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DEVELOPMENT OF AN ENVIRONMENTAL PERFORMANCE RANKING USING TOPSIS

CLARA CHUN MARQUÍNEZ GARCÍA

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TÍTULO: Desarrollo de un ranking sobre desempeño ambiental usando TOPSIS

RESUMEN:

El desempeño ambiental se ha convertido, recientemente, en una materia importante para muchos gobernantes, por ello, existen varios indicadores que lo evalúan y a partir de los cuales se llevan a cabo diferentes rankings. El objetivo de este trabajo es desarrollar un ranking sobre el desempeño ambiental, utilizando la Técnica para el orden de preferencia por similitud con la solución ideal (TOPSIS), y compararlo con el obtenido por el 2020 EPI. TOPSIS es un método de análisis de decisión basado en criterios múltiples que se utiliza para ordenar alternativas, teniendo en cuenta la maximización de una distancia a una solución ideal negativa y la minimización de una distancia a una solución ideal positiva. Los resultados obtenidos muestran que hay diferencias entre las puntuaciones obtenidas por ambos métodos, consecuentemente el ranking global presenta ciertas variaciones. El nuevo ranking obtenido, utilizando este método alternativo, permite un cálculo sencillo, práctico y útil para la gestión ambiental.

TITLE: Development of an environmental performance ranking using TOPSIS

ABSTRACT:

In the recent years, the environmental performance of a country has become an important aspect for governments and policy makers, so several indicators have been development to assess this topic, and from which different rankings have been carried out. So, the aim of this study is to develop an environmental performance ranking, using the Technique for order preference by similarity to the ideal solution (TOPSIS) method, and compare it with the 2020 EPI ranking. TOPSIS is a multi-criteria decision making analysis used to rank different alternatives, based on various decision criteria, taking into account the maximization of the distance to a negative ideal solution and the minimization to a positive ideal solution. The results obtained present differences when comparing scores, so the global ranking has also changed in some way from the original one. The new ranking obtained, using an alternative method, provides a simple, practical and useful way to calculate environmental measurements.

PALABRAS CLAVE: Índice de desempeño ambiental, ranking, método TOPSIS, desarrollo sostenible.

KEYWORDS: Environmental Performance Index, ranking, TOPSIS method, sustainable development.

SÍNTESIS DE LAS CONCLUSIONES EN ESPAÑOL:

Tras aplicar el método TOPSIS a los datos de 2020 EPI, se obtuvieron diferencias respecto a los obtenidos con éste, lo que permite evaluar de otra manera la situación de los países y las políticas que implementan en esta materia. En el procedimiento se han utilizado los indicadores y las ponderaciones que propone el 2020 EPI, por lo que los resultados obtenidos heredan en parte los problemas que este podía tener por la elección subjetiva de los pesos y de los indicadores. Sin embargo, este método proporciona unos resultados más consistentes, que la media ponderada, al basarse en la distancia euclidiana a un punto, y pueden ser de utilidad para la elaboración de políticas de desarrollo sostenible más objetivas.

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1. INTRODUCTION

In recent years, the environmental performance of a country has become an important aspect to be measured, as societies are more aware of environmental problems like pollution or climate change, and the idea of a sustainable future is becoming more popular. We can see, for example, that many countries have subscribed to the Kyoto Protocol in 1997 or the Paris Agreement in 2015, which aim to reduce the greenhouse gases emissions.

Another example can be that the World Bank has increased the lending portfolio for environmental projects, and it establishes measurements and policies to reduce the adverse environmental effects of Bank-supported activities (Segnestam, 1999). Therefore, the increasing concern about the environmental performance has become an interesting topic for various researchers.

The environmental performance of a country can be measured in different ways and several indicators have been developed for it (Färe *et al.*, 2004; Wendling *et al.*, 2020; WIPO, 2021; Zhou *et al.*, 2006). These indicators measure environmental issues as pollution, CO_2 emissions, biodiversity, environmental education, climate change, environmental health, and many others.

The use of one indicator or other depends on each case, like the objectives that want to be achieved. However, there are some characteristics that all of them should have. It should be closely linked to the environmental problem addressed in each situation, it should be composed of a limited number of variables to be more effective, and it should have a clear design to avoid confusion. It also must be realistic in terms of its costs, as it is costly to collect and to develop it, so the costs should be considered, and the data used for the development of it must be reliable (Segnestam, 1999).

For example, an index, that measures the degree in which a firm, an industry or a country produces good outputs and reduces bad outputs, was constructed by (Färe *et al.*, 2004), and in their study they concluded that an increase in the Gross Domestic Product (GDP) per capita will eventually demand an increase in environmental quality. The authors also found that countries, which are below the median level of environmental performance, have a higher use of oil in relation to output than the ones that are above the median level, so a reduction in the oil consumption would be beneficial regarding environment.

Another approach to measure environmental performance was used by (Zhou *et al.*, 2006), in which they carried out an analysis over 26 Organisation for Economic Co-operation and Development (OECD) countries. And the conclusions that they obtained were that there has been an improvement in the environmental performance of these countries, mainly due to technological enhancements.

Environmental performance indicators also are very important for companies because, as sustainability is becoming more important, stakeholders and the public opinion want to see environmental improvements. Therefore, nowadays, most companies, especially the ones that have high levels of environmental risk, have integrated environmental issues into their strategy formation and they regularly publish environmental reports. So, thanks to the corporate environmental policy is possible to see the objectives and goals of the company towards a sustainable development (Azzone *et al.*, 1996).

Moreover, environmental performance benefits companies which include environmental provisions on their balance sheets, as it is highly valued by investors because they can actually see the reliability of the information. So, companies can increase their competitive advantage and lower the litigation risk, which therefore will increase their market value. However, environmental performance also has its disadvantage, it is costly, so this will lead to lower revenue and then, it possibly decreases the market value (Baboukardos, 2018).

In addition, the ISO standard on environmental management systems provide guidance to companies to determine whether the company´s environmental performance is achieving the objective, that are set by the company´s administration, and to identify improvements that are needed (Jasch, 2000).

The index that we will use in this study is the 2020 Environmental Performance Index (EPI). It was developed by the Yale University, and it is a measurement that "provides a data-driven summary of the state of sustainability around the world" (Wendling *et al.*, 2020: II). It is composed of 32 individual indicators across 11 categories, and it ranks 180 countries in terms of environmental health and ecosystem vitality. Therefore, it can be used as a policy tool for governments because with the information that it provides, they can see the problems, set targets, and use the best policies to achieve the United Nations Sustainable Development Goals and they can move towards a sustainable future.

This index is also used as a sub indicator in the Global Innovation Index developed by the World Bank (WIPO, 2021). This global index aims to measure the level of innovation in a society, and it is composed of two sub-indices, one that considers the elements and factors of an economy that promote innovation, and the other measures the results of innovative activities of an economy. The EPI is part of the innovation input sub-index, as it provides information on whether countries are establishing environmental policy targets. In addition, the World Bank also has a ranking of countries in terms of environmental performance, using this Global Innovation Index.

The objective of this work is to develop a new indicator through a multi-criteria decision analysis method, so we can obtain a new environmental performance ranking of the countries studied that can be compared with the EPI developed by the Yale University, and to see the differences between the two and argue the advantages and disadvantages of each of them.

The EPI is one of the best indexes to evaluate the sustainable development of a country, as it grouped together several metrics about natural resource management and protection of human health from environmental risks. It makes available data and information that governments and policy makers can use to achieve the international sustainable development goals, which in some cases policies can be hard to implement.

However, the EPI has its limitations, it presents some gaps especially in agriculture, water resources and biodiversity, and it does not include spillover environmental impacts from countries' activities. It can also improve its data collection, reporting and verification.

One of the reasons to investigate about this topic, is because I think the sustainable development of a country is very important to assure a good future for our society, and it should be a big concern for everyone because it affects all of us, as we can see all the natural disasters that have been happening recently, therefore it should be preserved, and the application of measurements and policies are important to achieve that. So, with this study maybe we can see some solutions to reach it.

Another reason is that the first semester of this year I went on an Erasmus mobility to Belgium, and while living there and spending time with Belgians and people from other nationalities, I felt that the Belgian society is more aware of the environmental protection and ecological status than here in Spain, so I want to see whether this is actually true. It also got me wondering how well Spain is doing, in these terms, compared to other countries.

2. ENVIRONMENTAL INDEXES

Environmental performance is an important topic nowadays, as a good environmental performance is becoming a big concern for many organizations, governments or countries and the objective of many polices. And societies are more aware of environmental problems like pollution or climate change or the natural disasters that have been happening these recent years, so the necessity of an environmentally sustainable future is becoming more popular. In order to achieve this environmental sustainability, environmental performance has to be measured so governments, nations or organizations can evaluate their situation and therefore, act by implementing measures or policies in specific aspects to improve their performance. For this reason, environmental indexes are developed. In this sense, the newspaper, El País, published the last 18th May a piece of news about how four indicators, that are used to measure the climate change progress, have registered record levels this past year. The General Secretary of the United Nations has defined this as the human failure to confront climate disasters, and he claimed that the solution is the transition to renewable energies before it is too late, and he also requested nations to accelerate the establishment of this type of energies. With this example, we can see the importance of environmental indicators

As mentioned before, there are several indicators that measure different variables related to the environmental performance, that provide useful information to everyone interested in it, especially organizations, governments or policy makers. Some of the main environmental indicators are described below:

2.1. SUSTAINABLE DEVELOPMENT GOALS INDEX (SDGI)

The SDGI is an indicator developed by the United Nations, that measures a country's performance on the 17 sustainable development goals:

1. No poverty: Eradicate poverty in all its forms.
2. Zero hunger: Reduce as much as possible hunger and malnutrition.
3. Good health and well-being: Provide a good health for everyone, increase life expectancy and reduce mortality.
4. Quality education: Achieve inclusive and quality education for all.
5. Gender equality: End any kind of discrimination against women.
6. Clean water and Sanitation: Access to safe and affordable drinking water for everyone.
7. Affordable and clean energy: Extend infrastructure and improve technologies to provide clean and more efficient energy.
8. Decent work and economic growth: Promote sustained economic growth, higher productivity and innovation.
9. Industry, innovation and infrastructure: Increase investments in infrastructure and technological progress.
10. Reduced inequalities: Decrease income inequality.
11. Sustainable cities and communities: Make cities sustainable with investments in public transport, green public spaces or urban planning.
12. Responsible consumption and production: Efficient management of our natural resources to reduce our ecological footprint.
13. Climate action: Help vulnerable regions to adapt to climate change and to invest in low-carbon development, to integrate disaster risk measures or sustainable management.
14. Life below water: Manage and protect marine and coastal ecosystems from pollution, promoting its conservation and sustainable use.

