigate the impact of bottom trawling include further regulation on the frequency and location of bottom trawling, on the technology of trawling nets, or even complete bans on the practice (McConnaughey et al. 2020). While critical for long-term sustainability, all these solutions could also result in short-term catch reductions. Thus, to meet the growing seafood demand — projected to increase by 80 percent by 2050 (Naylor et al. 2021) — the world needs to find new ways to produce seafood and even to learn to eat different types of seafood (see Focus Box 10-1).

The 2024 EPI Fisheries indicators paint a broad picture of the sustainability of countries' fisheries, quantifying the prevalence of harmful and wasteful fishing practices, and estimating the health of fish stock populations.

2. Indicators

Domestic Fish Stock Status
(15% of issue category)
We measure the percentage of a country's total catch that comes from collapsed fish stocks, based on an assessment of all fish stocks within a country's exclusive economic zone(s).

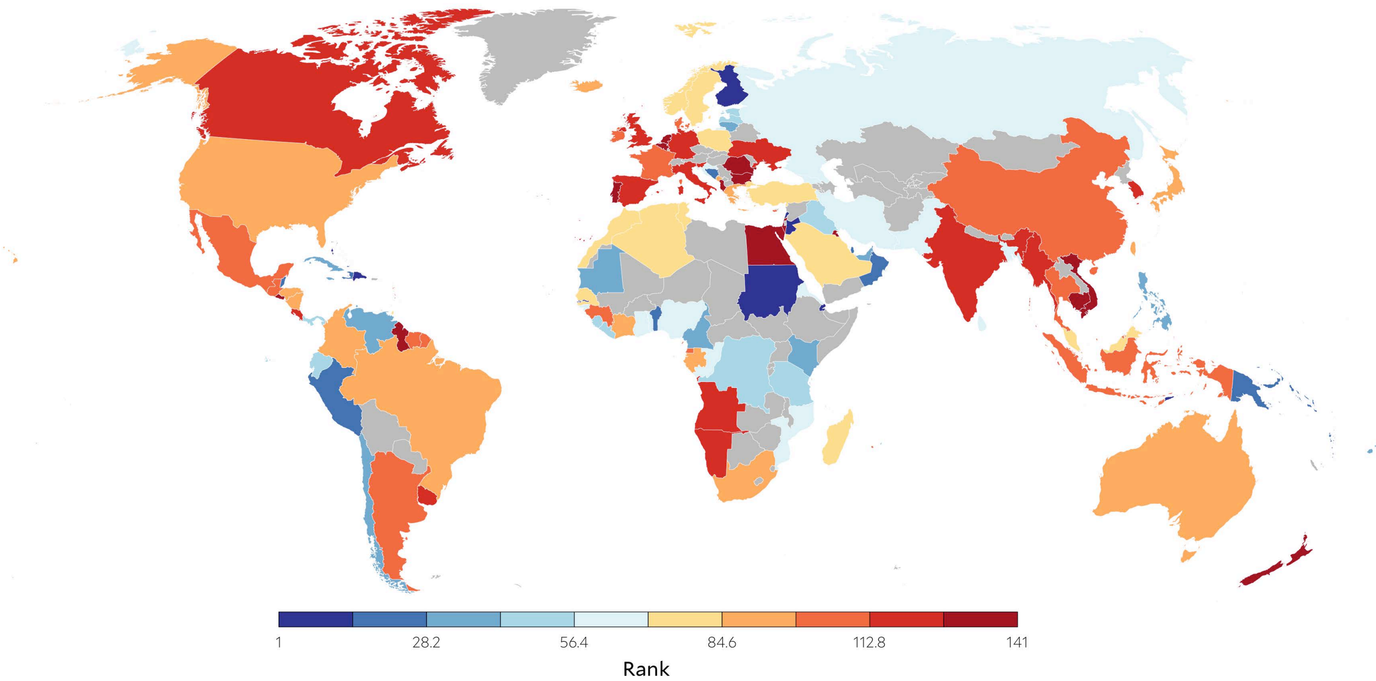
Domestic Marine Trophic Index
(5% of issue category)
We measure how fast the trophic level of fish stocks changed over the last decade. The decline of the trophic level of fish catches may represent a phenomenon commonly known as "fishing down the food web".

Fish Caught by Bottom Trawling and Dredging
(60% of issue category)
Bottom trawling and dredging are wasteful and destructive practices that indiscriminately catch marine life and can damage sensitive ecosystems along the seafloor. The 2024 EPI uses two variants of this indicator:

- Domestic: The proportion of the total catch in a country's exclusive economic zone(s) caught by any country using bottom trawling and dredging. This indicator measures whether countries allow bottom trawling in the marine regions under their jurisdiction (25%).
- Global Ocean: The proportion of a country's total catch across the global ocean caught by bottom trawling and dredging. This indicator measures how much countries use bottom trawling, either in their own waters, those of other countries, or on the high seas (35%).

Fish Catch Discarded
(20% of issue category)
We measure the proportion of a country's total catch in the global ocean that is discarded instead of landed and used. This indicator serves as a proxy of bycatch and thus of untargeted and wasteful fishing practices.

Map 10-1. Global rankings on Fisheries.



Map 10-2. Fisheries scores.

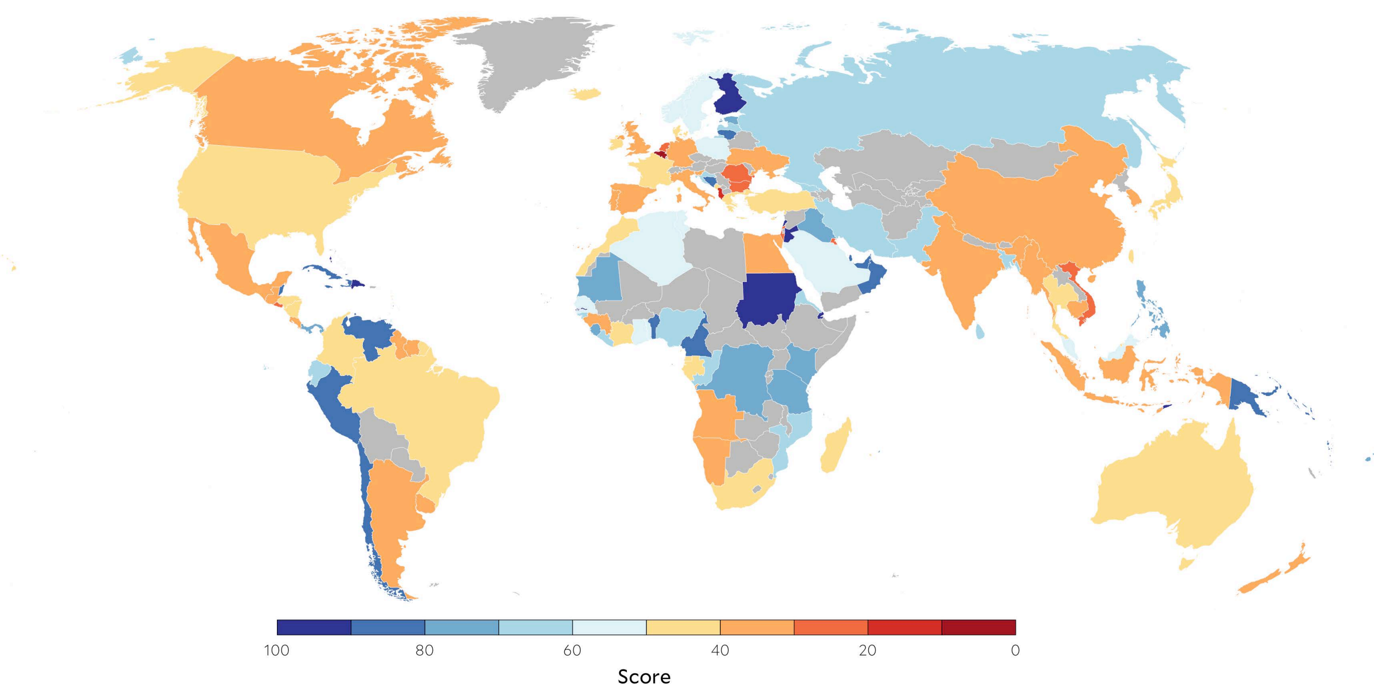


Table 10-1. Global rankings, scores, and regional rankings (REG) on the Fisheries issue category.

RANK	COUNTRY	SCORE	REG	RANK	COUNTRY	SCORE	REG	RANK	COUNTRY	SCORE	REG
1	Antigua and Barbuda	97.3	1	61	Nigeria	63.4	19	121	South Korea	34.9	21
2	Singapore	97.1	1	61	Sri Lanka	63.4	2	122	Uruguay	34.4	28
3	Djibouti	96.4	1	63	Iran	63.3	9	123	Namibia	34.2	31
4	Lebanon	96.2	1	64	Bangladesh	63.2	3	124	Italy	34.0	13
5	Sudan	95.8	2	65	Russia	63.0	1	125	Spain	33.7	14
6	Dominican Republic	95.7	2	66	Pakistan	62.2	4	126	Ukraine	33.4	3
6	Jordan	95.7	3	67	Croatia	62.1	5	127	Canada	33.1	15
6	Tonga	95.7	2	68	Georgia	61.2	2	128	Egypt	32.4	14
9	Timor-Leste	95.5	3	69	Republic of Congo	61.0	20	129	Cambodia	31.8	22
10	Saint Lucia	94.0	3	70	Togo	58.9	21	130	New Zealand	31.4	16
11	Bahamas	91.6	4	71	Ghana	58.6	22	131	Guyana	31.1	29
12	Kiribati	91.4	4	72	Senegal	58.4	23	131	Portugal	31.1	17
13	Gambia	91.1	2	73	Trinidad and Tobago	58.1	17	133	Viet Nam	29.4	23
14	Maldives	90.5	1	74	Poland	57.8	6	134	Israel	27.5	15
15	Finland	90.4	1	75	Malta	56.9	2	135	Romania	24.5	12
16	Bosnia and Herzegovina	89.9	1	76	Saudi Arabia	56.0	10	136	Kuwait	23.3	16
17	Oman	88.8	4	77	Norway	54.2	3	137	Netherlands	22.5	18
18	Papua New Guinea	88.6	5	78	Sweden	52.4	4	138	El Salvador	21.6	30
18	Qatar	88.6	5	79	Malaysia	52.0	13	139	Bulgaria	20.9	13
20	Benin	88.3	3	80	Algeria	51.6	11	140	Albania	15.8	14
21	Marshall Islands	86.9	6	81	Tunisia	50.3	12	141	Belgium	8.0	19
22	Haiti	86.8	5	82	Dominica	49.6	18	NA	Afghanistan	NA	NA
23	Belize	86.7	6	82	Morocco	49.6	13	NA	Armenia	NA	NA
24	St. Vincent and Grenadines	86.1	7	82	Türkiye	49.6	7	NA	Austria	NA	NA
25	Micronesia	85.3	7	85	Madagascar	49.3	24	NA	Azerbaijan	NA	NA
26	Peru	85.0	8	86	Nicaragua	48.9	19	NA	Belarus	NA	NA
27	Solomon Islands	84.8	8	87	Japan	48.5	14	NA	Bhutan	NA	NA
28	Grenada	84.0	9	88	Australia	48.1	5	NA	Bolivia	NA	NA
28	Vanuatu	84.0	9	89	Brazil	47.9	20	NA	Botswana	NA	NA
30	Jamaica	83.2	10	89	Montenegro	47.9	8	NA	Burkina Faso	NA	NA
31	Venezuela	82.5	11	91	Greece	47.8	9	NA	Burundi	NA	NA
32	Chile	81.9	12	91	South Africa	47.8	25	NA	Central African Republic	NA	NA
33	Cameroon	81.6	4	93	Gabon	47.5	26	NA	Chad	NA	NA
34	Cuba	81.4	13	93	Iceland	47.5	6	NA	Czech Republic	NA	NA
35	Barbados	80.4	14	95	United States of America	46.5	7	NA	Eswatini	NA	NA
36	Lithuania	80.1	2	96	Côte d'Ivoire	46.4	27	NA	Ethiopia	NA	NA
37	United Arab Emirates	80.0	6	96	Taiwan	46.4	15	NA	Hungary	NA	NA
38	Kenya	77.1	5	98	Colombia	46.2	21	NA	Kazakhstan	NA	NA
38	Mauritania	77.1	5	99	Honduras	45.3	22	NA	Kyrgyzstan	NA	NA
40	Philippines	76.4	10	100	Denmark	44.7	8	NA	Laos	NA	NA
41	Samoa	75.9	11	100	Equatorial Guinea	44.7	28	NA	Lesotho	NA	NA
42	Fiji	75.8	12	102	Thailand	44.2	16	NA	Luxembourg	NA	NA
42	Seychelles	75.8	7	103	Cyprus	43.6	10	NA	Malawi	NA	NA
44	Mauritius	75.7	8	104	France	43.2	9	NA	Mali	NA	NA
45	Sierra Leone	75.3	9	105	Brunei Darussalam	41.4	17	NA	Moldova	NA	NA
46	Comoros	73.4	10	106	Ireland	40.6	10	NA	Mongolia	NA	NA
47	Dem. Rep. Congo	73.0	11	107	Indonesia	39.9	18	NA	Nepal	NA	NA
48	Iraq	72.7	7	108	China	39.6	19	NA	Niger	NA	NA
49	São Tomé and Príncipe	72.6	12	109	Guatemala	39.0	23	NA	North Macedonia	NA	NA
50	Tanzania	71.7	13	110	Suriname	38.9	24	NA	Paraguay	NA	NA
51	Panama	71.6	15	111	Argentina	38.5	25	NA	Rwanda	NA	NA
52	Estonia	70.4	3	112	Mexico	38.4	26	NA	Serbia	NA	NA
53	Cabo Verde	70.2	14	113	Guinea	38.2	29	NA	Slovakia	NA	NA
54	Ecuador	69.9	16	114	United Kingdom	38.1	11	NA	Switzerland	NA	NA
55	Latvia	69.0	4	115	Angola	37.6	30	NA	Tajikistan	NA	NA
56	Bahrain	68.9	8	116	India	37.0	5	NA	Turkmenistan	NA	NA
57	Liberia	68.8	15	117	Germany	36.4	12	NA	Uganda	NA	NA
58	Guinea-Bissau	67.0	16	117	Slovenia	36.4	11	NA	Uzbekistan	NA	NA
59	Mozambique	66.9	17	119	Myanmar	36.0	20	NA	Zambia	NA	NA
60	Eritrea	66.0	18	120	Costa Rica	35.7	27	NA	Zimbabwe	NA	NA

Asia-Pacific **Eastern Europe** **Former Soviet States** **Global West**

Greater Middle East **Latin America & Caribbean** **Southern Asia** **Sub-Saharan Africa**

Table 10-2. Regional rankings and scores on Fisheries.

Latin America & Caribbean

Country	Score	Rank
Antigua and Barbuda	97.3	1
Dominican Republic	95.7	2
Saint Lucia	94.0	3
Bahamas	91.6	4
Haiti	86.8	5
Belize	86.7	6
St. Vincent and Grenadines	86.1	7
Peru	85.0	8
Grenada	84.0	9
Jamaica	83.2	10
Venezuela	82.5	11
Chile	81.9	12
Cuba	81.4	13
Barbados	80.4	14
Panama	71.6	15
Ecuador	69.9	16
Trinidad and Tobago	58.1	17
Dominica	49.6	18
Nicaragua	48.9	19
Brazil	47.9	20
Colombia	46.2	21
Honduras	45.3	22
Guatemala	39.0	23
Suriname	38.9	24
Argentina	38.5	25
Mexico	38.4	26
Costa Rica	35.7	27
Uruguay	34.4	28
Guyana	31.1	29
El Salvador	21.6	30
Bolivia	NA	NA
Paraguay	NA	NA

Eastern Europe

Country	Score	Rank
Bosnia and Herzegovina	89.9	1
Lithuania	80.1	2
Estonia	70.4	3
Latvia	69.0	4
Croatia	62.1	5
Poland	57.8	6
Türkiye	49.6	7
Montenegro	47.9	8
Greece	47.8	9
Cyprus	43.6	10
Slovenia	36.4	11
Romania	24.5	12
Bulgaria	20.9	13
Albania	15.8	14
Czech Republic	NA	NA
Hungary	NA	NA
North Macedonia	NA	NA
Serbia	NA	NA
Slovakia	NA	NA

Southern Asia

Country	Score	Rank
Maldives	90.5	1
Sri Lanka	63.4	2
Bangladesh	63.2	3
Pakistan	62.2	4
India	37.0	5
Afghanistan	NA	NA
Bhutan	NA	NA
Nepal	NA	NA

Global West

Country	Score	Rank
Finland	90.4	1
Malta	56.9	2
Norway	54.2	3
Sweden	52.4	4
Australia	48.1	5
Iceland	47.5	6
United States of America	46.5	7
Denmark	44.7	8
France	43.2	9
Ireland	40.6	10
United Kingdom	38.1	11
Germany	36.4	12
Italy	34.0	13
Spain	33.7	14
Canada	33.1	15
New Zealand	31.4	16
Portugal	31.1	17
Netherlands	22.5	18
Belgium	8.0	19
Austria	NA	NA
Luxembourg	NA	NA
Switzerland	NA	NA

Former Soviet States

Country	Score	
Russia	63.0	1
Georgia	61.2	2
Ukraine	33.4	3
Armenia	NA	NA
Azerbaijan	NA	NA
Belarus	NA	NA
Kazakhstan	NA	NA
Kyrgyzstan	NA	NA
Moldova	NA	NA
Tajikistan	NA	NA
Turkmenistan	NA	NA
Uzbekistan	NA	NA

Asia-Pacific

Country	Score	Rank
Singapore	97.1	1
Tonga	95.7	2
Timor-Leste	95.5	3
Kiribati	91.4	4
Papua New Guinea	88.6	5
Marshall Islands	86.9	6
Micronesia	85.3	7
Solomon Islands	84.8	8
Vanuatu	84.0	9
Philippines	76.4	10
Samoa	75.9	11
Fiji	75.8	12
Malaysia	52.0	13
Japan	48.5	14
Taiwan	46.4	15
Thailand	44.2	16
Brunei Darussalam	41.4	17
Indonesia	39.9	18
China	39.6	19
Myanmar	36.0	20
South Korea	34.9	21
Cambodia	31.8	22
Viet Nam	29.4	23
Laos	NA	NA
Mongolia	NA	NA

Sub-Saharan Africa

Country	Score	Rank
Djibouti	96.4	1
Gambia	91.1	2
Benin	88.3	3
Cameroon	81.6	4
Kenya	77.1	5
Mauritania	77.1	5
Seychelles	75.8	7
Mauritius	75.7	8
Sierra Leone	75.3	9
Comoros	73.4	10
Dem. Rep. Congo	73.0	11
São Tomé and Príncipe	72.6	12
Tanzania	71.7	13
Cabo Verde	70.2	14
Liberia	68.8	15
Guinea-Bissau	67.0	16
Mozambique	66.9	17
Eritrea	66.0	18
Nigeria	63.4	19
Republic of Congo	61.0	20
Togo	58.9	21
Ghana	58.6	22
Senegal	58.4	23
Madagascar	49.3	24
South Africa	47.8	25
Gabon	47.5	26
Côte d'Ivoire	46.4	27
Equatorial Guinea	44.7	28
Guinea	38.2	29
Angola	37.6	30
Namibia	34.2	31
Botswana	NA	NA
Burkina Faso	NA	NA
Burundi	NA	NA
Central African Republic	NA	NA
Chad	NA	NA
Eswatini	NA	NA
Ethiopia	NA	NA
Lesotho	NA	NA
Malawi	NA	NA
Mali	NA	NA
Niger	NA	NA
Rwanda	NA	NA
Uganda	NA	NA
Zambia	NA	NA
Zimbabwe	NA	NA

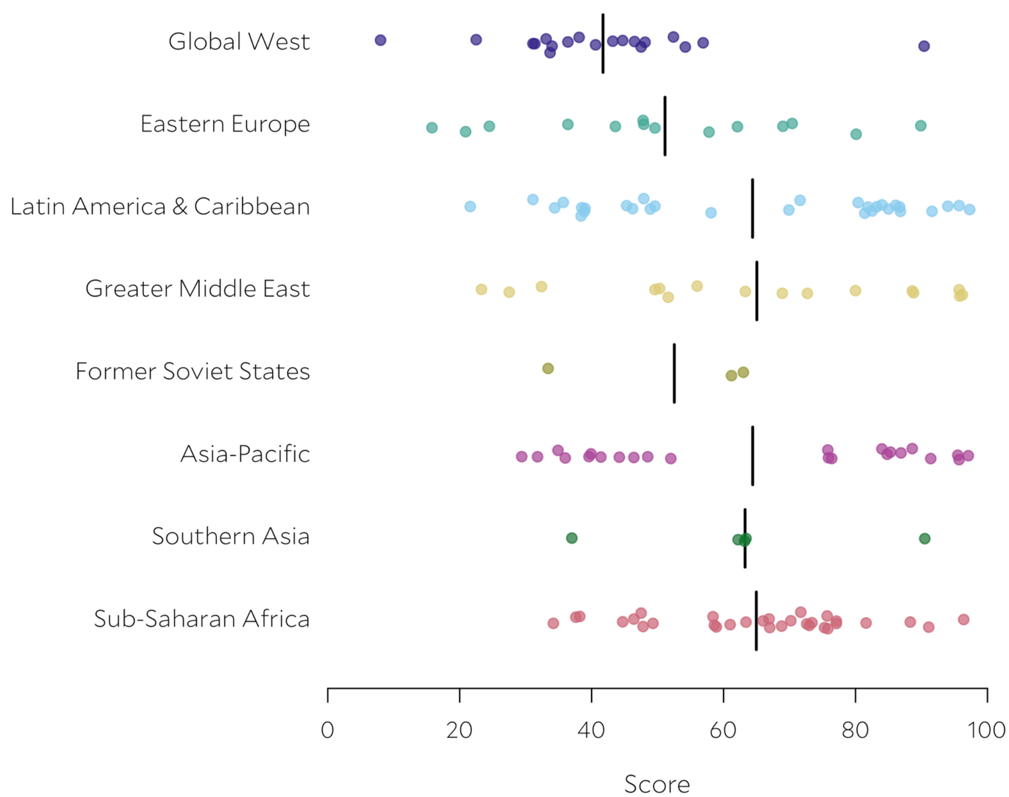
Greater Middle East

Country	Score	Rank
Lebanon	96.2	1
Sudan	95.8	2
Jordan	95.7	3
Oman	88.8	4
Qatar	88.6	5
United Arab Emirates	80.0	6
Iraq	72.7	7
Bahrain	68.9	8
Iran	63.3	9
Saudi Arabia	56.0	10
Algeria	51.6	11
Tunisia	50.3	12
Morocco	49.6	13
Egypt	32.4	14
Israel	27.5	15
Kuwait	23.3	16

3. Global Trends

Total global fisheries and aquaculture production continues to increase, reaching 178 million tonnes in 2020 (FAO 2022). Practically all the recent growth in production comes from aquaculture, which surpassed wild-caught fishery for human consumption in 2016 (Boyd, McNevin, and Davis 2022). While aquaculture production grew over 600 percent from 1990 to 2020, output for marine capture fisheries has flattened at around 80 million tons for the past 30 years (FAO 2022). Wild captures have stagnated despite the improvement in the quality of boats and capture technology (Squires and Vestergaard 2013), and the 22 billion U.S. dollars of annual harmful, "capacity-enhancing" fisheries subsidies dispensed by countries across the world (Sumaila et al. 2019). The stagnation of global marine capture, at a time when over 90 percent of global fish stocks are overexploited or exploited at the maximum sustainable rate (FAO 2022), shows that wild-capture fisheries are reaching the biophysical limits of the global ocean. While the Food and Agriculture Organization (FAO) estimates that annual production from wild-capture fisheries could reach 96 million tonnes by 2030 through a combination of reducing discards, developing underfished stocks, and allowing overfished stocks to recover, meeting the growing demand for seafood will require finding new sustainable ways of producing food in the ocean (see Focus Box 10-1).

Figure 10-1. Distribution of regional scores on Fisheries. Vertical bars show regional averages.



For the last two decades, Asia has been the world's largest fishery producer, accounting for 70 percent of total fishery and aquaculture production (Pham et al. 2023; FAO 2022). Global fisheries production has gradually shifted from the Atlantic Ocean to the Pacific and Indian Oceans (Pauly and Zeller 2016). Among Asian countries, China contributed 71 million tonnes of fish production in 2023, nearly 40 percent of the global output, and was responsible for more than 15 percent of the catch from marine capture fisheries (FAS 2024). The second largest producer, Indonesia, contributed only 11 million tonnes, underscoring China's pivotal role in the future of fisheries management. Although China has faced criticism for illegally fishing in other countries' waters (Urbina 2020), producing great amounts of bycatch, and extensive use of trawling, Chinese seafood production from wild capture decreased by nearly 10 percent between 2018 and 2023 (FAS 2024). Chinese policymakers have stated a goal to reduce catch from capture fisheries, and decreased output goals outlined in the country's most recent Five-Year Plan (2021–2025) will almost certainly lead to further decrease (Kritzer et al. 2023).

Since 2015, the global fishing fleet has decreased in size by just under 10 percent (FAO 2022), signaling efforts to alleviate pressure on fisheries and promote long-term sustainable practices in the industry. Continued efforts to adopt sustainable fishery management, coupled with improved data collection in low and middle-income countries, will be essential for ensuring the long-term viability of seafood as an important source of nutrition. By further developing sustainable aquaculture and continuing to address overfishing, countries can safeguard their vital marine ecosystems.

4. Leaders and Laggards

Countries' fishery output is uncorrelated with their performance in the EPI Fisheries indicators. The largest fish producers are China, India, Peru, Indonesia, the United States, Russia, and Viet Nam, which together account for nearly 60 percent of the world's fisheries and aquaculture production (FAO 2022). Wide variation in these countries' scores on the EPI's Fisheries indicators suggests that sustainable fisheries can be attained regardless of the size of a country's fishing industry.

Peru is the top-performing country in South America and prevails among the big fishing nations. Its success stems in large part from the sustainable management of its anchoveta population. The anchoveta, primarily used to make fish meal for feed and fertilizer, accounts for 84.5 percent of catches from Peruvian waters and has been historically overfished. But in 2009, the Peruvian government implemented bold policy changes to enhance the sustainability of its anchoveta fishery, such as adopting a rights-based approach that assigned fishing quotas to various companies and even decommissioning around a quarter of the Peruvian fishing fleet (World Bank 2017). Today, the anchoveta fishery is managed sustainably, and its population has rebounded, although it is threatened by warming ocean temperatures (Stokstad 2022).

Smaller nations with fishing industries composed primarily of artisanal fishermen tend to perform well on the EPI indicators. Countries like Antigua and Barbuda, Tonga, Gambia, Djibouti, the Maldives, and Sudan are top performers despite relying on different oceans and fish populations. Their common success at fishing sustainability is a consequence of their reliance on small-scale fishing and the absence of bottom-trawling. Bottom-trawling is also highly correlated with the amount of bycatch, as much of the catch via bottom-trawling is composed of unwanted species, which are then thrown overboard. Consequently, countries with less developed commercial fishing operations tend to perform well on the indicators tracking bottom trawling and the catch discarded. In general, small-scale fishing is better aligned with global sustainability goals than larger fishery operations and is more important for local food security (Pauly 2018; Teh and Pauly 2018; Canty and Deichmann 2022).

