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Comparative global environmental measurement analysis based on environmental performance index

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Abstract

The importance of environmental sustainability stems from its contributions to the present and the future. Protecting biodiversity, achieving healthier conditions by reducing pollution, effectively combating global warming, and using resources efficiently is important for a clean and healthy future. To ensure environmental sustainability, the continuity of environmental measurement models is also required. Therefore, The Environmental Performance Index (EPI), consisting of 11 categories and 40 indicators, is published periodically every year by Yale and Columbia University researchers in partnership with the World Economic Forum. This study aims to perform a regional comparison by compiling EPI reports published between 1995-2022 and to reveal the relationship between country income levels and determined indicators. Within the scope of this study, the most important indicators were first selected with Pareto analysis according to EPI indicator weights. The selected indicators were compared in detail by dividing the 180 countries included in the 1995-2022 EPI report into regions. In the next stage of the study, the relationship of the selected indicators with income level was examined statistically. According to the results of the study, a statistically significant difference was found between the income levels of the countries with the nineteen EPI indicators selected.

1. Introduction

Environmental sustainability is critical in today's world since it entails preserving our planet's sensitive ecosystems, natural resources, and biodiversity for the benefit of present and future generations. Adopting sustainable behaviors is critical for mitigating the terrible effects of climate change, deforestation, pollution, and resource depletion. A harmonic cohabitation with nature by implementing eco-friendly initiatives such as renewable energy sources, efficient waste management, and conservation efforts, ensuring clean air, clean water, and a stable climate can be built. Environmental sustainability not only protects humanity's health and prosperity, but it also assures the survival of innumerable species, promoting a balanced and resilient planet for future generations.

Environmental sustainability and environmental performance measurement are inextricably linked and play critical roles in our attempts to conserve and protect our planet. Environmental sustainability refers to a set of activities and policies that strive to reduce our ecological footprint while also fostering the long-term well-being of both the environment and human society. To ensure the efficiency of sustainability measures, environmental performance must constantly be measured and assessed. People and institutions can monitor the results of their actions, identify areas for improvement, and hold individuals, organizations, and governments accountable for their contributions to environmental destruction or preservation through evaluating environmental performance. Everyone can set reasonable goals, assess performance, and promote a culture of continuous improvement by integrating measurement into the search for sustainability. This will ultimately help the environment move toward a more sustainable future.

Measuring environmental performance is important for a variety of reasons. It holds individuals, companies, and governments accountable for their environmental impact, instilling accountability. By identifying specific environmental challenges, regions that require immediate action can be better understood. Regular measuring allows us to set targets and to work toward real development. Furthermore, it allows us to compare the environmental practices of various companies, fostering healthy competition and knowledge-sharing. Measuring environmental performance also helps with efficient resource allocation, informed policymaking, and transparent communication with stakeholders. Additionally, it promotes ongoing improvement and adaptability to changing environmental issues, and so plays an important part in our journey toward sustainability and the protection of the planet's future.

Environmental performance, which must be measured to ensure environmental sustainability, has been carried out from the past to the present. The Environmental Performance Index (EPI) is an extensive framework created by Yale and Columbia University researchers in partnership with the World Economic Forum. EPI is a data-driven overview of the global level of sustainability. The EPI ranks 180 nations on climate change performance, environmental health, and ecosystem vitality using 40 performance indicators across 11 issue areas. These metrics show how near countries are to meeting stated environmental policy targets on a national basis. The EPI produces a scorecard that recognizes environmental leaders and laggards and gives practical suggestions for countries seeking to move toward a more sustainable future (Wolf et al., 2022). The EPI framework showing 3 policy objectives, 11 issue categories, and 40 indicators is presented in Figure 1.

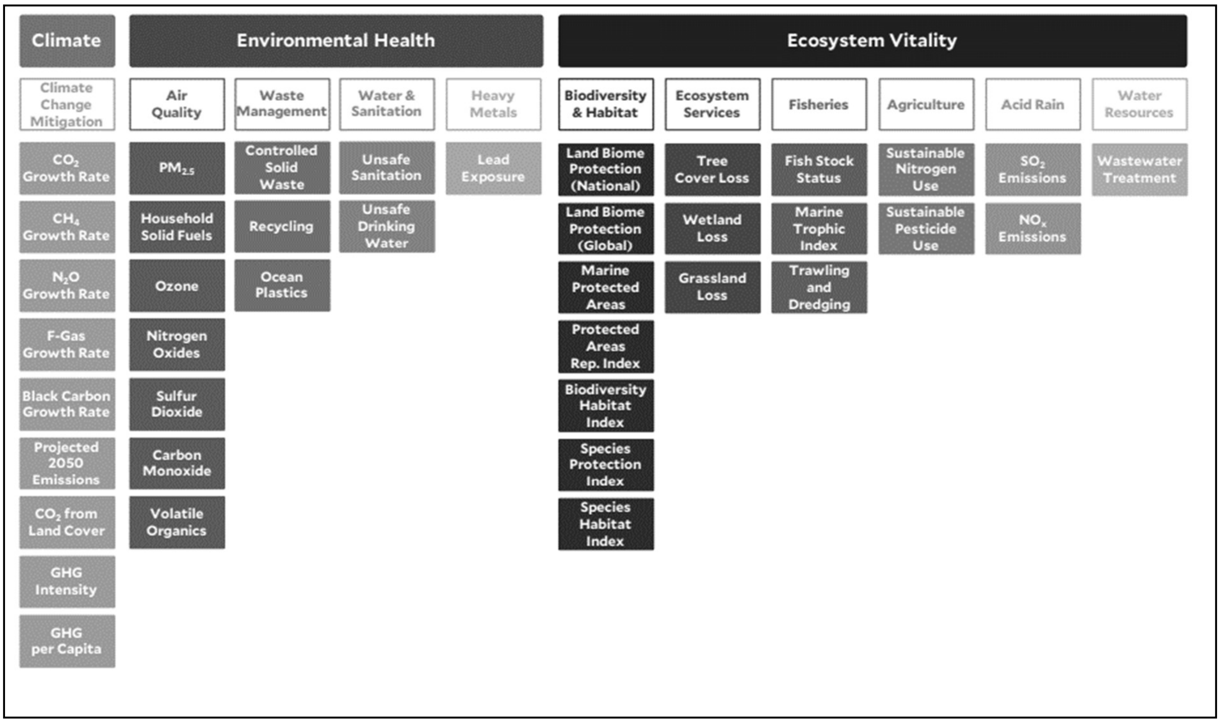

Figure 1. EPI Framework (https://epi.yale.edu/)