15. Life on land: Reduce natural habitats and biodiversity losses.
16. Peace, justice and strong institutions: Reduce all type of violence, and end conflicts and insecurity.
17. Partnerships for the goals: Enhance global partnership and cooperation.

It also shows the progress of each country towards these SDGs, as well as the areas where improvement is necessary. As well as the EPI, it scores countries on a 0-100 scale, being 0 the worst performance and 100 the best outcome, highlighting their strengths and weaknesses. To construct the composite index, they use several individual indicators for each goal, in total 115 indicators where 85 were global indicators and 30 were used specifically for the OECD countries. The method used was based on the arithmetic mean of the indicators that compose each goal to score it, then the score of each goal is averaged between all 17 goals to obtain the final score. The weights used are equal for each indicator, so in order to improve the total score, countries have to focus on all goals, especially in those that they are far to achieve.

The 2020 SDGI ranked 166 countries of all over the world, where Sweden was placed in first place, followed by Denmark and Finland. The top 20 was mostly represented by OECD countries.

2.2. GLOBAL GREEN ECONOMY INDEX (GGEI)

The GGEI is an indicator developed by Dual Citizen since 2010 which aims to measure the environmental sustainability performance of a country to facilitate stakeholders the understanding of policies or investments. It measures 160 countries across 18 indicators from two approaches, one shows the progress of each indicator from 2005 to the present and the other focuses on the distance between a country's current performance and a global environmental sustainability target. It is defined in four dimensions, climate change, sector decarbonization, green markets and environmental health, where each of them is composed of a few indicators. Climate change & Social equity refers to Greenhouse gases (GHG) emissions/GDP, GHG emissions per capita, income inequality measures by the Gini coefficient and gender inequality in the workplace; Sector decarbonization determines the performance of efficiency sectors, specifically for buildings, electricity & heat, manufacturing & construction, transport and waste & resource efficiency; Green markets & ESG investment dimension focuses on green investment attractiveness, green innovation and gender equality in governance; and Environmental health wants to measure the consequences of human activity in ecosystems, so it takes into account agriculture, air quality, biodiversity, forests, oceans and water stress.

The GGEI gives equal weight for the indicators in each dimension, and each dimension also has an equal weight (25%) in the total score, while the two approaches have different weights, given 25% to the progress over time and 75% to the distance to the environmental sustainability targets. It then ranks the countries in a 0-100 scale. The 2022 results show that Sweden ranks first in the aggregated index, and then Switzerland and Norway, being the top 10 represented by European countries. However, the countries with higher progress over the years are Jordan, Uruguay and Israel.

2.3. GLOBAL INNOVATION INDEX (GII)

The GII is another indicator that can measure the environmental performance of a country, it specifically measures the innovation ecosystem performance of 132 countries and tracks innovation. Its objective is to define metrics and methods that can display the innovation of a society. It is composed of two sub-indices, the Innovation Input Sub-index and the Innovation Output Sub-index, each one is determined from several variables. The Input sub-index includes elements of an economy that promote and facilitate innovation activities, like Institutions which refers to political, regulatory and business environments, or Human capital and research that includes education, tertiary education and R&D, Infrastructure, where the EPI is included, as an indicator within the Ecological sustainability element, as well as ICTs and General infrastructure pillars. Market sophistication is another element included which refers to credit, investment and trade, diversification and market scale, and Business sophistication which is defined by knowledge workers, innovation linkages and knowledge absorption. On the other hand, the Output sub-index focuses on the results of innovative activities, which are knowledge and technology outputs and creative outputs. Although the main objective of this indicator is to measure innovation, it includes a specific element related to the environmental performance, so it can also provide useful information in this matter.

The two sub-indexes are given the same weight in the total score, and they are calculated from a total of 81 individual indicators. Each of the elements of the variables that compose the sub-indexes are calculated as the weighted average of the individual indicators and then they are normalized to a 0-100 scale.

The 2021 results place Switzerland as the country with the highest innovation (65.5), followed by Sweden and then United States of America, while the worst innovation performance is given to Angola with just a 15 score.

2.4. ECOLOGICAL FOOTPRINT (EF)

The ecological footprint was introduced for the first time by Wackernagel & Rees (1996), and it is defined as the area of land and water required to produce the goods and services demanded from the human activity. It can be seen as a measure of environmental sustainability, as it shows how much countries consume and the actual amount they have. So, the EF helps countries improve their environmental sustainability and well-being, governments optimize public investments and citizens to be aware of their impact on the planet.

The EF accounting measures the demand and supply of nature, on the demand side the ecological footprint counts all the productive areas like cropland, grazing land, fishing grounds or forests, that a society uses, and it measures the ecological assets required to produce the natural resources consumed and to absorb waste. The supply side refers to the biocapacity of a society, the productivity of the ecological assets. So, it basically, measures how fast humans consume resources and generate waste (energy, settlement, paper, food) compared to how fast nature absorbs our waste like carbon footprint and built-up land, and produces new resources like forests, cropland, pasture and fisheries. Both sides are measured in global hectares because they are comparable and standardized. So, if the ecological footprint generated is higher that the biocapacity of the region, there is a biocapacity deficit or ecological deficit, and if it is vice versa, there is a biocapacity reserve.

2.5. ENVIRONMENTAL VULNERABILITY INDEX (EVI)

The Environmental Vulnerability Index is an indicator that focuses on the potential damage to the natural environment, and it was developed by the South pacific Applied Geoscience Commission (SOPAC) and the United Nations Environment Programme (UNEP). It provides countries with useful information to learn how vulnerable they and to understand the influence that social and economic variables have on environmental sustainability. Countries are able to analyze their status, so they can modify their policy measures (Kaly *et al.*, 2004).

The EVI uses 50 indicators grouped into issue categories, Climate change, Biodiversity, Water, Agriculture and fisheries, Human health aspects, Desertification and Exposure to natural disasters, that at the same time compose three sub-indices, Hazards, Resistance and Acquired vulnerability. Each indicator is normalized into a 1-7 vulnerability scale, being 7 the most vulnerable, and then, they are averaged into a single final score. So instead of ranking countries on a scale from best to worst, they classify countries whether they are vulnerable or not. These indicators are 'smart', in the sense that they indicate various conditions and processes that must be operating correctly if the measure is favorable. And they were designed to be policy relevant. For example, it uses indicators as high wind, wet periods, sea temperatures, tsunamis, country dispersion, isolation, ecosystem imbalance, among others.

3. ENVIRONMENTAL PERFORMANCE INDEX (EPI)

The 2020 Environmental Performance Index (EPI) is an indicator developed by the Yale University that “provides a data-driven summary of the state of sustainability around the world” (Wendling *et al.*, 2020), ranking 180 countries on environmental health and ecosystem vitality. So, with the EPI everyone is able to see the leaders and laggards of environmental performance and to get practical information to move towards a sustainable future. It offers help for policy makers to see the problems, set the correct targets, track trends, understand outcomes, and make the best policies.

The EPI uses 32 performance indicators across 11 issue categories, and it focuses on two **policy objectives**, environmental health and ecosystem vitality (Figure 3.1).

The policy objective Environmental health (HTL) represents 40% of the total indicator and it is composed of four different **issue categories**, Air quality (AIR), Sanitation and drinking water (H2O), Heavy metals (HMT) and Waste management (WMG). Simultaneously, each issue category of HTL is composed of several indicators, being in total 7 indicators:

- AIR uses three indicators, Ambient particulate matter pollution (PMD) that measures the PM_{25} exposure, Household air pollution from solid fuels (HAD) that measures the exposure to household pollution caused by household solid fuels, and Ozone (OZD) that measures the ground-level ozone pollution.
- H2O is composed of Unsafe sanitation (USD) which refers to the exposure to inadequate sanitation facilities, and Unsafe drinking water (UWD).
- HMT is equal to Lead exposure indicator (PBD) which refers to the exposure to lead contamination in the environment.
- WMG uses Solid waste (MSW) which measures the proportion of controlled household and commercial waste.

