Human Environment Index and its Efficacy

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Abstract

The need for the human environment index (HEI) has been felt for a long time because there is no single characteristic that could help measure the existing environmental state of a place quantitatively. There are several natural conditions that influence the environment and no global targets can be set because of the enormous diversity of environmental issues across countries and regions. The construction of the HEI aims to represent the three basic dimensions of the human environment that include green land, blue sky, and clean water by a single number. Being expressed in different units these are transformed into dimension indices using linear transformations, and they are pooled to obtain the HEI. For combining them we use an averaging method. This index, in turn, exhibits the managerial efforts a country/area makes for ensuring the environmental sustainability. The ranking of the countries / areas based on the index produces a sense of competition to improve their investment towards the environmental protection goal, which is the most important factor for our survival and well-being. Further, this index is expected to fulfil an urgent need for a composite index to monitor the environmental characteristics of countries and regions irrespective of their affiliation to the United Nations (UN) in a single number on a regular basis, This attempts to measure the relative progress towards the environmental protection goal. As this measures the relative change its value needs to be interpreted with extra caution. We need to update this index at a regular interval for making it a stronger tool of our environment protection goal just like UN human development index (HDI), which is being computed by the UNDP regularly.

Keywords: Dimension Index, Distance-based Human Environment Index, Environmental Distance, Goal Posts, Indicators, Index

Introduction

The Human Environment Index (HEI) is a composite index to measure the average achievement of a country / area in three basic dimensions of the human environment that represent the **green land**, the **blue sky** and the **clean water**. These dimensions relate to the three leading outcome indicators consisting of percentage forested land (**land indicator**), carbon dioxide emissions per capita (**air indicator**), and the percentage access to improved water and sanitation facilities (**water indicator**) respectively. These indicators jointly constitute a sustainable environment for the survival of the mankind and its surroundings, and the composite index helps capture the human progress towards the environmental protection goal quantitatively in a unified way.

The indictors are uncorrelated, adequate and mutually reinforcing. The index, in turn, aims to quantify the status of a country's / area's human environment scenario across the world in a unified way for monitoring its progress to ensure the environmental sustainability. Its main objective is to motivate all countries / areas irrespective of their current status with the United Nations (UN) for accomplishing the targets of the three basic dimensions that help to have a good sustainable environment. The latest available values of the outcome indicators are obtained directly from the UN website for the Millennium Development Goals (MDGs) Indicators for computing the HEI. For more details see Singh and Shansieve-Cohen (2002), World Wide Fund for Nature (2002) , Sinha (2004) and Human Development Report (2009).

2. Dimension Index

For computing the HEI we need to measure the performance in each dimension (indicator) under consideration and this is obtained by using the dimension index for each indicator. The general formula for the dimension index given below converts the performance of each indicator between 0 and 1 without using its original units.

$$\text{Dimension Index} = \frac{\text{actual value - minimum value}}{\text{maximum value - minimum value}}.$$

But this formula is useful only when a high value of an indicator is considered better. For example, these situations arise in the case of land and water components. However, this criterion does not work in the case of the air indicator where a low value of the emission of carbon dioxide is appreciated. In this case we need to follow the formula mentioned below.

$$\text{Dimension Index} = \frac{\text{maximum value - actual value}}{\text{maximum value - minimum value}}.$$

Obviously, this requires the identification of the minimum and maximum values for each of the underlying indicator. Note that this is the same as the human development index (HDI) where these values, referred to as 'goalposts', are selected considering various factors that influence a particular indicator.

2.1 Reference Points: Fixed versus Flexible Goalposts

For calculating the dimension index we have a choice between fixed and flexible goalposts. It is worthwhile to note that an index based on fixed goalposts may be used for comparison of performances of a country or countries for a number of years while that based on flexible goalposts (observed maximum and minimum values) is helpful only for a particular year. In view of these predicaments a fixed goalpost technique is preferred for the land, air and

water indices on which the HEI is based. The HDI is also computed using indices based on fixed goalposts. The fixed goalposts for the leading environmental indicators are given below in **Table 1**.

<div align="center">Table 1. Goalposts for computing the HEI</div>

Indicators	Maximum Value	Minimum Value
Land	95%	-95%
Air	85	0
Water	100%	0%

3. Indicators and Indices

Next, we discuss indicators and their indices

3.1 Land and Water Indices

The land indicator, being in percentage, is unit free, but its value may vary between -100% to 100%, where -100% shows the scenario where a country with 100% forest cover in the reference (base) year reduces to a 0% forest cover in the current year while 100% indicates the scenario when a country changes its forest cover from 0% in the reference year to 100% in the current year. As 100% forest cover does not appear to portray a realistic scenario, and therefore a more realistic goalposts (minimum and maximum values) for land indicator could be fixed as -95 and 95. Thus, the land index could be obtained as follows:

$$\text{Land Index} = \frac{\text{actual land indicator value - (-95)}}{95 - (-95)}.$$

This reduces to

$$\text{Land Index} = \frac{\text{actual land indicator value} + 95}{190}.$$

For obtaining the water index we use the goalposts as 100% (maximum value) and 0% (minimum value), and therefore the water index formula appears as:

$$\text{Water Index} = \frac{\text{actual water indicator value - 0}}{100 - 0}.$$

This simplifies the water index formula to:

$$\text{Water Index} = \frac{\text{actual value}}{100}.$$

3.2 Interpretation of Dimension Indices for Land and Water Components

Primarily, the dimension index is used for converting an indicator value into a pure (absolute) number or a fraction with no unit of measurement. It is the basic requirement for combining various indicators to obtain the HEI. However, the numerator that shows the difference between the actual and the minimum values of the indicator may be considered as the **relative contribution** of a country to the environmental protection goal with respect to that indicator. The division by the difference between maximum and minimum values makes the contribution unit less (a pure quantity). Thus the dimension index, in turn, facilitates a comparison among the countries with respect to that indicator.

Obviously, as the actual value of the indicator approaches to the maximum value the dimension index goes closer to unity. But when the actual value of the indicator tends towards the minimum value, the dimension index comes nearer to zero.

3.3 Air Index

For measuring the achievements of the managerial efforts towards the **blue sky** the observed quantity of carbon dioxide emissions (in metric tons) per capita is expressed as a value between 0 and 1 by applying the following formula of the dimension index:

$$\text{Dimension Index (Air)} = \frac{\text{maximum value - actual value}}{\text{maximum value - minimum value}}.$$

On putting the goalpost values the following expression for the dimension index of the air indicator is obtained:

$$\text{Air Index} = \frac{85 - \text{actual value}}{85}.$$

3.4 Interpretation of Dimension Index for Air Component

In the above-mentioned formula the actual value is subtracted from 85 (the maximum goalpost value) unlike the earlier formulae where the minimum goalpost value is subtracted from the actual value. This difference is adopted because 'less emissions of carbon dioxide' represents more blueness of the sky. Thus, the numerator reveals the **relative contribution** of a country to the air component of the environment while the denominator makes it unit less. Further, this formula reveals that the dimension index goes to unity as the actual amount of the emissions of carbon dioxide approaches to the minimum goalpost value. On the contrary, the

dimension index tending to zero shows almost no contribution by the country concerned towards the 'blue sky'.

Note that the indicators could be made free from their units of measurement in several ways, but the numerators of the formulae that we have used show a special significance for the construction of the HEI.

4. HEI Formula

For simplicity of the notations let us denote the dimension indices for the land, air and water indicators by L, A, and W respectively. The HEI is computed by the formula given below:

$$HEI = \frac{L + A + W}{3}.$$

Note that the HEI lies between zero and unity, i.e. $0 \leq HEI \leq 1$.

This shows that the HEI is the arithmetic mean of the three-dimension indices giving equal weight to each indicator. This expression, in turn, reveals that each of the three components of the environment is equally important for living in pleasant surroundings. A lower value of HEI describes the poor environmental conditions while a higher value suggests better environmental scenarios. This may also be looked upon as an environmental LAW (e-LAW). However, the formula could be looked upon as a special case of the general HEI (GHEI) formula that could be defined as $GHEI = \sum_{i=1}^{n} w_i DI_i \Big/ \sum_{i=1}^{n} w_i$; where w_i represents the weight of the ith dimension index (DI_i). For this paper we consider $w_i = 1$ and n = 3. **Figure 1** portrays a diagrammatic representation of the human environment index. **Table 2** provides the values of the land indicator for 198 countries / areas in 2009 while **Table 3** shows the carbon dioxide (CO_2) emissions in metric tons of (CO_2) per capita (CDIAC) for 198 countries / areas in 2006 and the air indicator for 2009 and **Table 4** gives the percentages of improved drinking water sources and sanitation facilities with values of the water indicator for 198 countries / areas in 2009.

