2010
ENVIRONMENTAL PERFORMANCE INDEX

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INTRODUCTORY NOTES

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Disclaimers

The 2010 Environmental Performance Index (EPI) tracks national environmental results on a quantitative basis, measuring proximity to an established set of policy targets using the best data available. Data constraints and limitations in methodology make this a work in progress. Further refinements will be undertaken over the next few years. Comments, suggestions, feedback, and referrals to better data sources are welcome at: http://epi.yale.edu or epi@yale.edu.

The word "country" is used loosely in this report to refer both to 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 is under dispute.

Acknowledgments

The 2008 Environmental Performance Index (EPI) represents the result of extensive consultations with subject-area specialists, statisticians, and policymakers around the world. Since any attempt to measure environmental performance requires both an in-depth knowledge of each dimension as well as the relationships between dimensions and the application of sophisticated statistical techniques to each, we have drawn on the expertise of a network of individuals, including: John van Aardenne, Matthias Bruckner, Geneviève Carr, Tom Damassa , Adrian Deveny, Monique Dubé, Samah Elsayed, Majid Ezzati, James Galloway, Thomas Gumbricht, Tomáš Hák, Matthew Hansen, Kelly Hodgson, Bart Holvoet, Richard Houghton, Jonathan Koomey, Mette Loyche-Wilkie, Erin Madeira, Emilio Mayorga, Denise Mauzerall, Sascha Müller-Kraenner, Freddy Nachtergaele, John O'Connor, Daniel Pauly, László Pintér, Annette Prüss-Ustün, Carmen Revenga, Richard Robarts, Carrie Rickwood, Matthew Rodell, Phil Ross, Lee Schipper, Helga Willer, Louisa Wood, and John Volpe.

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The 2010 EPI is built upon the work of a range of data providers, including our own prior data development work for the Pilot 2006 EPI, 2008 EPI, and the 2005 Environmental Sustainability Index. The data are drawn primarily from international, academic, and research institutions with subject-area expertise, success in delivering operational data, and the capacity to produce policy-relevant interdisciplinary information tools. We are indebted to the data collection agencies listed in the Methodology Section.

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EXECUTIVE SUMMARY

Environmental sustainability has emerged as a critical policy focus across the world. While a great deal of attention has recently been focused on climate change, other issues including water quality and availability, air pollution, deforestation and land use changes, biodiversity, and the sustainability of agriculture and fisheries have also gained prominence on the public agenda. Governments are increasingly being asked to explain their performance on a range of pollution control and natural resource management challenges with reference to quantitative metrics. The move toward a more data-driven empirical approach to environmental protection promises to better enable policymakers to spot problems, track trends, highlight policy successes and failures, identify best practices, and optimize the gains from investments in environmental protection.

The 2010 Environmental Performance Index (EPI) ranks 163 countries on 25 performance indicators tracked across ten well-established policy categories covering both environmental public health and ecosystem vitality. These indicators provide a gauge at a national government scale of how close countries are to established environmental policy goals. This proximity-to-target methodology facilitates cross-country comparisons as well as analysis of how the global community performs collectively on each particular policy issue.

In our data-rich Information Age, more sophisticated metrics have transformed decisionmaking in every corner of society from business to sports. But only recently have environmental policymakers begun to demand a similar quantitative foundation for their decisionmaking. The EPI provides a framework for greater analytic rigor in the environmental domain but, at the same time, reveals severe data gaps, weaknesses in methodological consistency, and the lack of any systematic process for verifying the numbers reported by national governments. Likewise, the EPI makes vivid the need for better data collection, analysis, review, and verification as an essential underpinning for the trust required to make future worldwide policy cooperation effective. It also provides a model of transparency with all of the underlying data available online at http://epi.yale.edu.

One of the biggest weaknesses in the current framework is the lack of ability to track changes in performance over time. Thus, the 2010 EPI offers a pilot exercise – focused on a small handful of indicators for which time series data are available – designed to make clear the potential for highlighting which countries have gained the most ground and which are falling back, as well as the issues on which global performance is improving and those on which it is deteriorating. The 2010 EPI also spells out some of the critical drivers of good environmental results including the level of development, good governance, and concerted policy effort.

The overall EPI rankings provide an indicative sense of which countries are doing best against the array of environmental pressures that every nation faces. From a policy perspective, greater value derives from drilling down into the data to analyze performance by specific issue, policy category, peer group, and country. This analysis can assist in refining policy choices, understanding the determinants of environmental progress, and maximizing the return on governmental investments. More generally, the EPI provides a powerful tool for steering individual countries and the world as a whole toward environmental sustainability.

POLICY CONCLUSIONS

- Environmental decisionmaking can be made more fact-based and empirical. A data-driven approach to policymaking promises to make decisionmaking more analytically rigorous and yield systematically better results.
- While the 2010 EPI demonstrates the potential for better metrics and more refined policy analysis, it also highlights the fact that significant data gaps and methodological limitations hamper movement in this direction.
- Policymakers should move to establish better data collection, methodologically consistent reporting, mechanisms for verification, and a commitment to environmental data transparency.
- Policymakers need to set clear policy targets and shift toward more analytically rigorous environmental protection efforts at the global, regional, national, state/provincial, local, and corporate scales.
- Wealth correlates highly with EPI scores. In particular, wealth has a strong association with environmental health results. But at every level of development, some countries fail to keep up with their income-group peers while others achieve outstanding results. Statistical analysis suggests that in many cases good governance contributes to better environmental outcomes.
- Environmental challenges come in several forms,

varying with wealth and development. Some issues arise from the resource and pollution impacts of industrialization – including greenhouse gas emissions and rising levels of waste – and largely affect developed countries. Other challenges, such as access to safe drinking water and basic sanitation, derive from poverty and under-investment in basic environmental amenities and primarily affect developing nations. Limited endowments in water and forest resources constrain choices but need not necessarily impair performance.

- The EPI uses the best available global data sets on environmental performance. However, the overall data quality and availability is alarmingly poor. The lack of time-series data for most countries and the absence of broadly-collected and methodologically-consistent indicators for basic concerns, such as water quality, still hamper efforts to shift pollution control and natural resource management onto more empirical grounds.
- The 2010 EPI represents a work-in-progress. It aims not only to inform but also to stimulate debate on defining the appropriate metrics and methodologies for evaluating environmental performance. Feedback, comments, suggestions, and criticisms are all welcome in the Contact section at http://epi.yale.edu.

Figure 1.1 Map Of Country EPI Scores By Equidistant Intervals (Robinson Projection)

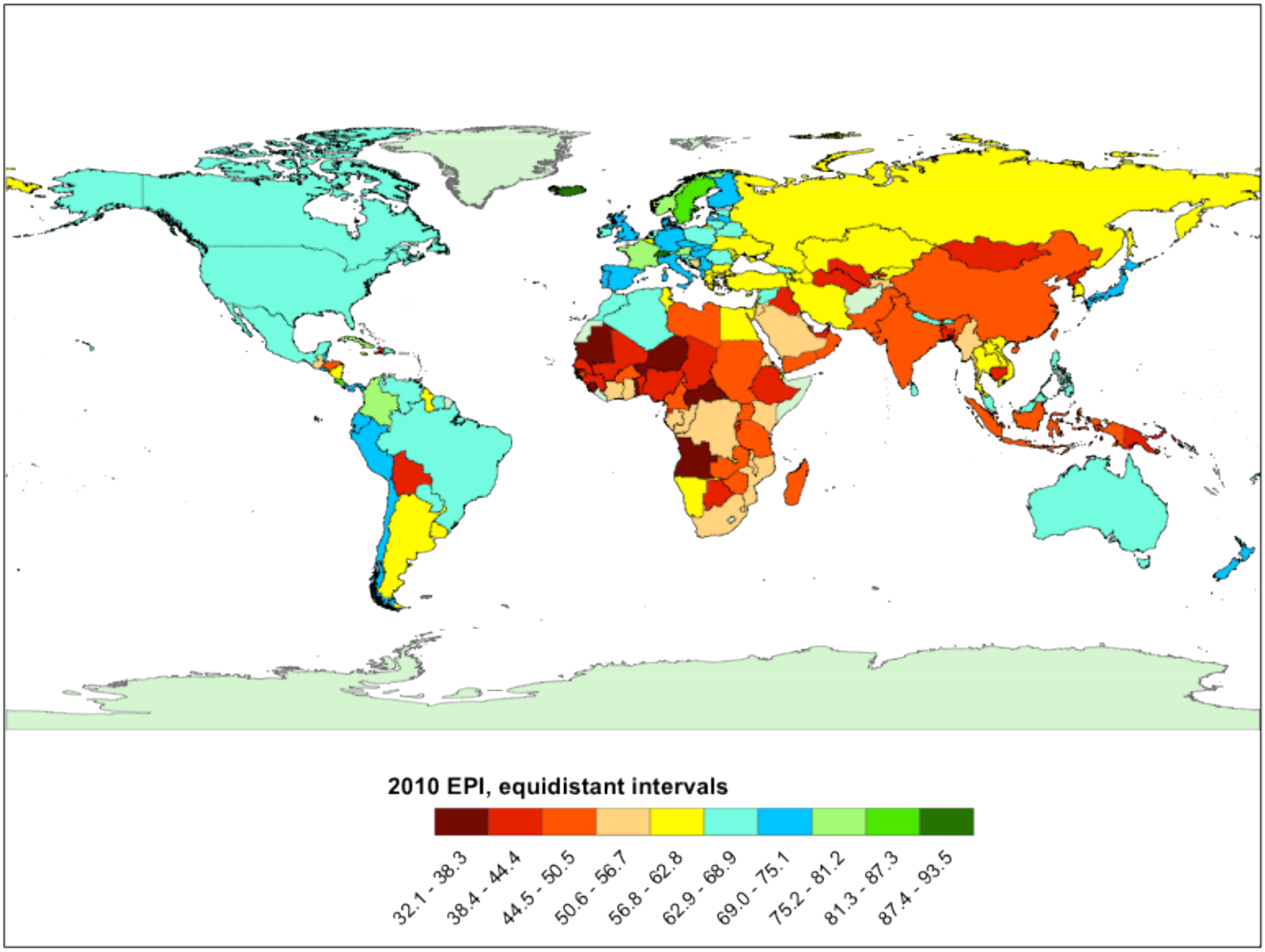

Table 1.1 EPI Scores (by rank)*

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Iceland	93.5	56	Syria	64.6	111	Tajikistan	51.3
2	Switzerland	89.1	57	Estonia	63.8	112	Mozambique	51.2
3	Costa Rica	86.4	58	Sri Lanka	63.7	113	Kuwait	51.1
4	Sweden	86.0	59	Georgia	63.6	114	Solomon Islands	51.1
5	Norway	81.1	60	Paraguay	63.5	115	South Africa	50.8
6	Mauritius	80.6	61	United States	63.5	116	Gambia	50.3
7	France	78.2	62	Brazil	63.4	117	Libya	50.1
8	Austria	78.1	63	Poland	63.1	118	Honduras	49.9
9	Cuba	78.1	64	Venezuela	62.9	119	Uganda	49.8
10	Colombia	76.8	65	Bulgaria	62.5	120	Madagascar	49.2
11	Malta	76.3	66	Israel	62.4	121	China	49.0
12	Finland	74.7	67	Thailand	62.2	122	Qatar	48.9
13	Slovakia	74.5	68	Egypt	62.0	123	India	48.3
14	United Kingdom	74.2	69	Russia	61.2	124	Yemen	48.3
15	New Zealand	73.4	70	Argentina	61.0	125	Pakistan	48.0
16	Chile	73.3	71	Greece	60.9	126	Tanzania	47.9
17	Germany	73.2	72	Brunei	60.8	127	Zimbabwe	47.8
18	Italy	73.1	73	Macedonia	60.6	128	Burkina Faso	47.3
19	Portugal	73.0	74	Tunisia	60.6	129	Sudan	47.1
20	Japan	72.5	75	Djibouti	60.5	130	Zambia	47.0
21	Latvia	72.5	76	Armenia	60.4	131	Oman	45.9
22	Czech Republic	71.6	77	Turkey	60.4	132	Guinea-Bissau	44.7
23	Albania	71.4	78	Iran	60.0	133	Cameroon	44.6
24	Panama	71.4	79	Kyrgyzstan	59.7	134	Indonesia	44.6
25	Spain	70.6	80	Laos	59.6	135	Rwanda	44.6
26	Belize	69.9	81	Namibia	59.3	136	Guinea	44.4
27	Antigua & Barbuda	69.8	82	Guyana	59.2	137	Bolivia	44.3
28	Singapore	69.6	83	Uruguay	59.1	138	Papua New Guinea	44.3
29	Serbia & Montenegro	69.4	84	Azerbaijan	59.1	139	Bangladesh	44.0
30	Ecuador	69.3	85	Viet Nam	59.0	140	Burundi	43.9
31	Peru	69.3	86	Moldova	58.8	141	Ethiopia	43.1
32	Denmark	69.2	87	Ukraine	58.2	142	Mongolia	42.8
33	Hungary	69.1	88	Belgium	58.1	143	Senegal	42.3
34	El Salvador	69.1	89	Jamaica	58.0	144	Uzbekistan	42.3
35	Croatia	68.7	90	Lebanon	57.9	145	Bahrain	42.0
36	Dominican Republic	68.4	91	Sao Tome & Principe	57.3	146	Equatorial Guinea	41.9
37	Lithuania	68.3	92	Kazakhstan	57.3	147	North Korea	41.8
38	Nepal	68.2	93	Nicaragua	57.1	148	Cambodia	41.7
39	Suriname	68.2	94	South Korea	57.0	149	Botswana	41.3
40	Bhutan	68.0	95	Gabon	56.4	150	Iraq	41.0
41	Luxembourg	67.8	96	Cyprus	56.3	151	Chad	40.8
42	Algeria	67.4	97	Jordan	56.1	152	United Arab Emirates	40.7
43	Mexico	67.3	98	Bosnia & Herzegovina	55.9	153	Nigeria	40.2
44	Ireland	67.1	99	Saudi Arabia	55.3	154	Benin	39.6
45	Romania	67.0	100	Eritrea	54.6	155	Haiti	39.5
46	Canada	66.4	101	Swaziland	54.4	156	Mali	39.4
47	Netherlands	66.4	102	Côte d'Ivoire	54.3	157	Turkmenistan	38.4
48	Maldives	65.9	103	Trinidad and Tobago	54.2	158	Niger	37.6
49	Fiji	65.9	104	Guatemala	54.0	159	Togo	36.4
50	Philippines	65.7	105	Congo	54.0	160	Angola	36.3
51	Australia	65.7	106	Dem. Rep. Congo	51.6	161	Mauritania	33.7
52	Morocco	65.6	107	Malawi	51.4	162	Central African Rep.	33.3
53	Belarus	65.4	108	Kenya	51.4	163	Sierra Leone	32.1
54	Malaysia	65.0	109	Ghana	51.3			
55	Slovenia	65.0	110	Myanmar	51.3			

*** Owing to changes in methodologies and underlying data, 2010 EPI scores and ranks cannot be directly compared to 2006 and 2008 scores and ranks.**

1.

THE PURPOSE OF THE ENVIRONMENTAL PERFORMANCE INDEX

There has never been a more pressing need for effective environmental policies as there is today. Nonetheless, policymakers trying to parse through the growing body of environmental data face complex challenges such as incomplete and conflicting data, causal complexity, varying values and preferences, and uncertainty. The 2010 Environmental Performance Index (EPI) addresses these difficulties by providing a structure that grounds environmental policymaking in a set of quantitative indicators, permitting comparative analysis via peer-group benchmarking and a mechanism identifying leaders, laggards, and best practices.

The 2010 Environmental Performance Index is a compilation of carefully selected indicators gleaned from an extensive review of the scientific literature and consultations with experts in different domains. To this end, the 2010 EPI covers a comprehensive yet manageable body of information about core pollution and resource management issues. While there is no widely-accepted answer to the proper scope of an environmental index, we believe that our set of 25 indicators presents the most relevant and pressing issues with detailed methodology and critical transparency.

The 2010 EPI draws upon ten years of research and six reports (from the pilot Environmental Sustainability Index in the year 2000 to the 2008 EPI) as well as feedback from more than 70 governments and hundreds of policymakers to present a refined analysis of current environmental issues. The 2010 EPI seeks to offer an indispensible tool for enhanced environmental policymaking. Through its proximity-to-target approach that uses current environmental status relative to a policy target, the EPI seeks to meet the need to track on-the-ground environmental results.

Specifically, the 2010 EPI:

- highlights current environmental problems and high-priority issues;
- tracks pollution control and natural resource management trends at regional, national, and international levels;
- identifies policies currently producing good results;
- identifies where ineffective efforts can be halted and funding redeployed;
- provides a baseline for cross-country and cross-sectoral performance comparisons;
- facilitates benchmarking and offers decision-making guidance;
- spotlights best practices and successful policy models.

The 2010 EPI also elucidates linkages between environmental policy and other issue areas such as public health, revealing new, effective leverage points for change.

As more accurate information – particularly time-series data – becomes available, policymakers will be able to track their country's progress toward policy targets. If investments are made in data and monitoring, future EPIs will be able to gauge the trajectory of the global community toward stronger environmental performance.

The EPI is, in part, a response to the 2000 Millennium Declaration and the Millennium Development Goals (MDGs). Major global efforts are underway in education improvement, healthcare expansion, and poverty reduction. Meanwhile, the achievement of environmental sustainability goals has fallen behind. This lag is partially due to the lack of clearly-defined environmental goals which would help to illuminate the problems we face, quantify the burdens imposed by environmental degradation, measure policy progress, and assure private and public funders of the return on their investments.

Any multi-issue environmental performance measurement system can be characterized largely in terms of how it achieves two core functions: (1) specifying an architecture that identifies high-priority issues; and (2) calculating metrics on a common scale. The Ecological Footprint,[1] for example, is based on an architecture that includes natural resources that are related to consumption but omits non-consumption issues such as pollution and waste management. Its core metric is land area associated with consumption processes. On the other hand, Green GDP[2] or Environmental Accounts are based on environmental assets that are commercially exploited and quantify that in terms of economic value expressed in units of currency.

The EPI, by contrast, incorporates all high-priority issues, including resource consumption, depletion of environmental assets, pollution, species loss, and so on. It is flexible enough to incorporate almost any issue deemed to be a high priority. It is flexible in this regard because the metric it relies on is proximity-to-target, as opposed to land area or economic value. None of these three approaches is uniformly superior to the others. They function best in complement to each other.

Given the billions spent on environmental programs and remediation, there is a need for robust metrics to guide policy. The Yale Center for Environmental Law and Policy and the Center for International Earth Science Information Network at Columbia University's Earth Institute offer the 2010 EPI as a path to set explicit environmental targets, measure quantitative progress toward these goals, and undertake policy evaluation. We hope that by being transparent about the limitations of this exercise and the data that underpin it, the 2010 EPI will encourage more rigorous and transparent data collection and analysis around the globe.

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1 http://www.footprintnetwork.org

2 http://en.wikipedia.org/wiki/Green_gross_domestic_product

Table 1.2 EPI Scores (alphabetical)

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
23	Albania	71.4	59	Georgia	63.6	5	Norway	81.1
42	Algeria	67.4	17	Germany	73.2	131	Oman	45.9
160	Angola	36.3	109	Ghana	51.3	125	Pakistan	48.0
27	Antigua & Barbuda	69.8	71	Greece	60.9	24	Panama	71.4
70	Argentina	61.0	104	Guatemala	54.0	138	Papua New Guinea	44.3
76	Armenia	60.4	136	Guinea	44.4	60	Paraguay	63.5
51	Australia	65.7	132	Guinea-Bissau	44.7	31	Peru	69.3
8	Austria	78.1	82	Guyana	59.2	50	Philippines	65.7
84	Azerbaijan	59.1	155	Haiti	39.5	63	Poland	63.1
145	Bahrain	42.0	118	Honduras	49.9	19	Portugal	73.0
139	Bangladesh	44.0	33	Hungary	69.1	122	Qatar	48.9
53	Belarus	65.4	1	Iceland	93.5	45	Romania	67.0
88	Belgium	58.1	123	India	48.3	69	Russia	61.2
26	Belize	69.9	134	Indonesia	44.6	135	Rwanda	44.6
154	Benin	39.6	78	Iran	60.0	91	Sao Tome & Principe	57.3
40	Bhutan	68.0	150	Iraq	41.0	99	Saudi Arabia	55.3
137	Bolivia	44.3	44	Ireland	67.1	143	Senegal	42.3
98	Bosnia & Herz.	55.9	66	Israel	62.4	29	Serbia & Montenegro	69.4
149	Botswana	41.3	18	Italy	73.1	163	Sierra Leone	32.1
62	Brazil	63.4	89	Jamaica	58.0	28	Singapore	69.6
72	Brunei Darussalam	60.8	20	Japan	72.5	13	Slovakia	74.5
65	Bulgaria	62.5	97	Jordan	56.1	55	Slovenia	65.0
128	Burkina Faso	47.3	92	Kazakhstan	57.3	114	Solomon Islands	51.1
140	Burundi	43.9	108	Kenya	51.4	115	South Africa	50.8
148	Cambodia	41.7	113	Kuwait	51.1	94	South Korea	57.0
133	Cameroon	44.6	79	Kyrgyzstan	59.7	25	Spain	70.6
46	Canada	66.4	80	Laos	59.6	58	Sri Lanka	63.7
162	Central Afr. Republic	33.3	21	Latvia	72.5	129	Sudan	47.1
151	Chad	40.8	90	Lebanon	57.9	39	Suriname	68.2
16	Chile	73.3	117	Libya	50.1	101	Swaziland	54.4
121	China	49.0	37	Lithuania	68.3	4	Sweden	86.0
10	Colombia	76.8	41	Luxembourg	67.8	2	Switzerland	89.1
105	Congo	54.0	73	Macedonia	60.6	56	Syria	64.6
3	Costa Rica	86.4	120	Madagascar	49.2	111	Tajikistan	51.3
102	Côte d'Ivoire	54.3	107	Malawi	51.4	126	Tanzania	47.9
35	Croatia	68.7	54	Malaysia	65.0	67	Thailand	62.2
9	Cuba	78.1	48	Maldives	65.9	159	Togo	36.4
96	Cyprus	56.3	156	Mali	39.4	103	Trinidad and Tobago	54.2
22	Czech Republic	71.6	11	Malta	76.3	74	Tunisia	60.6
106	Dem. Rep. Congo	51.6	161	Mauritania	33.7	77	Turkey	60.4
32	Denmark	69.2	6	Mauritius	80.6	157	Turkmenistan	38.4
75	Djibouti	60.5	43	Mexico	67.3	119	Uganda	49.8
36	Dominican Republic	68.4	86	Moldova	58.8	87	Ukraine	58.2
30	Ecuador	69.3	142	Mongolia	42.8	152	United Arab Emirates	40.7
68	Egypt	62.0	52	Morocco	65.6	14	United Kingdom	74.2
34	El Salvador	69.1	112	Mozambique	51.2	61	United States	63.5
146	Equatorial Guinea	41.9	110	Myanmar	51.3	83	Uruguay	59.1
100	Eritrea	54.6	81	Namibia	59.3	144	Uzbekistan	42.3
57	Estonia	63.8	38	Nepal	68.2	64	Venezuela	62.9
141	Ethiopia	43.1	47	Netherlands	66.4	85	Viet Nam	59.0
49	Fiji	65.9	15	New Zealand	73.4	124	Yemen	48.3
12	Finland	74.7	93	Nicaragua	57.1	130	Zambia	47.0
7	France	78.2	158	Niger	37.6	127	Zimbabwe	47.8
95	Gabon	56.4	153	Nigeria	40.2			
116	Gambia	50.3	147	North Korea	41.8			

*** Owing to changes in methodologies and underlying data, 2010 EPI scores and ranks cannot be directly compared to 2006 and 2008 scores and ranks.**

2.
THE EPI FRAMEWORK

The 2010 EPI measures the effectiveness of national environmental protection efforts in 163 countries. Reflecting our belief that on-the-ground results are the best way to track policy effectiveness, EPI indicators focus on measurable outcomes such as emissions or deforestation rates rather than policy inputs, such as program budget expenditures. Each indicator can be linked to well-established policy targets.

The EPI measures two core objectives of environmental policy:

1. Environmental Health, which measures environmental stresses to human health; and
2. Ecosystem Vitality, which measures ecosystem health and natural resource management.

The 2010 EPI relies on 25 indicators that capture the best worldwide environmental data available on a country scale. We chose the indicators through a careful analytical process that included a broad review of the environmental science literature, in-depth consultation with scientific experts in each policy category, evaluation of candidate data sets, identification of proxy variables where necessary, and expert judgment. The EPI also incorporates criteria from other policy assessments, including the Millennium Ecosystem Assessment, the Intergovernmental Panel on Climate Change, the Biodiversity Indicator Partnership, and the Global Environmental Outlook-4. Although several significant gaps in issue area coverage remain (see Box 2.1), the 2010 EPI offers a comprehensive look across the pollution control and natural resource management challenges every country faces.

The 25 indicators reflect state-of-the-art data and the best current thinking in environmental health and ecological science. Some represent direct measures of issue areas; others are proxy measures that offer a rougher gauge of policy progress by tracking a correlated variable. Each indicator corresponds to a long-term public health or ecosystem sustainability target. For each country and each indicator, a proximity-to-target value is calculated based on the gap between a country's current results and the policy target. These targets are drawn from four sources: (1) treaties or other internationally agreed upon goals; (2) standards set by international organizations; (3) leading national regulatory requirements; or (4) expert judgment based on prevailing scientific consensus.

The data matrix covers all of the countries for which an EPI can be calculated. In a few cases – such as for the access to water and sanitation, water quality index, emissions from land use change and carbon-dioxide emissions per electricity generation metric – imputation methods were used to fill gaps. Where country values are imputed they are clearly denoted in the separately downloadable spreadsheet. Further information on the imputation methods are available in the indicator metadata.

Using the 25 indicators, scores are calculated at three levels of aggregation, allowing analysts to drill down to better understand the underlying causes of high or low performance (see Figure 2.1). Compared to the 2006 and 2008 EPIs, the structure of the EPI has changed in 2010 as a result of methodological refinements, so a comparison of EPI rankings across years is of indicative value only.

The aggregation process proceeds in the following steps:

1. Scores are calculated for each of the ten core policy categories based on one to four underlying indicators. Each underlying indicator represents a discrete data set. The ten policy categories are as follows: (1) Environmental Burden of Disease; (2) Water Resources for Human Health; (3) Air Quality for Human Health; (4) Air Quality for Ecosystems; (5) Water Resources for Ecosystems; (6) Biodiversity and Habitat; (7) Forestry; (8) Fisheries; (9) Agriculture; and (10) Climate Change. Each indicator's weight is shown in Table 2.1, and the process of establishing the weights is discussed in Section 2.5 below. This level of aggregation permits analysts to track countries' relative performance within these well-established policy areas or at the disaggregated indicator level.
2. Scores are next calculated for the objectives of Environmental Health and Ecosystem Vitality with weights allocated as shown in Table 2.1.
3. The overall Environmental Performance Index is then calculated, based on the mean of the two broad objective scores. The rankings are based on the Index scores.

Figure 2.1 Construction of the EPI (Environmental Performance Index Framework)

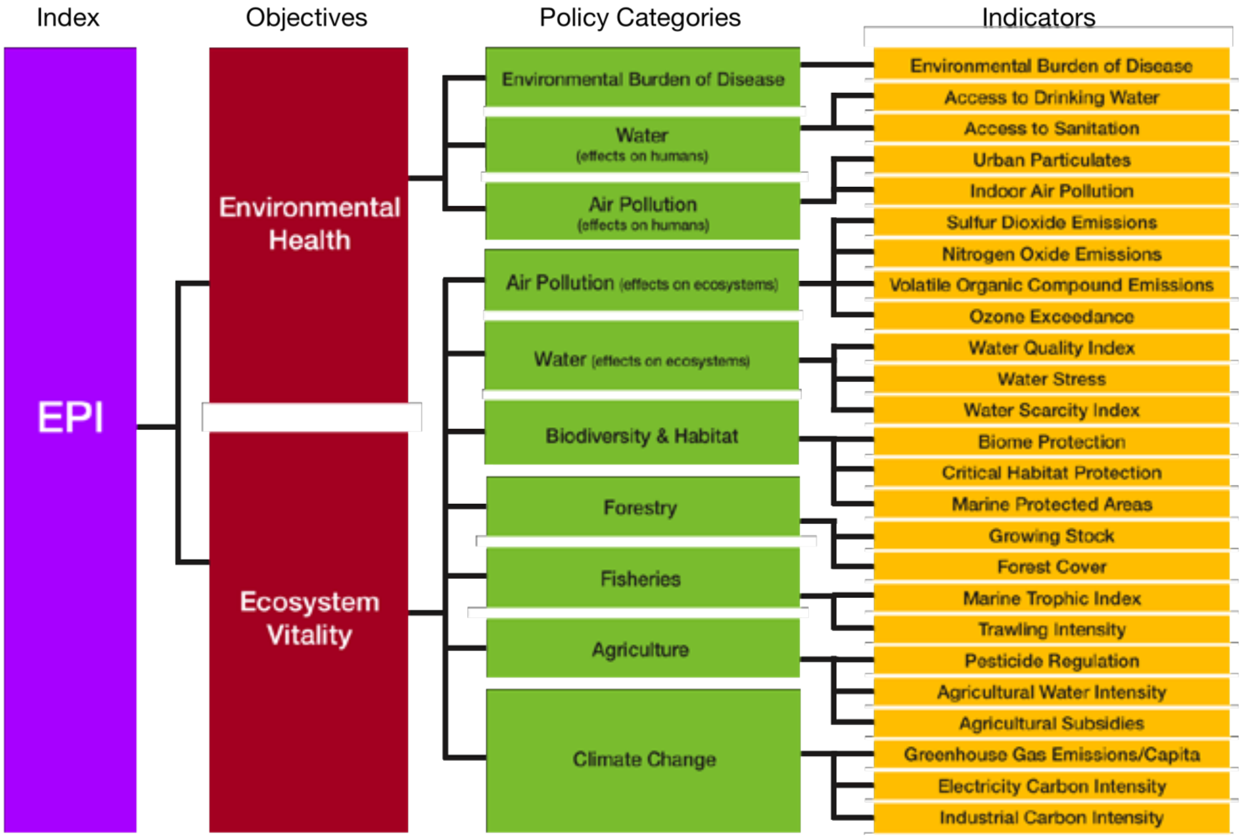
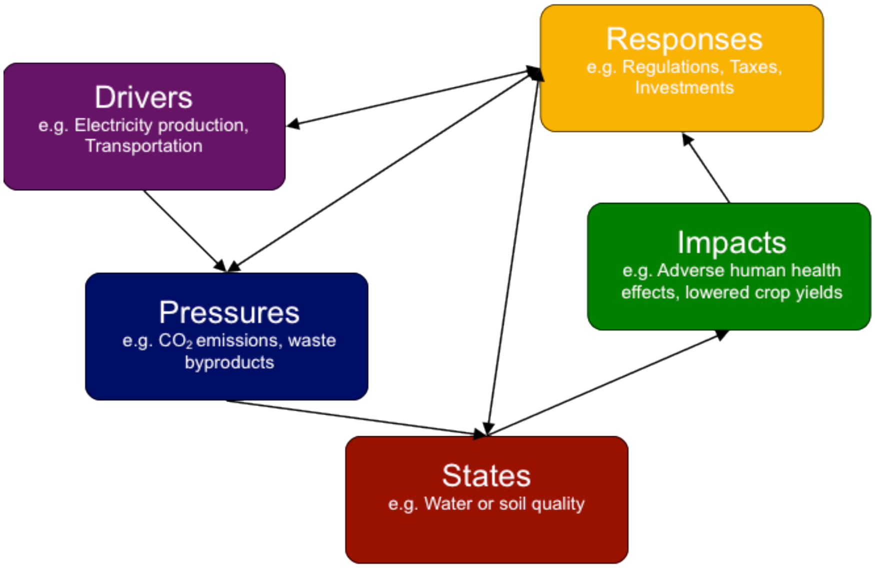


Figure 2.2 DSPIR Framework for environmental assessment



2.1
INDICATOR SELECTION

For each of the major policy categories identified, we sought indicators to cover the full spectrum of the underlying issues. The following four criteria were used to determine the most appropriate metrics:

Relevance

The indicator tracks the environmental issue in a manner that is applicable to countries under a wide range of circumstances.

