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The Impact of Environment on Human Development and Sustainable Development in Arab Countries

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Abstract:

Introduction: This study explored the effect of environmental variables on Human Development in Arab countries.

Methods: Principal Component Analysis and hierarchical clustering were applied to data from the Human Development Report 2025, while additional data from other sources were used to compare Arab countries' environmental performance.

Results: The Principal Component Analysis clearly shows that rich Gulf countries lose a significant share of their Human Development Index due to planetary pressures (per capita carbon dioxide emissions and per capita material footprint). Additionally, a hierarchical clustering method was also implemented, classifying the 22 Arab countries into 4 groups: Group 1 (Algeria, Comoros, Egypt, Iraq, Jordan, Lebanon, Libya, Morocco, Palestine, Tunisia), Group 2 (Djibouti, Mauritania, Somalia, Sudan, Syria, Yemen), Group 3 (Bahrain, Kuwait, Oman, Saudi Arabia, United Arab Emirates) and Group 4 (Qatar).

Discussion: The results obtained by applying Principal Component Analysis and a hierarchical clustering method agree perfectly with the ranking provided by the new Planetary pressures-adjusted Human Development Index introduced by the United Nations Development Programme in 2021. The analysis shows that ranking countries only by their Human Development Index score, while ignoring sustainability and environmental effects, yields a potentially misleading ranking.

Conclusion: The performance of Arab countries was also explored through different environmental indicators, including: the Environmental Sustainability Index, the Human Sustainable Development Index, the Ocean Health Index, the National Sustainable Development Index, the Planetary pressures-adjusted Human Development Index, the Environmental Performance Index, the Sustainable Development Goals Index, and the Climate Change Performance.

Keywords: Arab countries, Human development, Environment, Index, Planetary pressures, Sustainable development.

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1. INTRODUCTION

The League of Arab States (LAS) includes the following 22 countries: Algeria, Bahrain, Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates (UAE), and Yemen. According to WorldData, the total population of

these 22 countries is around 480 million (as of June 2025), representing about 5.9% of the world's population (WorldData.info, 2024). In 2000, the population of the 22 Arab countries was about 280 million, representing approximately 5% of the world's population, meaning that the population has increased by 71% in 24 years.

More than 76% of inhabitants live in seven countries: Egypt (23.9%), Sudan (10.4%), Algeria (9.6%), Iraq (9.4%), Yemen (8.2%), Morocco (7.8%), and Saudi Arabia (6.9%) (Table **1**) (WorldData.info, 2024).

Table 1. Number of inhabitants in countries of the Arab League in March 2024.

Country	Population (in millions)	Country	Population (in millions)	Country	Population (in millions)
Algeria	46.16	Lebanon	5.49	Somalia	18.36
Bahrain	1.58	Libya	6.81	Sudan	50.04
Comoros	0.85	Mauritania	4.74	Syria	23.59
Djibouti	1.15	Morocco	37.46	Tunisia	12.20
Egypt	114.54	Oman	4.58	UAE	10.48
Iraq	45.07	Palestine	5.04	Yemen	39.39
Jordan	11.44	Qatar	2.70	-	-
Kuwait	4.85	Saudi Arabia	33.26	**Total**	**479.78**

Source: WorldData (WorldData.info, 2024).

The 22 Arab countries can be subdivided into two groups. The first group of African countries includes Algeria, Comoros, Djibouti, Egypt, Libya, Mauritania, Morocco, Somalia, Sudan, and Tunisia, while the second group of Middle East countries includes Bahrain, Kuwait, Iraq, Jordan, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, UAE, and Yemen.

Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE are also members of the Gulf Cooperation Council (GCC).

The Middle Eastern Arab countries are often grouped as the “West Asia region,” which includes the GCC sub-region and the Mashriq sub-region (Iraq, Jordan, Lebanon, Palestine, Syria, and Yemen).

Although Arab countries share religion, culture, language, and a great part of lifestyle, the Arab League is characterised by huge differences in terms of economic status (World Bank, 2024; Boutayeb, 2023), health indicators (World Health Organization, 2024; Boutayeb & Serghini, 2006), education achievements (ESCWA, 2024), human development (Boutayeb & Serghini, 2006; UNDP, 2024), and sustainable development (ESCWA, 2021; El-Zein *et al.*, 2014; Boutayeb, 2024).

Over the last two decades, numerous environmental indicators have been proposed by various authors and international organisations to address the lack of environmental variables in the calculation of the Human Development Index (HDI) and to promote sustainability (Esty *et al.*, 2005; Togtokh & Gaffney, 2010; Togtokh, 2011; Bravo, 2014; Halpern *et al.*, 2012; Jin *et al.*, 2020; UNDP, 2020; Block *et al.*, 2024; Sachs *et al.*, 2025).

Without being exhaustive, we will consider the following environmental composite indicators:

- The Environmental Sustainability Index (ESI) published in 2005 by Esty and collaborators as a composite indicator based on 21 indicators classified into five categories (Esty *et al.*, 2005),
- The Human Sustainable Development Index (HSDI) proposed by Togtokh and Gaffney in 2010, augmenting the HDI by adding the CO_2 emissions as a fourth variable (Togtokh & Gaffney, 2010; Togtokh, 2011) and also considered by Bravo in 2014 (Bravo, 2014),
- The Ocean Health Index (OHI) was proposed by Halpern *et al.* in 2012 as a linear weighted sum of the scores for each of the public goal indices (I_1, I_2, . . ., I_{10}) and the appropriate weights for each of the following public goals: (1) Food provision (Fisheries, Mariculture), (2) Artisanal fishing opportunity, (3) Natural products, (4) Carbon storage, (5) Coastal protection, (6) Tourism and recreation, (7) Coastal livelihoods and economies (Livelihoods, Economies), (8) Sense of place, (9) Clean water, (10) Biodiversity (Halpern *et al.*, 2012). The OHI 2025 covered 220 coastal countries and territories.
- The National Sustainable Development Index (NSDI) published by Jin *et al.* in 2020 as a composite index constructed from 12 single indices derived from the three sustainable development dimensions (economy, society, and environment) (Jin *et al.*, 2020).
- The Planetary pressures-adjusted Human Development Index (PHDI) introduced by UNDP in the Human Development Report 2021-2022 and subsequently in the reports (HDR 2023-2024 and HDR 2025) (UNDP, 2020),
- The Environmental Performance Index (EPI), released in 2024 by Esty *et al.*, extending their previous work (ESI). The EPI is a comprehensive composite index derived from 58 performance indicators related to 11 environmental issue categories, and three policy objectives (improving environmental health, protecting ecosystem vitality, and mitigating climate change) (Block *et al.*, 2024).
- The Sustainable Development Goals Index (SDGI) was launched by the Sustainable Development Solutions Network (SDSN) and the Bertelsmann Stiftung in 2016 to track SDG progress (Sachs *et al.*, 2025).
- The Climate Change Performance Index (CCPI) estimates GHG (Greenhouse Gas Emissions) in 63 countries and the European Union, which together contribute to more than 90% of global greenhouse gas emissions. The CCPI uses 14 indicators covering Greenhouse Gas Emissions (40% of the overall score), Climate Policy (20%), Energy Use (20%), and Renewable Energy (20%) (Climate Change Performance Index, 2025).