Figure 1. Diagrammatic representation of the human environment index
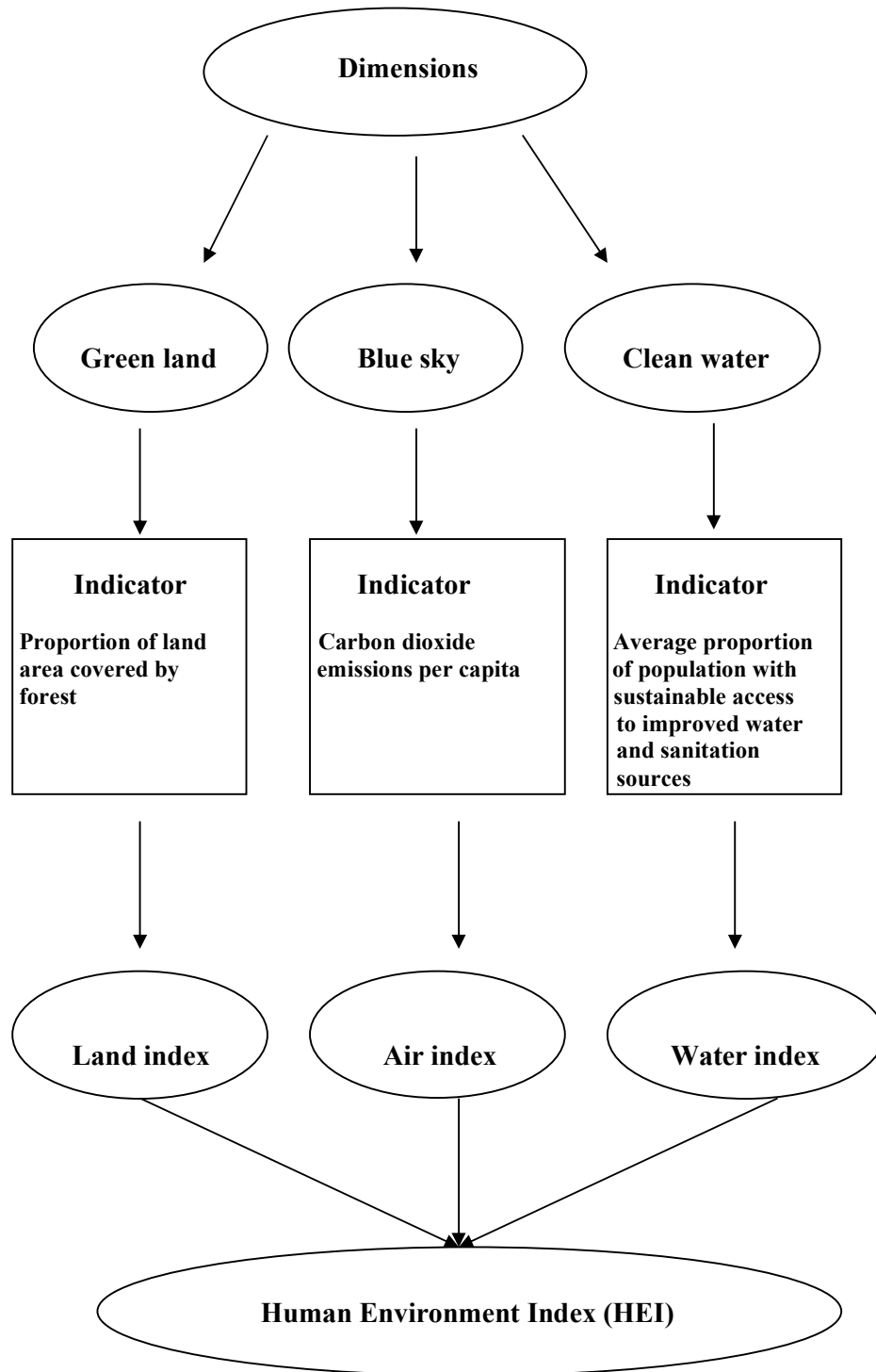
Table 2. Values of the land indicator for 198 countries / areas in 2009

Countries / Areas	% Forested Land in 2000	% Forested Land in 2005	Land Indicator in 2009
Afghanistan	1.6	1.3	-0.3
Albania	28.1	29.0	0.9
Algeria	0.9	1.0	0.1
Angola	47.9	47.4	-0.5
Anguilla	71.4	71.4	0.0
Antigua and Barbuda	21.4	21.4	0.0
Argentina	12.3	12.1	-0.2
Armenia	10.8	10.0	-0.8
Aruba	2.2	2.2	0.0
Australia	21.4	21.3	-0.1
Austria	46.4	46.7	0.3
Azerbaijan	11.3	11.3	0.0
Bahamas	51.5	51.5	0.0
Bahrain	0.5	0.6	0.1
Bangladesh	6.8	6.7	-0.1
Barbados	4.0	4.0	0.0
Belarus	37.8	38.0	0.2
Belgium	22.0	22.0	0.0
Belize	72.5	72.5	0.0
Benin	24.2	21.3	-2.9
Bermuda	20.0	20.0	0.0
Bhutan	66.8	68.0	1.2
Bolivia	55.4	54.2	-1.2
Bosnia and Herzegovina	43.1	43.1	0.0
Botswanarazil	22.1	21.1	-1.0-1.8
British Virgin Islands	59.0	57.2	-0.1
Brunei Darussalam	24.5	24.4	-1.8
Bulgaria	54.6	52.8	2.3
Burkina Faso	30.5	32.8	-0.5
Burundi	29.5	29.0	-1.8
Cambodia	7.7	5.9	-6.2
Cameroon	65.4	59.2	-2.4
Canada	48.0	45.6	0.0
Cape Verde	33.6	33.6	0.3
Cayman Islands	20.4	20.7	0.0
Central African Republic	48.4	48.4	-0.3
Chad	36.8	36.5	-0.3
Chile	9.8	9.5	0.4
China	21.1	21.5	2.2
Colombia	19.0	21.2	-0.2
Comoros	58.7	58.5	-1.4
Congo	4.3	2.9	-0.3
Cook Islands	66.1	65.8	0.0
Costa Rica	66.5	66.5	0.3
Cote d'Ivoire	46.5	46.8	0.2
Croatia	32.5	32.7	0.1
Cuba	38.1	38.2	2.5
Cyprus	22.2	24.7	0.2
Czech Republic	18.7	18.9	0.2
Democratic Republic of the Congo	34.1	34.3	-0.7
Denmark	59.6	58.9	0.3

Djibouti	11.5	11.8	0.0
Dominica	0.2	0.2	-1.8
Dominican Republic	63.1	61.3	0.0
Ecuador	28.4	28.4	-3.6
Egypt	42.8	39.2	0.0
El Salvador	0.1	0.1	-1.2
Equatorial Guinea	15.6	14.4	-2.7
Eritrea	60.9	58.2	-0.2
Estonia	15.6	15.4	1.0
Ethiopia	52.9	53.9	-0.6
Faeroe Islands	12.5	11.9	0.0
Fiji	0.1	0.1	0.0
Finland	54.7	54.7	0.1
France	73.8	73.9	0.4
French Guiana	27.9	28.3	0.0
French Polynesia	91.8	91.8	0.0
Gabon	28.7	28.7	-0.2
Gambia	84.7	84.5	0.9
Georgia	40.8	41.7	0.0
Germany	39.7	39.7	0.0
Ghana	31.7	31.7	-2.6
Greece	26.8	24.2	1.2
Greenland	27.9	29.1	0.0
Grenada	0.0	0.0	0.0
Guadeloupe	12.2	12.2	-0.7
Guam	47.9	47.2	0.0
Guatemala	47.1	47.1	-2.5
Guinea	38.8	36.3	-0.7
Guinea-Bissau	28.1	27.4	-1.7
Guyana	75.4	73.7	0.0
Haiti	76.7	76.7	-0.2
Honduras	4.0	3.8	-7.0
Hungary	48.5	41.5	0.8
Iceland	20.7	21.5	0.1
India	0.4	0.5	0.1
Indonesia	22.7	22.8	-5.2
Iran (Islamic Republic of)	54.0	48.8	0.0
Iraq	6.8	6.8	0.0
Ireland	1.9	1.9	0.9
Israel	8.8	9.7	0.3
Italy	8.0	8.3	1.8
Jamaica	32.1	33.9	-0.2
Japan	31.5	31.3	0.0
Jordan	68.2	68.2	0.0
Kazakhstan	0.9	0.9	0.0
Kenya	1.2	1.2	-0.1
Kiribati	6.3	6.2	0.0
Korea, Dem. People's Rep. of	3.0	3.0	-5.2
Korea, Republic of	56.6	51.4	-0.3
Kuwait	63.8	63.5	0.0
Kyrgyzstan	0.3	0.3	0.0
Lao People's Dem. Rep.	4.5	4.5	-1.7
Latvia	71.6	69.9	0.9
Lebanon	46.5	47.4	0.5
Liberia	12.8	13.3	-3.2