Performance orientation

The indicator provides empirical data on ambient conditions or on-the-ground results for the issue of concern, or is a "best available data" proxy for such outcome measures.

Data quality

The data represent the best measures available. All potential data sets were reviewed for quality and verifiability. Those that did not meet baseline quality standards were discarded.

Performance indicators ideally track a given country's state of environment compared to targets. This would be the "states" category of the widely-used DSPIR (driving forces, pressures, states, impacts, responses) environmental assessment framework (Figure 2.2). However, data gaps forced us to use non-state indicators in some cases. Examples include SO2, NOx, and NMVOC emissions per populated land area, which are "pressure" indicators, and Pesticide Regulation and Biome Protection, which are "response" indicators. Examples include S02, NOx, and NMVOC emissions per populated land area, which are "pressure" indicators, and Pesticide Regulation and Biome Protection, which are "response" indicators.

2.2
TARGETS

The EPI measures environmental performance using a carefully chosen set of policy targets (see last column of Table 2.1). When possible, targets are based on international treaties and agreements. For issues with no international agreements, targets are derived from environmental and public health standards developed by international organizations and national governments, the scientific literature, and expert opinion. The source of targets for each indicator is found in the Indicator Profiles and Metadata in Appendix A. Where targets could not be established based on any scientific criteria, we set targets that are sufficiently ambitious so that all countries have some room to improve. In some cases they may also represent an ideal state, such as 0% of the population exposed to indoor air pollution. Other targets, such as the Convention on Biological Diversity's recommended 10% of national territory under protected areas, represent political compromises. We recognize that such targets do not necessarily reflect environmental performance required for full sustainability.

Note that only a few of the indicators have explicit targets established by consensus at a global scale. This suggests a need for clearer long-term goals for environmental policy by the international community.

2.3
DATA SOURCES AND TYPES

The indicators of the EPI are based on a wide range of data sets from international organizations, NGOs, government agencies, and academia.

The data include:

- official statistics that are measured and formally reported by governments to international organizations (but which are not independently verified);
- modeled data; and
- spatial data compiled by research or international organizations; and
- observations from monitoring stations.

Our long term goal is to derive most indicators from data collected by either *in situ* or remote sensing monitoring systems. We feel these sources will best capture on-the-ground performance that is the result of country policy decisions and investments. We tested a number of remote sensing derived data sets for inclusion in the 2010 EPI, but we judged that these preliminary methods and results were not yet sufficiently mature to merit incorporation. Preliminary results, however, are provided in box text in Chapter 4.

2.4.
DATA GAPS AND COUNTRY DATA COVERAGE

The 2010 EPI uses the best environmental data available, but complete country coverage is precluded by limits in both quality and quantity in data sources. Of a possible 192 United Nations recognized countries, the 2010 EPI covers 163, which is up from the 149 covered in the 2008 EPI. Still, almost 30 countries and dozens of other jurisdictions cannot be included in the EPI because data are not available in one or more of the ten policy categories.

BOX 2.1
MISSING DATA

After more than a decade of work on environmental indicators, significant gaps in environmental data and monitoring remain. Environmental data and monitoring gaps include insufficient information related to the following:

- toxic chemical exposures;
- heavy metals (lead, cadmium, mercury)
- exposure;
- ambient air quality concentrations;
- municipal and toxic waste management;
- nuclear safety;
- pesticide safety;
- wetlands loss;
- species loss;
- freshwater ecosystems health;
- agricultural soil quality and erosion; and
- comprehensive greenhouse gas emissions.

As data become available, future iterations of the EPI may be able to track these areas, but considerable resources will need to be invested in new data collection efforts to make this possible. Missing data is also an issue in terms of country coverage in particular data sets. To allow some data sets to be used and thus the issue tracked in the 2010 EPI, some data was imputed. These imputed figures are noted in the spreadsheet file available at http://epi.yale.edu/files. The scope of these gaps shows the seriousness of problems in international sustainability reporting. We hope that international data collectors strive to achieve greater and more accurate coverage as the technological tools and financial resources become available.

Due to a lack of data, limited country coverage, methodological inconsistencies, lack of identifiable targets, or otherwise poor quality metrics, some policy relevant and scientifically important issues cannot be included in the EPI. Box 2.1 covers some of these issues, and Chapter 4 addresses others.

We would prefer not to use unverified country reported data or modeled data since they may not reliably capture what is happening on the ground. Yet, given the lack of data based on direct monitoring, the EPI contains a mixture of some “measured” data sets (most of which are not verified by independent parties) and some “modeled” indicators with a degree of imputation for missing data.

2.4
CALCULATING THE EPI

This section provides details on the methods used to transform the raw data to proximity-to-target scores ranging from zero (worst performance) to 100 (at target). The actual transformations performed on each indicator are provided in the Indicator Profiles and Metadata found in Appendix A.

The transformation process is completed in a number of steps. In the first step, we examined the raw data for each indicator and corrected for skewed distributions by employing a logarithmic transformation. This is described in greater detail below. In the second step, we trimmed the tails in a process called “winsorization.” We assume that extreme values (greater than three times the interquartile range) and outliers (greater than 1.5 times the interquartile range) most likely reflect data processing rather than actual performance. This is especially true for those indicators derived from modeled or spatial data. Accordingly, we winsorized at the 95th or 97th percentile of the distribution. In a small number of cases even this level of winsorization left significant outliers, and in such cases, we winsorized at a greater level based on a comparison of the two alternative values.
In the third step, we use the following formulas to convert the raw or winsorized data into a proximity-to-target score. Where high values in the raw data are considered good from an environmental point of view (e.g. biome protection), we use this formula:

100 -[(target value - winsorized value) x 100 / (target value - minimum winsorized value)]

Where high values are considered bad from an environmental perspective (e.g., SO2 emissions), we use this formula:

100 -[(winsorized value - target value) x 100 / (maximum winsorized value - target value)]

As mentioned above, in our first step we employed a logarithmic transformation for a number of indicators. These include the Environmental Burden of Disease, Urban Particulates, Sulfur Dioxide, Nitrogen Oxides, Non-Methane Volatile Organic Compounds, Ozone Exceedance, Water Stress, Marine Protected Areas, Agriculture Water Intensity, Greenhouse Gas Emissions Per Capita, CO2 Emissions Per Electricity Generation and Industrial Greenhouse Gas Emissions Intensity.

Logarithmic transformation of selected indicators represents a significant change from our past practice.

Table 2.1 Weights (as % of total EPI score), Sources, and Targets of EPI Objectives, Categories, Subcategories, and Indicators

Index	Objectives	Policy Categories	Indicators	Data Source	Target
EPI	Environmental Health (50%)	**Environmental burden of disease (25%)**	**Environmental burden of disease (25%)**	World Health Organization	10 DALYs (Disability Life Adjusted Years) per 1,000 population
		Air pollution (effects on humans) (12.5%)	**Indoor air pollution* (6.3%)**	World Development Indicators	0%population using solid fuels
			Outdoor air pollution (Urban Particulates)* (6.3%)	World Development Indicators	20 ug/m3 of PM_{10}
		Water (effects on humans) (12.5)	**Access to water* (6.3%)**	World Development Indicators	100% population with access
			Access to sanitation* (6.3%)	World Development Indicators	100% population with access
	Ecosystem Vitality (50%)	**Air Pollution (effects on ecosystem) (4.2%)**	**Sulfur dioxide emissions per populated land area (2.1%)**	Emissions Database for Global Atmospheric Research (EDGAR) v3.2, United National Framework Convention on Climate Change (UNFCCC), Regional Emissions Inventory in Asia (REAS)	0.01 Gg SO2/sq km
			Nitrogen oxides emissions per populated land area* (0.7%)	EDGARv3.2, UNFCCC, REAS	0.01 Gg NOx /sq km
			Non-methane volatile organic compound emissions per populated land area* (0.7%)	EDGARv3.2, UNFCCC, REAS	0.01 Gg NMVOC /sq km
			Ecosystem ozone* (0.7%)	Model for OZone and Related chemical Tracers (MOZART) II model	0 ppb exceedance above 3000 AOT40. AOT40 is cumulative exceedance above 40 ppb during daylight summer hours
		Water (effects on ecosystem) (4.2%)	**Water quality index (2.1%)**	United Nations Environment Programme (UNEP) Global Environmental Monitoring System (GEMS)/Water	Dissolved oxygen: 9.5mg/l (Temp<20ºC), 6mg /l (Temp>=20ºC); pH: 6.5 - 9mg/l; Conductivity: 500µS; Total Nitrogen: 1mg/l; Total phosphorus: 0.05mg/l; Ammonia: 0.05mg/l
			Water stress index* (1%)	University of New Hampshire Water Systems Analysis	0% territory under water stress
			Water scarcity index* (1%)	Fand and Agricilture Organization (FAO)of the UN	0 fraction of water overuse
		Biodiversity & Habitat (4.2%)	**Biome protection (2.1%)**	International Union for Conservation of Nature (IUCN), CIESIN	10% weighted average of biome areas
			Marine protection* (1%)	Sea Around Us Project, Fisheries Centre, University of British Columbia	10% of Exclusive Economic Zone (EEZ)
			Critical habitat protection* (1%)	Alliance for Zero Extinction, The Nature Conservancy	100% AZE sites protected
		Forestry (4.2%)	**Growing stock change* (2.1%)**	FAO	ratio >=1 n cubic meters / hectare
			Forest cover change* (2.1%)	FAO	% no decline
		Fisheries* (4.2%)	**Marine trophic index (2.1%)**	UBC, Sea Around Us Project	no decline of slope in trend line
			Trawling intensity (2.1%)	UBC, Sea Around Us Project	0% area with combined bottom trawl or dredge catch within declared EEZ areas
		Agriculture (4.2%)	**Agricultural water intensity* (0.8%)**	FAO	10% water resources
			Agricultural subsidies (1.3%)	Yale Center for Environmental Law & Policy, World Development Report, Organization of Economic Cooperation and Development (OECD)	0 Nominal Rate of Assistance (NRA)
			Pesticide regulation (2.1%)	UNEP-Chemicals	22 points
		Climate Change (25%)	**Greenhouse gas emissions per capita (including land use emissions) (12.5%)**	World Resources Institute (WRI) Climate Analysis Indicator Tool (CAIT), Houghton 2009, World Development Indicators (WDI) 2009	2.5 Mt CO_2 eq. (Estimated value associated with 50% reduction in global GHG emissions by 2050, against 1990 levels)
			CO2 emissions per electricity generation (6.3%)	International Energy Agency	0 g CO_2 per kWh
			Industrial greenhouse gas emissions intensity (6.3%)	WRI-CAIT, WDI, Central Intelligence Agency	36.3 tons of CO2 per $mill (USD, 2005, PPP) of industrial GDP (Estimated value associated with 50% reduction in global GHG emissions by 2050, against 1990 levels)

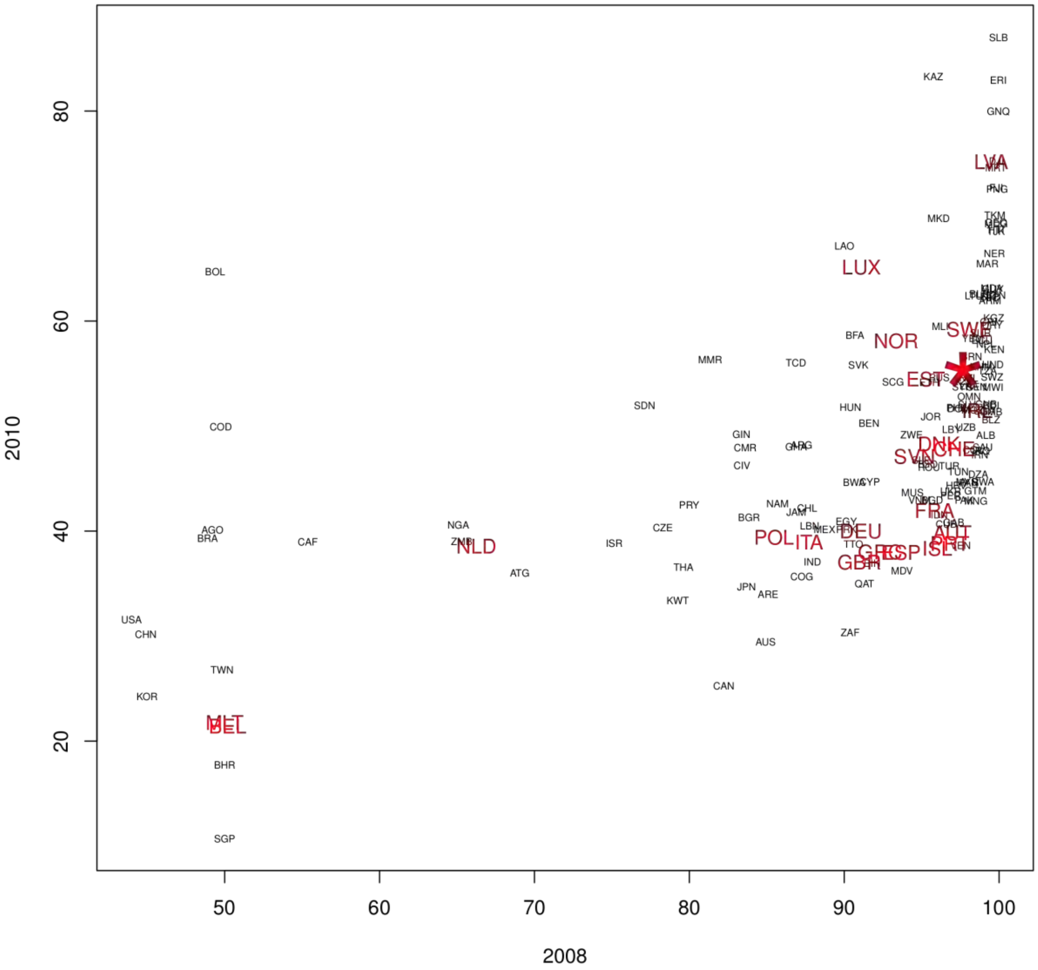
This methodological refinement serves two purposes.

First, and most importantly, most of the indicators have a sizeable number of countries very close to target, and we used logarithmic scales to more clearly differentiate among the best environmental performers. Using raw (untransformed) data, as we did in 2008, caused the EPI to ignore small differences among top-performing countries and only acknowledge the more substantial differences between leaders and laggards. The use of the log transformation has the effect of "spreading out" these leading countries, allowing the EPI to reflect important differences not only between the leaders and laggards, but among best-performing leaders as well.

Secondly, logarithmic transformation improves the interpretation of differences between countries at opposite ends of the scale. For example, consider two comparisons of Urban Particulates (Outdoor Air Pollution): top-performers Venezuela and Grenada (having PM10 values of 10.54 and 20.54, respectively), and low performers Libya and Kuwait (87.63 and 97.31, respectively). Both comparisons involve differences of 10 units on the raw scale (μg/m3), but we acknowledge that they are substantively different. Venezuela is an order of magnitude better than Grenada, while Libya and Kuwait differ by a much smaller amount in percentage terms. Compared to the use of the raw measurement scale, the log scale somewhat downplays the differences between the leaders and laggards, while more accurately reflecting the nature of differences at all ranges of performance. Thus, the 2010 EPI encourages continued improvements by the leaders, where even small improvements can be difficult to make, but provides relatively fewer rewards for the same amount of improvement among the laggards. Such improvements by the leaders would be rewarded by increasing scores in future EPIs.

The impact of this change on the EPI can be seen in the Air Pollution (ecosystems) policy category, where each of the underlying performance indicators have been logarithmically transformed. Figure 2.3 shows the 2008 proximity to target values on the x-axis, with

Figure 2.3 2008 EPI and 2010 EPI Air Quality for Ecosystems Proximity to Target Values (Finland * and Europe highlighted in red)



the 2010 air performance indicator on the y-axis. Note the large number of countries awarded proximity to target values above 95% in 2008. In comparison, the 2010 EPI performance indicators for this leading group are now spread over a range of values between 50 and 100. Finland is highlighted with a red star, and the other European countries are highlighted with red country codes. In 2008, Sweden, Finland, and France, for example, all had virtually identical proximity to target values above 95%, and the 2008 EPI essentially ignored the differences. The 2010 EPI now provides meaningful separation between these leading countries.

2.5

DATA AGGREGATION AND WEIGHTING

In the environmental indicator arena, aggregation is an area of methodological controversy. While the field of composite index construction has become a well-recognized subset of statistical analysis, there is no clear consensus on how best to construct composite indices that combine disparate issues. Various aggregation methods exist, and the choice of an appropriate method depends on the purpose of the composite indicator as well as the nature of the subject being measured. While we have assigned explicit weights in the construction of the EPI, the actual implicit weights differ slightly owing to the country score variances in each policy category.

In the EPI framework, the Environmental Health and Ecosystem Vitality objectives each contribute 50% to the overall EPI score. This equal division of the EPI into sub-scores related to humans and nature is not a matter of science but rather a policy judgment. Yet this equal weighting of the two overarching objectives reflects a widely held intuition that both humans and nature matter. This approach, used in the 2008 and 2006 Pilot EPIs, has not been contested. For every deep ecologist who favors more weight being placed on Ecosystem Vitality, there is a “humans first” environmental policymaker who prefers that the tilt go the other way.

In 2008 we calculated a simple average of the untransformed Environmental Health and Ecosystem Vitality objective scores. In reality this gave lower implicit weight to the Ecosystem Vitality score because its range and variance is much lower. In 2010 the Environmental Health scores range from 0.06 to 95.09 whereas the untransformed Ecosystem Vitality scores range from 29.42 to 83.25. In order to ensure that Ecosystem Vitality contributes equally in the aggregation, we rescaled the objective so that its minimum and maximum country scores match those of Environmental Health.

We now turn to a discussion of the weighting of indicators within policy categories and the rules governing the inclusion or exclusion of countries that were missing data for certain indicators. Table 2.1 shows the weight (in percentile of total EPI) of each policy category and indicator.

Within the Environmental Health objective, the Environmental Burden of Disease (EBD) indicator is weighted 50% and thus contributes 25% to the overall EPI score. We gave EBD a high weight in Environmental Health because it integrates the impacts of a large number of environmental stressors on human health. The effects of Water and Air Pollution on human health comprise the remainder of the Environmental Health objective and are each allocated a eighth of the total score. Within Air Pollution (effects on humans) and Water (effects on humans), the constituent indicators are equally weighted.

If the EBD score was missing, we did not calculate an Environmental Health or EPI score. If one of two indicators in Air Pollution or Water were missing (but not both), we averaged around them to calculate the policy category score.

Within the Ecosystem Vitality objective, the Climate Change indicator carries 50% of the weight (i.e., 25% within the overall EPI). This focus on greenhouse gas emissions reflects the importance attached to climate change in policy discussions and its potentially far reaching impacts across all aspects of ecosystem health and natural resource management. The remaining policy categories – Air, Water, Biodiversity, Forestry, Fisheries, and Agriculture – are each equally weighted to cover the remaining 50% of the Ecosystem Vitality objective.

To be included in the overall EPI, we required scores for each of the policy categories within Ecosystem Vitality except in the case of Fisheries, and then only for landlocked countries.[3]

For the Air Pollution (effects on ecosystems) category, we had data on ozone exceedences for all countries, and we required that there be data for Sulfur Dioxide (SO2) because of its multiple environmental impacts. If data for any of the other air pollutants was missing, we averaged around them.

For the Water (effects on ecosystems) category, we had complete country coverage for the Water Quality Index (WQI) owing to data imputation. No Water Quality Index was reported for several countries that had surface water areas of less than 10 square kilometers, so for these countries we averaged around WQI. The Water Stress Index (WATSTR) was available for all but the smallest countries, in terms of geographic area, owing to the grid cell size of the original data source.

Either WATSTR or the Water Scarcity Index (WSI) was required in order to calculate the policy category score; if both were present we averaged them, and if one indicator was missing we averaged around it.

For the Biodiversity & Habitat category, if the Marine Protected Areas (MPAEEZ) and Critical Habitat Protection (AZE) indicators were missing, then the Biome Protection (PACOV) indicator received 100% of the weight. Landlocked countries have no marine protected areas, and countries without alliance for zero extinction sites (see Metadata) could not receive a score for Critical Habitat Protection. If either AZE or MPAEEZ were missing, then PACOV was given 75% of the weight and the other indicator received the remaining 25%. If all three Biodiversity & Habitat indicators were present, then PACOV received 50% of the category weight, and AZE and MPAEEZ received 25% each.

For the Forestry category, if one of the two constituent indicators was missing, we substituted the other value due to the very high correlation between Forest Cover Change and Growing Stock Change. If both indicators were available, then a simple average was calculated.

For the Fisheries category, all non-landlocked countries were required to have both the Marine Trophic Index and Trawling Intensity indicators, to which we applied an equal weight.

For the Agriculture category, we applied principal component analysis (PCA) to determine the weighting for the component indicators. Pesticide Regulation (PEST) received 50% of the policy category weight, Agricultural Subsidies (AGSUB) received 30%, and Agriculture Water Intensity (AGWAT) the remaining 20%. PEST and AGSUB indicators were required in order to calculate the policy category score.

All three Climate Change indicators were necessary in order to calculate at the policy category score. For Carbon Intensity of Electricity Generation we imputed some country scores. The weightings given were 50% to Greenhouse Gas Emissions/Capita, 25% Carbon Intensity of Electricity Generation, and 25% Industrial Greenhouse Gas Emissions.

3.
RESULTS AND ANALYSIS

The 2010 EPI provides policymakers, scientists, and other experts with a quantitative basis for comparing, analyzing, and understanding environmental performance and its underlying drivers for more than 160 countries. It reveals a set of environmental problems where progress is being made and others where it is not. It also highlights points of policy leverage. While some policy and performance correlations are well established – e.g. the strong relationship between national income and environmental health outcomes – the reality is that they are not uniform within and across country peer groups. For every issue, some countries rank higher in the index than their economic circumstances would suggest. This result means that other factors, such as good governance, also shape outcomes. The 2010 EPI provides a basis for identifying best practices linked to strong environment and development policy, and highlighting performance leaders, laggards, and outliers.

3.1
OVERALL EPI RESULTS

The EPI is comprised of 163 countries with sufficient data for inclusion in the 2010 EPI. Iceland ranked highest, with a score of 93.5, followed by Switzerland (89.1), Costa Rica (86.4), Sweden (86.1), and Norway (81.1). As expected, developed countries with sufficient financial resources, a commitment to environmental management, and sophisticated policy systems make up a large portion of top performers. European countries constitute more than half of the countries ranked in the top 30 (Figure 3.1). Exceptions exist, however. Costa Rica, a middle-income country, outperforms most developed countries, and Cuba, with strong Environmental Health scores and low levels of industrial pollution, ranks ninth.

The countries with the worst environmental performance are Sierra Leone (32.1), the Central African Republic (33.3), Mauritania (33.7), Angola (36.4), and Togo (36.4). These sub-Saharan African countries are among the poorest in the world, lack resources for health care or basic environmental investments, and have weak policy capacity. Some hyper-arid but wealthy countries also make it into the bottom third of countries, owing largely to a lack of water resources and high greenhouse gas emissions – though it should be noted that in 2010 we include desalinated water for the first time as part of renewable water resources. This is in recognition of the fact that for some countries there are few alternative supplies.

The middle ranks represent a more diverse set of countries. Some developed countries with strong performances on Environmental Health objectives have poor performance on climate change and emissions, while some developing countries have moderate scores on both Environmental Health and Ecosystem Vitality objectives. Canada (66.4) is ranked at 46, the Philippines (65.7) is ranked at 50, Poland (63.1) is ranked at 63, and Laos (59.6) is ranked at 80.

Most of the world's largest economies find themselves lagging behind the top performers. The US (63.5) is ranked at 61 – just outside the first tercile – penalized mostly for poor performance on the Climate Change and Air Pollution (effects on ecosystems) policy categories. Better, but also not among the top 10 are Germany (73.2, rank 17) and Japan (72.5, rank 20). Again, the problem areas for these countries are environmental air quality, climate change, and – in the case of Germany – fisheries management.

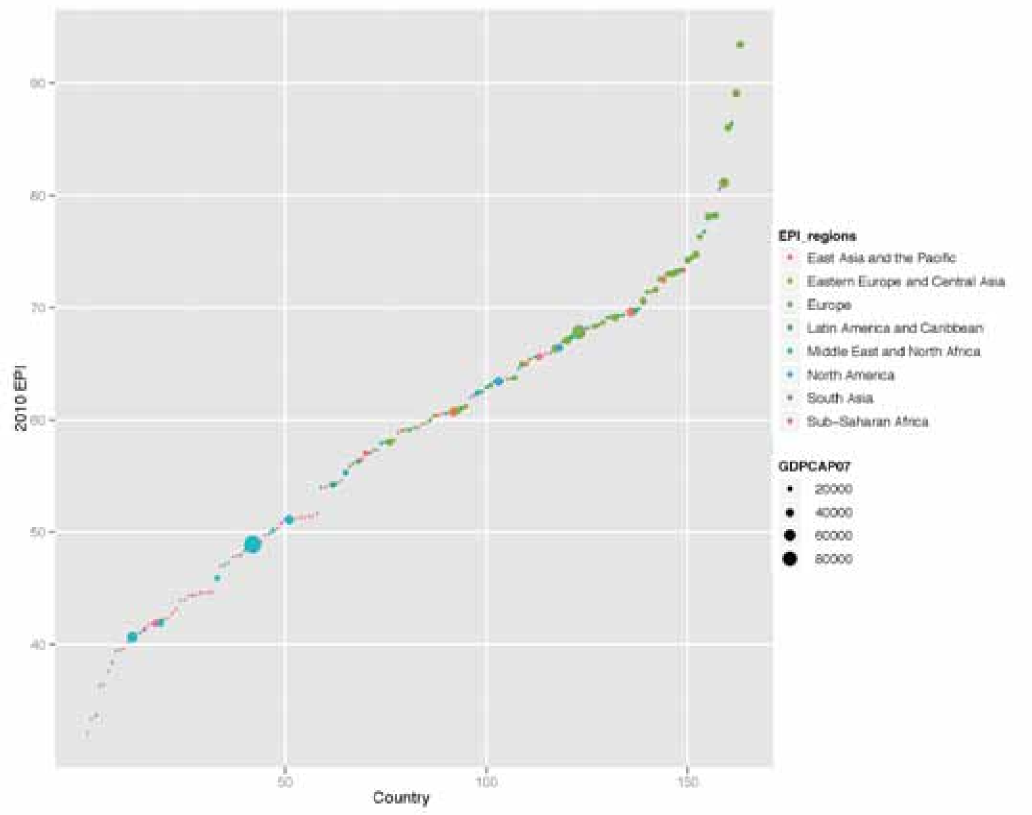
The BRIC countries – Brazil, Russia, India, and China – occupy the ranks 62 (just behind the US), 69, 123, and 121, respectively. These countries struggle with the pressures of large populations, rapidly growing industrial bases, and histories of pollution and resource mismanagement. Thus, these countries score poorly on the Ecosystem Vitality objective, and their health care systems are not entirely able to offset the environmental stressors that contribute to low scores on Environmental Burden of Disease. Overall, their environmental problems are more diverse and require all-encompassing strategies to remedy, including increased environmental investments, regulatory overhaul, more efficient and transparent institutions, and more effective enforcement of environmental laws and regulations.

Other country groupings are discussed in detail in Section 3.3 on the Cluster Analysis.

Table 3.1 shows the correlation of the 2010 EPI with its constituent objectives and policy categories, demonstrating that Environmental Health has a stronger correlation with the overall EPI when compared to Ecosystem Vitality. This is for reasons discussed in greater detail below.

Historically, the Environmental Health objective has received the bulk of policy attention, resources, and

Figure 3.1 EPI performance by Region and GDP per capita



monitoring. The Environmental Burden of Disease indicator, which is half of the overall Environmental Health score, reflects a mixture of:

- past and current investments in protecting human health, including availability and access to public health infrastructure;
- environmental stressors such as poor air and water quality;
- natural conditions, including weather and susceptibility to natural disasters; and
- societal and behavioral risk factors such as obesity and cardiovascular health.

Economic development correlates with all four aspects but the link is most direct with respect to the extent and quality of the health care system. The strong correlation is evident in the ranking of countries in the Ecosystem Health objective and underlying policy categories. The top 25 countries in this category are all industrialized, high-income countries, perhaps with the exception of Qatar, which uses its oil and gas revenues to provide a free health care system.

Since the EPI allocates 50% of the overall weight to the Environmental Health objective, it is not surprising that wealthy countries benefit greatly from their ability to manage environmental health. We use the term “manage” because the Environmental Burden of Disease (EBD) can mask the true exposure of people to harmful environmental substances.

EBD, measured in DALYs (disability-adjusted life years), is essentially a health gap measure, which can be influenced in two ways. The environmental threat can be reduced or removed, or the health care system can be advanced enough to address the threat through treatment. In wealthy countries, the latter may mitigate the negative environmental effects of air and water pollution.

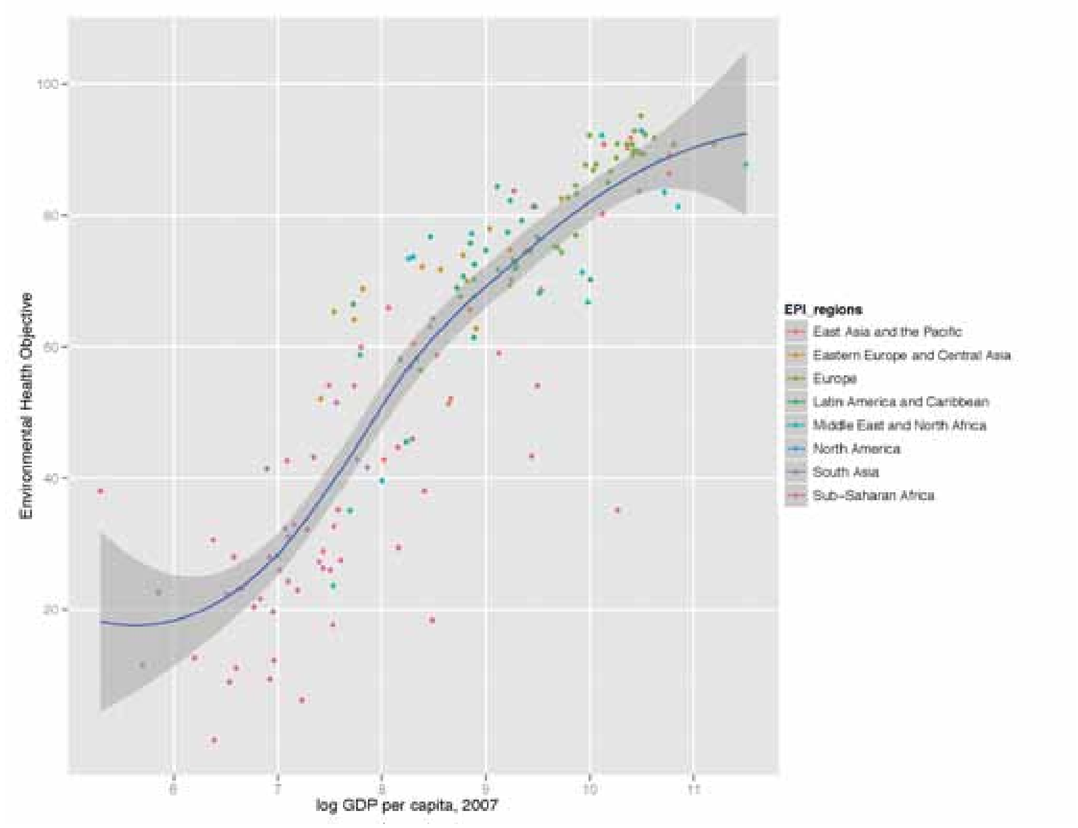
To correct for this, the Environmental Health objective also includes indicators that account for indoor and outdoor air pollution as well as access to clean water and sanitation. Low-performing countries have not made the investments necessary to curtail environmental pollutants, provide adequate water and sanitation to their citizens, or build effective health care systems.