2. MATERIALS AND METHOD

In this study, Principal Component Analysis (PCA) is used to illustrate the effect of the two environmental variables (CO_2 emissions per capita and material footprint per capita) on the HDI in the Arab region. The PCA is one of the most popular data mining statistical methods used to uncover patterns and structure in the data by revealing the correlations between variables and the eventual

clustering between individuals. It summarizes the information by replacing the original variables with linear combinations of these variables. Technically, spectral analysis of the data matrix determines the eigenvalues in descending order and the associated eigenvectors. The first axis associated with the largest eigenvalue in absolute value gives the greatest summary of information, while supplementary information is given by the second axis, the third axis, and so on. The projection of variables and individuals onto the plane formed by the first and second axes provides an illustration of the relationships between variables and between individuals, as well as an analysis of individuals and variables. The quality of the graphical interpretation depends on the percentage of variance explained by the first and second eigenvalues. The PCA also provides the correlation between all the variables used, including supplementary variables (eventually).

It is worth stressing that the interpretation and analysis of PCA data and graphs along the second axis should be made in relation to the results provided by the first axis. Among different data analysis methods, PCA is the most commonly used for quantitative data, while factor analysis is the preferred method for qualitative data. Moreover, PCA may yield the same classification (for individuals/countries) as a clustering method, while providing important information on the correlations between different variables.

To complement the PCA results, a hierarchical clustering method is implemented as an alternative multivariate approach to confirm or refute them.

Besides the UNDP's data used to run the PCA and the hierarchical clustering method, data from other sources are also used to compare the performance of Arab countries in terms of environmental indicators and to track the evolution of Arab countries in terms of sustainability.

3. RESULTS AND DISCUSSION

3.1. Data used to Run the Principal Component Analysis

A Princiapal Component Analysis is carried out using data provided by the HDR 2025 on life expectancy at birth (LEB in years), expected years of schooling (EYS in years), mean years of schooling (MES in years), per capita income (GNI in 2021 PPP $), CO_2 emissions per capita (CO_2 in tonnes), and the material footprint per capita (MFP in tonnes). These 6 variables are associated with the 22 Arab countries. However, the CO_2 index and the MFP index are used instead of the raw data because PHDI is computed as the product of the HDI and (1 – index of planetary pressures), where (1 – index of planetary pressures) serves as an adjustment factor (Table **2**) (UNDP, 2020; UNDP, 2025).

Table 2. Data used for PCA, as provided by the HDR 2025 (UNDP, 2025).

Country	LEB (years)	EYS (years)	MYS (years)	GNI PPP$	CO_2 (tonnes)	CO_2 (Index)	MFP (tonnes)	MFP (Index)
UAE	82.9	15.6	13.0	71142	24.1	0.685	39.8	0.559
Qatar	82.4	13.1	10.8	105353	42.6	0.444	74.1	0.179
Bahrain	81.3	15.9	11.1	52819	24.6	0.679	24.6	0.728
Kuwait	80.4	15.9	7.6	56612	23.0	0.699	40.8	0.548
Oman	80.0	13.4	11.9	36096	16.9	0.779	38.5	0.574
Saudi Arabia	78.7	16.9	11.6	50299	19.9	0.74	23.5	0.739
Jordan	77.8	13.1	10.2	9222	1.9	0.976	7.4	0.918
Lebanon	77.8	11.7	10.4	11299	3.6	0.953	10.3	0.886
Tunisia	76.5	14.7	7.6	12011	2.6	0.966	7.3	0.919
Algeria	76.3	15.5	7.4	15114	3.9	0.949	8.8	0.902
Morocco	75.3	15.1	6.2	8653	1.8	0.976	5.8	0.935
Iraq	72.3	12.4	6.8	12654	3.9	0.949	3.2	0.964
Syria	72.1	7.4	5.9	3918	1.1	0.986	2.2	0.976
Egypt	71.6	13.1	10.1	16218	2.4	0.969	3.9	0.956
Libya	69.3	12.9	7.8	19831	8.9	0.884	12.7	0.859
Yemen	69.3	7.5	5.5	1018	0.3	0.996	1.6	0.982
Mauritania	68.5	7.9	4.9	6267	0.9	0.988	5.8	0.936
Comoros	66.8	13.3	6.0	3481	0.5	0.993	5.1*	0.940*
Sudan	66.3	8.6	4.0	2810	0.4	0.995	4.2	0.954
Djibouti	66.0	6.2	4.0	6368	0.4	0.994	11.0	0.878
Palestine	65.2	13.0	10.1	6547	0.7	0.992	4.9	0.946
Somalia	58.8	7.5	1.9	1475	0.0	1.000	3.7	0.959

Note: * Value not provided by HDR 2025; it is estimated from countries of similar economic status.

3.1.1. Correlation between Variables

Applying the PCA to the data in Table **2** yields interesting insights into the relationships among the six variables, particularly regarding the impact of environmental variables on HDI in the Arab region.

First of all, Table **3** shows that the first and second components explain, respectively, 75.42% and 15.48% of the variance, and consequently, the first plane will explain 90.91% of the variance.

Secondly, Table **4** indicates that the first four variables (those used to compute the HDI) are positively correlated with each other and negatively correlated with the two environmental variables (CO_2 and MFP), which are, in turn, highly positively correlated with each other (R=0.95).

It is worth highlighting the strong negative correlation (-0.99) between GNI and the CO_2 index in Arab countries. The relationship between GDP and CO_2 emissions has been explored by researchers in different regions of the world (Zhigolli & Fetai, 2024; Obiora *et al*., 2021; Rajabi Kouyakhi, 2022).

Using data from the Western Balkan countries (2011-2022), Zhigolli and Fetai investigated the relationship between CO_2 emissions as the dependent variable and GDP per capita, energy consumption, and industrial production as independent variables. Their model revealed a negative relationship between CO_2 emissions and GDP per capita, and a positive relationship with energy consumption, while industrial production was not significant at all. They concluded that these relations could help in projecting the policies that protect the environment (Zhigolli & Fetai, 2024).

Obira *et al*. explored the effect of economic growth on carbon emissions mitigation. They analysed data from 44 countries, including developed, emerging, and developing countries.

Their findings indicated that carbon emissions by the power industry have been mitigated in developed countries, while increased domestic credit to the private sector has increased emissions from the power industry, transport sector, buildings, and other sectors in emerging and developing countries. The authors also stressed that, across all economies, increasing domestic savings will reduce all levels of carbon emissions (Obiora *et al*., 2021).

Stressing that the hot, arid Middle Eastern countries are among the world's largest energy consumers and emitters of carbon dioxide and greenhouse gases in general, Kouyakhi investigated the driving forces of CO_2 emissions in 12 Middle Eastern countries and found that

population growth (53.89%), energy intensity (31.97%) and economic growth (18.42%) are the main drivers of CO_2 emissions in 12 Middle East countries. They suggested reforming energy subsidies and improving energy efficiency as the most efficient approach (Rajabi Kouyakhi, 2022).

In the case of Arab countries, the CO_2 emissions per capita are between 19 and 36 MT in the six GCC countries, between 1 and 9 MT in Algeria, Egypt, Iraq, Jordan, Lebanon, Libya, Morocco, Syria, and Tunisia, and less than 1MT in Comoros, Djibouti, Mauritania, Somalia, Sudan, and Yemen. Coal, fossil fuels, oil, and gas contribute about 90% of CO_2 emissions in the Arab region and globally. For example, in Qatar, about 75% of CO_2 emissions are driven by gas. In Egypt, it is estimated that more than 250 MT of CO_2 are emitted annually from burning fuels and industrial processes, including electricity generation, transport, and heating (Amer *et al*., 2022).

Gulf Cooperation Council countries with high CO_2 emissions use little renewable energy, while a recent study found bidirectional causality between renewable energy and CO_2 emissions in Middle Eastern countries. More precisely, it is estimated that a unit increase in renewable energy reduces CO_2 emissions by 0.22% (Addis, 2026).

