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Analysis of environmental issues worldwide: a study from the biplot perspective

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ABSTRACT

Environmental issues have been a concern for some time worldwide. The main purpose of this study is to analyse whether there are differences in the scores obtained by a broad sample of countries in the Environmental Performance Index according to the geographic area in which the country is located. We apply the biplot, a statistical technique that provides a graphic representation of multivariate data, combining individuals (in our study, the countries grouped by geographic areas) and variables relating to two sets of environmental indicators included in the Environmental Performance Index (ecosystem services and environmental health). The results emphasise that countries from Africa and, to a lesser extent, Asia, usually focus on ecosystems services, whereas countries from Europe, North America and, to a lower degree, South American countries, tend to focus on environmental health. The analyses also provide us with interesting findings about the existence of five separate groups with clear differences between them (Europe, Africa, South America, Asia, North America); Africa in particular has significant features that make it different from the remaining areas concerning climate change. Our approach uses an innovative statistical technique to analyse countries' environmental performance, so that it can tell us whether countries are more concerned about or undertake greater effort on some issues and it allows us to detect differences according to geographic areas.

1. Introduction

Environmental issues have been a concern for some time worldwide, acquiring special emphasis after the UN Conference in 1992 (UNCED, 1992). Environmental problems affect everything, from the tiniest organism to the greatest country, and they vary according to living conditions, the structure of the sector or the geographic and socio-economic situation of the country: "the major environmental issues at a country level have to do with land use and transportation, the quality and availability of water and sanitation services, air quality, solid and liquid waste management, as well as noise and the aesthetic role of the environment" (Akca et al., 2007, p. 177). Pollution and environmental degradation, for instance, are regarded as a serious problem in industrialised countries, where economic development has usually meant an increase in emissions and damage to the environment. Munasinghe (1993, p. 1) states that "mankind's attitude towards the environment has evolved to encompass the more proactive design of projects and policies that will help anticipate and minimise environmental degradation".

In this context, environmental indicator systems are fundamental tools in quantifying impact. They are especially useful given that they quantify the status and trends of key environmental parameters and provide information on the environment that allows authorities and countries to make informed decisions (Tong et al., 2006; Niemeijer et al., 2008). Moreover, environmental indicators must address the major environmental issues particularly as concerns the natural environment and human health.

To help to understand and manage environmental issues, a number of environmental indicators have been implemented. One of the most important has been the Ecological Footprint, focussed on calculating the land area needed for the production and maintenance of goods and services consumed by a determined community. Another environmental indicator refers to the Environmental Sustainability Index; its values in a specific country range from 0 (for the most unsustainable) to 100 (for the most sustainable). The Renewability and Energy Sustainability Index takes yet another perspective and considers the economic system as an open thermodynamic system within the biosphere and accounts for all the flows in units of aggregate energy (Siche et al., 2008).

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Previous studies have been based on different types of indicators. For instance, Mori and Christodoulou (2012) use the Ecological Footprint and Environmental Sustainability Index to discuss conceptual requirements for a city sustainability index and to review existing major sustainability indices. Kortelainen (2008) has built an Environmental Performance Index by applying frontier efficiency techniques and a Malmquist index approach.

In this research, we use the Environmental Performance Index (EPI) derived from the Environmental Sustainability Index, used in previous analyses (Siche et al., 2008; Vachon and Mao, 2008; Mori and Christodoulou, 2012). This index includes a set of environmental indicators in key areas that should be of interest to policymakers in every country, and that can also be addressed through appropriate policies. "It focuses on two overarching environmental objectives: reducing environmental stresses to human health and promoting ecosystem services and sound natural resource management" (Esty et al., 2008, p. 17). These broad goals also reflect the policy priorities of environmental authorities around the world and the international community's attempt to adopt Goal 7 of the Millennium Development Goals (MDGs), to "ensure environmental sustainability".

Using the environmental indicators proposed by the EPI, this study aims to analyse whether there are differences in scores obtained from a sample of 149 countries worldwide in the Environmental Performance Index depending on the geographic area in which the country is located.

We employ a statistical technique called the biplot, which provides a graphic representation of multivariate data (Gabriel, 1971). While a scatter plot shows the distribution of the two variables, a biplot represents three or more variables (Gabriel and Odoroff, 1990) on a space of two or three dimensions. Biplot offers a visual representation based on two types of vectors derived from two types of information: individuals and variables. In the interpretation of biplots, points on the plane represent individuals (in our study, the countries grouped by geographic areas) and the vectors reflect variables (in our study, variables related to environmental health and ecosystem services) which correspond to the environmental indicators drawn up in the EPI.

Biplot methodologies have been used in previous studies (e.g. Basille et al., 2008; Ceschina et al., 2012). In this research we focus on the HJ-Biplot given that "this method achieves an optimum quality of representation for both rows and columns, since both are represented on the same reference system. The method is closely related to principal component analysis (PCA), since variance and covariance matrices are plotted on planes that account for most of the inertia" (González-Cabrera et al., 2006, p. 64).

This approach uses an innovative statistical technique to analyse countries' environmental performance. It will allow us to check and analyse whether the scores obtained from the indicators proposed in the environmental performance index are similar in different countries or whether there are differences depending on the geographic area in which the country is located.

This analysis can tell us whether countries are more concerned about or undertake greater effort on some issues and it allows us to detect differences according to geographic areas. Also, the statistical approach used renders a visual representation that facilitates the identification of associations among observations, among variables, and among variables and observations.

The paper is structured as follows: after the introduction, in Section 2, we analyse the different environmental indicators, focussing especially on the Environmental Performance Index and its components. Section 3 describes our research methods, including the sample and analysis techniques. In Section 4, the results of the empirical analysis are given and then discussed in Section 5. Section 6 summarises the main findings and consequences and presents the conclusions.

2. Environmental indicators: an overview

Recently, composite indicators have been used for concerns such as quality of life and the environment, mainly in order to rank performance at country level (Karavanas et al., 2009). Furthermore, they provide information on the status of the environment and assess the environmental impact of development.

Hansen (1996), Jasch (2000) and Perotto et al. (2008) held that the development of indicators at the national, regional, local or field level had become a commonly used approach to meet the crucial need for assessment tools. Such tools are a prerequisite to the implementation of the concept of sustainability, and especially its environmental component. Along this line, Smeets and Weterings (1999) and Hammond et al. (1995) state that the goal of environmental indicators is to communicate information about the environment and about the human activities that affect it. Likewise, environmental indicators should enable or promote information exchange regarding the issue they address. Communication demands simplicity and indicators always simplify a complex reality. Hence, according to Smeets and Weterings (1999, p. 5), environmental indicators are used for three major purposes: "to supply information on environmental problems, in order to enable policy-makers to value their seriousness, to support policy development and priority setting, by identifying key factors that cause pressure on the environment, and to monitor the effects of policy responses".

Research on environmental indicators started with recognition of the major environmental pollution issues during the 1960s. At that time, research mainly focussed on indices of environmental pollution, particularly river and air pollution at a local level. By the end of the 1980s, the growing pollution and concerns over increasing desertification and decreasing biodiversity highlighted the importance of research and development regarding environmental indicators. Subsequently, the World Bank carried out a series of studies on environmental indicators to monitor environmental progress, measure environmentally sustainable development and provide additional explanations of environmental performance indicators (Tong et al., 2006). Similarly to the World Bank, other international organisations have also developed environmental indicators (e.g. Environmental Performance Index, Millennium Development Indicators, Organisation for Economic Cooperation and Development, United Nations Environment Program, Global Reporting Initiative, World Resources Institute, among others) that are used to reflect environmental concerns (Van de Kerk and Manuel, 2008).