In contrast, several European countries, despite performing well in many other EPI categories, perform poorly in the Fisheries indicators. Belgium, the Netherlands, Portugal, Spain, Italy, and Germany, all of whom have sophisticated industrial fishing operations, are in the bottom quartile of Fisheries performance. The European seas are some of the most heavily trawled regions of the global ocean. Over 40 percent of the seabed in the Northern Atlantic Ocean off the coast of the Iberian Peninsula as well as of the Adriatic, North, and Tyrrhenian Seas is trawled (Amoroso et al. 2018). Even marine protected areas are heavily trawled, sometimes even more intensely than unprotected regions of the ocean (Dureuil et al. 2018). In 2024, Greece became the first European country to announce plans to ban bottom trawling from marine protected areas by 2030. European's strong demand for seafood and well-developed commercial fishing industries incentivize bottom-trawling, an effective but harmful way of capturing fish.

Finland outperforms all other countries in the Global West by a wide margin, as well as Baltic states like Latvia and Lithuania. Finland's commercial fishing industry has gradually scaled down in favor of fishing for leisure, and the country now has one of the highest participation rates in recreational fishing (Salmi and Mellanoura 2020). Even among commercial fishermen in Finland, 96 percent are classified as small-scale fishers, one of the highest rates in Europe (Salmi et al. 2022). Crucially, among countries in the region, Finland gives the lowest amount of harmful subsidies to the fishing industry (Skerritt and Sumaila 2021). Finland also excels at supporting its small-scale fishers, making funding through programs like the EU-sponsored Fisheries Local Action Group (FLAG) more accessible than other countries, such as Sweden (Salmi et al. 2022).

Besides using gear and methods that enable more targeted and less destructive fishing, countries relying primarily on small-scale fishing have implemented diverse policies to improve sustainability. Several countries in the Coral Triangle region, such as Papua New Guinea, the Philippines, the Solomon Islands, and Timor-Leste, are good example. These countries perform well even among peers with high reliance on artisanal fisheries. The Coral Triangle region has pioneered integrated ocean management, a holistic management process that balances ecosystem health and economic activities (Winther et al. 2020). Coral Triangle governments extensively involve local fishermen in discussions about fishery management policy, developing a deeper understanding of the impacts of overfishing and how to manage fisheries to foster food security, mitigate climate change, and abate threats to marine biodiversity (Hendriks 2022). Similar efforts to involve small-scale fisheries in policy discussions have recently occurred in Latin America and the Caribbean (de Oliveira Leis et al. 2019). Nonetheless, illegal, unreported, and unregulated fishing methods are prevalent in some countries in Southeast Asia and the Coral Triangle region, such as Indonesia (Williams et al. 2019). Methods like blast fishing, which uses explosives to stunt or kill fish, are very harmful to marine ecosystems, particularly to coral reefs, and can devastate thriving habitats (Hampton-Smith, Bower, and Mika 2021).

Focus 10-1

Sustainable Aquatic Food for the 21st century

The ocean once seemed inexhaustible. But with nearly all marine fish stocks exploited at or beyond their maximum sustainable capacity, it is now clear that we are close to reaching the biological limit of wild fisheries' ability to produce food. Even if underfished stocks are developed, overfished stocks allowed to recover, and fish discards minimized, it is unlikely that we can ever catch more than 100 million tonnes of wild fish per year (FAO 2022). Today we consume over 180 million tonnes of aquatic foods, and demand keeps growing. One way to address this challenge would be to eat all the food we capture in the ocean instead of using it to feed other animals. Using all wild-caught seafood and byproducts for direct human consumption could sustainably double their contribution to human nutrition (Cardinaals et al. 2023). If we opt instead to keep expanding aquaculture and inland fisheries to meet the growing demand for aquatic food, it is paramount that we manage them sustainably to minimize their environmental impacts.

Predatory fish and crustacea species—such as tuna, salmon, and shrimp—are among the most highly demanded seafoods in global markets but farming them sustainably is an enormous challenge. Tuna, given their need for large amounts of feed, vast open water swimming, and late sexual maturity, are notoriously difficult to farm (Block 2019). While the feed efficiency of most farmed species has increased in recent years (Naylor et al. 2021), salmon aquaculture still requires almost two kilograms of wild-caught fish for every kilogram of farmed salmon produced. Salmon farms are susceptible to parasites and bacterial infections, which contribute to ever more frequent mass-mortality events (Singh, Sajid, and Mather 2024). To combat infections, salmon aquaculture uses huge amounts of antibiotics. For example, the salmon aquaculture industry in Chile, the second largest in the world after Norway, used 463.4 tonnes of antimicrobials in 2021 alone (Avendaño-Herrera, Mancilla, and Miranda 2023). Shrimp aquaculture suffers from similar sustainability problems, plus being a dominant driver of mangrove deforestation (Goldberg et al. 2020).

Given these challenges, the most promising avenue to sustainably increase the production of aquatic foods is non-fed aquaculture of bivalves and seaweed (Duarte, Bruhn, and Krause-Jensen 2022). Besides producing protein without the need of any feed, seaweed and bivalve aquaculture has multiple environmental benefits. For example, seaweed sequesters carbon and mitigates ocean acidification and deoxygenation, and bivalves filter the water and remove nitrogen from the water (Barrett et al. 2022). Improving technology in marine permaculture, which focuses on recreating a whole seaweed ecosystem instead of targeting one species, has also shown to be very productive in nations like the Philippines (Spillias, von Herzen, and Holmgren 2024). However, expanding the production of bivalves and seaweed-based foods must be accompanied by increasing demand for these products. Policies to incentivize sustainable food choices are therefore imperative (Ammann et al. 2023).

In sum, while we have pushed the oceans to the limit of their capacity to produce wild fish, there are still big opportunities to sustainably increase the production of aquatic foods. However, the biggest challenge for policymakers will be to shape consumer preference and create a market for novel and unconventional foods.

Countries lagging in fisheries management can learn lessons both from peers with large industrial fishing capacities, like Peru, and from smaller fishing nations. Eliminating the use of bottom-trawling while still meeting the growing demand for seafood requires a rapid expansion of more sustainable approaches to seafood production, such as non-fed aquaculture (Sumaila et al. 2022) and transitioning to small-scale methods of marine capture. For example, between 2005 and 2015, when Peru was trying to save the dwindling anchoveta population, the number of artisanal fishermen increased by 52.7 percent and the artisanal fleet by 14 percent (Castillo Mendoza et al. 2018). To ensure a healthy marine ecosystem, governments must also incorporate all voices in policy conversations. The low scores of so many countries in the EPI's Fisheries indicators highlight the need for effective policy solutions that rely on the incorporation of a wide array of perspectives.

5. Methods

The FAO serves as the most important international repository of country-level fisheries data and statistics. In *The State of World Fisheries and Aquaculture* reports, published every two years, the FAO synthesizes data on the status and trends of the global fisheries industry (FAO 2022). While new technologies and data-collection systems have improved the coverage and accuracy of fisheries data in recent years, persistent gaps hamper our ability to manage fishery resources sustainably. Fisheries data from developing countries are particularly incomplete, often reported in handwritten logs that are easy to manipulate (Roberson, Kiszka, and Watson 2019). Landings from artisanal fisheries, which can occur anywhere along the coast instead of in big ports, are less likely to be completely recorded and incorporated into country statistics (Machado et al. 2021).

The 2024 EPI Fisheries indicators are based on data from *Sea Around Us*, a research initiative at the University of British Columbia, which attempts to harmonize and fill gaps in the FAO's fisheries data. Through a combination of data interpolation, expert consultation, and synthesis of sources from the scientific literature, *Sea Around Us* produces reconstructed time series of fisheries catch (including both landings and discards), broken down by gear and end use (Pauly and Zeller 2016; 2015).

Indicator Background

The *Domestic Fish Stock Status* indicator measures the percentage of a country's total catch coming from stocks classified as collapsed. A "stock" in a given area is defined as a species of fish (or in some cases a genus or family) that occurs in the catch records for at least five consecutive years, over at least a 10-year time span, and which has a total catch of at least 1000 tonnes over that period (Kleisner and Pauly 2015). *Sea Around Us* classifies stocks as "collapsed" if landings below 10 percent a prior year's peak. The area of analysis is a country's Exclusive Economic Zone (EEZ). For countries with multiple EEZs, we averaged values weighting them by the proportion of the total catch originating from each EEZ. Since continuing to exploit overfished stocks impedes their recovery and can lead to progressively smaller catches, this indicator captures trends in the health of countries' fisheries.

The *Regional Marine Trophic Index* (MTI), developed by *Sea Around Us*, offers a picture of the average trophic level of a countries' catch while accounting for the geographic expansion of fisheries farther offshore (Kleisner, Mansour, and Pauly 2014). As such, this indicator can measure the rate at which countries are depleting larger predator species — such as tuna and swordfish — and altering the functioning of marine ecosystems. This well-documented process — known as "fishing down the food web" — leads countries to target increasingly smaller species (Essington, Beaudreau, and Wiedenmann 2006). The 2024 EPI measures the slope in the ten most recent MTI values to assess how the trophic composition of a country's catch is changing through time. The MTI values exclude species with a trophic level below 3.2 so that abiotic-driven booms in the abundance of low-trophic-level species — such as sardines and anchovies — do not skew the results. As for the Fish Stock Status indicator, the spatial unit of analysis is a country's EEZ. For countries with multiple EEZs, we average slope values weighting by the proportion of total catch coming from each EEZ.

The 2024 EPI uses two indicators related to *Fishing with Bottom Trawling and Dredging*. One indicator, included in the EPI since 2020, quantifies the proportion of a country's total catch across the global oceans (including EEZs of other nations as well as the high seas) that is caught with bottom trawling and dredging. In addition, we introduce a new indicator quantifying the proportion of fish caught with bottom trawling and dredging in a country's EEZ(s), either by the country in control of the EEZ or by foreign fleets fishing there. The EPI focuses on bottom trawling and dredging methods of fishing because they are especially indiscriminate (Davies et al. 2009) and damaging to sensitive ecosystems along the seafloor (Clark et al. 2019).

Finally, as a more direct measure of bycatch and wasteful fishing practices, the 2024 EPI introduces the *Fish Catch Discarded* indicator. Specifically, we measure the proportion of a country's total catch across the global ocean that is discarded. Approximately ten percent of global fish catches are thrown overboard instead of returned to land and used (Zeller et al. 2018; Gilman et al. 2020). Discarded fish can be dead or alive, but their survival is typically low. Hence, discarded fish worsen overfishing and ecological degradation without contributing to food security.

Data Sources

We use data from *Sea Around Us* to construct the five Fisheries indicators in the 2024 EPI. *Sea Around Us* follows multiple steps to obtain, verify, and augment datasets from the FAO spanning the years 1950 to 2019 (Pauly and Zeller 2015). The resulting datasets are freely available for download from www.seaaroundus.org (see the Technical Appendix for details about the exact datasets used and how to find them on the *Sea Around Us* website).

Limitations

Three main limitations must be considered when interpreting the results of the EPI's Fisheries indicators: the quality and completeness of the underlying data, the limited scope of the indicators, and the focus on seafood production rather than consumption.

Important gaps and uncertainties persist in global fisheries data, especially from developing countries and regarding illegal, unreported, and unregulated fishing. Despite promising development in the application of artificial intelligence to identify illegal fishing activity (Watson et al. 2023) and other lower-tech but ingenious research in recent years — such as equipping seagoing birds with transponders to track illegal fishing vessels (Weimerskirch et al. 2020) — better data collection and reporting methods could improve our understanding of ocean and fishery health. Efforts to supplement FAO data with information from the scientific literature and expert judgment are not a substitute for reliable fishing logs. While assessing the status of fish stocks based on time series of catch enables fisheries scientists to estimate the sustainability of fisheries in data-poor countries, it is not as accurate as surveying the biomass and reproductive parameters of fish populations directly (Branch et al. 2011).

The EPI's Fisheries indicators rely on catch data to assess the status of fish stocks and estimate functional changes in marine ecosystems, as well as to quantify the prevalence of bottom trawling and dredging. However, other wasteful and harmful practices, such as dynamite and cyanide fishing, are not yet captured in the EPI indicators (Bailey and Sumaila 2015; Murray et al. 2020). Aquaculture and inland fisheries produce a growing fraction of global aquatic food, but their many environmental impacts are also not assessed in the EPI indicators.

The EPI's indicators do not explicitly monitor the health of coral reefs, mangroves, and other important ecosystems. The EPI team anticipates that more research and better data reporting on these critical issues will enable the development of new indicators in subsequent iterations of the report.

Finally, the EPI's Fisheries indicators focus solely on the sustainability of fishing nations. As such, countries that import fish caught using unsustainable practices in other countries may appear to perform well in fisheries indicators that fail to capture the outsourcing of environmental degradation. Many countries with access to the sea, such as the United States, still rely heavily on imported seafood that has been caught via unsustainable practices elsewhere (Gephart, Froehlich, and Branch 2019). As consumption-based accounting of seafood improves (Guillen et al. 2019; West et al. 2019), EPI indicators may be able to track fisheries scores for inland and landlocked countries. The EPI's sister project, the Global Commons Stewardship Index (*https://gcsi.unsdsn.org/*) already incorporates metrics that estimate countries' impact on marine ecosystems embodied in their international imports.

Weighting Rationale

The relatively small weight of the Fisheries issue category (2 percent of the overall EPI) does not reflect the importance of the issue, as fishing is the dominant threat to biodiversity in countries' seas (O'Hara, Frazier, and Halpern 2021). Instead, the category's weight reflects limitations in the quality and completeness of the underlying data, as well as a negative correlation between Fisheries scores and scores of other EPI categories. Ideally, in composite indicators, different components should be positively correlated with each other so that they all contribute information to the overall score (OECD and JRC 2008). Rather than eliminating this important issue entirely from the EPI framework, the 2024 EPI team opted to reduce its relative weight.

The reasons above also influenced the weighting of different indicators within the Fisheries issue category. The *Fish Stock Status* and *Regional Marine Trophic Index* indicators were weakly or negatively correlated with the other indicators in the category, and are also the most uncertain, and hence were assigned a smaller relative weight. New indicators, such as the *Fish Catch Discarded* indicator, are usually introduced as pilots with a small weight.

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Chapter 11. Air Pollution

1. Introduction

In parts of the world, air pollution is a severe threat to biodiversity and ecosystem vitality (Agathokleous et al. 2020; Stevens et al. 2020). Sulfur dioxide and nitrogen oxide are two primary precursors of acid rain (Grennfelt et al. 2020). Acid rain alters soil chemistry, causing the release of aluminum from clay particles and the loss of soil nutrients such as calcium and magnesium, compromising forest health (Grennfelt et al. 2020). Acid rain also contributes to the acidification of water bodies and their pollution with aluminum leaching from the soil, which together threaten aquatic biodiversity (EPA 2016).

Ozone pollution also harms ecosystems (Agathokleous et al. 2020). Ozone inhibits plants' photosynthetic activity (Lovett et al. 2009), affecting both the function of natural ecosystems and the productivity of croplands. For some sensitive crops, such as soybeans, prolonged ozone exposure can lead to yield losses of more than 16 percent (Van Dingenen et al. 2009). Ozone exposure effects on agricultural productivity may have caused economic losses of up to US$26 billion in 2000 (Van Dingenen et al. 2009).

The Air Pollution issue category of the 2024 EPI includes indicators to track the growth rate emissions of acid rain precursors and measure ozone exposure across countries' croplands and Key Biodiversity Areas.

2. Indicators

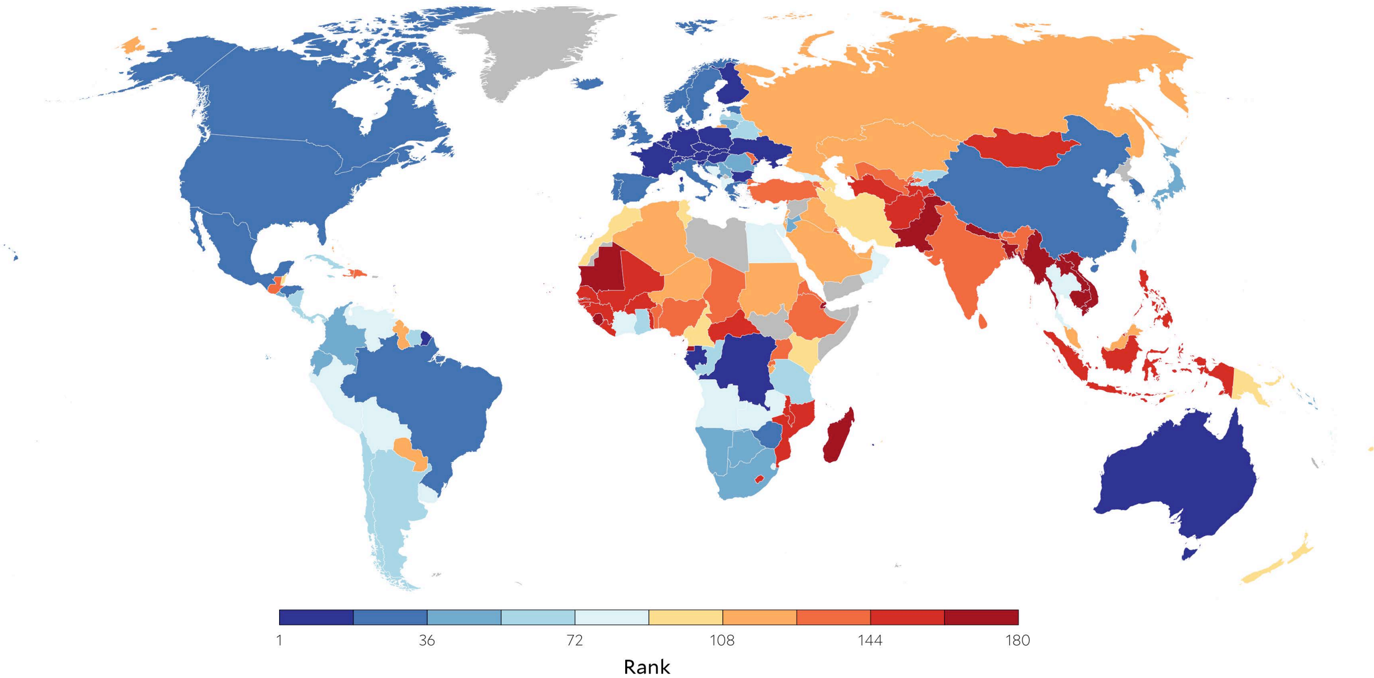
Sulfur Dioxide Emissions Growth Rate
(42% of issue category)
We measure the average annual rate of sulfur dioxide emissions over the years 2013 to 2022 and adjust for economic trends to isolate change due to policy effort rather than economic fluctuation. A score of 100 indicates a country is cutting emissions by ≥3.94% per year, and a score of 0 indicates that a country has among the worst (≥95th-percentile) rates of emissions growth in the world.

Nitrogen Oxides Emissions Growth Rate
(42% of issue category)
We measure the average annual rate of nitrogen oxides emissions over the years 2013 to 2022 and adjust for economic trends to isolate change due to policy effort rather than economic fluctuation. A score of 100 indicates a country is cutting emissions by ≥3.94% per year, and a score of 0 indicates that a country has among the worst (≥95th-percentile) rates of emissions growth in the world.

Ozone Exposure in Croplands
(8% of issue category)
As a proxy for ozone pollution effects on crop productivity, we measure the average ground-level concentration of ozone across a country's cropland.

Ozone Exposure in Key Biodiversity Areas
(8% of issue category)
As a proxy for ozone pollution effects on biodiversity, we measure the average ground-level concentration of ozone across a country's Key Biodiversity Areas.

Map 11-1. Global rankings on Air Pollution.



Map 11-2. Air Pollution scores.

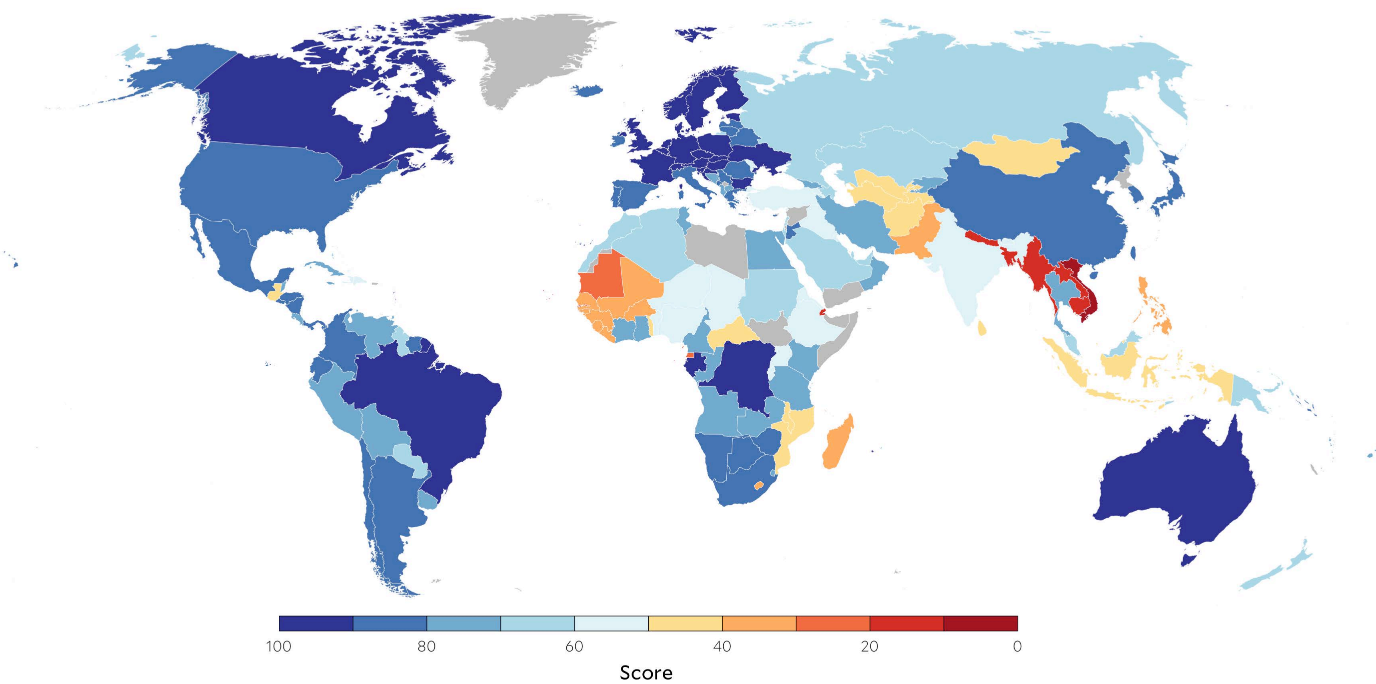


Table 11-1. Global rankings, scores, and regional rankings (REG) on the Air Pollution issue category.

RANK	COUNTRY	SCORE	REG
1	Dem. Rep. Congo	100.0	1
2	Gabon	98.9	2
3	Australia	95.9	1
4	Belgium	94.3	2
4	Luxembourg	94.3	2
6	Slovakia	94.1	1
7	Czech Republic	93.8	2
8	Poland	93.5	3
9	Hungary	93.3	4
10	Austria	92.9	4
10	Ukraine	92.9	1
12	Finland	92.8	5
12	France	92.8	5
14	Slovenia	92.7	5
15	Germany	92.6	7
15	Netherlands	92.6	7
17	Switzerland	92.5	9
18	Bulgaria	92.3	6
19	United Kingdom	92.0	10
20	Estonia	91.5	7
21	Croatia	91.1	8
22	Norway	90.9	11
23	Canada	90.8	12
24	Brazil	90.6	1
24	Sweden	90.6	13
26	Denmark	90.3	14
27	Iceland	89.8	15
28	Italy	89.5	16
29	Spain	89.3	17
30	Mexico	89.1	2
30	United States of America	89.1	18
32	Portugal	88.7	19
32	Zimbabwe	88.7	3
34	Greece	88.0	9
35	Honduras	87.8	3
36	China	87.3	1
36	Ireland	87.3	20
36	Montenegro	87.3	10
36	South Korea	87.3	1
40	Romania	86.8	11
41	Taiwan	86.5	3
42	Japan	86.4	4
43	Serbia	86.3	12
44	Ecuador	85.7	4
45	Jordan	85.5	1
46	South Africa	85.3	4
47	El Salvador	85.1	5
48	Colombia	84.9	6
49	Namibia	84.0	5
50	Botswana	83.5	6
51	Cyprus	83.3	13
51	Malta	83.3	21
53	Lithuania	83.2	14
54	Marshall Islands	83.0	5
54	Solomon Islands	83.0	5
56	Latvia	82.4	15
56	Nicaragua	82.4	7
58	Belarus	81.9	2
59	Singapore	81.8	7
60	Kiribati	81.1	8
61	Chile	80.9	8
61	Panama	80.9	8
63	Argentina	80.5	10
64	Suriname	80.3	11
65	Costa Rica	79.8	12
66	Cuba	78.8	13
67	Ghana	78.3	7
68	Tanzania	77.7	8
69	Jamaica	77.4	14
70	Kyrgyzstan	77.3	3
71	Micronesia	76.6	9
71	Republic of Congo	76.6	9
73	Grenada	76.5	15
74	Venezuela	76.1	16
75	Thailand	75.8	10
75	Uruguay	75.8	17
77	Côte d'Ivoire	75.6	10
78	Zambia	75.4	11
79	Eswatini	75.3	12
80	Bosnia and Herzegovina	75.2	16
80	Samoa	75.2	11
82	North Macedonia	74.7	17
82	Peru	74.7	18
84	Albania	74.5	18
85	Bolivia	73.9	19
85	Georgia	73.9	4
87	Oman	73.6	2
88	Vanuatu	73.5	12
89	Egypt	73.3	3
90	Angola	73.2	13
91	St. Vincent and Grenadines	72.8	20
92	Kenya	72.6	14
93	Trinidad and Tobago	72.5	21
94	Antigua and Barbuda	72.0	22
95	Cameroon	71.7	15
96	Belize	71.0	23
97	Fiji	70.7	13
97	Iran	70.7	4
99	Tonga	70.4	14
100	Barbados	70.0	24
100	Tunisia	70.0	5
102	Mauritius	69.6	16
103	Morocco	69.1	6
103	New Zealand	69.1	22
105	Saint Lucia	68.6	25
106	Papua New Guinea	68.2	15
107	Dominica	68.1	26
108	Azerbaijan	67.0	5
108	Timor-Leste	67.0	16
110	Bahamas	66.1	27
111	Maldives	65.9	1
112	Qatar	65.3	7
113	Israel	65.2	8
113	Russia	65.2	6
115	United Arab Emirates	65.1	9
116	Algeria	63.7	10
117	Lebanon	62.5	11
118	Sudan	62.4	12
119	Paraguay	62.3	28
120	Kazakhstan	61.7	7
121	Guyana	61.2	29
122	Malaysia	60.7	17
123	Saudi Arabia	60.5	13
124	Burundi	59.6	17
125	Niger	57.9	18
126	Iraq	57.3	14
127	Eritrea	56.3	19
128	Haiti	55.7	30
129	India	55.3	2
130	Uganda	54.5	20
131	Nigeria	54.4	21
132	Armenia	54.2	8
132	Moldova	54.2	8
134	Ethiopia	53.9	22
135	Chad	52.4	23
136	Kuwait	51.8	15
137	Dominican Republic	51.7	31
138	Rwanda	51.2	24
139	Bhutan	50.9	3
140	Benin	50.4	25
141	Türkiye	50.0	19
142	Guatemala	49.8	32
143	Uzbekistan	49.2	10
144	Sri Lanka	49.1	4
145	Mongolia	48.2	18
146	Central African Republic	47.7	26
147	Malawi	47.5	27
148	Indonesia	46.2	19
149	Togo	45.3	28
150	Turkmenistan	43.5	11
151	Afghanistan	42.0	5
152	Brunei Darussalam	41.9	20
153	Mozambique	41.3	29
154	Tajikistan	41.0	12
155	Burkina Faso	39.8	30
156	Philippines	39.7	21
156	Senegal	39.7	31
158	Mali	36.7	32
159	Guinea-Bissau	35.0	33
159	Lesotho	35.0	33
161	Liberia	34.1	35
162	Guinea	33.8	36
163	Comoros	33.4	37
164	Sierra Leone	33.0	38
165	Bahrain	32.5	16
166	Pakistan	32.2	6
167	Madagascar	31.2	39
168	Gambia	26.4	40
169	Mauritania	23.0	41
170	Equatorial Guinea	22.3	42
171	São Tomé and Príncipe	20.4	43
172	Seychelles	17.5	44
173	Djibouti	16.8	45
174	Laos	16.2	22
175	Nepal	15.8	7
176	Cambodia	14.5	23
177	Cabo Verde	14.3	46
178	Bangladesh	13.3	8
179	Myanmar	12.5	24
180	Viet Nam	7.5	26

Asia-Pacific **Eastern Europe** **Former Soviet States** **Global West**

Greater Middle East **Latin America & Caribbean** **Southern Asia** **Sub-Saharan Africa**

Table 11-2. Regional rankings and scores on Air Pollution.