Libyan Arab Jamahiriya	35.9	32.7	0.0
Luxembourg	0.1	0.1	0.0
Madagascar	33.5	33.5	-0.3
Malawi	22.4	22.1	-1.7
Malaysia	37.9	36.2	-2.1
Maldives	65.7	63.6	0.0
Mali	3.0	3.0	-0.4
Malta	10.7	10.3	0.0
Mauritania	1.1	1.1	0.0
Mauritius	0.3	0.3	-0.5
Mexico	18.7	18.2	-0.6
Mongolia	34.3	33.7	-0.3
Montserrat	6.8	6.5	0.0
Morocco	35.0	35.0	0.1
Mozambique	9.7	9.8	-0.3
Myanmar	24.9	24.6	-3.5
Namibia	52.5	49.0	-0.5
Nepal	9.8	9.3	-1.9
Netherlands	27.3	25.4	0.2
Netherlands Antilles	10.6	10.8	0.0
New Caledonia	1.5	1.5	0.0
New Zealand	39.2	39.2	0.3
Nicaragua	30.7	31.0	-2.9
Niger	45.6	42.7	0.0
Nigeria	1.0	1.0	-2.2
Niue	14.4	12.2	-3.9
Norway	58.1	54.2	0.3
Oman	30.4	30.7	0.0
Pakistan	0.0	0.0	-0.2
Palau	2.7	2.5	1.5
Panama	86.1	87.6	-0.2
Papua New Guinea	57.9	57.7	-1.5
Paraguay	66.5	65.0	-2.2
Peru	48.7	46.5	-0.4
Philippines	54.1	53.7	-2.7
Portugal	26.7	24.0	2.1
Puerto Rico	39.2	41.3	0.1
Qatar	45.9	46.0	0.0
Republic of Moldova	0.0	0.0	0.1
Romania	9.9	10.0	0.0
Russian Federation	27.7	27.7	0.0
Rwanda	47.9	47.9	5.6
Saint Kitts and Nevis	13.9	19.5	0.0
Saint Lucia	14.7	14.7	0.0
Saint Vincent and the Grenadines	27.9	27.9	1.0
Samoa	26.4	27.4	0.0
Sao Tome and Principe	60.4	60.4	0.0
Saudi Arabia	28.4	28.4	0.0
Senegal	1.3	1.3	-1.2
Serbia and Montenegro	46.2	45.0	0.4
Seychelles	26.0	26.4	0.0
Sierra Leone	88.9	88.9	-1.3
Singapore	39.8	38.5	0.0
Slovakia	3.4	3.4	0.1
Slovenia	40.0	40.1	1.3

Solomon Islands	61.5	62.8	-7.1
Somalia	84.7	77.6	-0.6
South Africa	12.0	11.4	0.0
Spain	7.6	7.6	3.0
Sri Lanka	32.9	35.9	-2.3
Sudan	32.2	29.9	-1.3
Suriname	29.7	28.4	0.0
Swaziland	94.7	94.7	1.4
Sweden	30.1	31.5	0.2
Switzerland	66.7	66.9	0.6
Syrian Arab Republic	30.3	30.9	0.1
Tajikistan	2.4	2.5	0.0
Thailand	2.9	2.9	-0.6
The for. Yugoslav Rep. of Macedonia	29.0	28.4	0.0
Timor-Leste	35.8	35.8	-3.7
Togo	57.4	53.7	-1.8
Tonga	8.9	7.1	0.0
Trinidad and Tobago	5.0	5.0	-0.3
Tunisia	44.4	44.1	0.6
Turkey	6.2	6.8	0.1
Turkmenistan	13.1	13.2	0.0
Uganda	8.8	8.8	-2.2
Ukraine	20.6	18.4	0.1
United Arab Emirates	16.4	16.5	0.0
United Kingdom	3.7	3.7	0.2
United Republic of Tanzania	11.6	11.8	-2.3
United States	42.2	39.9	0.1
United States Virgin Islands	33.0	33.1	-2.7
Uruguay	30.6	27.9	0.5
Uzbekistan	8.1	8.6	0.2
Vanuatu	7.8	8.0	0.0
Venezuela	36.1	36.1	-1.6
Viet Nam	55.7	54.1	3.7
Yemen	36.0	39.7	0.0
Zambia	1.0	1.0	-3.0
Zimbabwe	60.1	57.1	-4.1
	49.4	45.3	

Table 3. Carbon dioxide (CO_2) emissions in metric tons of (CO_2) per capita (CDIAC) for 198 countries / areas in 2006 and the air indicator for 2009

Countries	Carbon dioxide emissions in 2006	Air Indicator 2009
Afghanistan	0.027	0.027
Albania	1.356	1.356
Algeria	3.979	3.979
Angola	0.639	0.639
Anguilla	4.125	4.125
Antigua and Barbuda	5.058	5.058
Argentina	4.434	4.434
Armenia	1.452	1.452

Aruba	22.260	22.260
Australia	18.120	18.120
Austria	8.626	8.626
Azerbaijan	4.170	4.170
Bahamas	6.532	6.532
Bahrain	28.816	28.816
Bangladesh	0.267	0.267
Barbados	4.569	4.569
Belarus	7.067	7.067
Belgium	10.278	10.278
Belize	2.903	2.903
Benin	0.355	0.355
Bermuda	8.771	8.771
Bhutan	0.588	0.588
Bolivia	1.219	1.219
Bosnia and Herzegovina	6.988	6.988
Botswana	2.567	2.567
Brazil	1.862	1.862
British Virgin Islands	4.443	4.443
Brunei Darussalam	15.475	15.475
Bulgaria	6.251	6.251
Burkina Faso	0.055	0.055
Burundi	0.024	0.024
Cambodia	0.287	0.287
Cameroon	0.201	0.201
Canada	16.720	16.720
Cape Verde	0.594	0.594
Cayman Islands	11.134	11.134
Central African Republic	0.059	0.059
Chad	0.038	0.038
Chile	3.650	3.650
China	4.621	4.621
Colombia	1.392	1.392
Comoros	0.108	0.108
Congo	0.397	0.397
Cook Islands	4.838	4.838
Costa Rica	1.786	1.786
Cote d'Ivoire	0.364	0.364
Croatia	5.198	5.198
Cuba	2.630	2.630
Cyprus	9.210	9.210
Czech Republic	11.273	11.273
Democratic Republic of the Congo	0.036	0.036
Denmark	9.934	9.934
Djibouti	0.596	0.596
Dominica	1.735	1.735
Dominican Republic	2.117	2.117
Ecuador	2.373	2.373
Egypt	2.249	2.249
El Salvador	0.955	0.955
Equatorial Guinea	8.789	8.789
Eritrea	0.118	0.118
Estonia	13.077	13.077
Ethiopia	0.074	0.074
Faeroe Islands	13.973	13.973

Fiji	1.932	1.932
Finland	12.676	12.676
France	6.244	6.244
French Guiana	4.444	4.444
French Polynesia	3.168	3.168
Gabon	1.569	1.569
Gambia	0.201	0.201
Georgia	1.245	1.245
Germany	9.742	9.742
Ghana	0.402	0.402
Greece	8.665	8.665
Greenland	9.770	9.770
Grenada	2.292	2.292
Guadeloupe	4.848	4.848
Guam	24.954*	24.954
Guatemala	0.903	0.903
Guinea	0.148	0.148
Guinea-Bissau	0.169	0.169
Guyana	2.039	2.039
Haiti	0.192	0.192
Honduras	1.032	1.032
Hungary	5.731	5.731
Iceland	7.421	7.421
India	1.311	1.311
Indonesia	1.457	1.457
Iran (Islamic Republic of)	6.645	6.645
Iraq	3.248	3.248
Ireland	10.378	10.378
Israel	10.344	10.344
Italy	8.062	8.062
Jamaica	4.503	4.503
Japan	10.108	10.108
Jordan	3.617	3.617
Kazakhstan	12.636	12.636
Kenya	0.332	0.332
Kiribati	0.314	0.314
Korea, Dem. People's Rep. of	3.577	3.577
Korea, Republic of	9.891	9.891
Kuwait	31.166	31.166
Kyrgyzstan	1.059	1.059
Lao People's Democratic Republic	0.248	0.248
Latvia	3.260	3.260
Lebanon	3.780	3.780
Liberia	0.219	0.219
Libyan Arab Jamahiriya	9.190	9.190
Luxembourg	24.518	24.518
Madagascar	0.148	0.148
Malawi	0.077	0.077
Malaysia	7.194	7.194
Maldives	2.894	2.894
Mali	0.048	0.048
Malta	6.296	6.296
Mauritania	0.547	0.547
Mauritius	3.076	3.076
Mexico	4.140	4.140

Mongolia	3.625	3.625
Montserrat	12.034	12.034
Morocco	1.469	1.469
Mozambique	0.097	0.097
Myanmar	0.207	0.207
Namibia	1.383	1.383
Nepal	0.117	0.117
Netherlands	10.288	10.288
Netherlands Antilles	22.834	22.834
New Caledonia	12.358	12.358
New Zealand	7.365	7.365
Nicaragua	0.783	0.783
Niger	0.068	0.068
Nigeria	0.672	0.672
Niue	2.296	2.296
Norway	8.615	8.615
Oman	16.250	16.250
Pakistan	0.886	0.886
Palau	5.801	5.801
Panama	1.955	1.955
Papua New Guinea	0.745	0.745
Paraguay	0.662	0.662
Peru	1.401	1.401
Philippines	0.792	0.792
Portugal	5.672	5.672
Puerto Rico	0.538*	0.538
Qatar	56.243	56.243
Republic of Moldova	2.041	2.041
Romania	4.574	4.574
Russian Federation	10.925	10.925
Rwanda	0.084	0.084
Saint Kitts and Nevis	2.726	2.726
Saint Lucia	2.338	2.338
Saint Vincent and the Grenadines	1.653	1.653
Samoa	0.851	0.851
Sao Tome and Principe	0.662	0.662
Saudi Arabia	15.784	15.784
Senegal	0.353	0.353
Serbia and Montenegro	5.096	5.096
Seychelles	8.643	8.643
Sierra Leone	0.173	0.173
Singapore	12.829	12.829
Slovakia	6.952	6.952
Slovenia	7.583	7.583
Solomon Islands	0.371	0.371
Somalia	0.020	0.020
South Africa	8.588	8.588
Spain	8.026	8.026
Sri Lanka	0.618	0.618
Sudan	0.287	0.287
Suriname	5.356	5.356
Swaziland	0.896	0.896
Sweden	5.604	5.604
Switzerland	5.611	5.611
Syrian Arab Republic	3.527	3.527

