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Ranking and Evaluation of G7 Countries and Turkey by GGGI Indicators Using ENTROPY, CRITIC and EDAS Methods

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Abstract

The rapid increase in industrialization in societies causes environmental problems to emerge as an important problem. In all societies, the approach to the environment is becoming more sensitive and it is observed that studies on environmental performance have started to increase. The Global Green Growth Index (GGGI), an important measure of environmental performance, has been publishing reports comparing countries' performance scores since 2005. This study examines the changes in the rankings in the post-2010 period by using the Global Green Growth Index data to determine the environmental performance rankings of G7 countries and Turkey. The main objective of the study is to contribute to the realization of sustainable development by determining the position of G7 countries and Turkey according to GGGI. In the study, the performance ranking of the countries for the years 2010-2020 was made by using the ENTROPI and CRITIC weighting methods, which are among the Multi-Criteria Decision Making methods (MCDM), and the EDAS ranking method. In addition, sensitivity analysis was performed to determine the importance of criterion weights affecting performance rankings. While Germany exhibits the best performance in general, it is observed that Turkey performs lower than developed countries. It has been determined that the indicator of efficient and sustainable resource use has a significant impact on the environmental performance of countries.

Keywords: Global green growth index, Sustainability, CRITIC, ENTROPY, EDAS

G7 Ülkeleri ve Türkiye'nin ENTROPY, CRITIC ve EDAS Yöntemleriyle GGGI Göstergelerine Göre Sıralaması ve Değerlendirilmesi

Öz

Toplumlarda endüstrileşmenin hızla artması, çevre ile ilgili sorunların önemli bir problem olarak karşımıza çıkmasına neden olmaktadır. Tüm toplumlarda çevreye olan yaklaşım oldukça duyarlı hale gelmekte ve

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bununla ilgili çevre performansına yönelik çalışmaların da artmaya başladığı gözlenmektedir. Önemli bir çevresel performans ölçeği olan Küresel Yeşil Büyüme Endeksi (KYBE), 2005'ten bu yana ülkelerin performans puanlarını karşılaştıran raporlar yayınlamaktadır. Bu çalışmada, G7 ülkeleri ve Türkiye'nin çevre performans sıralamalarını belirlemek için Küresel Yeşil Büyüme Endeksi verileri kullanılarak 2010 sonrası dönemde sıralamadaki değişimler incelenmektedir. Çalışmanın temel amacı, KYBE'ne göre G7 ülkeleri ve Türkiye'nin geldiği noktayı belirleyerek sürdürülebilir kalkınmanın gerçekleşmesine katkıda bulunmaktır. Çalışmada Çok Kriterli Karar Verme yöntemlerinden (ÇKKV) ENTROPİ ve CRITIC ağırlıklandırma yöntemleri ile EDAS sıralama yöntemi kullanılarak 2010-2020 yıllarına ait ülkelerin performans sıralaması yapılmıştır. Ayrıca performans sıralamalarını etkileyen kriter ağırlıklarının önemini belirlemek için duyarlılık analizi gerçekleştirilmiştir. Almanya genel olarak en iyi performansı sergilerken, Türkiye'nin gelişmiş ülkelere göre daha düşük performans sergilediği gözlenmektedir. Verimli ve sürdürülebilir kaynak kullanımı göstergesinin, ülkelerin çevresel performansları üzerinde önemli bir etkiye sahip olduğu tespit edilmiştir.

Anahtar Kelimeler: Küresel yeşil büyüme endeksi, Sürdürülebilirlik, CRITIC, ENTROPİ, EDAS

1. INTRODUCTION

Parallel to the increase in human population and production, the growth of the world economy has brought about environmental problems. The recent rapid increase in environmental problems and the risks of global warming have prompted industrialized countries to take environmental protection measures. For this purpose, national and international institutions for the protection of the environment have been created, numerous international meetings have been held, treaties and agreements have been concluded, and various environmental performance indices have been established.

In the global world where access to resources is limited, the understanding of sustainable development has gained importance, especially in the last decade, to ensure effective use of resources and balanced economic growth. Recent economic crises, climate change, resource depletion, and health problems such as the pandemic COVID-19 have put the concepts of green economy, low carbon economy, sustainable production and consumption on the sustainable development agenda.