Latin America & Caribbean		
Country	Score	Rank
Brazil	90.6	1
Mexico	89.1	2
Honduras	87.8	3
Ecuador	85.7	4
El Salvador	85.1	5
Colombia	84.9	6
Nicaragua	82.4	7
Chile	80.9	8
Panama	80.9	8
Argentina	80.5	10
Suriname	80.3	11
Costa Rica	79.8	12
Cuba	78.8	13
Jamaica	77.4	14
Grenada	76.5	15
Venezuela	76.1	16
Uruguay	75.8	17
Peru	74.7	18
Bolivia	73.9	19
St. Vincent and Grenadines	72.8	20
Trinidad and Tobago	72.5	21
Antigua and Barbuda	72.0	22
Belize	71.0	23
Barbados	70.0	24
Saint Lucia	68.6	25
Dominica	68.1	26
Bahamas	66.1	27
Paraguay	62.3	28
Guyana	61.2	29
Haiti	55.7	30
Dominican Republic	51.7	31
Guatemala	49.8	32

Eastern Europe		
Country	Score	Rank
Slovakia	94.1	1
Czech Republic	93.8	2
Poland	93.5	3
Hungary	93.3	4
Slovenia	92.7	5
Bulgaria	92.3	6
Estonia	91.5	7
Croatia	91.1	8
Greece	88.0	9
Montenegro	87.3	10
Romania	86.8	11
Serbia	86.3	12
Cyprus	83.3	13
Lithuania	83.2	14
Latvia	82.4	15
Bosnia and Herzegovina	75.2	16
North Macedonia	74.7	17
Albania	74.5	18
Türkiye	50.0	19

Southern Asia		
Country	Score	Rank
Maldives	65.9	1
India	55.3	2
Bhutan	50.9	3
Sri Lanka	49.1	4
Afghanistan	42.0	5
Pakistan	32.2	6
Nepal	15.8	7
Bangladesh	13.3	8

Global West		
Country	Score	Rank
Australia	95.9	1
Belgium	94.3	2
Luxembourg	94.3	2
Austria	92.9	4
Finland	92.8	5
France	92.8	5
Germany	92.6	7
Netherlands	92.6	7
Switzerland	92.5	9
United Kingdom	92.0	10
Norway	90.9	11
Canada	90.8	12
Sweden	90.6	13
Denmark	90.3	14
Iceland	89.8	15
Italy	89.5	16
Spain	89.3	17
United States of America	89.1	18
Portugal	88.7	19
Ireland	87.3	20
Malta	83.3	21
New Zealand	69.1	22

Former Soviet States		
Country	Score	Rank
Ukraine	92.9	1
Belarus	81.9	2
Kyrgyzstan	77.3	3
Georgia	73.9	4
Azerbaijan	67.0	5
Russia	65.2	6
Kazakhstan	61.7	7
Armenia	54.2	8
Moldova	54.2	8
Uzbekistan	49.2	10
Turkmenistan	43.5	11
Tajikistan	41.0	12

Asia-Pacific		
Country	Score	Rank
China	87.3	1
South Korea	87.3	1
Taiwan	86.5	3
Japan	86.4	4
Marshall Islands	83.0	5
Solomon Islands	83.0	5
Singapore	81.8	7
Kiribati	81.1	8
Micronesia	76.6	9
Thailand	75.8	10
Samoa	75.2	11
Vanuatu	73.5	12
Fiji	70.7	13
Tonga	70.4	14
Papua New Guinea	68.2	15
Timor-Leste	67.0	16
Malaysia	60.7	17
Mongolia	48.2	18
Indonesia	46.2	19
Brunei Darussalam	41.9	20
Philippines	39.7	21
Laos	16.2	22
Cambodia	14.5	23
Myanmar	12.5	24
Viet Nam	7.5	25

Sub-Saharan Africa		
Country	Score	Rank
Dem. Rep. Congo	100.0	1
Gabon	98.9	2
Zimbabwe	88.7	3
South Africa	85.3	4
Namibia	84.0	5
Botswana	83.5	6
Ghana	78.3	7
Tanzania	77.7	8
Republic of Congo	76.6	9
Côte d'Ivoire	75.6	10
Zambia	75.4	11
Eswatini	75.3	12
Angola	73.2	13
Kenya	72.6	14
Cameroon	71.7	15
Mauritius	69.6	16
Burundi	59.6	17
Niger	57.9	18
Eritrea	56.3	19
Uganda	54.5	20
Nigeria	54.4	21
Ethiopia	53.9	22
Chad	52.4	23
Rwanda	51.2	24
Benin	50.4	25
Central African Republic	47.7	26
Malawi	47.5	27
Togo	45.3	28
Mozambique	41.3	29
Burkina Faso	39.8	30
Senegal	39.7	31
Mali	36.7	32
Guinea-Bissau	35.0	33
Lesotho	35.0	33
Liberia	34.1	35
Guinea	33.8	36
Comoros	33.4	37
Sierra Leone	33.0	38
Madagascar	31.2	39
Gambia	26.4	40
Mauritania	23.0	41
Equatorial Guinea	22.3	42
São Tomé and Príncipe	20.4	43
Seychelles	17.5	44
Djibouti	16.8	45
Cabo Verde	14.3	46

Greater Middle East		
Country	Score	Rank
Jordan	85.5	1
Oman	73.6	2
Egypt	73.3	3
Iran	70.7	4
Tunisia	70.0	5
Morocco	69.1	6
Qatar	65.3	7
Israel	65.2	8
United Arab Emirates	65.1	9
Algeria	63.7	10
Lebanon	62.5	11
Sudan	62.4	12
Saudi Arabia	60.5	13
Iraq	57.3	14
Kuwait	51.8	15
Bahrain	32.5	16

3. Global Trends

Over the past three decades, the global community has made enormous progress in curbing nitrous oxide and sulfur oxide emissions. During the 1970s and 1980s, acid rain was one of the world's leading environmental concerns (Grennfelt et al. 2020). But since then, governments, businesses, and scientists have taken drastic measures to limit emissions of acid rain precursors. This combined effort is one of the greatest success stories of the previous century and a model for dealing with emerging environmental challenges, such as climate change (Ritchie 2023).

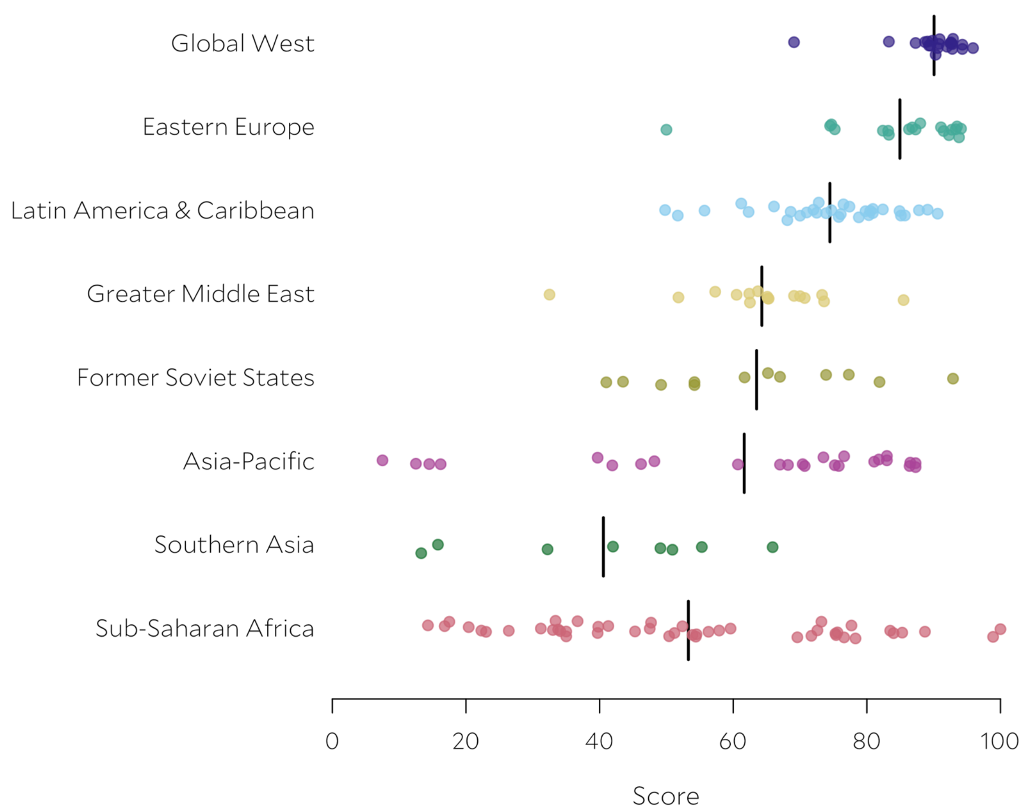
The Global West earns the highest average score on the 2024 EPI Air Pollution issue category (Figure 11-1). This region has led the way in tackling acid rain, with SO_2 and NO_x emissions falling by 90 and 67 percent, respectively, since 1990 (Hoesly and Smith 2024). Over the past two decades, however, the sharpest reductions occurred in the Asia-Pacific, mainly driven by China. Between 2005 and 2006, China introduced regulations to desulfurize coal-fired power plants (van der A et al. 2017), contributing to a 73 percent reduction in sulfur dioxide emissions since then.

Southern Asia is the only region where emissions of acid rain precursors continue to grow rapidly (Figure 11-2). Between 2013 and 2022, sulfur dioxide emissions in Southern Asia grew by 36 percent, and nitrogen oxide emissions grew by 12 percent (Hoesly and Smith 2024).

In many countries, increasing industrialization over the past decade has been accompanied by rising emissions of harmful pollutants. For instance, 73 countries (out of the 180 scored by the EPI) saw rising sulfur dioxide emissions between 2012 and 2022, with the growth in 33 countries exceeding 50 percent. For nitrogen oxide, 91 countries had emission increases over the last decade; in 20 countries, the increase was more than 50 percent. Growing vehicle and coal use in the developing world has exacerbated air pollution, threatening biodiversity and public health (Macaulay et al. 2019).

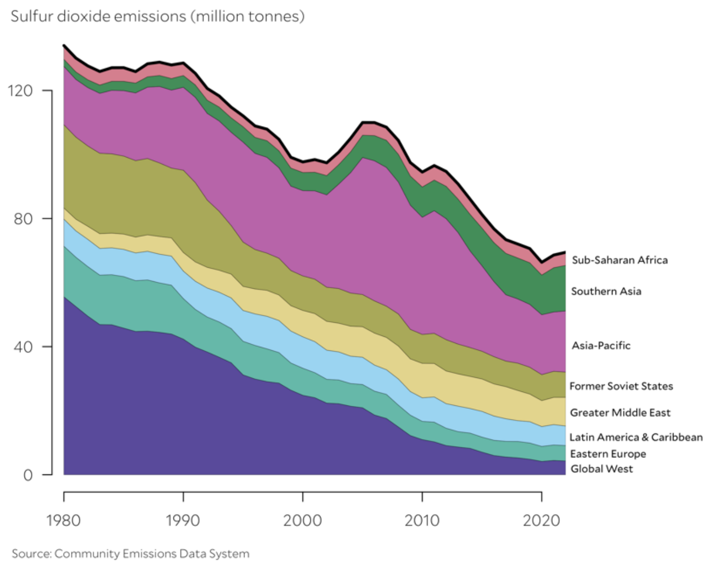
In contrast to the global success in reducing emissions of acid rain precursors, ground-level ozone pollution has worsened, especially in developing regions of the tropics, East Asia, and the Persian Gulf (Wang et al. 2022). EPI analyses show that the average ozone concentration across the world's croplands increased by 2.6 percent over the last two decades. While anthropogenic emissions of ozone precursors are the main reason behind rising pollution trends (Wang et al. 2022), climate change is also a contributor because warmer temperatures

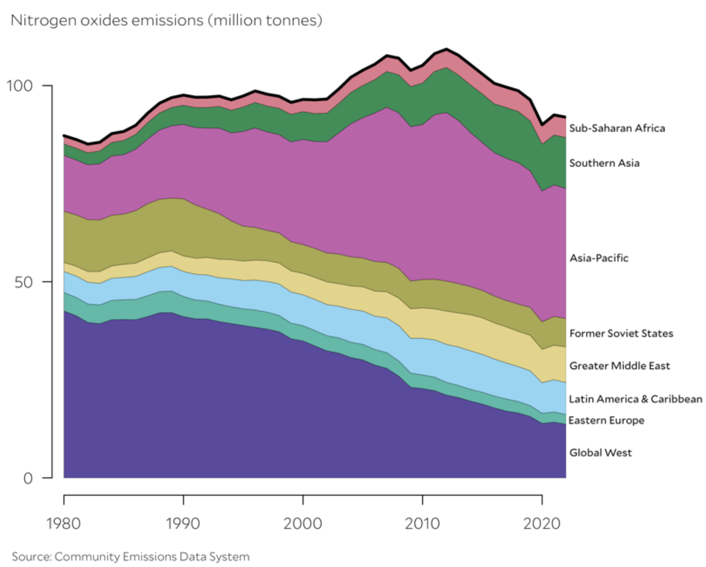
Figure 11-1. Distribution of regional scores on Air Pollution. Vertical bars show regional averages.



accelerate the chemical reactions that produce ozone (Fiore et al. 2012).

Figure 11-2. Global emissions of acid rain precursors are going down.





4. Leaders and Laggards

The Democratic Republic of the Congo (DRC) and Gabon achieved the highest scores on the Air Pollution issue category of the 2024 EPI. Both countries have substantially reduced sulfur oxide and nitrogen oxide emissions over the last decade (Hoesly and Smith 2024). Gabon's government has banned flaring in the oil industry and importing old vehicles (Ayetor et al. 2021; USAID 2022). What sets these two countries apart, however, is their strong performance in the two pilot indicators of ozone pollution, which boosted their issue category scores ahead of other countries with similar, even sharper reductions in emissions of acid rain precursors. Despite their remarkable recent progress, the DRC and Gabon need to do more to mitigate air pollution, as their absolute emissions are still high and might increase due to the recent mining boom in these countries (Martínez-Alonso et al. 2023).

Low levels of ozone pollution exposure across croplands and Key Biodiversity Areas are also the key reason why Australia (ranked 3rd globally) outperforms its Global West peers, most of which have also achieved substantial reductions in their emissions of acid rain precursors. Australia's strong record reflects a broad social consensus on the need to implement clean technologies and governmental legislation such as the National Environment Protection (Ambient Air Quality) Measure, which establishes targets of maximum concentration of sulfur dioxide, nitrogen dioxide, ozone, and other air pollutants with the goal of protecting both human health and ecosystem vitality (Australian Government 2021).

Global Air Pollution laggards are concentrated in Southeast Asia, including Vietnam, Laos, and Cambodia. These countries have some of the world's highest emission growth rates for SO_2 and NO_X. In Laos, for example, sulfur dioxide emissions increased more than 20-fold from 2012 to 2022 (Hoesly and Smith 2024). Rapid economic growth and a heavy reliance on coal have driven skyrocketing SO_2 and NO_X emissions in recent years (Liu et al. 2023). We note, however, that a recent study accounting for the installation of flue gas desulfurization technology in the Hongsa power plant — Laos' only coal power plant — reports much lower SO_2 emissions in the country (O'Neill et al. 2024). While flue gas desulfurization technology can remove up to 92 percent of SO_2 emissions from coal-fired power plants (O'Neill et al. 2024), the 6000 percent increase in coal production in Laos over the past two decades (IEA 2021) and increases in industrial energy consumption are still driving rising emissions of acid rain precursors. Accelerating the phaseout of coal-generated electricity is essential to mitigating both climate change and air pollution.

In India, sulfur dioxide emissions rose 29 percent between 2013 and 2022, a period during which India surpassed China as the world's largest emitter of anthropogenic sulfur dioxide (Li et al. 2017). The primary source of emissions is coal power plants, followed by construction and manufacturing (Kuttippurath et al. 2022). Recently, stricter environmental regulations, the implementation of flue desulfurization technology, and the expansion of renewable energy have slowed the growth rate of pollutant emissions (Kuttippurath et al. 2022). If this trend continues, India may be able to replicate the success of China, simultaneously mitigating climate change and the harms of air pollution.

5. Methods

Tracking acid rain precursor emissions can help evaluate the impact of policies and technologies for air pollution control, highlighting successful practices for mitigating environmental acidification. While improvements in ground-based monitoring and remote sensing have refined estimates of pollutant emissions, it is still difficult to track pollution flows as they move away from sources and are deposited into remote ecosystems. Indicators tracking pollutant emissions are helpful metrics of countries' contributions to local, regional, and global pollution but do not always reflect threats to the ecosystems of the emitting countries. Conversely, indicators of exposure to pollution help estimate the impacts of pollution in particular ecosystems, even though pollution may have originated in distant places. The 2024 EPI Air Pollution indicators are a mix of both types of metrics (emission- and exposure-based), offering an overview of countries' contribution to, and degradation from, air pollutants noxious to ecosystem vitality.

Indicator Background

To track countries' contributions to environmental acidification, we calculate their SO_2 and NO_x growth rates over ten-year periods. When emissions fall, we assess whether the decreases are linked to economic decline. We reward countries that achieve falling emissions while GDP continues to grow, as this suggests successful implementation of policies and technologies for pollution control. To this end, we calculated adjusted growth rates as follows:

Adjusted growth rate = Raw growth rate × (1 – r)

where r is Spearman's correlation coefficient between 10 years of emissions and GDP. Countries where r is close to 1, meaning that emissions are tightly linked to economic activity, will have their negative growth rate adjusted towards zero. In contrast, countries where r is close to -1, suggesting decoupling of emissions from economic growth, will have their emission growth rate adjusted to be even more negative.

To track the potential impacts of ground-level ozone pollution on countries' croplands and biodiversity, we calculate the average ozone concentration across countries' croplands and Key Biodiversity Areas. Key Biodiversity Areas (KBAs) are places of particular importance for the persistence of biodiversity, either because they cover the habitat of threatened or endemic species and ecosystems or because they support critical ecological processes (IUCN 2022).

Data Sources

Sulfur dioxide and nitrogen oxide emissions data come from the Community Emissions Data System (CEDS), a project managed by the Pacific Northwest National Laboratory. The 2024 EPI indicators are based on the latest release of the CEDS dataset of historical anthropogenic emissions of reactive gases and aerosols, covering the period between 1750 and 2022 (Hoesly and Smith 2024). The CEDS emissions dataset estimates country-level emissions based on temporal trends in fuel use, technology, and emission controls (Hoesly et al. 2018). Combustion emissions data from the energy sector come from the International Energy Agency statistics, while non-combustion emissions data come from the Emissions Database for Global Atmospheric Research (EDGAR). The latest CEDS emissions dataset is freely available for download from: *https://zenodo.org/records/10904361*

Ground-level ozone concentration data come from the European Center for Medium-Range Weather Forecast's Atmospheric Composition Reanalysis 4 (EAC4) dataset, which is freely available from the Copernicus Atmospheric Data Store (ads.atmosphere.copernicus.eu). This dataset is based on satellite measurements coupled with atmospheric chemistry and transport models, resulting in a global map of ozone concentration at a 0.75° × 0.75° spatial resolution. The 2024 EPI indicators cover the period from 2003 to 2022 (data from 2023 became available recently but not in time to be included in this edition of the EPI).

To calculate cropland ozone exposure, we used global cropland maps from the Global Land Analysis & Discovery laboratory in the Department of Geographical Sciences at the University of Maryland. Since the ozone concentration data is available at a relatively coarse spatial resolution, we used the reduced-resolution (0.025 × 0.025 degrees) cropland maps, available for the years 2003, 2007, 2011, 2015, and 2019. These maps are freely available for download from:
https://glad.umd.edu/dataset/croplands

Maps of KBAs come from the September 2018 version of the World Database of Key Biodiversity Areas. This database includes more than 16,000 KBAs contributing to the conservation of more than 13,100 species (BirdLife International 2023).

Limitations

Global datasets of country-level pollutant emissions sometimes lag in accounting for the installation of technology that can substantially reduce emissions, such as scrubbers and other flue gas desulfurization technology. The contrasting estimates of SO_2 emissions in Laos between the CEDS data and O'Neill et al.'s (2024) study offer an example. In general, data are more reliable in higher-income countries with more transparent and robust data reporting protocols.

Ground-level ozone concentrations in one country can result from the transboundary flow of pollution emitted in upwind countries and thus do not reflect local environmental policies. Other air pollutants, such as fine particulate matter, can influence ozone formation rates (Jiang et al. 2022), further obscuring links between policy and ozone exposure. The indicators also do not account for the differences in the sensitivity of different crops and species to ozone exposure, which substantially influences the ecological and economic consequences of air pollution (Van Dingenen et al. 2009).

Weighting Rationale

The Air Pollution issue categories receive 6 percent of the overall 2024 EPI weight, given the increasing evidence about air pollution's threat to biodiversity and ecosystem functioning (Agathokleous et al. 2020; Jaureguiberry et al. 2022). The two ozone-exposure indicators receive a smaller weight (8 percent of the issue category each) because they are new additions to the EPI and are less directly linked to policy interventions.

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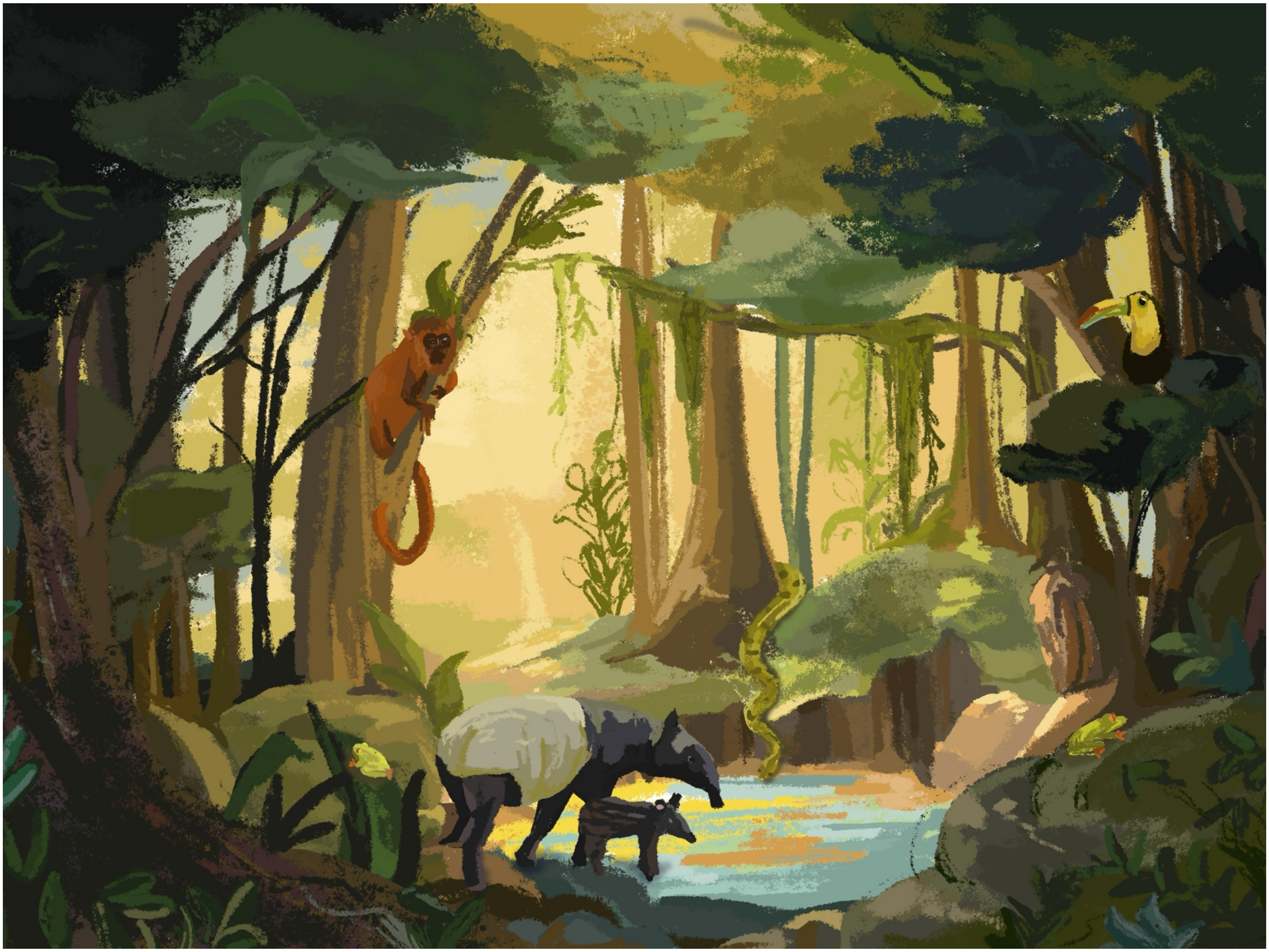


Chapter 12. Forests

1. Introduction

Forests are key to human flourishing. They regulate climate, supply food and medicine, and hold aesthetic and cultural importance. Besides depriving humanity of invaluable ecosystem services, deforestation and forest degradation are a major source of carbon emissions (Harris et al. 2012; Kruid et al. 2021; Gatti et al. 2021) and key drivers of biodiversity loss (Giam 2017; Chase et al. 2020). While quantifying the economic costs of ecosystem loss and degradation is extremely challenging, some scholars estimate that land degradation costs the world nearly 10 percent of global GDP each year (Sutton et al. 2016).