Overall, the Environmental Health objective conveys the strong message that – with a few notable exceptions – economic development generates good public health (Figure 3.2). Although relatively few countries perform well above expectations compared to their income level, quite a number perform well below.

Table 3.1 Kendall’s tau correlation coefficient between the 2010 EPI and various components

Component	EPI10
Environmental Health	0.58
Ecosystem Vitality	0.20
Environmental Burden of Disease	0.52
Air pollution (human health effects)	0.56
Water pollution (human health effects)	0.51
Air pollution (ecosystem effects)	-0.08
Water pollution (ecosystem effects)	0.28
Biodiversity	0.11
Forests	0.36
Fisheries	0.11
Agriculture	0.25
Climate change	0.01

Figure 3.2 Environmental Health by log GDP per capita (gray in scatter plot represents approximately 2 standard deviations)



For the Ecosystem Vitality objective the effect of income is much more difficult to decipher (Figure 3.3) and requires unpacking at the policy category and indicator level. In Section 2.5 we describe the rescaling of the Ecosystem Vitality objective to cover the same range as the Environmental Health objective. In Figure 3.4, which represents the untransformed distribution, one can see that scores for Ecosystem Vitality are concentrated in a narrower range (ranging from about 30-83) than for Environmental Health (ranging from 0-95). This reflects the larger number of indicators in the objective. It also reflects the fact that some countries score high on one policy category (e.g. Biodiversity & Habitat) but low on another (e.g. Climate Change) – such that good performance in the one “cancels” bad performance in the other, dampening the overall range in scores.

Figure 3.3 Ecosystem Vitality by log GDP per capita (gray in scatter plot represents approximately 2 standard deviations)

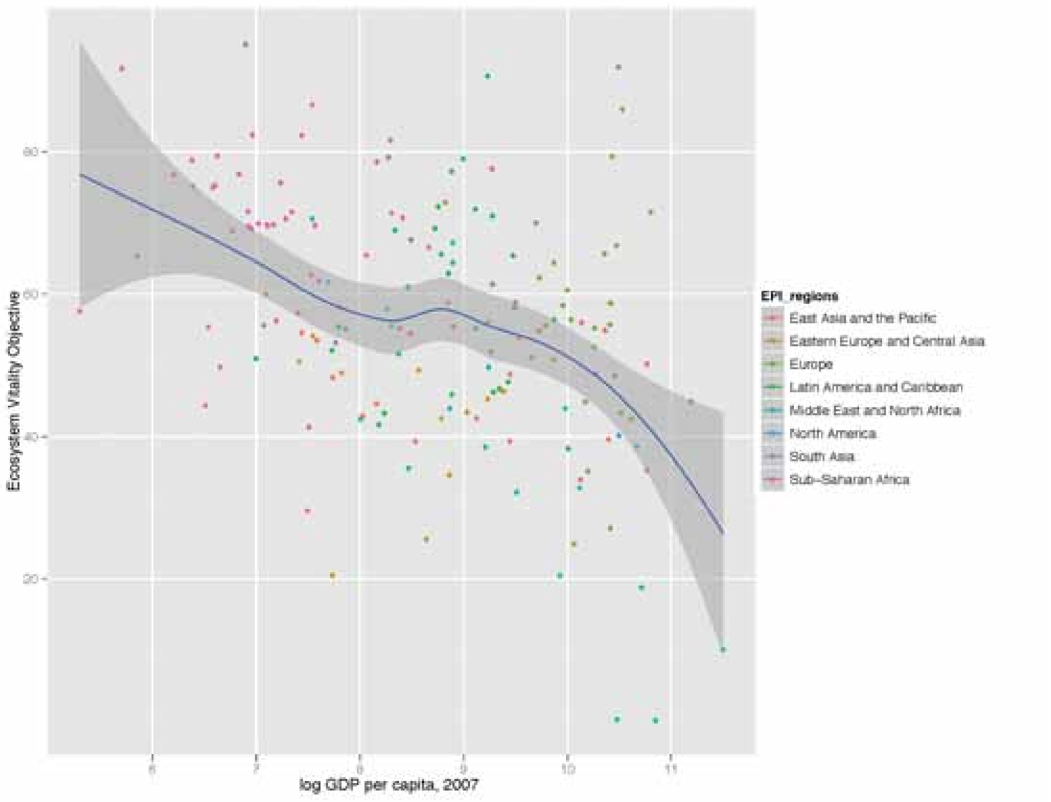


Figure 3.4 Relationship between Environmental Health and Ecosystem Vitality Scores

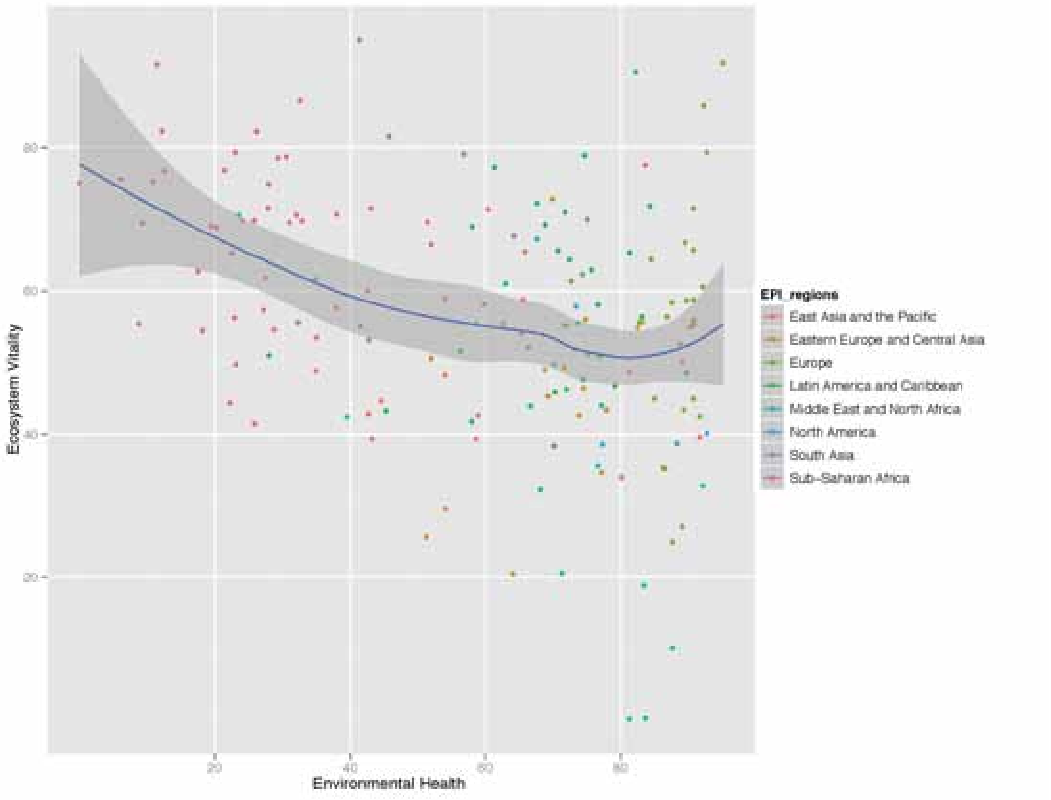
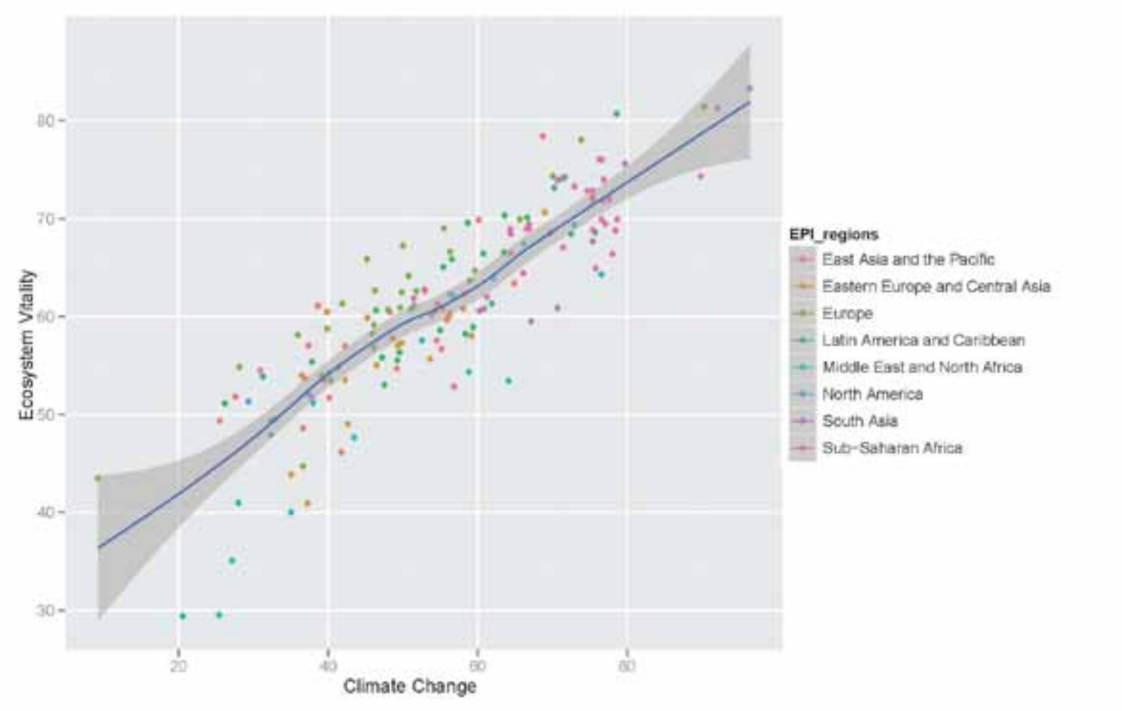


Figure 3.5 Relationship of the Climate Change policy category to Ecosystem Vitality (gray in scatter plot represents approximately 2 standard deviations)



The Climate Change policy category makes up half the weight of the Ecosystem Vitality objective. Climate Change performance is a strong predictor, therefore, of overall objective performance (Figure 3.5), though the other categories nudge country scores up or down slightly.

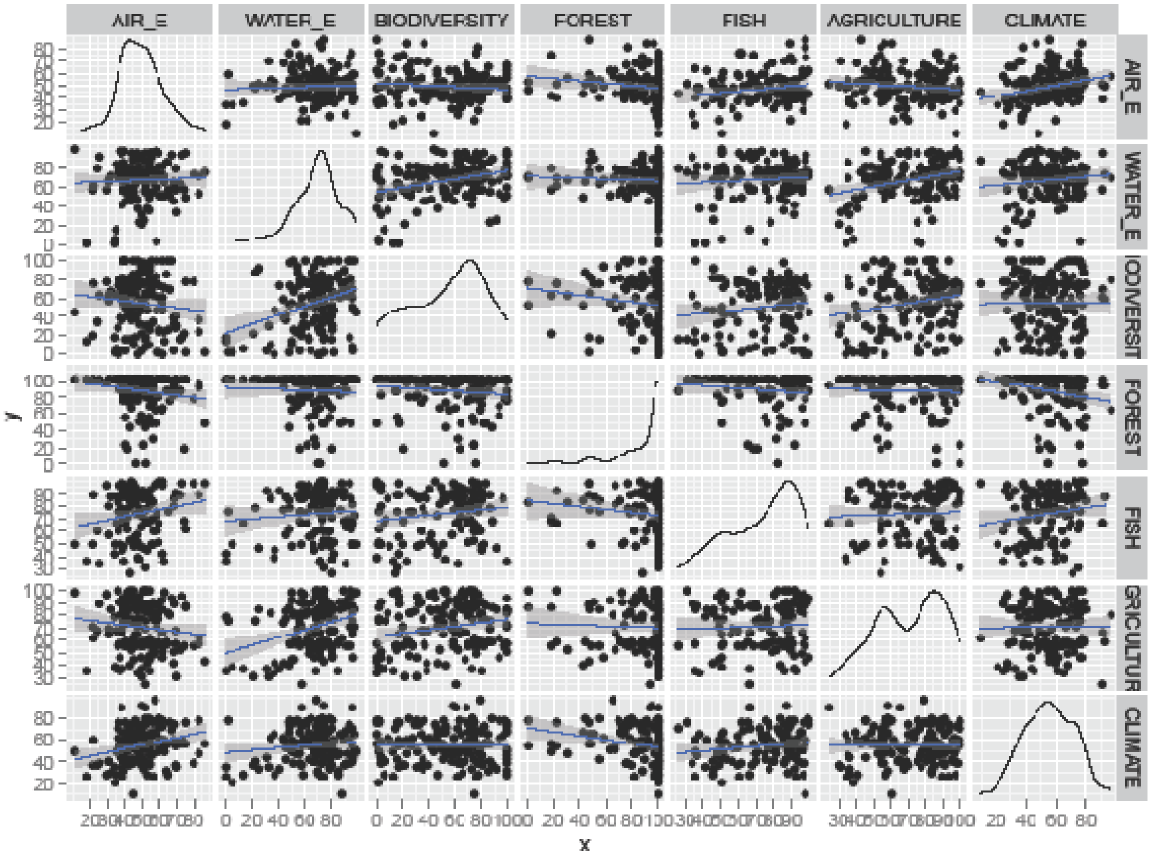
Achieving high marks in Ecosystem Vitality requires concerted efforts across a whole spectrum of environmental issues – from air pollution and climate change to fisheries and agriculture. Ultimately, it is not surprising that country characteristics – rich vs. poor, geographically large vs. small island states, densely vs. thinly settled, autocratic vs. democratic – significantly influence Ecosystem Vitality scores. Scores depend on a wide range of factors such as levels of industrialization, fossil fuel and resource consumption, trade, and environmental protection. The challenge and opportunity in understanding the Ecosystem Vitality objective lies in the interplay between its policy categories and their relationship to external drivers such as macro-economic conditions, institutional capacity, and regulatory stringency.

The components of the Ecosystem Vitality objective all represent relevant aspects in environmental protection and management. It is, however, less clear how they tie together, and what synergies and potentially negative feedback mechanisms exist. The scatterplot matrix in Figure 3.6 sheds some light on the relationships between biodiversity protection, sustainable forestry and fisheries, air and water quality management as well as climate change protection. The matrix shows each component plotted against all others while the main diagonal shows the distribution of each policy category. The mostly random scatter indicates that, contrary to the Environmental Health components, no clear-cut and simple relationships exist. It is more likely – but further research is necessary – that the pathways linking, for example, agricultural management to ecological water quality are not captured well by the EPI indicators. Thus, while the EPI gives a snapshot of the overall ability of a country to manage its environmental resources and to protect the health of its citizens from environmental pollution, it requires digging deep into the underlying policy objectives and indicators to begin to understand how sectoral practices affect outcomes in other areas. One important aspect in this context is the need for higher resolution spatial and time series data since country-level aggregates cannot show how local conditions change over time.

Countries that scored well in Ecosystem Vitality often did so for very different reasons. Of the two countries with the best objective scores, Iceland's performance can primarily be attributed to good environmental management and a low-carbon economy. Nepal's high score, however, arises from limited development and somewhat lower environmental stresses on the land, air, and water.

Countries varied considerably with respect to the influence of Environmental Health or Ecosystem Vitality

Figure 3.6 Scatter plot matrix of country scores in the seven Ecosystem Vitality policy categories



on their overall rank. Some low-ranked countries, such as the United Arab Emirates (rank 152) have high Environmental Health scores. This result suggests they have on-going challenges with one or more of the Ecosystem Vitality policy categories. Nepal, despite its top Ecosystem Vitality score, ranks at 88 in the EPI because of a very low Environmental Health score.

Because so many countries had high Environmental Health scores, poor performance in Ecosystem Vitality played a critical role in the overall rankings. Belgium, South Korea, and the United States exemplify countries ranked well below many members of their peer groups due to substantially lower Ecosystem Vitality scores.

3.2
RESULTS BY PEER GROUPINGS

Although overall country ranking on the EPI is of interest, experience has shown that analysts are most interested in understanding how their countries rank within relevant regional, economic, and political peer groups. Peer group analysis gives policymakers a way to contextualize their policy choices in light of the performance of other countries with similar socioeconomic, political, or geographic situations. The policies and programs of peer group leaders provide insight into best practices and illuminate the most efficient approaches to improving Environmental Health and Ecosystem Vitality among countries facing similar challenges and opportunities. To facilitate this analysis, Tables 3.1 through 3.6 provide the within-region ranks and overall EPI scores for major world regions.

Organization for Economic Cooperation and Development (OECD) countries occupy four of the top five ranks in the 2010 EPI (Tables 3.7 and 1.1). All of the OECD countries are in the top half of the index, and most are in the top quarter. All of these relatively wealthy countries score highly in the Environmental Health category. But their scores for the various metrics of Ecosystem Vitality vary widely. Some of these nations, notably those in Scandinavia, have distinct geographic advantages such as large land areas and low population densities. But their success is also a function of concerted policy effort and deep commitment to environmental values across their public and business communities.

The Least Developed Countries (LDCs) (Table 3.8), score much lower than OECD countries on the EPI. None of the LDCs fall in the top half, and the bottom 18 countries in the EPI are all from this group. With little access to financial resources for immediate needs like nutrition and disease, many of these countries struggle to make even baseline efforts on environmental health.

Their lack of development translates into limited pollution stress and thus contributes to relatively strong scores on ecosystem-related air pollution and climate change. Many also make admirable efforts on biodiversity conservation.

Other peer groups, such as the African Union (Table 3.14), the Alliance of Small Island States (Table 3.15), the Desert Countries (Table 3.17), and the Newly Independent States (Table 3.16), are spread across the EPI. Each of these peer groups is largely populated by developing countries that experience a number of challenges. The Desert Countries peer grouping reveals the ecological difficulties these countries face. The top ten countries in this peer group are in the second tercile of the total EPI ranking. And the bottom two – Mauritania, and Niger – fall in the bottom 5% of the overall ranking.

The Free Trade Areas of the Americas peer group (Table 3.13) overlaps with most of the America regional grouping, with the exception of Cuba. The member countries fall in a wide range, from Costa Rica, which ranks 4th in the overall EPI, to Haiti, which ranks 151st. Still, more than half of the countries are in the top third of the EPI. For the European Union member countries, however, the spread is much narrower. All the countries fall in the top half of overall ranking, with seven making the top ten.

High population density countries are spread throughout the EPI (Table 3.18). Germany, for example, sits in the 14th position while Burundi ranks 147th. High population density generates special challenges, but the high-ranked performers in this category demonstrate that population density is not an insurmountable barrier to good environmental quality. Many of the lower-ranked countries in this grouping face challenges, but can look to their higher-ranking peers for guidance on how to develop in an environmentally sustainable manner.

Overall, geographic peer groups show much more diversity than do groupings like the OECD and the LDCs. This result implies that countries in the midst of economic transitions vary widely in how well they fold environmental protection into their development strategies. Population density is not a determinant of EPI score, as can be seen in Table 3.18. Mauritius ranks 35th in the overall EPI, and a number of other densely settled countries have relatively high EPI scores in spite of low resource to population ratios. Further analysis of these peer groups and of countries grouped by income deciles can be found at the website: http://epi.yale.edu

Table 3.1 Americas

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Costa Rica	86.4	11	Dominican Republic	68.4	21	Uruguay	59.1
2	Cuba	78.1	12	Suriname	68.2	22	Jamaica	58.0
3	Colombia	76.8	13	Mexico	67.3	23	Nicaragua	57.1
4	Chile	73.3	14	Canada	66.4	24	Trinidad & Tob.	54.2
5	Panama	71.4	15	Paraguay	63.5	25	Guatemala	54.0
6	Belize	69.9	16	United States	63.5	26	Honduras	49.9
7	Antigua & Barb.	69.8	17	Brazil	63.4	27	Bolivia	44.3
8	Ecuador	69.3	18	Venezuela	62.9	28	Haiti	39.5
9	Peru	69.3	19	Argentina	61.0			
10	El Salvador	69.1	20	Guyana	59.2			

Table 3.2 Asia and Pacific

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	New Zealand	73.4	10	Malaysia	65.0	19	China	49.0
2	Japan	72.5	11	Sri Lanka	63.7	20	India	48.3
3	Singapore	69.6	12	Thailand	62.2	21	Pakistan	48.0
4	Nepal	68.2	13	Brunei	60.8	22	Indonesia	44.6
5	Bhutan	68.0	14	Laos	59.6	23	Papua N. G.	44.3
6	Maldives	65.9	15	Viet Nam	59.0	24	Bangladesh	44.0
7	Fiji	65.9	16	South Korea	57.0	25	Mongolia	42.8
8	Philippines	65.7	17	Myanmar	51.3	26	North Korea	41.8
9	Australia	65.7	18	Solomon Islands	51.1	27	Cambodia	41.7

Table 3.3 Eastern Europe and Central Asia

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Albania	71.4	7	Macedonia	60.6	13	Ukraine	58.2
2	Serbia & Monte.	69.4	8	Armenia	60.4	14	Kazakhstan	57.3
3	Croatia	68.7	9	Turkey	60.4	15	Bosnia & Herze.	55.9
4	Belarus	65.4	10	Kyrgyzstan	59.7	16	Tajikistan	51.3
5	Georgia	63.6	11	Azerbaijan	59.1	17	Uzbekistan	42.3
6	Russia	61.2	12	Moldova	58.8	18	Turkmenistan	38.4

Table 3.4 Europe

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Iceland	93.5	16	Albania	71.4	31	Poland	63.1
2	Switzerland	89.1	17	Spain	70.6	32	Bulgaria	62.5
3	Sweden	86.0	18	Serbia & Monte.	69.4	33	Russia	61.2
4	Norway	81.1	19	Denmark	69.2	34	Greece	60.9
5	France	78.2	20	Hungary	69.1	35	Macedonia	60.6
6	Austria	78.1	21	Croatia	68.7	36	Armenia	60.4
7	Malta	76.3	22	Lithuania	68.3	37	Turkey	60.4
8	Finland	74.7	23	Luxembourg	67.8	38	Azerbaijan	59.1
9	Slovakia	74.5	24	Ireland	67.1	39	Moldova	58.8
10	United Kingdom	74.2	25	Romania	67.0	40	Ukraine	58.2
11	Germany	73.2	26	Netherlands	66.4	41	Belgium	58.1
12	Italy	73.1	27	Belarus	65.4	42	Cyprus	56.3
13	Portugal	73.0	28	Slovenia	65.0	43	Bosnia & Herze.	55.9
14	Latvia	72.5	29	Estonia	63.8			
15	Czech Republic	71.6	30	Georgia	63.6			

Table 3.5 Middle East and North Africa

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Algeria	67.4	8	Lebanon	57.9	15	Sudan	47.1
2	Morocco	65.6	9	Jordan	56.1	16	Oman	45.9
3	Syria	64.6	10	Saudi Arabia	55.3	17	Bahrain	42.0
4	Israel	62.4	11	Kuwait	51.1	18	Iraq	41.0
5	Egypt	62.0	12	Libya	50.1	19	United Ar. Em	40.7
6	Tunisia	60.6	13	Qatar	48.9			
7	Iran	60.0	14	Yemen	48.3			

Table 3.6 Sub-Saharan Africa

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Mauritius	80.6	15	South Africa	50.8	29	Senegal	42.3
2	Djibouti	60.5	16	Gambia	50.3	30	Eq. Guinea	41.9
3	Namibia	59.3	17	Uganda	49.8	31	Botswana	41.3
4	Sao Tome & Prin.	57.3	18	Madagascar	49.2	32	Chad	40.8
5	Gabon	56.4	19	Tanzania	47.9	33	Nigeria	40.2
6	Eritrea	54.6	20	Zimbabwe	47.8	34	Benin	39.6
7	Swaziland	54.4	21	Burkina Faso	47.3	35	Mali	39.4
8	Côte d'Ivoire	54.3	22	Zambia	47.0	36	Niger	37.6
9	Congo	54.0	23	Guinea-Bissau	44.7	37	Togo	36.4
10	Dem. Rep. Congo	51.6	24	Cameroon	44.6	38	Angola	36.3
11	Malawi	51.4	25	Rwanda	44.6	39	Mauritania	33.7
12	Kenya	51.4	26	Guinea	44.4	40	Cen. Afr. Rep.	33.3
13	Ghana	51.3	27	Burundi	43.9	41	Sierra Leone	32.1
14	Mozambique	51.2	28	Ethiopia	43.1			

Table 3.7 Organization for Economic Cooperation and Development Member Countries

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Iceland	93.5	11	Germany	73.2	21	Ireland	67.1
2	Switzerland	89.1	12	Italy	73.1	22	Canada	66.4
3	Sweden	86.0	13	Portugal	73.0	23	Netherlands	66.4
4	Norway	81.1	14	Japan	72.5	24	Australia	65.7
5	France	78.2	15	Czech Republic	71.6	25	United States	63.5
6	Austria	78.1	16	Spain	70.6	26	Poland	63.1
7	Finland	74.7	17	Denmark	69.2	27	Greece	60.9
8	Slovakia	74.5	18	Hungary	69.1	28	Turkey	60.4
9	United Kingdom	74.2	19	Luxembourg	67.8	29	Belgium	58.1
10	New Zealand	73.4	20	Mexico	67.3	30	South Korea	57.0

Table 3.8 Least Developed Countries (LDCs)

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Nepal	68.2	14	Yemen	48.3	27	Cambodia	41.7
2	Maldives	65.9	15	Tanzania	47.9	28	Chad	40.8
3	Djibouti	60.5	16	Burkina Faso	47.3	29	Benin	39.6
4	Laos	59.6	17	Sudan	47.1	30	Haiti	39.5
5	Sao Tome & Prin.	57.3	18	Zambia	47.0	31	Mali	39.4
6	Eritrea	54.6	19	Guinea-Bissau	44.7	32	Niger	37.6
7	Dem. Rep. Congo	51.6	20	Rwanda	44.6	33	Togo	36.4
8	Malawi	51.4	21	Guinea	44.4	34	Angola	36.3
9	Mozambique	51.2	22	Bangladesh	44.0	35	Mauritania	33.7
10	Solomon Islands	51.1	23	Burundi	43.9	36	Central Afr. Rep.	33.3
11	Gambia	50.3	24	Ethiopia	43.1	37	Sierra Leone	32.1
12	Uganda	49.8	25	Senegal	42.3			
13	Madagascar	49.2	26	Equatorial Guinea	41.9			

Table 3.9 European Union (EU) Member Countries

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Sweden	86.0	10	Portugal	73.0	19	Romania	67.0
2	France	78.2	11	Latvia	72.5	20	Netherlands	66.4
3	Austria	78.1	12	Czech Republic	71.6	21	Slovenia	65.0
4	Malta	76.3	13	Spain	70.6	22	Estonia	63.8
5	Finland	74.7	14	Denmark	69.2	23	Poland	63.1
6	Slovakia	74.5	15	Hungary	69.1	24	Bulgaria	62.5
7	United Kingdom	74.2	16	Lithuania	68.3	25	Greece	60.9
8	Germany	73.2	17	Luxembourg	67.8	26	Belgium	58.1
9	Italy	73.1	18	Ireland	67.1	27	Cyprus	56.3

Table 3.10 Association of Southeast Asian Nations (ASEAN) and China, Japan, and South Korea

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Japan	72.5	6	Brunei	60.8	11	China	49.0
2	Singapore	69.6	7	Laos	59.6	12	Indonesia	44.6
3	Philippines	65.7	8	Viet Nam	59.0	13	Cambodia	41.7
4	Malaysia	65.0	9	South Korea	57.0			
5	Thailand	62.2	10	Myanmar	51.3			

Table 3.11 Asian Pacific Economic Cooperation Member Countries

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	New Zealand	73.4	8	Philippines	65.7	15	Viet Nam	59.0
2	Chile	73.3	9	Australia	65.7	16	South Korea	57.0
3	Japan	72.5	10	Malaysia	65.0	17	China	49.0
4	Singapore	69.6	11	United States	63.5	18	Indonesia	44.6
5	Peru	69.3	12	Thailand	62.2	19	Papua N.G.	44.3
6	Mexico	67.3	13	Russia	61.2			
7	Canada	66.4	14	Brunei	60.8			

Table 3.12 Organization of the Petroleum Exporting Countries (OPEC) Member Countries

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Ecuador	69.3	5	Saudi Arabia	55.3	9	Iraq	41.0
2	Algeria	67.4	6	Kuwait	51.1	10	United Ar. Em.	40.7
3	Venezuela	62.9	7	Libya	50.1	11	Nigeria	40.2
4	Iran	60.0	8	Qatar	48.9	12	Angola	36.3

Table 3.13 Free Trade Area of the Americas (FTAA) Member Countries

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Costa Rica	86.4	10	Dominican Rep.	68.4	19	Guyana	59.2
2	Colombia	76.8	11	Suriname	68.2	20	Uruguay	59.1
3	Chile	73.3	12	Mexico	67.3	21	Jamaica	58.0
4	Panama	71.4	13	Canada	66.4	22	Nicaragua	57.1
5	Belize	69.9	14	Paraguay	63.5	23	Trinidad & Tob.	54.2
6	Antigua & Barb.	69.8	15	United States	63.5	24	Guatemala	54.0
7	Ecuador	69.3	16	Brazil	63.4	25	Honduras	49.9
8	Peru	69.3	17	Venezuela	62.9	26	Bolivia	44.3
9	El Salvador	69.1	18	Argentina	61.0	27	Haiti	39.5

Table 3.14 African Union Member Countries

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Mauritius	80.6	17	Mozambique	51.2	33	Ethiopia	43.1
2	Algeria	67.4	18	South Africa	50.8	34	Senegal	42.3
3	Egypt	62.0	19	Gambia	50.3	35	Eq. Guinea	41.9
4	Tunisia	60.6	20	Libya	50.1	36	Botswana	41.3
5	Djibouti	60.5	21	Uganda	49.8	37	Chad	40.8
6	Namibia	59.3	22	Madagascar	49.2	38	Nigeria	40.2
7	Sao Tome & Prin.	57.3	23	Tanzania	47.9	39	Benin	39.6
8	Gabon	56.4	24	Zimbabwe	47.8	40	Mali	39.4
9	Eritrea	54.6	25	Burkina Faso	47.3	41	Niger	37.6
10	Swaziland	54.4	26	Sudan	47.1	42	Togo	36.4
11	Côte d'Ivoire	54.3	27	Zambia	47.0	43	Angola	36.3
12	Congo	54.0	28	Guinea-Bissau	44.7	44	Mauritania	33.7
13	Dem. Rep. Congo	51.6	29	Cameroon	44.6	45	Cen. Afr. Rep.	33.3
14	Malawi	51.4	30	Rwanda	44.6	46	Sierra Leone	32.1
15	Kenya	51.4	31	Guinea	44.4			
16	Ghana	51.3	32	Burundi	43.9			

Table 3.15 Alliance of Small Island States

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Mauritius	80.6	7	Suriname	68.2	13	Trinidad & Tob.	54.2
2	Cuba	78.1	8	Maldives	65.9	14	Solomon Islands	51.1
3	Belize	69.9	9	Fiji	65.9	15	Guinea-Bissau	44.7
4	Antigua & Barb.	69.8	10	Guyana	59.2	16	Papua N.G.	44.3
5	Singapore	69.6	11	Jamaica	58.0	17	Haiti	39.5
6	Dominican Republic	68.4	12	Sao Tome & Prin.	57.3			

Table 3.16 Russia and Newly Independent States (NIS) Member Countries that were Republics of the Former Soviet Union

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Belarus	65.4	5	Kyrgyzstan	59.7	9	Tajikistan	51.3
2	Georgia	63.6	6	Azerbaijan	59.1	10	Uzbekistan	42.3
3	Russia	61.2	7	Ukraine	58.2	11	Turkmenistan	38.4
4	Armenia	60.4	8	Kazakhstan	57.3			

Table 3.17 Desert Countries

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Antigua & Barbuda	69.8	10	Kazakhstan	57.3	19	Uzbekistan	42.3
2	Algeria	67.4	11	Jordan	56.1	20	Bahrain	42.0
3	Morocco	65.6	12	Saudi Arabia	55.3	21	Iraq	41.0
4	Israel	62.4	13	Kuwait	51.1	22	United Ar. Em.	40.7
5	Egypt	62.0	14	Libya	50.1	23	Turkmenistan	38.4
6	Djibouti	60.5	15	Qatar	48.9	24	Niger	37.6
7	Iran	60.0	16	Yemen	48.3	25	Mauritania	33.7
8	Namibia	59.3	17	Pakistan	48.0			
9	Azerbaijan	59.1	18	Oman	45.9			

Table 3.18 High Population Density

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	Mauritius	80.6	10	Maldives	65.9	19	India	48.3
2	Malta	76.3	11	Philippines	65.7	20	Rwanda	44.6
3	Germany	73.2	12	Sri Lanka	63.7	21	Bangladesh	44.0
4	Antigua & Barb.	69.8	13	Belgium	58.1	22	Burundi	43.9
5	Singapore	69.6	14	Jamaica	58.0	23	Bahrain	42.0
6	Serbia & Monte.	69.4	15	Lebanon	57.9	24	North Korea	41.8
7	El Salvador	69.1	16	Sao Tome & Prin.	57.3	25	Haiti	39.5
8	Nepal	68.2	17	South Korea	57.0			
9	Netherlands	66.4	18	Trinidad & Tobago	54.2			

3.3
CLUSTER ANALYSIS

Countries that have similar EPI scores may still have very different patterns of environmental results across the 10 policy categories and 25 indicators. To help governments identify peer countries that are similarly situated with respect to their pollution control and natural resource management challenges, we performed a statistical procedure known as cluster analysis. This process allows grouping of countries in terms of overall similarity across the 25 indicators, generating seven country clusters that can be useful as a way to help countries look beyond their income-level or geographic peer groups for models of environmental success in countries facing similar challenges. Within each peer group, countries have a better basis for benchmarking their environmental performance because the group members are similar with respect to the indicators used for the classification. This provides a good starting point in the search for best practices.