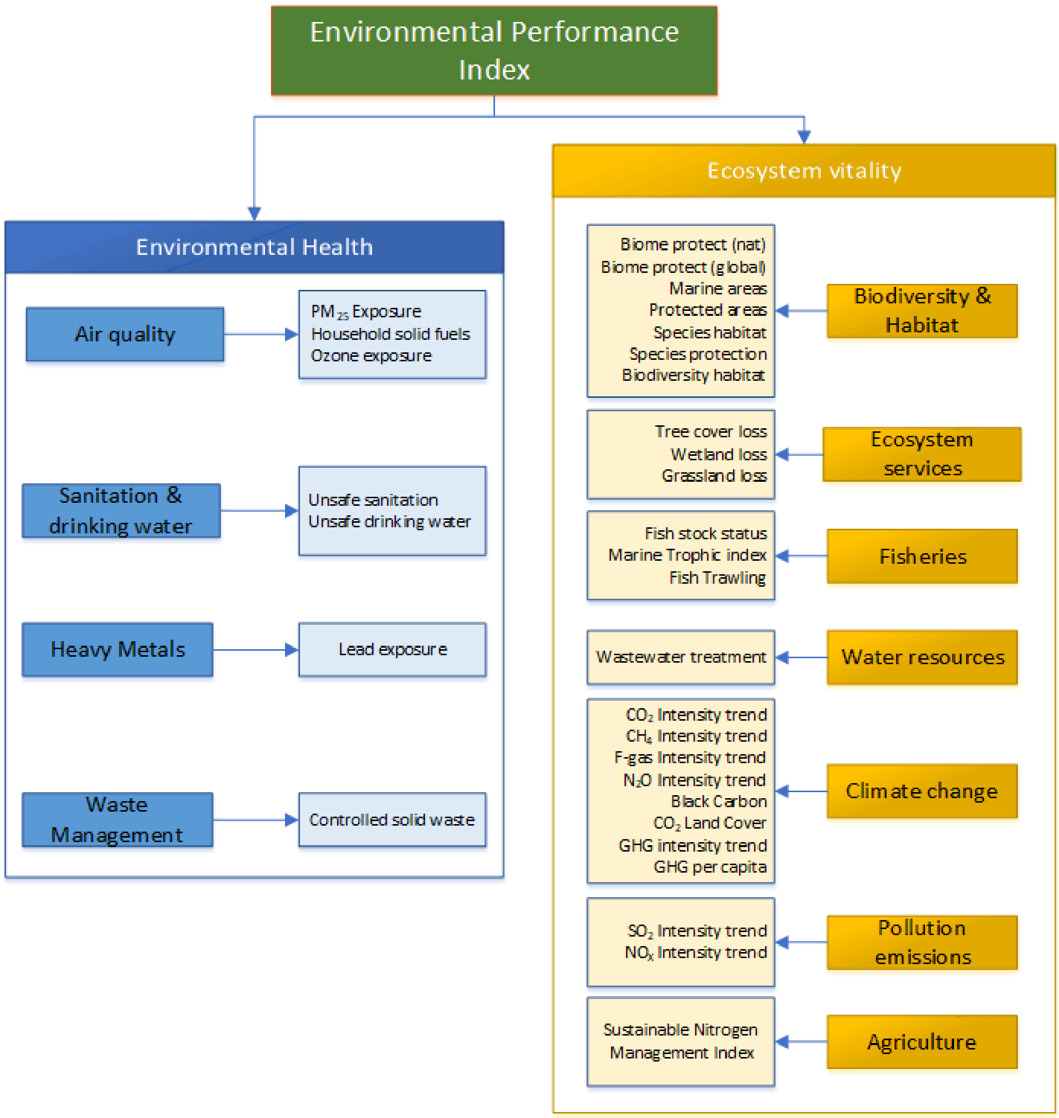
On the other hand, the policy objective, Ecosystem vitality (ECO) is composed of seven issue categories: Biodiversity and habitat (BDH), Ecosystem services (ECS), Fisheries (FSH), Climate change (CCH), Pollution emissions (APE), Agriculture (AGR and Water resources (WRS).

- BDH is represented by seven indicators, which are Terrestrial Biome Protection (national) (TBN) and Terrestrial Biome Protection (global) (TBG) which measure the proportion of the area of a country`s biome types that are covered by protected areas, another is Marine protected areas (MPA) which was calculated as the percentage of a country’s total exclusive economic zone designated as marine protected areas, Protected areas representativeness index (PAR) as the proportion of biologically scaled environmental diversity included in a country´s terrestrial protected areas, Species habitat index (SHI) that measures the percentage of suitable habitat that remains intact for each species in a country, Species protection index (SPI) which assess the species-level ecological representativeness, and the Biodiversity habit index (BHV) which measures the effects of habitat loss.
- ECS is made of three indicators: Tree cover loss (TCL) as the percentage of forest lost, Grassland loss (GRL) which represents the proportion of gross losses in grassland areas, and Wetland loss (WTL) as the proportion of gross losses in wetland areas.
- FSH category uses three indicators: Fish stock status (FSS) which represents the percentage of a country´s total catch that comes from overexploited or

collapsed stocks, Regional marine trophic index which refers to the health of a country´s fishing stock, and Fish caught by trawling (FGT).

- ➢ CCH is composed by eight indicators: CO_2 intensity trend (CDA) which refers to the CO_2 growth rate, Methane intensity trend (CHA) as the CH_4 growth rate, F-gasses intensity trend (FGA) which represents the F-gas growth rate, N_2O intensity trend (NDA) which also represents its growth rate, Black carbon intensity trend (BCA), GHG emissions per capita (GHP), CO_2 from land cover (LCB) which estimates CO_2 emissions from land cover, and GHG emission intensity growth rate (GIB) that is calculated as the annual average growth rate in GHG emissions per unit of GDP.
- ➢ APE uses two indicators, SO_2 intensity trend (SDA) and NO_X intensity trend (NXA) which refers to their growth rates.
- ➢ AGR is represented by the Sustainable nitrogen management index (SNM).
- ➢ WRS as the wastewater treatment level (WWT) which indicates the percentage of wastewater that undergoes at least primary treatment.

Figure 3.1: Frame of the 2020 EPI showing the two policy objectives, the 11 issue categories and the 32 indicators.



Source: Self-elaboration based on Wendling *et al.* (2020).

For each indicator, a weight has been established within each level of aggregation and a contribution to the total EPI score (Table 3.1).

Table 3.1: Organization of the 2020 EPI indicators. Weights within each level of aggregation and total weight contribution to the total EPI score.

	Agregation Level			Total EPI Weigth
	Policy Objetive	Issue Category	Indicator	
2020 EPI	**Environmental health (HLT)** 40%	**Air quality (AIR)** 50%	**PM_{25} Exposure (PMD)** 55%	11%
			Household solid fuels (HAD) 40%	8%
			Ozone exposure (OZD) 5%	1%
		Sanitation & Drinking water (H2O) 40%	**Unsafe sanitation (USD)** 40%	6.4%
			Unsafe drinking water (UWD) 60%	9.6%
		Heavy metals (HMT) 5%	**Lead exposure (PBD)** 100%	2%
		Waste management (WMG) 5%	**Controlled solid waste (MSW)** 100%	2%
	Ecosystem vitality (ECO) 60%	**Biodiversity & Habitat (BDH)** 25%	**Terrestrial Biome protection national (TBN)** 20%	3%
			Terrestrial Biome protection global (TBG) 20%	3%
			Marine protected areas (MPA) 20%	3%
			Protected areas representativeness index (PAR) 10%	1.5%
			Species habitat index (SHI) 10%	1.5%
			Species protection index (SPI) 10%	1.5%
			Biodiversity habitat index (BHV) 10%	1.5%
		Ecosystem services (ECS) 10%	**Tree cover loss (TCL)** 90%	5.4%
			Grassland loss (GRL) 5%	0.3%
			Wetland loss (WTL) 5%	0.3%
		Fisheries (FSH) 10%	**Fish stock status (FSS)** 35%	2.1%
			Marine trophic index (RMS) 35%	2.1%
			Fish caught by trawling (FGT) 30%	1.8%
		Climate change (CCH) 40%	**CO_2 intensity trend (CDA)** 55%	13.2%
			CH_4 intensity trend (CHA) 15%	3.6%
			F-gas intensity trend (FGA) 10%	2.4%
			N_2O intensity trend (NDA) 5%	1.2%
			Black carbon intensity trend (BCA) 5%	1.2%
			CO_2 from land cover (LCB) 2.5%	0.6%
			GHG intensity trend (GIB) 5%	1.2%
			GHG per capita (GHP) 2.5%	0.6%
		Pollution emissions (APE) 5%	**SO_2 intensity trend (SDA)** 50%	1.5%
			NO_X intensity trend (NXA) 50%	1.5%
		Agriculture (AGR) 5%	**Sustainable nitrogen management index (SNM)** 100%	3%
		Water resources (WRS) 5%	**Wastewater treatment (WWT)** 100%	3%

Source: Self-elaboration based on Wendling *et al.* (2020).

The 2020 EPI was constructed by using a weighted average of the different indicators, and whose formula is described below. These weights reflect a subjective best judgement, as well as they are determined by data quality and analysis of global trends. However, the weights of the policy objectives were given by the spread of each one, so as Environmental health is more spread it was given a 40% and Ecosystem vitality a 60% to have a more balanced final score.

The EPI is calculated by the sum of the Environmental health policy (HLT) multiplied by its weight (40%) and the Ecosystem vitality policy (ECO) multiplied by its weight (60%):

$$EPI = HLT \times 0.4 + ECO \times 0.6 \tag{3.1}$$

Where Environmental health (HLT) is calculated as the sum of the four categories that compose it (Air quality (AIR), Sanitation and drinking water ($H20$), Heavy metals (HMT) and Waste management (WMG)), each multiplied by their weights:

$$HLT = AIR \times 0.5 + H20 \times 0.4 + HMT \times 0.05 + WMG \times 0.05 \tag{3.2}$$

And Ecosystem vitality (ECO) is calculated as well as the sum of the seven categories that compose it (Biodiversity & Habitat (BDH), Ecosystem services (ECS), Fisheries (FSH), Climate change (CCH), Pollution emissions (APE), Agriculture (AGR) and Water resources (WRS)), each multiplied by their weights:

$$ECO = BDH \times 0.25 + ECS \times 0.1 + FSH \times 0.1 + CCH \times 0.4 + APE \times 0.05 + AGR \times 0.05 + WRS \times 0.05 \quad (3.3)$$

The EPI can also be calculated from the issue categories. It is the weighted average of each issue category times their weight:

$$EPI = AIR \times 0.2 + H2O \times 0.16 + HMT \times 0.02 + WMG \times 0.02 + BDH \times 0.15 + ECS \times 0.06 + FSH \times 0.06 + CCH \times 0.24 + APE \times 0.03 + AGR \times 0.03 + WRS \times 0.03 \quad (3.4)$$