There are many studies on environmental performance and environmental sustainability in the literature. Past studies including EPI scores, which form the basis and focus of this study, are reviewed. Stanwick and Stanwick (1998) aimed to investigate how an organization's corporate social performance is influenced by three key variables: its size, financial performance, and environmental impact. Through empirical testing of data spanning from 1987 to 1992, the study concludes that the corporate social performance of a firm is indeed affected by its size, profitability, and level of pollution emissions. Grafton and Knowles's (2004) article provided the first empirical test of the empirical relationships between national measures of social capital (civic and public), social divergence, and social capacity on various indicators of national environmental performance, using cross-country data from a sample of low-, middle-, and high-income countries. Overall, the results provided little empirical support for the hypothesis that social determinants have a statistically beneficial effect on national indicators of environmental quality but do show that higher population density is associated with increases in environmental degradation. According to Duit (2005), a nation's ability to produce environmental public goods is vital for its environmental performance. The EPI is significantly influenced by GDP per capita, making it a critical factor in determining a nation's capacity to provide environmental public goods. Higher GDP per capita implies better resources and, therefore, better-equipped nations to deliver environmental public goods. The objective of Samimi, Erami, and Yusef's (2010) paper is to assess the correlation between the EPI and economic growth in chosen developing nations. Research conducted on this topic highlights the detrimental effects of environmental degradation on economic progress. Utilizing a cross-sectional Weighted Least Squares (WLS) econometric approach, our analysis reveals a significant and positive impact of the EPI on the economic growth of the nations under scrutiny. Samimi, Kashefi, Salatin, & Lashkarizadeh , (2011) assessed the correlation between Environmental Performance and Human Development in various countries worldwide between 2006 and 2010. The outcomes of the research, utilizing a panel data regression model, revealed a meaningful and favorable association between EPI and HDI for all countries, including the developed ones. Nonetheless, in the situation of developing countries where environmental degradation occurs, the data suggests that an increase in the human development index does not always enhance Environmental Performance in these nations. In such cases, promoting public awareness and receiving support from international organizations such as the United Nations could be crucial in improving the situation. Samimi and Ahmadpour 's (2011) paper aimed to assess the EPI in OIC countries in both pre and post-financial crisis. This analysis utilizes EPI data from the Yale Center for Environmental Law & Policy spanning the years 2006-2010. The results reveal that while overall environmental performance in OIC countries demonstrated improvement from 2006-2008, the data for 2010 indicates a decline in environmental performance across the countries studied. It is possible that the financial crisis played a significant role in this trend, among other factors. In the study of Rogge (2012), the Data Envelopment Analysis provided every country with the opportunity to determine their ideal weightings to maximize their composite indicator score in comparison to other nations. While this flexibility is beneficial, it also has the potential to be disadvantageous as it may allow countries to appear as high achievers in ways that are difficult to justify, such as the over-emphasis or neglect of certain performance indicators. To illustrate this concern, this paper examines the EPI as calculated by the optimistic and pessimistic versions of the DEA model proposed by Zhou , Ang and Poh (2007). By analyzing both composite scores, the study identifies instances of undesirable specialization in performance. Chandrasekharan, Kumar, Raghunathan, & Chandrasekaran (2013) growth strategy was focused on utilizing the country's resources in an effective and balanced manner. They recognize the impact of natural resource depletion and pollution on various sectors of the economy, and to address this, they have developed an EPI. This index is designed to acknowledge the efforts made by states to prevent environmental degradation. In this article, they outline the methodology for constructing the EPI for the country, ranking states based on their EPI scores, and proposing options for devolving Central funds to states. Sima and Gheorghe's (2014) article provided an analysis of the 2014 EPI results, highlighting the main findings of the European Commission's research. While not intended as a full EPI assessment, the paper includes a correlation analysis between GDP/capita and EPI score, which reveals a moderate positive relationship between these two indicators. Additionally, a comparison between Romania and Switzerland demonstrates that Romania outperforms Switzerland in agriculture, with the greatest disparity between the two countries found in the area of water resources and sanitation. Wurie and Pillai's (2014) study aimed to explore the impact of population growth and consumption levels on environmental health in emerging nations. Additionally, the study proposes that cultural differences also play a role in affecting environmental health, independent of consumption and population expansion. The EPI (2010) serves as the basis for the outcome variable. The findings of the study suggest a significant correlation between environmental health and consumption levels in emerging nations. Fakher and Abedi's (2017) study delved into the effects of environmental quality (as measured by the EPI), direct foreign investment, and trade openness on economic growth within specific developing nations. To accomplish this, the study utilized the Auto Regressive Distributed Lag Model and ARDL bounds test methods. The findings revealed a noteworthy and positive correlation between the EPI and economic growth, as well as a positive and significant relationship with foreign direct investment. Shahabadi et al.'s study (2017) investigated the factors that affected the EPI in selected OPEC countries between 2000-2012, using a panel data approach. The findings indicate that governance index, internet users, and natural resource abundance have a positive and significant impact, while openness and carbon dioxide emissions per GDP have a negative and significant impact on the EPI in these countries. In Adeel-Farooq, Raji and Qamri (2023) study, the EPI developed by Yale University was utilized to measure environmental performance, rather than relying solely on CO_2 emissions as a single indicator. Empirical analysis was conducted using a range of estimators including fixed effect, random effect, Newey West, and generalized least square. The research uncovered a positive correlation between financial development and environmental performance in the countries studied. Almarafi et al.'s (2023) study uncovered the correlation between the EPI, Financial Development, and Economic Growth, by conducting a comprehensive literature review. Emphasizing publications from 2018 to 2022, the study ultimately found that environmental sustainability plays a crucial role in achieving economic growth and development in industrialized nations. As a result, policymakers must prioritize carbon costs and taxes, promote low-CO2 emissions technologies, reduce non-renewable energy subsidies, develop technology transfer programs, and establish a green trade policy. Cojocaru Bărbieru, Mihaila and Grosu (2023) research aimed to uncover the EPI and its GDP growth rate. By providing another incentive for companies in emerging countries to prepare sustainability reports, this study utilizes secondary data sources and descriptive statistical analysis to explore this relationship. Over the past decade, our analysis has revealed a weak positive correlation between EPI and GDP growth rate. Pujiati, Feronica, and Ridzuan (2023) study attempted to examine the relationship between the EPI and factors such as GDP per capita, government effectiveness, occupation index, population density, and innovation. This study's methodology is an example of a quantitative methodology. The study's findings demonstrate a strong and favorable correlation between the EPI and Government Effectiveness. The EPI and per capita GDP are positively correlated, with a major impact.

The goal of this study is to compare regional EPI scores for the last 27 years (1995-2022) and to examine whether there is a statistically significant relationship between nations' income levels and their environmental performance scores. The study seeks to answer the following research questions:

- How do EPI scores differ by world regions between 1995-2022?
- Is there a statistically significant relationship between income levels of nations and their environmental performance indicators?