Tajikistan	0.963	0.963
Thailand	4.295	4.295
The for. Yugoslav Rep. of Macedonia	5.340	5.340
Timor-Leste	0.158	0.158
Togo	0.191	0.191
Tonga	1.323	1.323
Trinidad and Tobago	25.294	25.294
Tunisia	2.264	2.264
Turkey	3.645	3.645
Turkmenistan	9.002	9.002
Uganda	0.090	0.090
Ukraine	6.855	6.855
United Arab Emirates	32.848	32.848
United Kingdom	9.395	9.395
United Republic of Tanzania	0.136	0.136
United States	18.994	18.994
United States Virgin Islands	121.299*	121.299
Uruguay	2.061	2.061
Uzbekistan	4.287	4.287
Vanuatu	0.415	0.415
Venezuela	6.311	6.311
Viet Nam	1.231	1.231
Yemen	0.976	0.976
Zambia	0.211	0.211
Zimbabwe	0.838	0.838

[* denotes the carbon dioxide emissions in 2003]

Table 4: Percentages of improved drinking water sources and sanitation facilities with values of the water indicator for 198 countries / areas in 2009

Countries	Water (2006)	Sanitation (2006)	Water Indicator 2009
Afghanistan	22	30	26.0
Albania	97	97	97.0
Algeria	85	94	89.5
Angola	51	50	50.5
Anguilla	60	99	79.5
Antigua and Barbuda	91	95	93.0
Argentina	96	91	93.5
Armenia	98	91	94.5
Aruba	100	100	100.0
Australia	100	100	100.0
Austria	100	100	100.0
Azerbaijan	78	80	79.0
Bahamas	100	100	100.0
Bahrain	100	100	100.0
Bangladesh	80	36	58.0
Barbados	100	99	99.5
Belarus	100	93	96.5
Belgium	100	100	100.0
Belize	91	47	69.0
Benin	65	30	47.5
Bermuda	100	100	100.0

Bhutan	81	52	66.5
Bolivia	86	43	64.5
Bosnia and Herzegovina	99	95	97.0
Botswana	96	47	71.5
Brazil	91	77	84.0
British Virgin Islands	98	100	99.0
Brunei Darussalam	100	100	100.0
Bulgaria	99	99	99.0
Burkina Faso	72	13	42.5
Burundi	71	41	56.0
Cambodia	65	28	46.5
Cameroon	70	51	60.5
Canada	100	100	100.0
Cape Verde	80	43	61.5
Cayman Islands	100	100	100.0
Central African Republic	66	31	48.5
Chad	48	9	28.5
Chile	95	94	94.5
China	88	65	76.5
Colombia	93	78	85.5
Comoros	85	35	60.0
Congo	71	20	45.5
Cook Islands	95	100	97.5
Costa Rica	98	96	97.0
Cote d'Ivoire	81	24	52.5
Croatia	99	99	99.0
Cuba	91	98	94.5
Cyprus	100	100	100.0
Czech Republic	100	99	99.5
Democratic Rep. of the Congo	46	31	38.5
Denmark	100	100	100.0
Djibouti	92	67	79.5
Dominica	97	84	90.5
Dominican Republic	95	79	87.0
Ecuador	95	84	89.5
Egypt	98	66	82.0
El Salvador	84	86	85.0
Equatorial Guinea	43	51	47.0
Eritrea	60	5	32.5
Estonia	100	95	97.5
Ethiopia	42	11	26.5
Faeroe Islands	100	100	100.0
Fiji	47	71	59.0
Finland	100	100	100.0
France	100	100	100.0
French Guiana	84	78	81.0
French Polynesia	100	98	99.0
Gabon	87	36	61.5
Gambia	86	52	69.0
Georgia	99	93	96.0
Germany	100	100	100.0
Ghana	80	10	45.0
Greece	100	98	99.0
Greenland	100	100	100.0
Grenada	95	97	96.0

Guadeloupe	98	64	81.0
Guam	100	99	99.5
Guatemala	96	84	90.0
Guinea	70	19	44.5
Guinea-Bissau	57	33	45.0
Guyana	93	81	87.0
Haiti	58	19	38.5
Honduras	84	66	75.0
Hungary	100	100	100.0
Iceland	100	100	100.0
India	89	28	58.5
Indonesia	80	52	66.0
Iran (Islamic Republic of)	94	83	88.5
Iraq	77	76	76.5
Ireland	100	100	100.0
Israel	100	100	100.0
Italy	100	100	100.0
Jamaica	93	83	88.0
Japan	100	100	100.0
Jordan	98	85	91.5
Kazakhstan	96	97	96.5
Kenya	57	42	49.5
Kiribati	65	33	49.0
Korea, Dem. People's Rep. of	100	59	79.5
Korea, Republic of	100	100	100.0
Kuwait	100	100	100.0
Kyrgyzstan	89	93	91.0
Lao People's Dem. Rep.	60	48	54.0
Latvia	99	78	88.5
Lebanon	100	98	99.0
Liberia	64	32	48.0
Libyan Arab Jamahiriya	72	97	84.5
Luxembourg	100	100	100.0
Madagascar	47	12	29.5
Malawi	76	60	68.0
Malaysia	99	94	96.5
Maldives	83	59	71.0
Mali	60	45	52.5
Malta	100	100	100.0
Mauritania	60	24	42.0
Mauritius	100	94	97.0
Mexico	95	81	88.0
Mongolia	72	50	61.0
Montserrat	100	96	98.0
Morocco	83	72	77.5
Mozambique	42	31	36.5
Myanmar	80	82	81.0
Namibia	93	35	64.0
Nepal	89	27	58.0
Netherlands	100	100	100.0
Netherlands Antilles	100	100	100.0
New Caledonia	100	100	100.0
New Zealand	100	100	100.0
Nicaragua	79	48	63.5
Niger	42	7	24.5

Nigeria	47	30	38.5
Niue	100	100	100.0
Norway	100	100	100.0
Oman	100	100	100.0
Pakistan	90	58	74.0
Palau	89	67	78.0
Panama	92	74	83.0
Papua New Guinea	40	45	42.5
Paraguay	77	70	73.5
Peru	84	72	78.0
Philippines	93	78	85.5
Portugal	99	99	99.0
Puerto Rico	100	100	100.0
Qatar	100	100	100.0
Republic of Moldova	90	79	84.5
Romania	88	72	80.0
Russian Federation	97	87	92.0
Rwanda	65	48	56.5
Saint Kitts and Nevis	99	96	97.5
Saint Lucia	98	89	93.5
Saint Vincent and the Grenadines	93	96	94.5
Samoa	88	100	94.0
Sao Tome and Principe	86	24	55.0
Saudi Arabia	100	100	100.0
Senegal	77	28	52.5
Serbia and Montenegro	99	92	95.5
Seychelles	88	88	88.0
Sierra Leone	53	11	32.0
Singapore	100	100	100.0
Slovakia	100	100	100.0
Slovenia	100	100	100.0
Solomon Islands	70	32	51.0
Somalia	29	23	26.0
South Africa	93	59	76.0
Spain	100	100	100.0
Sri Lanka	82	86	84.0
Sudan	70	35	52.5
Suriname	92	82	87.0
Swaziland	60	50	55.0
Sweden	100	100	100.0
Switzerland	100	100	100.0
Syrian Arab Republic	89	92	90.5
Tajikistan	67	92	79.5
Thailand	98	96	97.0
The for. Yugoslav Rep. of Macedonia	100	89	94.5
Timor-Leste	62	41	51.5
Togo	59	12	35.5
Tonga	100	96	98.0
Trinidad and Tobago	94	92	93.0
Tunisia	94	85	89.5
Turkey	97	88	92.5
Turkmenistan	72	62	67.0
Uganda	64	33	48.5
Ukraine	97	93	95.0
United Arab Emirates	100	97	98.5

United Kingdom	100	100	100.0
United Rep. of Tanzania	55	33	44.0
United States	99	100	99.5
United States Virgin Islands	100	100	100.0
Uruguay	100	100	100.0
Uzbekistan	88	96	92.0
Vanuatu	60	50	55.0
Venezuela	83	68	75.5
Viet Nam	92	65	78.5
Yemen	66	46	56.0
Zambia	58	52	55.0
Zimbabwe	81	46	63.5

4.1 Computation of HEI values

For computing the HEI values for various countries we obtain their land, air and water indices for these indicators using the formulas discussed above. **Table 5** provides these indices as well as the HEI values following the formula mentioned earlier.