The different categories that compose the two policy objectives are formed by single indicators. For example, AIR is composed of PM25 exposure (PMD), Household solid fuels (HAD) and Ozone exposure (OZD), each one multiplied by its weight:

$$AIR = PMD \times 0.55 + HAD \times 0.4 + OZD \times 0.05 \quad (3.5)$$

Equally, $H2O$ is calculated from Unsafe sanitation (USD), Unsafe drinking water (UWD):

$$H2O = USD \times 0.4 + UWD \times 0.6 \quad (3.6)$$

HMT is represented by Lead exposure (PBD): $HMT = PBD$ (3.7)

And WMG is equal to Controlled solid waste (MSW): $WMG = MSW$ (3.8)

From the other part, BDH calculated as follows:

$$BDH = TBN \times 0.2 + TBG \times 0.2 + MPA \times 0.2 + PAR \times 0.1 + SHI \times 0.1 + SPI \times 0.1 + BHV \times 0.1 \quad (3.9)$$

where TBN and TBG are Terrestrial biome protection national and global, respectively, MPA is Marine protected areas, PAR is Protected areas representativeness index. SHI refers to Species habitat index and SPI to Species protection index, and BHV is Biodiversity habitat index.

$$ECS = TCL \times 0.9 + GRL \times 0.05 + WTL \times 0.05 \quad (3.10)$$

Where TCL refers to Tree cover loss, GRL to Grassland loss and WTL is Wetland loss.

$$FSH = FSS \times 0.35 + RMS \times 0.35 + FGT \times 0.3 \quad (3.11)$$

which indicates that Fisheries (FSH) is calculated from Fish stock status (FSS), Marine trophic index (RMS) and Fish caught by trawling (FGT).

Similarly, CCH is calculated from its eight indicator (CO2 intensity trend (CDA), CH4 intensity trend (CHA), F-gas intensity trend (FGA), N2O intensity trend (NDA), Black carbon intensity trend (BCA), CO2 from land cover (LCB), GHG intensity trend (GIB) and GHG per capita (GHP)) times their weights:

$$CCH = CDA \times 0.55 + CHA \times 0.15 + FGA \times 0.1 + NDA \times 0.05 + BCA \times 0.05 + LCB \times 0.025 + GIB \times 0.05 + GHP \times 0.025 \quad (3.12)$$

APE is composed of SO_2 (SDA) and NO_x (NXA) intensity trends:

$$APE = SDA \times 0.5 + NXA \times 0.5 \quad (3.13)$$

Finally, AGR is represented by the Sustainable nitrogen management index (SNM):
$$AGR = SNM \tag{3.14}$$

And WRS is equal to Wastewater treatment (WWT): $WRS = WWT$ (3.15)

In case that there is missing data in some indicators, the formula gives a weight of zero to these indicators without data and redo the weights according to the indicators left.

The data used to create this index was obtained from external sources, like international governing bodies, nongovernmental organizations and academic centers. Then, with the data they constructed indicators on a 0 to 100 scale, worst to best performance, and after that they weighted and aggregated the scores into issue categories, then into policy objectives and lastly into an EPI score. In the following table (Table 3.2), it is shown the different sources from which the data has been obtained.

Table 3.2: Source of each indicator for the 2020 EPI.

<table>
<tr><th>INDICATOR</th><th>SOURCE</th></tr>
<tr><td>PMD</td><td rowspan="6">Institute for Health Metrics and Evaluation</td></tr>
<tr><td>HAD</td></tr>
<tr><td>OZD</td></tr>
<tr><td>USD</td></tr>
<tr><td>UWD</td></tr>
<tr><td>PBD</td></tr>
<tr><td>MSW</td><td>Wiedinmyer et al. 2014 & Kaza et al. 2018</td></tr>
<tr><td>TBN</td><td rowspan="3">World Database on Protected Areas</td></tr>
<tr><td>TBG</td></tr>
<tr><td>MPA</td></tr>
<tr><td>PAR</td><td rowspan="2">Commonwealth Scientific and Industrial Research Organization</td></tr>
<tr><td>BHV</td></tr>
<tr><td>SHI</td><td rowspan="2">Map of Life</td></tr>
<tr><td>SPI</td></tr>
<tr><td>TCL</td><td>Global Forest Watch</td></tr>
<tr><td>GRL</td><td rowspan="2">European Space Agency</td></tr>
<tr><td>WTL</td></tr>
<tr><td>FSS</td><td rowspan="3">Sea Around Us</td></tr>
<tr><td>RMS</td></tr>
<tr><td>FGT</td></tr>
<tr><td>CDA</td><td rowspan="6">Potsdam Institute for Climate Impact Research</td></tr>
<tr><td>CHA</td></tr>
<tr><td>FGA</td></tr>
<tr><td>NDA</td></tr>
<tr><td>GHP</td></tr>
<tr><td>GIB</td></tr>
<tr><td>BCA</td><td rowspan="3">Community Emissions Data Systems</td></tr>
<tr><td>SDA</td></tr>
<tr><td>NXA</td></tr>
<tr><td>LCB</td><td>Mullion Group</td></tr>
<tr><td>SNM</td><td>UMCES</td></tr>
<tr><td>WWT</td><td>UNSD, OECD, Eurostat, etc.</td></tr>
</table>

Source: self-elaboration based on Wendling *et al.* (2020).

This data selection focuses on obtaining the most useful and credible data to measure the performance on environmental outcomes and to compare differences between countries. So, these indicators were chosen because of their relevance in environmental aspects to most countries, their performance orientation as they are subjected to policy intervention and they can be measured as outcomes from polices, and they have an established methodology that facilitates the comparison. The indicators also verified the use of credible data, they cover at least 140 countries, so this gives spatial completeness to the analysis, and they provide data for several years, they provide recent datasets that are relevant for policymakers, and they were obtained from open sources which foster trust and increase the reach of information. In addition, the dimensions represent major environmental problems, and the policies define the principal objectives for policymakers.

The 2020 EPI has been applied to a total of 180 countries, which can be aggregated in different categories, one of which is by regions (Table 3.3)

Table 3.3: Regions in which the 2020 EPI is applied and number of countries in each region.

Region	**Nº countries**
Asia-Pacific	25
Eastern Europe	19
Former Soviet States	12
Global West	22
Greater Middle East	16
Latin America & Caribbean	32
Southern Asia	8
Sub-Saharan Africa	46
TOTAL	**180**

Source: Self-elaboration based on Wendling *et al.* 2020.

The results obtained by this 2020 EPI (Table 1.A) show that Denmark had the best environmental performance among the 180 countries, with a score of 82.5, followed by Luxembourg with a score of 82.3, and the third is Switzerland with a score of 81.5. The United Kingdom and France complete the top 5 with a score of 81.3 and 80, respectively.

On the other side, the worst environmental performance corresponds to Liberia, whose score is just 22.6, the second worst is Myanmar with a score of 25.1 and finally, Afghanistan with a score of 25.5 in the third place. It can be seen big economies like Japan which ranks 12th with a score of 75.1, Canada with the 20th place and a score of 71 or the United States located in the 24th place with a score of 69.3. Spain also has a good place; it is in the 14th place with a score of 74.3.

Overall, we can notice that the higher places in the ranking are taken by countries from the Global West region, except Japan that belongs to the Asia-Pacific region. These countries are characterized by high economic growth and developed regulations on sustainability, and they invest in programs that support environmental health, preservation of natural resources and reduction of greenhouse gas emissions.

While the worst environmental performance is mostly represented by countries from the Sub-Saharan Africa region, and some countries from Southern Asia, Asia-Pacific and Latin America and Caribbean. These countries are usually poor, with a weak government that cannot manage any regulation on environmental problems or sustainable development. They usually need international help to improve their performance.

Moreover, if we analyze the rankings of the countries on each issue category, we can see that countries with higher positions in the global ranking, have high positions in many categories. For example, Denmark, which ranks first in the global ranking, also is in first place in the Climate change category, which represents a 24% of the total EPI, and in categories like Heavy metals, Pollution emissions and Water resources. And it is in the top 10 in Sanitation & Drinking water, Waste management and Agriculture. Spain, which ranks 14th in the global ranking, is in good positions in categories like Biodiversity & Habitat where it is in 8th place, Pollution emissions where it ranks first, and within the top

20 in Climate change, Water resources and Sanitation & Drinking water. Or Japan, which is the only Asia-Pacific country in the top 15, that obtained high positions in Air quality (11th), in Sanitation & Drinking water (10th), in Heavy metals (1st) and in Fisheries (11th).

On the other hand, countries like Liberia, exhibits low positions in every issue category, below the median, which makes it to be in such a low position, for example in Air quality (121st), in Sanitation & Drinking water (167th) or in Ecosystem services (170th). However, we see countries like Botswana and Zambia, which have obtained the first positions in the Biodiversity & Habitat category, which represents the 15% of the total score, and in the case of Botswana 35th in Ecosystem services, but low positions in the rest of the categories, so they still get low positions in the global ranking, 103rd and 132nd, respectively.

In addition, it can be seen that most categories have in high positions Global west countries, with some exceptions, which sides with the fact that these countries rank in the highest places. However, the Biodiversity & Habitat, Ecosystem services and Fisheries categories show African, Asian or Middle east countries, like Botswana, Bhutan, Zimbabwe, United Arab Emirates, Bahrain, Niger, Tajikistan, Fiji or Kiribati, among others, rank in the highest places.

In addition, the analysis conducted for this EPI shows that it is positively correlated with wealth, which means that countries with higher economic growth will invest more in policies and programs related with sustainable development, especially the ones about environmental health. The report also shows that the EPI scores can be different from one policy objective to the other. Ecosystem vitality has a smaller range from Liberia to Denmark than the Environmental health from Lesotho to Finland, which means that is more costly to achieve the ecosystem vitality objective.

Finally, we must take into account that the 2020 EPI was constructed during the Covid-19 crisis, which affected public health systems and the economic activity of most countries, and it reduced the levels of pollution and the rise of wildlife. The environment also was affected by it, as air and water quality improved due to travel restrictions. However, the 2020 EPI cannot reflect these phenomena yet.