When the studies in the literature are examined, it is seen that EPI scores are included and studies on environmental measurement and sustainability are examined at the level of certain regions or countries. Improvements or criticisms of the EPI scoring system are also included in these studies. The fact that a deep comparison has not been performed in all world regions in the relevant studies indicates the gap in the literature. Hence, comparisons of environmental performance, which must be measured to ensure environmental sustainability, in all regions constitute the motivation of this study. Based on this motivation, all EPI reports published between 1995-2022 were examined in this study, and it was aimed to perform regional comparisons. Then, it is aimed to examine whether there is a statistical relationship between the values of the indicators in the EPI report according to the average income level of the countries in the regions. The main contributions of this study include a comprehensive evaluation of the regional comparison of EPI indicators using the study's 27-year dataset and a more in-depth examination of the differentiation of variables identified as significant based on country income levels. The study explains how EPI is formed for individuals or institutions who work in the field and highlights the elements that need closer examination. Additionally, it has an illuminating character on the type of roadmap that ought to be created in areas with income disparities. Theoretically, it advances the literature by highlighting the differences between the outcomes of the analysis carried out with comprehensive data and those outcomes acquired with one year's worth of data.

2. Materials and Methods

The EPI data of all countries for the 1995–2022 period was compiled for this study. Within the scope of the study, EPI data of all countries between 1995-2022 were obtained and the countries were divided into 8 regions as Asia-Pacific, Eastern Europe, Former Soviet States, Global West, Greater Middle East, Latin America & Caribbean, Southern Asia and Sub-Saharan Africa. All data between 1995-2022 were organized for 3 policy objectives, 11 issue categories, and 40 indicators under The EPI framework, which are shown in Figure 1 by regions of all countries. The steps of the study are shown in Figure 2. In the study, first, data compilation and indicator selection were made. Then, country segmentation and regional indicator calculations were performed. In the third stage of the study, regional comparisons were analyzed in detail, and in the last step, statistical tests were carried out according to income levels.

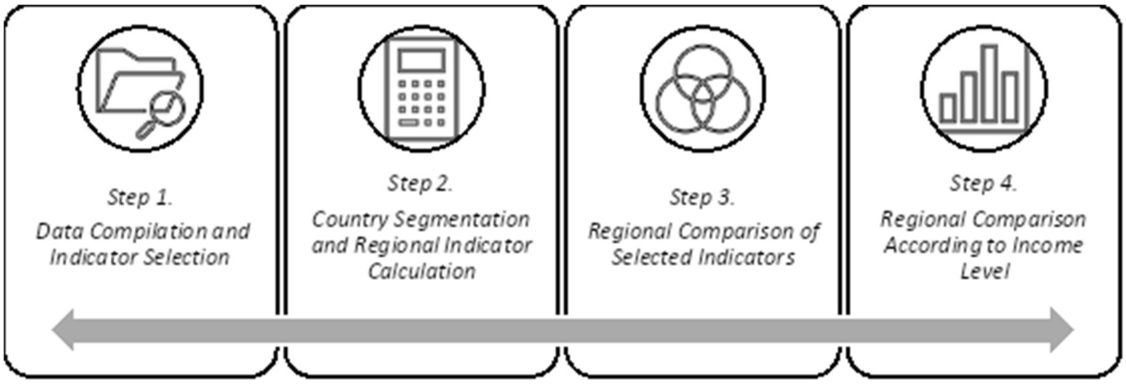

Figure 2. Steps of the Study

3. Findings and Discussion

The EPI is a data-driven overview of the global level of sustainability. The EPI ranks 180 nations on climate change performance, environmental health, and ecosystem vitality using 40 performance indicators across 11 issue areas. These metrics show how near countries are to meeting stated environmental policy targets on a national basis. The EPI produces a scorecard that recognizes environmental leaders and laggards and gives practical suggestions for countries seeking to move toward a more sustainable future (Wolf et al., 2022).

Step 1. Data Compilation and Indicator Selection

Within the scope of the study, first, EPI data were compiled. After the data arrangement was made on all indicators between 1995-2022, the effect of all indicators on the EPI score was calculated based on the indicator weights of 2022 and ranked from the most weighted indicator to the least weighted indicator. After this ranking, Pareto analysis was applied, and it was decided that 19 out of 40 sub-indicators should be used in the continuation of the study by the 80-20 rule. Since 19 indicators determined by Pareto constitute 80 percent of the calculated EPI score, analyses were continued on these indicators within the scope of the study. The Pareto chart is presented in Figure 3. The selected parameters are shown in Table 1.

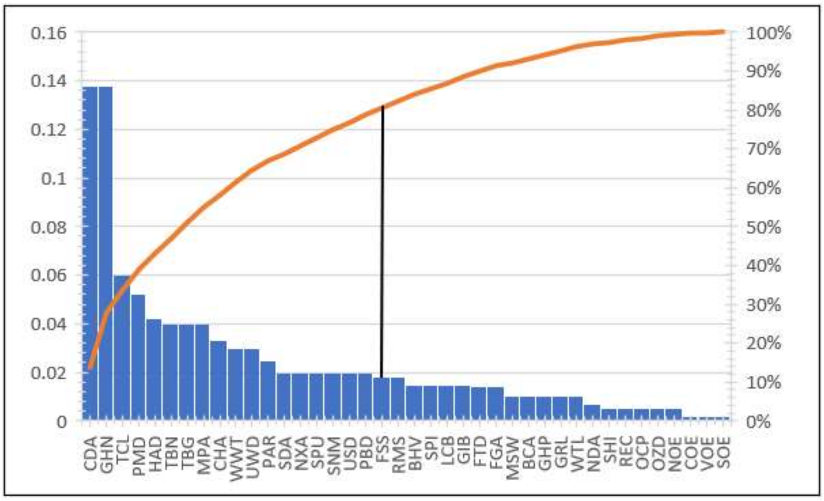

Figure 3. Pareto Chart for Indicator Selection

Table 1. Selected Indicators and Their Calculated Weights

CDA	"Adjusted emissions growth rate for carbon dioxide"	0.138
GHN	"Projected GHG Emissions in 2050"	0.138
TCL	"Tree cover loss"	0.060
PMD	"PM2.5 exposure"	0.052
HAD	"Household solid fuels"	0.042
TBN	"Terrestrial biome protection (national weights)"	0.040
TBG	"Terrestrial biome protection (global weights)"	0.040
MPA	"Marine protected areas"	0.040
CHA	"Adjusted emissions growth rate for methane"	0.033
WWT	"Wastewater treatment"	0.030
UWD	"Unsafe drinking water"	0.030
PAR	"Protected Areas Representativeness Index"	0.025
SDA	"Adjusted emissions growth rate for sulfur dioxide"	0.020
NXA	"Adjusted emissions growth rate for nitrous oxides"	0.020
SPU	"Sustainable Pesticide Use"	0.020
SNM	"Sustainable Nitrogen Management Index"	0.020
USD	"Unsafe sanitation"	0.020
PBD	"Lead exposure"	0.020
FSS	"Fish Stock Status"	0.018

As it is illustrated in Table 1, the PMD, HAD, USD, UWD and PBD indicators were selected under the Environmental Health category. TCL, PMD, HAD, TBN, TBG, MPA, CHA, WWT, PAR, SDA, NXA, SPU, SNM, USD, PBD and FSS indicators were selected under the Ecosystem Vitality category. CDA, GNH and TCL parameters are sub-indicators selected under the Climate Change Policy Objective category.