Table 5. The human environment index (HEI) values for 198 countries / areas in 2009

Countries / Areas	Land Index	Air Index	Water Index	HEI Value
Afghanistan	0.498	1.000	0.260	0.586
Albania	0.505	0.984	0.970	0.820
Algeria	0.501	0.953	0.895	0.783
Angola	0.497	0.992	0.505	0.665
Anguilla	0.500	0.951	0.795	0.749
Antigua and Barbuda	0.500	0.940	1.000	0.813
Argentina	0.499	0.948	0.935	0.794
Armenia	0.496	0.983	0.945	0.808
Aruba	0.500	0.738	1.000	0.746
Australia	0.499	0.787	1.000	0.762
Austria	0.502	0.899	1.000	0.800
Azerbaijan	0.500	0.951	0.790	0.747
Bahamas	0.500	0.923	1.000	0.808
Bahrain	0.501	0.661	1.000	0.721
Bangladesh	0.499	0.997	0.580	0.692
Barbados	0.500	0.946	0.995	0.814
Belarus	0.501	0.917	0.965	0.794
Belgium	0.500	0.879	1.000	0.793
Belize	0.500	0.966	0.690	0.719
Benin	0.485	0.996	0.475	0.652
Bermuda	0.500	0.897	1.000	0.799
Bhutan	0.506	0.993	0.665	0.721
Bolivia	0.494	0.986	0.645	0.708
Bosnia and Herzegovina	0.500	0.918	0.970	0.796
Botswana	0.495	0.970	0.715	0.727
Brazil	0.491	0.978	0.840	0.770
British Virgin Islands	0.499	0.948	0.990	0.812
Brunei Darussalam	0.491	0.818	1.000	0.769

Bulgaria	0.512	0.926	0.990	0.810
Burkina Faso	0.497	0.999	0.425	0.641
Burundi	0.491	1.000	0.560	0.683
Cambodia	0.467	0.997	0.465	0.643
Cameroon	0.487	0.998	0.605	0.697
Canada	0.500	0.803	1.000	0.768
Cape Verde	0.502	0.993	0.615	0.703
Cayman Islands	0.500	0.869	1.000	0.790
Central African Republic	0.498	0.999	0.485	0.661
Chad	0.498	1.000	0.285	0.594
Chile	0.502	0.957	0.945	0.801
China	0.512	0.946	0.765	0.741
Colombia	0.499	0.984	0.855	0.779
Comoros	0.493	0.999	0.600	0.697
Congo	0.498	0.995	0.455	0.650
Cook Islands	0.500	0.943	0.975	0.806
Costa Rica	0.502	0.979	0.970	0.817
Cote d'Ivoire	0.501	0.996	0.525	0.674
Croatia	0.501	0.939	0.990	0.810
Cuba	0.513	0.969	0.945	0.809
Cyprus	0.501	0.892	1.000	0.798
Czech Republic	0.501	0.867	0.995	0.788
Democratic Republic of the Congo	0.496	1.000	0.385	0.627
Denmark	0.502	0.883	1.000	0.795
Djibouti	0.500	0.993	0.795	0.763
Dominica	0.491	0.980	0.905	0.792
Dominican Republic	0.500	0.975	0.870	0.782
Ecuador	0.481	0.972	0.895	0.783
Egypt	0.500	0.974	0.820	0.765
El Salvador	0.494	0.989	0.850	0.777
Equatorial Guinea	0.486	0.897	0.470	0.617
Eritrea	0.499	0.999	0.325	0.608
Estonia	0.505	0.846	0.975	0.775
Ethiopia	0.497	0.999	0.265	0.587
Faeroe Islands	0.500	0.836	1.000	0.779
Fiji	0.500	0.977	0.590	0.689
Finland	0.501	0.851	1.000	0.784
France	0.502	0.927	1.000	0.810
French Guiana	0.500	0.948	0.810	0.753
French Polynesia	0.500	0.963	0.990	0.818
Gabon	0.499	0.982	0.615	0.698
Gambia	0.505	0.998	0.690	0.731
Georgia	0.500	0.985	0.960	0.815
Germany	0.500	0.885	1.000	0.795
Ghana	0.486	0.995	0.450	0.644
Greece	0.506	0.898	0.990	0.798
Greenland	0.500	0.885	1.000	0.795
Grenada	0.500	0.973	0.960	0.811
Guadeloupe	0.496	0.943	0.810	0.750
Guam	0.500	0.706	0.995	0.734
Guatemala	0.487	0.989	0.900	0.792
Guinea	0.496	0.998	0.445	0.647
Guinea-Bissau	0.491	0.998	0.450	0.646
Guyana	0.500	0.976	0.870	0.782
Haiti	0.499	0.998	0.385	0.627

Honduras	0.463	0.988	0.750	0.734
Hungary	0.504	0.933	1.000	0.812
Iceland	0.501	0.913	1.000	0.804
India	0.501	0.985	0.585	0.690
Indonesia	0.473	0.983	0.660	0.705
Iran (Islamic Republic of)	0.500	0.922	0.885	0.769
Iraq	0.500	0.962	0.765	0.742
Ireland	0.505	0.878	1.000	0.794
Israel	0.502	0.878	1.000	0.793
Italy	0.509	0.905	1.000	0.805
Jamaica	0.499	0.947	0.880	0.775
Japan	0.500	0.881	1.000	0.794
Jordan	0.500	0.957	0.915	0.791
Kazakhstan	0.500	0.851	0.965	0.772
Kenya	0.499	0.996	0.495	0.664
Kiribati	0.500	0.996	0.490	0.662
Korea, Democratic People's Republic of	0.473	0.958	0.795	0.742
Korea, Republic of	0.498	0.884	1.000	0.794
Kuwait	0.500	0.633	1.000	0.711
Kyrgyzstan	0.500	0.988	0.910	0.799
Lao People's Democratic Republic	0.491	0.997	0.540	0.676
Latvia	0.505	0.962	0.885	0.784
Lebanon	0.503	0.956	0.990	0.816
Liberia	0.483	0.997	0.480	0.654
Libyan Arab Jamahiriya	0.500	0.892	0.845	0.746
Luxembourg	0.500	0.712	1.000	0.737
Madagascar	0.498	0.998	0.295	0.597
Malawi	0.491	0.999	0.680	0.723
Malaysia	0.489	0.915	0.965	0.790
Maldives	0.500	0.966	0.710	0.725
Mali	0.498	0.999	0.525	0.674
Malta	0.500	0.926	1.000	0.809
Mauritania	0.500	0.994	0.420	0.638
Mauritius	0.497	0.964	0.970	0.810
Mexico	0.497	0.951	0.880	0.776
Mongolia	0.498	0.957	0.610	0.689
Montserrat	0.500	0.858	0.980	0.779
Morocco	0.501	0.983	0.775	0.753
Mozambique	0.498	0.999	0.365	0.621
Myanmar	0.482	0.998	0.810	0.763
Namibia	0.497	0.984	0.640	0.707
Nepal	0.490	0.999	0.580	0.690
Netherlands	0.501	0.879	1.000	0.793
Netherlands Antilles	0.500	0.731	1.000	0.744
New Caledonia	0.500	0.855	1.000	0.785
New Zealand	0.502	0.913	1.000	0.805
Nicaragua	0.485	0.991	0.635	0.704
Niger	0.500	0.999	0.245	0.581
Nigeria	0.488	0.992	0.385	0.622
Niue	0.479	0.973	1.000	0.817
Norway	0.502	0.899	1.000	0.800
Oman	0.500	0.809	1.000	0.770
Pakistan	0.499	0.990	0.740	0.743
Palau	0.508	0.932	0.780	0.740
Panama	0.499	0.977	0.830	0.769

Papua New Guinea	0.492	0.991	0.425	0.636
Paraguay	0.488	0.992	0.735	0.739
Peru	0.498	0.984	0.780	0.754
Philippines	0.486	0.991	0.855	0.777
Portugal	0.511	0.933	0.990	0.811
Puerto Rico	0.501	0.994	1.000	0.831
Qatar	0.500	0.338	1.000	0.613
Republic of Moldova	0.501	0.976	0.845	0.774
Romania	0.500	0.946	0.800	0.749
Russian Federation	0.500	0.871	0.920	0.764
Rwanda	0.529	0.999	0.565	0.698
Saint Kitts and Nevis	0.500	0.968	0.975	0.814
Saint Lucia	0.500	0.972	0.935	0.802
Saint Vincent and the Grenadines	0.505	0.981	0.945	0.810
Samoa	0.500	0.990	0.940	0.810
Sao Tome and Principe	0.500	0.992	0.550	0.681
Saudi Arabia	0.500	0.814	1.000	0.771
Senegal	0.494	0.996	0.525	0.672
Serbia and Montenegro	0.502	0.940	0.955	0.799
Seychelles	0.500	0.898	0.880	0.759
Sierra Leone	0.493	0.998	0.320	0.604
Singapore	0.500	0.849	1.000	0.783
Slovakia	0.501	0.918	1.000	0.806
Slovenia	0.507	0.911	1.000	0.806
Solomon Islands	0.463	0.996	0.510	0.656
Somalia	0.497	1.000	0.260	0.586
South Africa	0.500	0.899	0.760	0.720
Spain	0.516	0.906	1.000	0.807
Sri Lanka	0.488	0.993	0.840	0.774
Sudan	0.493	0.997	0.525	0.672
Suriname	0.500	0.937	0.870	0.769
Swaziland	0.507	0.989	0.550	0.682
Sweden	0.501	0.934	1.000	0.812
Switzerland	0.503	0.934	1.000	0.812
Syrian Arab Republic	0.501	0.958	0.905	0.788
Tajikistan	0.500	0.989	0.795	0.761
Thailand	0.497	0.949	0.970	0.805
The former Yugoslav Rep. of Macedonia	0.500	0.937	0.945	0.794
Timor-Leste	0.481	0.998	0.515	0.665
Togo	0.491	0.998	0.355	0.614
Tonga	0.500	0.984	0.980	0.821
Trinidad and Tobago	0.498	0.702	0.930	0.710
Tunisia	0.503	0.973	0.895	0.791
Turkey	0.501	0.957	0.925	0.794
Turkmenistan	0.500	0.894	0.670	0.688
Uganda	0.488	0.999	0.485	0.657
Ukraine	0.501	0.919	0.950	0.790
United Arab Emirates	0.500	0.614	0.985	0.700
United Kingdom	0.501	0.889	1.000	0.797
United Republic of Tanzania	0.488	0.998	0.440	0.642
United States	0.501	0.777	0.995	0.757
United States Virgin Islands	0.486	0.000	1.000	0.353
Uruguay	0.503	0.976	1.000	0.826
Uzbekistan	0.501	0.950	0.920	0.790
Vanuatu	0.500	0.995	0.550	0.682