Green Development offers clear insights into the challenges of environmental sustainability, social and economic development. It provides a clear and coherent analysis of sustainable development in theory and practice [1]. Based on green development, green reordering is a comprehensive strategy to overcome the crises affecting our economy, climate, environment and social justice [2]. In this context, international organizations such as the United Nations and country governments have developed various measurement and tracking indices. These include Climate Change Performance Index (CCPI), Environmental Performance Index (EPI), Global Green Economy Index (GGEI) and Global Green Growth Index (GGGI).

GGGI was established as an international organization with 18 founding members who signed the founding agreement in 2012, and has 43 members, according to the list of members published on GGGI's official website in 2022. The group of G7 countries (USA, Germany, United Kingdom, Italy, France, Japan and Canada) was formed after the 1973 oil crisis by the seven most developed countries of the time. According to 2018 data, it generates 46% of the world's GDP, owns 58% of the world's wealth, and occupies 15% of the world's land area with 20 million square kilometers [3]. Except for the United Kingdom, there are no G7 countries that are members of the GGGI. Turkey is also not a member of GGGI.

GGGI consists of four green growth dimensions: efficient and sustainable resource use, natural capital protection, green economic opportunities and social inclusion. It aims to measure performance with these criteria and provide policy

makers with a system to measure and improve green growth performance. In 2019, GGGI introduced the first comparative Green Growth Index, a composite index that measures a country's performance in meeting sustainability goals across these four dimensions, including United Nations Sustainable Development Goals, Paris Climate Agreement, and Aichi Biodiversity targets. The indicator for green economy opportunities has the lowest performance value among the index values. According to GGGI data, GGGI levels increased by more than 10% in 48 countries, between 1% and 10% in 43 countries, and between 0% and 1% in 6 countries. The decrease in GGGI was between 1% and 10% in 13 countries and more than 10% in 7 countries. Although the values are not very high, the GGGI values of the countries for the year 2019 have increased compared to 2005. According to the GGGI report published in 2020, there are 119 countries that have achieved the Green Growth Index. (25 countries in Africa, 20 countries in the Americas, 35 countries in Asia, 36 countries in Europe and only 3 countries in Oceania). According to the same report, almost half of the countries have scores between 40 and 60, and these countries occupy about 77 million km^2 of the global land area. There are 41 countries with high scores, between 60 and 80, most of which are in Europe. The 6 countries with low scores, between 20 and 40, are predominantly from Africa and Asia. There are no countries with very low scores, below 20. Sweden, located in Northern Europe, has the highest green growth index with 78.72 points [4].

In our country, the "Green Growth" and "Sustainable Development" approaches are based on climate action in the 10th Development Plan. In addition, the National Climate Change Strategy Document covering the years 2010-2020 within the scope of combating climate change determines the basic policies, while another complementary basic document is the 2011-2023 National Climate Change Action Plan. These documents include measures related to energy, buildings, industry, transportation, agriculture, land use and forestry, waste sectors under the headings of climate change mitigation, adaptation, technology transfer, financing and capacity building [5].

To understand the performance of countries, it is very important to review the trends in the past years disaggregated by region and size. Understanding the causes and extent of upward and downward trends in the index will allow policymakers to gain insights into which areas of green growth require more attention. As more countries become members of GGGI, there is an opportunity to have a stronger global voice and reach, and to leverage lessons learned from the green growth pool. In this sense, the participation of the G7 countries and Turkey in the GGGI will be of great benefit to both sides.
In this study, the environment and sustainability-oriented data of the G7 countries, which are the 7 largest countries in the world in terms of economy and industrialization, and our country are listed with MCDM techniques. Performance ranking was performed using the longest available data set instead of a one-year assessment.

This study consists of four parts. In the first part of the study, literature studies that examine the environmental performance of countries in the world and Turkey were reviewed. In the next section, based on the relevant literature studies, the methods to be used in the study were determined and explained. In the research part of the study, the data obtained from the GGGI report and the performance of the G7 countries and Turkey were analyzed using the weighting methods CRITIC and ENTROPY and the EDAS ranking method. Efficient and sustainable resource use, natural capital protection, green economic opportunities and social inclusion indicators, which are the four main indicators of GGGI, were taken into consideration as ranking criteria. In weighting these criteria, sensitivity analyzes were performed for 2019 and 2020 and the findings obtained from the study were evaluated. In the conclusion part of the study, suggestions are presented based on the research findings.