Step 2. Country Segmentation and Regional Indicator Calculation

The second step of the study consists of examining the selected EPI indicators of 180 countries with data as of 1995. In this context, first, countries were combined under regions and the average score of the selected parameters between 1995 and 2022 was taken to perform regional comparisons. Countries were grouped as, Asia-Pacific, Eastern Europe, Former Soviet States, Global West, Greater Middle East, Latin America & Caribbean, Southern Asia, and Sub-Saharan Africa and evaluated on selected parameters. The 27-year regional averages of the 19 selected parameters are calculated and presented in Table 2. In Table 2, the world average was also calculated for the selected indicators.

Table 2. Regional Calculations of Selected Indicators

	PMD	**HAD**	**UWD**	**USD**	**PBD**	**TCL**
Asia-Pacific	35.078	28.883	38.312	44.205	52.436	23.593
Eastern Europe	27.277	47.493	60.69	69.235	57.182	21.405
Former Soviet States	10.452	36.386	45.516	43.327	42.161	36.272
Global West	68.225	89.059	92.028	91.623	76.252	20.761
Greater Middle East	7.95	62.856	44.385	54.44	30.507	40.975
Latin America & Caribbean	37.146	40.967	39.553	45.64	45.912	23.864
Southern Asia	21.801	18.76	25.359	27.127	29.731	33.506
Sub-Saharan Africa	32.109	11.103	9.639	10.174	36.116	24.578
World Average	30.005	41.938	44.435	48.221	46.287	28.119
	TBN	**TBG**	**MPA**	**WWT**	**PAR**	**SDA**
Asia-Pacific	42.72	41.648	12.482	17.249	12.143	59.095

Eastern Europe	21.405	69.619	41.962	42.743	29.747	84.402
Former Soviet States	36.272	52.992	23.274	16.727	14.761	74.216
Global West	20.761	66.187	45.44	79.829	41.861	95.262
Greater Middle East	40.975	25.022	9.833	36.078	7.48	58.89
Latin America & Caribbean	23.864	54.271	14.249	11.85	41.929	64.139
Southern Asia	33.506	55	4.707	5.096	13.585	38.25
Sub-Saharan Africa	24.578	61.311	3.803	5.723	27.498	53.687
World Average	30.51	53.256	19.469	26.912	23.625	65.993

	NXA	**SPU**	**SNM**	**FSS**	**CDA**	**GHN**	**CHA**
Asia-Pacific	58.649	22.383	32.276	46.561	28.469	48.912	42.819
Eastern Europe	79.299	40.608	50.646	33.062	50.806	42.907	39.253
Former Soviet States	68.096	40.037	47.535	20.699	46.92	41.786	42.744
Global West	91.324	44.841	50.866	22.078	52.83	33.092	38.863
Greater Middle East	48.539	40.099	34.479	44.61	24.86	21.309	42.205
Latin America & Caribbean	50.508	37.084	29.514	31.584	30.155	48.944	35.704
Southern Asia	39.143	32.806	35.625	52.108	15.953	32.29	41.92
Sub-Saharan Africa	44.837	30.471	31.893	41.743	25.925	47.753	40.223
World Average	60.049	36.041	39.104	36.556	34.49	39.624	40.466

Step 3. Regional Comparison of Selected Indicators

In the third step of the study, regional comparisons of the selected indicators were made according to the world average. Regional comparisons are visualized and interpreted separately for the indicators selected under the main indicators Environmental Health, Ecosystem Vitality and Climate Change Policy Objective.

Regional comparisons are visualized and interpreted separately for the indicators selected under the main indicators Environmental Health, Ecosystem Vitality and Climate Change Policy Objective. In Figure 4, the position of the PMD, HAD, USD, UWD and PBD sub-indicators selected under the Environmental Health indicator against the world averages is seen as regional.