This indicator has been used by different authors to study the relation of it with other variables or used as a part of a bigger index. For example, Ponce de Leon Barido & Marshall, (2014) used the EPI to explain the performance of CO_2 emissions, and it also was part of a composite sustainability index developed by Strezov *et al.* (2017).

Several authors used the EPI as a dependent variable to analyze how some factors like country´s constitution, culture, social capital and levels of income inequalities depend on environmental performances (Cepparulo *et al.*, 2019; Kumar *et al.*, 2019; Grafton & Knowles, 2004; Morse, 2018). Moreover, the data for specific regions or group of countries was of interest for a few authors like Apostoaie & Maxim, (2017) that focus on the European Union, Chowdhury & Islam, (2017) focused on BRICS countries, and the OPEC and OECD countries were the central point of Shahabadi *et al.*, (2016) and Ozymy & Rey, (2013), respectively.

There is also some literature about the relation of the economic sectors with environmental performance. For instance, Chakraborty & Mukherjee, (2013) found that there is a positive correlation between services and higher scores of the EPI, while high percentages of industry and manufacturing exports lead to lower scores of the EPI (Kheirollahi *et al.*, 2014). Furthermore, these relationships vary depending on the policy objective (Apostoaie & Maxim, 2017).

4. RANKING OF COUNTRIES BASED ON ENVIRONMENTAL PERFORMANCE USING TOPSIS

The methodology of the EPI has been criticized by some authors (Kanmani, A. *et al.*, 2020) for its subjective choice of the indicators, that could introduce bias, and for its poor performance as an environmental performance indicator. It is also criticized for not giving any specific policy recommendation and for its choice of weights that do not take into account the ecological process that developing countries have experienced.

Therefore, we seek to apply a simple mathematical method that using the data from the 2020 EPI, can develop, an alternative ranking of the countries studied.

Multiple-criteria decision analysis methods help in the process of decision making, as well as in hierarchy processes of alternatives or to organized processes and facilitate the obtaining of the correct decision based on the objectives established, thanks to the systematic analysis of the alternatives and an organized process (Palacios, R. & Pacheco, J., 2016).

There are several multiple-criteria decision analysis (MCDA) methods, each of them can be used in different application. Some common MCDA methods used are the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), the Analytic Hierarchy Process (AHP), the Complex Proportional Assessment (COPRAS), the ELECTRE and the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE). The multitude of methods sometimes can make researchers struggle to choose between one or another, as there is not a method that is suitable for every problem, so it may depend on the characteristics of the problem to choose a specific one.

In the study of Palacios Saldaña, R. & Pacheco Bonrostro, J., (2016), a comparison of different MCDA methods was made. They interpreted, for example, that the Analytic Hierarchy Process (AHP), which is a method that assign in advance the weights of each criterion that represent their contributions to the final score, does not satisfy a consistent axiomatic system, leading to a questionable classification of the alternatives. The ELECTRE is characterized for reducing the number of efficient alternatives, and it is based on the division of the alternatives in more optimal subgroups taking into account the decision criteria. Or the VIKOR, which is a method that is not usually applied independently, but it is used when the decision maker does not know his preferences. They also explained that the TOPSIS is an intuitive method, with the ability to efficiently identify the best alternative, and it is highly used because of its easy comprehension. Finally, they concluded that when choosing one method or another, the one chosen must be understandable for the decision maker because it depends on him the confidence of the results.

In another study made by Roszkowska (2011), it was presented the advantages of the TOPSIS. It describes the TOPSIS as a simple, rational and comprehensible method with intuitive and clear logic, easy to compute and with a good computational efficiency. It also has the capacity to measure the relative performance of an alternative with a simple mathematical formula and has the possibility of visualization.

TOPSIS (The Technique for Order Preference by Similarity to Ideal Solution) method (Hwang &Yoon, 1981) is used in this study to develop a new environmental performance ranking, using the indicators and weights proposed by the 2020 EPI. The TOPSIS is a multiple-criteria decision analysis (MCDA) method that ranks different alternatives (in this case, countries) depending on various decision criteria (in this case, issue categories).

This method is used by several researchers to rank alternatives in different application areas (Behzadian *et al.*, 2012; Chen & Hwang, 1992; Yoon &Hwang, 1995; Zyoud &Fuchs-Hanusch, 2017; Bilbao-Terol *et al.*, 2014).

For the development of the ranking, TOPSIS uses the Euclidian distance to the positive ideal solution (PIS) and to the negative ideal solution (NIS), and it scores first the alternative with the shortest distance to the PIS and the farther distance to the NIS. The positive ideal solution refers to the score that is the best performance among the alternatives in each criterion, while the negative ideal solution is the worst performance in each criterion. It considers that the best solution not only has to be as near as possible to the positive ideal solution, but also it has to be as far as possible to the negative ideal solution. In addition, the attribute values used have to be numeric, monotonically increasing and decreasing, and have measurable units.

The bibliographic review made by Behzadian *et al.* (2012) about the TOPSIS method gathers 266 papers published since 2000. In the following lines, some recent applications are presented.

Bulut (2021) study was also interested in developing an alternative for the 2018 EPI, so his study focused on generating a new composite index, using a different methodology that the one used in the EPI that includes the TOPSIS method. It uses the values of 24 indicators for the 180 countries, and it decided to use the countries as the criteria. The new index obtained showed differences from the 2018 EPI, some countries like Armenia, Azerbaijan, Bolivia or Hungary decrease their scores, while others like China, Chile, Maldives or Bahrain increase it. It also presented important differences in the top rank, Malta, Israel and Sweden lead the top 3, while Switzerland, France, Denmark or Luxemburg significantly decrease their ranks.

TOPSIS method was also used in the Lombardi Netto *et al.* (2021) study to rank top fifteen green bonds, based on different criteria, in which the EPI is included. The study proposes several multiple-criteria decision analysis to develop new rankings that are compared with the ranking generated by specialized media. For the TOPSIS method, the fifteen green bonds are chosen as the alternatives, and seven variables (assets, dividend yield, country's EPI, returns, expenses, risks and share) as the decision criteria. The results obtained indicated that the TOPSIS ranking presented some differences from the specialized media ranking, concluding that they are not correlated.

Moreover, Vicens-Colom *et al.* (2021) measured sustainable tourism in Spain using the TOPSIS method with equally weighted criteria. They proposed a scenario where a tourist has to choose an apartment, having to choose between several alternatives and taking into account attributes like number of rooms, distance to the airport, rental cost, etc., that are considered as the decision criteria. With the results obtained, they concluded that the use of multi-criteria decision analysis to measure sustainability is an adequate strategy, as it able to maximize the values of the indicators.

There are several approaches to this method, but in this study, the classical approach will be used. The principal steps are described as follows:

Step 1. Define the **decision matrix D**, where the number of criteria (issue categories) is named as n and the number of alternatives (countries) is m.

$$D = (X_{ij})_{m\times n} \tag{4.1}$$

Step 2. Calculate the **normalized decision matrix**, as the criteria are expressed in different scales, it is necessary to normalize them to make easier the comparison. The normalization formula goes as follows:

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m}(X_{ij})^2}}, i = 1,2,\dots,m \;\; j = 1,2,\dots,n \qquad (4.2)$$

Step 3. Determine the **weighted normalized decision matrix**, as each criterion do not have the same importance for the total score. The following formula calculates the weighted normalized value:

$$v_{ij} = w_j \times r_{ij}, i = 1,2,\dots,m \;\; j = 1,2,\dots,n \qquad (4.3)$$

where w_j is the weight of each criterion.

Step 4. Find the positive ideal (A^+) and negative ideal (A^-) solutions. They are determined as follows:

$$A^+ = \{v_1^+,\dots,v_n^+\} = \{(max_i\, v_{ij}, j \in J)(min_i\, v_{ij}, j \in J')\}\; i = 1,2,\dots,m \qquad (4.4)$$

$$A^- = \{v_1^-,\dots,v_n^-\} = \{(min_i\, v_{ij}, j \in J)(max_i\, v_{ij}, j \in J')\}\; i = 1,2,\dots,m \qquad (4.5)$$

where J refers to the criteria that indicates profits or benefits, and J' refers to the criteria that indicates costs or losses.

Step 5. Determine the distance measures by calculating the difference between each alternative and the PIS (d_i^+) and NIS (d_i^-), using the Euclidean distance.

$$d_i^+ = \{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2\}^{1/2} i = 1,2,\dots,m \qquad (4.6)$$

$$d_i^- = \{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2\}^{1/2} i = 1,2,\dots,m \qquad (4.7)$$

Step 6. Calculate the relative proximity of each alternative to the ideal solutions (PIS and NIS) by computing the proximity index:

$$R_i = \frac{d_i^-}{d_i^+ + d_i^-} \;\; i = 1,2,\dots,m \qquad (4.8)$$

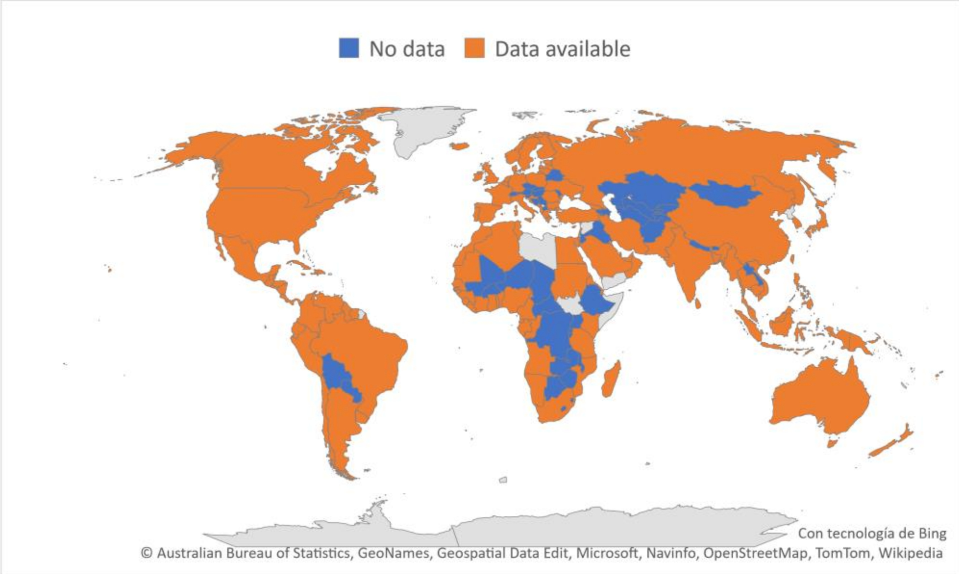
where R_i values are in a scale of 0-1. The closer the R_i value is to 1, the better is the score of the alternative.