Cluster Analysis Technique

Following the cluster analysis used in the 2008 EPI, the 2010 EPI uses the k-means clustering method developed by Hartigan and Wong (Hartigan and Wong 1979) to determine cluster membership. K-means is a non-hierarchical method that requires the specification of the number of clusters, k, and then iteratively finds the disjoint partition of the objects into k homogeneous groups such that the sum of squares within the clusters is minimized. As long as the data are not skewed each variable receives approximately the same weight in the cluster. Because of the new use of logarithmic transformation with some indicators in 2010, there is less skewness in the performance indicators and, as a result, a more satisfying clustering of countries.

As in 2008 EPI, we use the proximity-to-target indicators, scaled using the square root of the weights allocated to them in the 2010 EPI, so that the sum-of-squares (variance-like) calculations of k-means would be on the scale of these weights. We also center the indicators at 0, so positive or negative values in the clustering summary of the group centers indicate better or worse than average performance. The k-means clustering algorithm coupled with Hartigan's 'rule of thumb' indicates 6-7 clusters. Because the 2008 EPI used 7 clusters, we chose to continue using 7 clusters for consistency and easy of interpretation from an environmental performance and socio-economic development perspective.

As was the case in 2008, several interesting patterns become apparent as a result of the cluster analysis. First, the weights given to Environmental Burden of Disease, Indoor Air Pollution, Outdoor Air Pollution, Access to Drinking Water, Access to Sanitation, Greenhouse Gas Emissions per Capita, CO2 Emissions Per Electricity Generation, and Industrial GHG Emissions Intensity result in their being the primary drivers of the clustering. Other indicators (receiving less weight in the EPI) contribute in smaller ways to differences between the clusters. Secondly, there are some differences between the 2010 and 2008 cluster analysis; specifically, the use of logarithmic transformation for some of the indicators in 2010 increases the ability to differentiate between countries performing close to the target (and with a less severe penalty on the lagging countries). In 2008, some of the clusters were driven by indicators where there was little or no variability among the leading countries on the untransformed scale of the data; now, this is less of an issue (except for a few indicators like FORGRO and FORCOV where many of the countries achieve the target).

The following tables show the country clusters, and Figure 3.7 shows the relative performance of each cluster across the 25 indicators.

Table 3.19 Cluster Group Analysis Results and Attributes

CLUSTER ONE

Attributes

This cluster is comprised largely of Middle Eastern, South Asian, and African developing countries. They perform poorly on environmental health indicators but about average on ecosystem performance indicators, except biome protection. Along with cluster three, they have low greenhouse gas emissions per capita.

Countries

Bangladesh
Djibouti
Eritrea
Gambia
India
Iraq
Mauritania
Pakistan
Sao Tome and Principe
Senegal
Sri Lanka
Sudan
Swaziland
Yemen

CLUSTER TWO

Attributes

These predominantly Middle Eastern and Asian nations perform well in terms of environmental burden of disease and indoor air pollution. They have roughly average results on most other indicators, but poor air pollution performance. Their scores on urban particulates and industrial carbon dioxide performance scores fall far below other clusters.

Countries

Bulgaria
China
Egypt
Iran
Jordan
Kyrgyzstan
Lebanon
Morocco
Moldova
North Korea
Syria
Tajikistan
Thailand
Tunisia
Turkey
Uzbekistan
Vietnam

CLUSTER THREE

Attributes

These mostly undeveloped, African nations perform very poorly on environmental health indicators but well on the climate change indicators due to their low greenhouse gas per capita. Low income helps explain poor health infrastructure and limited fossil fuel-based development.

Countries

Benin
Burkina Faso
Burundi
Chad
Cote d’Ivoire
DR Congo
Ethiopia
Ghana
Guinea
Guinea-Bissau
Haiti
Kenya
Madagascar
Malawi
Mali
Mozambique
Nepal
Niger
Nigeria
Rwanda
Sierra Leone
Tanzania
Togo
Uganda

CLUSTER FOUR

Attributes

These geographically disparate countries tend to feature rich natural resources with limited development. These countries tend toward average performance on many indicators while tracking closer to the strong performers in environmental health.

Countries

Albania
Algeria
Antigua & Barbuda
Azerbaijan
Belarus
Belize
Bhutan
Bosnia & Herzegovina
Colombia
Costa Rica
Cuba
Dominican Republic
Ecuador
El Salvador
Fiji
Georgia
Guatemala
Guyana
Honduras
Jamaica
Kazakhstan
Latvia
Lithuania
Macedonia
Maldives
Mauritius
Mexico
Nicaragua
Panama
Paraguay
Peru
Philippines
Romania
Russian Federation
Serbia and Montenegro
Solomon Islands
South Africa
Suriname
Ukraine
Venezuela

CLUSTER FIVE

Attributes

Many of these countries have productive natural resources but have experienced political strife. They perform poorly on environmental health. Their climate change scores are generally below average. However, they have low greenhouse gas and air pollution emissions.

Countries

Angola
Bolivia
Botswana
Cambodia
Cameroon
Central African Republic
Congo
Equatorial Guinea
Gabon
Indonesia
Laos
Mongolia
Myanmar
Namibia
Papua New Guinea
Zambia
Zimbabwe

CLUSTER SIX

Attributes

This small cluster is comprised of mainly fossil fuel producing and processing nations. They perform very well on the environmental burden of disease but poorly on outdoor air pollution. Their scores are among the lowest in some of the water indicators, but most notably, they have the worst greenhouse gas per capita performance of all the clusters.

Countries

Argentina
Armenia
Bahrain
Brunei Darussalam
Kuwait
Libya
Oman
Qatar
Saudi Arabia
Trinidad and Tobago
Turkmenistan
United Arab Emirates
Uruguay

CLUSTER SEVEN

Attributes

These mostly developed, wealthy nations perform the best in the environmental health categories. While generally trending toward the top of the pack on most indicators, they have the lowest score for agricultural subsidies and the second-lowest performance on greenhouse gas emissions per capita.

Countries

Australia
Austria
Belgium
Brazil
Canada
Chile
Croatia
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Israel
Italy
Japan
Luxembourg
Malaysia
Malta
Netherlands
New Zealand
Norway
Poland
Portugal
Singapore
Slovakia
Slovenia
South Korea
Spain
Sweden
Switzerland
United Kingdom
United States

Figure 3.7 Cluster Analysis Derived Centers of 2010 EPI Indicators (The cluster center (y-axis) shows the standardized difference between the cluster's average and the EPI average on each indicator.)

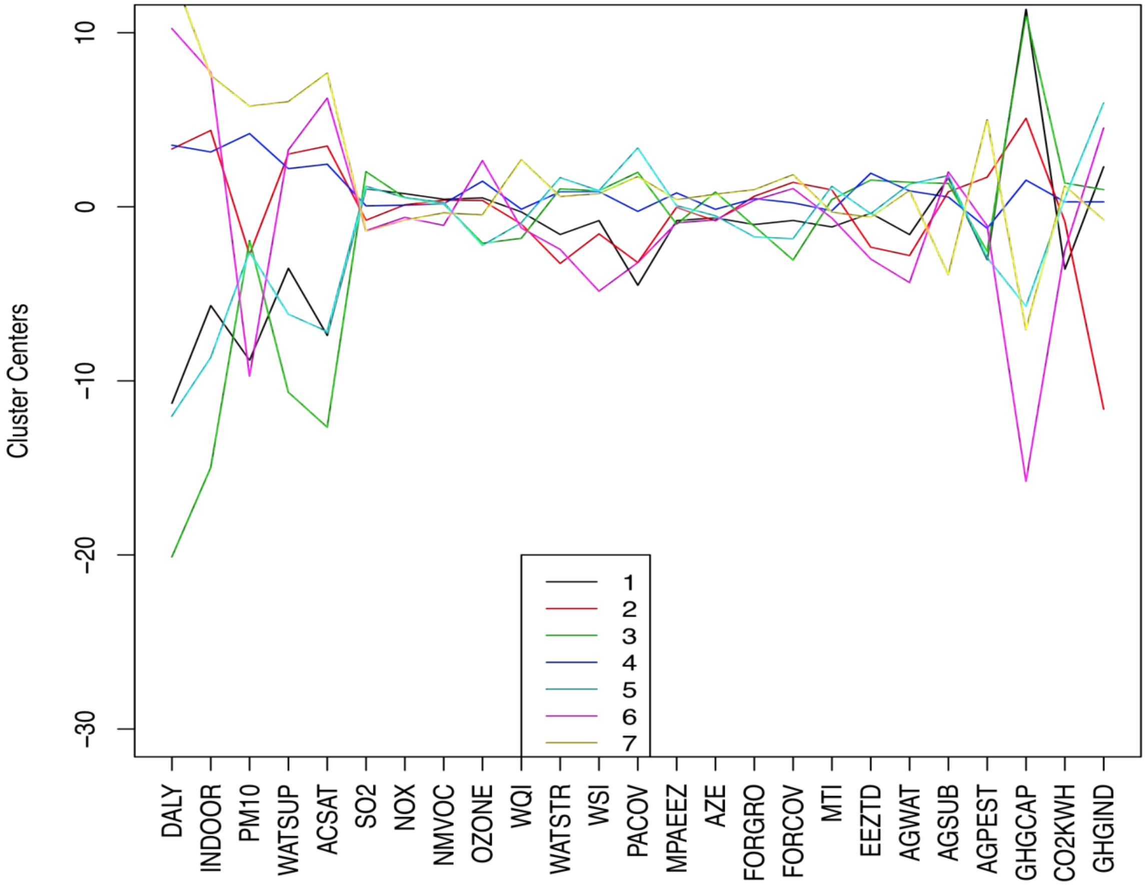


Table 3.20 Kendall’s tau correlation coefficients between the 2010 EPI and potential drivers of environmental performance.

Variable	EPI10
Per capita GDP (2007)	0.59
Population density (2006)	0.13
Percent of population in urban areas (2006)	0.44
2009 Ecological Footprint (accounts for 2007)	-0.31
World Bank CPIA Stringency of business regulatory environment (2006)	0.27
World Bank CPIA Institutions and policies for environmental sustainability (2006)	0.23
World Bank CPIA Accountability, transparency and corruption of the public sector (2006)	0.26
Trade as percent of GDP (2006)	0.13
Taxes as percent of international revenue (2006)	-0.43
Climate change policy score (0,1,2 for cap and trade and/or carbon tax policies)	0.45
Transparency Internationals Corruption Perception Index (2006)	0.54

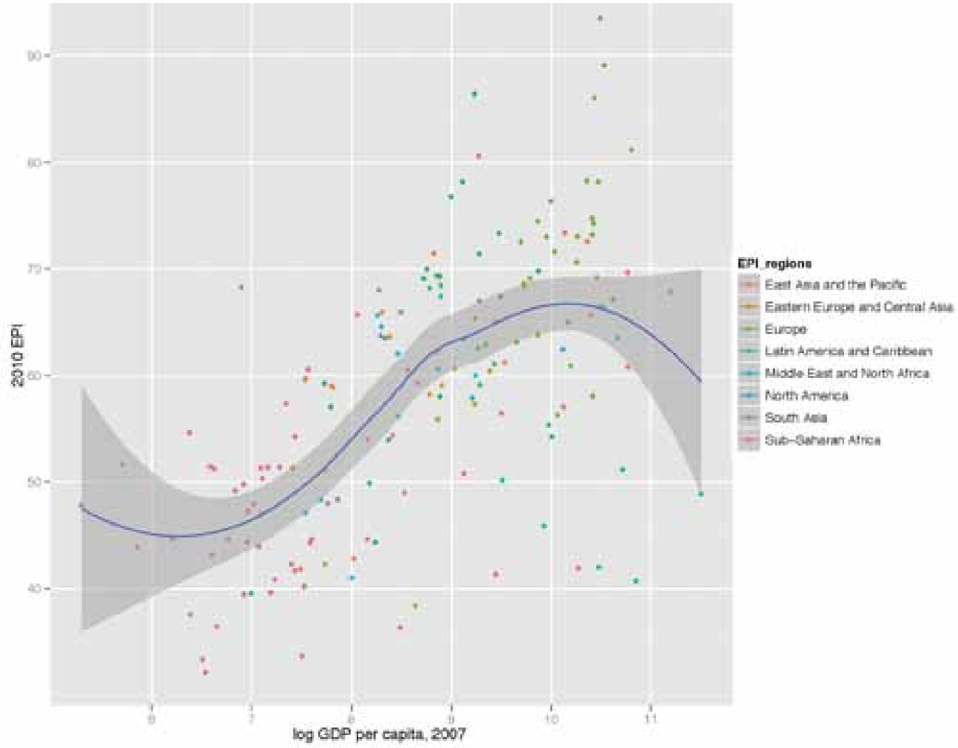
3.4
EPI DRIVERS

Among a selection of potential drivers for good environmental performance that include income, population density, urbanization, ecological footprint, corruption, institutional and regulatory system variables, trade openness, and climate change policies, three stand out for their clear correlation: per capita income, corruption (the accountability, transparency, and corruption of the public sector), and government effectiveness. Table 3.20 shows the correlations of the 2010 EPI with these potential drivers.

3.4.1
GDP PER CAPITA

As mentioned earlier, per capita GDP is correlated with higher performance on the EPI (Figure 3.8). The overall R-square between the 2010 EPI and log of GDP is0.59 The spread in EPI scores is greater at higher levels of income, reflecting disparate performance on Ecosystem Vitality. Poorer countries tend to have more uniformly low scores below 50.

Figure 3.8 Relationship of 2010 EPI and GDP per capita (log scale)



3.4.2
CORRUPTION

The control of corruption measure is aggregated from a number of indicators gauging perceptions of corruption, conventionally defined as the exercise of public power for private gain (Kaufmann et al. 2007). Environmental performance is correlated with corruption as measured by the Corruption Perceptions Index (Figure 3.9). Countries with high levels of perceived corruption tend to have low levels of environmental performance, whereas countries with low levels perform better on the EPI. This relationship is particularly marked for the Environmental Health objective and the Water Quality Index indicator.

3.4.3
GOVERNMENT EFFECTIVENESS

Government effectiveness measures the competence of the bureaucracy, the quality of policymaking, and public service delivery (Kaufmann et al. 2007). A slight positive relationship exists between government effectiveness and EPI performance (Figure 3.10). Particularly, government effectiveness positively correlates with performance on the greenhouse gas emissions per capita, health ozone, growing stock, and water quality indicators. Government effectiveness shows a slight negative correlation with performance on the sulfur dioxide indicator.

Figure 3.9 Relationship of 2010 EPI and Control of Corruption

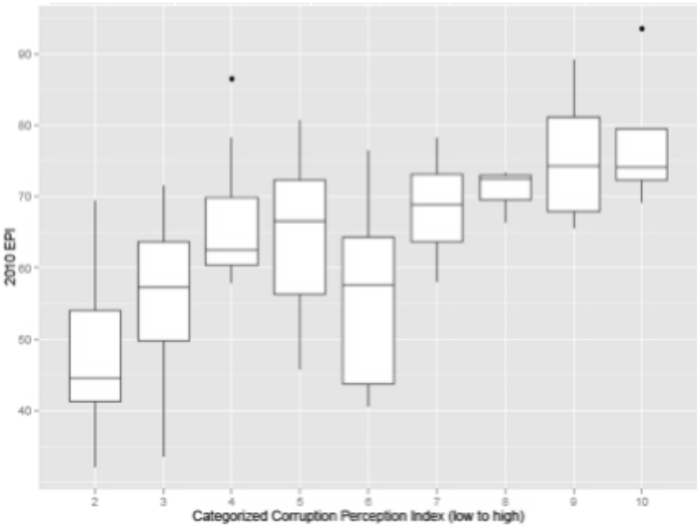


Figure 3.10 Relationship of 2010 EPI and Regulatory Rigor

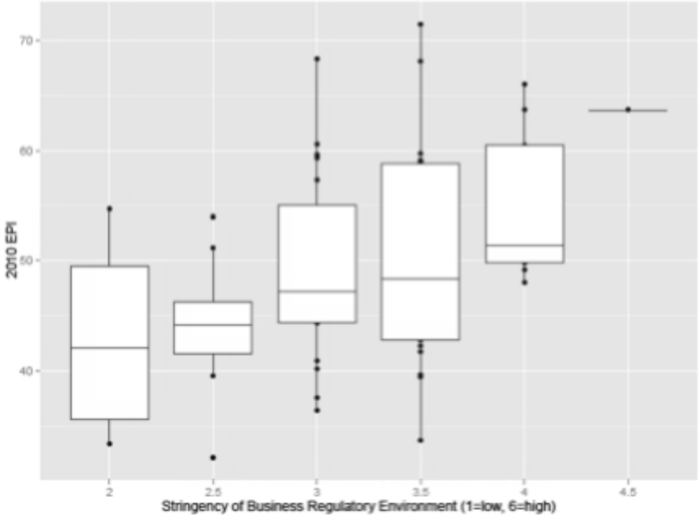
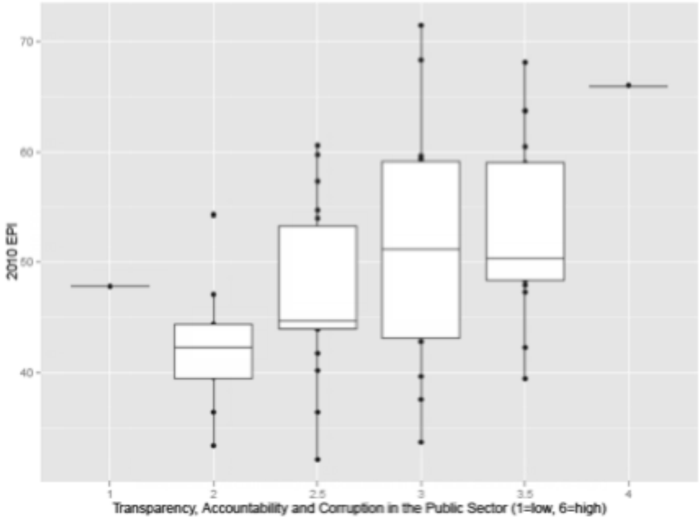


Figure 3.10 Relationship of 2010 EPI and Government Effectiveness



4.
POLICY CATEGORY RESULTS & FUTURE DIRECTIONS

One of the major values of the EPI is the ability to drill down below the aggregate EPI to see what is driving performance in any given country. This chapter describes the policy focus of each category, the indicators selected, and data gaps and deficiencies. The sections on data gaps and deficiencies focuses on indicators we would have liked to have included but which are not yet sufficiently mature as well as future directions for environmental performance measurement within that policy category. Note that detailed information on the data sources and methodologies used to produce the indicators is provided in Appendix A (Indicator Profiles).

ENVIRONMENTAL HEALTH

The Environmental Health objective in the 2010 EPI aims to capture health outcomes resulting from the environmental burden of disease (EBD) and risk factors such as poor water and sanitation and indoor and outdoor air pollution.

4.1
ENVIRONMENTAL BURDEN OF DISEASE

Policy Focus

Environmental conditions have significant direct and indirect impacts on human health. According to a 2004 World Health Organization report, exposure to environmental risk factors was partially responsible for 85 of the 102 reported major diseases. Addressing these environmental risk factors could potentially result in 40% fewer deaths from malaria, 41% fewer deaths due to lower respiratory infections, and 94% fewer deaths from diarrheal disease. Overall, the environmental burden of disease reduces the number of healthy years of life by almost a quarter (WHO, 2006). Approximately 13 million deaths could be prevented every year by addressing environmental problems such as air and water pollution and through public health measures such as improved access to water and sanitation and the use of cleaner fuels (WHO, 2008).

Indicator Selected

Environmental burden of disease: The only indicator in this category is the environmental burden of disease (EBD). The World Health Organization captures the environmental impact on human health through disability adjusted life years (DALYs). DALYs are the sum of the number of life years lost due to premature mortality caused by environmentally influenced disease and the years of healthy life lost due to disability caused by such disease. The target for the 2010 EPI is 0 DALYs lost.

Data Gaps and Deficiencies

Conceptually the overall EBD estimate has some limitations. It mixes information on the capacity of the health care system in a given country with information on the environmental risk factors. If one were solely interested in the risk factors, then outcome measures such as EBD would not be appropriate, but we feel that this indicator better reflects the situation “on the ground” and the tradeoffs that countries sometimes make between investment in the environment and other social goals.

Perhaps the greater limitation is that it would be very difficult to estimate what the burden of disease would be without environmental factors, since the number of factors is quite comprehensive. Producing a counterfactual – disability life years lost without these environmental factors – is difficult. The EBD exercise employs many assumptions, and is imperfect, but it is the best indicator currently available on a country basis. Narrowing the EBD to a smaller subset of environmental variables would be desirable, and is something that we initially attempted to do by collating measures of EBD for water and sanitation, indoor air pollution, and urban air pollution separately. However, experts cautioned against adding risk factors that have the same outcome (e.g. indoor and outdoor air pollution) (Ezzati, *personal communication*).

More specifically, the data used to develop the toxics exposure DALY remain limited. Although the EBD includes a DALY related to exposure to toxics, the reality is that data on toxic chemicals manufacture and disposal are limited, and that there are virtually no data on illegal releases. Though we sought to include a direct measure of hazardous waste management, data were insufficient to do so. Box 4.1 addresses the issue of toxic chemicals.

BOX 4.1
TOXIC CHEMICALS

By Rahmalan Bin Ahamad, Technical University of Malaysia (UTM)

The Environmental Performance Index (EPI) presents a powerful management tool to measure progress towards achievement of policy targets set for human health and ecosystem vitality. Accordingly, priority policy targets and indicators to measure progress of the respective policies are decided and developed to take advantage of its abilities. Human health and ecosystems are facing ever-increasing threats from these substances as a result of their uncontrolled release. Toxic substances are defined as any chemical or mixture of chemicals that may be harmful if inhaled, ingested, or absorbed through the skin. Two main types of toxic chemicals that have gained serious attention are: (a) heavy metals, including lead, cadmium, mercury, arsenic and chromium, and (b) persistent organic compounds, including polychlorinated biphenyls, dioxins and furans.

Toxic substances are released into the environment by natural processes as well as human activities. Anthropogenic release of toxic chemicals into the environment may occur accidentally through major industrial disasters, but the most prevalent form of release is through the disposal of domestic waste, emissions of industrial waste into wastewaters, agricultural and domestic use of pesticides, burning of coal and fossil fuels, mining and metal refining. Exposure and accumulation of toxic chemicals in human body tissues have caused chronic and acute health effects and even premature deaths.

Most heavy metals are persistent and bioaccumulate, increasing long-term health risks even at low levels of exposure. Heavy metals in agricultural soils may be extracted by crops and plants, hence increasing the chance of impacts on human health as crops and plants enter the food supply chain (Shaffer M., 2001). In aquatic systems, heavy metals bioaccumulate in aquatic life, posing the danger of human exposure to heavy metals toxicity from consumption of fish, shellfish and marine mammals. Concentrations of heavy metals, including mercury, in aquatic life can be thousands of times higher than the surrounding water (UNEP, 2008). Some heavy metals, such as lead, are toxic even at very low exposure levels. Lead has acute and chronic effects on human health, including neurological, cardiovascular, renal, gastrointestinal, haematological and reproductive effects. Heavy metals released into the atmosphere are subject to atmospheric dynamics. Once released into the atmosphere, they are transported on a local, regional and intercontinental scale. Mercury, for example, is a global pollutant, as it has the potential, once emitted from a source, to be transformed to different chemical forms, transported through the atmosphere, and deposited long distances from the point of origin (NAS, 2009).

Organic compounds or persistent organic pollutants (POPs) to varying degrees resist photolytic, biological and chemical degradation. Halogenated organic compounds tend to accumulate into fatty tissues due to their low water solubility and high lipid solubility. They are also semi-volatile, enabling them to move long distances in the atmosphere before deposition occurs. Many of POPs have been or continue to be used in large quantities, yet even at low concentrations pose serious threats to human health and ecosystems due to their environmental persistence and their ability to bioaccumulate and biomagnify. For example, the persistence of polychlorinated biphenyls (PCBs), combined with the high partition coefficients of various isomers, provide the necessary conditions for PCBs to bioaccumulate in organisms up to factors of 120,000 and 270,000 in some species (Ritter et.al., 1997).

Global concern regarding the effects of toxic chemicals on human health and ecosystems is evident from the international community's adoption of three conventions relating to toxic substances: (1) the 2004 Stockholm Convention on Persistent Organic Pollutants, (2) the 2004 Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals in International Trade, and (3) the 1992 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

The 2010 EPI indicator that comes closest to addressing the issue of toxics is the Pesticide Regulation indicator within the Agriculture policy category, which examines the legislative status of countries on two landmark agreements on pesticide usage, the Stockholm and Rotterdam conventions. The Stockholm Convention aims to reduce or eliminate the use of POPs internationally. Countries that agree to the Stockholm Convention promise to outlaw nine out of twelve POPs identified by the Forum on Chemical Safety and International Programme for Chemical Safety: aldrin, chlordane, dieldrin, endrin, heptachlor, HCB, mirex, and toxaphene. The Rotterdam Convention on Prior Consent Procedure for Certain Hazardous Chemicals in International Trade calls for mutual responsibility in monitoring the movement of hazardous toxics. The Rotterdam Convention resulted in an international agreement to use proper labeling in the exportation of hazardous materials, and allowed countries to decide whether or not to ban these chemicals.

Despite increasing awareness of the threats posed by toxic chemicals to human health and ecosystems, data on the release and circulation of toxic chemicals on a country-by-country basis are not available. This has prevented the EPI from including a toxics category.

4.2

AIR POLLUTION (EFFECTS ON HUMAN HEALTH)

Policy Focus

The WHO estimates that, of all diseases, lower respiratory tract infections are the second most attributable to environmental factors (WHO, 2006). Such infections are frequently caused by air pollution, which is estimated to cause approximately 2 million premature deaths worldwide per year. The 2010 EPI captures the health risks posed by air pollution with two indicators: Indoor Air Pollution and Urban Particulates. These indicators represent environmental risks faced by countries at different positions on the economic spectrum. Three billion people in the poorest developing countries rely on biomass in the form of wood, charcoal, dung, and crop residue as their cooking fuel, leading indoor air pollution to pose greater health risks in developing nations (Ezzati and Kammen, 2002). Meanwhile, outdoor air pollution tends to pose more severe risks in rapidly developing and developed nations with high levels of industrialization and urbanization. Thus, the air pollution indicators selected for use in the 2010 EPI identify the relevant environmental risks to countries at different development levels.

Indicators Selected

Indoor Air Pollution: Burning solid fuel indoors releases harmful chemicals and particles that present an acute health risk. These chemicals and particles can become lodged in the lungs when inhaled, leading to numerous respiratory problems, including acute lower respiratory tract infections. One recent study concluded that 4.6% of all deaths worldwide are attributable to acute lower respiratory tract infections caused by indoor fuel use (WHO, 2006).

This indicator is a measure of the percentage of a country's inhabitants using solid fuels indoors. The 2010 EPI uses data produced for the World Health Organization's EBD study that capture exposure to indoor smoke risks (Smith et al., 2004). The data are adjusted to account for reported ventilation in each measured home to best estimate actual exposure. The target for Indoor Air is set by expert judgment at zero, which reflects the opinion that any amount of solid fuel used indoors poses a risk to human health and is therefore considered undesirable. Many developing countries have already achieved this target, indicating that 100% coverage is not an unrealistic expectation.

Urban Particulates: Particles suspended in outdoor air contribute to acute lower respiratory infections and cardiovascular diseases, as well as lung cancer. Lung cancer adds more to the global disease burden for all cancers than any other cancer, and it is estimated that 5% of the lung cancer disease burden worldwide is attributable to outdoor air pollution (WHO, 2006 and Cohen, 2004). Urban Particulates measures the concentration of small particles, between 2.5 and 10 micrometers (PM 2.5 to PM10) in diameter, suspended in the air. These particles are dangerous to human health because they are small enough to be inhaled and become lodged deep in lung tissue.

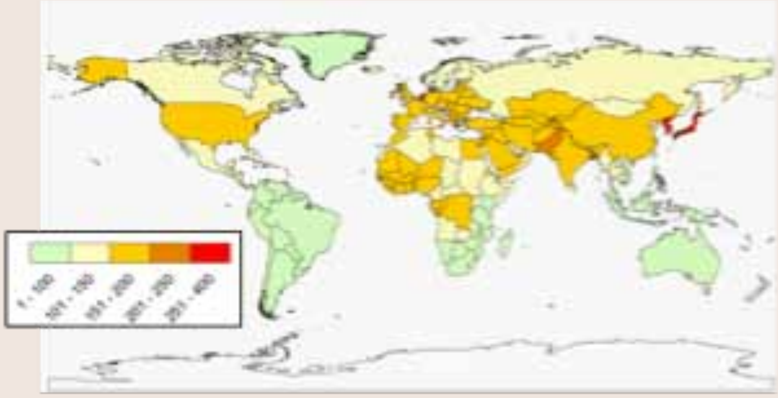
To develop country level indicators, we took city level estimates of particulate concentrations developed by the World Bank (using a combination of in situ measurement and models), and created a weighted average with the weights being determined by city population size. The target for Urban Particulates is set at an annual mean of 20 micrograms per cubic meter, which is derived from the air quality guidelines set by the WHO (WHO, 2005). This target is set at the level necessary to minimize outdoor air pollution risks to human health. It is not feasible to set a zero target because many regions have substantial natural background concentrations of small airborne particles.

Data Gaps and Deficiencies

The urban particulates data have a couple of deficiencies. For one, they are partially based on models and not on actual *in situ* measurements. Air quality monitoring stations can cost upwards of US $30,000 to run over the course of one year, putting them well beyond the reach of most developing countries. Second, they reflect only exposures in larger cities. Yet there are significant anthropogenic emissions of particulates in rural areas. CIESIN, working with Battelle, will be working on new metrics of air quality derived from satellite data. These will have the advantage of providing wall-to-wall coverage of particulates and other pollutants such as ground-level ozone. A pilot example is found in Box 4.2.