Recognizing the importance of healthy forests to tackle climate change and biodiversity loss, leaders of 145 countries pledged to halt and reverse forest loss and degradation by 2030 in the Glasgow Leaders' Declaration on Forests and Land Use. The world has already made some progress toward this worthy goal. In the past 20 years, fragmentation decreased in over three quarters of forests worldwide (Ma et al. 2023), and notable reforestation efforts took place (Tong et al. 2023). At the same time, however, tropical primary forests, which are among the most biodiverse and carbon-rich ecosystems on the planet, have been hotspots of deforestation and fragmentation (Hoang and Kanemoto 2021; Ma et al. 2023). The world loses more than 10 football (soccer) fields of humid tropical primary forests every minute (Weisse, Goldman, and Carter 2024), and only than 40 percent of remaining forests have high ecosystem integrity (Grantham et al. 2020). The 2024 EPI introduces new indicators on forest loss, net cover change, and integrity to help disambiguate these conflicting trends and provide a more nuanced understanding of countries' efforts to halt and reverse deforestation.

2. Indicators

Loss of Humid Tropical Primary Forests
(30% of issue category)
Humid tropical primary forests are the most biodiverse terrestrial ecosystems on the planet and provide irreplaceable ecosystem services. This indicator measures annual losses of tree cover in these critical ecosystems relative to their extent in 2001, using a 30 percent minimum tree cover canopy density.

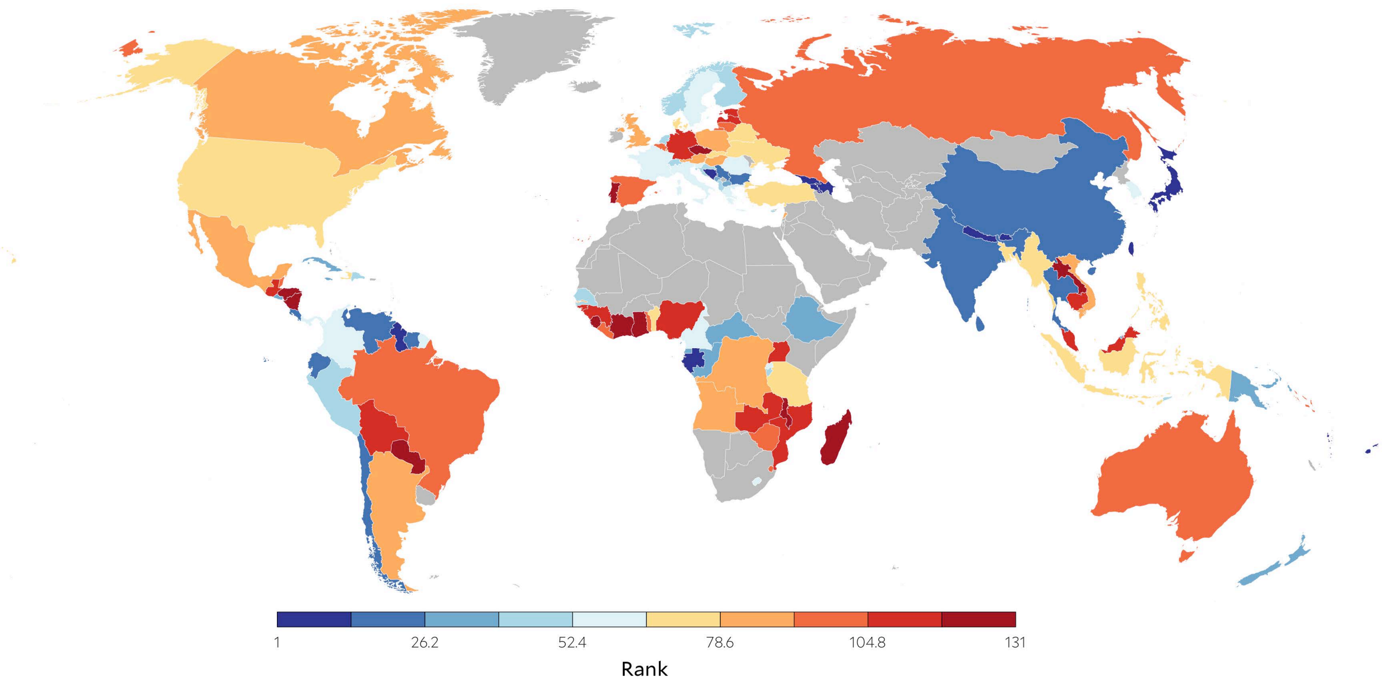
Loss of Intact Forest Landscapes
(30% of issue category)
Intact forest landscapes are large and pristine mosaics of forests and naturally treeless ecosystems and play a disproportionate role in storing carbon, harboring biodiversity, and providing many other ecosystem services. This indicator measures annual losses of tree cover in these critical expanses of pristine forests relative to their extent in 2000, using a 30 percent minimum tree cover canopy density.

Lasting Tree Cover Loss
(25% of issue category)
Not all types of tree cover loss are the same. Depending on what drives tree cover loss, forests have different likelihoods of regrowing in the short- to medium-term. With some drivers, such as urbanization and commodity-driven deforestation, tree cover loss is typically permanent. With others, such as wildfires and forestry operations, tree cover typically starts recovering almost immediately after being lost. The indicator measures annual losses of tree cover relative to their extent in 200, using a 30 percent minimum tree cover canopy density. We then estimate "lasting" tree cover loss by partially discounting losses that are likely to be transient or more difficult for governments to control, e.g., losses due to wildfires.

Net Tree Cover Change
(10% of issue category)
Forest landscapes are highly dynamic, and tree cover losses are often followed by regrowth, either locally or elsewhere. This indicator quantifies the net percent change in tree cover between 2000 and 2020.

Forest Landscape Integrity Index
(5% of issue category)
Going beyond measurement of changes in tree cover, this indicator estimates the integrity of forest landscapes based on observed and inferred human disturbances and losses of forest connectivity.

Map 12-1. Global rankings on Forests. Countries with less than 10 percent tree cover in 2000 are not scored in this category and are shown in gray.



Map 12-2. Forest scores. Countries with less than 10 percent tree cover in 2000 are not scored in this category and are shown in gray.

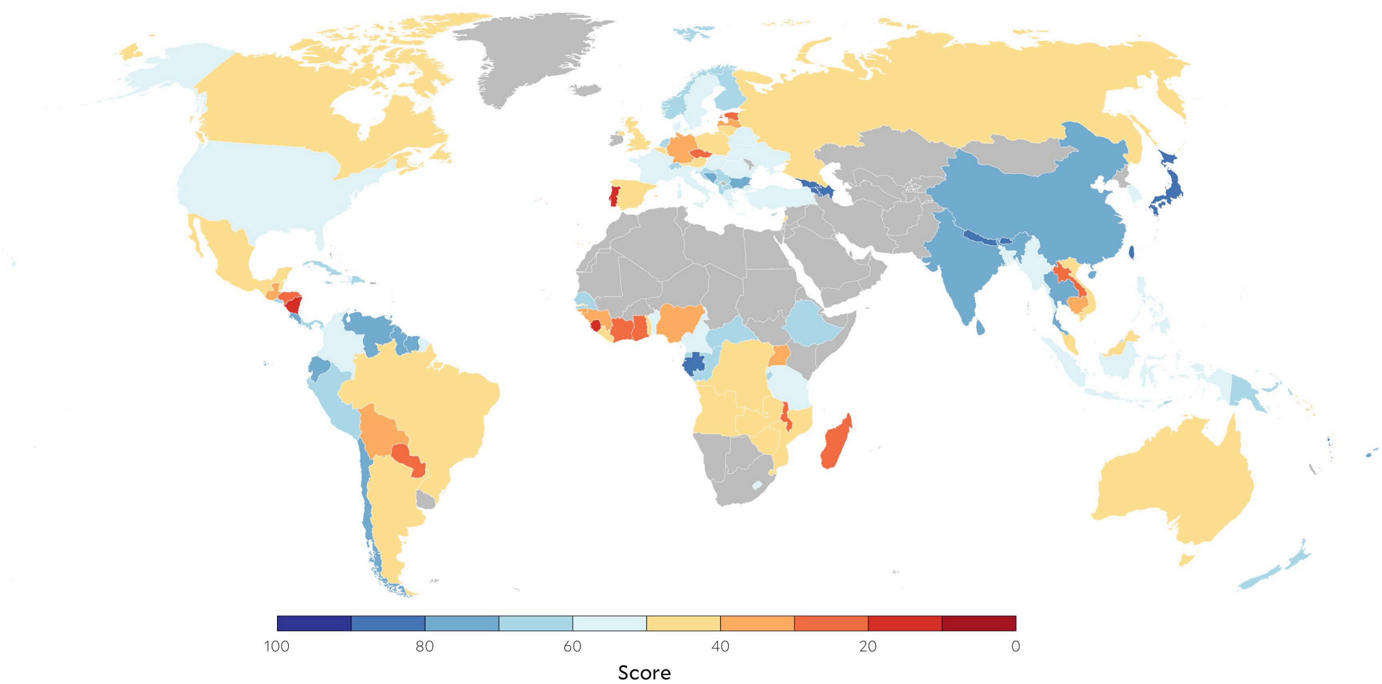


Table 12-1. Global rankings, scores, and regional rankings (REG) on the Forests issue category.

RANK	COUNTRY	SCORE	REG	RANK	COUNTRY	SCORE	REG	RANK	COUNTRY	SCORE	REG
1	Bhutan	86.7	1	61	South Korea	57.5	10	121	Malawi	28.2	27
2	Georgia	85.2	1	62	Romania	57.1	11	122	Côte d'Ivoire	26.2	28
3	Taiwan	85.1	1	63	Colombia	57.0	17	123	Ghana	25.2	29
4	Armenia	83.4	2	64	Dominica	56.4	18	124	Laos	24.5	19
5	Azerbaijan	82.3	3	65	Sweden	56.2	7	125	Madagascar	23.5	30
6	Vanuatu	81.9	2	66	Italy	55.0	8	126	Czech Republic	22.5	19
7	Saint Lucia	80.7	1	67	Ukraine	54.8	4	127	Paraguay	20.6	28
8	Nepal	80.6	2	68	Türkiye	54.7	12	128	Honduras	20.2	29
9	Gabon	80.5	1	69	Tanzania	54.4	12	129	Sierra Leone	17.4	31
10	Japan	80.1	3	70	Slovakia	53.5	13	130	Nicaragua	16.7	30
11	Guyana	79.8	2	71	Benin	53.2	13	131	Portugal	16.5	19
12	Bosnia and Herzegovina	76.2	1	72	Indonesia	52.7	11	NA	Afghanistan	NA	NA
13	St. Vincent and Grenadines	75.5	3	73	Belarus	52.5	5	NA	Algeria	NA	NA
14	Fiji	75.3	4	74	United States of America	51.9	9	NA	Bahamas	NA	NA
15	India	73.8	3	75	Myanmar	51.5	12	NA	Bahrain	NA	NA
16	China	73.1	5	76	Bangladesh	51.4	6	NA	Botswana	NA	NA
17	Maldives	72.9	4	76	Haiti	51.4	19	NA	Burkina Faso	NA	NA
17	Suriname	72.9	4	78	Denmark	51.0	10	NA	Cabo Verde	NA	NA
19	Trinidad and Tobago	72.6	5	79	Philippines	50.6	13	NA	Chad	NA	NA
20	Costa Rica	72.3	6	80	Hungary	50.1	14	NA	Djibouti	NA	NA
21	Bulgaria	72.1	2	81	Gambia	49.9	14	NA	Egypt	NA	NA
22	Ecuador	71.3	7	82	Angola	49.2	15	NA	Eritrea	NA	NA
22	Venezuela	71.3	7	83	Argentina	48.9	20	NA	Iceland	NA	NA
24	Thailand	70.7	6	84	Mexico	48.8	21	NA	Iran	NA	NA
25	Chile	70.3	9	85	Lebanon	48.5	1	NA	Iraq	NA	NA
26	Sri Lanka	70.0	5	85	Viet Nam	48.5	14	NA	Ireland	NA	NA
27	Serbia	69.3	3	87	Poland	48.4	15	NA	Israel	NA	NA
28	Jamaica	68.7	10	88	Canada	47.6	11	NA	Jordan	NA	NA
29	Central African Republic	68.6	2	89	Austria	47.5	12	NA	Kazakhstan	NA	NA
30	Republic of Congo	67.9	3	90	Dem. Rep. Congo	47.1	16	NA	Kenya	NA	NA
31	Montenegro	67.8	4	91	United Kingdom	46.4	13	NA	Kiribati	NA	NA
32	New Zealand	67.4	1	92	Luxembourg	46.1	14	NA	Kuwait	NA	NA
33	El Salvador	67.0	11	93	Lithuania	45.9	16	NA	Kyrgyzstan	NA	NA
34	Equatorial Guinea	66.6	4	94	Zimbabwe	45.7	17	NA	Mali	NA	NA
35	Cuba	66.0	12	95	Barbados	45.4	22	NA	Malta	NA	NA
36	Papua New Guinea	65.3	7	96	Eswatini	44.6	18	NA	Marshall Islands	NA	NA
37	Comoros	65.1	5	97	Spain	44.5	15	NA	Mauritania	NA	NA
38	North Macedonia	64.6	5	98	Brazil	44.0	23	NA	Mauritius	NA	NA
39	Brunei Darussalam	64.2	8	99	Russia	43.9	6	NA	Micronesia	NA	NA
40	Ethiopia	63.8	6	100	Belgium	43.6	16	NA	Moldova	NA	NA
41	Burundi	63.7	7	101	Liberia	42.4	19	NA	Mongolia	NA	NA
42	Senegal	63.5	8	101	Togo	42.4	19	NA	Morocco	NA	NA
43	Grenada	63.1	13	103	Australia	42.3	17	NA	Namibia	NA	NA
44	Timor-Leste	62.6	9	103	Belize	42.3	24	NA	Niger	NA	NA
45	Albania	62.4	6	105	Solomon Islands	42.0	15	NA	Oman	NA	NA
46	Netherlands	62.0	2	106	Mozambique	41.5	21	NA	Pakistan	NA	NA
47	Croatia	61.7	7	107	Malaysia	41.0	16	NA	Qatar	NA	NA
48	Norway	61.4	3	108	Zambia	40.0	22	NA	Samoa	NA	NA
49	Dominican Republic	61.1	14	109	Germany	38.5	18	NA	São Tomé and Príncipe	NA	NA
49	Switzerland	61.1	4	110	Cambodia	37.6	17	NA	Saudi Arabia	NA	NA
51	Finland	60.8	5	111	Uganda	34.1	23	NA	Seychelles	NA	NA
52	Cyprus	60.6	8	112	Bolivia	33.7	25	NA	South Africa	NA	NA
53	Peru	60.1	15	112	Guinea-Bissau	33.7	24	NA	Sudan	NA	NA
54	Panama	60.0	16	114	Guatemala	33.3	26	NA	Tajikistan	NA	NA
55	Lesotho	59.6	9	115	Nigeria	32.9	25	NA	Tonga	NA	NA
56	Slovenia	58.9	9	116	Latvia	31.8	17	NA	Tunisia	NA	NA
57	France	58.6	6	117	Guinea	30.6	26	NA	Turkmenistan	NA	NA
58	Cameroon	58.4	10	118	Estonia	28.9	18	NA	United Arab Emirates	NA	NA
59	Rwanda	58.3	11	119	Singapore	28.8	18	NA	Uruguay	NA	NA
60	Greece	58.2	10	120	Antigua and Barbuda	28.7	27	NA	Uzbekistan	NA	NA

Asia-Pacific **Eastern Europe** **Former Soviet States** **Global West**

Greater Middle East **Latin America & Caribbean** **Southern Asia** **Sub-Saharan Africa**

Table 12-2. Regional rankings and scores on Forests.

Latin America & Caribbean		
Country	Score	Rank
Saint Lucia	80.7	1
Guyana	79.8	2
St. Vincent and Grenadines	75.5	3
Suriname	72.9	4
Trinidad and Tobago	72.6	5
Costa Rica	72.3	6
Ecuador	71.3	7
Venezuela	71.3	8
Chile	70.3	9
Jamaica	68.7	10
El Salvador	67.0	11
Cuba	66.0	12
Grenada	63.1	13
Dominican Republic	61.1	14
Peru	60.1	14
Panama	60.0	16
Colombia	57.0	17
Dominica	56.4	18
Haiti	51.4	19
Argentina	48.9	20
Mexico	48.8	21
Barbados	45.4	22
Brazil	44.0	23
Belize	42.3	24
Bolivia	33.7	25
Guatemala	33.3	26
Antigua and Barbuda	28.7	27
Paraguay	20.6	28
Honduras	20.2	29
Nicaragua	16.7	30
Bahamas	NA	NA
Uruguay	NA	NA

Eastern Europe		
Country	Score	Rank
Bosnia and Herzegovina	76.2	1
Bulgaria	72.1	2
Serbia	69.3	3
Montenegro	67.8	4
North Macedonia	64.6	5
Albania	62.4	6
Croatia	61.7	7
Cyprus	60.6	8
Slovenia	58.9	9
Greece	58.2	10
Romania	57.1	11
Türkiye	54.7	12
Slovakia	53.5	13
Hungary	50.1	14
Poland	48.4	15
Lithuania	45.9	16
Latvia	31.8	17
Estonia	28.9	18
Czech Republic	22.5	19

Southern Asia		
Country	Score	Rank
Bhutan	86.7	1
Nepal	80.6	2
India	73.8	3
Maldives	72.9	4
Sri Lanka	70.0	5
Bangladesh	51.4	6
Afghanistan	NA	NA
Pakistan	NA	NA

Global West		
Country	Score	Rank
New Zealand	67.4	1
Netherlands	62.0	2
Norway	61.4	3
Switzerland	61.1	4
Finland	60.8	5
France	58.6	6
Sweden	56.2	7
Italy	55.0	8
United States of America	51.9	8
Denmark	51.0	10
Canada	47.6	11
Austria	47.5	12
United Kingdom	46.4	13
Luxembourg	46.1	14
Spain	44.5	15
Belgium	43.6	16
Australia	42.3	17
Germany	38.5	18
Portugal	16.5	19
Malta	NA	NA
Ireland	NA	NA
Iceland	NA	NA

Former Soviet States		
Country	Score	Rank
Georgia	85.2	1
Armenia	83.4	2
Azerbaijan	82.3	3
Ukraine	54.8	4
Belarus	52.5	5
Russia	43.9	6
Kyrgyzstan	NA	NA
Kazakhstan	NA	NA
Moldova	NA	NA
Tajikistan	NA	NA
Turkmenistan	NA	NA
Uzbekistan	NA	NA

Asia-Pacific		
Country	Score	Rank
Taiwan	85.1	1
Vanuatu	81.9	2
Japan	80.1	3
Fiji	75.3	4
China	73.1	5
Thailand	70.7	6
Papua New Guinea	65.3	7
Brunei Darussalam	64.2	8
Timor-Leste	62.6	9
South Korea	57.5	10
Indonesia	52.7	11
Myanmar	51.5	12
Philippines	50.6	13
Viet Nam	48.5	14
Solomon Islands	42.0	15
Malaysia	41.0	16
Cambodia	37.6	17
Singapore	28.8	18
Laos	24.5	19
Kiribati	NA	20
Marshall Islands	NA	NA
Micronesia	NA	NA
Mongolia	NA	NA
Samoa	NA	NA
Tonga	NA	NA

Sub-Saharan Africa		
Country	Score	Rank
Gabon	80.5	1
Central African Republic	68.6	2
Republic of Congo	67.9	3
Equatorial Guinea	66.6	4
Comoros	65.1	5
Ethiopia	63.8	6
Burundi	63.7	7
Senegal	63.5	8
Lesotho	59.6	9
Cameroon	58.4	10
Rwanda	58.3	11
Tanzania	54.4	12
Benin	53.2	13
Gambia	49.9	14
Angola	49.2	15
Dem. Rep. Congo	47.1	16
Zimbabwe	45.7	17
Eswatini	44.6	18
Liberia	42.4	19
Togo	42.4	20
Mozambique	41.5	21
Zambia	40.0	22
Uganda	34.1	23
Guinea-Bissau	33.7	24
Nigeria	32.9	25
Guinea	30.6	26
Malawi	28.2	27
Côte d'Ivoire	26.2	28
Ghana	25.2	29
Madagascar	23.5	30
Sierra Leone	17.4	31
Botswana	NA	NA
Burkina Faso	NA	NA
Cabo Verde	NA	NA
Chad	NA	NA
Djibouti	NA	NA
Eritrea	NA	NA
Kenya	NA	NA
Mali	NA	NA
Mauritania	NA	NA
Mauritius	NA	NA
Namibia	NA	NA
Niger	NA	NA
São Tomé and Príncipe	NA	NA
Seychelles	NA	NA
South Africa	NA	NA

Greater Middle East		
Country	Score	Rank
Lebanon	48.5	1
Algeria	NA	NA
Bahrain	NA	NA
Egypt	NA	NA
Iran	NA	NA
Iraq	NA	NA
Israel	NA	NA
Jordan	NA	NA
Kuwait	NA	NA
Morocco	NA	NA
Oman	NA	NA
Qatar	NA	NA
Saudi Arabia	NA	NA
Sudan	NA	NA
Tunisia	NA	NA
United Arab Emirates	NA	NA

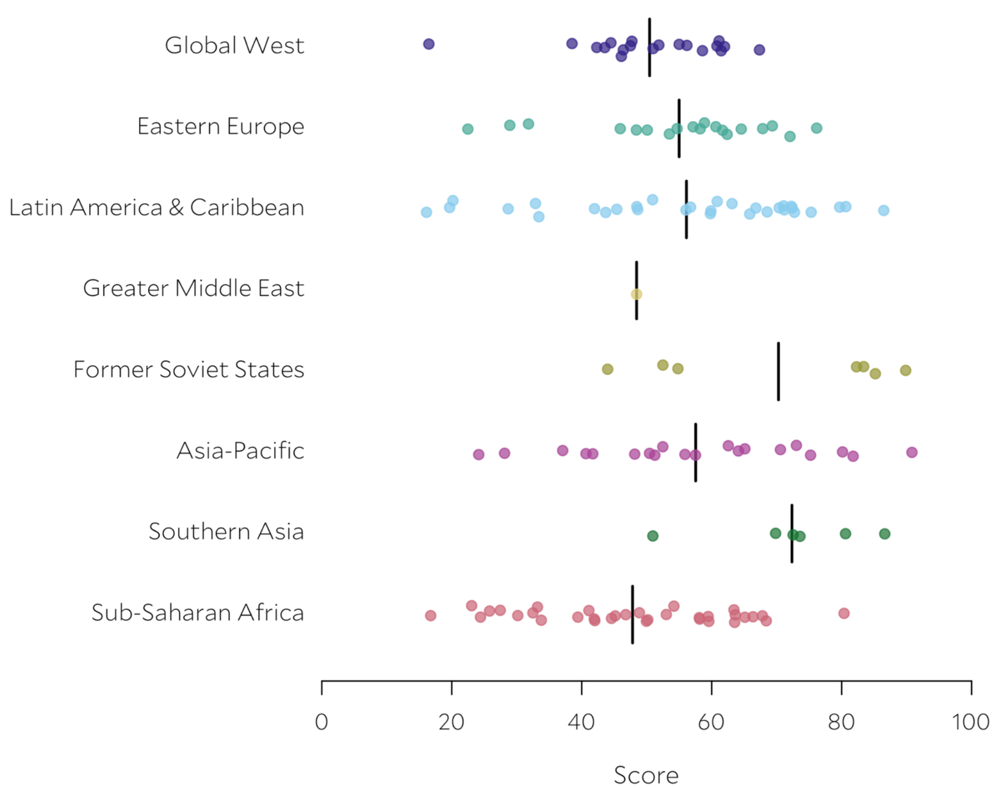
3. Global Trends

Since 2000, about 12 percent of global tree cover has been lost (Global Forest Watch 2024). While growth of tree plantations and natural forest regeneration compensates for some of this loss, these younger forests store less carbon and are less biodiverse than lost old-growth forests (Smith et al. 2021). Countries failed to meet Target 15.2 of the Sustainable Development Goals, which aimed to halt deforestation by 2020. In fact, the rate of tree cover loss has accelerated in recent years (Global Forest Watch 2024). If current trends continue, the world is also unlikely to achieve the targets in the Glasgow Leaders' Declaration on Forests and Land Use.

Forests' ability to provide ecosystem services depends on their structural integrity. Forest degradation can be as damaging to its carbon sequestration potential as outright deforestation (Erb et al. 2018; Nunes et al. 2023). In contrast to tree cover, forest *integrity* cannot be readily measured from satellites, hindering analyses of forest integrity trends. But the little that we do know is worrying. In 2020, only 40.5 percent of forests still had high landscape-level integrity, less than a third of which are in nationally protected areas (Grantham et al. 2020). Some of the forests with the lowest integrity are in affluent European countries, such as Denmark, the Netherlands, and Ireland, where most lands were converted to agriculture and other economic activities a long time ago. While, on average, the integrity of European forests has been slowly improving over the past two decades, one third of European forests continues to deteriorate (Maes et al. 2023). In contrast, the forests with the highest integrity are in remote areas of Canada, Russia, and the Amazon, which are experiencing increasing economic pressures.

Not all types of tree cover loss are equally damaging to the environment. Different drivers of deforestation vary in both their permanence and in their impacts to ecosystem services. Worryingly, in many places tree cover loss is not only accelerating but is also becoming more permanent. Over the last half century, deforestation in lowland rainforests of Southeast Asia and Latin America has been increasingly driven by industrial-scale agricultural commodity producers, as opposed to shifting agriculture by small-scale farmers (Rudel et al. 2009; Austin et al. 2017). While forests can typically regrow after small-scale farmers shift to a new location, commodity-driven deforestation is almost always permanent (Curtis et al. 2018). Shifting agriculture is the driver of almost all deforestation in Africa, especially in the Congo Basin (Tyukavina et al. 2018). In Europe, North America, Oceania, and most of Asia, deforestation is typically transient and driven by either forestry or wildfires (Curtis et al. 2018). However, the loss of tree cover due to wildfires has been increasing across most of the world over the last two decades, due in part to climate change and forest management (Tyukavina et al. 2022).

Figure 12-1. Distribution of regional scores on Forests. Vertical bars show regional averages.



It is important to distinguish not just between different *drivers* of deforestation but also between the different *types of forest* being lost. Intact Forest Landscapes — areas of at least 500 square kilometers with pristine mosaics of forests and naturally treeless ecosystems — play a disproportionate role in storing carbon and providing habitats for biodiversity (Potapov et al. 2017). Yet, between 2000 and 2020, the world lost 155 million hectares (12 percent) of its remaining intact forest landscapes. Worse, the rate of loss has accelerated, with the annual average loss increasing from 7.1 million hectares between 2000 and 2013 to 9 million hectares between 2013 and 2020 (Sims, Potapov, and Goldman 2022). Unfortunately, this trend is unlikely to stop without strong and urgent action. Around 20 percent of tropical intact forest landscapes are designated as extractive concessions, including mining, oil, and gas projects (Grantham et al. 2021). Countries must act quickly to halt the loss and fragmentation of these last frontiers of forest wilderness.