Venezuela	0.492	0.926	0.755	0.724
Viet Nam	0.519	0.986	0.785	0.763
Yemen	0.500	0.989	0.560	0.683
Zambia	0.484	0.998	0.550	0.677
Zimbabwe	0.478	0.990	0.635	0.701

4.2 Illustration of the Computation of HEI

An illustration of the construction of the HEI for China using its values of land, air and water indices is given below.

$$\text{HEI} = \frac{1}{3}(\text{land index}) + \frac{1}{3}(\text{air index}) + \frac{1}{3}(\text{water index})$$

$$\text{HEI} = \frac{1}{3}(0.512) + \frac{1}{3}(0.946) + \frac{1}{3}(0.765)$$

$$\text{HEI} = 0.741$$

The diagram, shown below, portrays the process.

Dimension   **Indices**   **HEI**

Land   **Air**   **Water**   **Environment**
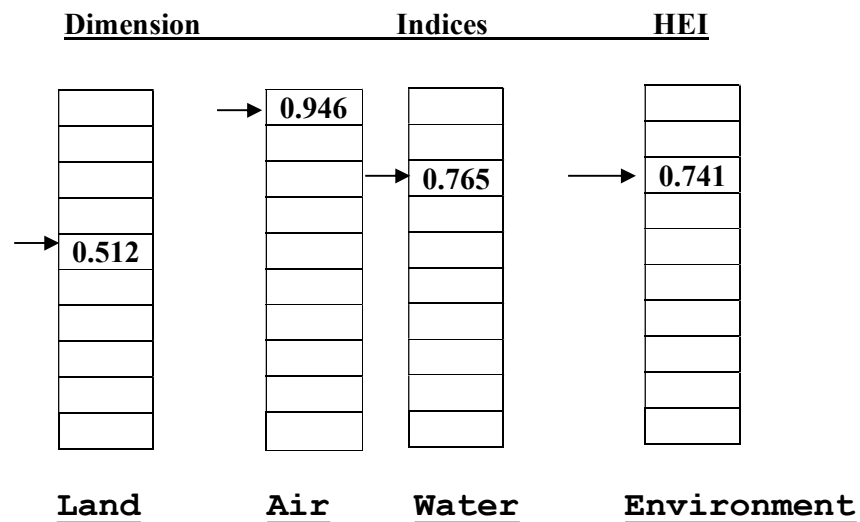
Table 6. The ranks of 198 countries in 2009 based on their HEI 2009 values arranged in descending order

Rank	Countries	HEI 2009
1	Puerto Rico	0.831
2	Uruguay	0.826
3	Tonga	0.821
4	Albania	0.820
5	French Polynesia	0.818
6	Niue	0.817
7	Costa Rica	0.817
8	Lebanon	0.816
9	Georgia	0.815
10	Saint Kitts and Nevis	0.814
11	Barbados	0.814
12	Antigua and Barbuda	0.813
13	British Virgin Islands	0.812

14	Switzerland	0.812
15	Hungary	0.812
16	Sweden	0.812
17	Portugal	0.811
18	Grenada	0.811
19	Mauritius	0.810
20	Saint Vincent and the Grenadines	0.810
21	Samoa	0.810
22	Croatia	0.810
23	France	0.810
24	Bulgaria	0.810
25	Cuba	0.809
26	Malta	0.809
27	Armenia	0.808
28	Bahamas	0.808
29	Spain	0.807
30	Slovakia	0.806
31	Cook Islands	0.806
32	Slovenia	0.806
33	Thailand	0.805
34	New Zealand	0.805
35	Italy	0.805
36	Iceland	0.804
37	Saint Lucia	0.802
38	Chile	0.801
39	Norway	0.800
40	Austria	0.800
41	Kyrgyzstan	0.799
42	Serbia and Montenegro	0.799
43	Bermuda	0.799
44	Greece	0.798
45	Cyprus	0.798
46	United Kingdom	0.797
47	Bosnia and Herzegovina	0.796
48	Germany	0.795
49	Greenland	0.795
50	Denmark	0.795
51	Belarus	0.794
52	Ireland	0.794
53	Turkey	0.794
54	The former Yugoslav Rep. of Macedonia	0.794
55	Korea, Republic of	0.794
56	Argentina	0.794
57	Japan	0.794
58	Netherlands	0.793
59	Israel	0.793
60	Belgium	0.793
61	Guatemala	0.792
62	Dominica	0.792
63	Jordan	0.791
64	Tunisia	0.791
65	Uzbekistan	0.790
66	Ukraine	0.790
67	Malaysia	0.790
68	Cayman Islands	0.790

69	Syrian Arab Republic	0.788
70	Czech Republic	0.788
71	New Caledonia	0.785
72	Finland	0.784
73	Latvia	0.784
74	Singapore	0.783
75	Algeria	0.783
76	Ecuador	0.783
77	Guyana	0.782
78	Dominican Republic	0.782
79	Montserrat	0.779
80	Colombia	0.779
81	Faeroe Islands	0.779
82	El Salvador	0.777
83	Philippines	0.777
84	Mexico	0.776
85	Estonia	0.775
86	Jamaica	0.775
87	Republic of Moldova	0.774
88	Sri Lanka	0.774
89	Kazakhstan	0.772
90	Saudi Arabia	0.771
91	Oman	0.770
92	Brazil	0.770
93	Brunei Darussalam	0.769
94	Suriname	0.769
95	Iran (Islamic Republic of)	0.769
96	Panama	0.769
97	Canada	0.768
98	Egypt	0.765
99	Russian Federation	0.764
100	Viet Nam	0.763
101	Myanmar	0.763
102	Djibouti	0.763
103	Australia	0.762
104	Tajikistan	0.761
105	Seychelles	0.759
106	United States	0.757
107	Peru	0.754
108	Morocco	0.753
109	French Guiana	0.753
110	Guadeloupe	0.750
111	Anguilla	0.749
112	Romania	0.749
113	Azerbaijan	0.747
114	Aruba	0.746
115	Libyan Arab Jamahiriya	0.746
116	Netherlands Antilles	0.744
117	Pakistan	0.743
118	Iraq	0.742
119	Korea, Democratic People's Republic of	0.742
120	China	0.741
121	Palau	0.740
122	Paraguay	0.739
123	Luxembourg	0.737

124	Guam	0.734
125	Honduras	0.734
126	Gambia	0.731
127	Botswana	0.727
128	Maldives	0.725
129	Venezuela	0.724
130	Malawi	0.723
131	Bhutan	0.721
132	Bahrain	0.721
133	South Africa	0.720
134	Belize	0.719
135	Kuwait	0.711
136	Trinidad and Tobago	0.710
137	Bolivia	0.708
138	Namibia	0.707
139	Indonesia	0.705
140	Nicaragua	0.704
141	Cape Verde	0.703
142	Zimbabwe	0.701
143	United Arab Emirates	0.700
144	Gabon	0.698
145	Rwanda	0.698
146	Comoros	0.697
147	Cameroon	0.697
148	Bangladesh	0.692
149	India	0.690
150	Nepal	0.690
151	Fiji	0.689
152	Mongolia	0.689
153	Turkmenistan	0.688
154	Burundi	0.683
155	Yemen	0.683
156	Swaziland	0.682
157	Vanuatu	0.682
158	Sao Tome and Principe	0.681
159	Zambia	0.677
160	Lao People's Democratic Republic	0.676
161	Mali	0.674
162	Cote d'Ivoire	0.674
163	Sudan	0.672
164	Senegal	0.672
165	Angola	0.665
166	Timor-Leste	0.665
167	Kenya	0.664
168	Kiribati	0.662
169	Central African Republic	0.661
170	Uganda	0.657
171	Solomon Islands	0.656
172	Liberia	0.654
173	Benin	0.652
174	Congo	0.650
175	Guinea	0.647
176	Guinea-Bissau	0.646
177	Ghana	0.644
178	Cambodia	0.643