Among Arab and African countries, Morocco (with less than 2 MT of CO_2 emissions per capita) is a leader in renewable energy (El Hafdaoui *et al*., 2024; El Hafdaoui *et al*., 2025; Berahab *et al*., 2021; Benbba *et al*., 2024).

It should be stressed that for statistical validation, the PCA is justified by the values of the

Kaiser-Meyer-Olkin (KMO: 0.852) index for the sampling quality and Bartlett's sphericity test ($p<0.0001$)

As illustrated in Fig. (**1**), the PCA reveals a clear distinction between the four variables (EYS, MYS, LEB, and GNI) on the right and the two environmental variables (CO_2 and MFP) on the left. Moreover, the six variables are correlated with component 1 (their projections are close to the unit sphere), which will allow for proper interpretation.

Table 3. Variance explained by each component.

Component	Value	% of Variance Explained	% of Cumulated Variance Explained
1	4525	75.421	75.421
2	929	15.484	90.906
3	285	4.749	95.655
4	203	3.382	99.036
5	47	0.779	99.816
6	11	0.184	100

Table 4. Correlation matrix (between variables).

	LEB	EYS	MYS	GNI	CO_2	MFP
LEB	1	0.703	0.779	0.734	-0.725	-0.674
EYS	-	1	0.709	0.532	-0.514	-0.410
MYS	-	-	1	0.639	-0.618	-0.555
GNI	-	-	-	1	-0.988	-0.953
CO_2	-	-	-	-	1	0.955
MFP	-	-	-	-	-	1

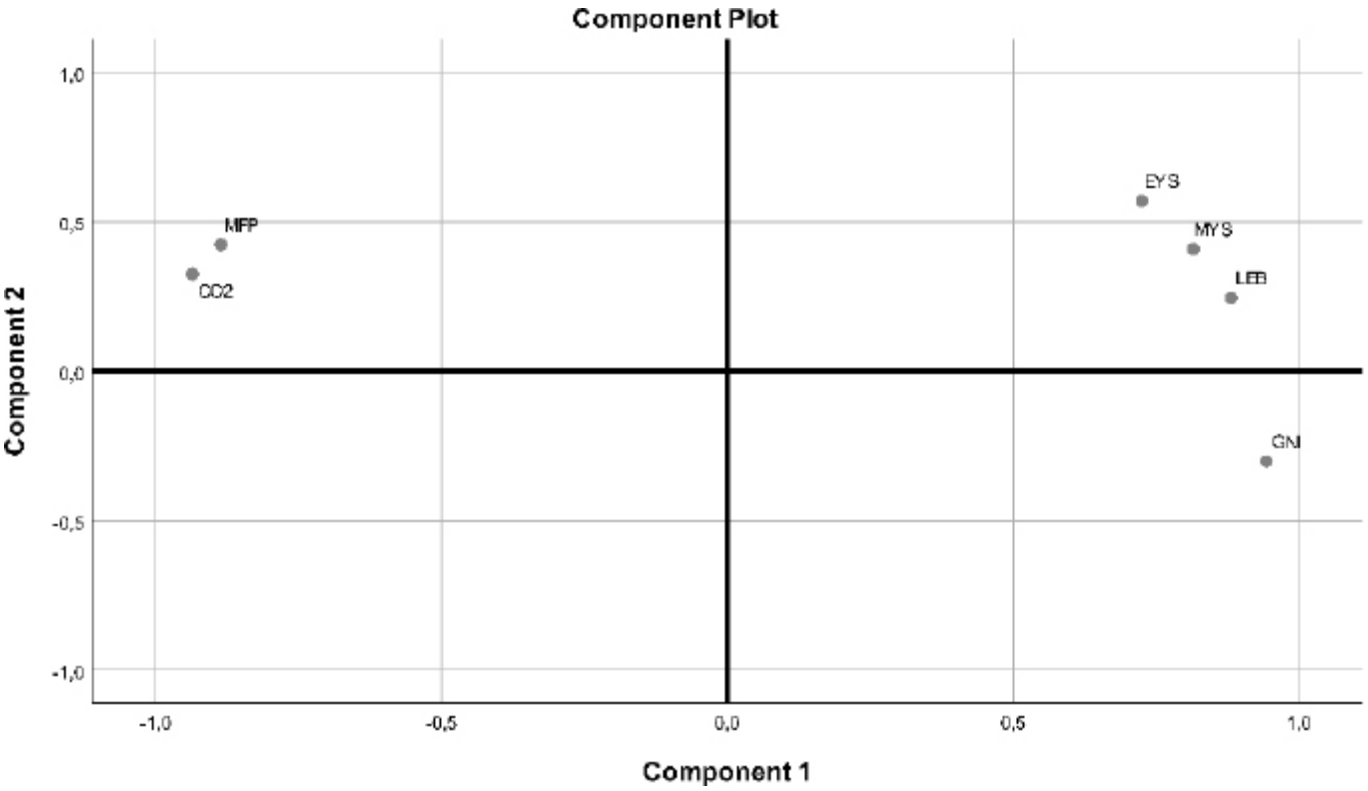

Fig. (1). Variables projected on the first plane (Component1xComponent2).

3.1.2. Clusters of Countries

3.1.2.1. Axis 1: Axis of Human Development

Associated with the projection of variables on the first plane, the corresponding projection of countries exhibits broadly four clusters: Cluster **1** (Qatar alone) and Cluster **2** (grouping the other five GCC countries) are projected on the right side of the first plane, while the remaining 16 Arab countries are projected on the left side of the first plane, grouped into Cluster **3** and Cluster **4**. The third cluster consists of 12 countries belonging to the high development group (Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Tunisia) and the medium development group (Iraq, Palestine, Comoros) while the fourth cluster includes four countries with low human development (Djibouti, Somalia, Sudan and Yemen) and two countries at the bottom of the medium human development group (Syria and Mauritania).

The first axis also indicates that the extreme countries are Qatar on the right side and Somalia on the left side. This extreme opposition is explained by the fact that Qatar has high scores in LEB, YES, MYS and GNI, combined with low scores in CO_2 index and MFP index, while Somalia has the lowest scores in LEB, YES, MYS and GNI, combined with very high scores in CO_2 index and MFP index.

The fact that Qatar constitutes a cluster can mainly be explained by its very high per capita income and high CO_2 and MFP indices. Indeed, Qatar has a GNI (105353 PPP$) which is more than double that of Saudi Arabia's GNI and 71.4 times that of Somalia (1475 PPP$). However, it is also the country emitting the highest quantities of CO_2 (42.6 tonnes per capita) and MFP (74.1 tonnes per capita) globally and regionally.

Cluster **2** comprises GCC countries (except Qatar), which belong to the very high human development group. These five countries also have high emissions of CO_2 and MFP. They are only surpassed by Qatar in terms of planetary pressures.

Cluster **3** is grouping countries with high and medium human development. Except for Libya (emitting 8.9 tonnes of CO_2 per capita), the CO_2 emission of the nine countries together is 21.3 tonnes per capita, with an average of 2.37 tonnes per capita.

Finally, Cluster **4** is a set of six countries with the lowest HDI in the Arab region (<0.6). Their level of CO_2 emission is very low (0.52 tonnes per capita on average).