Humid tropical primary forests should also be a top conservation priority. Their destruction leads to irreversible loss of biodiversity and worsens the climate crisis. Primary tropical forests hold roughly half of all the tropical forest carbon stock, as they are 35 percent more efficient at carbon storage than non-primary forests (Mackey et al. 2020). Losses of humid tropical primary forests in 2023 alone caused 2.4 gigatonnes of carbon dioxide emissions, roughly equivalent to half of the annual fossil fuel emissions of the United States (Weisse, Goldman, and Carter 2024). Globally, the loss of tropical primary forest has remained relatively constant over the last years, but the hotspots of deforestation have changed. In Latin America, Brazil and Colombia managed to slash their deforestation rates in 2023 relative to 2022, but their success was offset by sharp increases of deforestation in Nicaragua and Bolivia (Weisse, Goldman, and Carter 2024). In Southeast Asia, the loss of primary forests has rapidly accelerated in Laos, while other countries, such as Indonesia and Malaysia, have managed to keep their losses at record-low levels (Turubanova et al. 2018). Given that a large fraction of humid primary forest loss is driven by production of commodities traded in international markets (see Focus 10-1), countries that produce and consume these commodities must together share responsibility for the protection of these irreplaceable ecosystems.

4. Leaders and Laggards

Countries with robust policies aimed at preserving the integrity of their forests, focusing in areas of high ecological value, lead the Forests ranking in the 2024 EPI. Some leaders have achieved highly developed economies, like Taiwan and Japan, while managing to preserve their existing stock of pristine forests. Other leaders, such as Guyana, are developing countries aiming for economic growth in harmony with the conservation of their natural resources. The best example is Bhutan, which leads the world in forest conservation and sustainable management. Environmental sustainability is one of the four pillars of Bhutan's Gross Natural Happiness philosophy, and the constitution of this landlocked mountainous kingdom commits the country to maintain at least 60 percent of its total area covered in forests in perpetuity (AFoCO-EML 2021). Bhutan has a strong tradition of community participation in forest management (Zangmo et al. 2024) and strives to use its forests sustainably to remain carbon neutral country (van den Heuvel 2022).

Net Tree Cover Change

Most top-performing countries in the pilot *Net Tree Cover Change* indicator are European, e.g., Denmark, the Netherlands, Belarus, and Lithuania, but Bangladesh also emerges as a strong regional leader in Southern Asia. While some of these countries' large proportional gains result in part from their low starting forest cover in 2000, government-led reforestation strategies have made much progress. For example, almost all of Denmark was once covered in forests, but logging and agricultural expansion reduced forest cover to only 2 percent of the country's land area two centuries ago. Since then, tree cover has been gradually re-expanding thanks to large plantations efforts, reaching close to 12.5 percent in the year 2000 and 13.4 percent in 2020. Under its National Forest Program, Denmark aims to reach up to 25 percent forest cover by the end of the century through a combination of afforestation and natural forest regeneration. Similarly, Poland's forest cover was reduced to 21 percent after the Second World War, but by 2015 it had bounced back to over 30 percent thanks to reforestation efforts (Banach, Skrzyszewska, and Skrzyszewski 2017). Poland's National Program for Increasing Forest Cover aims to continue to increase forest cover to one third of the country's land by 2050, focusing on natural regeneration and multifunctional forests. In Southern Asia, Bangladesh has been a regional pioneer in planting mangrove forests on newly accreted coastal lands (Uddin et al. 2022).

In contrast, the largest proportional net losses of tree cover over the last two decades occurred in Sub-Saharan, South Asian, and Latin American and Caribbean countries such as Sierra Leone, Guatemala, and Laos. Their low performance stems from a combination of economic pressures and institutional problems. Sierra Leone, for example, has one of the highest deforestation rates, having started with high forest coverage but low availability of cropland. Foreign investment on commodities such as oil palm in Sierra Leone has driven much of the deforestation (Ordway, Asner, and Lambin 2017), exacerbated by outdated forest management policies, corruption, and insufficient funding and staffing for forest protection (Fayiah 2021). In Laos, agricultural expansion — largely fueled by demand and investment from China (Weisse, Goldman, and Carter 2024) — has been the main driver of primary forest loss in recent years (Chen et al. 2023; Feng et al. 2021; Zeng et al. 2018).

Lasting Tree Cover Loss

We measured the lowest levels of lasting tree cover loss in mountainous countries from the Caucasus region and the Himalayas, such as Armenia, Azerbaijan, Georgia, Nepal, and Bhutan. The main pressures on forests in the Caucasus region are fuelwood demand by local communities and livestock grazing (United Nations 2019). While these pressures can lead to forest degradation, they are less likely to cause large scale loss of tree cover that can be detected from satellite imagery (Cortner et al. 2024). Nepal's low rates of lasting tree cover loss stem in part from its long-standing community forestry program (Shrestha, Shrestha, and Bawa 2018). However, other factors, such as high emigration rates, have also contributed to low tree cover loss rates in Nepal (Oldekop et al. 2018).

The highest rates of lasting tree cover loss are in biodiverse tropical countries in West Africa and South Asia, such as Ghana, Guinea, Cambodia, and Laos. Deforestation in these countries usually results from a combination of agricultural expansion, mining, and illegal logging. For instance, between 1986 and 2015, agricultural expansion caused 78 percent of deforestation in Ghana's Ashanti region (Acheampong et al. 2019). This lasting tree cover loss is also heightened by the dependence of local populations on forest resources: a survey of families living in three forest districts in Ghana showed that agriculture constituted 60 percent of the average total rural household income (Appiah et al. 2009).

Portugal's unexpectedly low score in this category can be largely attributed to high wildfire losses in 2017 in areas where forestry typically is the dominant driver of deforestation. As explained in our Methods section, we place a higher penalty on tree cover losses where forestry is the dominant driver of deforestation, because losses due wildfires are more difficult to control through policy. That is, a misclassification of the dominant driver of Portugal's tree cover loss in 2017 led to an underestimation of the country's performance in the *Lasting Tree Cover Loss* indicator. While Portugal's low score does not necessarily reflect the quality of its national policy, it should be seen as a warning sign. The extreme fire season of 2017 — during which half a million hectares of forest burned — is likely a prelude to what the future holds for the region, as wildfires become ever more likely with rising temperatures and more frequent droughts (Turco et al. 2019).

Intact Forest Landscapes

Leaders of the *Intact Forest Landscape* indicator include geographically diverse countries with large swaths of pristine forests, such as Japan, Finland, and Kazakhstan. The Lapland region of Finland has been under protection since 1922, showcasing early and successful legislative efforts to conserve critical forest landscapes (Varmola et al. 2004). The Finnish public and forest owners largely agree on the importance of maintaining forest health alongside wood production (Kangas and Niemeläinen 1996). Nonetheless, there are rising concerns that current Finnish policy is evolving to favor production over conservation, potentially undermining its success so far (Kröger and Raitio 2017).

Countries in Central and Latin American, such as Honduras, Nicaragua, and Paraguay, suffered some of the greatest losses of intact forest landscapes over the last two decades. These countries' poor performance stems from a combination of rapidly expanding agriculture and insufficient law enforcement. For example, in Honduras and Nicaragua, up to 30 percent of deforestation could be linked to cocaine trade (Sesnie et al. 2017), and illegal marijuana plantations — often inside protected areas — are the leading driver of deforestation in Paraguay (Pechinski 2021).

Humid Tropical Primary Forests

Leaders in humid primary tropical forest conservation are spread around the world and include both wealthy countries, such as Australia and Taiwan, and developing countries, such as Senegal, Bhutan, and Nepal. The Australian success results, at least in part, from the engagement of Aboriginal communities. The Wet Tropics Regional Agreement in 2005 played a pivotal role in fostering collaboration between governments and Rainforest Aboriginal peoples, recognizing Aboriginal cultural heritage and promoting cooperative rainforest management (Hill et al. 2011).

Nicaragua had the highest rate of primary forest loss, losing 4.2 percent of its remaining primary forests in 2023 alone (Weisse, Goldman, and Carter 2024). In addition to agricultural expansion and cattle ranching, gold mining is an important driver of deforestation in Nicaragua. Since 2021, the area of mining concessions more than doubled, now covering around 15 percent of Nicaragua's land area (Radwin 2024). A large fraction of the loss of primary forests in the country has occurred inside protected areas, especially in Bosawás and Indio Maíz biosphere reserves, and has been accompanied by illegal land grabbing and displacement of indigenous communities (Radwin 2023). An investigation by the Organized Crime and Corruption Reporting Project shows that the government of Nicaragua has been complicit in this illegal deforestation, even cracking down on environmental and Indigenous advocacy groups (Chavkin et al. 2021).

Forest Landscape Integrity

Countries with the highest forest landscape integrity include tropical nations, such as Guyana, Suriname, and Gabon, and nations with large boreal forests, such as Russia and Canada. Guyana's success at maintaining high forest integrity is particularly impressive. While part of the reason of its high forest integrity is that almost 90 percent of the population lives in coastal areas away from forests, the country has strict environmental protection laws and effective forest management practices (Sutherland 2017). Guyana's government collaborates with indigenous groups to patrol and sustainably manage its forests (Arsenault 2021). Moreover, Guyana has partnered with Norway in one of the most successful examples of international finance, reducing emissions from deforestation and forest degradation (REED+ program) and slashing already low rates of tree cover loss by 35 percent (Roopsind, Sohngen, and Brandt 2019). Guyana has put almost all its forests on the carbon market. The country plans to continue its partnership with Norway and recently signed a carbon credit deal worth US$750 million with Hess Corporation — an oil company —

with 15 percent of the funds going to indigenous groups (Selibas 2023).

On the other side of the spectrum, small, dense countries, such as Singapore, Denmark, and the Netherlands, score lowest on *forest landscape integrity*, as urban areas and infrastructure intensify pressure on forest lands (Grantham et al. 2020). In Denmark and the Netherlands, like most European countries, historical conversion of forests into farmland not only eliminated most forest cover but also undermined the integrity of the remaining forest patches.

Focus 12.1

Addressing imported deforestation

The world is connected by international trade, and consumption of imported goods in one country can drive deforestation in the countries where those goods are produced. This coupling of consumption in one country and deforestation in another country is known as "imported deforestation." While the indicators in the 2024 EPI do not account for imported deforestation, it is an important component of environmental performance, and it casts a different light on individual countries' responsibility for global climate change and biodiversity loss. Many of the commendable reforestation efforts in recent years — particularly in the G7 countries, China, and India — have been offset by the transfer of ecosystem degradation to other countries. For example, although the United Kingdom reforested an area of 17,000 ha per year between 2010 and 2013, it imported 31,000 ha of deforestation each year over the same period (Pendrill, Persson, Godar, and Kastner 2019). In 2015, more than 90 percent of the deforestation footprint of Japan, Germany, France, the United Kingdom, and Italy was located outside their borders (Hoang and Kanemoto 2021).

Simply comparing the areas of forests lost abroad and gained domestically can give a misleading picture of global trends in forest integrity — because not all forests are the same. Deforestation associated with international trade often affects areas of high ecological value, such as irreplaceable tropical primary forests (Hoang and Kanemoto 2021). Up to 40 percent of carbon dioxide emissions from tropical deforestation are driven by international trade of agricultural products, mainly beef and oilseeds (Pendrill, Persson, Godar, Kastner, et al. 2019). Arguably, both exporting and importing countries should share responsibility for the protection of the world's most biodiverse and carbon-rich ecosystems.

The European Union's Deforestation Regulation (EUDR), which will come into effect on December 30, 2024, addresses the problem of imported deforestation. With the EUDR, a group of major commodities — soy, cattle, palm oil, wood, cocoa, coffee, and rubber — *and* their derivative products will be banned from entering the European single market if raised or grown on land that experienced deforestation or forest degradation after December 31, 2020. Those commodities and products will also need to comply with the national regulations on deforestation of the producing countries to be eligible for import to the European Union (European Commission 2023).

Adoption of similar, "demand-side" policies in other large markets is critical to the EUDR's success. Without it, the legislation could simply result in trade being diverted to less environmentally conscientious markets. Fortunately, the European Union's initiative might have already provided impetus for change, as with the reintroduction of the FOREST Act in the United States Congress. Although the FOREST Act is a less ambitious piece of legislation, forbidding import of product from areas *illegally* deforested — as opposed to all deforested areas — it still shows an effort in trying to limit "imported" deforestation.

Despite its good intentions, the EUDR has faced backlash from commodity-exporting countries. A joint letter signed by 17 countries describes the regulation as, "an inherently discriminatory and punitive unilateral benchmarking system that is potentially inconsistent with World Trade Organization obligation," raising concerns about the unintended consequences of the legislation (Bono 2024). Those consequences could include diversion of resources, hindrance of the attainment of Sustainable Development Goals, and increased poverty resulting from the exclusion of smallholder farmers from international trade due to the high compliance costs of EUDR. Those concerns should not be dismissed, as it is likely that a lack of additional safeguards and cooperation between countries could undermine the efficacy of EUDR and similar initiatives (Zhunusova et al. 2022).

The Global Commons Stewardship Index — the EPI's sister project — measures environmental impacts embodied in international trade, including imported deforestation (Ishii et al. 2024).

5. Methods

Indicator Background

For the first time, the 2024 EPI incorporates data on both gains and losses of tree cover to develop a pilot indicator of *net* tree cover change. This indicator can contribute to tracking forest restoration efforts, an essential component of nature-based solutions to the climate and biodiversity crises. Target 2 of the Kunming-Montreal Global Biodiversity Framework is to ensure 30 percent of degraded ecosystems are under effective restoration by 2030. The indicator quantifies the net change in forest area between 2000 and 2020. We use global forest maps in which forests are defined based on tree height data obtained from air-borne lidar (Potapov et al. 2022). To calculate proportional rates of change, we divide the net change in forest area by the total forest area in the year 2000. Note that tree gains in these data include natural regeneration, restoration efforts, and tree regrowth inside plantations. Because young forests, and especially forest plantations, cannot replace the biodiversity and structure of old-growth forests (Gibson et al. 2011) on such a short time scale, a net gain in forest cover does not necessarily imply a positive trend in forest ecosystem services.

The 2024 EPI also introduces new indicators to distinguish between different types of deforestation and their contrasting impacts on biodiversity and ecosystem services. Different drivers of tree cover loss, such as agriculture, wildfires, and forestry, are dominant in different regions of the world (Curtis et al. 2018). Highlighting these different drivers is important because the likelihood of forests growing back after being lost to each of these drivers is very different. For example, forests rarely grow back after urbanization or commodity-driven deforestation but almost always after fires or forestry operations.

Our new pilot indicator of *Lasting Tree Cover Loss* attempts to distinguish between the contrasting ecological consequences of tree cover loss due to different deforestation drivers. The indicator places different weights on areas of tree cover loss based upon the likelihood of the underlying driver resulting in permanent deforestation (Table 12-3). While losses to shifting agriculture are not always permanent, we give it a heavy weight because it is common across the range of most threatened forest species (Kadoya et al. 2022). Wildfire losses get a low weight because they are not entirely under human control.

Table 12-3. Fraction of tree cover loss counted in areas with different dominant drivers of deforestation in the *Lasting Tree Cover Loss* indicator.

Dominant deforestation driver	% of tree cover loss counted
Urbanization	100
Commodity-driven deforestation	100
Shifting agriculture	75
Forestry	50
Wildfires	20

We always penalize a certain fraction of tree cover loss, regardless of the likelihood of tree regrowth, because it is almost always preferable not to lose tree cover to begin with. When old growth forests are lost, they take a long time to recover their biodiversity and stored carbon (Martin, Newton, and Bullock 2013; Smith et al. 2021). Moreover, since forests' evapotranspiration contributes to regional rainfall, deforestation from any reason can alter regional climates and hamper forest regrowth, especially in tropical regions (Smith, Baker, and Spracklen 2023; Flores et al. 2024).

Harnessing the latest developments on satellite-based forest mapping, the 2024 EPI introduces metrics to track losses of forest types with disproportionate impacts on biodiversity and ecosystem services. Humid tropical primary forests are the most biodiverse terrestrial ecosystems on the planet and should be a top conservation priority (Gibson et al. 2011). We quantified tree cover losses within areas mapped as humid tropical primary forests through supervised classification of Landsat satellite images (Turubanova et al. 2018). Our indicator of *Humid Tropical Primary Forest Loss* is based on a five-year moving average of annual losses relative to the extent of primary forests in 2001.

Similar to primary forests, large expanses of forest with minimum alteration by human activities, known as Intact Forest Landscapes, are a conservation priority due to their irreplaceable biodiversity and ecosystem functions (Potapov et al. 2017). Intact forest landscapes are defined as seamless mosaics of forests and natural treeless ecosystems without (remotely detected) signs of habitat fragmentation. Their minimum size is 500 km^2, as they should be large enough to maintain viable populations of wide-ranging species and all native biodiversity. We use global maps based on Potapov et al.'s (2017) method to quantify losses relative to the intact forest landscapes in 2000 in each country. As with the other tree cover loss indicators, we calculate a five-year moving average of annual losses. Given the tremendous value of intact forest landscapes and primary forests, we quantify all their cover losses, regardless of drivers. Target 1 of the Kunming-Montreal Biodiversity Framework calls for bringing "the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, *close to zero* by 2030."

Finally, areas that appear as forest in satellite images may be degraded, with lower biodiversity and carbon stores. Some studies estimate that degradation, rather than tree cover loss, accounts for most carbon losses in tropical forests (Baccini et al. 2017). While remote sensing of forest degradation remains limited (Gao et al. 2020), Grantham et al. (2020) combined information on observed and inferred human pressures with forest cover loss and fragmentation data to produce a global map of forest landscape integrity (publicly available at: https://www.forestintegrity.com/home). We averaged forest integrity across countries' territory to build a pilot indicator *Forest Landscape Integrity*.

Data Sources

Grantham et al. (2020) provides forest landscape integrity data, while all other indicators are based on data from Global Forest Watch. The main global dataset to track deforestation is based on Landsat satellite image analyses by Hansen et al. (2013). *Forest* is defined as areas with at least 30 percent canopy cover. To build our new *Lasting Tree Cover Loss* indicator, we complement these data with information about the fraction of total forest loss in a country occurring in areas with different dominant drivers of tree cover loss: urbanization, commodity-driven deforestation, shifting agriculture, forestry, and fires (Curtis et al. 2018). Global maps of intact forest landscapes are based on Potapov et al. (2017), and those of humid tropical primary forests are based on Turubanova et al. (2018). Finally, the data for the *Net Tree Cover Change* indicator was derived by comparing tree cover maps for 2000 and 2020 (Potapov et al. 2022). These maps define tree cover based on lidar-derived tree height data and are thus not directly comparable to the tree cover loss dataset based on Hansen et al. (2013). In the Potapov et al. (2022) dataset, tree cover is defined as areas with tree height greater than five meters. Tree cover gain includes natural regeneration, tree planting, and regrowth in plantations.

Limitations

EPI users must consider several limitations when interpreting the results of the Forest indicators. One limitation, discussed in depth in Focus Box 12-1, is that the indicators track only deforestation happening within countries' borders, and do not account for "imported deforestation".

Another set of limitations relates to the baseline (or lack thereof) used to measure forest loss and degradation. Except for the *Forest Landscape Integrity* indicator, the indicators quantify changes in forest cover relative to a baseline determined by the availability of satellite data (2001 for the indicator of humid tropical primary forests loss, and 2000 for the other indicators). While the EPI focuses on recent trends to be policy relevant, countries that replaced most of their forests with agriculture and other land uses *before* 2000 may appear to do better in these indicators than countries with similar deforestation *after* 2000. On the contrary, the *Forest Landscape Integrity* indicator is only available for the year 2020 and quantifies absolute forest integrity without reference to any baseline. As such, low scores may reflect forest loss and degradation that happened centuries ago, completely unrelated to recent policy. The *Net Tree Cover Change* indicator suffers from both types of limitations: it uses an arbitrary baseline and is based on single value of change between 2000 and 2020, obscuring links to recent policy.

While it is important to distinguish between drivers of deforestation, as argued above, our weights in Table 13-3 are subjective rather than empirical. The EPI team chose weights to roughly reflect the permanency and ecological impact of different deforestation drivers, as well as the degree to which they can be influenced through policy, but these factors have not been rigorously quantified. Moreover, we use a *static* map of the dominant drivers of deforestation at the landscape scale, based on analyses of satellite imagery from 2000 to 2015 (Curtis et al. 2018). The dominant driver of deforestation at any given location can change through time. Extrapolating from the static map, therefore, can lead to a misattribution of dominant drivers. In other words, we cannot verify the driver of tree cover loss in any given pixel in any given year. For example, in 2017, wildfires caused tree cover loss across large areas of Portugal, yet because our map identifies forestry as the usual dominant deforestation driver in that location, our indicator applies the 50 percent weight to Portugal's tree cover loss in that year rather than the 20 percent weight.

Binary classifications, such as the maps on which the new indicators tracking loss of humid tropical primary forests and of intact forest landscapes are based, are a valuable first step toward prioritizing the conservation of forests with high ecological value. But nature is not binary. A more powerful approach would quantify forest quality and integrity on a continuous scale. This could be done by coupling analysis of hyperspectral satellite imagery and other remotely sensed data to ground-based measurements of biodiversity and ecosystem properties. The SEED Biocomplexity Index (*https://seed-index.com/*) is an example of such an approach, and the EPI team hopes to incorporate it into its analyses as its spatial and temporal coverage improves.

Finally, the EPI currently lacks the data to track changes in the extent and integrity data of non-forest ecosystems. Non-forest ecosystems, such as wetlands and grasslands, are also important for biodiversity and provide essential services, but they are more difficult to characterize from space. The 2020 EPI introduced pilot indicators to track changes in the extent of wetlands and grasslands, but we drop these indicators in the 2024 EPI report because the underlying data were deemed to be too coarse and uncertain for rigorous quantification of ecosystem trends. However, the global quantifications of grassland (Bardgett et al. 2021) and wetland (Murray et al. 2022; Fluet-Chouinard et al. 2023) loss and degradation are active areas of research, so the EPI team expects to reintroduce metrics to track these ecosystems in future iterations of the report.

Weighting Rationale

Given the importance of primary forests and intact forest landscapes, we give these indicators the largest relative weights in the Forest category, 30 percent each. We assigned 25 percent of the category weight to the *Lasting Tree Cover Loss* indicator, since it is a refinement of a past EPI indicator, and it is applicable to most countries. The indicator of *Net Tree Cover Change*, being a pilot and based on a single 20-year period, gets 10 percent of the weight. Finally, the *Forest Landscape Integrity Index* gets only 5 percent because it, too, is a pilot indicator, with only one year of data and not as strongly linked to recent policy.

Materiality

We did not score the 59 countries with less than 10 percent forest cover in 2000, with forest defined based on height following Potapov et al. (2022). Moreover, only 81 countries have data on primary forests, only 63 have data on intact forest landscapes, and only 51 countries have both. For countries not scored in some (or any) Forest indicators, either because of materiality or lack of data, we redistributed the weight of those indicators to other indicators in the Ecosystem Vitality policy objective, in proportion to those other indicators' weights. In contrast to previous iterations of the EPI, if data for only some indicators in the Forests issue category was available, their weights were not rescaled to add up to a fixed weight for the issue category. Instead, the indicator weights are fixed, and the weight of the unavailable indicators was redistributed to other Ecosystem Vitality indicators. Therefore, for all the countries with more than 10 percent forest cover in 2000, but without *intact forest landscapes* nor *humid tropical primary forests* (such as Austria, Denmark, Lebanon, and South Korea), the Forest issue category contributes only 2 percent of the overall EPI, instead of 5 percent. In contrast, the Forest category contributes for 3.5 percent of the overall EPI weight for countries with *intact forest landscapes* but without *humid tropical primary forests* (such as Canada and Russia) and 5 percent for countries with both *intact forest landscapes* and *humid tropical primary forests* (such as the D.R.C., Brazil, Indonesia). With this change, the EPI emphasizes that halting deforestation, while important for every country, is especially urgent for countries with forests of high ecological value.

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Chapter 13. Biodiversity & Habitat

1. Introduction

The biodiversity crisis — the rapid loss of species and other types of biological diversity — has emerged as one of the most severe and irreversible environmental issues facing humanity, just behind climate change. Five times over the planet's history, asteroid collisions, massive volcanic eruptions, and other geological cataclysms have wiped out large fractions of the biodiversity of the planet, in what scientists call mass extinction events. Humans have now unleashed the sixth mass extinction. Over the last century, at least 200 species of vertebrates have gone extinct, a rate of extinction one hundred times faster than usual (Ceballos et al. 2015). Given that scientists have cataloged only a small fraction of the planet's biodiversity (Pimm et al. 2014), we are not even aware of what we are losing. Since biodiversity underpins the stability and healthy functioning of ecosystems and the services we derive from them (Díaz et al. 2006; Cardinale et al. 2012), its rapid loss poses a severe threat to human well-being.

In order of importance, land use change, resource exploitation, pollution, invasive species, and climate change are the main drivers of recent biodiversity loss (Jaureguiberry et al. 2022). Establishing protected areas (clearly defined areas of land and sea for the primary goal of biodiversity conservation) can be a powerful approach to tackle directly at least the two most important drivers — land use change and resource exploitation. Besides reducing direct human impacts on biodiversity, protected areas have many other benefits. They enhance the resilience of ecosystems to natural disturbance and anthropogenic climate change (Mellin et al. 2016). Lower rates of deforestation and ecosystem degradation in protected areas boost vegetation's carbon storage capacity, which contributes to mitigating climate change (Duncanson et al. 2023). And, under the right circumstances, protected areas can also contribute directly to human well-being (Ban et al. 2019; Fisher et al. 2024).

So far, countries have largely failed to achieve international conservation goals, such as the Aichi Biodiversity Targets (Buchanan et al. 2020). But in 2022, reflecting awareness about the severity of the biodiversity crisis, 196 countries agreed to redouble their commitments to protect biodiversity with the Kunming-Montreal Global Biodiversity Framework. Among other ambitious targets that the Framework sets for this decade, countries agreed to protect 30 percent of lands and seas by 2030 (known as the 30x30 goal), restore 30 percent of all degraded ecosystems, halve pollution, and halt species extinctions.

With a revamped and expanded set of Biodiversity & Habitat indicators, the 2024 EPI can help policymakers and other stakeholders identify conservation gaps and priorities, as well as track progress toward Target 3 (30x30) and Target 4 (halt extinction and reduce extinction risk) of the Kunming-Montreal Global Biodiversity Framework.

2. Indicators

Marine Key Biodiversity Area Protection
(12% of issue category)
Percentage of marine Key Biodiversity Area under protection in a country's exclusive economic zone.

Marine and Coastal Habitat Protection
(12% of issue category)
Percentage of important marine and coastal habitats — mangroves, salt marshes, seagrasses, coral reefs, cold corals, sea mounts, and knolls — under protection in a country's exclusive economic zone.

Marine Protection Stringency
(2% of issue category)
Industrial fishing effort inside protected areas relative to fishing effort in unprotected areas of a country's exclusive economic zone.