BOX 4.2
A PILOT COMBINED MULTI-POLLUTANT AIR QUALITY INDEX FOR JUNE 2006

A preliminary multi-pollutant air quality metric has been produced by researchers Jill Engel-Cox and Erica Zell at Battelle. This indicator combined monthly-mean satellite-based measurements of four pollutants for June 2006: PM2.5 (using AOD as a surrogate) from the MODIS sensor aboard the NASA Terra satellite; tropospheric ozone from a NASA product based on OMI observations of total column ozone and stratospheric ozone from the Microwave Limb Sounder (MLS); carbon Monoxide (CO) measured by the MOPITT instrument; and tropospheric NO2 from OMI. Observations within the boundaries of each country were averaged to provide a set of individual country-mean values for the four pollutants. A linear indexing scheme (1-100) was applied separately to each of the four pollutants to assign an index value to each country. The independent indices for each pollutant were summed to form the multi-pollutant index, with a minimum value for any country of 4 and a maximum value of 400 (see map).



4.3
WATER (EFFECTS ON HUMAN HEALTH)

Policy Focus

The Drinking Water and Adequate Sanitation indicators are included in the Environmental Health measurement because, according to the WHO, diarrhea is the disease most attributable to quality of the local environment. It is estimated that environment factors account for 94% of the global disease burden for diarrhea (WHO 2006). Measures of Drinking Water and Adequate Sanitation correlate strongly with diarrheal diseases. One of the main sources of diarrheal disease is contamination by fecal-oral pathogens, which is largely caused by inadequate drinking water and sanitation infrastructure. The WHO has estimated that 88% of diarrhea cases result from the combination of unsafe drinking water, inadequate sanitation, and improper hygiene (WHO, 2006 and Pruss-Ustun, 2004a).

Indicators Selected

Adequate Sanitation: The 2010 EPI uses an Adequate Sanitation indicator from the UNICEF-WHO Joint Monitoring Program. It represents the percentage of a country's population with access to an improved source of sanitation. This metric is used to estimate the environmental risk individuals face from exposure to poor sanitation. Those with access to adequate sanitation facilities are less likely to come into contact with harmful bacteria and viruses than those without access to such facilities. As an additional benefit, waste collection and treatment also reduce impacts to the environment.

The target for the Adequate Sanitation indicator is set at 100% (derived from UN Millennium Development Goal (MDG) 7, Target 10, and Indicator 31). This target reflects the belief that every person should have access to basic sanitation.

Drinking Water: The 2010 EPI uses a Drinking Water indicator from UNICEF-WHO Joint Monitoring Program that records the percentage of a country's population with access to an improved drinking water source. The WHO defines an improved drinking water source as piped water into dwelling, plot or yard; public tap/standpipe; tubewell/borehole; protected dug well; protected spring; and rainwater collection (UNICEF and WHO 2008).

The target for the Drinking Water indicator is set at 100% (derived from UN Millennium Development Goal (MDG) 7, Target 10, and Indicator 31). This target reflects the belief that every person ought to have access to safe drinking water. Many developed countries have already achieved this target, once again indicating that 100% coverage is not an unrealistic expectation.

Data Gaps and Deficiencies

The drinking water metric does not capture the quality of water that individuals receive. The water provided by a standpipe or even via indoor plumbing – to cite two examples of “improved water sources” – is not necessarily free of contaminants. In most developing countries, the well-off rarely drink tap water untreated.

Although it is included in the Ecosystem Vitality objective, the Water Quality Index does address water quality issues that are relevant to human health, such as high concentrations of nitrogen and phosphorus. However, it is very difficult to obtain reliable measurements of fecal coliform bacteria, since these tend to cluster heavily and not be widely dispersed.

ECOSYSTEM VITALITY

The EPI includes measures relevant to the goal of reducing the loss or degradation of ecosystems and natural resources – what we term the Ecosystem Vitality objective.

The core policy categories for Ecosystem Vitality include Climate Change, Air Effects on Ecosystems, Water Effects on Ecosystems, Biodiversity and Habitat, and Productive Natural Resources.

4.4

AIR POLLUTION (EFFECTS ON ECOSYSTEMS)

Policy Focus

Beyond its human health impacts, air pollution is also detrimental to ecosystems. Through direct exposure and accumulation, reactive compounds such as ozone (O3), benzene (C6H6), sulfur dioxide (SO2), nitrogen oxides (NOX), and volatile organic compounds (VOCs) negatively impact plant growth. Also, SO2 and NOX are the primary contributors to acid rain, which can diminish fish stocks, decrease biological diversity in sensitive ecosystems, degrade forests and soils, and diminish agricultural productivity.

Indicators Selected

Sulfur Dioxide Emissions: Sulfur dioxide is the major cause of acid rain, which degrades trees, crops, water, and soil. SO2 can also form hazardous aerosols under certain atmospheric conditions. The sulfur dioxide indicator is based on estimates of emissions compiled from three different sources. In order of prioritization, the 2010 EPI indicator uses the UNFCCC Secretariat’s annual reported greenhouse gas data of Annex I and non-Annex I countries released in 2009, a cooperative effort’s “Regional Emission Inventory in Asia” (REAS Version 1.1), and the Netherlands Environmental Assessment Agency’s modeled Emission Database for Global Atmospheric Research (EDGAR 3.2).

There are no internationally agreed upon standards for sulfur dioxide emissions. Such a target would be controversial for several reasons. First, because SO2 disperses, local concentrations of SO2 can be high in areas with relatively low emissions. Second, different ecosystems exhibit different levels of sensitivity to SO2, and so a uniform emissions target can be both too stringent for some localities and too lax for others. The 2010 EPI adopted the conservative target of 0.01 Gg sulfur dioxide emissions per square kilometer. Emissions are divided by populated land area (any area with >5 persons per square km) so that results will not be artificially lowered for countries with large unpopulated areas.

Nitrogen Oxide Emissions: Nitrogen oxides are a group of highly reactive gases. They contribute to the formation of ground-level ozone, fine particulates, and acid rain. The damages associated with NOX overlap heavily with those listed for SO2 and acid rain. Additionally, nitrogen from NOX emissions can dissolve in water and lead to eutrophication.

The NOX indicator is based on estimates of emissions compiled from the same three sources as for SO2. NOX emissions were not included in the 2008 EPI because sufficient data was not available, but the inclusion here reflects a step forward in emissions measurements and reporting. For the same reasons stated for SO2, there are no internationally agreed upon targets. Consequently, we adopted the same target of 0.01 Gg emissions per square kilometer of populated land area.

Non-Methane Volatile Organic Compound Emissions: Non-methane volatile organic compounds, or NMVOCs, are a sub-category of volatile organic compounds, which contain carbon and are active in atmospheric reactions. Notably, they often react with NOX to form ozone, which can damage plant surfaces and irritate animal tissues.

The NMVOCs indicator is based on estimates of emissions compiled from the same three sources as for SO2 and NOX, and the same target was used. Like NOx, NMVOCs emissions were not included in the 2008 EPI because sufficient data was not available.

Regional Ozone: In the troposphere, ozone shields the planet from dangerous ultraviolet radiation. At ground-level, however, ozone is dangerous to living organisms. Ozone corrosively damages plant surfaces and irritates animal tissues. Plants can also directly absorb ozone through their pores, which can severely inhibit their functioning and growth. Ozone has the potential to degrade overall ecosystem health and productivity.

The ecological ozone metric seeks to specifically assess the impact of ozone on ecosystems. The Mozart-II measurement is not ideal because of its heavy reliance on modeled data rather than direct measurements and the outdated data (from the year 2000), but because of the significant impact of ozone on ecosystem vitality, we have included the indicator in hopes that in situ monitoring of ozone will become more widespread.

The ecological ozone indicator measures the extent to which high ozone concentrations are present during the vegetative growing season. Because ozone acutely affects plant development, the growing season and daylight intensity are important factors. For the 2010 EPI we used the same indicator we developed for the 2008 EPI. This indicator was calculated by summing ozone exceedences for each summer daylight hour over areas of exceedence, and then dividing by the country area.

The rationale for this method was as follows. Ozone's negative effects on plants are most acute at particularly high levels or prolonged exposure. The parameter that we chose for assessing the critical level of ozone exposure for vegetation is the "Accumulated Ozone Threshold" from the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops. The target stipulates that long-term ozone exposure should not exceed 3,000 ppb-hours over the three-month summer period (Mauzerall and Wong 2001). Any exposure over the threshold of 40 ppb counts as an exceedance. Thus, we used a gridded data set of vegetated areas and we summed values >=40 ppb per grid cell, and where cells exceeded 3,000 ppb-hour for the entire summer they were added to the total exceedance figure. Thus, if a cell had 50 ppb over a total of 60 daylight hours, it would meet the threshold, and if it had greater than 60 hours it would exceed it.

Data Gaps and Deficiencies

There is room for improvement in these indicators. The SO2, NOX, and NMVOCs indicators use multiple data sources to triangulate actual emissions but lack an internationally agreed upon target. The modeled ozone data is less robust, but has a well-defended target. Importantly, the temporal aspect of emissions is still a question that lacks measurement and regulatory consistency. For example, the question of whether to use daily averages or hourly maximums of pollutant concentrations is still unresolved and may vary depending on the pollutant in question.

Existing data sources for air pollution concentrations and emissions are either incomplete or difficult to use in global comparisons. Air quality monitoring systems vary significantly between countries, often producing fundamentally dissimilar data. In addition, many countries have too few monitoring stations to produce representative samples.

In comparison with monitoring station data, air pollution transport models provide relatively easy access to data. The benefit of models is that they are able to generate values for large spatial domains, but they also carry with them a level of uncertainty, making it inadvisable to rely on them exclusively. Using models in conjunction with *in situ* monitoring or emissions data, as we have here, can help to produce a more balanced picture.

A complete air pollution index for the EPI would contain indicators for particulate matter, ozone, NO2 and SO2, carbon monoxide (CO), lead, methane, ammonia, mercury, black carbon, persistent organic compounds, VOCs, and benzene. We removed CO from this policy category because its effects are primarily on human health, and methane because it is mostly a greenhouse gas. Unfortunately, reliable data for the remainder of the pollutants listed are not available.

Ideally, future iterations of the EPI would look at concentrations of the pollutants relative to the buffering capacity of specific ecosystems. Early iterations of the Environmental Sustainability Index used exceedence maps, but these have not been updated.

An ideal performance measure for ecosystem vitality and air pollution would include time-specific emissions quantities, the mapping of pollutant movement, the ecological sensitivity to pollutants by area, and the level of clear policy commitments to emissions reductions. The European Union is a model in this regard because it meets all of these monitoring goals; however, there are no global datasets with all of these measures.

4.5

WATER (EFFECTS ON ECOSYSTEMS)

Policy Focus

Water is essential for economic development and for the wellbeing of humans and ecosystems. The intensification of many industrial and agricultural processes and the construction of dams and levees have affected the quality and availability of water. Where water resources are over-subscribed or heavily polluted, it negatively impacts aquatic ecosystems.

Monitoring water quantity and quality is essential for proper water management. This is all the more true as climatic and land use changes affect the abundance of water resources, the timing and amounts of rainfall, and rainwater runoff. Yet the number of monitoring stations remains inadequate in many countries.

Water issues are, by nature, interdisciplinary and multi-faceted. No single index can provide comprehensive information about water availability, use, quality, and access. The 2010 EPI contains three indicators that measure water quality, water stress (a measurement of areas within the country where water resources are oversubscribed), and water scarcity (a national level measure of water use divided by available water).

Indicators Selected

Water Quality Index: Many different physical, chemical, and biological parameters can be used to measure water quality. The 2010 EPI Water Quality Index (WQI) uses three parameters measuring nutrient levels (Dissolved Oxygen, Total Nitrogen, and Total Phosphorus) and two parameters measuring water chemistry (pH and Conductivity). These parameters were selected because they cover issues of global relevance (eutrophication, nutrient pollution, acidification, and salinization) and because they are the most consistently reported. The data were taken from the United Nations Global Environmental Monitoring System (GEMS) Water Programme, which maintains the only global database of water quality for inland waters, and the European Environment Agency's Waterbase, which has better European coverage than GEMS.

For the nutrient measurements, dissolved oxygen is the measure of free (i.e., not chemically combined) oxygen dissolved in water. It is essential to the metabolism of all aerobic aquatic organisms and at reduced levels has been shown to cause both lethal and sub-lethal effects. Nitrogen and phosphorus are naturally occurring elements essential for all living organisms, and are often found in growth-limiting concentrations in aquatic environments. Increases in nitrogen and/or phosphorus in natural waters, which result largely from agricultural runoff and synthetic fertilizers or from municipal and industrial wastewater discharge, can result in significant water quality problems, including harmful algal blooms, hypoxia and declines in wildlife and wildlife habitat. Excesses have also been linked to higher amounts of chemicals that that are harmful for humans (EPA, 2010).

The last two parameters, acidity and alkalinity, are measured by pH – an important indicator of water quality in inland waters because it can affect aquatic organisms, both directly through impairing respiration, growth and development of fish, and indirectly through increasing the bioavailability of certain metals such as aluminum and nickel. Electrical conductivity is a measure of the ability of water to carry an electric current, which is dependent on the presence of ions. Increases in conductivity can lead to ecosystem changes that reduce biodiversity and alter community composition (Weber-Scannell and Duffy, 2007).

The WQI is a proximity-to-target composite of water quality, adjusted for monitoring station density in each country, with the maximum score of 100. Data were available to compute indicator values for 85 countries: 74 countries had recent data, and 11 had data from pre-1990 for which a regression model was used to impute post-1990 scores. A multiple imputation model based on statistical relationships between countries with data and a number of covariates (variables that can predict WQI scores) was used to compute WQIs for an additional 110 countries that had more than 10 sq. km of surface water bodies. Countries with surface water less than 10 sq. km were averaged around.

Water Stress Index: Water Stress is calculated as the percentage of a country's territory affected by oversubscription of water resources. The 2010 EPI utilizes data from the University of New Hampshire's Water Systems Analysis Group. The target for each country is to have no area of its territory affected by oversubscription. Water use is represented by local demands summed by domestic, industrial, and agricultural water withdrawals, and then divided by available water supply to yield an index of local relative water use. A high degree of oversubscription is indicated when the water use is more than 40% of available supply (WMO, 1997). Unlike the Water Scarcity Index (described below), the Water Stress Index helps to capture subnational variation in water use vs. availability. Thus, a country like Brazil, which is overall water-abundant, nevertheless has about 2% of its territory under water stress.

Water Scarcity Index: This indicator is derived from national-level data from FAO's AQUASTAT. The indicator represents the overuse of water derived by subtracting the recommended use fraction (0.4) from the ratio of total freshwater withdrawals (including surface and both renewable and fossil ground water) to total renewable water resources (not including desalinated or treated waste water). This proportion is then multiplied by a weight which is the ratio of freshwater withdrawal to total withdrawals (freshwater, desalinated water and treated wastewater). The target is <=0 overuse. The purpose of the weighting is to recognize that some arid countries require desalinated water owing to a lack of freshwater.

To illustrate the calculation of this indicator, we take the case of water-scarce United Arab Emirates (UAE). In 2005, UAE used 2.8 billion m3/yr of freshwater, but had only 0.15 billion m3/yr of renewable water. The raio of freshwater withdrawal to renewable water is 18.67, and from this the recommended use fraction 0.4 is subtracted, to arrive at an adjusted ratio of 18.27. However, in the case of UAE, only 70% (0.7) of the total water withdrawal is from renewable and non-renewable sources (such as fossil aquifers), while 23.8% are withdrawals from desalinated water and 6.2% from reuse of treated wastewater. To account for this, the overuse is weighted by the ratio of freshwater withdrawal to total water withdrawals (freshwater, desalinated and treated wastewater). Thus, the weighted water overuse is 18.27 x 0.7, or 12.79.

Data Gaps and Deficiencies

EPI 2010 provides a valuable snapshot of surface water issues for the countries for which data is available. However, as in other areas, there is a need for improvement in data scope, availability, reliability, and quality. For water quality, while the GEMS/Water database is a comprehensive global database with almost 4 million entries for lakes, reservoirs, rivers, and groundwater systems from more than 3,000 monitoring stations, there are still major gaps in country coverage and many countries are represented by only a handful of stations. For water stress, the global hydrological monitoring network is actually shrinking in size from a peak in the 1980s, and the gap in *in situ* monitoring can only partially be made up for by satellite remote sensing data sources. According to the *World Water Development Report 3*, "Worldwide, water observation networks provide incomplete and incompatible data on water quantity and quality for managing water resources and predicting future needs – and these networks are in danger of future decline" (Grabs, 2009).

Growing global demand for fresh water will make achieving targets for the three water indicators increasingly difficult. Also, non-water pressures such as air pollution, climate change, land management, and economic development can greatly affect many aspects of water quality and quantity, making the prioritization of water resource monitoring, management, and protection particularly urgent. Continued over-abstraction (and particularly abstraction of fossil ground water) cannot be sustained indefinitely. More effective monitoring of water quality and quantity on a country-by-country basis must occur in order to better inform policymaking and international efforts toward efficient and sustainable use while meeting the Millennium Development Goals.

4.6
BIODIVERSITY & HABITAT

Policy Focus

Human activities have altered the world's terrestrial, freshwater and marine ecosystems throughout history, but in the last 50 years the extent and pace of these changes has intensified, resulting in what the Millennium Ecosystem Assessment calls "a substantial and largely irreversible loss in the diversity of life on Earth" (Millennium Ecosystem Assessment, 2005). The sheer number of species at risk of extinction (16,306 species of plants and animals listed as threatened globally) clearly reflects the threat. Biodiversity – plants, animals, microorganisms and the ecological processes that interconnect them – forms the planet's natural productivity. Protecting biodiversity ensures that a wide range of "ecosystem services" like flood control and soil renewal, the production of commodities such as food and new medicines, and finally, spiritual and aesthetic fulfillment, will remain available for current and future generations.

Conventional management approaches have focused on individual resources, such as timber or fish production, rather than on ecosystems as a whole. Metrics to measure performance have similarly been limited to simple output quantities (e.g., metric tons of fish caught). Recently policy goals have shifted away from this sectoral approach to managing natural resources. The result has been additional legislation aimed at maintaining the health and integrity of entire ecosystems, known as the "ecosystem approach."

For want of accurate country-level data on species conservation efforts and management of habitats, the 2010 EPI uses measures of protected area coverage by terrestrial biome and by area of coastline in addition to a measure of the protection of highly endangered species.

Indicators Selected

Biome Protection: This indicator measures the degree to which a country achieves the target of protecting at least 10% of each terrestrial biome within its borders, and represents a weighted average of protection by biome. Weights are determined by the size of the biome (larger biomes receive greater weight). We adopted a target of 10% of each biome protected because that is the target most faithful to the existing international consensus. At its 7th Conference of the Parties, The Convention on Biological Diversity (CBD) set the following target: "At least 10% of each of the world's ecological regions effectively conserved." We treat protected status as a necessary but not sufficient condition for an ecological region to be classified as "effectively conserved." How well protected areas are managed, the strength of the legal protections extended to them, and the actual outcomes on the ground, are all vital elements of a comprehensive assessment of effective conservation. Such measures are not available on a widespread basis, though there are efforts underway through the World Commission on Protected Areas (WCPA) Science and Management Theme to compile data on protected area management effectiveness with a goal of eventually aggregating to national level measures.

Critical Habitat Protection: Comparable indicators of species conservation by country can be difficult to develop. This is partly due to the fact that for countries with larger natural endowments (e.g. more endemic species), there are greater conservation burdens. Moreover, species are assessed as threatened on the basis of their global conservation status. Even if a country takes extensive measures to protect a species in its own territory, it might still rank poorly on an index that looks at the number of endangered species within its borders. Thus, a country with few species, threatened or otherwise, could receive a high score, while a country with many endemics and threatened species that is working hard to conserve them could be penalized because a neighboring country is doing little by way of biodiversity conservation (see Box 4.3 for a discussion of these issues).

The Critical Habitat Protection indicator partly addresses these issues by assigning countries responsibility for the protection of endangered species found at Alliance for Zero Extinction (AZE) sites. The Alliance for Zero Extinction is a joint initiative of 52 biodiversity conservation organizations. It aims to prevent extinctions by identifying and safeguarding key sites selected as the remaining refuges of one or more Endangered or Critically Endangered species, as identified by the IUCN Red List criteria. The IUCN standard provides a consistent approach for AZE site designation across the world. Because of the rigorous criteria used to assign AZE sites, this indicator provides a good measure of how many gravely endangered species are receiving immediate conservation protection. Our target is the protection of 100% of sites, with the justification that there are a finite number of sites and the species in question are highly endangered. Countries with no AZE sites on their territories have total scores averaged around this indicator.

Marine Protected Areas: Marine Protected Areas (MPAs) are the aquatic equivalent of terrestrial reserves. They are legally set aside for protection from human disturbances, such as fishing, industrial exploitation, and recreational activities (depending on the type of MPA). They help alleviate fishing mortality, reduce the harvesting of non-target species, and ensure fishing gear does not impact the marine environment. In addition to protecting biodiversity, MPAs aid in the restoration of commercially viable fish populations.

The Marine Protected Areas (MPA) indicator measures the percentage of a country's exclusive economic zone (EEZ) that is under protection. Protected area criteria were taken from MPA Global, a database developed in conjunction with the Sea Around Us Project. The indicator was calculated by comparing the area of MPA (in sq. km) to the country's total area of EEZ, as reported in the Global Maritime Boundaries database. Similar to biome protection, our target is the protection of 10% of EEZ waters.

Data Gaps and Deficiencies

Global information about the distribution of biodiversity, the condition of species and natural ecosystems, and the major stresses to ecosystems is not readily accessible. Much biodiversity information comes from field studies, whose data tend to be locally focused, inconsistently formatted, and dispersed across many scientific publications and databases. Many countries collect more detailed national-level data; however, it is generally unsuitable for the purposes of a global comparison. In response to this problem, some regions, such as the European Union, have begun establishing standards and protocols for biodiversity data collection. Yet even among countries participating in these efforts, significant information gaps remain.

For the 2010 EPI, we conducted a review of the entire 2010 Biodiversity Indicator Partnership (BIP) list of indicators and contacted a number of the lead agencies in hopes of supplementing our existing measures that focus on protected areas. Box 4.3 briefly highlights selected 2010 BIP measures of biodiversity that, with additional data or effort, could meet the EPI indicator selection criteria described in Chapter 2. It should be mentioned that protected areas coverage is a BIP indicator, and we are using BIP indicators in two other policy categories: Forest Cover Change (under Forests), and the Marine Trophic Index (under Fisheries).

It is hoped that the Group on Earth Observations-Biodiversity Observation Network (GEO-BON) will soon be able to synthesize field data and satellite observations to come up with a global and regional assessment of the status of biodiversity, though it may be years before country-level assessments are possible. Our own experimentation with using satellite data to assess deforestation – an important factor in habitat loss – is described in Box 4.4. The results were not sufficiently robust to be able to include in the 2010 EPI.

BOX 4.3

THE 2010 BIODIVERSITY INDICATOR PARTNERSHIP (2010 BIP)

By Mimi Stith, Consultant

In April 2002, 182 countries gathered at The Hague for the 6th Conference of the Parties to the Convention on Biological Diversity (CBD). There the commitment "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth" was made. During the 9th Conference of the Parties in 2008, it was mandated that the scientific advisory body would work with an expert group to generate a framework composed of a range of biodiversity indicators. The 2010 BIP was established for this purpose with support from the Global Environment Facility (GEF). The 2010 BIP is a consortium of international agencies, NGOs, and research institutions that is working to reduce the rates of biodiversity loss through the regular delivery of indicators at the global and national levels.

The Living Planet Index (LPI) is an indicator of change in global biodiversity based on change in population abundance of vertebrate species from all around the world. Biodiversity is perhaps most widely understood at the species level, so as a measure of trends in species abundance the LPI has a high degree of resonance with decisionmakers and the public and links clearly to ecological processes and ecosystem functions. The global LPI database can be disaggregated for subsets of data to: show trends in species abundance for particular taxonomic groups; show trends in species abundance for particular habitats or biomes; identify regions and ecosystems where the abundance of species is changing most rapidly; explore trends in abundance of species affected by different threat processes; and monitor trends in species listed in conventions such as CITES or CMS.

Similar to the LPI, the *Wild Bird Index* (WBI) aims to measure population trends of a representative suite of wild birds, acting as a barometer of habitat loss and other environmental hazards relevant to birdlife (e.g., toxics exposure). The WBI reflects an average trend for a group of species. Accordingly, a decrease in the WBI means that the balance of species' population trends is negative, representing biodiversity loss; if the WBI is constant, there is no overall change in species' trends; and an increase in the WBI means that the balance of species' trends is positive. An increasing WBI may or may not always equate with improving environmental conditions. For example, it could result from the expansion of one species at the cost of others. The methodology for producing WBIs is well developed: European WBIs have already been produced and are being used to measure progress towards the European Union's aim of halting biodiversity loss by 2010. The WBI only incorporates trend data from formally designed breeding bird surveys to deliver scientifically robust and representative indicators (see http://www.twentyten.net/wbi).

Because data are generated at the local level, the LPI and WBI are scalable and can be aggregated to the global and regional levels and disaggregated to the national or sub- national levels. They are particularly suited to tracking trends in the condition of habitats. At the present time, there are insufficient data to construct LPIs and WBIs for all countries. In terms of measuring conservation performance, these tools may not be appropriate for use at a national level given the difficulty of attributing country responsibility for the conservation status of species that migrate or that are found across a large number of neighboring countries. The same goes for indicators such as the BIP 2010's *Red List Index*, which is an index of change in extinction risk for certain taxonomic groups based on the IUCN Red List of threatened species. Nevertheless, WWF has produced guidance for national and regional use of the LPI in a report available at http://www.twentyten.net/lpi.

Invasive Alien Species (IAS) are plants, animals or microorganisms outside of their natural geographic range whose introduction and/or spread threatens biodiversity, food security, human health, trade, transport and/or economic development. They pose the second biggest threat to biodiversity globally, and in certain ecosystems (notably islands), the greatest threat to biodiversity. The cost of damage caused by invasive species is estimated as US$1.4 trillion per annum – close to 5% of GDP.

A potential country-level invasive alien species indicator could be calculated in two ways: in terms of the number of IAS documented within a country's borders, and in terms of a country's commitment to controlling the spread of IAS. A country's willingness to adopt legislation or to sign international agreements on IAS is an important metric for the latter. Another measure, but only relevant at the global level, is the Red List Index for impacts of invasive alien species, which shows the overall impact of IAS on the extinction risk of species globally. It is a measure of how fast IAS are driving the world's biodiversity to extinction (http://www.twentyten.net/invasivealienspecies).

BOX 4.4
TOTAL NITROGEN DEPOSITION EXCEEDANCES BY COUNTRY

Nitrogen deposition is one of the BIP 2010 indicators. Working with data provided by James Galloway, the lead on this indicator, CIESIN calculated those countries that have the greatest exceedance. Although nitrogen has always cycled between land, oceans, and atmosphere, human activities have resulted in a dramatic growth in the volume of nitrogen cycling in the Earth system. According to the BIP 2010 web site:

"Nitrogen in reactive forms is essential for life and use of nitrogen fertilizers is necessary to produce sufficient food for a growing human population. However, excessive levels of reactive nitrogen in the biosphere and atmosphere constitute a major threat to biodiversity in terrestrial, aquatic, and coastal ecosystems. Human activities have markedly increased the reactive nitrogen in the biosphere through fertilizer production, fossil fuel use, and widespread cultivation of legume crops, and crops like wetland rice that stimulate biological nitrogen fixation. More than 50% of all the synthetic nitrogen fertilizer ever used has been used since 1985. Globally, anthropogenic sources of Nr now exceed natural terrestrial sources.

Nitrogen is the limiting factor in many ecosystems and many native species are adapted to function best under low-nitrogen conditions. Higher-than-natural levels of reactive nitrogen as a result of nitrogen deposition in natural terrestrial ecosystems, especially temperate grasslands, shrublands, and forests, leads directly to lower plant diversity. Slow-growing plant species are out-competed by a small number of faster-growing species. Excessive levels of reactive nitrogen in water bodies, including rivers, coastal zones, and other wetlands, results from run-off of nitrogenous compounds from agricultural lands and atmospheric deposition. This excess Nr frequently leads to algal blooms and eutrophication, including low oxygen conditions. Eutrophication can cause major decreases in biodiversity in seaweeds, seagrasses, corals, and planktonic organisms."

Using the following steps, we calculated the total amount of Nitrogen deposited by country in non-agricultural vegetated areas in exceedance of the threshold of 1,000 mg/m2/year.

1. We resampled a -degree gridded nitrogen deposition surface to the grid cell size of 0.04767 deg (~5km at the equator). These data were from Detener *et al*. (2006).
2. Using 1000mg as the threshold, we created an exceedance grid whose value was the total nitrogen deposition in any grid cell minus 1,000mg, representing the total amount of deposition in excess of 1,000mg/ m2/yr.
3. We then computed the area of land outside agricultural areas that had deposition in excess of 1000mg/sqm/yr.
4. We created a 1-0 mask using output in step 2. We multiplied this grid by an area grid. The new grid value is the area of land in sq km affected by exceedances.
5. Using a country grid, we computed the total land area in each country that experience excess deposition.
6. To compute total deposition in each country, we:
   - multiplied the exceedance grid from step 2 by the area grid using the following formula: [(Exceedance grid /100) kg per ha * Area (sqkm) *100 ha.] The resulting grid value is in kilograms
   - we then calculated total deposition by country by summing the total deposition grid over the country area.
7. We then divided the total deposition by 1,000 to convert to tons of deposition, and divided this by the total affected area to arrive at tons of nitrogen deposition per square kilometer of affected land area.

The results are found in the table below. The BENELUX countries are at the very high end, followed by China, Germany, and the Czech Republic. Clearly, heavily populated regions are at a disadvantage – but so too are those countries that are downwind of large industrial countries, such as Bhutan and Laos.

Country	tons per sq. km affected land area	Country	tons per sq. km affected land area
Luxembourg	1.416	Romania	0.209
Belgium	1.380	Myanmar	0.202
China	1.303	Sweden	0.164
Netherlands	1.143	Afghanistan	0.162
Germany	0.920	Pakistan	0.151
Czech Republic	0.892	Taiwan	0.140
Hong Kong	0.834	Serbia and Montenegro	0.118
Liechtenstein	0.798	Japan	0.101
Bangladesh	0.781	Lithuania	0.094
Nepal	0.769	Belarus	0.093
India	0.703	Bosnia-Herzegovina	0.092
Switzerland	0.694	Ireland	0.085
Slovakia	0.662	Republic of Moldova	0.071
Poland	0.586	Ethiopia	0.069
Austria	0.585	Albania	0.064
Hungary	0.492	Uganda	0.059
France	0.466	Brazil	0.045
Bhutan	0.450	Canada	0.045
Viet Nam	0.390	Macedonia	0.044
Italy	0.362	Sudan	0.042
Korea	0.360	Russia	0.039
Slovenia	0.347	Congo, Dem. Rep.	0.038
Laos	0.329	Kenya	0.038
United Kingdom	0.310	Argentina	0.038
Thailand	0.307	Bulgaria	0.029
North Korea	0.253	Cambodia	0.029
United States of America	0.247	Colombia	0.019
Ukraine	0.243	Venezuela	0.018
Croatia	0.212	Paraguay	0.012

4.7
FORESTRY

Policy Focus

Forests cover almost 30% of the Earth's terrestrial surface (FAO 2006). They harbor much of the world's biodiversity, provide invaluable ecosystem services (e.g., oxygen supply and flood control), and are a major source of traditional medicines, food products, biomass energy, wood for construction, and pulp for paper. Deforestation rates are particularly high in the tropical regions of Southeast Asia, South America, and Africa. Forest planting, the natural expansion of forests, and landscape restoration are only partially offsetting these losses.

Because forests store carbon in their biomass and soils, deforestation is contributing somewhere between 8-20% of total annual global carbon emissions (van der Werf 2009). At the Copenhagen climate conference (Conference of Parties 15 of the UN Framework Convention on Climate Change) it was agreed that a mechanism for Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (known as REDD) should be put into place. This could provide an important new source of funds to underwrite forest conservation, though some criticize the text for including plantation forests and for use of the term "sustainable forest management," which many construe as meaning business as usual for the logging industry.

One of the major barriers to establishing sustainable forest practices is the lack of long-term monitoring systems to regularly assess the performance and condition of forests. Even when the scope is limited only to commercial wood production, experts have struggled to develop cost-effective methods for measuring forest resources and products. The forestry metric included in the 2010 EPI is meant to be a starting point for measuring forest management on an international scale. Its inclusion highlights the importance of forests as a global resource as well as the need for more robust international monitoring efforts.