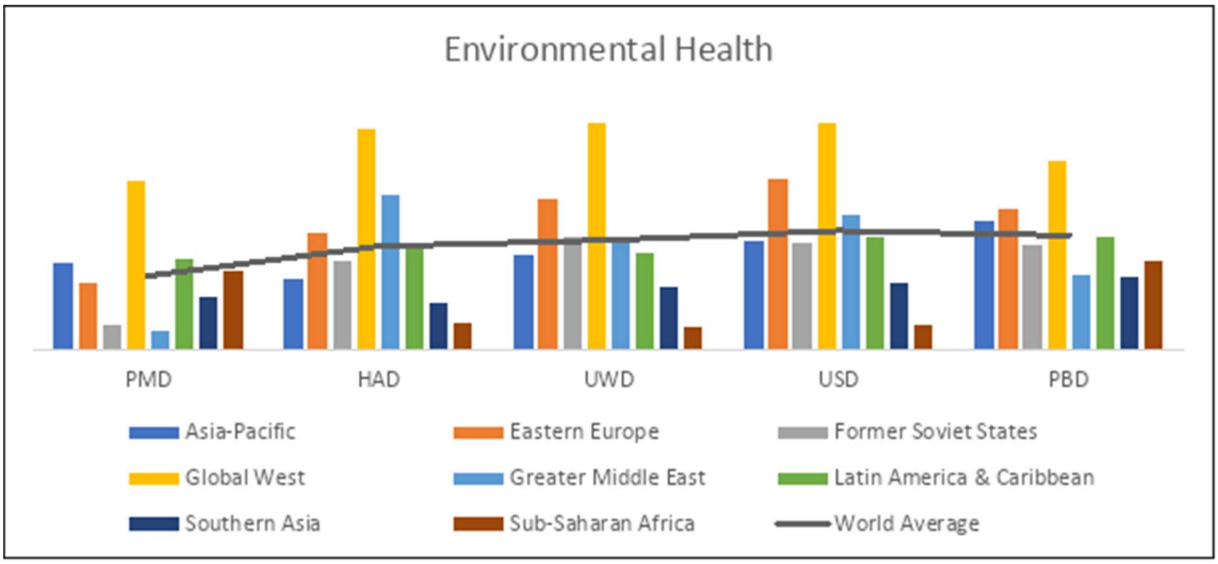

Figure 4. Regional Comparisons for Environmental Health Indicators

PMD means PM2.5 exposure. According to Indoor Air Hygiene Institute, PM2.5 are small particles that are suspended in the air for longer periods and have a diameter of less than 2.5 micrometers (more than 100 times smaller than a human hair). Due to their ability to penetrate the respiratory system deeply, reach the lungs, and enter the bloodstream, PM2.5 poses a health danger (Devadmin, 2021). Average particulate matter concentrations in certain developing nations are 4–15 times higher than WHO air quality guidelines (Yalçın, Tepe, Doğan, & Çizmeci, 2021). Because coal-fired power stations and other highly polluting sectors dominate in the Greater Middle East and Former Soviet States, these regions are more exposed to PM2.5 particles. Additionally, it is subject to violent sand and dust storms with high atmospheric PM2.5 concentrations (Schuster, 2022). Global West, on the other hand, adheres to stronger laws and makes use of cleaner technologies. The Western world no longer employs coal-fired power plants in favor of greener ones that rely on solar, electricity, and natural gas (International Agency for Research on Cancer, 2010). These all lower the exposure to PM2.5.

HAD indicates household solid fuels. Solid fuels are fuels, including coal, biomass, charcoal, wood or straw, animal dung, and crop waste, that are used to cook, heat, light, boil water and generate income for homes (Chen et al., 2020; Debbi et al., 2014). It is seen in the research of the International Agency for Research on Cancer that both urban and rural African communities frequently use biomass, and 89% of households in the surveyed nations rely on some form of solid fuel, which includes both biomass and charcoal. Almost all families in Africa's rural areas use biomass energy. Across Asia, 74% of households report using solid fuels, primarily biomass. Significant disparities in the utilization of coal and biomass energy may be seen throughout the developing globe. People in both urban and rural areas are converting to modern fuels. The richest countries such as the Global West have already adopted modern fuels due to their convenience and cleanliness, but countries such as Sub-Saharan Africa and Southern Asia cannot use these modern fuels because they cannot afford them. This situation has increased the use of household solid fuels (International Agency for Research on Cancer, 2010).

UWD represents unsafe drinking water. Centers for Disease Control and Prevention says that water that has parasites, pathogens, or poisonous substances in it is considered unsafe. Many things, including human or animal waste, pesticides, and other chemicals, can introduce harmful bacteria, parasites, and toxins into water. Diseases including cholera, typhoid, and polio are spread due to contaminated water and insufficient sanitation (Centers for Disease Control and Prevention, 2022). Open defecation is the most common cause of water pollution. In Nepal and India in Southern Asia, 32% of the population has open defecation. As a result, access to clean water becomes difficult. In Sub-Saharan Africa, although this percentage is less – about 23% of the population – faces an open defecation like Southern Asia. At the same time, clean water in Sub-Saharan Africa is only available in certain locations, and Africa has a high risk of desertification, which will further reduce water availability. When all these situations are combined, it becomes difficult for people in this region to access clean water (National Geographic, n.d.). Global West also has advanced wastewater treatment plants and extensive pipelines. This makes it easier to reach clean drinking water.

USD stands for unsafe sanitation. One of the biggest health and environmental issues in the world, especially for the poorest people, is unsafe sanitation. Lack of access to adequate sanitation is a major risk factor for infectious diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid and polio. Additionally, it makes malnutrition, particularly childhood stunting, worse. Regions with robust economies, including the Global West and Eastern Europe, have developed sanitary infrastructure. With rising income, more sanitation facilities are typically provided. Southern Asia and Sub-Saharan Africa lack the economic resources necessary to set up suitable sanitation facilities. This suggests that their sanitation is not as safe (Ritchie & Roser, 2021).

PBD is short for lead exposure. The Centers for Disease Control and Prevention defines Lead exposure as when people are exposed to lead through touching, ingesting, or inhaling lead or lead dust (Centers for Disease Control and Prevention, 2022). Lead exposure is increased in low- and middle-income nations such as Sub-Saharan Africa, Greater Middle East and Southern Asia due to expanding industrial activities, such as chemical manufacture and use, high lead-acid battery demand, and the prevalence of other vulnerabilities, such as poverty and malnutrition (Kordas, Ravenscroft, Cao, & McLean, 2018). Although these situations are in the Global West and Eastern Europe, these regions are more developed and are better at mitigating and managing these situations.

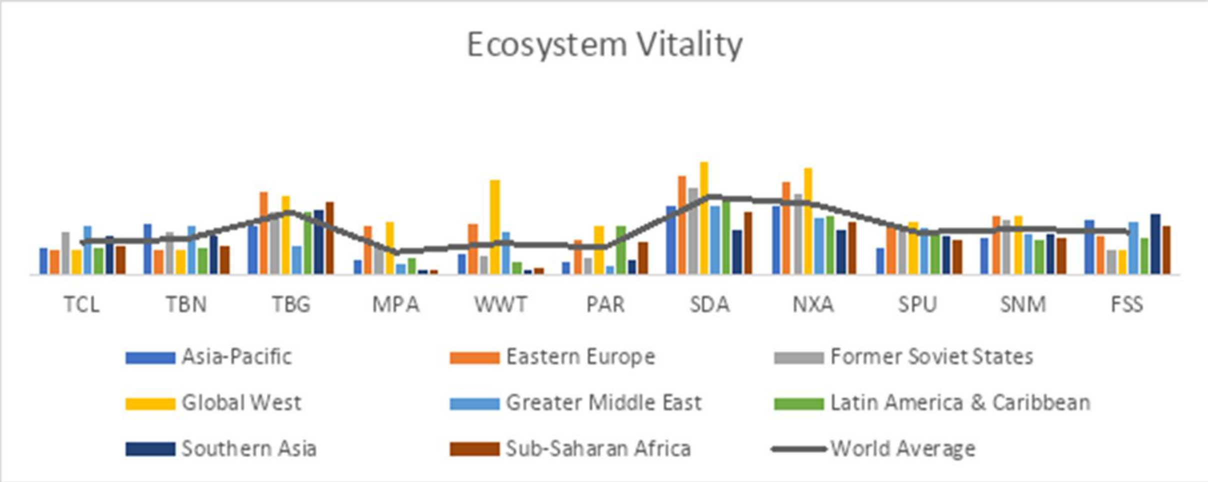

Figure 5. Regional Comparisons for Ecosystem Vitality Indicators

TCL means tree cover loss. According to the World Resources Institute Research tree cover loss is defined as the total elimination of trees for whatever reason, including damage brought on by people or by purely natural occurrences. The Asia-Pacific area is home to many nations that have implemented programs to lessen deforestation and encourage reforestation. For instance, China's Natural Forest Protection Program, which aims to expand forest cover and stop deforestation, has been put into effect. The embargo on new logging concessions implemented by Indonesia similarly serves to lower deforestation rates (World Resources Institute Research, n.d.).