Protected Area Representativeness Index
(12% of issue category)
How well a country's terrestrial protected areas represent its ecological diversity.

Species Protection Index
(16% of issue category)
How well a country's terrestrial protected areas overlap with the ranges of its animal and plant species.

Terrestrial Biome Protection
(10% of issue category)
Average percentage of the area of different biomes under protection, weighting biomes according to their rarity in the country.

Terrestrial Key Biodiversity Area Protection
(10% of issue category)
Percentage of terrestrial Key Biodiversity Area under protection in a country.

Protected Area Effectiveness
(2% of issue category)
Percentage of protected areas in a country in which the area of croplands and buildings is growing more than 0.5% per year.

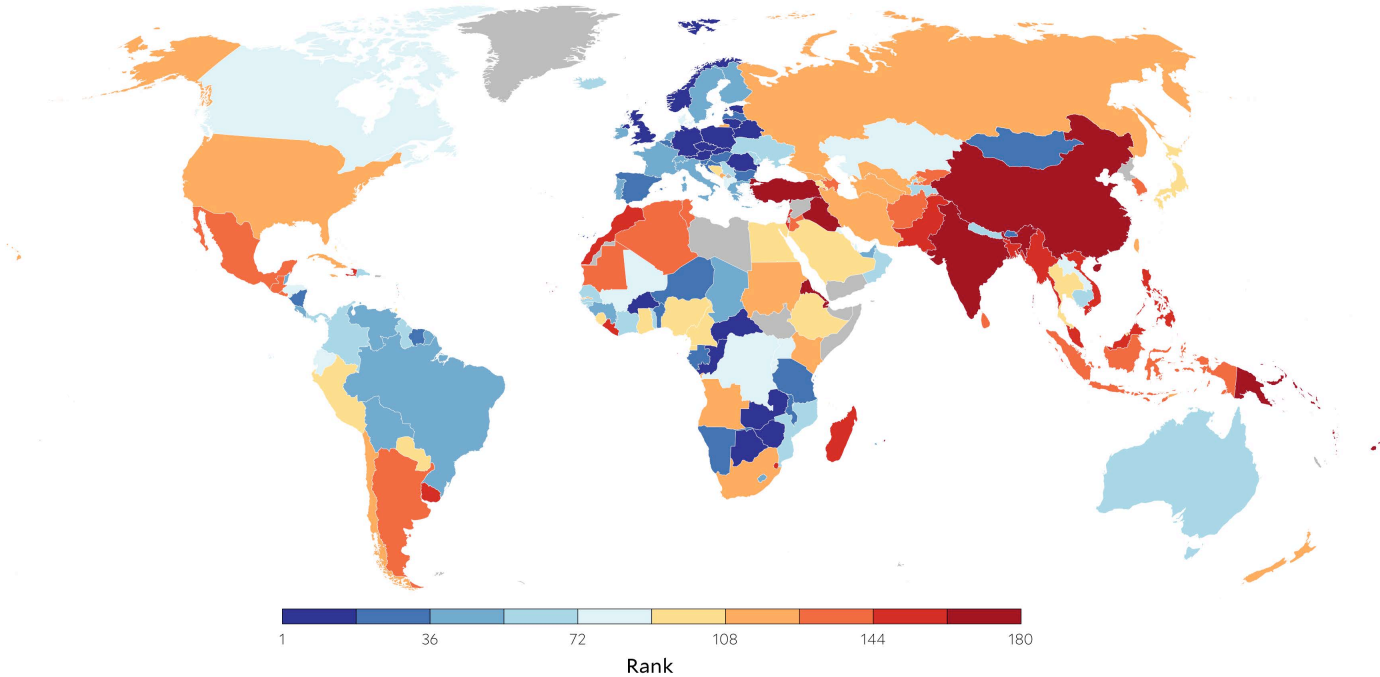
Croplands and Buildings inside Protected Areas
(2% of issue category)
Percentage of the total area protected in a country that is covered by croplands and buildings.

Red List Index
(12% of issue category)
Average extinction risk of species in a country.

Species Habitat Index
(8% of issue category)
Percentage of suitable habitat for a country's species that remains intact relative to 2001.

Bioclimatic Ecosystem Resilience Index
(2% of issue category)
Ecosystems' capacity to retain species diversity under climate change as a function of ecosystem area, connectivity, and integrity.

Map 13-1. Global rankings on Biodiversity & Habitat.



Map 13-2. Biodiversity & Habitat scores.

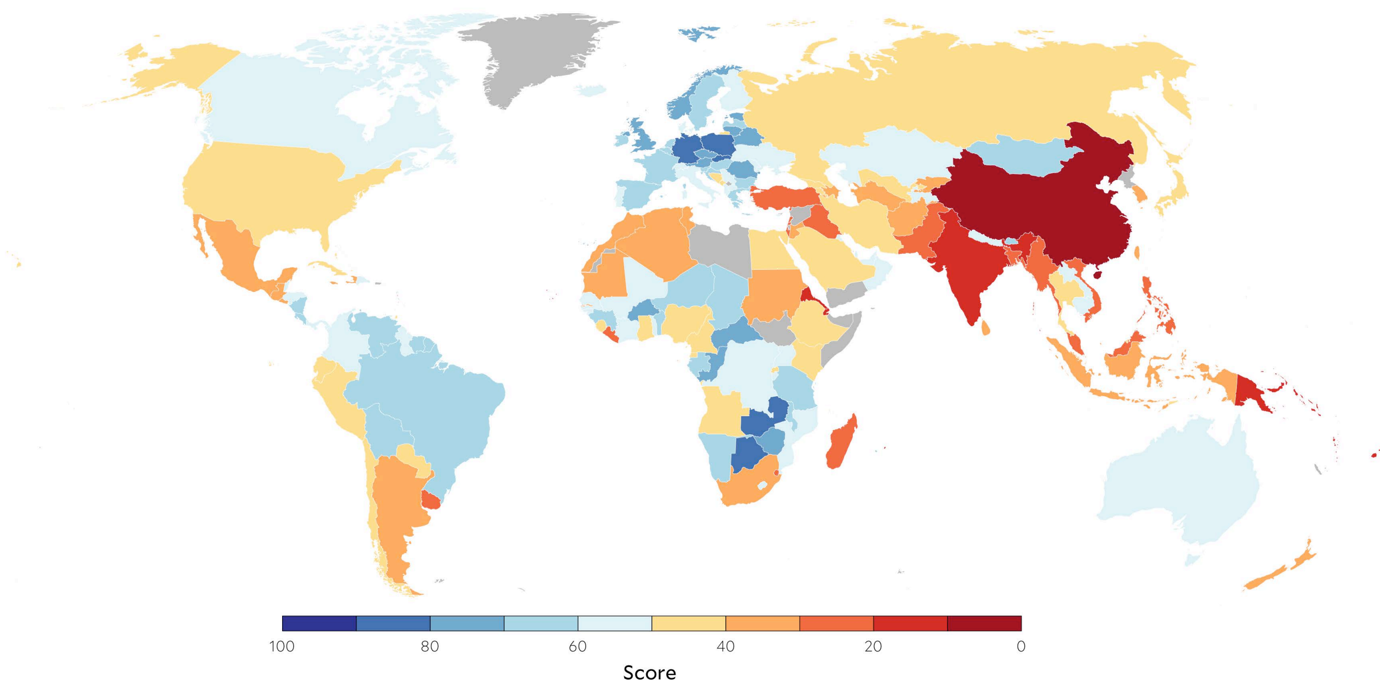


Table 13-1. Global rankings, scores, and regional rankings (REG) on the Biodiversity & Habitat issue category.

RANK	COUNTRY	SCORE	REG
1	Botswana	85.6	1
2	Luxembourg	84.8	1
3	Zambia	83.7	2
4	Germany	82.4	2
5	Slovakia	81.9	1
6	Poland	81.4	2
7	Czech Republic	78.9	3
8	Estonia	78.8	4
9	Lithuania	74.9	5
10	Austria	74.3	3
11	Burkina Faso	73.3	3
12	Romania	71.9	6
13	Norway	71.6	4
13	Republic of Congo	71.6	4
15	Central African Republic	71.5	5
15	United Kingdom	71.5	5
17	Belarus	70.4	1
18	Zimbabwe	70.2	6
19	Niger	69.9	7
20	Croatia	69.6	7
21	Namibia	69.5	8
22	Bulgaria	69.2	8
23	Latvia	68.4	9
24	Malawi	68.1	9
25	Malta	67.1	6
26	Hungary	66.9	10
26	Spain	66.9	7
28	Belgium	66.2	8
29	Bhutan	65.7	1
30	Nicaragua	65.5	1
31	Tanzania	65.3	10
32	Slovenia	64.9	11
33	Suriname	64.8	2
34	Mongolia	64.2	1
35	Gabon	64.0	11
36	Benin	63.9	12
37	Bolivia	63.5	3
38	Costa Rica	63.3	4
39	Ireland	62.5	9
40	Greece	62.4	12
41	Brazil	62.3	5
42	France	61.5	10
43	Venezuela	61.3	6
44	Guinea	61.0	13
45	Netherlands	60.5	11
46	Chad	60.3	14
47	Sweden	60.0	12
48	Portugal	59.8	13
48	Switzerland	59.8	13
50	Finland	59.1	15
50	Lesotho	59.1	15
52	United Arab Emirates	59.0	1
53	Italy	58.5	16
54	Belize	57.8	7
55	Mozambique	57.1	16
56	Dominican Republic	57.0	8
57	Cambodia	56.9	2
58	Panama	56.6	9
59	Guyana	56.5	10
59	Senegal	56.5	17
61	Côte d'Ivoire	56.2	18
61	Oman	56.2	2
63	Colombia	55.5	11
64	Australia	55.2	17
65	Iceland	54.8	18
65	Togo	54.8	19
67	Nepal	54.2	2
68	Guinea-Bissau	53.8	20
68	Ukraine	53.8	2
70	Tajikistan	53.7	3
71	Serbia	53.4	13
72	Moldova	53.3	4
73	Denmark	53.1	19
74	North Macedonia	53.0	14
75	Canada	52.9	20
76	Antigua and Barbuda	52.5	12
77	Dem. Rep. Congo	52.0	21
78	Uganda	51.9	22
79	Burundi	51.6	23
80	Cyprus	51.2	15
81	Mali	51.0	24
82	Laos	50.6	3
83	Kuwait	50.5	3
83	Seychelles	50.5	25
85	Honduras	50.4	13
86	Albania	50.3	16
87	Kazakhstan	50.2	5
88	Qatar	50.1	4
89	Rwanda	49.9	26
90	Ecuador	49.8	14
91	Trinidad and Tobago	49.5	15
92	Comoros	49.0	27
93	Peru	48.6	16
94	Armenia	47.6	6
95	Egypt	47.5	5
95	Paraguay	47.5	17
97	Japan	47.4	4
98	Brunei Darussalam	47.3	5
99	Nigeria	47.1	28
100	Bahamas	46.4	18
101	Thailand	45.9	6
102	Bosnia and Herzegovina	45.8	17
102	Ethiopia	45.8	29
104	Saudi Arabia	45.4	6
105	Equatorial Guinea	45.3	30
105	Sierra Leone	45.3	30
107	Cameroon	45.2	32
108	Ghana	45.0	33
109	Georgia	44.4	7
109	Timor-Leste	44.4	7
111	Uzbekistan	44.0	8
112	Kenya	43.8	34
113	Cuba	42.8	19
113	Iran	42.8	7
115	Chile	42.5	20
116	Montenegro	42.1	18
117	Russia	41.6	9
118	Angola	41.5	35
119	United States of America	40.7	21
120	South Africa	39.5	36
121	Sudan	39.2	8
121	Turkmenistan	39.2	10
123	New Zealand	38.5	22
124	Taiwan	38.4	8
125	Gambia	38.3	37
126	Jamaica	38.2	21
127	Tunisia	38.1	9
128	Kyrgyzstan	37.0	11
129	Azerbaijan	36.7	12
130	Mauritania	36.2	38
131	Guatemala	36.0	22
132	El Salvador	35.5	23
133	St. Vincent and Grenadines	35.1	24
134	Singapore	35.0	9
135	Argentina	34.7	25
136	São Tomé and Príncipe	33.2	39
137	Algeria	33.0	10
138	Sri Lanka	32.9	3
139	Jordan	32.8	11
139	South Korea	32.8	10
141	Afghanistan	31.7	4
141	Mexico	31.7	26
143	Indonesia	30.7	11
144	Kiribati	30.5	12
145	Morocco	30.1	12
146	Haiti	30.0	27
146	Saint Lucia	30.0	27
148	Eswatini	29.8	40
149	Israel	29.6	13
150	Bangladesh	29.1	5
151	Uruguay	28.9	29
152	Malaysia	28.0	13
153	Dominica	27.7	30
154	Madagascar	26.4	41
155	Bahrain	25.8	14
156	Liberia	25.7	42
157	Samoa	25.6	14
158	Pakistan	25.3	6
159	Viet Nam	24.8	15
160	Philippines	24.6	16
161	Lebanon	23.6	15
162	Myanmar	23.0	17
163	Grenada	21.0	31
164	Iraq	20.0	16
164	Türkiye*	20.0	19
166	Papua New Guinea	19.8	18
167	Cabo Verde	19.2	43
168	Vanuatu	18.1	19
169	Djibouti	17.5	44
170	Fiji	17.0	20
171	Eritrea	16.6	45
172	Tonga	15.7	21
173	Mauritius	13.4	46
174	Solomon Islands	13.2	22
175	Marshall Islands	12.6	23
176	Barbados	12.2	32
177	Maldives	12.0	7
178	India*	11.2	8
179	China*	9.5	24
180	Micronesia	4.4	25

* these countries restrict public access the vast majority of their protected area data on the WDPA, so their scores underestimate their actual performance.

Asia-Pacific **Eastern Europe** **Former Soviet States** **Global West**

Greater Middle East **Latin America & Caribbean** **Southern Asia** **Sub-Saharan Africa**

Table 13-2. Regional rankings and scores on Biodiversity & Habitat.

Latin America & Caribbean		
Country	Score	Rank
Nicaragua	65.5	1
Suriname	64.8	2
Bolivia	63.5	3
Costa Rica	63.3	4
Brazil	62.3	5
Venezuela	61.3	6
Belize	57.8	7
Dominican Republic	57.0	8
Panama	56.6	9
Guyana	56.5	10
Colombia	55.5	11
Antigua and Barbuda	52.5	12
Honduras	50.4	13
Ecuador	49.8	14
Trinidad and Tobago	49.5	15
Peru	48.6	16
Paraguay	47.5	17
Bahamas	46.4	18
Cuba	42.8	19
Chile	42.5	20
Jamaica	38.2	21
Guatemala	36.0	22
El Salvador	35.5	23
St. Vincent and Grenadines	35.1	24
Argentina	34.7	25
Mexico	31.7	26
Haiti	30.0	27
Saint Lucia	30.0	27
Uruguay	28.9	29
Dominica	27.7	30
Grenada	21.0	31
Barbados	12.2	32

Eastern Europe		
Country	Score	Rank
Slovakia	81.9	1
Poland	81.4	2
Czech Republic	78.9	3
Estonia	78.8	4
Lithuania	74.9	5
Romania	71.9	6
Croatia	69.6	7
Bulgaria	69.2	8
Latvia	68.4	9
Hungary	66.9	10
Slovenia	64.9	11
Greece	62.4	12
Serbia	53.4	13
North Macedonia	53.0	14
Cyprus	51.2	15
Albania	50.3	16
Bosnia and Herzegovina	45.8	17
Montenegro	42.1	18
Türkiye*	20.0	19

Southern Asia		
Country	Score	Rank
Bhutan	65.7	1
Nepal	54.2	2
Sri Lanka	32.9	3
Afghanistan	31.7	4
Bangladesh	29.1	5
Pakistan	25.3	6
Maldives	12.0	7
India*	11.2	8

Global West		
Country	Score	Rank
Luxembourg	84.8	1
Germany	82.4	2
Austria	74.3	3
Norway	71.6	4
United Kingdom	71.5	5
Malta	67.1	6
Spain	66.9	7
Belgium	66.2	8
Ireland	62.5	9
France	61.5	10
Netherlands	60.5	11
Sweden	60.0	12
Portugal	59.8	13
Switzerland	59.8	13
Finland	59.1	15
Italy	58.5	16
Australia	55.2	17
Iceland	54.8	18
Denmark	53.1	19
Canada	52.9	20
United States of America	40.7	21
New Zealand	38.5	22

Former Soviet States		
Country	Score	Rank
Belarus	70.4	1
Ukraine	53.8	2
Tajikistan	53.7	3
Moldova	53.3	4
Kazakhstan	50.2	5
Armenia	47.6	6
Georgia	44.4	7
Uzbekistan	44.0	8
Russia	41.6	9
Turkmenistan	39.2	10
Kyrgyzstan	37.0	11
Azerbaijan	36.7	12

Asia-Pacific		
Country	Score	Rank
Mongolia	64.2	1
Cambodia	56.9	2
Laos	50.6	3
Japan	47.4	4
Brunei Darussalam	47.3	5
Thailand	45.9	6
Timor-Leste	44.4	7
Taiwan	38.4	8
Singapore	35.0	9
South Korea	32.8	10
Indonesia	30.7	11
Kiribati	30.5	12
Malaysia	28.0	13
Samoa	25.6	14
Viet Nam	24.8	15
Philippines	24.6	16
Myanmar	23.0	17
Papua New Guinea	19.8	18
Vanuatu	18.1	19
Fiji	17.0	20
Tonga	15.7	21
Solomon Islands	13.2	22
Marshall Islands	12.6	23
China*	9.5	24
Micronesia	4.4	25

Sub-Saharan Africa		
Country	Score	Rank
Botswana	85.6	1
Zambia	83.7	2
Burkina Faso	73.3	3
Republic of Congo	71.6	4
Central African Republic	71.5	5
Zimbabwe	70.2	6
Niger	69.9	7
Namibia	69.5	8
Malawi	68.1	9
Tanzania	65.3	10
Gabon	64.0	11
Benin	63.9	12
Guinea	61.0	13
Chad	60.3	14
Lesotho	59.1	15
Mozambique	57.1	16
Senegal	56.5	17
Côte d'Ivoire	56.2	18
Togo	54.8	19
Guinea-Bissau	53.8	20
Dem. Rep. Congo	52.0	21
Uganda	51.9	22
Burundi	51.6	23
Mali	51.0	24
Seychelles	50.5	25
Rwanda	49.9	26
Comoros	49.0	27
Nigeria	47.1	28
Ethiopia	45.8	29
Equatorial Guinea	45.3	30
Sierra Leone	45.3	30
Cameroon	45.2	32
Ghana	45.0	33
Kenya	43.8	34
Angola	41.5	35
South Africa	39.5	36
Gambia	38.3	37
Mauritania	36.2	38
São Tomé and Príncipe	33.2	39
Eswatini	29.8	40
Madagascar	26.4	41
Liberia	25.7	42
Cabo Verde	19.2	43
Djibouti	17.5	44
Eritrea	16.6	45
Mauritius	13.4	46

Greater Middle East		
Country	Score	Rank
United Arab Emirates	59.0	1
Oman	56.2	2
Kuwait	50.5	3
Qatar	50.1	4
Egypt	47.5	5
Saudi Arabia	45.4	6
Iran	42.8	7
Sudan	39.2	8
Tunisia	38.1	9
Algeria	33.0	10
Jordan	32.8	11
Morocco	30.1	12
Israel	29.6	13
Bahrain	25.8	14
Lebanon	23.6	15
Iraq	20.0	16

* these countries restrict public access the vast majority of their protected area data on the WDPA, so their scores underestimate their actual performance

3. Global Trends

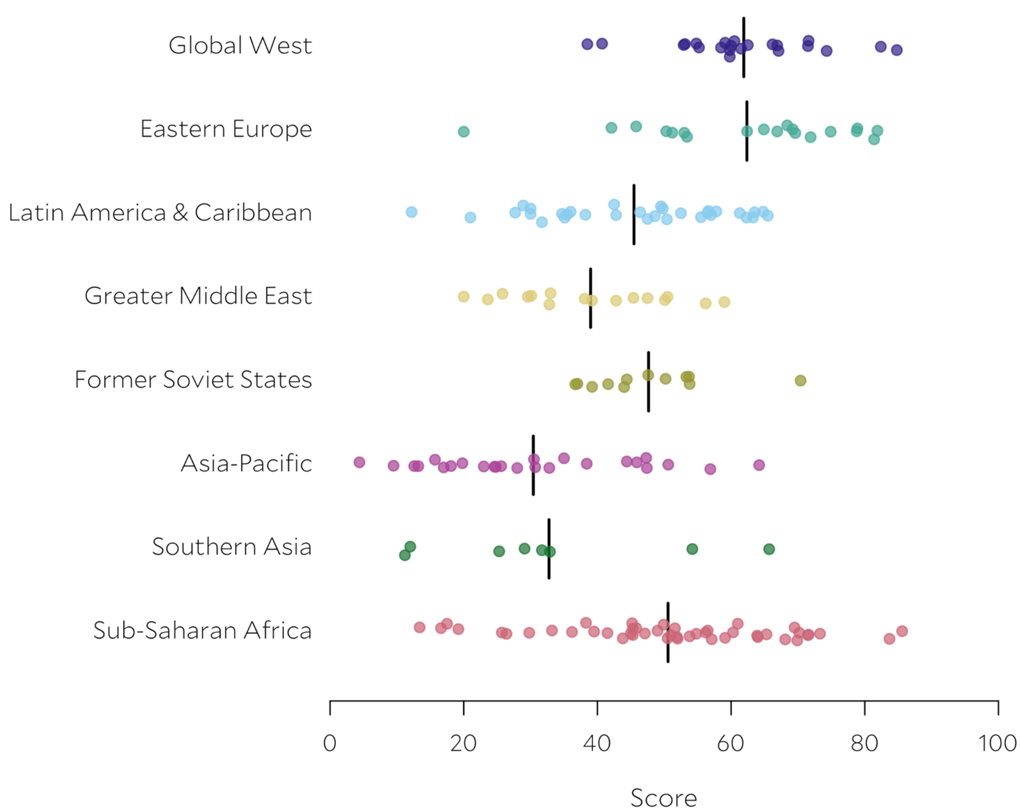
Across most of the world, nature is in decline (Díaz et al. 2019). Over the last three decades, the world has lost more than 10 percent of its wilderness areas, with particularly pronounced losses in the Amazon and central Africa (Watson et al. 2016). The wilderness that remains is poorly protected despite its importance for avoiding further species extinctions (Di Marco et al. 2019). Less than a quarter of the world's rivers over 1000 km flow uninterrupted to the ocean (Grill et al. 2019), and over one million kilometers of the global river network carries wastewater, often poorly treated (Ehalt Macedo et al. 2022). In the oceans, no place is free of human impacts, either from fishing, chemical and noise pollution, or climate change (Halpern et al. 2008). Coral reefs, the most biodiverse marine ecosystems, are also among the most threatened. After a whole year of record-breaking surface ocean temperatures (Erdenesanaa 2024), 2024 witnessed the 4th mass coral bleaching event (NOAA 2024). Without drastic climate mitigation efforts to keep warming below 1.5ºC, most coral reefs are likely to be lost by the end of the century (Frieler et al. 2013).

However, even necessary and well-intended efforts to mitigate climate change can negatively affect ecosystems and biodiversity. Offshore wind projects are growing rapidly, adding pressure on coastal areas (Paolo et al. 2024). On land, wind, photovoltaic, and hydropower projects can contribute to the degradation of important biodiversity areas (Rehbein et al. 2020), as does mining for minerals essential for the energy transition (Sonter et al. 2020). To alleviate mining pressures on land, some propose to start mining the deep sea, but this would threaten one of the last relatively pristine corners of the planet (Heffernan 2019).

As a result of these widespread human impacts, close to one million species of animals and plants are threatened with extinction (Díaz et al. 2019). Over the last half-century, the abundance of wildlife populations has plummeted by nearly 70 percent worldwide and 94 percent in Latin America (WWF 2022) (Living Planet Report 2022). Even in remote protected areas in the heart of the Amazon, bird populations have declined in recent decades (Blake and Loiselle 2024). Humans and their livestock now outweigh all wild terrestrial mammals combined more than 50 times (Greenspoon et al. 2023).

Countries are stepping up their conservation efforts to halt and reverse these alarming trends of biodiversity loss. Globally, 17 percent of land and 8 percent of the ocean are under some type of protection, according to the World Database on Protected Areas (WDPA). While that is still far from the 30x30 target, 28 countries and territories, most of them in Europe and Africa, have already protected more than 30 percent of their land (Table 13-3). Seven countries have implemented protected areas in more than 30 percent of their Exclusive Economic Zones (EEZ) (Table 13-4). Many Asian countries, home to dense populations and rapidly expanding croplands

Figure 13-1. Distribution of regional scores on Biodiversity & Habitat. Vertical bars show regional averages.



(Molotoks et al. 2018), have lagged behind peers from other regions in expanding their protected areas (Farhadinia et al. 2022). Unless they dramatically accelerate the designation of protected areas, these countries are unlikely to meet the 30x30 target.

Table 13-3. Countries and territories that have protected at least 30 percent of their land without accounting for Other Area-Based Conservation Measures and indigenous lands, according to the WDPA (May 2024 version).

Country	% of land protected
New Caledonia	59.7
Venezuela	56.9
Luxembourg	55.8
Bhutan	49.7
Brunei Darussalam	46.9
Liechtenstein	42.6
Hong Kong	41.9
Zambia	41.3
Greenland	41.1
Bulgaria	41.0
Slovenia	40.4
Namibia	39.9
Tanzania	39.9
Cambodia	39.7
Poland	39.6
Cyprus	38.7
Croatia	38.5
Belize	37.6
Germany	37.6
Guinea	37.6
Slovakia	37.6
Republic of Congo	36.8
Greece	35.2
New Zealand	33.4
Bolivia	30.9
Brazil	30.6
Malta	30.6
Trinidad and Tobago	30.6

Table 13-4. Countries in which implemented protected areas cover at least 30 percent of the exclusive economic zone, according to the Marine Protection Atlas (2024-04-26 update).

Country	% protected
Monaco	>99
Palau*	97
United Kingdom*	56
Kazakhstan	49
Australia	45
Argentina	43
France	32

*More than 30% of EEZ is highly or fully protected.

Expanding protected areas to meet the 30 x 30 target would have major benefits for biodiversity (e.g., protecting more than one thousand vertebrates that currently lack any protection), and ecosystem services (Zeng, Koh, and Wilcove 2022). But some scientists call for even more ambitious conservation goals (Wilson 2016). Protecting nearly half of global land could provide 90 percent of current ecosystem services, but it will be challenging because more than one-third of critical conservation areas are also highly suitable for agriculture, renewable energy, oil and gas, mining, and urban expansion (Neugarten et al. 2024).

Despite progress toward protecting 30 percent of land and seas, EPI analyses show that in 23 countries, more than 10 percent of the land protected is covered by croplands and buildings, and in 35 countries, there is more fishing effort inside marine protected areas than outside. In many protected areas, especially in Africa, deforestation continues, sometimes at higher rates than in similar areas without official protection (Wolf et al. 2021). A recent study found that in most countries, protected areas lack the rangers and other personnel required to enforce protection and proper management (Appleton et al. 2022). Involving local and indigenous communities in efforts to conserve biodiversity can help improve the effectiveness of protected areas (Garnett et al. 2018). Across the tropics, deforestation rates in areas managed by indigenous people are as low as in officially protected areas, and in Africa, they are lower (Sze et al. 2022).