2. LITERATURE RESEARCH

GGGI has initiated a very important sustainability study on a global scale. The aim of this study is to create several scenarios that correspond to the situation of the countries of the world and the situation of other countries. An examination of the

situation of Turkey in GGGI, which it is not yet a member of regarding the available data, will provide important data for monitoring its place in the ranking over the years and for making a membership decision. Monitoring the GGGI ranking of G7 countries (with the exception of England, which is a GGGI member), which take important positions in setting social and economic policy at the global level, can also contribute to membership decisions. In this way, GGGI's global green development practices can be more widely disseminated and global action can be taken more quickly. For this purpose, environmental performance studies conducted in Turkey and in other countries which play an important role in the countries' achieving their sustainability goals have been investigated. In the discussed framework, the relevant literature studies have been summarized.

Alkaya utilized DEA to determine the efficiency of OECD countries based on their environmental performance in 2022 [6]. As a result of the study, Denmark, Finland, Sweden, Iceland, Colombia, Latvia, Lithuania and Luxembourg were classified as efficient countries based on their environmental performance, while other OECD countries were classified as inefficient. Korea and Turkey were found to be the two least efficient countries in terms of environmental performance.

Altıntaş conducted a study for the 2020 Environmental Performance Index scores of 19 countries in the G20 countries [7]. The criteria weights of the EPI components of the countries were determined using the ENTROPY method. Countries' environmental performance was ranked using ROV, ARAS, and COPRAS methods. As a result of the research, it was found that the most important component that determines environmental performance of each country is water resources. In another study in Altıntaş assessed the environmental performance of the countries in the G7 group using the 2018 EPI components [8]. The ranking of countries was conducted using the CODAS and TOPSIS methods, which are part of the MCDM methods. As a result of the study, the ranking of environmental performance of countries which was made using the CODAS method was identified to be in the following order: England, France, Japan, Germany, Canada, Italy and the USA. According to the TOPSIS method, this ranking was determined as England, France, Germany, Japan, Canada, Italy and USA.

Liu et. al. used one of the MCDM methods, BWM (Best Worst Method), to evaluate the environmental performance of 30 provincial administrative regions in China in 2021. A linear programming model was developed to determine the weights of the criteria used in the analysis [9].

Ok et.al. classified EU countries and Turkey based on the most important indicators of green growth in 2021 [10]. Turkey and EU countries were classified into groups considering the 5 most important indicators of green growth. As a result of the analysis, countries that were homogeneous in terms of the main indicators of green growth and had similarities among themselves were divided into groups, and it was investigated whether Turkey had similar characteristics to the other countries in the same group, and the statistical results were evaluated.

Akhanova et. al. made use of the SWARA method to determine the weighting of categories and indicators in Kazakhstan's Building Sustainability Assessment in 2020, and the results of the research are expected to provide a useful reference for green building decision makers in the country [11].

Dang et. al. used MCDM methods to assess the environmental quality of OECD countries in 2020. The ENTROPY method was utilized to weight the criteria, and the VIKOR method was used to rank OECD countries according to their environmental quality [12].

Matsumoto et. al. used DEA to measure the environmental performance of European countries in 2020 [13]. As a result of the study, it was found that environmental performance was negatively affected by the 2007-2008 financial crisis and that both economic and environmental variables significantly affected the overall productivity of countries.

In the 2019 study by Wu et. al., a quantitative environmental performance assessment model was developed based on the hybrid MCDM approach, with key environmental indicators based on ISO 14031 environmental performance assessment (EPE) dimensions [14]. As a result of the study, it was found that the three most important environmental indicators are factory sewage discharge, greenhouse gas emissions and the rate of green product designs in reducing CO2.

In 2017, Cucchiella et. al. conducted a study with MCDM methods using Eurostat data to assess the current sustainability performance of European countries from an environmental and energy perspective [15].

Eğilmez et. al. contacted experts from academia, government, and industry to determine the environmental sustainability performance of 27 U.S. and Canadian metropolitan areas, and a methodology was developed in 2015 [16]. A hierarchical fuzzy MCDM approach was developed by establishing criteria in accordance with sustainability performance evaluation forms prepared with experts and proposals were put forward.

Guo et. al. developed the ENTROPY-based DEMATEL model to promote the green development of China's economy and evaluate sustainability indicators, in 2015 [17]. To show that development will be the main driving force, they concluded that energy is not only the most influential factor, but also a causal factor.

Halkos et. al. examined the environmental performance of 110 countries in 2014 and used DEA to examine countries' mandated emission-reduction percentages [18].

3. METHOD AND MATERIALS

The application of MCDM techniques based on GGGI data and 4 basic performance indicators in monitoring countries' green growth rankings will make significant contributions in identifying strengths and weaknesses relative to member countries, as well as development opportunities and sustainability risks.