TBN is used instead of Terrestrial biome protection (national weights). Large-scale ecological variation is organized under the biome concept. Terrestrial biomes can be identified by their dominating flora, which is primarily influenced by temperature and rainfall. Biomes are climatically similar geographic areas with a prevailing plant kind (Forseth, 2010). Terrestrial biome protection (national weights) value is found to give greater weight to biomes that are relatively rare within a country – and less weight to prevalent biomes (EPI, 2020). Because the Greater Middle East and Asia Pacific feature significant terrestrial biomes such as tropical rainforests, deserts, and grasslands as well as vast undeveloped lands, these regions prioritize protecting terrestrial biomes (Matthew R. Fisher, n.d.). Global West and Eastern Europe, in comparison, have seen rapid urbanization for a very long time. A large number of lands have been impacted by human activity. Therefore, they could not protect terrestrial biomes.

TBG is used instead of Terrestrial biome protection (global weights). TBG value is found to give greater weight to biomes that are relatively rare across the globe – and less weight to prevalent biomes (EPI,2020). Global West and Eastern Europe have rarer terrestrial biomes and are more successful at protecting them than Greater Middle East and Asia Pacific countries. Therefore, their values are higher.

MPA is short for marine protected areas. A park or other protected area that contains some marine or Great Lakes territory is referred to as a "marine protected area" in general (National Marine Protected Areas Center, n.d.). European Environment Agency reports state that developed and economically well-developed countries such as Global West and Eastern Europe countries are better in terms of establishment and management of marine protected areas than the less developed Sub-Saharan Africa and Southern Asia countries, whose priorities are economic development and growth (European Environment Agency, 2018).

WWT represents wastewater treatment. The removal of contaminants from wastewater, often known as sewage, before it enters aquifers or natural water bodies including rivers, lakes, estuaries, and seas is known as wastewater treatment. Any distinction between clean water and dirty water depends on the type and concentration of pollutants found in the water as well as on its intended usage because pure water cannot be found in nature (i.e., outside of chemical laboratories) (Nathanson & Ambulkar, 2023). According to WHO reports as substantial investments are presumed to be required, governments in economically underdeveloped and still developing regions like Sub-Saharan Africa, Southern Asia, and Asia Pacific are uninterested in sanitation programs. As a result, particularly in poorer nations, advancements in the provision of sanitation services have trailed behind those in the water supply. The installation of stringent rules on wastewater management is a result of the global Western and Eastern Europe's prioritization of environmental protection, sanitation, and public health. To guarantee wastewater is processed properly and safely discharged back into the environment, governments in these regions have made investments in wastewater treatment plants, cutting-edge technologies, and effective processes. (World Health Organization, 2005).

PAR signifies the Protected Areas Representativeness Index. The Protected Areas Representativeness Index (PARI) metric assesses how effectively terrestrial protected areas reflect a nation's natural diversity (Environmental Performance at Index, 2020). The Protected Areas Representativeness Index may change based on historical, political, and economic events. For instance, a nation is better at constructing and preserving protected areas the more politically stable it is. The ability of a nation to strengthen and expand its protection zones depends on how well its economy is doing (Janishevski, Noonan-Mooney, Gidda, & Mulongoy, 2008). It has a higher index than Latin America and the Global West, Greater Middle East and Asia Pacific regions, which are at a better level politically and economically.

SDA implies an adjusted emissions growth rate for sulfur dioxide. Based on the American Lung Association electricity production, commercial boilers, and other industrial operations including metal processing and petroleum refining are the main sources of sulfur dioxide emissions. Diesel engines are another major source, including old buses and trucks, locomotives, ships, and off-road diesel equipment (American Lung Association, 2023). In recently growing areas like Sub-Saharan Africa and Southern Asia, new and unregulated industrial operations are conducted using fossil fuels like low-quality coal and lignite. However, because they are already developed, areas like the Global West and Eastern Europe have undergone several industrial laws and utilize clean energy sources like natural gas (IEA, 2023). While the use of low-quality coal and lignite increases sulfur dioxide emissions, the use of clean energy such as natural gas reduces the emission rate.

NXA signifies an adjusted emissions growth rate for nitrous oxides. The amount of N2O in the atmosphere is rising as a result of human activities like agriculture, fuel burning, wastewater management, and industrial processes. 40% of the world's total N2O emissions are caused by human activity. Agriculture, land usage, transportation, manufacturing, etc. all emit nitrous oxide (United States Environmental Protection Agency, 2023). The use of nitrogen fertilizers, high temperatures and high humidity cause more nitrous oxide release (Zhang et al., 2023). These circumstances are extremely typical in places like Southern Asia and Sub-Saharan Africa. To limit nitrous oxide emissions, the Global West and Eastern Europe have tight laws and policies for agriculture. These stringent laws and policies help in reducing emissions.

SPU is short for sustainable pesticide use. Since they help ensure the sustainable production of food and feed, pesticides are frequently utilized in agriculture. They can also pose significant dangers to the environment, and human and animal health if handled incorrectly or inappropriately. To guarantee that existing pesticides adhere to current health, environmental, and safety regulations, governments set stringent standards for both the registration of new pesticides and the reevaluation of pesticides that are currently on the market. Sustainable use of pesticides contributes to further risk reduction. The OECD aims to ensure effective and long-lasting pest management measures, including resistance management, by improving training and promoting better compliance with existing standards (OECD, n.d). Therefore, regions containing OECD countries such as Global West and Eastern Europe have a high SPU. The Asia-Pacific and Sub-Saharan Africa regions that do not work on this issue are low.

SNM is short for Sustainable Nitrogen Management. Although nitrogen is a necessary component for life, it can have negative effects on the environment, ecosystems, and human health if it is not properly handled. A resolution to speed up efforts to considerably reduce nitrogen waste from all sources, particularly through agricultural practices, was accepted by the UN Environment Assembly (Geneva Environment Network, n.d.). To manage nitrogen, both the employment of machinery and fertilizers is useful. Infrastructure and technology are more advanced in economically developed regions like Eastern Europe, the former Soviet Union, and the Global West. As a result, the SNM value of these regions is higher. In addition, there are numerous government laws and education campaigns on sustainable agriculture in these areas. Due to its poor performance in both political and economic spheres, nitrogen management is also subpar in places like Sub-Saharan Africa and Asia-Pacific (Xin et al., 2015).