Sometimes, the problem is not a lack of enforcement, but that destructive activities *are* allowed inside protected areas. For example, while the world has protected 8 percent of the ocean, less than 3 percent is highly or fully protected (Marine Conservation Institute 2024). In Europe, marine protected areas (MPAs) cover approximately 30 percent of territorial waters, but the majority are trawled more intensely than non-protected areas, leading to substantial declines in the abundance of sensitive species such as sharks and rays (Dureuil et al. 2018). Greece is the first European country to announce plans to ban bottom trawling from all protected areas (McVeigh and Smith 2024). But even in areas closed to trawling in the Mediterranean Sea, illegal fishing is common (Poortvliet 2022).

Powerful lobbies from the fishing industry commonly oppose initiatives to enforce full protection within MPAs, fearing a reduction in catches and revenue (Early 2024). But the creation of Revillagigedo National Park, the largest fully protected MPA in North America, did not affect the catches of industrial fishers (Favoretto et al. 2023), nor did the creation of U.S. National Monuments in the Pacific Ocean, two of the largest MPAs in the world (Lynham et al. 2020). Indeed, by allowing fish stocks to recover and thrive, MPAs often benefit fisheries (C. M. Roberts et al. 2001; Bucaram et al. 2018; Lenihan et al. 2021).

Protected areas are fixed in space but, under climate change, the spatial distribution of species and biomes is not (Elsen et al. 2020; Dobrowski et al. 2021). Many species cannot migrate fast enough to keep up with shifting climates, and widespread land use change and habitat fragmentation further constrain their migration and ability to persist (Asamoah, Beaumont, and Maina 2021). In 87 percent of the world's ecoregions, there is not enough area of intact habitats likely to remain climatically stable to achieve area-based conservation goals (Dobrowski et al. 2021). Explicitly considering the shifting distribution of biodiversity under climate change when designing protected area networks is, therefore, key to minimizing the risk of climate-driven extinctions. Many European and African countries score poorly in the 2024 EPI's pilot indicator of Bioclimatic Ecosystem Resilience. These countries should prioritize ecosystem restoration efforts to create corridors that facilitate species migrations as climate continues to change.

4. Leaders and Laggards

Botswana leads the world in the 2024 EPI Biodiversity and Habitat indicators. The country's protected areas cover 29 percent of its territory, almost achieving the 30x30 target with more than five years still to go. Botswana's protected areas are strategically placed to represent most of the country's biomes, ecosystems, and species, earning the country high scores across a suite of EPI biodiversity indicators. While some Key Biodiversity Areas still lack protection, the country's species and ecosystems are generally well conserved, which is reflected in high scores in the *Species Habitat Index* and the *Red List Index*. Botswana has achieved both economic development and biodiversity conservation through its support of community-based ecotourism (Maude and Reading 2010; Mbaiwa 2015).

Zambia, Botswana's northern neighbor, is also a leader in biodiversity conservation, ranked 3rd worldwide. Zambia has protected over 40 percent of its land, and the country's species and biomes are well represented in protected areas. Zambia's population density, however, is over five times higher than Botswana's, which has contributed to higher ecosystem degradation outside protected areas — reflected in lower *Red List Index* and *Species Habitat Index* scores. Zambia's protected areas also suffer from underfunding, lack of benefit sharing with local communities, corruption, and poor governance, among other problems, all of which have contributed to large reductions in wildlife densities in most protected areas (Lindsey et al. 2014). Ongoing problems of cropland and human settlement encroachment in Zambian protected areas are reflected in a relatively low score (54, rank 100th) in the pilot indicator of *Protected Area Effectiveness*. Increasing the participation of local communities in the management of protected areas, as well as addressing human-wildlife conflicts, can help Zambia reap more economic and conservation benefits from its expansive protected area network (Bwalya Umar and Kapembwa 2020).

Luxembourg and Germany lead the Global West in biodiversity conservation, having protected nearly 56 and 38 percent of their land, respectively. A substantial fraction of this protected land (26 percent in Germany and 30 percent in Luxembourg), however, is covered by cropland and buildings, resulting in low scores in the pilot *Cropland and Buildings in Protected Areas* indicator. In contrast, cropland and buildings cover less than 6 percent of Slovakia's protected areas, which extend over 37 percent of the country's land. Germany has also protected over 45 percent of its EEZ, but as in other European countries (Dureuil et al. 2018), destructive fishing practices such as bottom trawling are allowed inside protected areas. Indeed, the pilot indicator of *Marine Protection Stringency* estimates that fishing effort in German MPAs is nearly two times higher than in unprotected areas of its EEZ.

Nicaragua is another example of a country with large, strategically placed protected areas that are nonetheless failing to halt biodiversity and habitat loss. In 2024, terrestrial protected areas in Nicaragua covered over 21 percent of the country's territory and over 90 percent of its Key Biodiversity Areas. And while marine protected areas cover only over 3 percent of the country's EEZ, they protect 97 percent of its marine and coastal Key Biodiversity Area, such as Cayos Miskitos on the northeastern coast of the country. But many of Nicaragua's protected areas are ineffective. In recent years, there has been rampant deforestation inside protected areas, such as in the Indio Maiz and Bosawás nature reserves (Radwin 2023), and the country has one of the highest rates of primary tropical forest loss in the world (see Chapter 12). The failure of Nicaragua's protected areas to halt biodiversity loss is reflected in its low scores on the Red List Index (40.9, rank 117th) and the Species Habitat Index (0, rank 138th).

Nicaragua's neighbor, Costa Rica, has been long recognized for its commitment to biodiversity conservation (Andrews 2023). The country is close to achieving its 30x30 goals, with nearly 26 and 29 percent of lands and seas under protection, respectively, in 2024. Despite their extent, however, Costa Rica's protected areas leave a large fraction of species, important habitats, and Key Biodiversity Areas unprotected. Other countries in Latin America have similar problems. For example, Chile has made impressive progress in protecting over 40 percent of its EEZ through the creation of large and remote marine protected areas, such as Nazca-Desventuradas and Mar Juan de Fernández. But the coast of Chile, where many important habitats occur, remains largely unprotected. Peru also lags in marine protection despite its recent efforts to create new MPAs. A large fraction of its key marine and coastal habitats remain unprotected. And its few marine protected areas are not highly protected, scoring poorly in our pilot *Marine Protection Stringency* indicator. Conservation organizations have criticized the Peruvian government's decision to allow industrial fishing and deep-sea cod fishing in its recently created Nazca Ridge Nature Reserve (Sierra Praeli 2021).

Oman recently created several large, protected areas, making it the country with the largest improvement in the EPI's biodiversity indicators over the last decade. Oman also earns high scores in indicators of protected area stringency and effectiveness, as well as in indicators measuring the overall state of biodiversity both inside and outside protected areas. To maintain this progress, Oman must commit to the long-term preservation of its newly created reserves. In many countries, the degazetting, downgrading, and downsizing of protected areas threaten the aim of long-term preservation of biodiversity (Golden Kroner et al. 2019). For example, in 2007, Oman downsized the Arabian Oryx Sanctuary (today called Al Wusta Wildlife Reserve) by 90 percent after discovering oil in the area

(Qin et al. 2019). This downsizing, which led UNESCO to remove the Arabian Oryx Sanctuary from its World Heritage List, highlights the tensions between biodiversity conservation and economic development (Neugarten et al. 2024). Still, Oman's conservation efforts have contributed to the recovery of the Arabian Oryx, which was once extinct in the wild. Today, despite ongoing poaching, approximately 650 Oryx live in the Al Wusta Wildlife Reserve (Al Rawahi et al. 2022).

Bhutan is a notable outlier among its lagging peers in Southern Asia. Bhutan has protected half of its territory and gets a perfect score in the pilot indicator of *Protected Area Effectiveness*. Bhutan has prioritized environmental conservation and pioneered policies to ensure the effective management of its protected areas. In partnership with the World Wildlife Foundation, the government of Bhutan introduced the Bhutan for Life initiative, securing long-term funding to support the management of its protected areas (Schwartz 2017). Bhutan's partnership with international aid organizations to finance conservation and development projects has been key to its success (Devkota et al. 2023).

In contrast to Bhutan's expansive protected area network, Bangladesh has protected less than 5 percent of its land. And the little that is protected continues to lose forest, sometimes at higher rates than surrounding, non-protected areas (Rahman and Islam 2021; Ullah et al. 2022). In some protected areas, local communities contribute to deforestation, while in others, the main threats are state-sponsored projects (Al Hasnat 2023).

India's position near the bottom of the Biodiversity & Habitat ranking is likely an underestimation of the country's conservation efforts. For unclear reasons, India, along with Türkiye and China, decided to restrict public access to over 95 percent of the protected area data submitted to the World Database of Protected Areas (WDPA). This lack of transparency aggravates the underreporting of data from many Asian countries to the WDPA (Farhadinia et al. 2022). But even after complementing the WDPA with data from local sources, a recent study estimated that the coverage of Indian protected areas in 2020 was only 6 percent, substantially lagging most of its neighbors (Farhadinia et al. 2022). While the coverage of protected areas is low, accounting for other effective area-based conservation measures (OECMs) could allow India to achieve the target of 30 percent protection of its land by 2030 (Sengupta et al. 2024). But even with OECMs, achieving connectivity, representativeness, and effectiveness targets will prove challenging.

China's position close to the bottom of the ranking is due in part to the restriction of public access to data on its protected areas through the WDPA. The WDPA reports, without making the underlying data available, that China's protected areas cover 15.6 and 5.5 percent of its land and seas, respectively. Other sources report 18 percent coverage of terrestrial protected areas (Wei et al. 2021). For China's marine protected areas, the only publicly available dataset was compiled by Bohorquez et al. (2021), but the lack of detailed spatial information on protected areas' location precludes their inclusion in the EPI's analyses. Therefore, China's score in the EPI's biodiversity indicators likely underestimates the level of protection of China's marine biodiversity. We urge the Chinese government to compile and make available a dataset of its protected areas to enable robust scientific research and the proper recognition of their efforts to protect biodiversity. Bohorquez et al.'s (2021) analyses show that, while shallow marine habitats near the coast are generally well protected, ecosystems in deeper waters are not (especially underwater canyons and seamounts). China's MPAs cover less than 10 percent of the most important habitats for the country's 218 species of marine megafauna, nearly half of which are globally threatened (Li et al. 2023). Despite these conservation gaps, the creation of new MPAs in China has slowed down since 2008 (Hu et al. 2020), highlighting the need for the Chinese government to redouble its efforts to meet the targets of the Kunming-Montreal Global Biodiversity Framework (Zhou et al. 2021).

Island states are overrepresented near the bottom of the 2024 EPI Biodiversity ranking. Having evolved in isolation, island biodiversity is more vulnerable to the impacts of invasive species (Russell and Kueffer 2019). Island species make up nearly two-thirds of confirmed extinctions (Tershy et al. 2015). Small island states also have limited land, which makes the proportional impacts of habitat loss more severe and the task of balancing conservation with other development priorities more difficult (Russell and Kueffer 2019). For example, Barbados has protected just over 1 percent of its land, despite having strong environmental policies and being a leader in climate change mitigation and adaptation. Island nations can maximize biodiversity gains by prioritizing the conservation of endemic species habitats. Also, campaigns to eradicate invasive species from islands, though challenging and expensive, can yield large conservation benefits (H. P. Jones et al. 2016).

5. Methods

The 2024 EPI biodiversity indicators can help track progress toward several 2030 targets of the Kunming-Montreal Global Biodiversity Framework (*https://www.cbd.int/gbf/targets*):

- Target 1: "Ensure that all areas are under participatory, integrated and biodiversity inclusive spatial planning and/or effective management processes addressing land- and sea-use change, to bring the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, close to zero by 2030, while respecting the rights of indigenous peoples and local communities."
- Target 3: "Ensure and enable that by 2030 at least 30 percent of terrestrial and inland water areas, and of marine and coastal areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed

through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures, recognizing indigenous and traditional territories, where applicable, and integrated into wider landscapes, seascapes and the ocean, while ensuring that any sustainable use, where appropriate in such areas, is fully consistent with conservation outcomes, recognizing and respecting the rights of indigenous peoples and local communities, including over their traditional territories."

- Target 4: "Ensure urgent management actions to halt human induced extinction of known threatened species and for the recovery and conservation of species, in particular threatened species, to significantly reduce extinction risk, as well as to maintain and restore the genetic diversity within and between populations of native, wild and domesticated species to maintain their adaptive potential, including through in situ and ex situ conservation and sustainable management practices, and effectively manage human-wildlife interactions to minimize human-wildlife conflict for coexistence."

- Target 8: "Minimize the impact of climate change and ocean acidification on biodiversity and increase its resilience through mitigation, adaptation, and disaster risk reduction actions, including through nature-based solutions and/or ecosystem-based approaches, while minimizing negative and fostering positive impacts of climate action on biodiversity."

The 2024 EPI includes eight indicators based on countries' protected areas that are directly relevant to different aspects of Target 3. Going beyond simply measuring the percentage of land or seas covered, the *Terrestrial Biomes Protection* indicator, the *Protected Area Representativeness Index*, and the *Species Protection Index* help assess whether countries' protected areas are *representative* of the full range of biodiversity in a country at different scales of organization, from biomes to ecological communities and endemic species. The *Marine* and *Terrestrial Key Biodiversity Area Protection* and *the Marine and Coastal Habitat Protection* measure whether areas of particular importance to biodiversity and ecosystem functions and services are protected. The pilot indicators of *Marine Protection Stringency*, *Protected Area Effectiveness*, and *Cropland and Buildings in Protected Areas* help assess whether protected areas are *effectively* conserved and managed, as well as whether activities inside protected areas are *fully consistent* with conservation outcomes.

Halting the biodiversity crisis requires conservation efforts both inside and outside of protected areas. The *Species Habitat Index* helps assess the rate of loss of suitable habitats for a country's biodiversity, and thus can inform on progress toward Target 1. The *Species Habitat Index* and the *Red List Index* are directly relevant to Target 4, since they serve as proxies for the general extinction risk of a country's species.

Finally, the pilot *Bioclimatic Ecosystem Resilience Index* assesses the capacity of landscapes within a country to retain biodiversity as species shift their distributions under climate change. This indicator informs Target 8 by helping guide conservation and restoration efforts to increase the integrity and connectivity of a country's habitats, thereby increasing their resilience to climate impacts.

Terrestrial Biome Protection

The *Terrestrial Biome Protection* indicator measures countries' progress toward the protection of 30 percent of the planet's 14 terrestrial and freshwater biomes.

Indicator Background

We first calculated the percentage of each country's biomes covered by protected areas. We capped protection percentages at 30 percent so that values higher than 30 in one biome did not offset lower values in other biomes. Then, we calculated a weighted sum of the protection percentages for all biomes within that country. Protection percentages are weighted according to the prevalence of each biome type within that country. This indicator evaluates a country's efforts to achieve 30 percent protection for all biomes within its borders.

Data Sources

Spatial data on terrestrial protected areas come from the March 2024 release of the World Database on Protected Areas (WDPA), a joint initiative of UNEP's World Conservation Monitoring Centre (WCMC) and the International Union for Conservation of Nature (IUCN). The WDPA contains data on over 290,000 protected areas in 244 countries and territories. The WDPA is updated monthly and is publicly available on its free online platform, https://www.protectedplanet.net/.

Biome boundary data come from the World Wildlife Fund's "Terrestrial Ecoregions of the World" dataset (Olson et al. 2001). Country boundary data come from the Gridded Population of the World version 4.11 boundary file (CIESIN 2018).

Limitations

Biomes are coarse units of biological organization that do not capture fine-scale variation in species assemblages. The 14 biomes defined by Olson et al. (2001) can be further subdivided into 867 ecoregions, which other studies have used to assess progress toward area-based protection targets (Dinerstein et al. 2017). Rather than doing that, the EPI team uses biomes to provide a broad overview of the representativeness of countries' protected areas and includes other indicators that offer a more fine-grain view, such as the *Species Protection Index* and the *Protected Area Representativeness Index*.

Protected Area Representativeness Index

The *Protected Area Representativeness Index* (PARI) assesses whether protected areas adequately represent the ecological diversity of a country. Often, governments establish protected areas in places of low value for agriculture and other land uses rather than where they maximize biodiversity representation (Venter et al. 2018).

Indicator Background

The PARI calculation starts with a global grid of environmental variables (such as climate, terrain, and soils) at a 30-arcsecond (approximately 1 km) spatial resolution. By combining this environmental information with species occurrence records, the PARI then models the ecological composition of each grid cell. Then, for each cell, the PARI calculates the proportion of all ecologically similar cells that are under protection. Finally, the geometric mean of proportional protection values for all cells within a country's borders corresponds to that country's PARI score (ranging between 0 and 1). Hoskins et al. (2020) describes the general modeling approach, and further details about PARI's calculation are available at: *https://www.bipindicators.net/indicators/protected-area-representativeness-index-parc-representativeness*

Data Sources

The Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia's national science agency, calculates the *Protected Area Representativeness Index*. CSIRO used protected area boundary data from the March 2024 release of the WDPA. In the calculation of PARI, CSIRO used climate data from WorldClim (*https://www.worldclim.org/*), soil data from SoilGrids (*https://www.soilgrids.org/*), and other environmental data from EarthEnv (*https://www.earthenv.org/*). Species occurrence records for birds, mammals, and amphibians come from the Map of Life project (*https://mol.org/*), while records for vascular plants, invertebrates, and other terrestrial vertebrates come from the Global Biodiversity Information Facility (*https://www.gbif.org/*).

Limitations

PARI values are derived from modeling the ecological similarity of different locations across the Earth's surface, which involves uncertainty. Spatial biases in species occurrence records can lead to inaccurate models of species distributions and ecological similarity due to national differences in funding and data reporting (Beck et al. 2014).

Species Protection Index

The *Species Protection Index* (SPI) measures how well a country's protected areas cover the habitat needed for its species to survive. This indicator is a useful complement to measurements of the extent of countries' protected areas, as it helps ensure that protected areas contribute to species protection on national and global scales (Jetz et al. 2022).

Indicator Background

National SPI values are the average of a country's Species Protection Scores (SPS). SPS quantifies how much of a species' range is protected relative to the fraction of its range necessary for the species to thrive. While it is hard to estimate how much range protection is needed to assure the survival of different species, the SPS calculations assume that species with small ranges require a larger fraction than common, widespread species. The SPS calculations allocate the responsibility for species conservation equitably among countries. For example, if a species requires half of its range to be protected at the global level, each country needs to protect half of the species' range within its borders to achieve a perfect national SPS score. A country's SPI value is the average of SPS values for all country's species, weighted by the fraction of each species' range occurring within the country. As such, country-endemic species weigh the most.

Data Sources

Map of Life produces the SPI and national values, and methodological details are available at *https://mol.org/*. Map of Life models species' ranges based on literature- and expert-based information on habitat restrictions and satellite land-cover and environmental data. Map of Life includes species range maps for more than 30 thousand species of plants and animals, which are calibrated with more than 350 million location records. Protected area boundary data come from the January 2024 release of the WDPA. Country boundary data come from the Global Administrative Areas database, GADM, version 3.6 (*https://gadm.org/*).

Limitations

As with PARI, SPI values are based on uncertain models of species ranges, which are affected by spatial bias in available species occurrence data. Also, as with all other indicators based on coverage of protected areas, that a species range falls within a protected area does not guarantee that the species is effectively protected.

Key Biodiversity Area Protection

Key Biodiversity Areas (KBAs) are places of particular importance for the persistence of biodiversity. A place can be designated as a KBA according to criteria encompassing different levels of biodiversity, from genetic diversity to species and ecosystems (IUCN 2022). Some KBAs contribute to the global persistence of threatened species or ecosystems. Others host species found in few other places. Some KBAs serve as ecological refugia and enable other important biological processes. Yet others are ecosystems of high integrity or irreplaceable attributes. All are conservation priorities.

Indicator Background

The *Terrestrial Key Biodiversity Area Protection* indicator measures the percentage of all the areas designated as a KBA within a country's territory that falls within protected areas. The *Marine Key Biodiversity Area Protection* indicator is the same but for KBAs within a country's Exclusive Economic Zone (EEZ).

Data Sources

The World Database of Key Biodiversity Areas is updated twice per year. The 2024 EPI indicators use the September 2018 version, which includes more than 16,000 KBAs contributing to the conservation of more than 13,100 species (BirdLife International 2023). Protected area boundaries come from the March 2024 release of the WDPA.

Limitations

The KBA dataset is constantly expanded and refined, and it still does not include all important areas for biodiversity. Also, coverage by a protected area does not guarantee effective conservation. All indicators based on protected area coverage must be complemented with indicators of protected area effectiveness and direct metrics of the state of ecosystems and species populations.

Marine and Coastal Habitat Protection

Marine biodiversity is not distributed homogeneously across countries' seas (Selig et al. 2014). Some habitat types have disproportionate value for biodiversity conservation and the provisioning of ecosystem services. In tropical coastal areas, mangroves, seagrass meadows, and coral reefs offer essential habitats for species at different stages of their life cycle (Honda et al. 2013). In combination, these three habitat types also provide coastal communities with enhanced protection from storms (Guannel et al. 2016). Mangroves, seagrasses, and salt marshes — known as "blue carbon" ecosystems — are also exceptionally valuable for carbon sequestration (Macreadie et al. 2021). In the open ocean, seamounts are biodiversity hotspots (Morato et al. 2010), as are cold-water corals in the deep ocean (J. M. Roberts, Wheeler, and Freiwald 2006). When establishing marine protected areas, countries should prioritize the conservation of these invaluable ecosystems (Kumagai et al. 2022).

Indicator Background

The *Marine and Coastal Habitat Protection* indicator follows the methodology of the Local Proportion of Habitats Protected Index developed by Kumegai et al. (2022). The indicator uses maps of the distribution of six important marine and coastal habitats: coral reefs, seagrasses, mangroves, saltmarshes, cold corals, and seamounts and knolls. Scores are based on the proportion of the extent of important habitats within a country's exclusive economic zone that is covered by marine protected areas.

Data Sources

Maps of marine and coastal habitats come from the Ocean Data Viewer, a platform managed by the United Nations Environmental Program (UNEP) and the World Conservation Monitoring Center (WCMC). The Ocean Data Viewer compiles habitat maps from a variety of sources. Cold coral maps are from Freiwald et al.'s (2018) dataset; warm-water coral maps come from UNEP-WCMC et al. (2018); knolls and seamounts from Yesson et al. (2011); mangroves from Bunting et al. (2018); saltmarshes from Mcowen et al. (2017), and seagrasses from (UNEP-WCMC and Short 2020). EEZ boundaries come from the Glanders Marine Institute's Maritime Boundaries Database. Protected area boundaries come from the March 2024 release of the WDPA.

Limitations

There are still gaps in our knowledge of the spatial distribution of marine habitats, deep-sea habitats like seamounts (Gevorgian et al. 2023), and cold corals (Lim, Wheeler, and Conti 2021). And, as with all protected area indicators, coverage does not guarantee effective protection.

Marine Protection Stringency

While marine protected areas (MPAs) cover 8 percent of the ocean, less than 3 percent is highly or fully protected (Marine Conservation Institute 2024). The 2024 EPI introduces a pilot indicator that compares fishing effort inside and outside MPAs as a proxy of *Marine Protection Stringency*.

Indicator Background

The *Marine Protection Stringency* indicator is based on a global spatial dataset of daily fishing effort at a 0.01º-degree resolution. The dataset reports hours of fishing effort using different fishing gears. We excluded pole-and-line fishing and "pots and traps" as these fishing gears are typical of small-scale and artisanal fishers and have a much smaller impact on marine ecosystems per hour than other types of gear. For all other gear types, we summed daily fishing effort values to get annual totals. Then, we added all fishing effort inside MPAs in a country's EEZ and divided that by the total area of the MPAs, obtaining a measurement of the total annual fishing effort per unit area. We did the same across unprotected areas of the country's EEZ. Finally, we calculated the ratio of fishing effort inside MPAs to fishing effort outside MPAs. An indicator score of 50 indicates that fishing effort is the same inside and outside MPAs. A score of 100 means that fishing effort is 100 times lower inside MPAs than outside, while a score of 0 means the opposite.

Data Sources

Fishing effort data come from the Global Fishing Watch and it is based on tracking fishing boats with automatic identification systems (AIS) (Kroodsma et al. 2018). Researchers from Global Fishing Watch used 22 billion AIS positions to train two convolutional neural networks: one to predict vessel characteristics and the other one to identify fishing activity. The dataset is freely available after registration on the Global Fishing Watch's website: *https://globalfishingwatch.org/*. EEZ boundaries come from the Glanders Marine Institute's Maritime Boundaries Database. Protected area boundaries come from the March 2024 release of the WDPA.

Limitations

Tracking fishing effort using AIS data is a powerful approach to assessing global fishing activity, but it offers an incomplete picture. Fishing vessels sometimes deactivate their AIS devices before entering areas to engage in illegal fishing (Welch et al. 2022). Also, the fraction of industrial fishing ships publicly tracked with AIS varies across regions and is highest in Europe (Paolo et al. 2024).

A sole focus on fishing activity also offers an incomplete picture of marine protection stringency and potential biodiversity outcomes. The MPA Guide (*https://mpa-guide.protectedplanet.net/*) offers a more general framework to assess the quality of the marine protected areas. The MPA Guide classifies protected areas according to their level of protection, stage of establishment, enabling conditions, and expected outcomes. While assessments based on the MPA Guide are not available for all marine protected areas, a recent study assessed the world's 100 largest MPAs (which together account for nearly 90 percent of global MPA coverage) and found that one-quarter of the assessed MPA coverage is not implemented and one third is incompatible with nature conservation (Pike et al. 2024).

Land cover and land-cover change in protected areas

Establishing protected areas does not guarantee effective, long-term protection of biodiversity and habitats. Around one-third of global protected land is under intense human pressure (K. R. Jones et al. 2018). Protected areas around the world continue to lose forest (Wolf et al. 2021), and both croplands (Vijay and Armsworth 2021) and human settlements (Guan et al. 2021) are common inside protected areas. As proxies of protected areas' effectiveness, the 2024 EPI harnesses recent developments in remote sensing and machine learning to develop pilot indicators of human land cover and its dynamics inside protected areas.

Indicator Background

For more than 42,000 protected areas around the world, we used global maps of land cover at a 10-m resolution to quantify the fraction covered by croplands and the fraction covered by the built environment in 2017 and 2022.

The *Croplands and Buildings in Protected Areas* indicator measures the fraction of all the land protected in a country that was covered by croplands and buildings in 2022 and thus contributes little to the conservation of natural ecosystems.

Some protected areas, such as "Protected Landscapes" (IUCN category V), allow a mix of uses, including sustainable agriculture and permanent human settlements (Dudley et al. 2010). However, the rapid growth of these types of human land cover could signal that a protected area is failing to effectively protect its natural habitats. Hence, the *Protected Area Effectiveness* pilot indicator measures the percentage of protected areas in a country in which the *growth* of croplands and buildings between 2017 and 2022 covered more than 2.5 percent of the protected area.