Indicators Selected

Growing Stock Change: Growing stock is defined as the standing volume of the trees (in cubic meters) in a forest above a certain minimum size. Higher growing stock signifies more standing biomass, which often translates to better forest conditions. Growing stock change takes the total growing stock in 2005 as a ratio of the growing stock in the year 2000; a ratio of >=1 means that the growing stock has remained unchanged or is growing, and a ratio of <1 means that the growing stock is being depleted. The 2010 EPI target is zero change. This is consistent with the logic that cutting forests faster than their rate of regrowth is an unsustainable and environmentally harmful policy.

It is important to note that standing tree volume alone is not a sufficient metric for detailed analysis of forest health. For example, the diversity and distribution of tree species and ages is important for future wood supply and biodiversity. In terms of carbon sequestration, soil carbon must also be examined, which may not be directly correlated to a forest's tree volume. Another specific objection to using growing stock as an indicator is that converting primary forests to forest plantations may increase tree volume, but degrade overall ecological conditions.

Forest Cover Change: Forest cover change (percent change per annum) is a metric frequently used in global assessments of deforestation. The 2010 EPI measures the change in area between 2000 and 2005, and considers the target to be no change. Thus, countries that are actively afforesting are not explicitly rewarded, but countries that are losing forest cover are penalized.

Data Gaps and Deficiencies

There are many different potential variables that could go into an indicator measuring forest sustainability. The United Nations Forum on Forests has outlined seven principal areas of concern, which are also the key foci of the UN Food and Agriculture Organization's Forest Resources Assessment (FRA). A comprehensive list of more than 400 sustainability variables, crafted as an extension of the Pan-European Criteria and Indicators for Sustainable Forest Management, is used as a foundation by the Ministerial Conference on the Protection of Forests in Europe (MCPFE, 2007). While capturing these metrics in a forest management indicator would be ideal, only a handful of countries have forest monitoring systems developed enough to produce meaningful reports on these criteria.

Though there are many areas of concern when measuring the sustainability of forest management, the core issue is whether forests are being cut at a faster rate than they are regrowing, which as mentioned above is measured as changes in growing stock. The only source of country-by-country data for growing stock is the FAO's Forest Resources Assessment (FRA), most recently conducted in 2005 (FAO 2006a). Even though other sources of regional growing stock data exist, the advantage of the FRA is that it provides a consistent reporting format across countries and is recognized as the main global reporting process.

On the other hand, within the FRA there are significant variations in data quality between countries due to differences in data collection methodology or differences in the frequency of measurements. One of the fundamental inconsistencies is that countries are allowed to choose what they consider to be a minimum tree size for inclusion in the growing stock measure. Countries also individually establish the height to which they calculate the volume and branch size they wish to include in this metric. Beyond these inconsistencies, some countries simply lack the resources to conduct regular forest surveys. Currently only 10% of the world's forested area has been assessed by field-based National Forest Inventories, which is the primary source of national-level forest data (Holmgren 2007). Furthermore, only around 50 nations have field-based inventories; the rest use satellite data or expert estimates. The FAO generally accepts values reported by countries, and it appears from the statistical tables that many countries simply repeat the same growing stock size from year to year. In the absence of an independent verification mechanism, there is little that can be done to validate the numbers.

The same is true for the forest cover change data reported by the FRA. This year we attempted to compile data on deforestation derived from Landsat-calibrated MODIS estimates processed by the South Dakota State University (SDSU). The data were only available at 18.5 km grid cell resolution. Preliminary results of this country-by-country assessment are found in Box 4.5. We found little agreement between the FRA forest cover change data and the MODIS derived deforestation estimates (R-square = 0.004). This could be due to a number of factors. For one, the FRA measures both afforestation and deforestation, and consequently many countries have positive forest cover change values, whereas the MODIS estimates only track the amounts of deforestation. Another factor is the forest cover threshold; FRA uses a threshold of 10% tree canopy cover to count an area as "forested", whereas the SDSU data considered 60% canopy cover to be the threshold. Finally, there is a real possibility that the numbers provided to the FAO by countries are essentially "made up" and bear little relationship to what's happening on the ground.

In a partnership with SDSU, the 2010 FRA will make use of satellite data to gauge deforestation rates, but the underlying data and results will not be released until March.

BOX 4.5

USING SATELLITE DATA TO TRACK DEFORESTATION

In order to assess deforestation rates by country, CIESIN used the Landsat-calibrated MODIS data processed by the South Dakota State University (SDSU). According to the data download pages on the SDSU Web site (http://globalmonitoring.sdstate.edu/projects/gfm/):

"This dataset represents 2000-2005 gross forest cover loss for the biome. A separate regression estimator (i.e. separate regression models and parameter estimates allowed for each stratum) and post-stratification was employed to estimate Landsat-calibrated forest cover loss area. For sample blocks with intensive change a simple linear regression model was applied using the proportion of area within the sample block classified as MODIS-derived forest loss as the auxiliary variable. For low-change blocks post-stratification based on VCF [vegetation cover fraction] tree canopy cover and the Intact Forest Landscapes map was implemented to partition blocks into areas of nearly zero change and areas of some change. The forest cover loss area estimates were then constructed from the sample mean Landsat-derived clearing within post-strata."

Hansen et al. (2008) conducted a pixel-by-pixel comparison of the tropical forest extent in the Congo Basin from their MODIS data against the Global Land Cover 2000 data set and found a reasonably high (82.7%) correspondence.

The forest cover change data available from South Dakota State include four forest types: boreal, temperate, dry tropical and subtropical, and humid tropical. CIESIN used the following processing steps to create country estimates of deforestation:

1. We downloaded and tiled together the four separate forest types to create a global mosaic.
2. We resampled the grid from 18.5km to 5km cell size, to match the land area and country boundary data grid cell size of CIESIN's Gridded Population of the World, v.3 (GPWv3).
3. We created a forest area mask that was based on "valid" grid cells. The SDSU data set only included valid grid cells (meaning grid cells with data) for forested areas. All other grid cells were considered null or "no data". The grid cell value was the percent forest cover change from 2000-2005.
4. We calculated the year 2000 forested area in each country by multiplying the forest area mask times the GPWv3 land area grid, and then using the product as an input file in zonal statistics with the country grid as the zone file.
5. We then calculated forest area change in each country by multiplying the percent forest cover change grid times the GPWv3 area grid. The resulting grid represents area of deforestation in each grid cell. The product was used as an input file in zonal statistics with the country grid.
6. Country results were exported to excel, with columns for total forest area, the forest area change from 2000-2005, the percent change in forest cover from 2000-2005, and the annual percent change.

The table below presents the results sorted from highest to lowest levels of deforestation. According to this analysis, tropical countries in Central and South America have high rates of deforestation, as do the Southeast Asian countries of Cambodia, Brunei, and Malaysia and Thailand. The temperate countries with the highest rates are Portugal and Canada, and the African nations with the highest rates are Madagascar, Uganda, and Mozambique. However, these numbers should be understood to be approximate, since the measurement error is uncertain.

Country	Area Deforested (sq. km)	Annual % Change in Forest	Country	Area Deforested (sq. km)	Annual % Change in Forest
Nicaragua	1921.7	1.57	Russia	113273.0	0.55
Cambodia	1576.8	1.56	Malawi	39.4	0.52
Brazil	132693.0	1.54	China	12380.4	0.48
Argentina	16320.2	1.45	Indonesia	25215.8	0.47
Brunei Darussalam	12.2	1.38	Sudan	161.5	0.46
Malaysia	9099.3	1.38	Ethiopia	32.1	0.45
Bolivia	3591.3	1.37	Estonia	820.1	0.43
Guatemala	1803.6	1.37	Slovakia	184.0	0.42
Paraguay	9806.7	1.32	Chad	6.0	0.40
Cuba	56.5	1.20	Central African	7.7	0.40
Peru	1056.7	1.19	Uruguay	23.0	0.40
Portugal	4614.6	1.18	East Timor	2.3	0.40
Belize	405.8	1.12	Somalia	6.9	0.40
Thailand	4457.1	1.11	Senegal	11.3	0.40
Venezuela	2626.4	1.08	Sweden	6051.2	0.38
Myanmar	6083.8	1.06	Spain	3512.4	0.37
Ecuador	859.2	1.00	Bulgaria	1326.6	0.35
Madagascar	220.1	0.98	Serbia and Montenegro	1045.3	0.35
Canada	136703.0	0.95	Andorra	7.6	0.32
Laos	2934.5	0.93	Latvia	649.1	0.31
Uganda	41.6	0.86	Bosnia-Herzegovina	407.7	0.27
Mozambique	5871.4	0.85	Kazakhstan	212.9	0.27
Honduras	265.6	0.85	Norway	1378.9	0.26
Colombia	2724.5	0.85	Belgium	172.6	0.26
Papua New Guinea	708.4	0.85	Romania	1069.9	0.25
Viet Nam	1086.0	0.83	Greece	118.5	0.25
Congo, Dem. Rep.	310.9	0.82	France	2851.2	0.25
Panama	297.1	0.82	Croatia	110.9	0.25
Guyana	257.2	0.81	Finland	3047.0	0.24
Cameroon	277.4	0.81	Morocco	67.3	0.23
Mexico	1389.7	0.81	Azerbaijan	26.3	0.22
Costa Rica	230.1	0.81	Poland	1270.0	0.22
Philippines	287.5	0.81	Ukraine	502.3	0.21
South Africa	2606.4	0.80	Nepal	136.9	0.21
Ivory Coast	446.4	0.80	Japan	755.4	0.21
Liberia	53.7	0.80	Korea	52.6	0.21
Trinidad and Tobago	78.6	0.80	Algeria	24.5	0.21
Gabon	78.0	0.80	Germany	1738.2	0.21
Bangladesh	181.4	0.80	Korea, North	382.4	0.21
Antigua and Barbuda	0.0	0.80	Turkey	598.8	0.21
Jamaica	26.1	0.80	Belarus	758.9	0.21
Congo	15.4	0.80	Austria	355.3	0.21
French Guiana	4.1	0.80	Lithuania	284.9	0.21
Martinique	12.9	0.80	United Kingdom	502.6	0.20

Nigeria	286.5	0.80	Netherlands	11.8	0.20
Sierra Leone	378.4	0.79	Luxembourg	24.0	0.20
Ghana	303.5	0.78	Italy	214.8	0.20
Mongolia	1322.7	0.76	Iran	11.2	0.20
Botswana	966.1	0.76	Pakistan	2.9	0.20
Guinea	109.8	0.76	Macedonia	19.0	0.20
Namibia	43.0	0.75	Tunisia	0.1	0.20
Australia	24325.9	0.75	Syrian Arab Republic	1.8	0.20
Zimbabwe	3825.9	0.75	Liechtenstein	1.3	0.20
Tanzania	2992.7	0.74	Ireland	78.8	0.20
Suriname	63.3	0.72	Hungary	24.3	0.20
United States of	97546.4	0.72	Egypt	0.8	0.20
Kenya	212.0	0.71	Slovenia	56.4	0.20
Zambia	3051.1	0.69	Republic of Moldova	0.2	0.20
Dominican Republic	84.5	0.65	Afghanistan	5.6	0.20
Angola	392.2	0.63	Denmark	51.0	0.20
Singapore	5.2	0.62	Iraq	2.9	0.20
India	1634.7	0.57	Georgia	44.2	0.20
Chile	1628.4	0.57	Albania	15.3	0.20
Swaziland	38.3	0.55	Bhutan	12.4	0.20
New Zealand	1412.9	0.55			

We also considered data from the Forest Stewardship Council (FSC) on the percent of forest area certified as sustainably managed. According to Bart Holvoet of FSC Belgium (*personal communication*), FSC certification is among the most suitable for performance measurement because it "comprises not only system based elements, but also performance based elements, thus allowing a real measurement in the field / in the forest of performance on the ground." Most other schemes are only system based and do not have such widespread support among environmental NGOs. Further, Holvoet argues that "FSC forest cover is well spread across all regions, and the core elements (the FSC principles and criteria) are equal all over the world…This common framework allows for a good comparison between countries as the 'rules of the game' are pretty equal…". This is not the case for the Pan-European Forest Certification (PEFC).

Although there are compelling reasons to include a measurement of forest stewardship in the EPI, we nevertheless concluded that FSC certification may not be adopted in a sufficiently wide range of countries (especially countries where most forest lands are state owned), and this could therefore introduce bias. We will continue to explore the inclusion of forest certification data in future rounds of the EPI.

4.8
FISHERIES

Overview

Few activities have a more direct impact on the marine ecosystem than fishing and aquaculture. Overfishing of species can be disastrous to marine biodiversity and ecosystem stability, and environmentally-destructive fishing equipment can devastate the habitat of marine creatures. Fisheries are also an important part of many countries' economies, especially in the developing world. Approximately half of global fish exports by value are attributable to developing countries, and fish accounts for nearly 20% of protein intake in those countries (excluding the fishmeal and fish oil used in livestock production). Approximately one billion people worldwide rely on fish as the most significant source of animal protein in their diets (WHO 2010). Demand continues to rise as population grows in developing countries, and as seafood has started to be seen as a healthy source of protein in developed countries. Yet, many fish stocks reached full exploitation levels by the 1970s. Fisheries management will be increasingly critical if supplies are to be sustained.

The indicators for fisheries use the concept of exclusive economic zones (EEZs): the area up to 200 nautical miles from shore over which a country has political and economic control. It is considered that fishing within this area is largely within countries' control, even if they permit foreign fishing vessels to fish in their waters. The EEZ is also where one could expect governments to be able to make relevant policy decisions to lessen the environmental harm done by fishing activities.

Indicators Selected

Marine Trophic Index: The Marine Trophic Index (MTI), a BIP 2010 indicator, is used to measure the degree to which countries are "fishing down the food chain," i.e., catching smaller and smaller fish within their exclusive economic zones (Pauly 1999). It is considered to be a measure of overall ecosystem health and stability, but also serves as a proxy measure for overfishing. Humans tend to fish at the top of the food chain, choosing large predatory fish at first. As these stocks are depleted, smaller species are chosen and the food chain becomes unbalanced. Overall, low MTIs put fisheries at much greater risk of collapse (Pauly 2006).

To calculate the MTI, each fish or invertebrate species is assigned a number based on its location in the food chain. Carnivores are assigned high numbers, and herbivores lower ones. The Index is calculated from datasets of commercial fish landings by averaging trophic levels for the overall catch. For our purposes, we are interested in monitoring the direction of change in average MTI since 1980. We measured the slope of the trend line and set the target score as zero, i.e. no further decline in trophic level.

Trawling Intensity: Bottom trawling is a common method for catching bottom-dwelling species such as shrimp and flounder. Bottom trawling boats are equipped with large nets held open by heavy metal equipment, which are dragged across the sea floor. The nets devastate marine fauna such as coral and sponges. Bottom trawling equipment has been described as the most destructive fishing gear in use today (Watson 2006). The environmental destruction caused by trawling is mirrored by the economic and social impacts it has on human communities that depend on marine resources for food and income. When nursery habitats such as seagrass beds are destroyed, the entire local environment is impacted and the productivity of local fisheries decreases.

Trawling is also extremely wasteful. The nets used in trawling catch more than just the species that are commercially valuable, and this by catch (which can include other fish and invertebrate species, marine mammals, seabirds, and turtles) is most often discarded. Bottom trawled fisheries have the highest discard rates of all fisheries.

The 2010 EPI Trawling Intensity indicator consists of the percentage of the shelf area in each country's EEZ that is fished using trawling. There are no direct data available for the area trawled on a country-by-country basis. However, fish landings data are acceptable as a proxy for each country's fishing fleet. Thus trawling ships can be counted and incorporated into this trawling metric. The target level selected for this indicator is 0% area trawled, reflecting the opinion that any use of this fishing method is ecologically undesirable.

Data Gaps and Deficiencies

Little has changed since the 2008 EPI. Many of the global datasets on fisheries are out of date or incomplete. Major data sources employed in this section of the 2010 EPI were the United Nations Food and Agriculture Organization's (FAO) fishing vessel database, and the Sea Around Us Project's fish landings database and Marine Trophic Index. Exclusive economic zone (EEZ) areas were taken from the Global Maritime Boundaries database, which was calculated using standard GIS methods. Though the FAO vessel database is used in one of this section's indicators, it should be noted that it is somewhat out of date. Some data have not been updated since 1996.

Attributing country responsibility for overfishing and destruction of what is in essence a global commons is a difficult task. Many commercial fishing fleets fish well beyond their EEZs, and some countries under-report their fish catches. Poor countries often have difficulties monitoring and controlling the fishing going on within their EEZs. Another possible approach to measuring sustainability of fishing would be to measure fish consumption per capita, especially of the rarest and most economically valuable species. However, this would tend to penalize countries that have high proportions of fish protein in their diets and that may also have abundant fishing grounds relative to their populations.

A growing proportion of total fish consumption is coming from aquaculture. Marine aquaculture has become a major industry in the Pacific Northwest, the North Atlantic, and off the coast of China and Chile, among other places. Although we are not yet able to measure the sustainability of aquaculture, a new effort to produce a Global Aquaculture Performance Index is now under way, and it is hoped that its results can be incorporated into future EPIs (see Box 4.6).

BOX 4.6
THE GLOBAL AQUACULTURE PERFORMANCE INDEX (GAPI)

By John Volpe, University of British Columbi

The Global Aquaculture Performance Index (GAPI), derived from the EPI methodology, employs the proximity-to-target approach to measure environmental performance of marine aquaculture. As global demand for seafood continues to increase despite growing threats to the ocean, GAPI provides a tool that enables key decision-makers- such as policymakers, seafood purchasers, and fish farmers- to more clearly understand how well the marine aquaculture industry is performing compared to ideal environmental targets. GAPI is unique in that it presents decision-makers with a science-based, data driven tool to make much more informed, balanced and ultimately more sustainable decisions.

Given the resolution of aquaculture data available, GAPIpresently assesses aquaculture at the country-species level (for instance, Scottish-Atlantic salmon). The suite of environmental indicators for which performance is assessed (e.g., energy consumption, feed sustainability, and impact of pathogens) have been derived from the plethora of existing aquaculture standards and assessment tools. Target values for these indicators have been determined by scientific literature and expert guidance, or where absent, the precautionary principle. Data are taken largely from publicly available databases, scientific literature or, in the absence of these, from national regulatory standards.

GAPI is both a policy and market-based decision tool that allows an informed analysis on multiple levels. From a policy perspective, it allows one to examine not only how well a country's aquaculture sector is performing relative to other countries, but it offers insight into the most effective opportunities for environmental improvement. From a markets perspective, GAPI allows seafood purchasers to compare their options not only among producers of an individual species but across species as well. This is a powerful tool in the marketplace given that the country-of-origin and the species type are often the only information available to the consumer. Additionally, GAPI can be used to quantitatively benchmark existing, evolving, or even conceptual aquaculture standards to determine and compare how close these come to meeting set ecological targets.

It is important to note that GAPI is not a standard-setting or seafood certification effort. GAPI does not attempt to define sustainable aquaculture or certify producers but instead makes use of available data and scientific research to assess the actual environmental performance of marine aquaculture. Like the EPI, GAPI is constantly evolving as new science and data become available. In spring 2010, the GAPI Project will launch a web-based, interactive tool that will allow users to access aquaculture data and assess seafood options. In 2011-12, GAPI will expand to incorporate both social and economic indicators to allow a more complete overview of aquaculture performance and an understanding of tradeoffs among environmental, social and economic drivers. Additionally, the GAPI Project is exploring applications at the farm level to better highlight specific performance leaders.

The GAPI Project is lead by Dr. John Volpe and his research team at the University of Victoria, Canada. The project is supported by the Lenfest Ocean Program. For more information go to http://web.uvic.ca/~gapi/Index.html

One of the major environmental problems associated with fisheries is their reliance on destructive capture techniques such as dynamite fishing and long lining. Both of these practices harm more species than they are intended to catch, lowering biodiversity and destroying habitat. However, data on these practices are not currently available.

While they provide information on unsustainable fishing practices, these proposed metrics fail to capture the socioeconomic factors that contribute to the overall sustainability of fisheries. One important socioeconomic measure is the landed value per fisherman. This metric would give a sense of the distribution of wealth among stakeholders, which is notoriously unequal. Like agriculture, government subsidies to the fishing industry contribute to overfishing. A regularly updated database on fishing subsidies is needed to conduct a proper assessment of their impact. If recent work at the University of British Columbia which has focused on developing broad indicators for fisheries management and aquaculture sustainability were expanded to cover more countries, future editions of the EPI could present a more accurate picture of the sustainability of fisheries. An indicator that measures compliance with the FAO's code of conduct for responsible fisheries could also be developed in order to provide positive feedback to countries that make efforts to improve their practices.

4.9
AGRICULTURE

Policy Focus

As agriculture depends so heavily on a country's natural resources (soil, water, and climate), sound environmental management in these areas is critical to creating a sustainable agricultural system. Growing populations and changes in diet, including the rise in demand for meat as countries such as China become more affluent, increase pressures on productive systems. In October 2009, FAO Director-General Jacques Diouf called for a five-fold increase in food production by 2050 to meet global demand for food. Already, agriculture has an enormous impact on the global ecosystem. It accounts for approximately 40% of land use and 85% of water consumption (FAO 2005).

Poor agricultural policy can result in potentially negative environmental impacts, including deforestation, soil degradation, overuse of non-renewable water sources, production of greenhouse gases (especially in livestock production), pollution from agrochemicals, and destruction of natural habitat and biodiversity. Experts estimate deforestation of tropical and dry forests may drive hundreds of thousands of species to extinction in the next 40 years. Conversely, well-managed agricultural systems can encourage the exact opposite, improving the quality of the environment around agricultural lands.

Agriculture is not just an environmental issue. It is a developmental, health, and economic issue, as well. The FAO estimates that 23% of children under five are malnourished. A stable food supply is critical to establishing the basis for long-term growth and development. Agriculture makes up 3% of the world's GDP – not an insignificant figure. Therefore, governments that support sustainable agriculture systems also help support sustainable development, health, and economic systems.

Indicators Selected

Agricultural Water Intensity: Agricultural water withdrawal is the annual quantity of water withdrawn for irrigation and livestock purposes.[4] Sources include renewable freshwater resources as well as renewable and fossil groundwater, desalinated water and treated wastewater. Because of water lost in distribution, irrigation withdrawals generally exceed actual crop consumptive use. We calculate withdrawals as a percent of total available water resources, and we set the target as an aspirational value of 10%, which is sufficiently low that all countries can make some progress towards this ratio.

The term "water requirement ratio" (sometimes also called "irrigation efficiency") is used to indicate the ratio between the net irrigation water requirements and crop water requirements, which is the volume of water needed to compensate for the deficit between potential evapotranspiration and effective precipitation over the growing period of the crop, and the amount of water withdrawn for irrigation including the losses. In the specific case of paddy rice irrigation, additional water is needed for flooding to facilitate land preparation and for plant protection. In that case, irrigation water requirements are the sum of rainfall deficit and the water needed to flood paddy fields. At the level of irrigation schemes, water requirement ratio values can vary from less than 20% to more than 95%. As far as livestock watering is concerned, the ratio between net consumptive use and water withdrawn is estimated to be between 60% and 90%.

Agricultural Subsidies: Public subsidies for agricultural production and agrochemical inputs exacerbate environmental pressures by encouraging intense chemical use, the expansion of agriculture to sensitive areas, and overexploitation of resources (OECD 2004). The Agricultural Subsidies indicator measures subsidies as a proportion of agricultural value. For countries where this data is available, we use the Nominal Rate of Assistance (NRA), defined as the price of a product in the domestic market, less its price at a country's border, expressed as a percentage of the border price, and adjusted for transport costs and quality differences (World Bank 2008). Where available, we used data on the Nominal Rate of Assistance (NRA) from the *World Development Report 2008*. NRA is defined as the price of a product in the domestic market, less its price at a country's border, expressed as a percentage of the border price, and adjusted for transport costs and quality differences (World Bank 2009). These were converted to the standard EPI proximity-to-target indicator.

For OECD countries, we converted their Producer Nominal Assistance Coefficient (NAC) values to fill in missing values. According to trade expert Kym Anderson (University of Adelaide), NAC is almost the same as NRA (a 50% NRA = a NAC of 1.50, eg). It is also similar to the PSE, since in % our NRA = 100*PSE/(100+PSE).

The NAC for the EU27 was 0.33 but we deferred to the values in the *World Development Report 2009* for EU countries that had both a NRA and NAC value. For all other missing values, we assumed that they had no subsidies. Low and middle-income countries without agricultural subsidies data were imputed a proximity-to-target score of 100, on the basis that most non-OECD countries do not subsidize their agricultural sector. There are few countries where such subsidies are a very significant share of the total. This methodology makes use of the best data available, and we hope to include a more accurate measure in future editions of the EPI as improved data sources arise. The EPI target is set at no agricultural subsidies.

Pesticide Regulation: Pesticides are a significant source of toxics in the environment, affecting both human and ecosystem health. Although newer pest control agents are often less toxic than earlier ones, pesticide-related problems remain, including the persistent use and mismanagement of toxic agents which remain in the environment beyond their intended usage as crop protection agents. Widespread use of agricultural chemicals can expose farm workers to acute levels of pesticide and the general population to low levels of pesticide residues on food. Acute exposure to pesticides has been linked to increases in headaches, fatigue, insomnia, dizziness, hand tremors, and other neurological symptoms. Pesticides also damage ecosystem health by killing beneficial insects, pollinators, and fauna.

Given the lack of pesticide use and impact data, the EPI measures Pesticide Regulation, a policy variable that tracks government attention to the issue. The Pesticide Regulation indicator is based on national participation in the Rotterdam Convention, which controls trade restriction and regulations for toxic chemicals, and the Stockholm convention, which bans the use of Persistent Organic Pollutants (POPs). POPs are toxic pollutants that bioaccumulate and move long distances in the environment. Accordingly the Pesticide Regulation indicator also considers national efforts to ban the nine POPs which are relevant to agriculture: Aldrin, Chlordane, DDT, Dieldrin, Endrin, Heptachlor, Hexachlorobenzene, Mirex, and Toxaphene.

The two treaties and nine pollutants create a total of 11 measures; each assigned two points, for a total possible target score of 22. Countries receive the full 22 points if they have signed both conventions and submitted a national implementation plan, as well as banned the 9 POPs. If countries have only signed the convention, but submitted no implementation plan, they receive a score of “1” for that measure, and if they are not party to the convention they receive a score of “0”. A banned pesticide receives a score of “2,” a restricted pesticide a score of “1,” and a pesticide with no regulation receives a “0”. Since the 2008 EPI was published, new data has been made available for countries participating in the Stockholm and Rotterdam Conventions, but not for the status of banned chemicals.

Data Gaps and Deficiencies

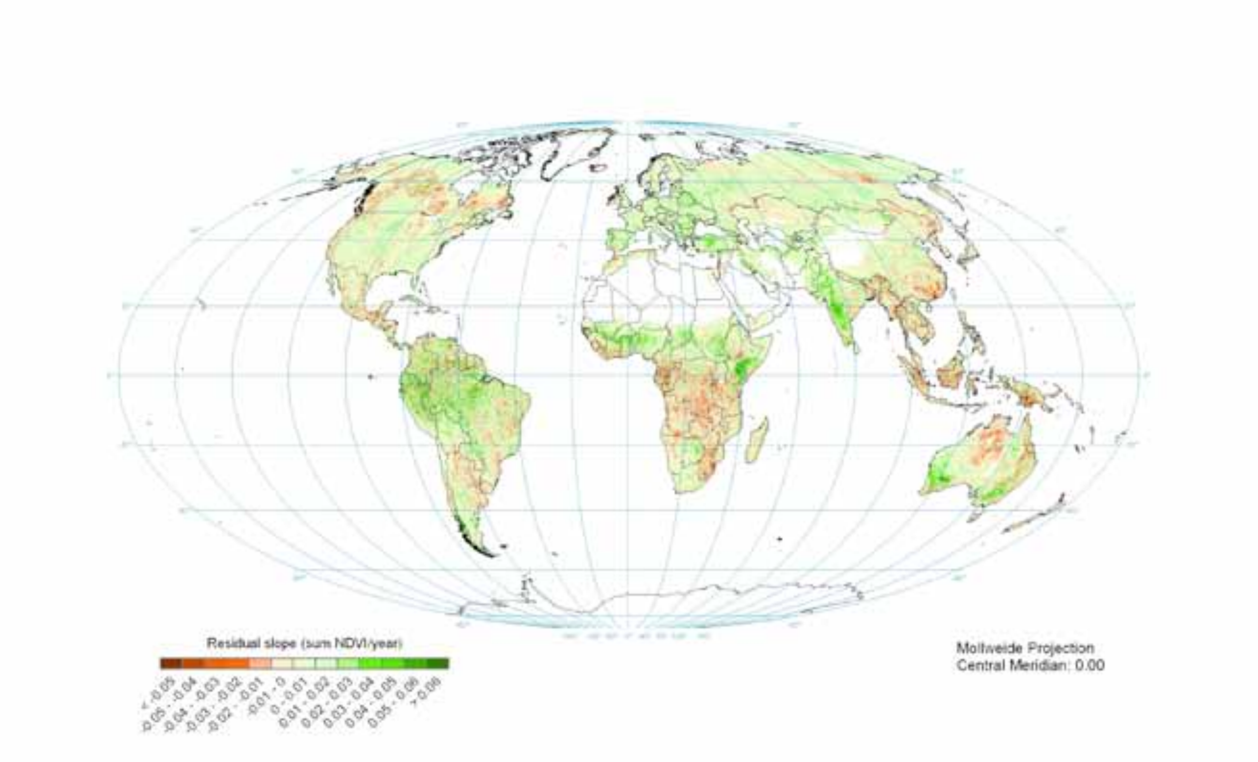
There are complications in measuring “sustainable” agriculture which relates in part to the diversity of systems, from animal husbandry to grain crops, and to the diversity of agricultural environments (see the Box 4.8 on Organic Agriculture). Ideally we would be able to include data on soil quality change, pesticide and fertilizer use, soil organic matter, unsustainable water usage, environmental effects of livestock production, and biodiversity and habitat loss due to agriculture. Unfortunately, consistent and reliable cross country comparative data for these indicators do not exist.

We did attempt to produce national level indicators on land degradation using data from the Global Assessment of Land Degradation and Improvement (GLADA) by FAO and World Soil Information (ISRIC), an ambitious update to the Global Assessment of Soil Degradation (GLASOD). Where GLASOD relied on expert opinion about the extent of degradation by country, GLADA developed a methodology based on long-term satellite records of “greenness” – the normalized difference vegetation index (NDVI). The results intially seemed promising (see Box 4.7) but we were cautioned not to interpret the results as indicative of land degradation, *per se* (Nachtergaele *personal communication*). This may be because the indicator mixes in the effects of deforestation and other vegetation cover change.

BOX 4.7
CHANGES IN "GREENNESS" IN AGRICULTURAL AREAS

FAO and World Soil Information (ISRIC) have been experimenting with different approaches to mapping land degradation on the global level. One approach seeks to examine trends in the Normalized Difference Vegetation Index (NDVI) derived from AVHRR satellite data over the 23 year period from 1981-2003, adjusted for rainfall trends over the same period (Bai et al. 2008, CIESIN 2008). Biomass production has been identified as a strong indicator for soil quality as it is an integral measure for soil, crop and environmental characteristics (Bindraban et al., 2000). Changes in biomass, as an indicator for changes in land quality, can be measured indirectly through the NDVI, which is a measure of greenness or vegetation abundance captured from satellite imagery. One approach involves looking at the predicted NDVI from rainfall data and comparing it to the actual greenness from the satellite data. Where the residual over time trends negative (the so-called "RESTREND"), it means that the greenness of the area is declining with respect to rainfall. The figure below shows the global patterns.