FSS implies fish stock status. Fish stock status, which takes into account all fish stocks located inside a country's exclusive economic zones (EEZs), is the proportion of a country's overall catch that originates from overexploited or failed stocks. This statistic provides insight into the effects of a nation's fishing activities within its EEZs because increased stock exploitation results in lesser catches when it continues and increases (EPI, 2020). Many traditional fisheries systems are built on different types of fishing ground closures, especially in parts of the Asia Pacific and Southern Asia. These closures give fish populations a sanctuary where they are either permanently or temporarily shielded from fishing activity (Lymer, Funge-Smith, Clausen, & Miao, 2008). These circumstances raise the value of the fish stock status. On the other hand, fish populations in the Global West and Former Soviet States may be impacted by the warming and acidity of the oceans. It decreases the stock in this instance.

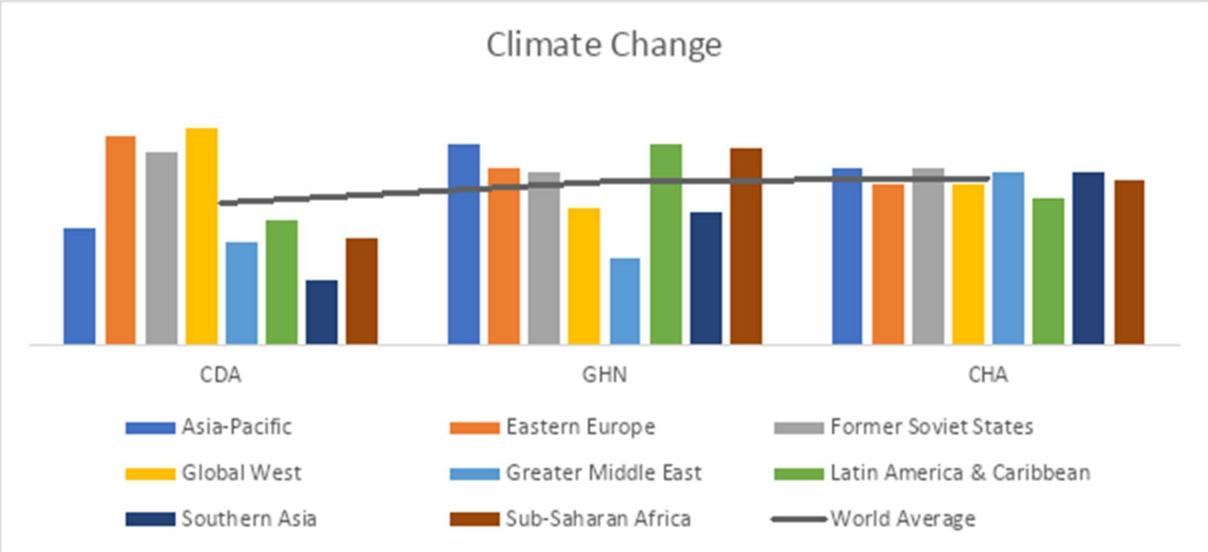

Figure 6. Regional Comparisons for Climate Change Indicators

CDA stands for adjusted emissions growth rate for carbon dioxide. Global climate change is mostly caused by carbon dioxide emissions. To prevent the worst effects of climate change, emissions must be drastically reduced worldwide. The world's largest per capita emitters of CO2 are the major oil-producing countries; this is especially true for those with relatively low population sizes. Most are in the Middle East. However, most of the major oil producers have a relatively small population, which means their total annual emissions are low. Therefore, emissions are higher in Global West and Eastern Europe with larger populations. Poorer countries, such as Sub-Saharan Africa and Southern Asia, also have lower emissions (Ritchie & Roser, 2020).

GHN means Projected GHG Emissions in 2050. Because they capture heat, greenhouse gases warm the globe. Almost all of the rise in greenhouse gases in the atmosphere over the past 150 years can be attributed to human activity. Burning fossil fuels for transportation, heat, and electricity is the main cause of human-related greenhouse gas emissions (United States Environmental Protection Agency, 2023). Because greenhouse gas emissions contribute to climate change, countries must reduce them. More greenhouse gas emissions are produced in the Global West, Southern Asia, and the Greater Middle East than in Asia-Pacific, Latin America and the Caribbean, regions with lower levels of industrial activity and population density (Lamb et al., 2021). No matter how many studies on greenhouse gas emissions are conducted, it is anticipated that things will remain the same in 2050 due to the lack of significant changes in population density and industrialization.

CHA implies an Adjusted emissions growth rate for methane. Methane emissions from human activity include livestock farming and natural gas line leaks. Additionally, natural sources like termites generate methane. In addition, atmospheric chemical reactions and natural soil processes contribute to the removal of CH4 from the atmosphere. 50–65 percent of the world's total CH4 emissions are caused by human activity (United States Environmental Protection Agency, 2023). Sources of methane emissions are widely distributed around the planet. As a result, the rate of emission growth is roughly the same across all regions. In comparison to other locations, temperatures and humidity are higher in Latin America and the Caribbean. This humidity and temperature may result in a slightly higher rate of increase in methane emissions (Rößger, Sachs, Wille, Boike, & Kutzbach, 2022).

Step 4. Regional Comparison According to Income Level

In the "regional parameter comparison according to income levels", which constitutes the fourth step of the study, hypotheses have been established. Since a total of nineteen indicators were selected, hypotheses were established for each indicator and an independent t-test was applied.

In this step of the study, before the hypotheses were established, the income levels of the countries in the eight regions in the study were obtained from the Worldbank Database (https://data.worldbank.org/). The income level of all the countries included in the study was compiled every year between 1995 and 2022; They were assigned to regions and the twenty-seven-year average income level was calculated regionally. According to the relevant dataset, the average income levels of the regions were determined as Low income (L), Lower middle income (LM), Upper middle income (UM), and High income (H). Table 3 shows the twenty-seven-year average income level of the regions in the study.

Table 3. Average Income Levels of the Regions

Regions	Average Income Level
Asia-Pacific	LM
Eastern Europe	UM
Former Soviet States	LM
Global West	H
Greater Middle East	UM
Latin America & Caribbean	UM
Southern Asia	LM
Sub-Saharan Africa	LM

After the regional income level average calculation, hypotheses were established and presented in Table 4.