3.1.2.2. Axis 2: Axis of Planetary Pressures-adjusted Human Development

Conditionally to the information provided by the first axis, the second component brings new interesting information on the impact of CO_2 and MFP. Projecting the six GCC countries on the second axis shows that these countries are ranked in descending order: 1. Saudi Arabia, 2. Bahrain, 3. UAE, 4. Oman, 5. Kuwait and 6. Qatar. In fact, this ranking coincides with the PHDI regional ranking of these six countries as indicated in Table **5** (S.A: 7^{th}, Bahrain: 10^{th}, UAE: 13^{th}, Oman: 14^{th}, Kuwait: 17^{th} and Qatar: 22^{d}). Moreover, the PCA illustration of Qatar as an isolated country is a fair translation of its ranking at the bottom of the Arab list, with a very low PHDI score (0.276), nearly 2.5 times lower than Saudi Arabia's score (0.666) and behind low-income countries like Sudan (0.498), Yemen (0.465) and Somalia (0.396) (Table **5**).

Projection on the second axis also shows that the six countries grouped in Cluster 4 have a PHDI lower than that of the 12 countries in Cluster 3, and especially those with the highest PHDI score (Egypt, Jordan, Algeria, Tunisia, Lebanon, and Morocco).

Interpreting Axis 1 and Axis 2 respectively as axes of Human Development and Planetary pressures-adjusted Human Development is confirmed by a PCA including the variables HDI and PHDI as supplementary variables. In this case, HDI appears highly correlated with Axis 1 (Pearson Correlation: 0.92) while PHDI is very highly correlated with Axis 2 (Pearson Correlation: 0.97).

The graphical results given by PCA in Fig. (**2**) show clearly that ranking countries only by their HDI score, while ignoring sustainability and environmental effects, yields a potentially misleading ranking. By the way, Togtokh made a similar remark in 2011 when he suggested revising HDI by including each nation's per capita carbon emissions, stressing that: "The UN goes out of its way to promote sustainable development, yet the Human Development Index (HDI) mostly ignores sustainability. Worse still, the index celebrates gas-guzzling developed nations. It is time that this failure—hidden in plain sight—was exposed and corrected" (Bravo, 2014).

Table 5. From HDI to PHDI: Very High Human Development countries lose a lot of HDI.

Country	HDI	Global Rank	Region Rank		Country	PHDI	Global Rank	Region Rank	% HDI lost
UAE	0.940	15	1	-	Egypt	0.726	46	1	3.7
S Arabia	0.900	37	2	-	Jordan	0.714	54	2	5.3
Bahrain	0.899	38	3	-	Algeria	0.706	57	3	7.5
Qatar	0.886	43	4	-	Tunisia	0.703	59	4	5.8
Oman	0.858	50	5	-	Lebanon	0.691	61	5	8.1
Kuwait	0.852	52	6	-	Morocco	0.679	63	6	4.4
Algeria	0.763	96	7	-	S Arabia	0.666	74	7	26.0
Egypt	0.754	100	8	-	Iraq	0.665	87	8	4.3
Jordan	0.754	100	8	-	Palestine	0.653	89	8	3.1
Lebanon	0.752	102	10	-	Bahrain	0.632	97	10	29.7
Tunisia	0.746	105	11	-	Libya	0.629	98	11	12.8
Libya	0.721	115	12	-	Comoros*	0.603	99	12	3.5
Morocco	0.710	120	13	-	UAE	0.585	110	13	37.8
Iraq	0.698	126	14	-	Oman	0.581	112	14	32.3
Palestine	0.674	133	15	-	Syria	0.553	119	15	2.0
Comoros	0.603	152	16	-	Mauritania	0.542	121	16	3.7
Syria	0.564	162	17	-	Kuwait	0.531	168	17	37.7
Mauritania	0.563	163	18	-	Sudan	0.498	176	18	2.5
Djibouti	0.513	175	19	-	Djibouti	0.480	180	19	6.4
Sudan	0.511	176	20	-	Yemen	0.465	191	20	1.1
Yemen	0.470	184	21	-	Somalia	0.396	191	21	2.0
Somalia	0.404	192	22	-	Qatar	0.276	192	22	68.8

Note: * Estimated because not provided by HDR 2025.

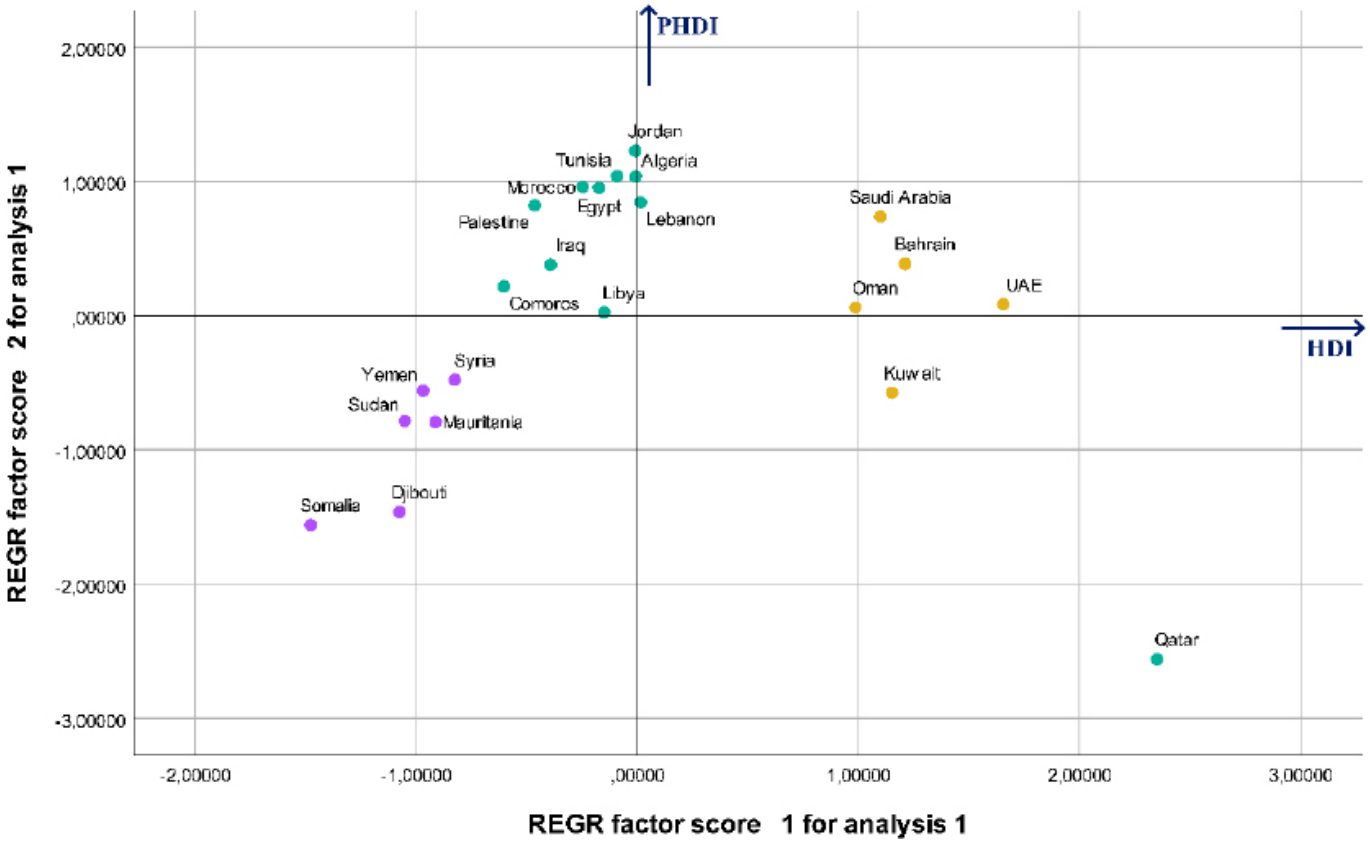

Fig. (2). Projection of countries on the first plane (Component1xComponent2).