Step 7. Rank the alternatives according to the R_i values in descending order.

In this study, the values used for the Decision matrix D (Equation 4.1) were the 2020 EPI scores for each issue category, which are already normalized in a 0-100 scale. We did not use the raw data because it was not available for the 32 indicators in many of them, there were only measures used to obtain them, so a series of complex equations would have been necessary to obtain them. Then, it was decided to use the issue categories as the decision criteria instead of the individual indicators because there was fewer missing data in the categories than in the indicators. And the normalization described in Equation 4.2 was applied to them, getting a score in a 0-1 scale.

However, missing data still be observed in the Ecosystem services and Fisheries categories. For the ecosystem services, there were four countries without data, Samoa, Tonga, Marshall Islands and Kiribati, which are small Pacific islands, so this category is not very relevant for them. Equally, in the Fisheries category there were 44 missing values that for the most part correspond to countries without sea and consequently there is not marine fishery, so this is probably the reason why they do not have data. Then, the NA values were replaced by the minimum score of the category. The following figure (Figure 4.1) shows a map of the countries without data.

Figure 4.1: Countries' availability of data for ECS and FSH issue categories.



Source: Self-elaboration based on 2020 EPI results.

In addition, the weights used to compute the weighted normalized decision matrix (Equation 4.3) are the same as the ones the 2020 EPI uses to calculate its final score (Equation 3.4). For the determination of the PIS and NIS (Equation 4.4, 4.5), it was supposed that all decision criteria were of maximization and minimization, respectively. Even though, in some cases the original data could negatively affect the environmental performance of a country, like pollution emissions or climate change, the EPI has already transformed them into a 0-100 scale, from worst to best performance, being 100 the perfect score which means that it has achieve an internationally recognized sustainability target. So, in the end all of them have a positive effect, as they increase the total score, and the higher the final score, the better environmental performance.

5. RESULTS

With the application of the TOPSIS method to the values of the EPI issue categories, we obtained an alternative environmental performance raking for the countries, that can be seen in Table 5.1. The resulted ranking for the 180 countries has changed in some aspects from the obtained with the EPI. Although the scores obtained from both methods are in different scale, we are going to transform the EPI scores to a 0-1 scale to facilitate the comparison.

In overall, the ranking shows some differences from the one obtained with the 2020 EPI, we see slightly variations between the two. For example, with the TOPSIS method, Japan is the country with the best environmental performance with a 0.73 score, followed by Denmark with a 0.728 score and France is in third place with 0.71, while the 2020 EPI ranked first Denmark then Luxemburg and in third place Switzerland. Japan is in 12th place, nevertheless the scores of the two indexes are similar, 0.75 in the 2020 EPI and 0.73 in the TOPSIS, so this does not mean that Japan got a higher score with this method, but the other countries were the ones that reduce their scores. Japan has the shortest distance to the positive ideal solution, but it has not the maximum distance to the negative ideal solution, that corresponds to Denmark. With this, we can see that the best environmental performance score does not necessarily mean that this country has the maximum distance to the negative ideal solution and the minimum distance to the positive ideal solution. As well, Liberia, which is the country with the worst performance, has not the maximum distance to the PIS, it is Chad the one that has it, but it has the minimum distance to the NIS.

On the other side, the worst environmental performance corresponds to Liberia with a 0.19 score, followed by Myanmar and then Afghanistan with a score of 0.195 and 0.21, respectively. We can see that these countries are the same ones that compose the top 3 worst environmental performance countries in the 2020 EPI, with small differences in the scores.

Moreover, it can be seen that the highest and lowest scores are lower than the 2020 EPI scores. On the one hand, the highest is 0.73 and the lowest is 0.19, while the 2020 EPI has the highest score in 0.82 and the lowest is 0.22. With the 2020 EPI, we could say that the scores were rather far from the perfect score, meaning that any country has a perfect environmental performance, but in this alternative ranking the scores are lower than the EPI, which increase even more the distance to reach the perfect performance.

We can also observe that the best environmental performances are still represented by the global west region, and the worst environmental performances correspond to sub-Saharan Africa countries, same as in the 2020 EPI (Figure 5.1).

Table 5.1: Global ranking of the 180 countries with their environmental performance score, and the ranking by regions, using TOPSIS method.

Rank	Country	Score	RnkReg	Rank	Country	Score	RnkReg	Rank	Country	Score	RnkReg
1	Japan	0.73	1	61	Serbia	0.47	15	121	Micronesia	0.33	17
2	Denmark	0.73	1	62	Tunisia	0.46	5	122	Iraq	0.33	15
3	France	0.71	2	63	Jamaica	0.46	13	123	Sao Tome and Principe	0.33	8
4	United Kingdom	0.71	3	64	Bahrain	0.46	6	124	Botswana	0.33	9
5	Finland	0.71	4	65	Brazil	0.46	14	125	Kenya	0.32	10
6	Sweden	0.70	5	66	Iran	0.46	7	126	Malawi	0.32	11
7	Norway	0.70	6	67	Belarus	0.45	3	127	Central African Republic	0.32	12
8	Germany	0.69	7	68	Albania	0.45	16	128	Sudan	0.32	16
9	Spain	0.68	8	69	Dominica	0.45	15	129	Guyana	0.31	30
10	Switzerland	0.68	9	70	Malaysia	0.45	6	130	Zimbabwe	0.31	13
11	Luxembourg	0.67	10	71	Montenegro	0.45	17	131	Mozambique	0.31	14
12	Netherlands	0.67	11	72	Trinidad and Tobago	0.45	16	132	Bhutan	0.31	3
13	Portugal	0.67	12	73	Tonga	0.45	7	133	Burkina Faso	0.31	15
14	Australia	0.67	13	74	Panama	0.44	17	134	Cabo Verde	0.31	16
15	Ireland	0.66	14	75	Lebanon	0.44	8	135	Tajikistan	0.31	12
16	Belgium	0.66	15	76	Mauritius	0.44	2	136	Dem. Rep. Congo	0.30	17
17	Iceland	0.66	16	77	Dominican Republic	0.44	18	137	Viet Nam	0.30	18
18	Italy	0.66	17	78	Armenia	0.43	4	138	Eswatini	0.30	18
19	Israel	0.65	1	79	Grenada	0.42	19	139	Pakistan	0.30	4
20	Canada	0.65	18	80	Saint Lucia	0.42	20	140	Comoros	0.30	19
21	Austria	0.65	19	81	Gabon	0.42	3	141	Papua New Guinea	0.30	19
22	Malta	0.64	20	82	Thailand	0.42	8	142	Angola	0.29	20
23	United States of America	0.64	21	83	El Salvador	0.42	21	143	Zambia	0.29	21
24	New Zealand	0.64	22	84	Algeria	0.41	9	144	Uganda	0.29	22
25	Greece	0.64	1	85	Suriname	0.41	22	145	Nigeria	0.29	23
26	Romania	0.63	2	86	Bahamas	0.41	23	146	Cambodia	0.29	20
27	Cyprus	0.63	3	87	Turkey	0.40	18	147	Guatemala	0.29	31
28	South Korea	0.61	2	88	Bosnia and Herzegovina	0.40	19	148	Solomon Islands	0.28	21
29	Estonia	0.60	4	89	Peru	0.40	24	149	Ethiopia	0.28	24
30	Slovenia	0.59	5	90	Egypt	0.40	10	150	Republic of Congo	0.28	25
31	Singapore	0.59	3	91	Belize	0.40	25	151	Laos	0.28	22
32	Czech Republic	0.59	6	92	Saudi Arabia	0.39	11	152	Eritrea	0.28	26
33	Lithuania	0.57	7	93	Uzbekistan	0.39	5	153	Tanzania	0.28	27
34	Croatia	0.57	8	94	South Africa	0.39	4	154	Niger	0.27	28
35	Slovakia	0.57	9	95	Maldives	0.39	1	155	Mongolia	0.27	23
36	Seychelles	0.56	1	96	Moldova	0.39	6	156	Rwanda	0.27	29
37	Latvia	0.55	10	97	Paraguay	0.39	26	157	Senegal	0.27	30
38	Taiwan	0.54	4	98	Georgia	0.38	7	158	Benin	0.26	31
39	Brunei Darussalam	0.54	5	99	Samoa	0.38	9	159	Bangladesh	0.26	5
40	Poland	0.53	11	100	Morocco	0.38	12	160	Guinea-Bissau	0.26	32
41	Chile	0.52	1	101	Kiribati	0.37	10	161	Vanuatu	0.26	24
42	Hungary	0.52	12	102	Namibia	0.37	5	162	Lesotho	0.26	33
43	Bulgaria	0.51	13	103	Fiji	0.37	11	163	Togo	0.26	34
44	Costa Rica	0.50	2	104	Azerbaijan	0.37	8	164	India	0.26	6
45	Kuwait	0.50	2	105	Kazakhstan	0.36	9	165	Madagascar	0.25	35
46	Uruguay	0.50	3	106	Bolivia	0.36	27	166	Haiti	0.25	32
47	Venezuela	0.50	4	107	Nicaragua	0.36	28	167	Nepal	0.25	7
48	Argentina	0.49	5	108	Turkmenistan	0.36	10	168	Djibouti	0.25	36
49	Colombia	0.49	6	109	Oman	0.36	13	169	Mauritania	0.24	37
50	Ecuador	0.49	7	110	China	0.35	12	170	Ghana	0.23	38
51	Mexico	0.49	8	111	Indonesia	0.35	13	171	Guinea	0.23	39
52	Barbados	0.48	9	112	Cameroon	0.35	6	172	Gambia	0.23	40
53	Cuba	0.48	10	113	Honduras	0.35	29	173	Mali	0.23	41
54	Jordan	0.48	3	114	Marshall Islands	0.34	14	174	Cote d'Ivoire	0.23	42
55	United Arab Emirates	0.48	4	115	Sri Lanka	0.34	2	175	Sierra Leone	0.22	43
56	St Vincent and the Grenadines	0.48	11	116	Timor-Leste	0.34	15	176	Chad	0.22	44
57	Russia	0.48	1	117	Equatorial Guinea	0.34	7	177	Burundi	0.22	45
58	Antigua and Barbuda	0.47	12	118	Qatar	0.34	14	178	Afghanistan	0.21	8
59	North Macedonia	0.47	14	119	Philippines	0.34	16	179	Myanmar	0.20	25
60	Ukraine	0.47	2	120	Kyrgyzstan	0.33	11	180	Liberia	0.19	46