Among the different environmental indicators, in our research we focus on the indicators proposed by the EPI, which offers a composite index of current national environmental protection efforts, drawn up by Esty et al. (2008). This index is derived from the Environmental Sustainability Index, previously used in different works (Siche et al., 2008; Vachon and Mao, 2008; Mori and Christodoulou, 2012).

The quantitative metrics underlying the EPI encompass 25 indicators chosen through a process in which the following aspects have been considered: an international review of the environmental science literature; an in-depth consultation with a group of scientific advisors in each policy category; the evidence from the Millennium Ecosystem Assessment, the Intergovernmental Panel on Climate Change, the Global Environmental Outlook-4, and other assessments; environmental policy debates surrounding multilateral environmental agreements; and expert judgement (Esty et al., 2008).

Indicators were sought to cover the full spectrum of environmental issues. Also, according to Dalal-Clayton and Bass (2000), these indicators are potentially more transparent, consistent and useful for decision-making than other approaches. To ensure the use of the best-suited metrics, the following indicator selection criteria were applied (Esty et al., 2008, p. 17):

- "Relevance: the indicator clearly tracks the environmental issue of concern in way that is relevant to countries under a wide range of circumstances.
- Performance orientation: the indicator tracks ambient conditions or on-the-ground results (or is a "best available data" proxy for such outcome measures).
- Transparency: the indicator provides a clear baseline measurement, has the ability to track changes over time, and is transparent with regard to data sources and methods.
- Data quality: the data used by the indicator should meet basic quality requirements and represent the best measure available".

These criteria used to select the indicators proposed by the EPI have also been considered by the Global Reporting Initiative (2006, 2011) when providing the guidelines for the development of sustainability reports by firms and the approach for reporting on ecosystem services. This fact reinforces the credibility of the use of these indicators at an international level.

Considering the relevance of the previous criteria for the indicators, the objectives of the environmental performance index focus on two policy categories: environmental health and ecosystem services.

The inclusion of an environmental health policy category in the EPI is an attempt to capture the effect that the environment has on quality of life globally, in the line of reducing environmental stresses on human health. With this goal in mind, it uses a set of indicators to reflect environmental health, such as environmental burden of disease, air pollution (effects on human health) and water (effects on human health).

The indicators linked to ecosystem services comprise relevant measures with the goal of reducing the loss or degradation of ecosystems and natural resources. The core policy categories for ecosystem services include: air pollution effects on ecosystems, water effects on ecosystems, biodiversity and habitat, productive natural resources (forestry, fisheries and agriculture) and climate change.

3. Research methods

3.1. Population and sample

With our research goals in mind, we selected most countries worldwide as our target population. This population was chosen in the interest of extending and generalising the results obtained in previous studies, and overcoming two of their limitations: the countries studied and the techniques used in the data analysis. Previous studies usually focussed on specific geographic contexts, such as western industrialised countries (Scruggs, 2003; Jahn, 1998; Crepaz, 1995), 21 OECD countries (Neumayer, 2003), 17 industrialised democracies (Scruggs, 1999, 2001) and 131 countries (Hosseini and Kaneko, 2011).

The sample we use comprises the 149 countries selected by Esty et al. (2008) (see Appendix 1), and incorporates the advantages derived from considering different geographic contexts: Europe (EU), Africa (AF), South America (SA), Asia (AS) and North America (NA) (see Appendix 2).

3.2. Analysis technique

The analysis of several environmental problems at once requires the storage of large volumes of data. In order to exploit the data to get a better understanding of the behaviour of several processes, it is important to identify the salient features underlying them. The reduction in the dimensionality of the problem enables us to summarise the information captured in a large number of variables by a smaller number of variables.

The technique we have chosen for this research is the biplot, which has been used in other environmental studies (e.g. González-Cabrera et al., 2006; Gardner et al., 2005; Aerni, 2009; Basille et al., 2008; Ceschina et al., 2012). However, it has not been applied to the Environmental Performance Index, thereby providing some degree of novelty to the current work. This method will allow us to check whether the indicators proposed by the EPI are similar across the different countries, or, in other words, whether environmental concerns are similar in different geographic areas.

Some of the seminal works and further implementations (e.g. Gabriel, 1971; Gabriel and Odoroff, 1990; Gower and Hand, 1996; Aldrich et al., 2004) describe the biplot technique as graphically depicting a data matrix X (nxp) derived from analysing n individuals according to p numerical characteristics. In this study, the n individuals are the 149 countries worldwide presented in Appendix 1, grouped into 5 geographic areas; the p numerical characteristics are the scores obtained by the countries selected concerning the policy categories proposed in the EPI in the last available year (2010), basically environmental burden of disease, air pollution (effects on human health), water (effects on human health), air pollution (effects on nature), water (effects on nature, biodiversity and habitat), forestry and climate change (see Appendix 2). The biplot offers a visual representation (usually in two or three dimensions), based on two types of vectors derived from two types of information: individuals (in rows) and variables (in columns). Hence, the vectors graphically represent individuals or rows and variables or columns. In Gabriel (1971) and Gabriel and Odoroff (1990), the method of obtaining the vectors is not specified, and the method of least squares and the decomposition in vectors and singular values of X is used. However, it is argued that although it reflects the statistical and geometric properties of the variables adequately, the individuals are not appropriately represented.

Galindo (1985) generalises the concept of simultaneous representation by creating a new type of biplot, the HJ-Biplot, applied to the whole data set, which allows individuals and variables to be represented with the same quality of representation. This type improves other approaches, such as Gabriel (1971).

Galindo (1985, 1986) defines the HJ-Biplot as a multivariate graphical representation of the matrix X (nxp) through vectors for their rows and for columns, so that both vectors can be depicted in the same reference systems with the highest quality of representation. Bachero et al. (2000) specifies that the HJ-Biplot is a technique derived from principal components analysis with an important objective: to reduce the volume of data in order to obtain information. To achieve this aim, it is necessary to analyse the initial points cloud in hyperspace by a simplified configuration in a smaller space.

As for the interpretation of biplots, points are used to represent individuals (in our study, the countries grouped by geographic areas) and axes to reflect variables (in our study, certain variables related to environmental health and ecosystem services), according to Gower and Hand (1996). As for the axes, they are new variables that are obtained as a linear combination of the variables observed. These axes are centred, that is, the origin coincides with the mean value of all the variables.

Interpretation is based on the angles between the vectors: variables with vectors displaying a small angle show similar behaviours, given that the angles between two vectors that link two variables are interpreted as correlations. Points of close individuals correspond to similar individuals and points of remote individuals have to do with non-similar individuals. Moreover, if there is a small angle between an individual and a variable, it means that the individual is significant in order to explain the variable and that the variable has a high value for the individual. Thus, a group of individuals close to a variable indicate that these individuals have taken predominant values for that variable.

The distance between the points reflects the variability of those points in the study. By analysing the length of the variables, we obtain their variability, which provides the researcher with an idea of the dispersion in the figure. When the variables are close, it is said that they are highly correlated, with similar behaviour; when they take different directions, they are highly correlated in an inverse sense; if they are perpendicular, they are independent (Dorado et al., 1999; Blasius et al., 2009; Gardner et al., 2005).

The software used to implement the HJ-Biplot was developed by Vicente-Villardón (2000), and contains the classical biplot, HJ-Biplots and simple correspondence analysis of a contingency table. Other statistical programmes for biplots developed by InfoStat (2004) and by Rohlf (2002) can also be used.