The quantity of CO_2 emitted by the six GCC countries (151.1 tonnes per capita) is more than 4.5 times higher than the quantity emitted by the remaining 16 Arab countries (33.3 tonnes per capita) and the CO_2 emitted by Qatar alone (42.6 tonnes) is 1.3 times that emitted by the 16 countries gathered in Cluster 2 and Cluster 3. Huge gaps are also seen in material footprint per capita between Qatar (74.1 tonnes), Kuwait (40.8 tonnes), UAE (39.8 tonnes) and Oman (38.5 tonnes) on the one side and Egypt (3.9), Iraq (3.2), Syria (2.2) and Yemen (1.6) on the other side.

In summary, PCA complements the PHDI ranking by clustering countries based on the effect of socioeconomic and environmental variables instead of a simple ranking.

3.1.3. Qatar as an Outlier Country and Comoros with Missing Data

To address Qatar as an outlier country, a new PCA was run with 21 countries (Qatar excluded), yielding a relative difference in the explained variation of the first two components of less than 5%.

Similarly, although only one value (Comoros' material footprint) was missing, the PCA was run with 21 countries (Comoros excluded), giving a relative difference in the explained variation of the first two components of less than 5%.

3.2. Hierarchical Clustering

To complement the PCA results, a hierarchical clustering method was implemented using the data in Table **2**.

As illustrated by Fig. (**3**), at level 5, the 22 Arab countries are grouped according to 4 clusters, namely: Cluster 1 (Algeria, Comoros, Egypt, Iraq, Jordan, Lebanon, Libya, Morocco, Palestine, Tunisia), Cluster 2 (Djibouti, Mauritania, Somalia, Sudan, Syria, Yemen), Cluster 3 (Bahrain, Kuwait, Oman, Saudi Arabia, UAE) and Cluster 4 (Qatar). This clustering confirms the previous results given by the PCA.

3.3. Data from Different Sources and other Environmental Indicators

Table **6** summarises the performance of the 22 Arab countries according to five composite indicators computed for large numbers of countries worldwide (Togtokh & Gaffney, 2010; Halpern *et al.*, 2012; Jin *et al.*, 2020; Block *et al.*, 2024; Sachs *et al.*, 2025). It gives the score and the global rank of each Arab country.

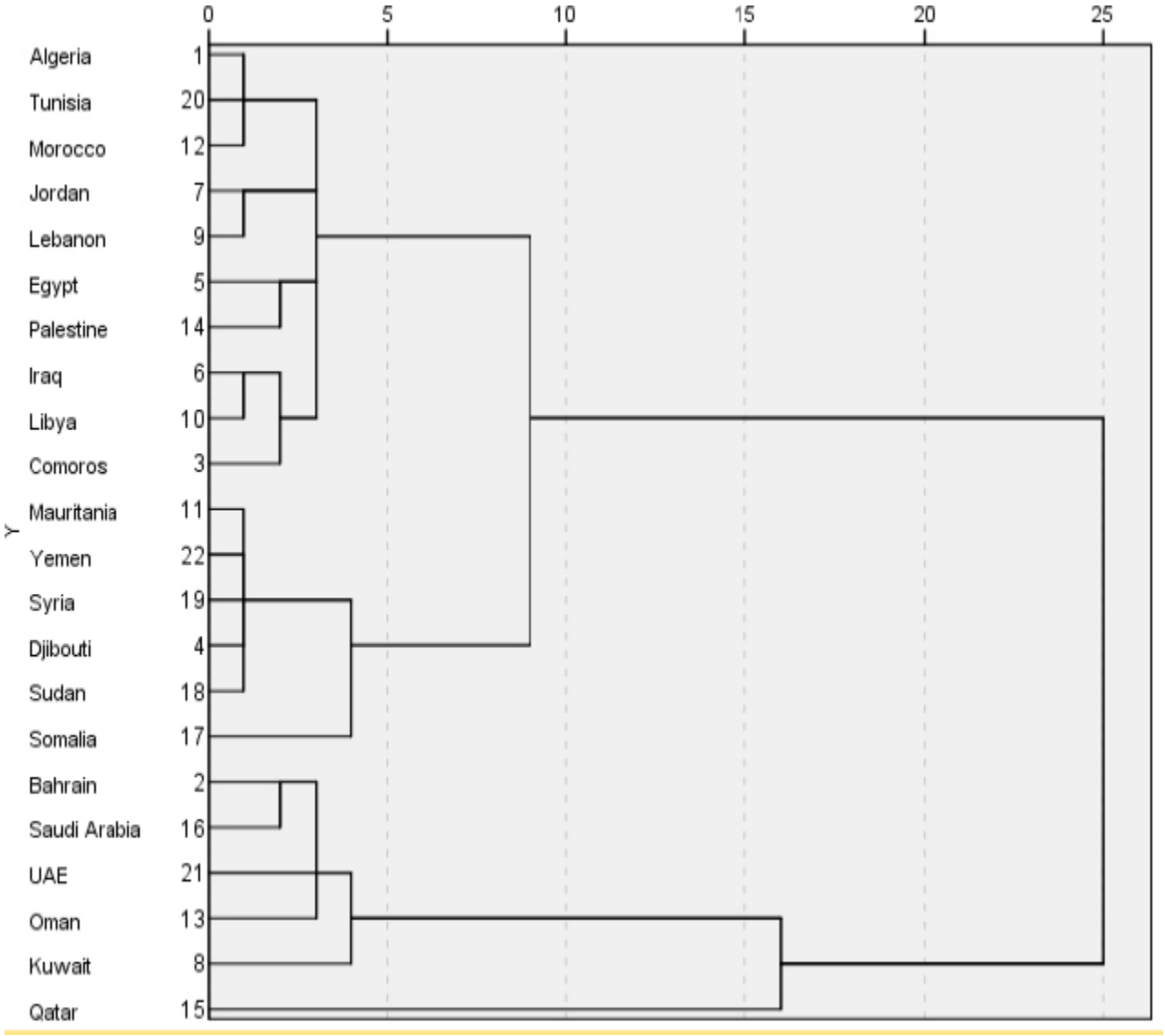

Fig. (3). Hierarchical clustering dendrogram.

Table 6. Performance of Arab countries according to different environmental indicators.

Country	HSDI 2010 Value	HSDI 2010 Rank	OHI 2025 Value	OHI 2025 Rank	NSDI 2020 Value	NSDI 2020 Rank	EPI 2024 Value	EPI 2024 Rank	SDGI 2025 Value	SDGI 2025 Rank
Algeria	0.734	76	65	178	0.594	49	41.7	114	70.1	79
Bahrain	0.719	82	72	100	0.342	159	35.3	157	64.4	110
Comoros	0.529	134	80	19	0.498	120	38.2	137	54.7	148
Djibouti	0.504	140	71	124	NA	NA	32.3	167	54.3	149
Egypt	0.692	94	71	123	0.449	139	43.7	101	68.1	91
Iraq	NA	NA	65	181	0.456	136	30.3	172	63.9	113
Jordan	0.738	73	66	164	0.510	108	47.3	77	71.0	71
Kuwait	0.685	97	80	24	0.326	160	44.4	95	63.3	118
Lebanon	NA	NA	45	220	0.514	104	39.9	126	61.7	125
Libya	0.777	51	54	217	0.469	134	NA	NA	NA	NA
Mauritania	0.533	130	69	143	0.436	140	34.6	159	57.9	132

Country	HSDI 2010 Value	Rank	OHI 2025 Value	Rank	NSDI 2020 Value	Rank	EPI 2024 Value	Rank	SDGI 2025 Value	Rank
Morocco	0.649	109	67	160	0.513	105	39.5	128	71.7	68
Oman	NA	NA	77	41	0.489	125	51.3	55	67.1	97
Qatar	0.424	151	85	7	0.432	141	46.8	82	65.1	107
Palestine	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S. Arabia	0.748	66	75	54	0.390	156	42.5	108	65.2	105
Somalia	NA	NA	65	177	NA	NA	NA	NA	46.1	164
Sudan	0.482	147	62	195	NA	NA	39.1	131	49.1	161
Syria	0.662	104	47	219	NA	NA	NA	NA	58.4	131
Tunisia	0.744	68	63	191	0.524	94	45.3	91	72.0	66
UAE	0.704	90	86	6	0.410	149	51.6	53	69.8	80
Yemen	0.538	217	59	208	0.414	146	NA	NA	47.7	163

Abbreviation: NA: not available data.