In assessing the green growth performance of 8 countries, the Green Growth Index, which is composed of four criteria, including efficient and sustainable resource use, natural capital protection, green economic opportunity, and social inclusion indicators was utilized. Dang used the ENTROPY method for criterion weighting while evaluating OECD countries in terms of environmental performance in 2019 [12]. Arsu et.al. used the CRITIC method for criterion weighting while evaluating the economic, social and environmental performances of OECD countries in 2021 [19]. In assessing the climate change performance of G7 countries in [8], Altıntaş applied the EDAS method to rank the countries' performance. In reviewing the literature related to the study, it was found that CRITIC and ENTROPY methods were used for criteria weighting and EDAS method was used for performance ranking. For this reason, the CRITIC and ENTROPY methods were used to weight the 4 criteria, and the EDAS method was used to rank the countries.

- **CRITIC Method**

The CRITIC method first entered the literature in 1995 with a study conducted by Diakoulaki et. al. [20]. The CRITIC (Criteria Importance Through Intercriteria Correlation) method aims to determine objective weights of relative importance in MCDM problems. The resulting weights include both contrast intensity and conflict, which are inherent in the structure of the decision problem. The developed method is based on analytical study of the evaluation matrix to extract all the information contained in the evaluation criteria [20].

The most important feature that distinguishes the CRITIC method from other methods is that it is an objective weighting, using the standard deviations of the criteria and the correlation between the criteria together, rather than subjective results derived from expert opinions [21].

The CRITIC method consists of five steps as follows [20]:

Step 1: Creating the Decision Matrix

The decision matrix contains the criteria values corresponding to different alternatives. It is created as in Equation (1):

$$X = \left[x_{ij}\right]_{m\times n} = \begin{bmatrix} x_{11} & \dots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

x_{ij}, i. alternative j. Indicates the criterion value.

Step 2: Normalization of Decision Matrix

In the normalization process, Equation (2) is used for maximization-oriented criteria and Equation (3) is used for minimization-oriented criteria (Equation 2, Equation 3):

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \quad (2)$$

$$r_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \quad (3)$$

Step 3: Creating the Relationship Coefficient Matrix

The correlation coefficients (ρ_{jk}) used to measure the degree of relations between the evaluation criteria are calculated as in Equation (4):

$$\rho_{jk} = \frac{\sum_{i=1}^{m}\left(r_{ij} - \overline{r_j}\right).\left(r_{ik} - \overline{r_k}\right)}{\sqrt{\sum_{i=1}^{m}(r_{ij} - \overline{r_j})^2 . \sum_{i=1}^{m}(r_{ik} - \overline{r_k})^2}}$$
$$j,k = 1,2 \dots \dots \dots \dots \dots \dots \dots \dots n \quad (4)$$

Step 4: Calculating C_j Values

C_j, which combines both features and expresses the total information found in j criteria, is calculated using the standard deviation σ_j of the column values of the normalized decision matrix. Equation 5 and Equation 6 can be used for these operations (Equation 5, Equation 6):

$$C_j = \sigma_j \sum_{k=1}^{n}(1 - \rho_{jk}) \quad j = 1,2 \dots \dots n \quad (5)$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(r_{ij} - \overline{r_j})^2}{m-1}} \quad (6)$$

Step 5: Calculating Criterion Weights

The objective weights of the criteria can be calculated with the help of Equation (7):

$$W_j = \frac{c_j}{\sum_{k=1}^{n} c_k} \quad j,k = 1,2 \dots \dots . n \quad (7)$$

Objective weight values are ordered from the largest to the smallest. It is concluded that the criterion with the highest weight is more important.

• ENTROPY Method

The term entropy, first defined by Rudolph Clausius in 1865, entered the literature as a measure of disorder and uncertainty and is used in thermodynamics [22]. Information entropy is a measure of uncertainty first introduced by Shannon in his 1948 article *A Mathematical Theory of Communication* and has since been widely used in engineering, management, and many other fields. According to the concept of information entropy, the number or quality of information obtained from the decision-making environment is one of the determinants of the accuracy and reliability of the decision-making problem. For this reason, entropy is a very good measure when applied with different considerations in different decision-making processes [23].

ENTROPY method consists of 5 stages [24].