4. Results of empirical analysis

According to González-Cabrera et al. (2006), several measures are essential for a correct implementation of the HJ-Biplot; specifically, eigenvalues and explained variance (Table 1) and the relative contribution of the factor to the element (Table 2) through which it is possible to detect the variables responsible for the position of axes and, therefore, the configuration obtained in them.

It can be deduced from this table that there is a dominant axis (axis 1) that takes 37.87% of the total inertia of the system. The trend in the eigenvalues is truncated in the fourth axis, achieving an accumulative inertia of 66.538. In other words, 66% of the total inertia is absorbed by only the first three factorial axes, indicating that this percentage of the total information is present on these three axes. Factorial plane 1–2 absorbs 54.860% of the total inertia. This factorial plane is used in the different figures to represent geographic areas and variables (see Figs. 1–3 where axis 1 – horizontal – and axis 2 – vertical – are represented). The remaining factors provide a smaller load of information.

Table 2 contains the contribution of each factor to the element, which lets us know the variables responsible for the positions of axes and their configuration.

Hence, the variables 'environmental burden of disease', 'water (effects on humans)' and 'air pollution (effects on humans)' make a high contribution to axis 1 and a low contribution to the remaining axes. In contrast, 'water (effects on nature)', 'biodiversity and habitat' and 'agriculture' heavily contribute to axis 2 (see Figs. 1–3 where axis 1 – horizontal – and axis 2 – vertical – are represented).

Table 1
Eigenvalues and explained variance.

Axis	Eigenvalue	Explained variance	Cumulative
Axis 1	22.460	37.871	37.871
Axis 2	15.043	16.988	54.860
Axis 3	12.472	11.679	66.538
Axis 4	11.335	9.645	76.184
Axis 5	10.314	7.986	84.169
Axis 6	9.206	6.362	90.531
Axis 7	8.475	5.392	95.923
Axis 8	6.097	2.790	98.714
Axis 9	4.140	1.286	100

Table 2
Relative contribution of the factor to the element.

Variables	Axis 1	Axis 2	Axis 3
Environmental burden of disease	842	2	5
Water (effects on humans)	857	4	1
Air pollution (effects on humans)	679	0	82
Air pollution (effects on nature)	154	48	583
Water (effects on nature)	33	497	180
Biodiversity & habitat	1	524	96
Forestry	339	119	5
Agriculture	98	304	17
Climate change	406	32	83

Analysis of the contributions to the different axes shows that the first axis (axis 1 horizontal) is explained by most indicators linked to environmental health (see Figs. 2 and 3), such as environmental burden of disease, water effects on humans and air pollution effects on humans, respectively (842, 857, 679). The second factorial axis (axis 2) is determined by the variables water effects on nature, biodiversity and habitat and agriculture (497, 524, 304).

Regarding the graphic representation, the five geographic areas which include the countries analysed (see Appendix 1; in our biplot, individuals) are presented in Fig. 1.

All the countries grouped in five geographic areas are represented by points (in the Figure, +) in four quadrants. The countries located in Africa and Asia are mainly represented in quadrants 1 (upper-right) and 4 (lower-right), whereas quadrants 2 (upper-left) and 3 (lower-left) contain the countries from Europe, North America and South America.

In Fig. 2, the following variables are displayed: environmental burden of disease, water effects on humans, air pollution effects on humans, water effects on nature, biodiversity and habitat, agriculture, air pollution effects on nature, forestry and climate change, the first three variables have to do with environmental health, while the remaining variables are associated with ecosystem services, according to the Environmental Performance Index.

As we have commented above, interpretation of the variables is based on the angles between the vectors, such that variables with vectors forming small angles are variables with similar behaviours. As can be observed from Fig. 2, the variables linked to environmental health, such as environmental burden of disease, water (effects on humans) and air pollution (effects on humans), show small angles and, therefore, have similar behaviours.

Similarly, for ecosystem services (variables: water effects on nature, biodiversity and habitat and agriculture), the variables are quite close, also showing a small angle. Hence, they are highly correlated and behave in a similar way.

In Fig. 3, the geographic areas (points) and the variables (vectors) representing Environmental Health and Ecosystem Services are displayed jointly.

As for the individuals, when they are close to a vector-variable, it implies that they take predominant values for that variable, in the sense that the individuals are significant to explain the variable and that the variable is of great value for the individuals.

In Fig. 3, it can be observed that the variables related to Environmental Health are mainly closer to the countries located in the geographic areas of Europe, North America and, to a lesser extent, to South American countries. Meanwhile, other variables associated with Ecosystem Services, such as air pollution (effects on nature), water (effects on nature), agriculture, climate change or biodiversity and habitat are mainly closer to Africa, and more residually to Asia and South America. Air pollution (effects on

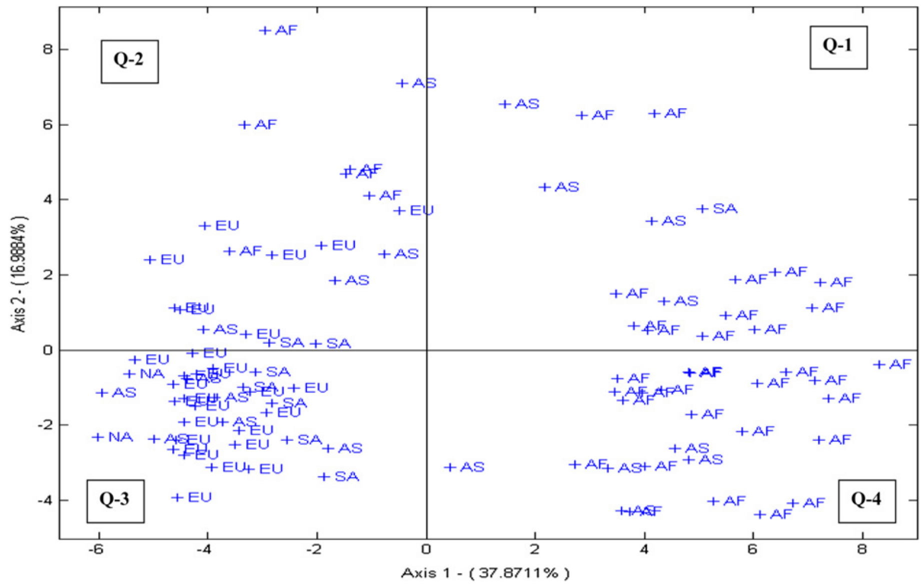

Fig. 1. Geographic areas including the 149 countries.

nature) and climate change stand out especially because of their closeness to Africa.

In order to check the differences among the different geographic areas and determine the variables responsible for these differences, we perform a canonical biplot. With this procedure, the elements of the rows (represented by geographic areas) are divided into *k* groups, which are completely different, so that these groups are separated with the maximum discriminating power among them. Also, the canonical biplot has an important advantage: it is possible not only to establish the differences between groups but also to characterise the variables responsible for them (Varas et al., 2005).

Table 3 exhibits the eigenvalues and explained variance obtained from implementing the multibiplot software.

The first eigenvalue gathers the highest variability, reaching 89% of the total. The following eigenvalues obtain lower variability. The variance analysis for each axis leads to the significance of the three first eigenvalues. Also, the global test of the model, based on Wilk's Lambda, shows a value of 5.8327 (with *F* statistics following a Snedecor's *F* with 36 & 511 d.f. and *p*-value of $0.0001 < 0.01$), and is statistically significant.

The canonical biplot is depicted in Fig. 4. It shows each group and a confidence circle at the centre that allows us to detect where the significant variables are located.