Global Residual Trend of Sum NDVI (RESTREND) 1981-2003 (Source: Bai et al., 2008, p.18)



A number of factors may explain why greenness appears to be declining in some regions. One could be changes in vegetation cover due to deforestation, changes in crop types, or urban development. Another could be changes in soil fertility. It is very difficult to identify the cause from satellite imagery. If you limit the examination to agricultural areas as identified in 2000, as we did for this pilot effort, then the changes are likely to be mostly due to land conversion for agriculture, though some portion of the change could be due to changes in crop type or soil fertility. The inability to distinguish between vegetation cover changes due to new crop types or deforestation and vegetation changes due to soil fertility loss means that this indicator cannot be strictly construed as a measure of land degradation. In fact, field data collected by FAO's Land Degradation Assessment in Drylands could not corroborate the changes identified by the satellite data at the country level (Nachtergaele, *personal communication*). Nevertheless, the results point to some interesting patterns that are worth exploring further (see table below).

Our data processing method was as follows:

1. We downloaded Global Residual Trend of Sum NDVI (RESTREND) 1981-2003 data from Geonetwork (available at http://www.fao.org/geonetwork/srv/en/ metadata.show?id=37056&currTab=distribution).
2. We created an agricultural area mask from data cropland and pasture grids produced by Ramankutty *et al*. (2008). A 5 arc-minute grid cell (~9km on a side at the equator) was considered to be cropland or pasture if the pixel value is >0.
3. We created a degraded area mask where RESTREND grid values were <0. We multiplied this with the agricultural area grid to generate degraded land mask.
4. We created an undegraded area mask where RESTREND grid values were >=0. We multiplied this by the agricultural area grid to generate an undegraded land mask.
5. We multiplied the degraded and undegraded masks by a land area grid (a resampled Gridded Population of the World, v.3 land area grid) to generate degraded and undegraded land area grids.
6. We used the Gridded Population of the World, v.3 country grid to compute zonal statistics on agricultural land areas by country that are degraded vs. undegraded.
7. These data were exported to Excel for further calculations.

The table below presents these pilot effort results. No firm conclusions should be drawn from these numbers, but it is interesting to note that the countries whose land areas are experiencing the greatest declines in greenness fall mostly in Africa, Western Asia, and South Asia. Many of them are densely populated or have experienced significant deforestation (e.g. Democratic Republic of Congo). However, some countries, such as New Zealand, Singapore, and Hong Kong, all with 61-62% declines, are more difficult to explain.

Country	**% of Agricultural Lands Experiencing Greenness Declines (1980-2003)**	**Country**	**% of Agricultural Lands Experiencing Greenness Declines (1980-2003)**
Swaziland	96.69	Senegal	26.96
Rwanda	77.21	India	26.66
Congo, Dem. Rep.	74.10	Bolivia	26.00
Occup. Palestinian T.	73.05	Cameroon	25.90
Zambia	72.92	USA	25.88
Korea, North	71.40	Austria	25.60
Angola	67.01	Belgium	25.52
Israel	65.43	Botswana	25.45
Algeria	63.86	Trinidad and Tobago	24.74
Tanzania	63.77	Somalia	24.42
Indonesia	63.28	Lebanon	23.79
Thailand	63.07	Chile	23.70
New Zealand	62.10	Ghana	23.38
Burundi	61.78	Puerto Rico	22.86
Singapore	61.71	Iraq	22.59
Congo	61.40	Central African Republic	21.41
Brunei Darussalam	61.30	Russia	21.17
Uruguay	61.26	Sudan	20.69
Hong Kong	61.11	Libyan Arab Jamahiriya	20.48
Malawi	61.08	Togo	20.44
Zimbabwe	61.00	Panama	19.56
Cambodia	60.82	Gambia	19.22
Papua New Guinea	60.60	Finland	18.97
Myanmar	60.46	Albania	18.71
East Timor	60.09	Syrian Arab Republic	17.88
Argentina	59.68	Peru	17.36
Bhutan	57.78	Bosnia-Herzegovina	16.98
Laos	57.45	Niger	16.62

Sierra Leone	57.31	Tajikistan	16.59
Macao	56.03	Macedonia	16.03
Gabon	55.86	Poland	15.30
Namibia	55.52	Czech Republic	15.17
Honduras	54.69	Spain	15.14
Korea	54.64	Kyrgyz Republic	14.59
Bangladesh	53.56	Portugal	14.58
Malaysia	52.70	Ecuador	14.40
Mozambique	51.37	Slovenia	14.09
Nicaragua	51.27	Sweden	14.00
Jordan	51.17	Nigeria	13.53
Dominican Republic	50.91	United Kingdom	13.09
Nepal	50.70	Switzerland	13.05
Guatemala	50.40	Serbia and Montenegro	13.02
Tunisia	50.10	Slovakia	12.66
Haiti	49.57	Bulgaria	12.57
Uganda	48.78	Georgia	12.37
Viet Nam	48.57	Benin	11.95
Philippines	48.37	Mongolia	11.93
Ireland	48.10	France	11.75
Japan	47.99	Norway	11.70
South Africa	47.85	Greece	11.19
Guinea-Bissau	47.78	Italy	11.15
Liberia	47.15	Germany	10.98
Mexico	47.05	Mali	10.94
Madagascar	46.73	Latvia	10.74
Egypt	45.98	Ukraine	10.36
Morocco	45.28	Pakistan	9.97
Guyana	44.10	Armenia	9.49
Taiwan	42.79	Romania	9.48
El Salvador	42.31	Chad	8.59
China	40.59	Iran	7.92
Cyprus	40.08	Croatia	7.00
Andorra	39.99	Turkey	6.37
Guinea	39.88	Mauritania	5.90
Ivory Coast	38.39	Lithuania	5.86
Paraguay	37.01	Yemen	5.67
Ethiopia	36.22	Eritrea	5.43
Hungary	35.98	Republic of Moldova	5.35
Lesotho	35.92	Oman	4.81
Cuba	35.12	Uzbekistan	4.69
Suriname	35.08	Burkina Faso	3.98
Costa Rica	34.19	Afghanistan	3.65
Sri Lanka	33.38	Estonia	3.24
Brazil	33.35	United Arab Emirates	2.88
Kazakhstan	32.94	Turkmenistan	2.54
Equatorial Guinea	32.69	Belarus	2.44
Belize	32.67	Denmark	1.63
Colombia	32.39	Saudi Arabia	0.42
Jamaica	31.99	Bahrain	0.00
Australia	31.53	Djibouti	0.00
Venezuela	30.74	Gibraltar	0.00
French Guiana	30.59	Kuwait	0.00
Canada	29.80	Liechtenstein	0.00
Azerbaijan	27.89	Luxembourg	0.00
Kenya	27.67	Solomon Islands	0.00
Netherlands	27.33	San Marino	0.00

The data landscape is not entirely bleak, however. The volume of data has increased over the past 10 years primarily as a result of the expansion of remote sensing and global efforts at cross-country data collection, synthesis and analysis. Globally comparable data have been developed, for example, on agro-ecosystem status (Wood et al. 2000), ecosystem status (MEA 2005), and organic agriculture (Willer and Yussefi 2007). Sectoral data have been compiled on carbon sequestration and storage (Watson *et al*. 2000), tree cover (University of Maryland 1999) and livestock environmental impacts (Steinfeld 2006). Regional and landscape-scale comparative indicators on agriculture and environment have been developed within the European Union (EU 2007). Detailed spatial mapping and overlays of agriculture and environmental data are available for the US from the USDA (national sample farm study by ERS) and the Heinz Center (2002), and in Kenya from a recent atlas by ILRI-WRI (WRI *et al*. 2007). A comprehensive review of indicators has been developed by the OECD (2007), and Buck *et al*. (2006) discuss indicators that are specific for landscape mosaic (or ecoagricultural) systems.

BOX 4.8
ORGANIC AGRICULTURE

Few policy categories changed as much from the 2008 EPI to the 2010 EPI as agriculture. The Intensive Cropland and Burned Land Area indicators were dropped, and the Agricultural Water indicator modified. In part, this is because of the difficulty of measuring environmental performance with regard to agriculture, as there is little agreement on how to measure the sustainability of an agricultural system (Rigby, 2000). However, conventional agriculture's reliance on fertilizers, pesticides, and fungicides derived from petrochemical sources; its dependence on government subsidies; its broad use of monocropping (which harms biodiversity); and its ignorance of the environmental impacts of extensive transportation all raise serious concerns regarding its environmental, economic, and social sustainability.

One major circle of debate surrounds the sustainability of organic agriculture. In a report on the environmental impacts of organic agriculture in Europe from the University of Hohenheim by Stolze, et. al., the authors find that while organic agriculture performs notably better than conventional agriculture on floral and faunal diversity, biological activity, and pesticide use, there were multiple indicators in which no definitive conclusion regarding which system was better for the environment. For a thorough discussion of the state of global organic agriculture, see Willer, Helga and Kilcher, Lukas, (Eds.) (2009) The World of Organic Agriculture - Statistics and Emerging Trends 2009. IFOAM, Bonn; FiBL, Frick; ITC, Geneva.

There are many factors that determine whether an agricultural system is sustainable or not. It must be able to support producers and consumers, and be supported by the environmental resources which it utilizes. In the long term, however, conventional agriculture's dependence on non-renewable inputs is clearly unsustainable. These issues call for more research to determine ways to produce food that will feed the world's growing population without sacrificing the interests of farmers, consumers, or our planet.

4.10
CLIMATE CHANGE

Policy Focus

The forecasted impacts of climate change- from sea level rise, coastal flooding, and extensive glacial deterioration to droughts, heat waves, and desertification- are already being felt globally and are projected to accelerate in severity. The impacts of climate change even at the "low end" (e.g., if we are able to limit global temperature rises to circa 2o C) will dramatically affect human health, water resources, agriculture, and ecosystems. While most greenhouse gas emissions (GHG) to date have originated in developed nations, developing countries are, and will continue to be, the most affected by climate change impacts (Stern 2006).

GHGs are emitted from a variety of human activities including electricity generation, transportation, industrial agriculture, forestry, and waste management (IPCC 2007). Globally, the energy sector generates the largest share of anthropogenic GHG emissions, but individual countries' emissions profiles vary greatly. Many developing nations have very low emissions from the energy sector but high GHG emissions from deforestation and agriculture. For example, Indonesia produces the third most GHGs in the world, behind China and the United States, due to rapid and extensive land use change (World Bank 2007). Some developed countries have actually reduced their energy sector emissions by investing in renewable energy technologies that can produce energy with low or no emissions. Recognizing the heterogeneity of GHG emission sources across countries is important for developing appropriate climate change mitigation strategies and highlights the complex nature of developing climate policy.

To capture various aspects of environmental performance on climate change, the 2010 EPI assesses three different indicators. First, GHG emissions per capita, including emissions from land use change. Second, carbon dioxide emissions per unit of electricity generation, and third, industrial GHG intensity per unit of generated PPP.

The Copenhagen accord provides a global consensus on the need to limit the rise in global average temperatures to no more than 2o Celsius. Consequently, there will likely be a long-term global emissions target set to 40-60% reductions in emissions from 1990 levels by 2050. On this basis, the 2010 EPI used a median target of 50% reductions below 1990 levels. The target is set to reflect how far a nation is from the long-term emissions reduction goal necessary to avoid the worst impacts of climate change, according to the judgment of the scientific community. This general target is incorporated into two of the three climate change indicators to focus climate change performance on long-term management goals.

Indicators Selected

Greenhouse Gas Emissions per Capita (including land use emissions): Countries with large populations tend to emit more GHGs (IPCC2007 WGIII). Therefore, simply measuring gross emissions is not a helpful way of comparing country performance. A more useful comparison of performance across countries is GHG emissions per capita. The GHGs in this calculation include CO2 from fossil fuels, land use change emissions, and non-CO2 gasses like methane and NOX, and are measured in metric tons of carbon dioxide equivalents. The lower the per capita emissions, the less the average person in a given country contributes to climate change. Developing nations generally have the lowest per capita emissions due to their relatively small industrial sectors and lifestyles with lower commercial energy intensities; however, they often rank among the highest for land use change emissions.

The 2010 EPI uses a target value of 50% reductions below 1990 levels by 2050, which equals 2.5 Mt CO2 -equivalent annually per person. Because the indicator divides by population, it is necessary to set a "target population" value. While population growth has major environmental implications, we chose to apply the median global population projection to 2050 across all countries.

CO2 Emissions per Electricity Generation: Emissions per capita are important but do not directly point to some of the most critical areas of the economy. The majority of global anthropogenic GHG emissions, about 65% (IEA 2009), come from the energy sector. Within this sector, the largest contributor is electricity generation, which makes up 41% of energy-related GHG emissions (IEA 2009). Therefore, the 2010 EPI uses the emissions intensity of the electricity sector to help measure countries' performance on climate change. IEA data for CO2 emissions is divided by the total associated electricity output. This reflects the relative efficiency of electricity production.

The target is set at zero emissions per unit of output as the theoretically ideal target for the indicator. Many climate change economists have argued that abating pollution to this point is not optimal due to the exponentially increasing costs of abating the last units of pollution. While these are important considerations, choosing an ideal indicator allows a greater spread among the countries' environmental performances. Ultimately, the relative distance to a target determines a country's EPI score rather than their absolute distance, and so an overly stringent target does not affect cross-country comparisons.

This indicator reflects a snapshot of current performance. It does not capture historical contributions to GHG emissions except through the implication of energy path-dependence. Where data are missing for emissions per unit output, values were imputed by calculating renewable energy consumption as a percentage of total energy consumption. For cogeneration facilities, heat output is converted to KWH to estimate total electricity emissions.

Industrial Greenhouse Gas Emissions Intensity: Differences in per capita emissions often have more to do with history and circumstance than current performance. Industrial emissions intensity, on the other hand, captures a largely contemporaneous process. The measurement reflects the total CO2 emitted by the industrial sector, divided by the total industrial GDP, measured as purchasing power parity (PPP). It is therefore a measure of emissions efficiency and offers insight into how a country's industrial economy is managed.

Countries that perform best on this indicator are those that have invested in low-carbon growth in their industrial sectors through energy conservation, investment in clean technologies, or other changes that result in industrial processes with lower emissions. It is a fair measure because it does not reflect shifts from industrial to service-based economies, as an emissions-per-GDP measure may, which has more to do with a development path than climate policy. The target for emissions intensity of the industrial sector is 36.3 tons CO2 per $1,000,000 (USD, 2005, PPP). This value is a reduction that is proportionate to the target for GHG emissions per capita.

Data Gaps and Deficiencies

Anthropogenic emissions of GHGs are the root of the climate change problem and are the core of the EPI indicators representing environmental performance for climate change. Emissions of GHGs have an impact on climate change regardless of where they are emitted, making emissions reductions in China as valuable as those in the United States. Because of the predicted severe and nearly ubiquitous impacts of GHGs, mitigation and monitoring of sectoral performances must occur at an international level with broad participation.

Despite the significant attention given to the issue of climate change, there are still major gaps in GHG inventories world-wide. Data availability varies by location and sector. Emissions data reporting from the industrial sector is widely available for most countries, although, even these data contain notable gaps. Though data on carbon dioxide emissions from fossil fuel combustion are gathered annually by several international agencies, data on other GHGs are still minimal.

Fortunately, GHG emissions monitoring and reporting are improving. The International Energy Agency (IEA) produces annual data on carbon dioxide emissions from fossil fuel combustion within each country, which are considered to be among the most reliable data. Data on other GHGs are reported every five years and provided to the IEA by national statistical offices in OECD countries, and collected from various sources in government and industry in non-OECD countries. Members of the UNFCCC self-report annual GHG emissions, but the accuracy depends upon the monitoring capacity of individual countries. In general, more countries and agencies are monitoring and compiling GHG emissions data, but the international body of data is far from sufficient to deconstruct the real drivers of climate change emissions within each country. The 2010 EPI uses IEA data, World Resource Institute's CAIT database, which includes UNFCC reports, Carbon Dioxide Information Analysis Center data, the World Bank's World Development Indicators, and information from the US Central Intelligence Agency.

In the future we would like to divide total GHG emissions into sectors in order to provide better insight into the performance of the economy. A particularly glaring example is transportation emissions, which make up 23% of global emissions from fossil fuels (OECD/ITF 2008). While total CO2 emissions from transportation are estimated, there is no international data on which to ground these numbers. See Box 4.10. More detail about which sectors are emitting what – including non-commercial energy consumption, transportation, agriculture, forestry, and waste disposal – would provide a better assessment of where and how climate change is being addressed in each country.

A major source of uncertainty is emissions from deforestation and changing land use. Emissions from this source were estimated to be 20-25% of the total annual GHG emissions worldwide (IPCC 2007 WGI), yet the data that exist are problematic. Attention through the UNFCCC reporting requirements and international programs like REDD have bolstered these measurements in recent years, but international calculations are too often unreliable (Box 4.8).

Improvements in data collection of GHG emissions can bolster future EPIs as well as the ability of policy makers to assess their own countries' performance on climate change.

BOX 4.9
THE FOREST CARBON INDEX

A new agreement on reducing emissions from deforestation and degradation (REDD) that emerged from the Copenhagen climate talks in December will soon create a major "forest carbon" market. This should stimulate investment in efforts to conserve forests for their carbon content as well as in forest monitoring and methods to evaluate the performance of forest conservation efforts. A new tool called the Forest Carbon Index (FCI, http://forestcarbonindex.org/) analyzes the potential of every country to combat climate change by storing carbon in forests, whether existing or newly planted (Deveny et al. 2009). The FCI illuminates the geography of potential forest carbon investments by compiling and mapping quantitative data relating to biological, economic, investment, and market readiness conditions on a country-by-country basis. By matching this data against expected changes in forest cover, the FCI also estimates likely forest carbon costs, quantities, and revenues for each country in the world.

Leading countries in the FCI, such as Brazil and Indonesia, may well be the future leaders in environmental performance with respect to forests, but the FCI does not measure past performance on forest management. The only metrics on past performance within the FCI include some general investment and governance risk metrics relating to the ease of doing business and corruption and political stability, but also include two "readiness" metrics more directly related to forests. These include a country's "environmental market experience" and a country's "remote sensing capacity". These both measure a country's relative readiness to participate in forest carbon markets, but do not necessarily measure actual success in forest management.

BOX 4.10
CLIMATE CHANGE AND TRANSPORTATION

Transportation is an important source of greenhouse gas emissions, accounting for about 13 percent of total anthropogenic CO2 and 23 percent of global CO2 emissions from fossil fuel combustion. Unfortunately, adequate data does not exist to deconstruct drivers of transportation emissions for many countries. The IEA tabulates total CO2 emissions from transportation, but the composition of emissions is not available for most countries. Without data on the amount work that these emissions generate – passenger-kilometers, freight ton-kilometers, or GDP generated from on road, rail, aviation, or marine vessels, an indicator utilizing total or per capita CO2 does not communicate enough about national transportation systems. In the future, we hope that transportation data becomes a priority for regulators around the world and that entities like the IEA and the World Transportation Forum will be able to provide the kind of detail that would allow for a useful deconstruction of transportation emissions for countries around the world.

5.
THE 2010 EPI, 2008 EPI, PILOT 2006 EPI, AND ENVIRONMENTAL SUSTAINABILITY INDEX

5.1
COMPARISON OF THE 2010 ENVIRONMENTAL PERFORMANCE INDEX AND THE 2008 ENVIRONMENTAL PERFORMANCE INDEX

The 2010 EPI and the 2008 EPI are both outcome-oriented performance indices. Like the 2008 EPI, the 2010 EPI is an attempt to assess current environmental conditions to provide policymakers with information they can use in formulating and assessing policy responses to environmental challenges through a data-driven approach. Both indices use a proximity-to-target approach to assess country performance relative to targets for environmental sustainability, focusing on areas where government policy can improve environmental conditions. Yet, it is important to note that owing to changes in the data and methods used in 2010 (described below and in Chapter 2), the results cannot be directly compared to the 2008 or 2006 Pilot EPIs. Thus, changes in country rank or score must be understood in this light.

While following the same general principles of construction and interpretation (i.e., an aggregation of proximity-to-target indicators into policy categories and objectives), the 2010 EPI differs from the previous index in both structure and content. The changes in structure are largely superficial – the same basic policy categories are used, but in 2010 we no longer used sub-categories for EBD, Water, and Air Pollution in Environmental Health or Forestry, Fisheries, and Agriculture in Productive Natural Resources. Instead, each of these is elevated to category level.

The content changes have been more significant. For most of the policy categories we have changed the indicators or the data sources for the indicators, and we have also changed the weighting applied to those indicators (see Table 2.1). Notably, Greenhouse Gas Emissions Per Capita in the Climate Change policy category now accounts for 12.5 percent of the overall EPI score. Except for Climate Change, each of the policy categories' weights under the Ecosystem Vitality objective have been reduced from 7.5 percent to 4.2 percent. This also means that the weight on Air Pollution (effects on ecosystems) has been increased from 2.5 to 4.2 percent.

While there are still 25 indicators overall, some of the indicators within the policy categories have been modified. The 2008 EPI measure of Local Ozone in the Environmental Health objective has been eliminated. The 2010 EPI adds Nitrogen Oxide Emissions and Non-Methane Volatile Organic Compounds in the Air Pollution (effects on ecosystems) policy category, and a national-level Water Scarcity Index has been added to the Water (effects on ecosystems) policy category, to balance the water stress measure which captures sub-national variation in water use to availability.

The Effective Conservation and Conservation Risk Index indicators have been dropped from the Biodiversity and Habitat policy category, while Biome Protection has been added. Forestry gains a Forest Cover Change measure, and Burned Land Area and Intensive Cropland have been eliminated from the Agriculture policy category. Within the Climate Change policy category, updated data sources from the World Resources Institute's Climate Analysis Indicator Tools (CAIT), land use change emissions data from Richard Hougton's research, and the latest data from the International Energy Agency were used to refine the measurements of the indicators.

One important change in the 2010 EPI is the use of the logarithmic transformation for the calculation of many of the indicators, including: Environmental Burden of Disease, Urban Particulates, Sulfur Dioxide Emissions, Nitrogen Oxide Emissions, Non-Methane Volatile Organic Compounds, Ozone Exceedance, Water Stress, Marine Protected Areas, Agricultural Water Stress, Greenhouse Gas Emissions Per Capita, Electricity Carbon Intensity, and Industrial Carbon Intensity. Most of these performance measures have a sizeable number of countries very close to the targets. The use of the logarithmic transformation has the effect of "spreading out" these leading countries, allowing the EPI to reflect important differences not only between the leaders and laggards, but also among leaders who achieve different degrees of high-end performance. A more detailed discussion of the benefits of log transformations can be found in Section 2.4.

A third methodological divergence from the 2008 EPI is the process of filling data gaps. The 2008 EPI employed limited and strategic use of data imputation, while in 2010 we sought to include more countries by averaging around gaps and by using imputation (more on this below). Averaging around implies changing the weights of other constituent indicators in a policy category to compensate for missing data. As a result of these methods, we were able to increase our country coverage by 14, from 149 to 163.[5] These changes help us to offer a globally relevant and globally applicable performance assessment tool.

Unfortunately, the inclusion of more advanced indicators often comes at the expense of geographical coverage. For this reason, we have used a suite of imputation methods, including regression and correlation analysis, to increase country coverage in these indicators: Access to Sanitation, Access to Drinking Water, Indoor Air Pollution, Water Quality Index, Greenhouse Gas Emissions Per Capita, Electricity Carbon Intensity, and Industrial Carbon Intensity. Since these imputed values may reflect the true but unknown values to varying degrees of accuracy, we have clearly marked them in the accompanying Excel data file.

The 2010 EPI demonstrates our commitment to identifying the best available, and developing the best possible, environmental performance indicators at the global level. We believe that the new 2010 EPI is a continued improvement and makes a significant contribution to environmental performance assessment.

Further discussion of the indicators we chose and the reasons for their inclusion can be found in Chapter 4 and in the Indicator Profiles and Metadata. Chapter 4 also includes an important discussion on data gaps and deficiencies. Here we provide a brief description of indicators that were changed. In the Environmental Health policy category, we removed the 2008 Local Ozone indicator because we wanted to reduce our dependence on modeled data, and one other indicator, Ecosystem Ozone, already depends upon this modeled data set. The 2010 EPI more fully captures the effects of air pollution on the environment, adding indicators for Nitrogen Oxide Emissions and Non-Methane Volatile Organic Compounds. We have further strengthened the water indicators by including the Water Scarcity Index as an indicator. The 2010 EPI has refined the Biodiversity and Habitat policy category by removing the 2008 Effective Conservation and Conservation Risk Index indicators, which depend on a one-time assessment of human impacted areas, and replacing them with the Biome Protection indicator. This indicator has been developed into a time series for the CIESIN/Yale Natural Resource Management Index (NRMI). In the Forestry category, we added Forest Cover Change, which is a commonly tracked metric for policy. In the Agriculture category we removed Intensive Cropland, the data for which are not updated, as well as Irrigation Stress, which depends on the same data set used in Water Stress. We also removed Burned Land Area, which proved to be difficult to interpret, inasmuch as land burning is a necessary land preparation method in many regions. We added Agricultural Water Intensity, a measure of the percentage of water going to agriculture.

One of the more significant changes in the 2010 EPI indicators concerns the Greenhouse Gas Emissions Per Capita indicator. This indicator has been given more weight, accounting for 12.5 percent of the overall 2010 EPI. The prioritization of this indicator reflects the diversity of important greenhouse gas (GHG) sources, which are often not accessible through global data sets. While a proper deconstruction of the drivers of GHG emissions in each country would offer a better suite of indicators, weighting the per capita emissions more heavily underscores the responsibility of more affluent countries to curb GHG emissions and serves as a target for a potential international agreement.

Despite the progress made in indicator development and data availability, the 2010 EPI once again highlights the glaring gaps in global environmental data. Several important environmental concerns such as population exposure to toxics and heavy metals (lead, mercury, and cadmium), loss of wetlands, waste management, transnational outsourcing and spill-over effects of "dirty" industries, cannot be measured adequately at the global level because of lack of data, targets, or scientific certainty. Although the 2010 EPI contains 163 countries, dozens of countries are not included because of the lack of information about key indicators. Our efforts to produce meaningful imputations fell short in these cases. These data limits make tracking and monitoring of both environmental progress and the success of policy and management efforts difficult. Although the 2010 EPI improves upon the 2008 EPI, much work remains to be done in establishing consistent data collection and monitoring of environmental metrics.

5.2

COMPARISON OF THE ENVIRONMENTAL SUSTAINABILITY INDEX AND THE ENVIRONMENTAL PERFORMANCE INDEX

Between 2000 and 2005 the Yale and Columbia team published four Environmental Sustainability Index reports (http://sedac.ciesin.columbia.edu/es/esi/) aimed at gauging countries' overall progress towards "environmental sustainability." These indices covered up to 76 different elements of sustainability across economic, social and environmental issues. Since then our focus has shifted to environmental performance, measuring the ability of countries to actively manage and protect their environmental systems and shield their citizens from harmful environmental pollution. This focus avoids the problem of comparing apples to oranges that inevitably occurs when one takes a “triple bottom line” approach – and centers the analysis on environmental performance issues for which all national governments can be held accountable.

Why this shift in our work? While sustainability research continues at a fast pace across the world, a commonly accepted and measurable definition of environmental sustainability remains elusive. Distinct approaches have emerged and consolidated within different disciplines, and cross-disciplinary exchange has promoted new advances, but the challenges are still formidable. In addition, the immediate value to policymakers was limited by the complexity of the problem; scientific uncertainties about cause-effect relationships; and the intricate and competing linkages between policy actions and the social, economic, and environmental aspects of sustainable development.

In contrast, environmental performance offers a more relevant and easily measured approach to reducing and managing environmental impacts. The possibility of selecting outcome-oriented indicators for which policy drivers can be identified and quantified is an appealing scenario for policymakers, environmental scientists and advocates, and the public alike. This method promotes action, accountability, and broad participation. The EPI’s proximity-to-target approach in particular highlights a country’s shortcomings and strengths compared to its peers in a transparent and easily visualized manner. These signals can be acted on through policy processes more quickly, more effectively, and with broader consensus than most sustainability metrics.

In some cases, the EPI targets can already be viewed as sustainability targets, while other indicators represent the most widely accepted or most widely agreed-upon policy goals. This partly reflects the varying degree of certainty regarding the scientific consensus of what a truly sustainable performance on a given indicator would be.

Aside from these main conceptual and structural differences, how exactly do the EPI and ESI differ from each other? A summary of the differences is shown in Table A for the 2005 ESI, Pilot 2006 EPI, 2008 EPI, and 2010 EPI.

In contrast to the relative measurements of the ESI, the EPI focuses on measuring performance rather than considering resource endowments and future trajectories. The sustainability thresholds of many environmental and socio-economic aspects are extremely difficult to determine and, given the dynamics of human and ecological change, might not exist in an absolute sense. The ESI evaluates environmental sustainability relative to the paths of other countries. The EPI, on the other hand, uses the distance to performance targets as the main criteria, acknowledging that these targets represent imperfect goal posts and can depend on local circumstances.

Although both the EPI and ESI are multi-tier, average-based indices, they significantly differ in the categories of which they are composed. In line with sustainability research, the ESI considers not only environmental systems, but also adapts the Pressure-State-Response framework to reflect institutional, social, and economic conditions. The EPI, in contrast, considers only ecological and human health outcomes regardless of the auxiliary factors influencing them. The basic premise of the EPI is therefore normative. Each country is held to the same basic conditions necessary to protect human and environmental health now and in the future. The benchmarks for these conditions are enshrined in the 25 indicator targets. As a result of the EPI’s narrowed scope, the categories and indicators tracked are both different and smaller in number.

Data quality and coverage play important roles in both the EPI and ESI. We believe that the value of a sustainability or a performance index is diminished if only a handful of countries can be included and compared. Yet, while the ESI makes relatively extensive use of imputation techniques to fill data gaps, the availability of actual ‘real’ data was given much higher weight in the EPI to reflect the relevance of observed data in the policy process (the 2010 and 2008 EPIs do make limited use of imputing missing values in selected variables to maintain country coverage). As our knowledge of cause-effect relationships and statistical methods for data imputation continues to increase, however, it is likely that model-based imputations will gain more credibility in the future and in some cases even outperform observations in accuracy.