First of all, it should be noted that the data in Table **6** span a large range of years (2010-2025), and hence one should be careful when comparing countries.

The Human Sustainable Development Index (HSDI 2010) was computed for 163 countries worldwide and yielded scores varying between 0.228 in Zimbabwe (Rank 163) and 0.917 in Norway (Rank 1). For this indicator, Arab countries obtained low scores, varying between 0.777 in Libya (Global rank 51) and 0.424 in Qatar (Global rank 151).

The Ocean Health Index (OHI) measures 10 benefits or goals that people want and need from the ocean. It covers 220 coastal countries and territories. For the 2025 assessment, the global OHI score was 72, still less than the pre-pandemic score of 75. In the Arab region, the best scores were achieved by UAE (86), Qatar (85), Kuwait (80) and Comoros (80), while Lebanon (45), Syria (47), Libya (54), and Yemen (59) had the lowest regional scores. The UAE (global rank 6) and Qatar (global rank 7) were in the top 10 countries worldwide.

The National Sustainable Development Index (NSDI 2020) covered 163 countries and varied from 0.232 in Ivory Coast to 0.747 in Australia. Algeria was ranked 49th and had the best score in the Arab region, followed by Tunisia (0.524, ranked 94th). Weak NSDI scores were associated globally and regionally with GCC countries: Qatar (141st), UAE (149th), Saudi Arabia (156th), Bahrain (159th) and Kuwait (160th).

The Environmental Performance Index (EPI 2024) included 180 countries and showed scores varying between a minimum of 24.6 in Viet Nam and a maximum of 75.7 in Estonia. The median EPI score also varied considerably by region (Table **7**). With an EPI score greater than 50, UAE (53th) and Oman (55th) were at the top of the Arab list, while Djibouti (167th) and Iraq (172th) were at the bottom, globally and regionally.

Data from different years are used to track countries' progress rather than to do comparisons (in space and in time) that may lead to inconsistent results. For example, using data (ESI 2005 and EPI 2024) (Table **7**), provided by the same teams of Yale University and Columbia University, shows that the environmental performance of the UAE and Iraq (two oil producers) evolved in opposite sides. While the UAE improved its global score and rank from 44.6 (global rank 110) in 2005 to 51.6 (global rank 53) in 2024, Iraq's global score went down from 33.6 (rank 143) to 30.3 (rank 172) during the same period of time. These results can be explained by the fact that the UAE is the regional leader in wastewater treatment and reuse, and has large networks of protected areas, compared to Iraq with less than 2% of protected land, degraded ecosystems and species facing a high extinction risk (Block *et al.*, 2024).

Table 7. Median EPI/ESI score by country and region.

Country	ESI 2005	Rank	EPI 2024	Rank	Region EPI 2024	EPI score	Rank
Estonia	58.2	27	75.7	1	Global West	66.9	1
Finland	75.1	1	73.8	4	Eastern Europe	59.8	2
UK	50.2	66	72.6	5	Latin America & Caribbean	49.2	3
Oman	47.9	83	51.3	55	Former Soviet States	45.5	4
UAE	44.6	110	51.6	50	Asia-Pacific	42.2	5
Egypt	44.0	115	43.7	101	Greater Middle-East	43.1	6
Iraq	33.6	143	30.3	172	Sub-Saharan Africa	38.4	7
Pakistan	39.9	131	25.5	179	Southern Asia	32.1	8
Viet Nam	42.3	127	24.6	180	**World (180 countries)**	**45.5**	-

The Sustainable Development Goals Index (SDGI) measures overall country progress using 17 key indicators, one per SDG, including those directly related to environment like: $SDGI_6$ (% of population using at least basic sanitation services), $SDGI_7$ (% of population with access to electricity), $SDGI_{11}$ (Annual mean concentration of PM2.5), $SDGI_{12}$ (Production-based nitrogen emissions per capita), $SDGI_{13}$ (CO_2 emissions from fossil fuel combustion and cement production per capita), $SDGI_{14}$ (% of mean area that is protected in marine sites), $SDGI_{15}$ (Red List Index of species survival) (Sachs *et al.*, 2025).

The Sustainable Development Goals Index (SDGI 2025) covered 167 countries and indicated scores varying globally between 41.6 in South Sudan (Rank 167) and 87.0 in Finland (Rank 1). It shows that many Arab countries are not on track to achieve the 17 goals in general and the environmental goals in particular. Most Arab countries are facing challenges in SDG_{12}, SDG_{13}, significant challenges in SDG_6, SDG_7, SDG_{11}, SDG_{14} and especially, major challenges in SDG_6, SDG_7, SDG_{11}, SDG_{12}, SDG_{13}, SDG_{14} and SDG_{15} (Table **8**).

The Sixth Global Environment Outlook report (GEO-6) released by UNEP in 2016 stressed that West-Asia countries (including 12 Arab countries of the Middle East) were challenged by biodiversity degradation, water stress, solid waste, climate change, clean energy consumption, conservation of marine sources and preservation of terrestrial ecosystems like forests, mountains, dry lands and wetlands (UNEP, 2016). More recently, a report of the FAO revealed that Arab countries (West-Asia and North Africa) were the most affected by water stress in 2021 (Fig. (**4**)) (FAO & UN-Water, 2024).

3.4. The Moroccan Case Study

In 2022, renewable energy sources (wind, solar, hydropower) represented 17.1% of the electricity generation mix in Morocco. Aligning with the global climate commitments and working to achieve SDGs, Moroccan authorities have launched short-term and long-term strategies aimed at reducing CO_2 emissions by targeting a high renewable energy share in the electricity mix (52% by 2030 and 70% by 2050). The high solar irradiance in the Moroccan desert (about 2500 kWh/m2/year) and the strong coastal wind reaching an average speed of 8m/s, constitute natural means for the achievement of clean energy innovation and technology transfer (El Hafdaoui *et al.*, 2024; El Hafdaoui *et al.*, 2025; Berahab *et al.*, 2021).