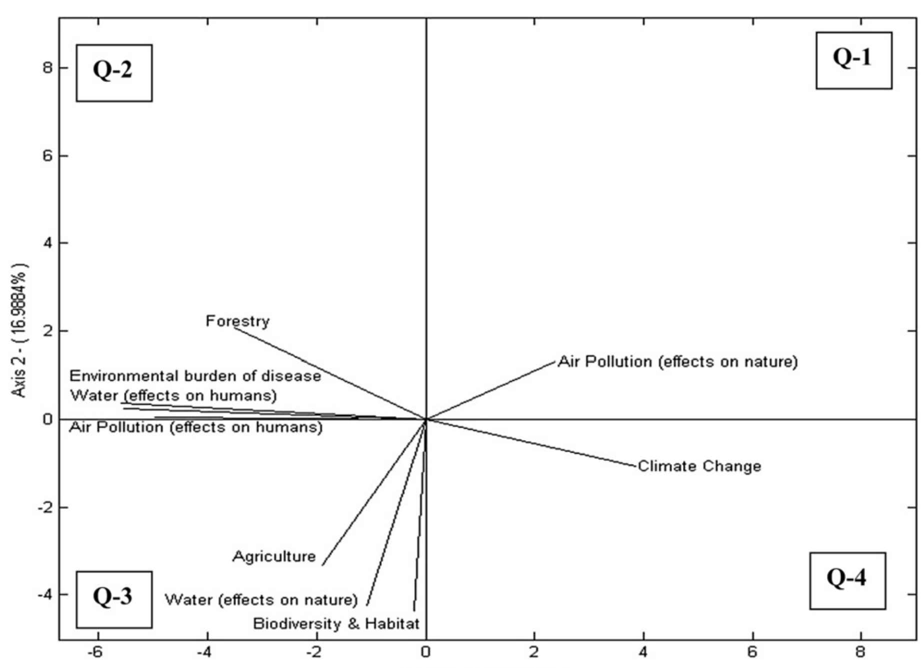

Fig. 2. Representation of the environmental performance indicators.

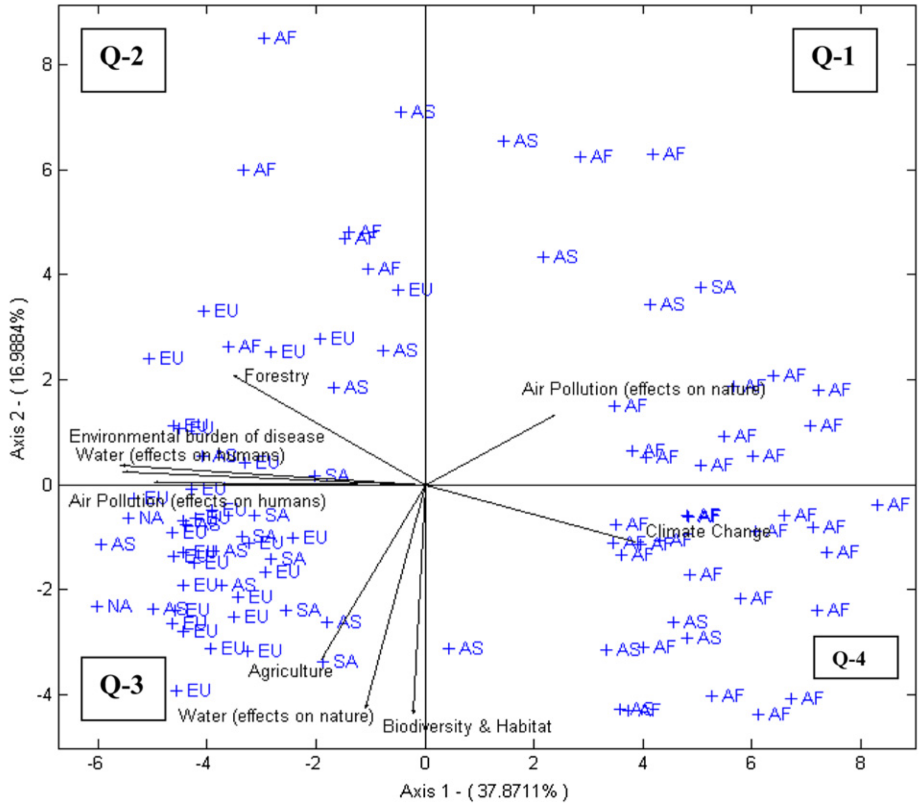

Fig. 3. Geographic zones and environmental indicators.

According to Fig. 4, GR2 represents the geographic area of Africa and shows characteristics significantly different from the rest of the areas considered in the research concerning the variable climate change. This result is consistent with the explained variance obtained with a p-value of $0.001 < 0.01$ (see Table 3).

Regarding the significance of the variables, the individual ANOVA tests are compiled in Table 4.

With regard to the significance of the variables, all of them are significant, except for biodiversity and habitat, and agriculture. These findings can be also observed in Table 5 (goodness-of-fit); they show the lowest values in the factorial axes (1 and 2).

The canonical biplot is also plotted in Fig. 5, reflecting both geographic areas and variables. Similarly to previous findings, GR2 contains a set of countries which display characteristics that are significantly different from the remaining areas; it again corresponds to Africa, appearing separated from the other groupings. At the same time, climate change is the variable that is closest to the GR2 group. This situation is also observed in the eigenvalues and explained variance with a statistical significance of 0.001 for geographic area 2 (Africa) and in the ANOVA test with a similar significance for the variable climate change.

5. Discussion

Recently, different organisations and authors have developed indicators to measure environmental issues worldwide. Among these, the Environmental Performance Index compiles information from 149 countries.

With the purpose of studying whether these countries grouped in five geographic zones show the same interest concerning environmental issues, we have employed an HJ-Biplot and a canonical biplot. Unlike other techniques, the biplot can easily allow us to detect differences in the behaviour of geographic areas with regard to different dimensions (EPI indicators) in a visual form, as well as the closeness of each country to a specific set of indicators. This technique enables to reflect both indicators and geographic areas, showing the closeness of the latter to the former. Also, it permits

Table 3
Eigenvalues and explained variance.

Dimension	Eigenvalue	% Explained variance	Cumulative	TSS[a]	ESS[b]	F[c]	p-Value
1	1.379	89	89	2.902	1.902	68.457	0
2	0.37	6.422	95.422	1.137	0.137	4.939	0.001
3	0.249	2.902	98.324	1.062	0.062	2.232	0.068
4	0.189	1.676	100	1.036	0.036	1.289	0.277
5	0	0	100	1	0	0	1

[a] TSS, total sum of squares.
[b] ESS, error sum of squares.
[c] Snedecor's F.