Step 1: Creating the decision matrix

As shown in Equation (8), a decision matrix with m decision options and n evaluation criteria is created (Equation 8):

$$X_{n\times m} = \begin{bmatrix} x_{11} & \dots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \dots & x_{nm} \end{bmatrix} \quad (8)$$

Step 2: Normalizing the decision matrix

The criteria are normalized with the help of Equation (9):

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{9}$$

Step 3: Calculating the entropy value

The entropy variable (E_j) is calculated with the help of the formula in Equation (10):

$$E_j = -k \sum_{i=1}^{n} r_{ij} \ln(r_{ij}) \qquad k = (\ln(n))^{-1} \tag{10}$$

Step 4: Finding the degrees of differentiation

The differentiation measure of the entropy variable(d_j) is found with the help of Equation (11).

$$d_j = 1 - E_j \tag{11}$$

Step 5: Finding the entropy weight

The objective weight of each criterion is found by using Equation (12).

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{12}$$

• EDAS Method

EDAS method (Evaluation based on Distance from Average Solution), a new MCDM method, was first introduced in 2015 by [25] and has been reported in the literature. The EDAS method is similar to MCDM methods COPRAS, MOORA, TOPSIS and VIKOR in terms of trying to find a solution based on distance. However, in the EDAS method, it is not necessary to calculate the best and the worst values. In the method, the best alternative is found by calculating the average solution distances of the alternatives according to each criterion.
For a case with n alternatives and m criteria, the steps are as follows [25]:

Step 1: Select the most important criteria that determine the alternatives.

Step 2: The decision matrix (X) is created as shown in Equation (13).

$$X = \left[x_{ij}\right]_{n\times m} \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix} \tag{13}$$

Here,

X_{ij}shows the performance value of the alternative i according to the jth criterion.

Step 3: The average solution is determined according to all criteria as shown in Equations (14) and Equations (15).

$$AV = \left[AV_j\right]_{1\times m} \tag{14}$$

$$AV_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \tag{15}$$

Step 4: According to equations (16) and (17), positive distance from the mean (PDA) and negative distance from the mean (NDA) are calculated according to the type of criteria (benefit and cost) (Equation 16 and Equation 17):

$$PDA = \left[PDA_{ij}\right]_{n\times m} \tag{16}$$

$$NDA = \left[NDA_{ij}\right]_{n\times m} \tag{17}$$

If the criterion j is benefit-based (Equation 18, Equation 19):

$$PDA_{ij} = \frac{\max\left(0, \left(X_{ij} - AV_j\right)\right)}{AV_j} \quad (18)$$

$$NDA_{ij} = \frac{\max\left(0, \left(AV_j - X_{ij}\right)\right)}{AV_j} \quad (19)$$

If the criterion j is cost-based (Equation 20 and Equation 21):

$$PDA_{ij} = \frac{\max\left(0, \left(AV_j - X_{ij}\right)\right)}{AV_j} \quad (20)$$

$$NDA_{ij} = \frac{\max\left(0, \left(X_{ij} - AV_j\right)\right)}{AV_j} \quad (21)$$

In Figure 1, PDA_{ij} and NDA_{ij} show the positive and negative distance of the i. alternative from the mean solution, respectively, in terms of the jth criterion.

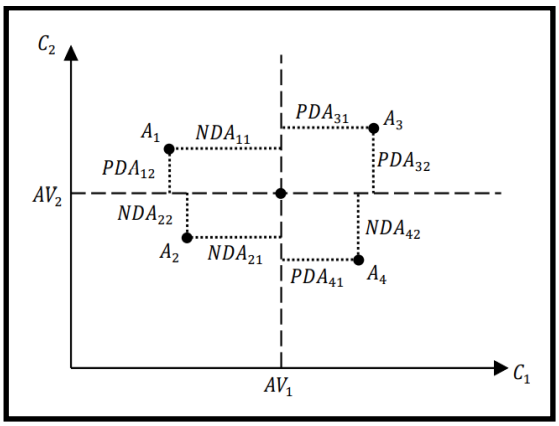

Figure 1. PDA and NDA values in a simple case [25]

Step 5: The weighted sum of PDA and NDA for all alternatives is determined (Equation 22 and Equation 23):

$$SP_i = \sum_{j=1}^{m} w_j \, PDA_{ij} \quad (22)$$

$$SN_i = \sum_{j=1}^{m} w_j \, NDA_{ij} \quad (23)$$

w_j, is the weight of the jth criterion.