179	United Republic of Tanzania	0.642
180	Burkina Faso	0.641
181	Mauritania	0.638
182	Papua New Guinea	0.636
183	Haiti	0.627
184	Democratic Republic of the Congo	0.627
185	Nigeria	0.622
186	Mozambique	0.621
187	Equatorial Guinea	0.617
188	Togo	0.614
189	Qatar	0.613
190	Eritrea	0.608
191	Sierra Leone	0.604
192	Madagascar	0.597
193	Chad	0.594
194	Ethiopia	0.587
195	Afghanistan	0.586
196	Somalia	0.586
197	Niger	0.581
198	United States Virgin Islands	0.353

4.3 Interpretation

The HEI, being the simple or unweighted arithmetic mean of the three-dimension indices of the three leading outcome indicators of the environment, measures an average achievement of a country in the three basic dimensions of the human environment. In other words, this quantifies an average outcome of the managerial efforts of a country towards these indicators. Also, as an index measures the relative change, it evaluates the relative human progress towards the sustainable environment. With the fixed goalposts approach the HEI is of special interest and significance for monitoring and comparing the progress made towards the environment. More specifically, it will help examine the advancement made by a country towards a better environment over the years until the presumed goalposts continue. Likewise, the performance a country could be compared with those of other countries as well. Sometimes, the HEI values-based ranks to countries, instead of its actual values; work more effectively for comparing the contributions made by countries / areas to the human environment. Also, a country's rank could be used as a pressure point to persuade policy makers to invest adequate resources in producing relevant data and to encourage international institutions to prepare comparable statistical data. Though Haq (1995) observed it for the HDI, this holds good for the HEI also. In this connection the sub-grouping of countries could play an important role because a country in each sub-group could try to achieve a better rank in the future, and those having a better ranking could try to maintain and improve it further. As the countries belonging to a sub-group are supposed to be relatively more homogeneous than those belonging to other

sub-groups, the ranking could generate a healthy competition among the countries of a sub-group for further improvement. This, in turn, could help adopt a more proactive policy towards the existing environmental scenarios. In other words, this could be considered as an important motivational factor for improving the existing environmental conditions. However, it should not be interpreted as a measure a country's progress towards the environmental conditions in the absolute term. Unlike the actual HEI value, a rank based on it merely reflects a relative position as compared with other ranks. An improvement in ranking may not necessarily reflect the progress made by the country. This could arise because other countries might have slipped down. On the contrary, an improvement in the index value surely indicates a progress of a country under the fixed goalpost framework. For example, the magnitude of the difference of the HEI values between the first and the second ranking countries may not be the same as that of between the second and the third ranking countries or that of between any two consecutive ranking countries. This suffers from the flaws of an ordinal data set.

5. Environmental Distance and Distance-Based Human Environment Index

With the land, air and water indices we may consider a three-dimensional space. Suppose that x_1, x_2 and x_3 denote these indices for one country while y_1, y_2 and y_3 represent the values for another country. We could, now, visualize the two points (x, y) in a three-dimensional space. The nonnegative number, d (x, y) denotes the distance between x and y, which may be defined as follows:

$$d(x, y) = |x_1 - y_1| + |x_2 - y_2| + |x_3 - y_3|.$$

This distance function becomes three times of the HEI when the other point is considered at the origin, i.e., $y_1 = 0$, $y_2 = 0$ and $y_3 = 0$.

Following the concept of the Euclidian distance, the **environmental distance (ED)** between two places may be defined as shown below:

$$ED = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + (x_3 - y_3)^2}.$$

This method could help in prioritization of countries for initiating remedial measures to minimize the environmental distance. As we may consider the distance of each country from the origin, i.e., from the place where $y_1 = 0$, $y_2 = 0$ and $y_3 = 0$, the **distance-based human environment index, HEI (D)** may be defined as given below:

$$HEI(D) = \sqrt{x_1^2 + x_2^2 + x_3^2}.$$

The HEI (D) is a special case of ED. See Han, et al.(2012) and Johnson and Wichern (2001) for a more detailed discussion on distance and its applications in data analysis. The values of HEI (D) along with the HEI are shown in **Table 8.**. The Pearson correlation between the two sets of the human environment index values is obtained as 0.964, which shows a very strong relationship between the two indices, as its p-value is 0.000. It is interesting to point out that one could also compute the distance functions using other y values like maximum and minimum values of indices. But the correlation between the HEI and the HEI (D) values yield a better result.

5.1 Illustrations

Though both the indices could serve the purpose, one should prefer the HEI to the HEI (D) for the sake of simplicity. However, this distance function could help out when more than ranking information is needed for a more detailed environmental investigation and monitoring because a higher rank on the basis of the HEI to a country does not mean that it shows better performance than a country having a lower rank with respect to all indices. For example, the land, air and water indices of US Virgin Islands and Niger are obtained as (0.486, 0.000, 1.000) and (0.500, 0.999, 0.245) respectively, which yield their HEI values as 0.581 and 0.383 with their HEI-ranks as 197 and 198 respectively. On comparing each of these two sets of indices separately, US Virgin Islands and Niger exhibit almost equal performance in the land component, while the former shows worse in the air quality and better in the water characteristics as compared with the latter. The **ED** method takes care of the issues of partially ordered sets referred to and discussed by Patil and Taillie (2001) to some extent.

Further, **Figure 2** illustrates the positions of Puerto Rico and US Virgin Islands in a three-dimensional space. The former yields the highest HEI value while the latter registers the lowest HEI value. Besides, HEI-1 and HEI-II denote the two extreme hypothetical situations with the land, air and water indices as (0, 0, 0) and (1, 1, 1) respectively. Obviously, Puerto Rico appears closer to the HEI-II while US Virgin Islands is placed nearer to the HEI-I.

As an illustration of the **ED** let us consider four countries that include the top two (Puerto Rico and Uruguay) and the bottom two (US Virgin Islands and Niger) ranking countries according to their HEI values. It is revealing to note that the environmental distance (0.0181108) between the top two ranking countries, Puerto Rico and Uruguay, is quite small as compared with the environmental distance (1.25229) between the bottom two countries, US

Virgin Islands and Niger. The difference between the two numbers arises due to a higher level of homogeneity between the top two countries than between the bottom two countries with respect to the leading indices. Also, environmentally, Puerto Rico and Uruguay maintain a longer distance from US Virgin Islands than from Niger because the former has the lower HEI value than that of the latter. The environmental distances could be informative as well as helpful for further environmental investigations and monitoring. These values could help implement the remedial measures for improving the existing the human environmental levels of a country or an area.

Table 7. A bivariate Table of HEI(D) values for Puerto Rico, Uruguay, Niger and US Virgin Islands

Countries / Areas	Puerto Rico (1)	Uruguay (2)	Niger (197)	US Virgin Islands (198)
Puerto Rico (1)	0	0.0181108	0.755017	0.994113
Uruguay (2)	0.0181108	0	0.755356	0.976148
Niger (197)	0.755017	0.755356	0	1.25229
US Virgin Islands (198)	0.994113	0.976148	1.25229	0

3D Scatterplot of Land Indices vs Air Indices vs Water Indices
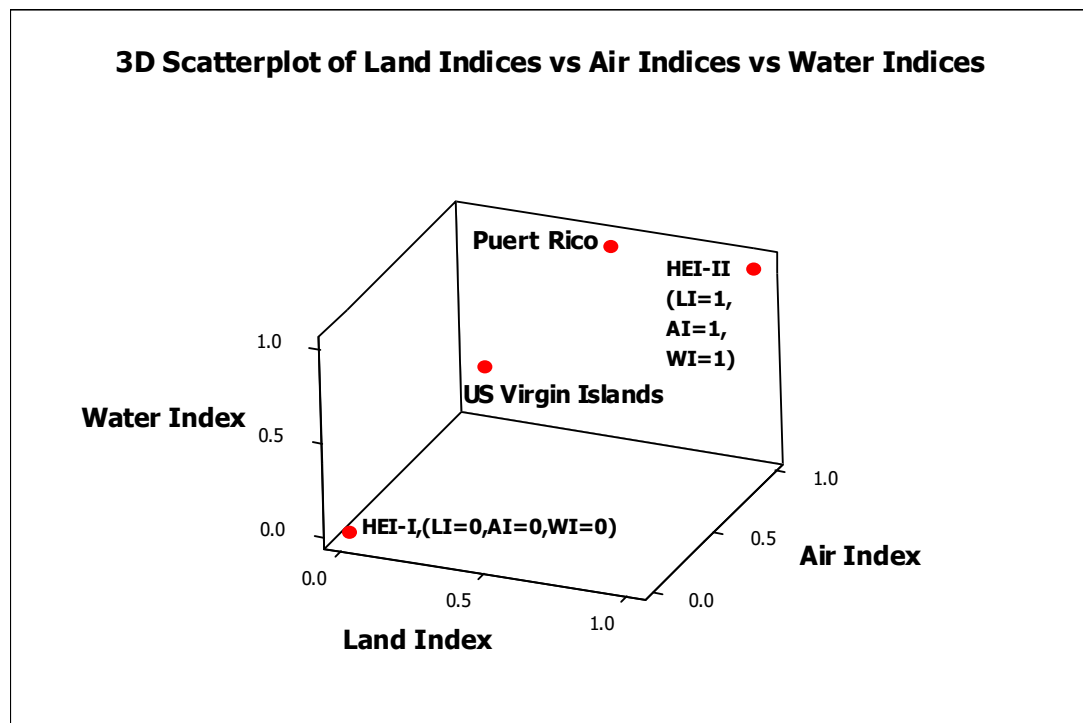
Figure 2. Three-dimensional plot of land, air and water indices showing Puerto Rico (HEI rank 1), US Virgin Islands (HEI rank 198), HEI-I (LI=0,AI=0,WI=0) and HEI-II (LI=1AI=1, WI=1)