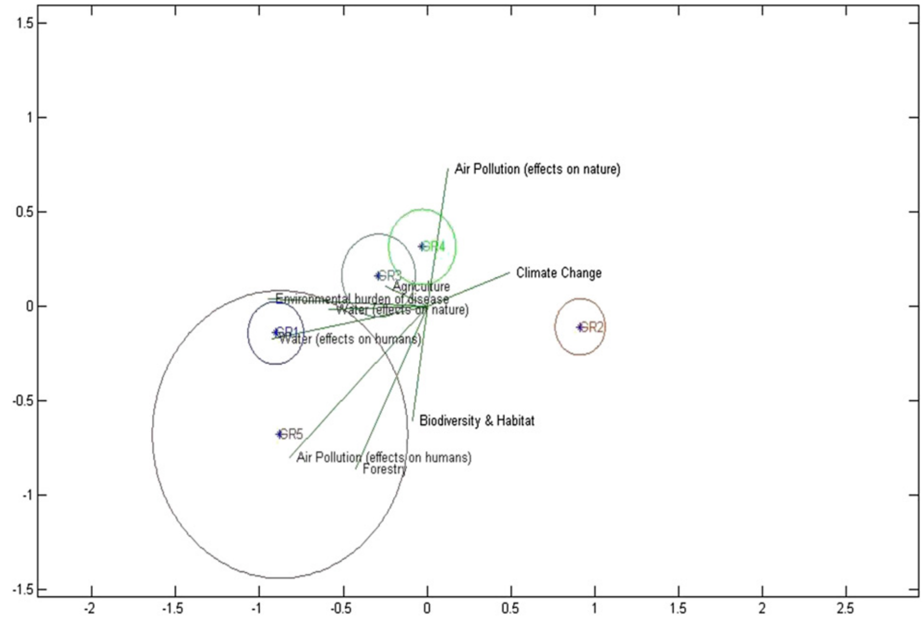

Fig. 4. Canonical biplot.

analysis of the different dimensions (set of EPI indicators) simultaneously.

Based on the interpretation of biplots developed by Gower and Hand (1996), the points reflect individuals (in our study, the countries grouped into 5 geographic areas) and the vectors represent variables (in our study, the variables related to Environmental Health and Ecosystem Services).

From the results obtained, it can be deduced that the core policy categories for ecosystem services are mainly closer to Africa, and more residually to Asia. The African countries specially stand out for their scores in air pollution (effect on nature) and climate change.

At the same time, Environmental Health concerns are mainly closer to the countries located in the geographic area of Europe, North America and, to a lesser extent, South American countries.

Similarly to Esty et al. (2008), we find that the relationship between environmental health and ecosystem services is weak, so that countries with high environmental health do not necessarily reach high scores in ecosystem services.

The results obtained through this methodology are in accordance with Esty et al. (2008, p. 24), who find that environmental health is highly correlated with wealth, indicating that many of the low-performing countries have not made the investments necessary to curtail environmental pollutants or to provide adequate water and sanitation to their citizens. Thus, a developed and wealthy country is likely to have access to more tax funds to devote to environmental policies. Also, their citizens may assume other values different from materialist values and require their governments to implement more environmental policies.

In addition to the direct relationship between the level of economic development in a country and its environmental performance, found by Wälti (2004, p. 612) and Esty et al. (2008), other factors may influence the environmental performance, such as the level of education and culture, the role played by public institutions in terms of transparency, rule of law and low levels of corruption, levels of industrialisation or competitiveness. Also, there are different elements that contribute to poor environmental health, including political, social, economic and infrastructural factors.

Concerning the results for ecosystem services, many of the countries are geographically located in arid regions or suffer from conflict or other such stresses (influence of factors such as poor management and lack of sanitation or pollution mitigation systems), such as some areas in Africa or Asia.

Hence, when checking the differences between groups of geographic zones and indicators, the canonical biplot shows five separate groups with the maximum discriminant power between

Table 4
Individual ANOVAs.

Indicators	Explained	Residual	F[a]	Sign.
Environmental burden of disease	73.158	74.842	35.19	0
Water (effects on humans)	69.397	78.603	31.784	0
Air pollution (effects on humans)	58.255	89.745	23.368	0
Air pollution (effects on nature)	7.878	140.122	2.024	0.09413
Water (effects on nature)	27.673	120.327	8.279	0
Biodiversity & habitat	2.975	145.025	0.738	0.5672
Forestry	19.756	128.244	5.546	0.00035
Agriculture	7.689	140.311	1.973	0.10176
Climate change	22.425	125.575	6.429	0.0001

[a] Snedecor's *F*.

Table 5
Goodness-of-fit.

Indicators	Axis 1	Axis 2
Environmental burden of disease	74.92	74.97
Water (effects on humans	71.34	72.35
Air pollution (effects on humans)	55.98	77.06
Air pollution (effects on nature)	1.26	18.51
Water (effects on nature)	28.49	28.5
Biodiversity & habitat	0.67	12.64
Forestry	15.04	39.46
Agriculture	5.1	5.47
Climate change	20.03	21.08

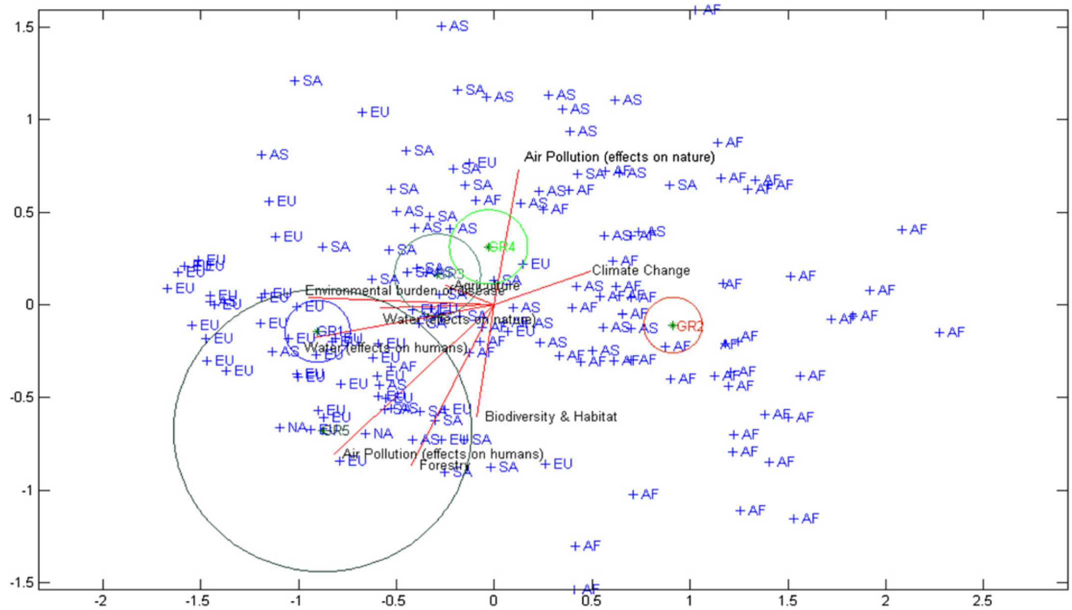

Fig. 5. Canonical biplot, geographic zones and environmental indicators.

them (GR1 Europe, GR2 Africa, GR3 South America, GR4 Asia, GR5 North America). Specifically, Africa – denoted by GR2 – has significant features that are different from the remaining areas concerning climate change.

According to Esty et al. (2008, p. 73), "the laggards on climate change are typically countries with particularly carbon-intensive industry and electricity generation sectors, such as United Arab Emirates and Australia, or countries with high rates of deforestation relative to their small populations. Deforestation occurring in developing nations in the tropics accounts for 20% of global emissions each year, which is a substantial fraction of total national emissions for many of these countries". Also, the highest-ranking nations in the climate change category are mainly countries with economies based on subsistence agriculture and a low industrial level mainly due to economic limitations.

These findings are in accordance with some studies focussed on West Africa (e.g. Wittig et al., 2007), which consider climate change as responsible for the economic, environmental and social alterations in some African countries. In the same vein, Brown et al. (2007) also point out that Africa is often cited as the continent most vulnerable to the adverse effects of climate change and therefore a priority for adaptation funding and projects. Among other things, "the reasons for this special vulnerability have to do with its heavy dependence on climate sensitive economic sectors, environmental change and degradation (e.g. desertification, coral bleaching, invasive species) and continued expansion of (often marginal) human settlements in hazard-prone areas, such as low-lying coasts" (Brown et al., 2007, p. 1149).