Step 6: the SP and SN values for all alternatives as shown in Equations below are normalized. (Equation 24 and Equation 25).

$$NSP_i = \frac{SP_i}{\max\limits_i SP_i} \quad (24)$$

$$NSN_i = 1 - \frac{SN_i}{\max\limits_i SN_i} \quad (25)$$

Step 7: As in Equation (26), the evaluation score (AS) is calculated for all alternatives (Equation 26).

$$AS_i = \frac{1}{2}\left(NSP_i + NSN_i\right) \quad (26)$$

It is between $0 \leq AS_i \leq 1$

Step 8: The alternatives are ranked according to the decreasing values of the evaluation score (AS). Among the alternatives under consideration, the alternative with the highest AS value is the best choice.

4. RESEARCH AND FINDINGS

GGGI performance indicators and country data published on the official GGGI website were used for the study. According to country performance data of G7 countries and Turkey, criteria weights were calculated annually using ENTROPY and CRITIC methods, which are criteria weighting methods from MCDM techniques and allow objective weighting. According to the data from the report published by the Global Green Growth Institute, the descriptive statistics of G7 and GGGI performance indicators of Turkey are shown in Table 1.

Table 1. Descriptive statistics of GGGI data of countries between 2010-2020

Country	Descriptive Statistics	Social Inclusion	Natural Capital Protection	Efficient and Sustainable Resource Use	Green Economic Opportunities
USA	Min	79.91	59.93	51.19	29.48
	Average	82.12	61.18	51.84	32.88
	Max	83.64	61.65	52.19	35.88
	Std.D.	1.61	0.55	0.34	2.26
Germany	Min	87.77	81.10	54.86	50.82
	Average	89.67	81.75	60.53	52.41
	Max	91.39	82.39	62.91	54.23
	Std.D.	1.49	0.47	2.50	1.20
UK	Min	87.31	76.29	61.95	31.87
	Average	89.11	77.76	63.11	36.87
	Max	90.49	78.89	63.74	38.64
	Std.D.	1.18	0.92	0.68	1.94
France	Min	87.01	75.61	57.68	36.93
	Average	88.89	76.83	60.08	39.98
	Max	91.03	78.09	62.08	41.86
	Std.D.	1.51	0.88	1.61	2.05
Italy	Min	83.29	77.91	60.92	41.23
	Average	84.97	79.51	62.79	42.41
	Max	86.24	80.40	63.74	44.11
	Std.D.	1.33	0.98	1.14	1.04
Japan	Min	79.76	62.29	54.93	33.75
	Average	80.32	65.62	56.86	36.71
	Max	80.77	70.97	58.05	41.95
	Std.D.	0.33	4.18	1.10	2.84
Canada	Min	84.54	56.60	56.22	32.45
	Average	85.99	56.91	56.59	33.86
	Max	86.91	57.08	56.98	35.01
	Std. D.	0.90	0.15	0.26	0.91
Turkey	Min	71.34	52.98	54.68	28.89
	Average	75.38	53.13	57.01	29.83
	Max	76.93	53.44	59.06	30.62
	Std.D.	2.08	0.14	1.96	0.60

As shown in Table 1, Germany compares favorably with other countries on indicators of social inclusion, natural capital protection, and green economy opportunities. On the indicator of efficient and sustainable use of resources, the United Kingdom showed the best performance. While Turkey outperformed other countries in social inclusion, natural capital protection and green economy opportunities indicators, the USA ranked lower than other countries in terms of effective and sustainable resource use performance.

Annual performance criteria weights between 2010 and 2020 calculated using GGGI data and an MCDM technique, ENTROPY, are shown in Table 2.

Table 2. "ENTROPY" weighting coefficients of criteria according to GGGI data between 2010-2020

ENTROPY	Social Inclusion	Natural Capital Protection	Efficient and Sustainable Resource Use	Green Economic Opportunities
2010	0.06	0.36	0.05	0.53
2011	0.07	0.39	0.05	0.50
2012	0.05	0.39	0.05	0.51
2013	0.05	0.40	0.06	0.49
2014	0.05	0.41	0.07	0.47
2015	0.05	0.42	0.07	0.47
2016	0.05	0.41	0.07	0.48
2017	0.05	0.40	0.08	0.48
2018	0.05	0.38	0.08	0.49
2019	0.05	0.38	0.08	0.49
2020	0.05	0.38	0.08	0.49

As shown in Table 2, the sum of the weighting coefficients of the performance indicators of natural capital protection and green economy opportunities is between 0.87 and 0.90. The sum of the weighting coefficient of the social inclusion indicator and the weighting coefficient of the efficient and sustainable resource use indicator is between 0.10 and 0.13. The lowest and highest performance weight coefficients calculated between 2010 and 2020 according to the ENTROPY method are between 0.42 and 0.47, and it is observed that there are significant differences between the criteria weights.