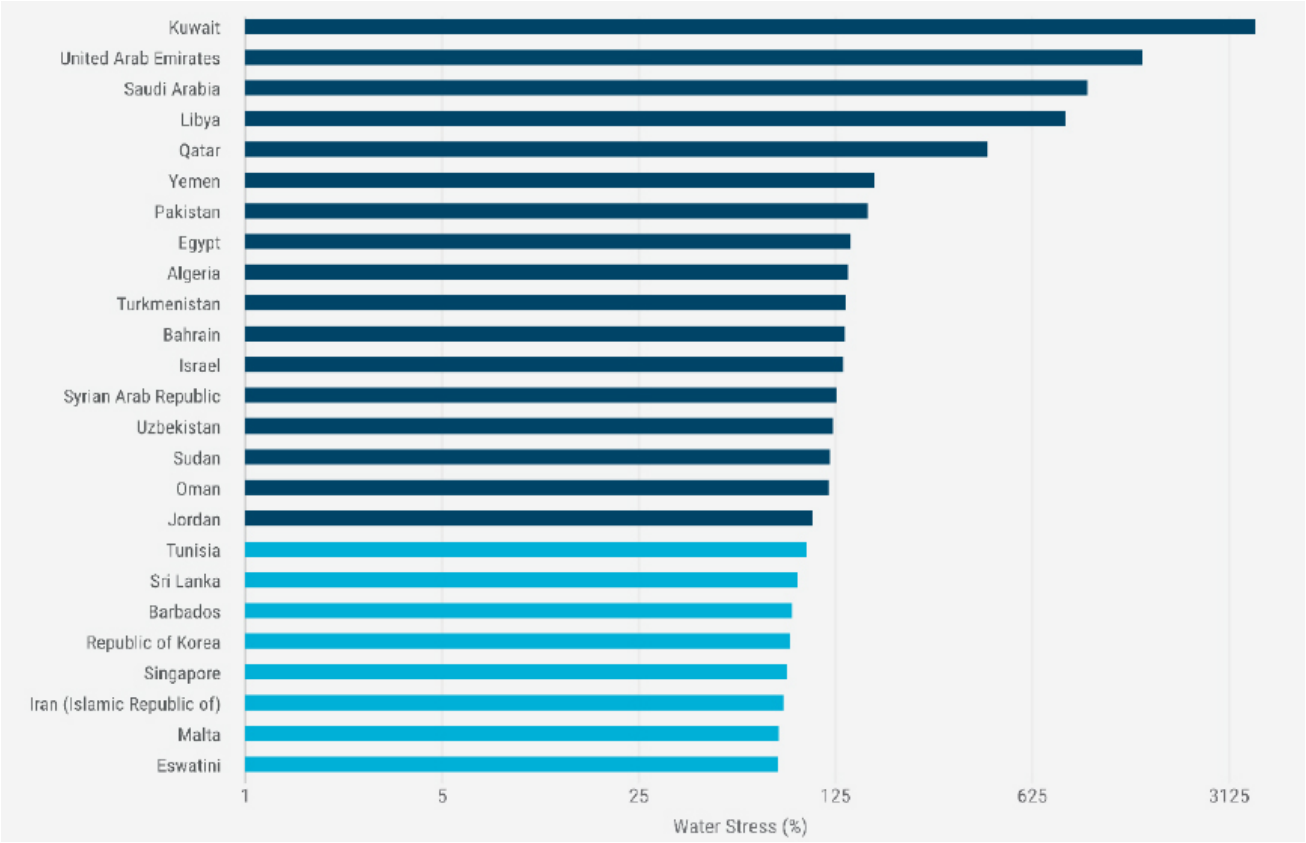

Fig. (4). Countries with high and critical water stress levels (water stress level > 75%), 2021.
Source: FAO (FAO & UN-Water, 2024), available under the Creative Commons Attribution-Non Commercial-Share Alike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO).

Table 8. Most Arab countries are facing challenges in achieving environmental goals.

Country	SDG_6	SDG_7	SDG_{11}	SDG_{12}	SDG_{13}	SDG_{14}	SDG_{15}
Algeria	S	M	S	A	S	S	M
Bahrain	M	S	M	M	M	M	M
Comoros	M	M	S	A	A	M	M
Djibouti	M	M	M	S	C	M	M
Egypt	S	S	M	C	C	M	M
Iraq	S	S	M	C	S	M	M
Jordan	S	C	M	C	C	S	M
Kuwait	M	S	M	M	M	M	S
Lebanon	M	M	S	S	M	M	S
Mauritania	M	M	M	C	A	M	M
Morocco	S	M	S	C	A	M	M
Oman	M	M	M	M	M	S	S
Qatar	M	M	S	M	M	S	M
Saudi Arabia	S	M	M	M	M	M	M
Somalia	M	M	S	A	A	M	M
Sudan	M	S	M	C	A	M	M
Syria	M	S	M	C	A	M	M
Tunisia	S	M	C	C	C	M	M
United Arab Emirates	M	S	M	M	M	M	M

Note: A = Achieved or on track, C = Challenges remain, S = Significant challenges remain, M = Major challenges remain

According to the Climate Change Performance Index (CCPI) report 2026, Morocco ranks 6th and is among the highest performers in the CCPI. This high ranking is provided by a high rating in GHG Emissions, Energy Use, and Climate Policy, and a low rating in Renewable Energy. The CCPI estimates GHG (Greenhouse Gas Emissions) in 63 countries and the European Union, which together contribute to more than 90% of global greenhouse gas emissions. The CCPI uses 14 indicators covering Greenhouse Gas Emissions (40% of the overall score), Climate Policy (20%), Energy Use (20%), and Renewable Energy (20%) (Climate Change Performance Index, 2025).

In 2025, Morocco had access to a high human development level (global rank 120th) and achieved the second best SDGI score in the Arab region (global rank 68th).

4. LIMITATIONS

This study had limitations such as missing data, a large range and heterogeneity of data (2005-2025), and use of secondary data.

CONCLUSION AND PERSPECTIVES

The analysis undertaken in this paper shows that Arab countries perform differently in terms of environmental indicators. Environmental issues are particularly affecting human development in rich countries of the Gulf. The six GCC countries are losing a large proportion of their HDI due to planetary pressures and hence, sliding seriously down in HDI ranking, with Qatar ranked last of the 193 countries for which PHDI was calculated in 2025.

However, all Arab countries are challenged by different environmental issues such as biodiversity loss; water stress and deteriorating water quality; persistent overexploitation of groundwater resources; unsustainable consumption patterns threatening water, energy and food security; air pollution; waste management; energy efficiency; and lack of peace and security in countries under devastating conflicts.

Despite the commitment of GCC developed countries to boosting the proportion of renewable energy in their overall energy mix, they rely heavily on fossil fuels, and consequently, they remain among the world's largest energy consumers and emitters of carbon dioxide and greenhouse gases (Rajabi Kouyakhi, 2022; Elrahmani *et al.*, 2021). In contrast, developing countries like Morocco are investing seriously in renewable energy, and hence, they are reducing their CO_2 emissions and greenhouse gases in general.

Although the gross national income per capita is one of the main three components involved in calculating the usual HDI, this study shows that adding planetary pressures as a fourth component yields a PHDI that is more respectful of sustainable development and its three components (economic growth, social inclusion, and environmental protection), seeking the well-being of societies and individuals of present and future generations.

As a perspective, the authors will work on a "Sustainable Human Equitable Development Index" (SHEDI) as soon as sufficient data are available both on the environment and inequality in all Arab countries.

AUTHORS' CONTRIBUTIONS

The authors confirm their contributions to the paper as follows: A.B.: Contributed to the research design, draft writing, and reference checking. M.L.E.N.: Contributed to the research design, simulations, figure plotting, and text

editing. W.B.: Contributed to the research design, data and parameters checking, and draft revision. All authors reviewed the results and approved the final version of the manuscript.

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Not applicable.

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information is available within the article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest financial or otherwise.