In the same sense, the Africa Partnership Forum (2007, p. 7) underscores that "Africa is particularly vulnerable to climate change because of its overdependence on rain-fed agriculture, compounded by factors such as widespread poverty and weak capacity. The main longer-term impacts include: changing rainfall patterns affecting agriculture and reducing food security; worsening water security; decreasing fish resources in large lakes due to rising temperature; shifting vector-borne diseases; rising sea level affecting low-lying coastal areas with large populations; and rising water stress".

6. Conclusions

The objective of this paper has been to analyse whether the scores obtained from the indicators proposed in the Environmental Performance Index are similar in different countries or whether there are differences depending on the geographic area in which the country is located, thereby indicating a specific focus in their environmental issues. In order to pursue that aim, we analysed a broad sample (149 countries) using a statistical technique – the biplot – applied to the Environmental Performance Index, in order to depict jointly the geographic zones and the most relevant indicators.

The tables and figures obtained show different objectives concerning environmental issues. From a statistical point of view, the eigenvalues, the variance explained, the goodness of fitness of the indicators and individual ANOVA ensure the validity of research. Hence, the biplot methodology and the canonical biplot can be applied to the Environmental Performance Index. The joint use of the EPI indicators and the biplot methods would allow us to depict the geographic zones and the most relevant indicators jointly, showing the closeness of the latter to the former. EPI indicators enable us to extend the analysis beyond a specific country or geographic area, thereby including different contexts in our study. They are especially meaningful, given that they take into consideration two of the highest priority goals in environmental management: to reduce environmental stress on human health and to promote ecosystem services. Unlike other techniques, the biplot can easily allow us to detect differences in the behaviour of geographic areas with regard to different dimensions (EPI indicators) in a visual form, as well as the closeness of each country to a specific set of indicators.

From the empirical analyses performed, we obtained certain conclusions: first, we detect that the indicators linked to environmental burden of disease, air pollution (effects on human health) and water (effects on human health) have a small angle; therefore, they display similar behaviours. We also found that there are quite close links among water effects on ecosystems, agriculture and biodiversity and habitat, derived from the small angles; hence, these indicators also behave in a similar fashion.

Additionally, in light of the location of the indicators in different geographic zones, we found that environmental health is more associated with the European area, while air pollution (effects on nature), water (effects on nature), agriculture, climate change and biodiversity and habitat are closer to African countries. Countries perform quite differently from one another depending on levels of industrialisation, fossil fuel and resource consumption, trade, and environmental protection. Moreover, there are other factors that may impact the scores reached in the EPI by different countries, such as per capita GDP, corruption, government effectiveness, accountability, competitiveness, etc. These variables may justify that different groups of countries reach similar scores in the EPI. For instance, per capita GDP is correlated with higher performance on the EPI. In particular, overall EPI scores are higher in countries that have a per capita GDP of $10,000 or higher. As for corruption, environmental performance appears to be correlated with corruption. Countries with high levels of corruption tend to have low levels of environmental performance, whereas countries with low levels of corruption perform better on the EPI. However, the analysis of their effects on EPI scores is beyond the objectives of this work.

The canonical biplot was used to check the differences between groups of geographic zones and indicators. We found that Africa in particular – denoted by GR2 – has significant features that are different from the remaining areas concerning climate change. Our findings emphasise the vulnerable situation of Africa, especially for climate change and degradation.

After analysing one of the most significant sets of indicators (the Environmental Performance Index), the results obtained show that, although environmental matters are a priority in most countries, not all countries share the same perspective on environmental issues.

Compared to other environmental-related works (e.g. Hosseini and Kaneko, 2011; Srebotnjak et al., 2011; Zafiriou et al., 2012), we extend previous literature by analysing a wider sample of countries, focussing on a broad set of indicators, which reflect the main environmental concerns worldwide. In this sense, as Siche et al. (2008) suggest, the Environmental Performance Index is more useful if it disaggregated into its individual components. Also, we improve the methodological approach, going beyond the Principal Component Analysis (PCA) and Factor Analysis (FA) used by Srebotnjak et al. (2011) and Zafiriou et al. (2012). Using the HJ-Biplot method instead of employing other perhaps more conventional ones, important advantages can be gained. When principal component analysis is used, the axes are combinations of the variables, but these do not appear on the plots, so that very important information concerning the correlations among them is lost, as is the information about the relative situation of the points with respect to the variables, which is interpreted in terms of greater or lesser preponderance in the HJ-Biplot method (González-Cabrera et al., 2006). Therefore, the analysis obtained is more representative and better shows the situation of the different geographic areas in regard to environmental matters.

As future research lines, it would be of interest to undertake a similar study with an extended time period, in order to study the evolution of the weight of the different components of EPI in countries and how environmental concerns evolve. Moreover, the environmental indicators related to environmental health and ecosystem services (such as adequate sanitation, indoor air pollution, urban particulates, regional ozone, water quality index, effective conservation, burnt land area or industrial carbon intensity) can be disaggregated and analysed specifically in order to study which environmental indicators affect each country or geographic area in a more detailed way. Additionally, similar research can be performed concerning other features of sustainable development, such as social or economic concerns, using the biplot methodology.

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Appendix 1

Countries in the sample

Albania	Chile	Germany	Laos	Norway	Sweden
Algeria	China	Ghana	Latvia	Oman	Switzerland
Angola	Colombia	Greece	Lebanon	Pakistan	Syria
Argentina	Congo	Guatemala	Lithuania	Panama	Taiwan
Armenia	Costa Rica	Guinea	Luxembourg	Papua New Guinea	Tajikistan
Australia	Côte d'Ivoire	Guinea-Bissau	Macedonia	Paraguay	Tanzania
Austria	Croatia	Guyana	Madagascar	Peru	Thailand
Azerbaijan	Cuba	Haiti	Malawi	Philippines	Togo
Bangladesh	Cyprus	Honduras	Malaysia	Poland	Trinidad & Tobago
Belarus	Czech Rep	Hungary	Mali	Portugal	Tunisia
Belgium	Dem, Rep. Congo	Iceland	Mauritania	Romania	Turkey
Belize	Denmark	India	Mauritius	Russia	Turkmenistan
Benin	Djibouti	Indonesia	Mexico	Rwanda	Uganda
Bolivia	Dominican Rep,	Iran	Moldova	Saudi Arabia	Ukraine
Bosnia and Herzegovina	Ecuador	Iraq	Mongolia	Senegal	United Arab Emirates
Botswana	Egypt	Ireland	Morocco	Sierra Leone	United Kingdom
Brazil	El Salvador	Israel	Mozambique	Slovakia	United States
Bulgaria	Eritrea	Italy	Myanmar	Slovenia	Uruguay
Burkina Faso	Estonia	Jamaica	Namibia	Solomon Islands	Uzbekistan
Burundi	Ethiopia	Japan	Nepal	South Africa	Venezuela
Cambodia	Fiji	Jordan	Netherlands	South Korea	Viet Nam
Cameroon	Finland	Kazakhstan	New Zealand	Spain	Yemen
Canada	France	Kenya	Nicaragua	Sri Lanka	Zambia
Central African Republic	Gabon	Kuwait	Niger	Sudan	Zimbabwe
Chad	Georgia	Kyrgyzstan	Nigeria	Swaziland	