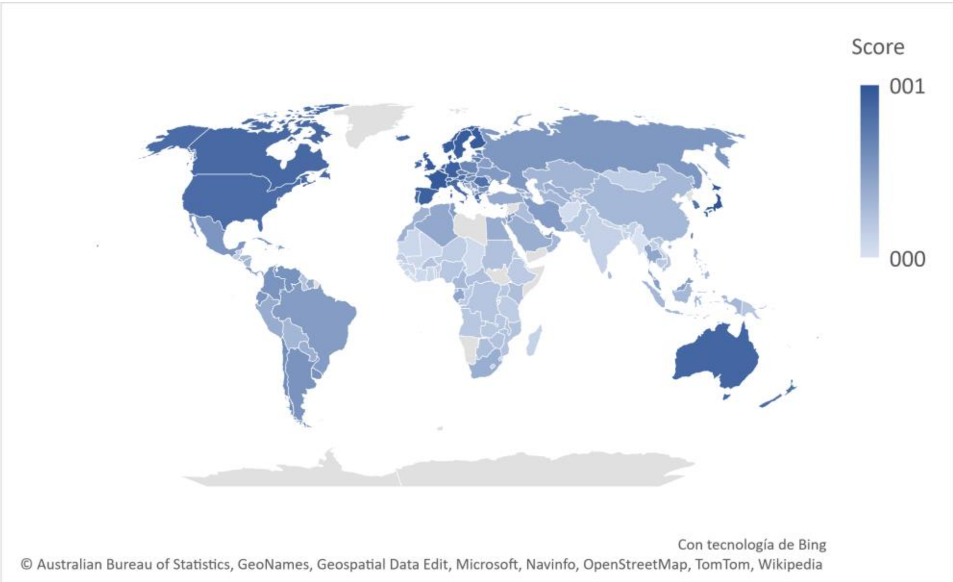
Asia-Pacific	Global West	Greater Middle East	Easter europe	Sub-Saharan Africa	Latin America & Caribbean	Former Soviet States	Southern Asia

Source: Self-elaboration.

The scores ‘differences, in relative terms, between the two indexes are not very high, being the highest difference the one from Luxemburg, which has a 0.151difference between the EPI score (0.823) and the TOPSIS (0.672). On the one hand, the country which score has changed the less is Micronesia with a difference of 0.00069 between the two scores. In terms of regions, the highest average difference is shown in the Global west region, which is 0.08, and this is probably because Luxemburg and Switzerland have high differences. In contrast, the Latin America and Caribbean region is the one with smallest average difference, 0.02752, but the Asia-Pacific region is very close to it, with a difference of 0.02754. This shows that Latin American and Asian countries do not change considerably their scores regardless of the method used.

Within regions, the rankings have also changed a bit. For example, in the Global west region, Denmark still holds the first place, but the last place is now taken by New Zealand, while in the 2020 EPI Portugal was the one in last place. However, the highest differences can be found in Luxemburg and Switzerland. In the sub-Saharan Africa region, the top 3 best countries still the same as in the EPI, being Seychelles, Mauritius and Gabon, but the top 3 worst countries have changed, Liberia still be the worst, but Sierra Leone and Côte d’Ivoire have been replaced by Burundi and Chad. The Eastern European countries ranking has change slightly, the first places is now taken by Greece, Romania and Cyprus, which are totally different from the ones in the EPI ranking, Slovenia which was the first one in the EPI has decreased 0.126 its score. On the other hand, the worst environmental performance countries still the same as in the EPI, which are Turkey, Bosnia Herzegovina and Montenegro. Asia-Pacific and Southern Asia also has similar rankings, with small changes. The Latin America and Caribbean ranking has changed, Chile still be in first place but it is now followed by Costa Rica and Uruguay, instead of Colombia and Mexico, while the worst countries still the same, Haiti, Guatemala and Guyana. Finally, the Former soviet states and Greater middle east countries have altered in some way. In the soviet states, Ukraine is now part of the top 3, being Belarus excluded. And Georgia now is in third worst place. In the Greater middle east region, United Arab Emirates is now in fourth place, being replaced by Jordan, and on the other side, Iraq has replaced Qatar in the second worst place.

Figure 5.1: Countries ranked, using TOPSIS method, from best to worst environmental performance in a chromatic scale.



Source: Self-elaboration.

6. CONCLUSIONS

The environmental performance of a population, nation or region has become an important aspect for many societies. Therefore, several indicators that can measure environmental performance have been developed, like the SDG index, the Global innovation index, the Global Green Economy index, the EPI, or the Ecological footprint, among others, and are widely used by governments, organizations and policymakers to improve their environmental objectives. These indicators measure environmental variables with different methods, and in most cases, they get different rankings for the countries studied.

So, in this study we propose an alternative method, which is a multiple-criteria decision analysis, to develop an alternative ranking and compare it with the one proposed by the the 2020 EPI. From a variety of MCDA methods, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was implemented. This method is very practical and useful to rank and select alternatives, and its calculations are rather simple and clear, so computationally it is not a difficult method, and it can be applied to various environments (Roszkowska, 2011). As it is not a complex method, it allows decision makers or policy makers fully understand the results obtained and where they have obtained, which improve the confidence of the scores, because in the end they are the ones that analyze and implement these results in policies or other matters. In addition, the TOPSIS fully uses attribute information, provides a cardinal raking of alternatives, and does not require attribute preferences to be independent (Chen &Hwang, 1992; Yoon & Hwang, 1995).

Therefore, we proceeded to apply the steps described in the methodology section to the EPI values, and the results obtained showed that there are differences to some extent between the two rankings, being the highest difference equal to 0.151 over 1. The region that presented the highest differences is the Global west due to Luxemburg and Switzerland that have the highest differences, so this slightly changes the global ranking, however, the Global west region still represents the top 20 with some exceptions, and the Sub-Saharan Africa region represents the countries with worst environmental performance.

Despite the fact, that during the process, we used the values and weights in the 2020 EPI scores, so that the possible problems that the EPI could have for the subjective election of weights and the indicators used, are probably inherited in the TOPSIS scores, this method provides a more objective score for the ranking, as instead of just doing a simple weighted average of them, it performed the Euclidian distance of each issue category value to alternative ideal solutions, that the positive one maximizes the benefit criteria and minimizes the cost criteria, and the negative one minimizes the benefit and maximizes the cost. So, this method can be useful to develop more objective sustainable development policies.

In conclusion, with the aggravation of climate change and the natural disasters that have been happening in these past years, environmental performance rankings among different countries have become an important and decisive tool for governments to control, in some way, their damage to the environment. They can be a useful analytic tool that contribute to make clear and to establish relative comparisons related to a country's effort towards an environmentally sustainable development and the achievement of the SDGs.

On the one hand, they promote and facilitate governments to self-evaluate their own measurements in this area, the level of accomplishment of the international goals established, and they also help governments to adjust their policies towards a better solution. In addition, their time evolution shows changes or tendencies that can be used as signals of negative outcomes or improvements that allows governments or organizations to make significant valuations. Their diffusion through the media also contributes to a positive perception from society towards the environment, as it facilitates society to access this information and improves transparency, so citizens can act more environmentally concern.

On the other hand, environmental performance rankings can improve a country's international prestige, as if the country is in a good place, this means that the country has environmental quality of the nature, resources, the air, the water, etc. These aspects are related to the environmental health of a country and consequently to the population's health, so a good ranking indirectly benefits a country's status, as it would be an attractive choice to life due to its air quality and respect to the environment, but it also can be attractive to businesses that are highly valued and are concerned about the environment, like tourism or technological companies.

In future research, other MCDA techniques could be applied to see if they present similar results, for example the TOPSIS method with unweighted criteria proposed by Liern & Pérez-Gladish (2017), and if there are significant differences analyze what could be the reasons. In addition, a different environmental performance index could be used to evade the limitations of the EPI, so the results do not have its problems.

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8. APPENDIX

Appendix A:

Table 1.A: 2020 EPI and policy objectives (HLT and ECO) scores for each country sorted by EPI values.