Table A Comparison of ESI and EPI objectives and design

Category	**2005 ESI**	**2006 EPI**	**2008 EPI**	**2010 EPI**
Objective	Gauges the long term environmental trajectory of countries by focusing on “environmental sustainability”	Assesses current environmental conditions		
Design	Provides a relative measure of past, current, and likely future environmental, socio-economic, and institutional conditions relevant to environmental sustainability	Provides an absolute measure of performance by assessing countries on a proximity-to-target basis		
Design and theoretical framework	Tracks a broad range of factors that affect sustainability using an adaptation of Pressure-State-Response framework	Focuses narrowly on areas within governmental control using a framework of absolute, fixed targets		
Structure	Multi-tier consisting of **5 components:** Environmental systems, Reducing environmental stresses, Reducing human vulnerability, Social and institutional capacity, Global stewardship undergirded by **21 indicators** and **76 variables** (Note: the variables in the ESI can be compared with indicators in the EPI and indicators in the ESI are more reflective of the policy categories in the EPI)	Multi-tier consisting of **2 objectives:** Environmental health and Ecosystem vitality, **6 categories:** environmental health, air quality, water resources, biodiversity and habitat, productive natural resources, and sustainable energy, **16 indicators**	Multi-tier consisting of **2 objectives:** Environmental health and Ecosystem vitality, **10 categories/sub-categories:** environmental health (comprising environmental burden of disease, air pollution (effects on humans), and water (effects on humans)), air pollution (effects on ecosystems), water (effects on ecosystems), biodiversity and habitat, productive natural resources (comprising forestry, fisheries, and agriculture), and climate change, **25 indicators**	Multi-tier consisting of **2 objectives:** Environmental health and Ecosystem vitality, **10 categories:** environmental burden of disease, air pollution (effects on humans), water (effects on humans), air pollution (effects on ecosystems), water (effects on ecosystems), biodiversity and habitat, forestry, fisheries, agriculture, and climate change, **25 indicators**
Data quality and coverage	Stringent grading system; flexible data requirements allow for missing data to be imputed	Stringent data quality requirements, no imputation of missing data	Stringent data quality requirements; imputation of missing data in selected indicators	
Environmental Health (EPI objective, ESI indicator)	Indicators compare mortality rates of environmentally related diseases using proxy indicators: child mortality, child death from respiratory diseases, and intestinal infectious diseases	Estimates environmentally-related impacts on health through child mortality, indoor air pollution, urban particulates concentration, access to drinking water, and adequate sanitation	Estimates environmental burden of disease directly using WHO-developed disability adjusted life year (DALYs), local ground-level ozone and urban particulate concentrations, indoor air pollution, access to drinking water, adequate sanitation	Estimates environmental burden of disease directly using WHO-developed disability adjusted life year (DALYs), urban particulate concentrations, indoor air pollution, access to drinking water, access to sanitation

Air Pollution	Measures effects of air pollution as well as levels of air pollution: Coal consumption per capita, anthropogenic NO2, SO2, and VOC emissions per populated land area, and vehicles in use per populated land area	Measures air quality: Percent of households using solid fuels, urban particulates and regional ground-level ozone concentration	Measures atmospheric conditions pertaining to both human and ecological health: Health – Indoor air pollution, urban particulates, local ozone Ecosystems – Regional ozone, sulfur dioxide emissions (as proxy for its ecosystem impacts when deposited)	Measures atmospheric conditions pertaining to both human and ecological health: Health – Indoor air pollution, and urban particulates Ecosystems – Regional ozone, sulfur dioxide, nitrogen oxides, and NMVOC emissions (as proxy for its ecosystem impacts when deposited)
Water Resources and Stress	Measures both water resources and stress: Quantity - Freshwater per capita and internal groundwater per capita Reducing stress – BOD emissions per freshwater, fertilizer and pesticides consumption per hectare arable land, percentage of country under water stress	Measures both water resources and stress: water consumption and nitrogen loading	Measures water stress through water stress index	Measures water stress through water stress index and overuse through water scarcity
Water Quality	Key water quality indicators: dissolved oxygen, electrical conductivity, phosphorus concentration, suspended solids	Proxy for water quality: nitrogen loading	Assesses water quality through composite Water Quality Index, which incorporates dissolved oxygen, pH, electrical conductivity, total nitrogen and total phosphorous concentrations	Assesses water quality through composite Water Quality Index, which incorporates dissolved oxygen, pH, electrical conductivity, total nitrogen and total phosphorous concentrations
Climate Change / Energy	Tracks emissions per capita and per GDP Eco-efficiency indicator includes a measure of energy efficiency and renewable energy	Links energy to climate change via CO_2 emissions per GDP, percent of renewable energy and energy efficiency	Explicitly assesses contributions to climate change through emissions per capita, emissions per electricity generated, and industrial carbon intensity	Explicitly assesses contributions to climate change through emissions per capita, emissions per electricity generated, and industrial carbon intensity
Biodiversity & Habitat	Focuses on species protection: Percentage of threatened birds, mammals, and amphibians in a country, the National Biodiversity Index (measures species richness and abundance), and threatened ecoregions	Focuses on biome and resource protection: wilderness protection, ecoregion protection, timber harvest rate, and water consumption	Focuses on biome protection, including marine areas, and species conservation through Effective conservation, Conservation Risk Index, and critical habitat protection, indicators	Focuses on biome protection, including marine areas, and species conservation through critical habitat protection, and critical habitat protection, indicators
Forests	Proxies for sustainable forest management: Annual change in forest cover and Percentage of total forest area that is certified for sustainable management	Proxy for sustainable forest management: Timber harvest rate	Proxy for sustainable forest management: Change in growing stock	Proxy for sustainable forest management: Change in growing stock and Forest Cover
Agriculture	Proxy for sustainable agriculture: Agricultural subsidies	Proxy for sustainable agriculture: Agricultural subsidies	Proxies for sustainable agriculture: Agricultural subsidies, Intensive cropland usage, Pesticide regulations, and Burned land area	Proxies for sustainable agriculture: Agricultural subsidies, Irrigation Stress, and Pesticide regulation
Fisheries	Proxy for sustainable fisheries management: Overfishing	Proxy for sustainable fisheries management: Overfishing	Proxy for sustainable fisheries management: Trawling intensity, Marine Trophic Index	Proxy for sustainable fisheries management: Trawling intensity, Marine Trophic Index

6.
TREND DATA

For the 2010 EPI we sought to obtain trend data for all indicators. Experience has shown that EPI country scores and ranks change from year to year for reasons that can largely – though not exclusively – be attributed to changes in the underlying index framework, methods, and data sources (see Chapter 3). Consistent trend data offer one of the few possible means to examine whether countries are making progress towards higher levels of environmental performance or slipping behind. Apart from the Water (effects on humans) and Climate Change policy categories, we could not find data with sufficiently long time series to conduct a trend analysis. Hence, our focus in this chapter is on these two categories, with brief treatment of shorter time series in Section 6.3.

With trend data it is important to recognize that when countries start from very low baselines, it is possible to register very large percentage growth improvements that may not be very meaningful. A country with only 3% coverage in the Access to Drinking Water and Access to Sanitation indicators could double its coverage by moving to 6% (a 100% improvement), and triple it by moving to 9% (a 200% improvement). This is true of most of the countries that have seen the most dramatic percentage growth improvements in water and sanitation coverage. By the same token, declines from 4% to 2% would represent a 50% decrease, though the population difference between these two coverage rates may not be very significant. In terms of greenhouse gas emissions, the signal is the opposite – declines are “positive” from an environmental viewpoint, and increases are “negative” – but the same principle applies. Many of the countries that have seen dramatic increases in emissions also started at a low base, and hence their percentage changes need to be understood in that light.

6.1
WATER (EFFECTS ON HUMAN HEALTH)

Consistent trend data on Access to Drinking Water and Access to Sanitation exist from 1990 to 2006. The trend data for access to improved water supplies (Figure 6.1) show generally positive results, with 97 countries raising their Access to Drinking Water coverage, and four countries (Cambodia, Ethiopia, Burkina Faso, and Chad) more than doubling their access. Fifty-five countries saw improvements in coverage of 10 percent or more.

Unfortunately, there were also retrenchments. With water supply, countries must constantly be expanding coverage just to keep pace with population growth. Any country that does not actively increase coverage, whether by government efforts or increases in income that result in people investing in their own water and sanitation infrastructure, will inevitably score lower on the Access to Drinking Water indicator as population grows. The countries that have seen declines are generally among the poorest, although some negative changes, such as that seen in Algeria (-9.6%), may be artifacts of the data rather than actual declines in coverage. A number of the countries in this group have seen prolonged armed conflicts or social unrest – among them Sierra Leone, Iraq, and the Occupied Palestinian Territory.

Figure 6.1 Percent Change in Access to Improved Water Supplies Between 1990 and 2006

1	Cambodia	242.11
2	Ethiopia	223.08
3	Burkina Faso	111.76
4	Chad*	100.00
5	Malawi	85.37
6	Mali	81.82
7	Viet Nam	76.92
8	Namibia	63.16
9	Mauritania	62.16
10	Guinea	55.56
11	Uganda	48.84
12	Paraguay	48.08
13	Laos*	46.34
14	Ghana	42.86
15	Cameroon	42.86
16	Myanmar	40.35
17	Eritrea	39.53
18	Kenya	39.02
19	Somalia*	38.10
20	Kiribati	35.42
21	China	31.34
22	Angola	30.77
23	Georgia	30.26
24	Ecuador	30.14
25	India	25.35
26	Nepal	23.61
27	Sri Lanka	22.39
28	El Salvador	21.74
29	Guatemala	21.52
30	Djibouti	21.05
31	Côte d'Ivoire	20.90
32	Madagascar	20.51
33	Togo	20.41
34	Tajikistan*	19.64
35	Bolivia	19.44
36	Honduras	16.67
37	Mozambique	16.67
38	Zambia	16.00
39	Romania	15.79
40	Kyrgyzstan*	15.58
41	Senegal	14.93
42	Azerbaijan	14.71
43	Tunisia	14.63
44	Turkey	14.12
45	Central African Republic	13.79
46	Dominican Republic	13.10
47	Nicaragua	12.86
48	Mongolia	12.50
49	Liberia	12.28
50	Tanzania	12.24
51	Philippines	12.05
52	Peru	12.00
53	Haiti	11.54
54	Indonesia	11.11
55	Morocco	10.67
56	Brazil	9.64
57	Sudan	9.38
58	Sao Tome and Principe*	8.86
59	Mexico	7.95
60	Armenia*	7.69
61	Syria	7.23
62	Dem. Rep. Congo	6.98
63	Micronesia	6.82
64	Trinidad and Tobago	6.82
65	Guyana*	5.68
66	Gabon*	4.82
67	Afghanistan*	4.76
68	Pakistan	4.65
69	Colombia	4.49
70	Chile	4.40
71	Egypt	4.26
72	Greece	4.17
73	Hungary	4.17
74	Zimbabwe	3.85
75	Botswana	3.23
76	Russia	3.19
77	Benin	3.17
78	Thailand	3.16
79	Portugal	3.13
80	Bangladesh	2.56
81	Papua New Guinea	2.56
82	Niger	2.44
83	Iran**	2.17
84	Argentina	2.13
85	Costa Rica*	2.08
86	Bosnia and Herzegovina	2.06
87	Swaziland*	1.69
88	Solomon Islands	1.45
89	Burundi	1.43
90	Lesotho*	1.30
91	Oman**	1.23
92	Gambia*	1.18
93	Suriname*	1.10
94	Jamaica	1.09
95	Albania*	1.04
96	Jordan	1.03
97	Malaysia	1.02
98	Bulgaria	0.00
99	Croatia	0.00
100	Latvia	0.00
101	Saint Kitts and Nevis	0.00
102	United States of America	0.00
103	Northern Mariana Islands	0.00
104	Saint Lucia	0.00
105	Kazakhstan	0.00
106	Rwanda	0.00
107	Equatorial Guinea	0.00
108	Cuba*	0.00
109	Panama*	0.00
110	Ukraine*	0.00
111	Libyan Arab Jamahiriya**	0.00
112	Palau	-1.11
113	Guinea-Bissau*	-1.72
114	Fiji	-2.08
115	Uzbekistan	-2.22
116	Moldova*	-3.23
117	Vanuatu**	-3.28
118	Samoa	-3.30
119	Nigeria	-6.00
120	Sierra Leone*	-7.02
121	Iraq	-7.23
122	Occupied Palestinian Territo	-7.29
123	Yemen*	-8.33
124	Marshall Islands**	-8.33
125	Comoros	-8.60
126	Algeria	-9.57
127	Maldives	-13.54
128		
129		

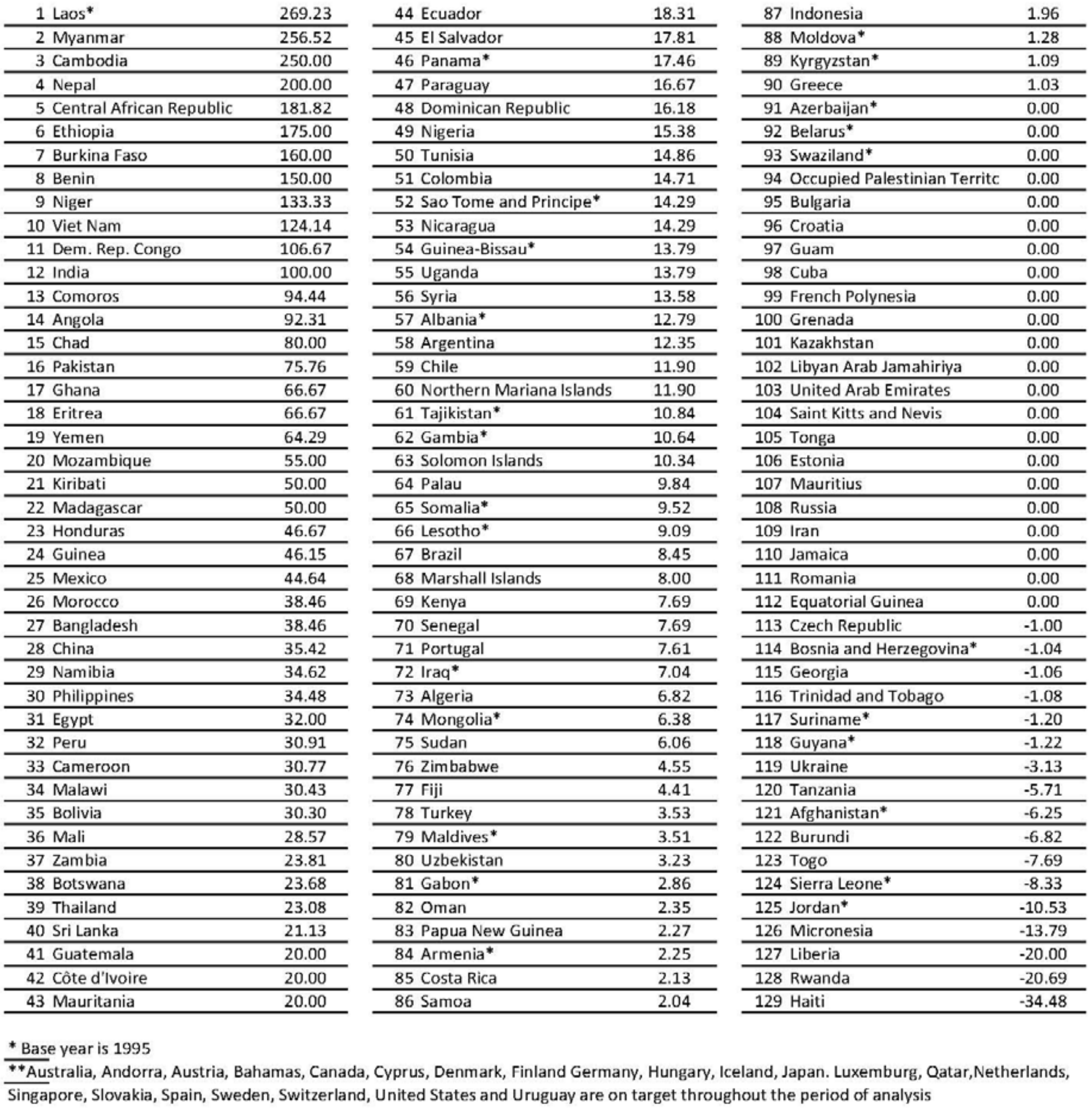
* Base year is 1995

**End year is 2000

***Aruba, Australia, Andorra, Austria, Barbados, Belarus, Canada, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, French Polynesia Germany, Guam, Iceland, Israel, Japan, Lebanon, Luxemburg, Malta, Mauritius, Netherlands, North Korea, Norway, Qatar, Singapore, Slovakia, Spain Sweden, Switzerland, Tonga, United States, United Arab Emirates, United Kingdom, and Uruguay are on target throughout the period of analysis

In terms of Access to Sanitation, the greatest increases have been in South and Southeast Asia, where Laos, Myanmar, Cambodia, and Nepal all more than tripled (>200% change) their coverage (Figure 6.2). Sixty-three countries saw improvements of 10% or more. Unfortunately, a number of countries also saw declines, the most precipitous of which were Jordan, Micronesia, Liberia, Rwanda, and Haiti, all with more than 10% declines. The last three have also been affected by civil war or chronic political instability.

Figure 6.2 Percent Change in Access to Improved Sanitation Between 1990 and 2006



1	Laos*	269.23
2	Myanmar	256.52
3	Cambodia	250.00
4	Nepal	200.00
5	Central African Republic	181.82
6	Ethiopia	175.00
7	Burkina Faso	160.00
8	Benin	150.00
9	Niger	133.33
10	Viet Nam	124.14
11	Dem. Rep. Congo	106.67
12	India	100.00
13	Comoros	94.44
14	Angola	92.31
15	Chad	80.00
16	Pakistan	75.76
17	Ghana	66.67
18	Eritrea	66.67
19	Yemen	64.29
20	Mozambique	55.00
21	Kiribati	50.00
22	Madagascar	50.00
23	Honduras	46.67
24	Guinea	46.15
25	Mexico	44.64
26	Morocco	38.46
27	Bangladesh	38.46
28	China	35.42
29	Namibia	34.62
30	Philippines	34.48
31	Egypt	32.00
32	Peru	30.91
33	Cameroon	30.77
34	Malawi	30.43
35	Bolivia	30.30
36	Mali	28.57
37	Zambia	23.81
38	Botswana	23.68
39	Thailand	23.08
40	Sri Lanka	21.13
41	Guatemala	20.00
42	Côte d'Ivoire	20.00
43	Mauritania	20.00
44	Ecuador	18.31
45	El Salvador	17.81
46	Panama*	17.46
47	Paraguay	16.67
48	Dominican Republic	16.18
49	Nigeria	15.38
50	Tunisia	14.86
51	Colombia	14.71
52	Sao Tome and Principe*	14.29
53	Nicaragua	14.29
54	Guinea-Bissau*	13.79
55	Uganda	13.79
56	Syria	13.58
57	Albania*	12.79
58	Argentina	12.35
59	Chile	11.90
60	Northern Mariana Islands	11.90
61	Tajikistan*	10.84
62	Gambia*	10.64
63	Solomon Islands	10.34
64	Palau	9.84
65	Somalia*	9.52
66	Lesotho*	9.09
67	Brazil	8.45
68	Marshall Islands	8.00
69	Kenya	7.69
70	Senegal	7.69
71	Portugal	7.61
72	Iraq*	7.04
73	Algeria	6.82
74	Mongolia*	6.38
75	Sudan	6.06
76	Zimbabwe	4.55
77	Fiji	4.41
78	Turkey	3.53
79	Maldives*	3.51
80	Uzbekistan	3.23
81	Gabon*	2.86
82	Oman	2.35
83	Papua New Guinea	2.27
84	Armenia*	2.25
85	Costa Rica	2.13
86	Samoa	2.04
87	Indonesia	1.96
88	Moldova*	1.28
89	Kyrgyzstan*	1.09
90	Greece	1.03
91	Azerbaijan*	0.00
92	Belarus*	0.00
93	Swaziland*	0.00
94	Occupied Palestinian Territc	0.00
95	Bulgaria	0.00
96	Croatia	0.00
97	Guam	0.00
98	Cuba	0.00
99	French Polynesia	0.00
100	Grenada	0.00
101	Kazakhstan	0.00
102	Libyan Arab Jamahiriya	0.00
103	United Arab Emirates	0.00
104	Saint Kitts and Nevis	0.00
105	Tonga	0.00
106	Estonia	0.00
107	Mauritius	0.00
108	Russia	0.00
109	Iran	0.00
110	Jamaica	0.00
111	Romania	0.00
112	Equatorial Guinea	0.00
113	Czech Republic	-1.00
114	Bosnia and Herzegovina*	-1.04
115	Georgia	-1.06
116	Trinidad and Tobago	-1.08
117	Suriname*	-1.20
118	Guyana*	-1.22
119	Ukraine	-3.13
120	Tanzania	-5.71
121	Afghanistan*	-6.25
122	Burundi	-6.82
123	Togo	-7.69
124	Sierra Leone*	-8.33
125	Jordan*	-10.53
126	Micronesia	-13.79
127	Liberia	-20.00
128	Rwanda	-20.69
129	Haiti	-34.48

* Base year is 1995

**Australia, Andorra, Austria, Bahamas, Canada, Cyprus, Denmark, Finland Germany, Hungary, Iceland, Japan. Luxemburg, Qatar,Netherlands, Singapore, Slovakia, Spain, Sweden, Switzerland, United States and Uruguay are on target throughout the period of analysis

Between water and sanitation, we see a number of Asian and sub-Saharan African countries making significant progress. Laos, Cambodia, and Burkina Faso are among those countries that have seen significant improvements in coverage (and now have above 60% of their populations with Access to Drinking Water), and if they continue on a similar trajectory they may well be on target to meet the MDGs.

6.2
CLIMATE CHANGE

The signal from the Climate Change trend data is even more difficult to discern than that of the Access to Drinking Water and Access to Sanitation indicators. This may be because of deficiencies in the underlying data, especially those dating to the early 1990s. Here we present trends for two indicators – Industrial Greenhouse Gas Emissions Intensity and CO2 Emissions per Electricity Generation. The third, Greenhouse Gas Emissions per Capita (including land use emissions), cannot be reliably assessed due to the fact that the land use emissions were imputed in some cases.

The trend data for Industrial GHG Emissions Intensity from 1990-2005 are found in Table 6.3. This is a measure of the carbon intensity of industrial production, and declines in intensity show that more goods are produced with fewer emissions. If the numbers are taken at face value, approximately 47 countries are improving, and 68 countries are either stagnant or seeing declines in industrial energy efficiency. For a few countries, improvements in efficiency can clearly be attributed to increases in either efficiency (improved plants or more efficient production systems – e.g. for Norway, Netherlands, and the UK) or to the use of renewable energy sources (e.g. Ghana). For others, such as the Democratic Republic of Congo, Bahrain, and Turkmenistan, the reasons for the increases in the energy efficiency of production are more opaque, and cannot be easily explained. For the countries at the other end that are seeing increases Industrial GHG Emissions Intensity, it is possible that some of them saw declines in real dollar values of production while retaining level emissions. Under this scenario, a country would see decreasing efficiency.

In terms of large industrialized countries, the United States has seen a 24% increase in Industrial GHG Intensity, perhaps owing to declines in industrial production without concomitant declines in emissions, whereas China has seen an increase of only 3.1%. China's industrial production has skyrocketed since 1990, and it appears that efficiency has largely kept pace, perhaps because of China's massive investment in energy-saving technology. Germany and Russia both saw significant improvements in efficiency of 20% and 7.9%, respectively. In the first instance, Germany has invested heavily in more efficient production methods, and, in the case of Russia, many inefficient Communist era factories have been shut down. These improvements are to be lauded.

For changes in CO2 Emissions per Electricity Generation from 1992-2007 (Table 6.4), some countries have invested heavily in hydroelectric energy and consequently have seen a decrease in emissions per unit of energy produced (e.g., Mozambique, Nepal, Colombia, and Zambia). As for the other top ranked countries such as Luxemburg and Tajikistan, it is unclear what is driving their improved performance. Most industrialized countries have seen declines of -4% to -40%. On the other end of the spectrum, some countries have seen preposterous increases of greater than 1,000% in Electricity Carbon Intensity. These are most likely artifacts of the data. Beyond these outliers, there are some surprising countries in the list of countries that have seen increases – including Iceland (heavily dependent on thermal energy), Chile, and New Zealand.

Figure 6.3 Percent Change in carbon emissions from industry per industrial GDP Since 1990

1	Congo, Dem. Republic	-100.00
2	Bahrain	-87.18
3	Turkmenistan	-76.31
4	Benin	-74.48
5	Norway	-69.32
6	Cameroon	-64.72
7	Tajikistan	-59.63
8	Nigeria	-58.19
9	Mongolia	-56.50
10	Ghana	-55.94
11	Syria	-54.41
12	Sudan	-54.09
13	United Kingdom	-48.87
14	Romania	-48.05
15	Yemen	-46.17
16	Iceland	-46.04
17	Gabon	-45.43
18	Canada	-44.07
19	Netherlands	-43.71
20	Trinidad & Tobago	-40.69
21	New Zealand	-40.23
22	Guatemala	-37.07
23	Azerbaijan	-35.84
24	Hungary	-29.76
25	Cote d'Ivoire	-28.65
26	France	-27.02
27	Estonia	-25.68
28	Ireland	-22.89
29	Uzbekistan	-22.54
30	Germany	-19.97
31	Finland	-19.61
32	Iran	-18.81
33	Australia	-18.45
34	Chile	-16.67
35	Lithuania	-15.81
36	Sweden	-9.71
37	Greece	-8.53
38	Russian Federation	-7.90
39	Egypt	-7.82
40	Thailand	-5.90
41	Armenia	-4.96
42	Kenya	-4.60
43	Austria	-4.28
44	Nepal	-4.23
45	Poland	-3.74
46	Switzerland	-3.71
47	Belarus	-3.01
48	Antigua & Barbuda	0.00
49	Burundi	0.00
50	Burkina Faso	0.00
51	Bahamas	0.00
52	Belize	0.00
53	Botswana	0.00
54	Central African Republic	0.00
55	Malaysia	0.56
56	Portugal	1.01
57	Tunisia	1.53
58	Algeria	2.70
59	China	3.13
60	Spain	3.70
61	Czech Republic	4.46
62	El Salvador	4.73
63	Mexico	5.27
64	Singapore	5.82
65	Ecuador	6.26
66	Venezuela	8.79
67	Korea (South)	11.18
68	Jordan	11.69
69	Indonesia	11.85
70	Albania	12.77
71	Italy	13.94
72	Turkey	14.79
73	Cyprus	14.82
74	Argentina	15.51
75	Peru	15.97
76	India	16.34
77	Denmark	17.63
78	Ukraine	18.40
79	Slovenia	19.64
80	Pakistan	19.84
81	Saudi Arabia	20.55
82	Mauritania	21.91
83	Honduras	23.46
84	Croatia	23.60
85	United States of America	23.81
86	Zambia	26.90
87	Brazil	27.42
88	Japan	27.59
89	Colombia	27.67
90	Bulgaria	27.84
91	Belgium	29.63
92	Tanzania	32.56
93	Paraguay	35.25
94	Togo	36.05
95	Dominican Republic	38.38
96	Bolivia	45.61
97	Slovakia	46.82
98	Luxembourg	46.95
99	Sri Lanka	49.04
100	Macedonia, FYR	53.37
101	Kyrgyzstan	65.90
102	Georgia	66.59
103	Costa Rica	68.05
104	United Arab Emirates	73.95
105	Oman	82.90
106	Ethiopia	91.69
107	Morocco	92.62
108	Philippines	95.03
109	South Africa	104.03
110	Vietnam	122.50
111	Angola	123.19
112	Uruguay	141.49
113	Latvia	156.01
114	Senegal	255.90
115	Bangladesh	411.14
116	Moldova	795.16
117		

Figure 6.4 Percent Change in Trends in emissions per kilowatt hour of energy produced (per generation) Since 1992

1	Mozambique	-99.74
2	Nepal	-92.71
3	Luxembourg	-86.80
4	Tajikistan	-63.74
5	Armenia	-58.95
6	Eritrea	-56.43
7	Georgia	-55.67
8	Colombia	-52.52
9	Zambia	-49.89
10	Azerbaijan	-48.76
11	Costa Rica	-48.69
12	Kyrgyzstan	-45.95
13	Zimbabwe	-44.33
14	Ethiopia	-43.30
15	Latvia	-40.46
16	Benin	-38.67
17	Qatar	-38.54
18	Portugal	-38.25
19	Lithuania	-37.06
20	Cambodia	-36.57
21	Singapore	-36.46
22	Slovak Republic	-35.90
23	Jordan	-34.37
24	Ireland	-32.66
25	Denmark	-32.54
26	Republic of Moldova	-28.05
27	Netherlands	-27.60
28	Italy	-27.53
29	United Kingdom	-23.78
30	Belgium	-23.39
31	Yemen	-23.37
32	Korea	-22.64
33	Germany	-21.82
34	Greece	-21.74
35	Myanmar	-21.52
36	Sweden	-21.49
37	Hungary	-20.23
38	Bahrain	-19.72
39	Serbia	-19.54
40	Tunisia	-18.78
41	Senegal	-18.31
42	Spain	-17.69
43	Dominican Republic	-17.30
44	Thailand	-17.13
45	Albania	-16.84
46	Switzerland	-16.46
47	Uzbekistan	-15.99
48	Egypt	-14.96
49	Angola	-14.94
50	Dem. Rep. of Congo	-14.91
51	Panama	-14.17
52	Turkey	-14.15
53	Morocco	-13.77
54	DPR of Korea	-13.67
55	Peru	-13.33
56	Mongolia	-12.18
57	Jamaica	-11.86
58	Saudi Arabia	-11.60
59	Malta	-9.51
60	Brunei Darussalam	-8.18
61	France	-8.14
62	Cyprus	-8.06
63	Ukraine	-8.06
64	Venezuela	-7.95
65	Cuba	-7.33
66	Argentina	-6.81
67	Belarus	-6.64
68	United States	-6.43
69	Hong Kong, China	-5.59
70	Slovenia	-5.29
71	Israel	-5.19
72	People's Rep. of China	-4.59
73	Islamic Rep. of Iran	-4.49
74	FYR of Macedonia	-3.58
75	Austria	-3.04
76	Czech Republic	-3.00
77	Lebanon	-2.27
78	South Africa	-1.26
79	Malaysia	-0.67
80	Algeria	-0.46
81	Gibraltar	-0.36
82	Netherlands Antilles	0.04
83	Kuwait	0.07
84	Canada	0.10
85	Bosnia and Herzegovina	0.69
86	Oman	0.79
87	Russian Federation	0.97
88	Trinidad and Tobago	1.38
89	India	4.17
90	Japan	4.53
91	Poland	4.89
92	Kazakhstan	5.87
93	Philippines	6.23
94	Mexico	6.78
95	Romania	7.04
96	Bulgaria	8.32
97	Pakistan	10.01
98	Australia	10.12
99	Syrian Arab Republic	10.79
100	Estonia	11.01
101	United Arab Emirates	11.80
102	Finland	12.16
103	Nigeria	13.75
104	El Salvador	14.34
105	Libyan Arab Jamahiriya	14.91
106	Indonesia	15.20
107	Ecuador	16.88
108	Uruguay	17.19
109	Botswana	17.74
110	Croatia	18.73
111	Nicaragua	19.06
112	Bangladesh	19.38
113	Brazil	20.03
114	Guatemala	22.44
115	Chinese Taipei	30.50
116	Bolivia	31.52
117	Vietnam	33.89
118	Iraq	37.04
119	Côte d'Ivoire	49.54
120	New Zealand	51.10
121	Gabon	56.86
122	Togo	63.41
123	Haiti	64.72
124	Sudan	71.83
125	United Rep. of Tanzania	81.56
126	Norway	92.10
127	Sri Lanka	106.99
128	Chile	112.73
129	Turkmenistan	133.59
130	Iceland	197.39
131	Namibia	265.07
132	Kenya	381.47
133	Honduras	982.45
134	Congo	1271.12
135	Cameroon	2491.41
136	Ghana	11818.66
137		
138		

6.3
OTHER TRENDS

We limited our analysis of change in other indicators to a subset of European and OECD countries. There are data for 36 countries showing declines in Urban Particulates (PM10 concentrations) of between 14% and 77% from 1990 and 2006. The former Soviet Bloc countries of Georgia, Belarus, Ukraine and Estonia have seen the greatest improvements, owing, most likely, to the shuttering of inefficient Soviet era industries. All of Western Europe and Canada have seen declines that average 20% or more. In terms of NOx emissions, again the former Soviet Bloc and Eastern European countries have seen heavy declines since 1990, with Moldova and Georgia seeing greater than 75% reductions. On the other hand, several countries saw increases, including Austria (+14%), Spain (+20%), Cyprus, and Greece (+25% each). Finally, recycling rates – for those few western European countries with data – have also increased dramatically and across the board from 1995-2007.

We have a shorter time series, from 2006-2009, for Biome Protection (weighted average percentage of biome area covered by protected areas). Although there have been changes in scores, the results most likely reflect improvements in the underlying protected areas database (the World Database of Protected Areas), which has been consistently improved since an international agency consortium effort re-launched the database in 2005. Thus, Albania, Swaziland, Romania, and the United Kingdom all apparently saw increases of 90% or more. On the opposite end, countries like the United

States saw apparent decreases of 24%, yet there is no evidence of any protected areas having been degazetted during this period. Such a move would trigger widespread protest in the U.S., particularly by NGOs.

6.4
CONCLUSIONS FROM THE TREND ANALYSIS

This preliminary trend analysis has raised more questions than it has answered, revealing that even with trend data, which in theory should enable one to tease out the countries with improving environmental performance, interpretation of results can be difficult. This is in part because it is difficult to distinguish between the signal (improving environmental performance) and the noise (confounding factors). The latter includes issues such as changes in the economic structure and output of major economies (for climate change metrics) and data collection methods (for water and sanitation and protected areas coverage). Nonetheless, we see this as a profitable area for further exploration, and hope that in the future sufficient high-quality data may be available to generate more reliable trends.

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APPENDIX A. INDICATOR PROFILES (METADATA)

APPENDIX B. OBJECTIVE AND CATEGORY RANKINGS

APPENDIX C. COUNTRY PROFILES

APPENDIX D. MAPS