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REFERENCES

Addis, AK (2026) The impact of renewable energy on CO2 emissions in Middle Eastern and BRICS economies. *Humanities and Social Sciences Communications,* 13, 194. [http://dx.doi.org/10.1057/s41599-026-06492-w]

Amer, EAAA, Meyad, EMA, Gao, Y, Niu, X, Chen, N, Xu, H & Zhang, D (2022) Exploring the link between natural resources, urbanization, human capital, and ecological footprint: A case of GCC countries. *Ecological Indicators,* 144, 109556. [http://dx.doi.org/10.1016/j.ecolind.2022.109556]

Benbba, R, Barhdadi, M, Ficarella, A, Manente, G, Romano, MP, El Hachemi, N, Barhdadi, A, Al-Salaymeh, A & Outzourhit, A (2024) Solar energy resource and power generation in Morocco: Current situation, potential, and future perspective. *Resources,* 13, 140. [http://dx.doi.org/10.3390/resources13100140]

Berahab, R, Chami, A, Derj, A, Hammi, I, Morazzo, M & Naciri, Y (2021) *Morocco's decarbonization pathway - Part II: Updated decarbonization scenarios*.Policy Center for the New South, Rabat, Morocco.

Block, S, Emerson, JW, Esty, DC, de Sherbinin, A & Wendling, ZA (2024) *Environmental performance inde*x.Yale Center for Environmental Law & Policy, New Haven, CT.

Boutayeb, A & Serghini, M (2006) Health indicators and human development in the Arab region. *International Journal of Health Geographics,* 5, 61. [http://dx.doi.org/10.1186/1476-072X-5-61] [PMID: 17194309]

Boutayeb, A (2023) Social determinants of health and adolescent childbearing in WHO Eastern Mediterranean countries. *International Journal for Equity in Health,* 22, 78. [http://dx.doi.org/10.1186/s12939-023-01861-2] [PMID: 37131177]

Boutayeb, A (2024) Sustainable developments goals in the Arab region. *Environment and Public Health Research,* 2, 2527. [http://dx.doi.org/10.59400/ephr2527]

Bravo, G (2014) The human sustainable development index: New calculations and a first critical analysis. *Ecological Indicators,* 37, 145-50. [http://dx.doi.org/10.1016/j.ecolind.2013.10.020]

El Hafdaoui, H, Khallaayoun, A & Ouazzani, K (2024) Long-term low carbon strategy of Morocco: A review of future scenarios and energy measures. *Results in Engineering,* 21, 101724. [http://dx.doi.org/10.1016/j.rineng.2023.101724]

El Hafdaoui, H, Khallaayoun, A & Al-Majeed, S (2025) Renewable energies in morocco: A comprehensive review and analysis of current status, policy framework, and prospective potential. *Energy Conversion and Management: X,* 26, 100967. [http://dx.doi.org/10.1016/j.ecmx.2025.100967]

Elrahmani, A, Hannun, J, Eljack, F & Kazi, MK (2021) Status of renewable energy in the GCC region and future opportunities. *Current Opinion in Chemical Engineering,* 31, 100664. [http://dx.doi.org/10.1016/j.coche.2020.100664]

El-Zein, A, Jabbour, S, Tekce, B, Zurayk, H, Nuwayhid, I, Khawaja, M, Tell, T, Mooji, YA, De-Jong, J, Yassin, N & Hogan, D (2014) Health and ecological sustainability in the Arab world: A matter of survival. *Lancet,* 383, 458-76. [http://dx.doi.org/10.1016/S0140-6736(13)62338-7] [PMID: 24452051]

Education in the Arab region: Closing gaps to ensure that no child is left behind. Policy Brief No. 9, E/ESCWA/CL2.GPID/2024. Available from: https://www.unescwa.org/sites/default/files/pubs/pdf/education-arab-region-closing-gaps-no-child-left-behind-english.pdf?utm_source=chatgpt.com

Environmental sustainability and human development: Perspectives from the Arab region. Available from: https://www.unescwa.org/publications/environmental-sustainability-human-development-perspectives-arab-region

Esty, DC, Levy, MA, Srebotnjak, T & de Sherbinin, A (2005) *Environmental Sustainability Index: Benchmarking National Environmental Stewardship*.Yale Center for Environmental Law & Policy, New Haven, CT.

Progress on the level of water stress: Mid-term status of SDG Indicator 6.4.2 and acceleration needs, with special focus on food security, 2024. Available from: https://www.fao.org/platforms/water-scarcity/Knowledge/knowledge-products/detail/progress-on-the-level-of-water-stress--mid-term-status-of-sdg-indicator-6.4.2-and-acceleration-needs--with-special-focus-on-food-security--2024/en

Halpern, BS, Longo, C, Hardy, D, McLeod, KL, Samhouri, JF, Katona, SK, Kleisner, K, Lester, SE, O'Leary, J, Ranelletti, M, Rosenberg, AA, Scarborough, C, Selig, ER, Best, BD, Brumbaugh, DR, Chapin, FS, Crowder, LB, Daly, KL,

Doney, SC, Elfes, C, Fogarty, MJ, Gaines, SD, Jacobsen, KI, Karrer, LB, Leslie, HM, Neeley, E, Pauly, D, Polasky, S, Ris, B, St Martin, K, Stone, GS, Sumaila, UR & Zeller, D (2012) An index to assess the health and benefits of the global ocean. *Nature,* 488, 615-20. [http://dx.doi.org/10.1038/nature11397] [PMID: 22895186]

Jin, H, Qian, X, Chin, T & Zhang, H (2020) A global assessment of sustainable development based on modification of the human development index *via* the entropy method. *Sustainability,* 12, 3251. [http://dx.doi.org/10.3390/su12083251]

Obiora, SC, Zeng, Y, Li, Q, Asiedu-Ayeh, E, Nneji, GU & Bamisile, O (2021) The economic growth and environmental sustainability nexus: A metanalysis of three economic types. *Journal of Environmental Planning and Management,* 65, 2556-86. [http://dx.doi.org/10.1080/09640568.2021.1973974]

Rajabi Kouyakhi, N (2022) CO_2 emissions in the Middle East: Decoupling and decomposition analysis of carbon emissions, and projection of its future trajectory. *Science of the Total Environment,* 845, 157182. [http://dx.doi.org/10.1016/j.scitotenv.2022.157182] [PMID: 35803418]

Sachs, JD, Lafortune, G, Fuller, G & Iablonovski, G (2025) Financing sustainable development to 2030 and mid-century. *Sustainable Development Report 2025.*Dublin University Press, Dublin. [http://dx.doi.org/10.25546/111909]

Togtokh, C & Gaffney, O (2010) Human sustainable development index. Available from: http://ourworld.unu.edu/en/the-2010-human-sustainable-development-index/

Togtokh, C (2011) Time to stop celebrating the polluters. *Nature,* 479, 269. [http://dx.doi.org/10.1038/479269a] [PMID: 22094652]

Technical note. Planetary pressures–adjusted Human Development Index. Available from: https://hdr.undp.org/system/files/documents/phditn.pdf

Human Development Report 2023–24: Breaking the gridlock: Reimagining cooperation in a polarized world. Available from: https://hdr.undp.org/content/human-development-report-2023-24

Human Development Report 2025: A matter of choice: People and possibilities in the age of AI. Available from: https://hdr.undp.org/content/human-development-report-2025

GEO-6: Global Environment Outlook: Regional assessment for West Asia. Available from: https://www.unep.org/resources/report/geo-6-global-environment-outlook-regional-assessment-west-asia

GNI per capita. Available from: https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD

Arab League. Available from: https://www.worlddata.info/alliances/arab-league.php

The Global Health Observatory: Explore a world of health data. Available from: https://www.who.int/data/gho

Zhigolli, G & Fetai, B (2024) The Relationship Between Co2 Emissions And Gdp Per Capita, Energy Consumption, Industrial Production In The Case Of Western Balkan Countries. *Economic Thought and Practice, Department of Economics and Business, University of Dubrovnik,* 33, 539-53. [http://dx.doi.org/10.17818/EMIP/2024/2.10]