Table 4. Hypotheses

Hypothesis No	Hypothesis Explanation
H1	There is a significant difference between the average PMD value of the regions and the average values of their income levels.
H2	There is a significant difference between the average HAD value of the regions and the average values of their income levels.
H3	There is a significant difference between the average CDA value of the regions and the average values of their income levels.
H4	There is a significant difference between the average GHN value of the regions and the average values of their income levels.
H5	There is a significant difference between the average TCL value of the regions and the average values of their income levels.
H6	There is a significant difference between the average UWD value of the regions and the average values of their income levels.
H7	There is a significant difference between the average USD value of the regions and the average values of their income levels.
H8	There is a significant difference between the average PBD value of the regions and the average values of their income levels.
H9	There is a significant difference between the average TBD value of the regions and the average values of their income levels.
H10	There is a significant difference between the average TBG value of the regions and the average values of their income levels.

H11	There is a significant difference between the average MPA value of the regions and the average values of their income levels.
H12	There is a significant difference between the average WWT value of the regions and the average values of their income levels.
H13	There is a significant difference between the average PAR value of the regions and the average values of their income levels.
H14	There is a significant difference between the average SDA value of the regions and the average values of their income levels.
H15	There is a significant difference between the average NXA value of the regions and the average values of their income levels.
H16	There is a significant difference between the average SPU value of the regions and the average values of their income levels.
H17	There is a significant difference between the average SNM value of the regions and the average values of their income levels.
H18	There is a significant difference between the average FSS value of the regions and the average values of their income levels.
H19	There is a significant difference between the average CHA value of the regions and the average values of their income levels.

Whether there is a significant difference between the regional income level average and the selected indicator averages was analyzed by independent t-test and the results are presented in Table 5.

Table 5. Hypotheses Results

Hypothesis	**t-value**	**p-value**	**Result***
H1	4.106	0.000534	Accepted
H2	4.443	0.000278	Accepted
H3	6.549	< 0.00001	Accepted
H4	10.537	< 0.00001	Accepted
H5	9.365	< 0.00001	Accepted
H6	4.844	0.00013	Accepted
H7	5.199	0.000067	Accepted
H8	7.919	< 0.00001	Accepted
H9	8.802	< 0.00001	Accepted
H10	9.985	< 0.00001	Accepted
H11	2.945	0.005318	Accepted
H12	2.713	0.00841	Accepted
H13	4.365	0.000323	Accepted
H14	9.91	< 0.00001	Accepted
H15	8.938	< 0.00001	Accepted
H16	13.111	< 0.00001	Accepted
H17	11.428	< 0.00001	Accepted
H18	8.301	< 0.00001	Accepted
H19	41.519	< 0.00001	Accepted

** The results are significant at $p < 0.05$*

As seen in Table 5, all p-values are lower than 0.05 and all hypotheses were accepted at the 95% significance level. Hence, it has been observed that there is a significant difference between the indicator averages of the regions and the average income levels. In addition, hypothesis tests were also evaluated at 90% and 99% confidence intervals. No significant difference was observed in the results of the additional analyses.

For sustainable development, the correlation between income level and environmental performance measurement is of utmost importance. The ability of a country to invest in environmentally friendly technologies and practices is frequently correlated with income level. Environmental performance measurement enables richer nations to maintain their ecological commitments by monitoring the efficacy of these efforts. Additionally, it draws attention to inequalities, encouraging international cooperation and assisting less developed countries in implementing greener measures. In the end, this link emphasizes how important it is to strike a balance between economic success and environmental well-being to ensure a sustainable future. It has been shown that there is a significant difference between the income levels of the selected indicators with this step of the study. The results found are in parallel with the studies related to EPI indicators and income level in the literature (Esty & Porter, 2005; Cracolici, Cuffaro, & Nijkamp, 2010; Samimi et al., 2011; Hsu, Lloyd, & Emerson, 2013; Fakher & Abedi, 2017; Morse, 2018; Alhassan, Usman, Ike, & Sarkodie, 2020; Sarkodie, 2021; Raza, Sui, Jermsittiparsert, Żukiewicz-Sobczak, & Sobczak, 2021; Adeel-Farooq et al., 2023; Bădîrcea, 2023).

4. Conclusion

A vital instrument for nations to evaluate and enhance their environmental management is the EPI. This index offers a thorough assessment of a country's environmental performance, considering several variables like biodiversity preservation, air quality, water resources, and efforts to battle climate change. Its importance is seen in the broader context of sustainability as well as in the assessment of environmental health. The EPI is essential for international comparisons because it allows nations to compare their performance to that of their counterparts and pinpoint best practices. By allowing countries to learn from one another's triumphs and errors, this information exchange promotes international collaboration on environmental challenges. The EPI encourages a shared commitment to preserving our planet for future generations in a globalized world where environmental concerns cut across national boundaries. In essence, the EPI is a catalyst for creating environmental consciousness and advancing a sustainable future for all, not just a measurement tool.

Within the scope of this study, all the necessary indicators for EPI scores of 180 countries between 1995-2022 were compiled and the most important indicators were selected by Pareto analysis. Then, the relevant countries were divided into eight regions and regional comparisons of the selected parameters were analyzed in depth. While making the comparative analysis, sub-indicators selected from the three main indicators used in the EPI index were examined separately. In the next stage of the study, whether there is a significant difference between the twenty-seven-year regional average of the selected indicators and the income levels of the regions to take the study one level further, was analyzed with the independent t-test. As a result, nineteen hypotheses were accepted, and it was revealed that there was a statistically significant difference and studies showing parallelism were stated in the literature. The fact that indicators of the EPI have interrelated relationships with each other was not considered within the scope of the study shows the limitations of the study. In future studies, it is planned to determine the relationship between EPI indicators and to make comparisons on a continental basis.

The findings of this study are important to environmental agencies and policy makers who are interested in enhancing environmental sustainability. The enhanced environmental performance in high-income countries indicates that economic resources have an important role to play in environmental protection. It is therefore recommended to provide financial support, capacity building and environmentally friendly technology transfer to improve environmental performance in low-income countries. Furthermore, comparisons between the regions conducted in the study suggest that different regions have different environmental concerns. For example, regions with poor air quality can put measures in place to reduce emissions, while regions lagging behind in terms of biodiversity can upscale conservation. In short, some strategies have to be developed by regions and income groups to preserve the environment, and long-term environmental performance measures such as EPI are an important tool in the process.

Statements & Declarations

Ethical Approval

Since this study did not recruit any human and/or animal subjects, this section does not apply.

Consent to Participate

Not applicable.

Consent to Publish

The authors confirm that the final version of the manuscript has been reviewed, approved, and consented for publication by all authors.

Author Contributions

All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by Murat Oturakci. previous studies were analyzed by Rabia Sultan Yildirim and global comparisons were performed by Busra Yilmaz. The first draft of the manuscript was written by Murat Oturakci and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript."

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Availability of data and materials

All data and materials are available in the manuscript.

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