Table 8. The HEI and the HEI (D) values for 198 countries in 2009

Countries / Areas	HEI	HEI (D)
Afghanistan	0.586	1.147
Albania	0.820	1.471
Algeria	0.783	1.400
gola	0.665	1.220
nguilla	0.749	1.337
Antigua and Barbuda	0.813	1.461
Argentina	0.794	1.422
Armenia	0.808	1.451
Aruba	0.746	1.340
Australia	0.762	1.367
Austria	0.800	1.435
Azerbaijan	0.747	1.334
Bahamas	0.808	1.450
Bahrain	0.721	1.299
Bangladesh	0.692	1.257
Barbados	0.814	1.461
Belarus	0.794	1.422
Belgium	0.793	1.422
Belize	0.719	1.288
Benin	0.652	1.205
Bermuda	0.799	1.433
Bhutan	0.721	1.298
Bolivia	0.708	1.277
Bosnia and Herzegovina	0.796	1.426
Botswana	0.727	1.302
Brazil	0.770	1.379
British Virgin Islands	0.812	1.459
Brunei Darussalam	0.769	1.382
Bulgaria	0.810	1.449
Burkina Faso	0.641	1.194
Burundi	0.683	1.246
Cambodia	0.643	1.195
Cameroon	0.697	1.264
Canada	0.768	1.377
Cape Verde	0.703	1.271
Cayman Islands	0.790	1.416
Central African Republic	0.661	1.217
Chad	0.594	1.153
Chile	0.801	1.436
China	0.741	1.320
Colombia	0.779	1.396
Comoros	0.697	1.265
Congo	0.650	1.203
Cook Islands	0.806	1.446
Costa Rica	0.817	1.467
Cote d'Ivoire	0.674	1.232
Croatia	0.810	1.453

Cuba	0.809	1.448
Cyprus	0.798	1.430
Czech Republic	0.788	1.412
Democratic Republic of the Congo	0.627	1.181
Denmark	0.795	1.425
Djibouti	0.763	1.367
Dominica	0.792	1.421
Dominican Republic	0.782	1.399
Ecuador	0.783	1.406
Egypt	0.765	1.368
El Salvador	0.777	1.394
Equatorial Guinea	0.617	1.123
Eritrea	0.608	1.163
Estonia	0.775	1.386
Ethiopia	0.587	1.147
Faeroe Islands	0.779	1.396
Fiji	0.689	1.246
Finland	0.784	1.405
France	0.810	1.453
French Guiana	0.753	1.343
French Polynesia	0.818	1.469
Gabon	0.698	1.261
Gambia	0.731	1.314
Georgia	0.815	1.464
Germany	0.795	1.426
Ghana	0.644	1.196
Greece	0.798	1.429
Greenland	0.795	1.426
Grenada	0.811	1.455
Guadeloupe	0.750	1.339
Guam	0.734	1.319
Guatemala	0.792	1.423
Guinea	0.647	1.200
Guinea-Bissau	0.646	1.200
Guyana	0.782	1.400
Haiti	0.627	1.180
Honduras	0.734	1.324
Hungary	0.812	1.457
Iceland	0.804	1.443
India	0.690	1.250
Indonesia	0.705	1.275
Iran (Islamic Republic of)	0.769	1.372
Iraq	0.742	1.327
Ireland	0.794	1.423
Israel	0.793	1.422
Italy	0.805	1.442
Jamaica	0.775	1.386
Japan	0.794	1.423
Jordan	0.791	1.416
Kazakhstan	0.772	1.381
Kenya	0.664	1.219
Kiribati	0.662	1.218
Korea, Democratic People's Republic of	0.742	1.332
Korea, Republic of	0.794	1.425
Kuwait	0.711	1.285

Kyrgyzstan	0.799	1.433
Lao People's Democratic Republic	0.676	1.236
Latvia	0.784	1.401
Lebanon	0.816	1.465
Liberia	0.654	1.208
Libyan Arab Jamahiriya	0.746	1.326
Luxembourg	0.737	1.325
Madagascar	0.597	1.154
Malawi	0.723	1.304
Malaysia	0.790	1.417
Maldives	0.725	1.299
Mali	0.674	1.234
Malta	0.809	1.452
Mauritania	0.638	1.189
Mauritius	0.810	1.455
Mexico	0.776	1.388
Mongolia	0.689	1.240
Montserrat	0.779	1.395
Morocco	0.753	1.348
Mozambique	0.621	1.174
Myanmar	0.763	1.372
Namibia	0.707	1.275
Nepal	0.690	1.254
Netherlands	0.793	1.423
Netherlands Antilles	0.744	1.336
New Caledonia	0.785	1.407
New Zealand	0.805	1.444
Nicaragua	0.704	1.273
Niger	0.581	1.144
Nigeria	0.622	1.171
Niue	0.817	1.475
Norway	0.800	1.435
Oman	0.770	1.380
Pakistan	0.743	1.333
Palau	0.740	1.317
Panama	0.769	1.376
Papua New Guinea	0.636	1.185
Paraguay	0.739	1.328
Peru	0.754	1.350
Philippines	0.777	1.396
Portugal	0.811	1.453
Puerto Rico	0.831	1.496
Qatar	0.613	1.168
Republic of Moldova	0.774	1.385
Romania	0.749	1.336
Russian Federation	0.764	1.362
Rwanda	0.698	1.264
Saint Kitts and Nevis	0.814	1.462
Saint Lucia	0.802	1.439
Saint Vincent and the Grenadines	0.810	1.453
Samoa	0.810	1.454
Sao Tome and Principe	0.681	1.240
Saudi Arabia	0.771	1.383
Senegal	0.672	1.229
Serbia and Montenegro	0.799	1.431

Seychelles	0.759	1.353
Sierra Leone	0.604	1.158
Singapore	0.783	1.404
Slovakia	0.806	1.447
Slovenia	0.806	1.444
Solomon Islands	0.656	1.211
Somalia	0.586	1.146
South Africa	0.720	1.279
Spain	0.807	1.444
Sri Lanka	0.774	1.389
Sudan	0.672	1.230
Suriname	0.769	1.373
Swaziland	0.682	1.241
Sweden	0.812	1.457
Switzerland	0.812	1.458
Syrian Arab Republic	0.788	1.410
Tajikistan	0.761	1.364
Thailand	0.805	1.445
The former Yugoslav Republic of Macedonia	0.794	1.422
Timor-Leste	0.665	1.222
Togo	0.614	1.167
Tonga	0.821	1.476
Trinidad and Tobago	0.710	1.268
Tunisia	0.791	1.415
Turkey	0.794	1.422
Turkmenistan	0.688	1.224
Uganda	0.657	1.213
Ukraine	0.790	1.414
United Arab Emirates	0.700	1.264
United Kingdom	0.797	1.429
United Republic of Tanzania	0.642	1.195
United States	0.757	1.358
United States Virgin Islands	0.353	1.112
Uruguay	0.826	1.485
Uzbekistan	0.790	1.414
Vanuatu	0.682	1.242
Venezuela	0.724	1.292
Viet Nam	0.763	1.363
Yemen	0.683	1.241
Zambia	0.677	1.238
Zimbabwe	0.701	1.270

5.2 HEI and HEI(D)

The Pearson correlation between the two sets of the human environment index values (HEI and HEI(D)) is obtained as 0.964, which shows a very strong relationship between the two indices, as its p-value is 0.000. However, this distance function could help out when more than ranking information is needed for a more detailed environmental investigation and monitoring because a higher rank on the basis of the HEI to a country does not mean that it shows better performance than a country having a lower rank with respect to all indices.

References

Han, J., Kamber, M. and Pie, J. (2012). *Data Mining Concepts and Techniques, 3rd Edition.* Morgan Kaufmann Publishers, An Imprint of Elsevier, M A 02451, USA.

Haq, M. (1995). *Reflections on Human Development*, Oxford University Press, New York, USA.

Human Development Report (2009). *Overcoming barriers: Human mobility and development*. Published for the United Nations Development Programme (UNDP), Palgrave Macmillan, New York, USA.

Johnson, Richard A. and Wichern, Dean W. (2001). *Applied Multivariate Statistical Analysis*, Third Edition. Prentice-Hall of India, New Delhi, India.

Patil, G. P. and Taillie, C. (2001). *Multiple Indicators, Partially Ordered Sets, and Linear Extensions: Multi-criterion Ranking Methods*.Technical Report, Statistical Ecology and Environmental Statistics, The Pennsylvania State University, University park, PA 16802, USA.

Singh, A. and Shansieve-Cohen, P. (2002). *The Human Environment Index.* Manuscript, UNEP, Division of Early Warning and Assessment-North America Office, Sioux Falls, South Dakota, USA

Sinha, Arun K. (2004). *A Statistical Analysis of the Human Environment Index.* Submitted to the United Nations Environment Programme, Global Resource Information Database (GRID), Division of Early Warning and Assessment-North America Office, Sioux Falls, South Dakota, USA.

World Wide Fund for Nature (2002). *Living Planet Report 2002*. WWF International, Switzerland.