Appendix 2

Geographic zones and variables

	Environmental burden of disease	Water (effects on humans)	Air pollution (effects on humans)	Air pollution (effects on nature)	Water (effects on nature)	Biodiversity and habitat	Forestry	Agriculture	Climate change
EU	65.50	95.73	52.97	49.16	91.24	77.02	100.00	54.55	68.97
AF	61.32	83.70	63.98	45.43	55.77	51.89	100.00	74.02	66.18
AF	0.00	29.70	43.47	40.13	64.76	58.43	94.79	54.55	53.85
SA	71.63	91.50	63.21	48.24	72.91	31.25	82.81	95.45	49.58
EU	62.31	93.23	68.66	61.96	50.52	55.34	63.02	92.84	49.85
AS	84.77	100.00	97.37	29.46	57.95	77.86	96.89	97.19	27.64
EU	86.86	100.00	84.15	39.83	97.55	100.00	100.00	84.54	50.07
EU	57.61	69.81	65.86	54.33	51.40	67.57	100.00	44.13	58.09
AS	39.85	46.84	2.78	42.98	79.96	14.92	87.64	54.55	70.72
EU	52.74	96.07	97.37	62.60	66.02	70.13	100.00	54.55	51.57
EU	80.96	100.00	94.30	21.44	56.53	20.20	100.00	70.00	36.65
SA	57.61	62.50	92.61	50.62	74.44	96.81	100.00	54.55	63.62
AF	16.40	30.55	28.43	50.30	68.62	74.20	22.24	99.80	54.71
SA	41.95	55.94	41.78	64.71	84.94	85.71	87.74	59.09	31.36
EU	69.04	96.33	74.11	36.98	96.73	2.83	100.00	45.45	42.65
AF	30.28	66.81	45.75	44.64	50.87	100.00	74.94	56.82	37.89
SA	58.50	79.33	90.18	39.31	85.63	61.31	82.42	90.73	46.44
AS	86.86	100.00	71.17	56.65	74.29	76.65	82.17	89.09	25.54
EU	65.50	98.58	63.26	41.33	68.68	66.94	100.00	95.44	39.92
AF	4.09	41.89	40.17	51.96	69.90	51.50	0.00	100.00	78.02
AS	27.75	29.42	30.34	55.66	95.00	81.73	48.88	54.55	56.29
AF	17.65	46.64	27.78	47.96	76.43	70.01	74.60	56.08	66.13
NA	86.86	100.00	97.37	25.27	90.72	61.91	100.00	89.53	37.34
AF	14.03	31.97	29.21	39.00	70.21	100.00	97.19	84.09	30.95
AF	6.71	5.17	5.94	56.04	55.28	73.51	82.89	77.03	75.43
SA	79.20	92.32	74.40	42.21	59.21	40.94	100.00	96.78	60.74
AS	62.31	70.01	40.07	30.19	65.95	57.22	100.00	69.05	40.18
SA	63.34	81.62	90.12	47.77	69.30	82.66	96.89	76.16	71.32
AF	31.04	30.11	25.24	35.70	74.52	72.46	97.70	100.00	70.68
SA	77.54	96.03	77.62	59.94	73.86	73.40	100.00	90.91	78.55
AF	10.17	40.97	43.57	46.25	62.98	62.93	100.00	88.64	76.66
EU	74.45	98.58	82.39	44.37	96.25	67.65	100.00	97.27	39.88
SA	74.45	91.12	97.37	40.66	74.08	49.63	100.00	83.20	66.60
EU	86.86	100.00	76.84	44.69	87.63	75.18	100.00	61.10	9.26
EU	75.96	99.44	96.14	40.34	79.67	100.00	100.00	83.61	41.91
AF	1.98	14.73	27.62	49.95	73.94	58.27	94.52	59.09	92.13
EU	80.96	100.00	97.37	48.30	80.37	52.71	100.00	87.45	46.15
AF	29.91	74.58	71.41	75.23	48.09	1.73	100.00	86.36	75.44
SA	55.08	83.91	95.95	51.69	54.99	86.06	100.00	69.48	56.58
SA	62.31	86.71	91.74	58.21	73.79	82.92	47.12	88.29	55.43
AF	61.32	79.20	50.32	40.95	43.94	59.17	100.00	73.52	62.12
SA	61.32	78.35	74.57	52.06	74.89	18.01	47.12	88.64	75.73
AF	8.39	23.36	100.00	79.98	73.08	77.06	77.07	54.55	37.44
AF	33.44	15.52	39.74	82.97	71.26	36.06	90.67	56.82	76.82
EU	59.41	97.19	91.37	54.47	89.67	88.53	95.37	85.76	36.00
AF	13.13	0.06	17.85	54.19	53.79	93.70	69.09	61.36	77.59
AS	63.34	38.04	76.90	72.72	93.83	16.93	100.00	95.45	60.20
EU	82.81	100.00	97.37	55.29	91.70	68.64	100.00	88.98	46.30
EU	82.81	100.00	97.37	41.97	79.90	67.43	100.00	84.12	56.36
AF	38.86	52.88	85.53	40.87	71.06	77.02	99.09	59.09	52.86
EU	69.04	95.21	55.26	69.43	57.70	26.85	100.00	56.82	54.38
EU	82.81	100.00	97.37	40.00	72.40	100.00	100.00	84.76	49.62
AF	29.17	32.76	40.46	48.06	88.92	74.70	51.28	90.91	64.34
EU	82.81	98.88	81.90	38.03	78.44	35.67	100.00	67.73	32.34
SA	51.27	87.57	35.42	43.85	79.94	48.35	66.95	52.27	54.99
AF	16.40	28.68	16.89	49.25	72.77	46.31	86.98	77.27	69.73
AF	4.43	25.33	16.28	52.11	72.75	75.02	88.30	56.82	75.40
SA	49.18	83.30	83.95	63.06	71.40	23.16	100.00	56.82	59.46
SA	29.54	18.34	34.82	68.69	64.24	3.14	82.89	50.00	58.37
SA	56.74	67.13	51.55	55.89	67.74	62.25	30.60	52.27	47.56
EU	66.64	100.00	97.37	51.81	67.66	49.97	100.00	82.48	51.34
EU	91.50	100.00	97.37	38.36	96.11	68.86	100.00	65.45	90.31
AS	39.35	50.11	37.55	37.08	68.35	38.65	100.00	35.68	60.25
AS	45.36	55.82	31.81	41.56	79.91	63.19	18.90	86.70	49.24
AS	61.32	85.29	72.90	47.30	45.92	42.32	100.00	82.38	52.56
AF	20.31	66.70	50.98	47.67	36.23	0.00	100.00	33.84	64.15
EU	84.77	100.00	97.37	51.48	95.95	7.03	100.00	75.29	40.36
EU	91.50	100.00	85.42	38.85	41.01	72.76	100.00	36.80	32.37
EU	86.86	100.00	89.75	38.94	73.63	72.37	100.00	86.29	47.97
SA	70.31	84.43	55.95	41.80	73.08	64.27	98.44	97.73	37.84
AS	86.86	100.00	87.00	34.72	82.64	63.16	100.00	67.99	48.28
AF	70.31	89.86	76.18	50.92	24.45	91.35	100.00	84.29	32.87

(*continued*)