Like the ENTROPY method, the CRITIC method is one of the most widely used MCDM methods in research for criterion weighting due to its advantages such as considering quantitative data and not requiring the opinions of decision makers [26]. For this reason, the criteria weighting in the study was also repeated using the CRITIC method. Annual performance criteria weights calculated using data from GGGI and CRITIC, a MCDM technique, for the period 2010 to 2020 were realized as shown in Table 3.

Table 3. "CRITIC" weight coefficients of criteria according to GGGI data between 2010-2020

CRITIC	Social Inclusion	Natural Capital Protection	Efficient and Sustainable Resource Use	Green Economic Opportunities
2010	0.27	0.23	0.19	0.31
2011	0.26	0.20	0.23	0.31
2012	0.26	0.18	0.26	0.30
2013	0.26	0.18	0.27	0.28
2014	0.26	0.17	0.28	0.29
2015	0.28	0.16	0.29	0.28
2016	0.28	0.18	0.29	0.25
2017	0.27	0.23	0.27	0.23
2018	0.27	0.23	0.24	0.26
2019	0.27	0.23	0.24	0.27
2020	0.27	0.23	0.24	0.26

As shown in Table 3, the difference between the lowest and highest performance weighting coefficients calculated annually between 2010 and 2020 using the CRITIC method for the performance indicators identified by GGGI ranges from 0.03 to 0.13. In addition, the weighting coefficients of the performance indicators calculated with CRITIC are more evenly distributed.

The ranking of country performance calculated with the EDAS method according to the criteria weights determined with ENTROPY method from the data of the study period used was realized as shown in Figure 2.

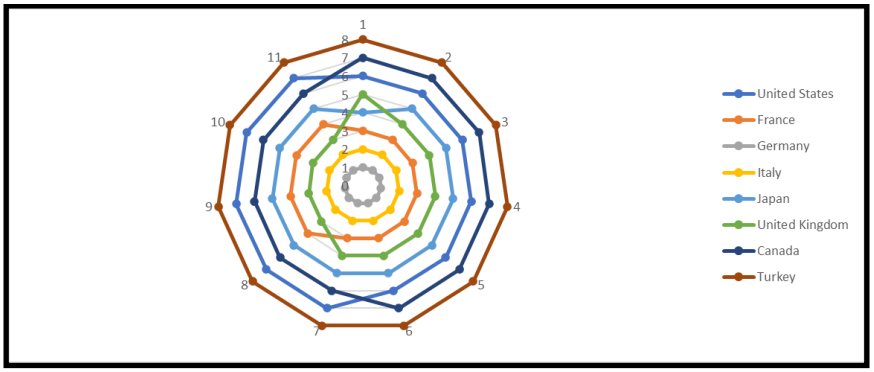

Figure 2. GGGI ENTROPY-EDAS country ranking

Based on GGGI data published regularly by the Global Green Growth Institute for the period 2010 to 2020, country performance rankings were calculated using ENTROPY criteria weighting and EDAS ranking methods. While Germany ranked first throughout the whole study period, Turkey performed worse than the other countries. According to the data of the GGGI index, which is based on the assessment within the framework of the criteria of efficient and sustainable resource use, natural resource protection, green economic opportunities and social inclusion, the United Kingdom moved from the fourth to the third place, displacing France from its position after 2016. According to the data of the report published by the Global Green Growth Institute, Canada moved from the seventh to the sixth rank, replacing the ranking of the USA after 2015. In the next stage of the study, the data of the study period and the criteria weights were recalculated using the CRITIC method. As a result, the ranking of country performance calculated using the EDAS MCDM method was produced according to the criteria weights obtained (see Figure 3).