Country	EPI	HLT	ECO	EPI rank
Denmark	82.5	91.7	76.4	1
Luxembourg	82.3	92.6	75.4	2
Switzerland	81.5	95	72.5	3
United Kingdom	81.3	91.7	74.3	4
France	80	91.5	72.3	5
Austria	79.6	88	74	6
Finland	78.9	99.3	65.3	7
Sweden	78.7	98.4	65.6	8
Norway	77.7	98.5	63.8	9
Germany	77.2	89.6	68.9	10
Netherlands	75.3	91	64.8	11
Japan	75.1	90.3	65.1	12
Australia	74.9	91.6	63.8	13
Spain	74.3	86.8	66	14
Belgium	73.3	86	64.8	15
Ireland	72.8	94.2	58.6	16
Iceland	72.3	98.1	55	17
Slovenia	72	68.9	74.1	18
New Zealand	71.3	88	60.2	19
Cada	71	91.7	57.3	20
Czech Republic	71	68.3	72.9	20
Italy	71	85.5	61.3	20
Malta	70.7	86.1	60.5	23
United States of America	69.3	82.8	60.3	24
Greece	69.1	80.6	61.4	25
Slovakia	68.3	64.3	70.9	26
Portugal	67	83.4	56.1	27
South Korea	66.5	81.4	56.6	28
Israel	65.8	83.6	54	29
Estonia	65.3	73	60.1	30
Cyprus	64.8	81.5	53.7	31
Romania	64.7	50	74.4	32
Hungary	63.7	54.1	70	33
Croatia	63.1	61.2	64.3	34
Lithuania	62.9	63.2	62.7	35
Latvia	61.6	58	64	36
Poland	60.9	58.9	62.3	37
Seychelles	58.2	50.8	63.1	38

Country	EPI	HLT	ECO	EPI rank
Singapore	58.1	85	40.2	39
Taiwan	57.2	59.2	55.8	40
Bulgaria	57	50.3	61.5	41
United Arab Emirates	55.6	55.2	55.9	42
North Macedonia	55.4	43.6	63.2	43
Chile	55.3	63.4	49.8	44
Serbia	55.2	47.8	60.2	45
Brunei Darussalam	54.8	74	42	46
Kuwait	53.6	57.3	51.2	47
Jordan	53.4	58.6	49.9	48
Belarus	53	55.9	51.1	49
Colombia	52.9	55	51.6	50
Mexico	52.6	47.5	55.9	51
Costa Rica	52.5	60.5	47.2	52
Armenia	52.3	43.5	58.1	53
Argentina	52.2	60.2	46.8	54
Brazil	51.2	49.7	52.2	55
Bahrain	51	49.2	52.2	56
Ecuador	51	50.2	51.5	56
Russia	50.5	53	48.8	58
Venezuela	50.3	46.5	52.9	59
Ukraine	49.5	49	49.9	60
Uruguay	49.1	67.7	36.7	61
Albania	49	44.5	52	62
Antigua and Barbuda	48.5	55.5	43.8	63
Cuba	48.4	50.5	47	64
Saint Vincent and the Gredines	48.4	44.1	51.3	64
Jamaica	48.2	45.5	50	66
Iran	48	48.3	47.8	67
Malaysia	47.9	55.4	42.9	68
Trinidad and Tobago	47.5	54.6	42.9	69
Panama	47.3	50.4	45.2	70
Tunisia	46.7	49.2	45	71
Azerbaijan	46.5	32.7	55.7	72
Paraguay	46.4	46.8	46.2	73
Montenegro	46.3	46.7	46.1	74
Dominican Republic	46.3	36.1	53.2	74
Gabon	45.8	27.9	57.8	76
Barbados	45.6	60.7	35.6	77
Thailand	45.4	48.4	43.5	78
Lebanon	45.4	53.1	40.3	78
Bosnia Herzegovina	45.4	43.9	46.4	78
Suriname	45.2	36.6	50.9	81

Country	EPI	HLT	ECO	EPI rank
Tonga	45.1	43.6	46	82
Mauritius	45.1	60	35.3	82
Algeria	44.8	50.4	41	84
Kazakhstan	44.7	40.8	47.3	85
Dominica	44.6	46.8	43.1	86
Moldova	44.4	45.6	43.6	87
Bolivia	44.3	35.9	49.8	88
Uzbekistan	44.3	29.7	54.1	88
Saudi Arabia	44	47.2	41.8	90
Peru	44	45.1	43.2	90
Turkmenistan	43.9	45	43.1	92
Bahamas	43.5	53.1	37	93
Egypt	43.3	33.8	49.7	94
El Salvador	43.1	42.5	43.5	95
Greda	43.1	46.3	40.9	95
South Africa	43.1	31.1	51	95
Saint Lucia	43.1	47.8	40	95
Turkey	42.6	51.3	36.9	99
Morocco	42.3	33.3	48.3	100
Belize	41.9	40.3	43	101
Georgia	41.3	38.7	43.1	102
Botswana	40.4	20.2	53.8	103
Namibia	40.2	22.5	52	104
Kyrgyzstan	39.8	33.7	43.8	105
Iraq	39.5	39.5	39.4	106
Bhutan	39.3	29.8	45.7	107
Nicaragua	39.2	40.2	38.6	108
Sri Lanka	39	42.1	36.9	109
Oman	38.5	43.4	35.2	110
Philippines	38.4	34.1	41.4	111
Burkina Faso	38.3	19.6	50.9	112
Malawi	38.3	26.5	46.2	112
Tajikistan	38.2	20.7	49.9	114
Equatorial Guinea	38.1	27.6	45.1	115
Indonesia	37.8	29	43.7	116
Honduras	37.8	33.4	40.7	116
Kiribati	37.7	22.9	47.5	118
Sao Tome and Principe	37.6	28.7	43.6	119
Samoa	37.3	42.4	33.9	120
China	37.3	41.8	34.4	120
Qatar	37.1	56.9	23.9	122
Zimbabwe	37	22.5	46.7	123

Country	EPI	HLT	ECO	EPI rank
Central African Republic	36.9	12.2	53.5	124
Dem. Rep. Congo	36.4	22.4	45.7	125
Guyana	35.9	33.5	37.5	126
Maldives	35.6	48	27.4	127
Uganda	35.6	25.7	42.2	127
Timor-Leste	35.3	28.9	39.5	129
Sudan	34.8	20.8	44.1	130
Laos	34.8	27.2	39.9	130
Zambia	34.7	21	43.9	132
Kenya	34.7	25.7	40.6	132
Fiji	34.4	34.7	34.2	134
Ethiopia	34.4	25.2	40.6	134
Mozambique	33.9	28.1	37.8	136
Eswatini	33.8	17.6	44.6	137
Rwanda	33.8	24.4	40	137
Cameroon	33.6	13.6	46.9	139
Cambodia	33.6	30.5	35.6	139
Vietnam	33.4	40.6	28.5	141
Pakistan	33.1	14.6	45.3	142
Micronesia	33	30.8	34.5	143
Cabo Verde	32.8	30.4	34.5	144
Nepal	32.7	21	40.5	145
Papua New Guinea	32.4	28.4	35.1	146
Mongolia	32.2	27.6	35.3	147
Comoros	32.1	27.3	35.3	148
Guatemala	31.8	30.8	32.5	149
Tanzania	31.1	27.4	33.5	150
Nigeria	31	13.9	42.4	151
Niger	30.8	17.1	39.9	152
Marshall Islands	30.8	32.6	29.6	152
Republic of Congo	30.8	18.1	39.2	152
Senegal	30.7	20.4	37.6	155
Eritrea	30.4	15.5	40.4	156
Benin	30	20.3	36.4	157
Angola	29.7	20.4	35.9	158
Togo	29.5	16.4	38.2	159
Mali	29.4	19.5	36	160
Guinea-Bissau	29.1	15.1	38.4	161
Bangladesh	29	22.4	33.5	162
Vanuatu	28.9	26.7	30.4	163
Djibouti	28.1	20.1	33.4	164
Lesotho	28	11.8	38.8	165
Gambia	27.9	21.4	32.1	166

Country	EPI	HLT	ECO	EPI rank
Mauritania	27.7	20	32.8	167
Ghana	27.6	20.1	32.6	168
India	27.6	16.3	35.2	168
Burundi	27	21.9	30.5	170
Haiti	27	21.8	30.5	170
Solomon Islands	26.7	20.4	30.9	172
Chad	26.7	14.9	34.6	172
Madagascar	26.5	22.1	29.4	174
Guinea	26.4	18.6	31.5	175
Cote d'Ivoire	25.8	19.4	30.1	176
Sierra Leone	25.7	19.1	30.2	177
Afghanistan	25.5	20	29.2	178
Myanmar	25.1	24.6	25.4	179
Liberia	22.6	21.3	23.6	180

Appendix B

Timeline: Distribution of the different parts of the study.

The information below shows the sections in which I have divided my study and what it is explained in each of them, and how I have distributed the hours established for this work between the different sections. As it is shown, I spent quite some time with the introduction of the study, where I present the topic studied and the objective of my work, but I spent more time with the in-depth description of the Environmental Performance Index, and with the methodology used, as I had to learn and understand both the EPI and TOPSIS method, and especially in the results section where I carried out the calculations of the method and then analyzed and interpreted the results obtained. On the other hand, the description of some environmental indexes, and the conclusions did not need that many hours, and finally I left a few hours to make a final review.

It is also considerable to mention that the objective and methodology presented in this study, is not the original idea that I presented at the beginning of the period, which was to see if there is a relation between the Environmental Performance Index and some environmentally related taxes. In the middle of the period, I decided to change to the current objective, I kept the EPI but instead of relating it with environmental taxes, I decided to develop an alternative environmental performance ranking using TOPSIS method. The reason for this change was that after analyzing the data and the objectives, I realized that to get good results I would have needed more time than the available.

TIMELINE:

1. Introduction: Definition of environmental performance, its indicators and utilities. Characteristics of a good indicator. Bibliographic review. Objective of this study and motivation. (25 hours)
2. Environmental indexes: Description of some of the main environmental indexes (SDGI, GGEI, GII, EF, EVI). (10 hours)
3. Environmental Performance Index (EPI): Definition of the EPI and its utilities. Description of the individual indicators that compose it, and its levels of aggregation. Methodology. Bibliographic review. (30 hours)
4. Ranking of countries based on environmental performance using TOPSIS: Introduction of Multiple-criteria decision analysis methods. Description of the TOPSIS method applied to this study. (35 hours)
5. Results: Description of the results obtained. (40 hours)
6. Conclusions (6 hours)

Final review: (4 hours)