	Environmental burden of disease	Water (effects on humans)	Air pollution (effects on humans)	Air pollution (effects on nature)	Water (effects on nature)	Biodiversity and habitat	Forestry	Agriculture	Climate change
AS	44.18	94.87	94.07	83.28	53.52	22.70	96.89	61.32	46.53
AF	25.07	30.38	48.09	57.33	62.84	76.36	90.96	48.39	66.86
AF	89.10	100.00	55.67	33.42	0.00	17.09	100.00	77.73	35.05
AS	48.51	86.59	77.58	60.31	51.56	25.77	100.00	81.47	56.20
AS	33.86	36.34	26.47	67.18	92.53	100.00	87.53	93.18	68.77
EU	59.41	86.79	94.59	75.19	95.27	76.29	100.00	87.52	55.55
AF	64.40	98.88	81.62	40.51	55.98	3.49	100.00	90.99	37.98
EU	60.35	79.29	97.37	62.44	81.92	46.53	100.00	85.23	59.65
EU	82.81	100.00	97.37	65.14	85.13	100.00	100.00	57.27	28.15
EU	69.04	93.83	79.47	69.81	79.85	40.18	100.00	67.27	36.53
AF	22.60	4.93	36.14	69.27	58.54	31.58	92.47	88.64	74.65
AF	9.17	56.86	36.74	53.74	49.06	97.95	76.80	56.82	76.77
AS	67.82	95.77	93.81	44.72	74.01	74.07	89.11	94.75	42.33
AF	1.35	34.65	0.00	59.50	73.38	24.32	79.74	58.71	78.39
AF	25.72	22.87	29.56	74.62	56.07	20.85	18.45	54.61	56.86
AF	70.31	96.63	97.37	43.70	74.38	44.96	86.45	93.01	72.92
SA	73.01	85.03	75.46	40.18	59.95	51.10	87.56	80.35	56.42
EU	59.41	79.59	76.66	63.16	50.44	12.76	100.00	97.73	49.34
AS	54.28	47.80	14.57	42.90	57.55	80.73	79.82	90.91	36.94
AF	64.40	69.63	95.09	65.49	57.11	25.46	100.00	82.11	56.64
AF	20.03	11.28	41.13	51.56	57.40	60.11	92.79	24.77	89.85
AS	37.89	72.66	22.07	56.33	66.49	33.75	73.18	90.91	64.94
AF	51.99	57.49	46.60	42.62	49.17	73.57	76.68	56.82	71.45
AS	36.49	49.55	42.99	57.80	69.09	79.58	64.68	79.55	96.36
EU	86.86	100.00	83.61	38.59	67.36	80.05	100.00	81.14	39.19
AS	82.81	100.00	97.37	54.62	94.98	65.73	100.00	99.18	38.71
SA	60.35	52.72	61.51	62.25	71.17	59.89	67.10	65.91	51.13
AF	0.00	0.00	0.22	66.45	50.90	68.89	76.39	79.55	75.40
AF	9.17	15.03	37.19	40.60	62.07	74.67	22.07	59.09	75.84
EU	82.81	100.00	97.37	58.14	97.54	46.63	100.00	70.00	65.68
AF	77.54	77.19	52.84	52.83	36.95	47.09	100.00	41.26	28.03
AS	43.04	67.81	17.38	42.97	48.15	52.85	42.70	40.23	67.14
SA	70.31	78.51	67.85	44.61	88.56	71.28	87.17	100.00	58.68
AS	35.15	19.14	50.96	72.58	63.72	15.63	87.45	52.27	55.88
SA	65.50	63.34	37.93	42.50	56.81	53.04	72.01	97.73	72.48
SA	61.32	70.49	52.25	43.40	74.60	52.81	96.89	100.00	70.20
AS	55.08	81.62	71.72	51.76	86.41	64.16	47.95	84.57	64.45
EU	70.31	79.25	80.90	39.44	79.60	80.44	100.00	76.56	45.93
EU	79.20	98.58	93.31	38.82	74.65	57.97	100.00	81.78	49.85
EU	64.40	73.94	87.95	46.11	73.44	63.55	100.00	87.59	50.80
EU	44.18	90.12	95.89	54.63	84.51	80.26	100.00	35.57	45.28
AF	5.81	26.62	43.07	44.69	73.05	85.03	100.00	59.09	64.45
AF	64.40	86.16	51.75	48.00	22.58	86.35	100.00	75.45	40.22
AF	19.76	39.77	29.63	53.74	75.94	78.10	87.40	59.09	51.44
AF	0.00	9.54	25.98	46.77	74.49	37.08	78.23	54.55	60.74
EU	70.31	100.00	97.37	55.82	94.59	100.00	100.00	82.32	45.20
EU	77.54	100.00	84.82	47.13	96.49	51.14	100.00	65.06	41.37
AS	55.90	35.98	68.27	87.03	74.37	0.51	47.12	42.73	55.14
AF	37.42	70.96	90.21	30.36	68.10	62.39	100.00	64.25	39.48
AS	75.96	85.86	82.83	24.26	78.32	34.19	98.44	68.02	36.69
EU	84.77	100.00	85.31	37.97	69.83	57.22	100.00	78.14	46.11
AS	41.41	76.63	23.91	53.85	78.77	73.99	54.56	83.73	79.71
AF	27.06	37.66	2.68	51.96	61.84	29.07	79.19	83.34	72.94
AF	29.91	37.46	54.92	54.69	80.76	30.07	97.94	45.70	77.09
EU	86.86	100.00	97.37	59.22	96.30	61.04	100.00	88.11	70.11
EU	89.10	100.00	90.96	47.84	93.46	100.00	100.00	70.00	73.83
AF	73.01	86.03	62.62	53.78	34.37	8.48	100.00	81.77	60.96
AS	38.37	67.06	64.37	68.57	44.47	38.06	92.45	40.68	59.18
AF	18.16	23.61	43.71	55.28	77.76	80.59	70.71	59.09	66.83
AS	55.90	96.03	54.48	36.59	77.73	79.77	89.85	90.01	52.97
AF	21.15	15.27	35.04	46.39	72.10	75.85	0.00	86.36	54.58
SA	67.82	90.34	54.70	38.79	73.15	61.56	96.89	93.18	26.24
AF	67.82	86.41	86.61	45.68	50.64	9.99	100.00	43.90	58.83
EU	65.50	90.68	76.13	46.21	62.83	17.14	100.00	64.13	53.62
AS	39.85	54.54	70.70	70.11	32.08	30.36	100.00	30.84	35.05
AF	15.19	31.37	50.00	51.49	64.66	87.50	44.07	58.67	78.62
EU	52.74	93.49	96.44	43.81	45.68	35.72	100.00	76.82	42.27
AF	89.10	98.32	48.63	34.00	5.27	1.17	100.00	39.09	20.58
EU	80.96	100.00	97.37	37.06	77.45	70.48	100.00	79.21	51.82
NA	79.20	99.14	95.66	31.59	70.23	65.92	100.00	83.82	29.37
SA	70.31	100.00	47.37	59.62	81.72	1.85	100.00	77.27	49.28
AS	51.99	87.41	65.07	49.90	21.53	21.75	100.00	30.00	37.27
SA	67.82	83.52	97.37	38.67	56.12	78.19	81.34	56.82	47.24

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(*continued*)

	Environmental burden of disease	Water (effects on humans)	Air pollution (effects on humans)	Air pollution (effects on nature)	Water (effects on nature)	Biodiversity and habitat	Forestry	Agriculture	Climate change
AS	62.31	73.46	41.47	42.95	78.05	41.28	100.00	84.03	58.22
AF	27.75	40.39	43.92	58.38	1.80	1.61	100.00	75.45	76.58
AF	11.61	36.86	36.76	39.05	70.28	100.00	74.36	72.73	66.56
AF	22.01	53.32	54.81	49.19	67.69	93.75	57.33	45.89	61.25

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