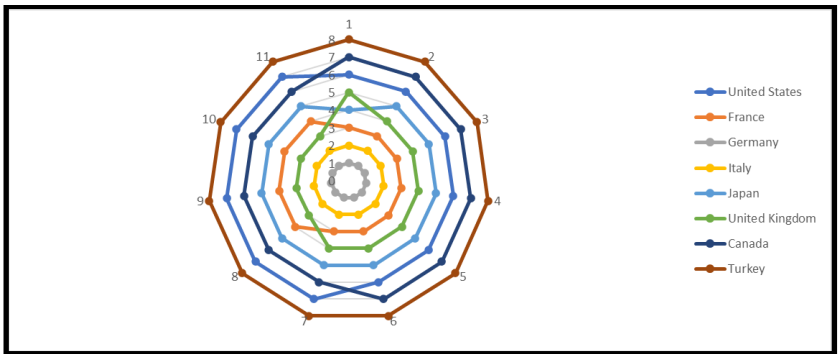

Figure 3. GGGI CRITIC-EDAS country ranking

According to GGGI data for the period 2010-2020, Germany ranks first in the country rankings calculated according to the CRITIC criteria weighting and the EDAS ranking method during the study period, while Turkey performs worse than the other countries. The United Kingdom, which is a member of GGGI, replaced France in the ranking after 2016, rising from the fourth to third place, similar to the results of the ENTROPY method. The ranking of other countries remained the same in all years, in contrast to the results obtained with the ENTROPY method.

- **Sensitivity Analysis**

MCDM assumes defining criteria by which selection results can be evaluated effectively. It also allows for comparison of relevant methods and selection of the most suitable one. The results of MCDM methods mostly depend on the values of the coefficients of the weighting criteria, that is, on the relative importance given to certain criteria. Sometimes the final selections display differences with minor changes in the weighting criteria coefficients. Therefore, the results of MCDM methods can be compared with an analysis of their sensitivity to these changes [27]. In this study, a sensitivity analysis was performed to control the effects of criterion weights on country performance. The weighting of the sensitivity analysis criteria is shown in Table 4. Here, combinations of 10 percent and 70 percent weighting of the criteria are considered separately. For example, in the case of "1117", the criteria for social inclusion, natural capital protection, and efficient and sustainable use of resources are assigned 10 percent weight, while the green economy opportunities criteria are assigned 70 percent weight. Similarly, the calculations were continued for four different situations according to the four criteria. With the sensitivity analysis carried out, it is aimed to reveal which of the criteria of social inclusion, natural capital protection, efficient and sustainable resource use and green economy opportunities for a green economy used in the evaluation of country performance plays a greater role in overall performance.

Table 4. Weight coefficients of criteria for sensitivity analysis between 2010-2020

Weight Code	Social Inclusion	Natural Capital Protection	Efficient and Sustainable Resource Use	Green Economic Opportunities
Equal Weight	0.25	0.25	0.25	0.25
1117	0.10	0.10	0.10	0.70
1171	0.10	0.10	0.70	0.10
1711	0.10	0.70	0.10	0.10
7111	0.70	0.10	0.10	0.10

As a result of the sensitivity analysis, it was found that there were no significant changes in the ranking of country performance according to the weighting coefficients ENTROPY and CRITIC. It has been observed that the most change was observed in the calculation conducted with the weighting coded "1171" in which social inclusion, natural capital protection and green economy opportunities indicators were found to have a significance level of 0.10, and the indicator of effective and sustainable resource use had a significance level of 0.70.

5. CONCLUSION

Environmental management has become an international issue in recent decades. Many researchers have highlighted the importance of using and managing natural resources [28-30]. Public concern about environmental pollution and degradation, as well as climate change, has led to global awareness of the need to reduce greenhouse gas emissions and protect the environment. Environmental quality has a significant impact on

human health, comfort and well-being. It also affects economic and social development. For this reason, government agencies, businesses, and social institutions have proposed a number of policies, procedures, and guidelines to promote environmentally conscious behavior.

Measuring environmental quality is critical since it provides evidence for creating and improving the quality of the environment, which improves the quality of people's lives [12]. For this purpose, in this study, annual country performance rankings were calculated for G7 countries and Turkey with GGGI's data between the years 2010-2020, using ENTROPY and CRITIC weighting and EDAS ranking methods. While Germany showed the best performance overall, Turkey performed lower than developed countries such as USA, UK, Germany, France, Japan, Italy and Canada.

The study also conducted sensitivity analyzes for the weighting coefficients of the country performance rankings based on performance indicators. In the calculation made with the criteria weights coded as "1171", it was observed that the indicator of effective and sustainable resource use is more effective in the ranking than the other criteria in the GGGI performance ranking for the G7 and Turkey. If Turkey improves its performance in terms of efficient and sustainable resource use in particular, it can achieve better results in the country rankings.

Consequently, it is considered that it would be beneficial to be taken into account by academic and political circles in the assessments to be made in Turkey and the G7.

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