Data Sources

Assessments of land cover change in protected areas use the DynamicWorld v1 dataset, a near real-time land use and land cover map at a 10-m resolution (Brown et al. 2022). Dynamic World uses artificial intelligence algorithms to automatically classify Sentinel-2 satellite imagery into nine classes: water, trees, grass, crops, shrub and scrub, flooded vegetation, built-up area, bare ground, and snow and ice. Protected area boundaries come from the WDPA.

Limitations

DynamicWorld offers a global land cover classification of unprecedented temporal and spatial resolution. But it is not perfect. The classification algorithm tends to be more accurate in temperate and tree-dominated biomes than in arid shrublands and rangelands, where it often confuses crops with shrubs (Brown et al. 2022). These classification errors can introduce biases and inaccuracies in our estimates of land cover change in protected areas in different countries.

By focusing only on land cover types of clear human origin (buildings and croplands), the indicators are only a conservative estimate of ecosystem loss and degradation within protected areas.

Red List Index

Target 4 of the Kunming-Montreal Global Biodiversity Framework calls for a halt to species extinctions and a reduction of extinction risk by 2030. The *Red List Index* tracks progress toward that target.

Indicator Background

The IUCN's Red List of Threatened Species assesses the conservation status of plants and animals (Rodrigues et al. 2006). Species' status on the Red List can change because their extinction risk changes or because of changes in knowledge about the state of their populations and the threats to their survival. The *Red List Index* tracks changes in the genuine conservation status of groups of species by accounting for changes in available knowledge (IUCN 2024). The index is available for five taxonomic groups in which all species have been assessed at least twice: birds, mammals, amphibians, warm-water reef-forming corals, and cycads. A country's *Red List Index* value measures its contribution to changes in the conservation status of the assessed species, weighting species by the fraction of their distribution occurring within the country (Rodrigues et al. 2014). Further details are available at: *https://unstats.un.org/sdgs/metadata/files/Metadata-15-05-01.pdf*.

Data Sources

The International Union for Conservation of Nature (IUCN) and BirdLife International compute and report the *Red List Index*. National agencies — including governmental, non-governmental organizations, and academic institutions — gather data from published and unpublished sources, experts, scientists, and conservationists and submit it to the IUCN or its partner organizations (*https://www.iucnredlist.org/about/partners*).

Limitations

The *Red List Index* is based on a limited number of species for which repeated assessments of conservation status are available. These species are a small fraction of the biodiversity of the planet, in part because assessing conservation status is challenging and involves uncertainties. Data availability varies across taxonomic groups. For example, while data to assess conservation status is available for almost all birds, a large fraction of amphibian species is data-deficient (Butchart and Bird 2010). Given that more data-deficient amphibians are likely to be threatened with extinction than other data-deficient groups (Borgelt et al. 2022), the heterogeneous availability of data could bias the picture of extinction risk trends offered by the *Red List Index*.

Since the *Red List Index* weights species according to the fraction of their range occurring within a specific region, countries rich in endemic species stand to lose more (Rodrigues et al. 2014). Also, a country's *Red List Index* can be affected by threats to species' persistence outside of a country's borders. Therefore, *Red List Index* scores do not always reflect the quality of a country's conservation policies.

Species Habitat Index

Habitat loss is the main driver of recent species extinctions (Jaureguiberry et al. 2022). The *Species Habitat Index* (SHI) measures changes in the extent of suitable habitat for a country's species.

Indicator Background

The first step in the SHI calculation is to measure, for each species, what fraction of suitable habitat remains intact within a country relative to a baseline set in 2001. A country's SHI is equal to the average fraction of habitat remaining intact for all species in the country, weighting species by the fraction of their global range found within the country. This weighting scheme encourages countries to prioritize the protection of endemic species' habitats.

Data Sources

The Map of Life project computes the SHI and makes it available on its website: *https://mol.org/indicators/habitat/background*. The index is based on habitat suitability maps for more than 30 thousand vertebrate species and select vascular plant groups. Maps of habitat suitability are modeled based on 1-km resolution satellite imagery, data from experts and the literature, and species occurrence records.

Limitations

The remote sensing data of land cover and land use change underpinning the SHI offer only a proxy for habitat suitability. Ecosystem degradation and threats to species populations cannot be fully characterized from space (Gao et al. 2020).

Since the SHI measures suitable habitat relative to a baseline set in 2001, countries that lost most of their species' habitats before that year may score better in the index than countries that suffered similar losses since then. While this focus on recent habitat loss is more relevant to assessing current conservation policies, it does not provide an absolute measure of the health of countries' biodiversity and habitats.

Bioclimatic Resilience Index

All the EPI indicators based on protected area coverage of biomes and species ranges, as well as the habitat suitability maps underpinning the *Species Habitat Index*, assume that species ranges and biomes are fixed in space. However, under climate change, the distribution of biodiversity around the world is shifting (Pecl et al. 2017). Habitat fragmentation makes it more difficult for species to migrate and keep up with a rapidly changing climate (Littlefield et al. 2019). To assess how the matrix of remaining suitable habitat in a country facilitates (or hampers) species migrations under climate change, the 2024 EPI introduces the *Bioclimatic Ecosystem Resilience Index* (BERI).

Indicator Background

The BERI is based on the global modeling of spatial changes in the composition of plant and animal communities under a plausible range of climate scenarios (Ferrier et al. 2020). BERI scores reflect how well connected each location is to areas of intact habitat in the surrounding landscape that are projected to support a similar composition of species in future climates. National scores are the aggregation of BERI values across countries' territories. For more details about the BERI, please see Ferrier et al. (2020).

Data Sources

The BERI was developed by researchers at CSIRO, and it is freely available online at: *https://data.csiro.au/collection/csiro:54238*. The 2024 EPI uses the BERI v2, a global dataset at 30-arcsecond resolution available for the years 2000, 2005, 2010, 2015, and 2020 (Harwood et al. 2022).

Limitations

All the input datasets used to calculate the BERI — such as estimates of connectedness, habitat suitability, and climate change projections — have associated uncertainty, which propagates through the modeling approach.

While the BERI can help track progress toward Target 8 of the Kunming-Montreal Global Biodiversity Framework, it only captures one aspect of ecosystem resilience. Moreover, the most recent estimates are from 2020, which only offers a baseline to track progress toward the 2030 target.

Weighting Rationale for Biodiversity & Habitat Indicators

The large weight of the Biodiversity & Habitat issue category (25 percent of the overall EPI) reflects the emergence of the biodiversity crisis as the most serious and irreversible environmental issue after climate change. The weight of the different indicators in the issue category corresponds to the recency and uncertainty of the underlying data, as well as the frequency and consistency of data updates. The pilot indicators of protected area effectiveness and stringency receive a lower weight while we wait for feedback from experts and the international scientific and policymaking community.

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Chapter 14. Methodology

1. Introduction

The Environmental Performance Index (EPI) is a composite indicator that synthesizes data on 58 key sustainability issues into a single metric of country-level performance. This chapter describes the steps we followed to construct the EPI: identifying and cleaning data, translating data into performance metrics, and aggregating individual metrics into an overall composite score.

A guiding principle of the EPI is to create metrics that are data-driven, analytically rigorous, transparent, reproducible, and easy to understand. While each of the issue category chapters of the report describes the methods and data sources behind specific indicators, this chapter focuses on the general processes behind the construction of the 2024 EPI and clarifies the assumptions behind its results. The online Technical Appendix — available for download from our website at epi.yale.edu — provides even further details on data sources and the specific calculations undergirding each indicator. Every step of the construction of the EPI results relies on open data and tools, and the code to reproduce each step of the analyses is also available for download from our website.

Every iteration of the EPI seeks to use the latest data and scientific advances to deliver robust environmental policy insights. To that end, we recognize that each report reflects a continual process of im-provement. We welcome feedback from the global research and policymaking community on our data sources and meth-odological choices.

2. Data Selection

Advances in sustainability research, data reporting, and remote sensing mean that each iteration of the EPI has access to environmental information of unprecedented depth and qual-ity. This section describes the criteria the EPI research team uses to identify reliable and relevant data. Only the best global data ultimately inform the EPI's analyses.

Inclusion Criteria

Each indicator in the EPI tracks a specific sustainability issue. Data underlying these indicators should allow the EPI team and policymakers to track country-level performance in environmental outcomes over time. To enable fair comparison of performance between countries, data should ideally track the same variables using consistent methods across the world. The most useful data for the purposes of the EPI comply with the following criteria:

- **Relevance**: Data should measure environmental issues that pertain to most countries.
- **Performance orientation**: Data should measure environmental issues that policy interventions can improve. Whenever possible, the EPI seeks not to penalize countries for environmental trends and resource endowments beyond their control.
- **Focus on outcomes**: Data should measure real-world environmental outcomes rather than policymakers' intentions, pledges, regulations, or other policy inputs.
- **Established methodology**: Data should be derived using methods that have been peer reviewed or endorsed by an international scientific organization.
- **Verified results**: Data should be independently verified by third-party scientific organizations or should have been submitted through a transparent reporting system amenable to audit. This means that the EPI team does not accept data directly from governments.
- **Spatial completeness**: Data should be available for most countries and is derived using a consistent methodology around the world.
- **Temporal completeness**: Data should be available for a period spanning several years to allow tracking changes in performance through time. It is also important that data producers and curators demonstrate a commitment to continue providing regular data updates in the future.
- **Recency**: Data should be as recent as possible to reflect a current picture of environmental performance. When indicators are based on recent and regularly updated data, scores respond faster to new policy interventions and are thus a more useful tool to gauge their effectiveness.
- **Open source**: Data should be freely accessible to the public. Open-source data have the greatest potential for raising awareness and driving policy change.

Ideally, the data underlying each EPI metric would satisfy all these criteria. Often, however, the EPI relies on datasets that fall short of some criteria for two reasons. First, an environmental issue may be so important to assessing environmental performance that we opt for developing metrics with imperfect data rather than not measuring the issue at all. In such cases, the indicators are presented as a signal to policymakers, but usually receive a lower weight in the overall EPI scores. Key examples include the data underlying the indicators of the Waste Management and Water Resources issue categories. Second, when measuring an emerging environmental issue, measurement methods may not be fully established, and global reporting systems may not exist. The EPI may rely on pilot metrics to draw attention to the issue, asking for feedback from the international scientific and policymaking community. Key examples in the 2024 EPI are our pilot metrics of protected area effectiveness and stringency.

Data Sources

Data that meet the inclusion criteria typically come from international organizations, research institutions, academia, and government agencies. These sources use a variety of methods to collect, curate, and verify global data, including:

- Remotely sensed data from satellite observations;
- Observations from monitoring stations;
- Surveys and questionnaires;
- Estimates derived from on-the-ground measurements and statistical models;
- Industry reports on resource consumption and pollutant emissions; and
- Government statistics reported through international organizations like the United Nations Environment Programme.

We detail the sources of the data behind each indicator in the 2024 Technical Appendix, available for download from epi.yale.edu.

3. Country Level Data

The EPI pays close attention to sovereignty issues when evaluating country performance. We look for global data with enough spatial resolution to monitor countries and their territories. Data often come in tables, using official ISO 3166 codes to identify countries and territories. As country definitions and boundaries change over time, we attribute historical data from dissolved countries like Yugoslavia or Sudan to their successor states. Yet, comparing trends across times of changing political borders requires caution.

Data concerning territories controlled or protected by other countries pose a challenge. While the EPI primarily tracks national environmental performance, we acknowledge policymaking occurs at various government levels. We decide whether to include certain territories in our datasets based on factors like their policy control and data reporting practices.

We aim to include major territories separately in the EPI database, even if they lack sufficient data for a full EPI score. Raw data files include data for 220 countries and territories and are available for download from our website. Details on how territories are handled are in the online Technical Appendix.

We understand the significance of sovereignty decisions. Our choices regarding data aggregation in the 2024 EPI report are not endorsements or rejections of claims to autonomy or recognition. Rather, they are practical decisions for our statistical calculations, made with care.

4. Indicator Construction

Data is most useful to policymaking when it is communicated clearly to decision-makers, researchers, the media, and the public. The EPI simplifies complex environmental data into straightforward indicators to assess sustainability progress. These indicators score each country in a scale ranging from 0 (worst performance) to 100 (best performance). While the EPI incorporates some indicators that are already scaled to intuitively score countries (such as the Red List Index, the Species Habitat Index, and Species Protection Index), most require further calculations to become indicators. Chapters 3 to 13 of this report delve into each of the 58 performance indicators, while the online Technical Appendix offers details on their specific calculations. The sections below offer a broad outline of the 2024 EPI data framework, explaining the methodological decisions guiding the transformation of raw data into indicators.

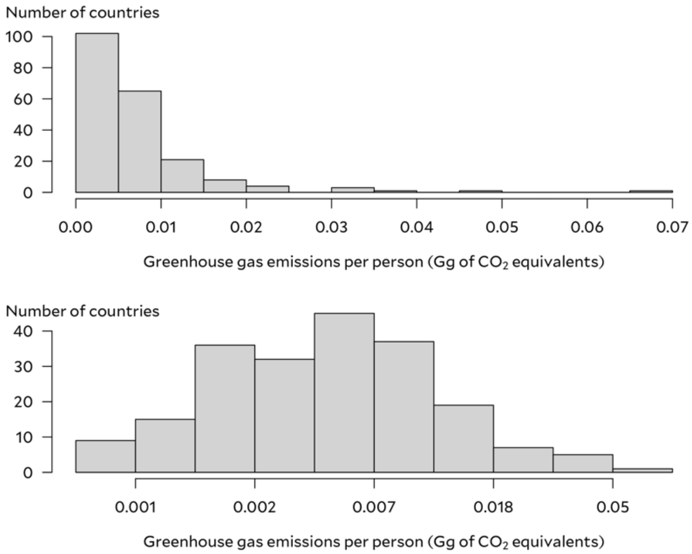
Standardization

Countries vary widely in the size of their territory, economy, and population. To allow fair comparisons between countries, we standardize data by dividing them by a common denominator, resulting in proportions, rates, and per capita units rather than raw units. For example, we divide total greenhouse emissions by countries' populations to compare per capita emissions. We do the same to compare countries' generation of wastewater and solid waste. Environmental health indicators from the Global Burden of Disease measure public health consequences of exposure to risk factors as disability-adjusted life-years lost per 100,000 people.

Transformation

In some environmental data sets, a few countries have extreme values, while the rest of the world clusters at one end of the distribution. These skewed distributions make it difficult to compare countries' performance as, except for the outliers, countries appear almost indistinguishable. In such cases, the EPI uses logarithmic transformations to improve our interpretation of results. For example, most countries have relatively low values of per capita greenhouse gas emissions, while a few countries — mostly small petrostates — have extreme values. Figure 14-1 shows how a logarithmic transformation helps spread values of per capita greenhouse emissions, facilitating comparisons between countries.

Figure 14-1. Transforming skewed data on *per capita* greenhouse gas emissions using the natural logarithm. Top panel: untransformed data. Bottom panel: transformed data.



Scoring

After standardizing and transforming raw data, when required, the final step is to rescale the data into a 0 to 100 score. This puts all indicators on a common, easy-to-interpret scale, facilitating comparisons and aggregation into a composite index. The EPI uses the distance-to-target approach for indicator scoring. Countries' scores reflect how close they are to targets of best and worst performance. The general formula for indicator scoring is:

Indicator Score = $(X - W) / (B - W) \times 100$

where X is a country's value, B is the target for best performance, and W is the target for worst performance. If a country's value is greater than B or smaller than W, we cap its score at 100 or 0, respectively.

The EPI sets targets of best and worst performance for each indicator according to the following hierarchy:

- Performance targets set in international agreements, treaties, or institutions. If there are no such targets, the EPI uses:
- Performance targets based on the recommendation of experts. If no such recommendations are available, the EPI uses:
- Performance targets based on percentiles of country scores.

International agreements and experts rarely set standards of worst performance, so the EPI often relies on percentiles for its worst performance targets. When setting percentile-based targets, we calculate percentiles using data across all available years and countries for each indicator — not just the data from the most recent year or from countries included in the EPI. The online Technical Appendix details each indicator's performance targets.

5. 2024 EPI Framework

The 2024 Environmental Performance Index integrates data on 58 performance indicators grouped into 11 environmental issue categories, three main policy objectives, and one overall EPI score for each country. The EPI's three main policy objectives reflect the way in which policymakers and researchers often compartmentalize environmental issues, although the EPI team recognizes overlap and important connections among them. Environmental Health measures the impacts of environmental pollution on human wellbeing and includes four issue categories: Air Quality, Sanitation & Drinking Water, Heavy Metals, and Waste Management. Ecosystem Vitality assesses the sustainability of natural resource use and the conservation of natural ecosystems, including six issue categories: Biodiversity & Habitat, Forests, Air Pollution, Agriculture, Fisheries, and Water Resources. Climate Change focuses on tracking countries' emissions of climate pollutants and currently includes only one issue category: Climate Change Mitigation.

These three policy objectives are aggregated into a single overall EPI score. While overall EPI scores provide a useful summary of overall performance, they are only a starting point for deeper analyses of environmental policy gaps and priorities. Scores at each level of the framework are available throughout this report and from our website, epi.yale.edu.

5. Weighting and Aggregation

Aggregating performance indicators into issue categories, policy objectives, and the overall EPI requires assigning a weight to each indicator. Some authorities on composite indexing advocate using geometric sums to aggregate scores because it helps prevent high scores in one indicator compensating for low scores in another (OECD and JRC 2008). To make the aggregation step easier to understand to a broad audience, however, the EPI uses arithmetic weighted sums instead. The weights used by the 2024 EPI (Figure 14-2) reflect three main factors: (1) the perceived importance of the issue; (2) the quality and timeliness of the data; and (3) statistical analyses to balance the spread of scores. These weights are only suggestions, and we encourage users to explore alternative weighting schemes. The 2024 EPI's data and code are available for download from epi.yale.edu for readers interested in exploring alternative weights and aggregation methods. Our website also includes an interactive tool to explore how alternative weights impact the results.

While the EPI team considers the three policy objectives of Climate Change, Ecosystem Vitality, and Environmental Health equally important, we do not weight them equally (Figure 14-2). Since the standard deviation of Environmental Health scores (18.8) is higher than that of Climate Change (12.2) and Ecosystem Vitality (13.2) scores, had we assigned one third of the overall weight to each policy objective, Environmental Health would have an outsized influence on overall scores. To account for this imbalance, the 2024 EPI gives a weight of 25 percent to Environmental Health, 30 percent to Climate Change, and 45 percent to Ecosystem Vitality. The methods sections of chapters 3 to 13 of the report explain the weighting rational for each issue category and its component indicators.

6. Materiality

While broad relevance is one of the inclusion criteria that guide the EPI's data selection process, countries are so varied in their ecosystems and physical environment that not every indicator is applicable to every country. We do not score land-locked countries on the Fisheries issue category and on indicators related to marine protected areas. For landlocked countries, we redistributed the weight of the Fisheries issue category to other Ecosystem Vitality indicators in proportion to these other indicators' base weights. The weight of indicators of marine protected areas are redistributed to other indicators in the Biodiversity & Habitat issue category. We also do not score countries that had less than 10 percent forest cover in 2000 on the Forest issue category, instead redistributing the weight across Ecosystem Vitality indicators.

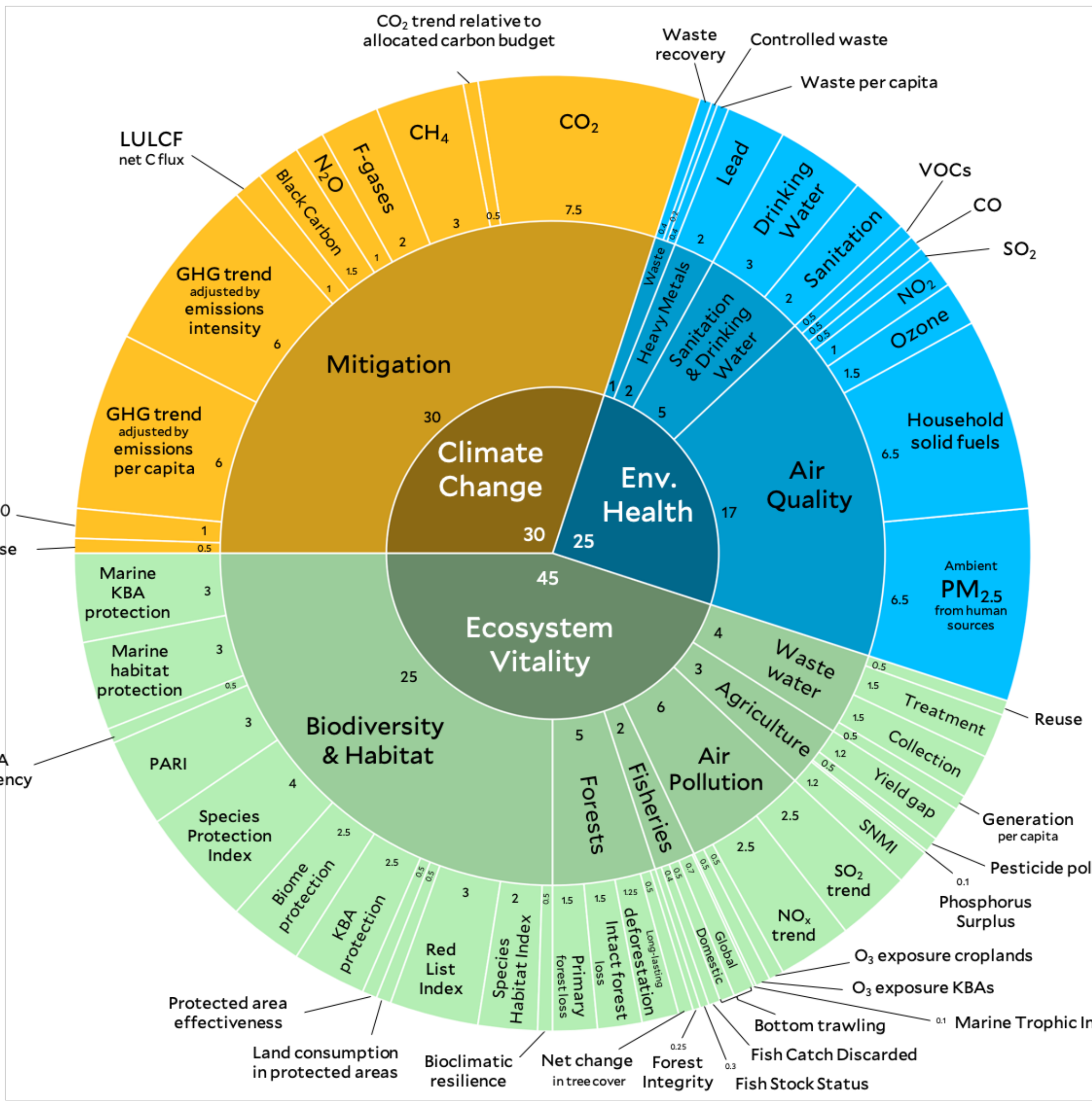


Figure 14-2. The 2024 EPI Framework. The framework organizes 58 indicators into 11 issue categories and three policy objectives, with weights shown at each level as a percentage of the total score.

7. Missing Data

Despite the EPI's efforts to use data sets with information available for most countries, sometimes we are forced to work with data from which some countries are missing. In such cases, the EPI team redistributes the weight of the missing indicator to other indicators in the issue category during the aggregation process. In the Agriculture category, however, there is substantial variation in the average scores of the component indicators. This could result in biased aggregated results if different countries are scored based on different subsets of indicators. For this reason, we used a statistical model to impute missing data and provide details in the online Technical Appendix. The Fisheries indicators suffered from a similar issue, but statistical models were unable to predict missing scores with an acceptable degree of confidence. Thus, we warn users to exercise caution with comparing countries based on their aggregated Fisheries scores.

8. Backcasting EPI Performance

The latest EPI scores offer a snapshot of the state of sustainability around the world based on the most recent data available. But analyzing trends in performance through time is of great interest to researchers and policymakers trying to understand whether policies and investments in sustainability programs are paying off, as well as for identifying issues where performance is deteriorating.

We warn users to interpret backcasted scores with extreme caution, since the timeseries of underlying indicators have heterogenous starting and end points. The EPI team uses linear interpolation to fill gaps in timeseries between 1995 and 2024. When indicator data do not cover this entire period, we extend the beginning and the end of the time series holding the oldest and most recent values constant. As a result, backcasted scores are an approximation to trends in performance, but they may mask real-world changes in performance. For this reason, we strongly recommend that those interested in studying performance trends rely on specific indicators for which gaps in the time series are more transparent. The Technical Appendix describes the temporal coverage for all 58 indicators.

9. Reference

OECD, and JRC. 2008. *Handbook on Constructing Composite Indicators: Methodology and User Guide*.

Yale Center for Environmental Law & Policy

The Yale Center for Environmental Law & Policy, a joint undertaking between Yale Law School and the Yale School of the Environment, advances fresh thinking and analytically rigorous approaches to environmental decision-making across disciplines and sectors. In addition to its research activities, the center aims to serve as a locus for connection and collaboration by all members of the Yale University community who are interested in environmental law and policy issues. The center supports a wide-ranging program of teaching, research, and outreach on local, regional, national, and global pollution control and natural resource management issues. These efforts involve faculty, staff, and student collaboration and are aimed at shaping academic thinking and policymaking in the public, private, and NGO sectors. *envirocenter.yale.edu*

McCall MacBain Foundation

The McCall MacBain Foundation is based in Geneva, Switzerland and was founded by John and Marcy McCall MacBain. Its mission is to improve the welfare of humanity by providing scholarships and other educational opportunities that nurture transformational leadership, and by investing in evidence-based strategies to address climate change, preserve our natural environment, and improve health outcomes.
www.mccallmacbain.org

Center for International Earth Science Information Network

The Center for International Earth Science Information Network (CIESIN) is part of the Columbia Climate School at Columbia University. CIESIN works at the intersection of the social, natural, and information sciences, and specializes in online data and information management, spatial data integration and training, and interdisciplinary research related to human interactions in the environment. Since 1989, scientists, decision-makers, and the public have relied on the information resources at CIESIN to better understand the changing relationship between human beings and the environment. From its offices at Columbia's Lamont-Doherty Earth Observatory campus in Palisades, New York, CIESIN continues to focus on applying state-of-the-art information technology to pressing interdisciplinary data, information, and research problems related to human interactions in the environment.
www.ciesin.columbia.edu

Disclaimer

The 2024 Environmental Performance Index tracks national environmental results on a quantitative basis, measuring proximity to policy targets using the best data available. Data constraints and methodological considerations make our project an ongoing effort, and we strive for improvements with every edition of the Index.

This report provides a narrative summary and analysis of the 2024 EPI, and we refer the reader to our website, *epi.yale.edu*, to explore the results in greater depth. We post all our data online for download as well as a Technical Appendix and other materials that document our methods, assumptions, and decisions. Comments, suggestions, feedback, and referrals to better data sources are welcome at epi@yale.edu.

We use the word country loosely in this report to refer to both countries and other administrative or economic entities. Similarly, the maps presented are for illustrative purposes and do not imply any political preference in cases where territory or sovereignty is under dispute.

Environmental Performance Index

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