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Analysis of Food Security Performances of G7 Countries: An Application with LOPCOW-based DNMA Method

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Abstract: Analyzing the food security performance of large economies is vital due to its significant impact on global food security policies and the broader economy. This study utilizes the most up-to-date data from 2022 obtained from the Global Food Security Index (GFSI) to assess the food security performances of G7 countries using the Logarithmic Percentage Change-driven Objective Weighting (LOPCOW) based Double Normalization-Based Multiple Aggregation (DNMA) Multi-Criteria Decision-Making (MCDM) method. Additionally, the food security performance of these countries is examined using various criterion weighting methods such as ENTROPY, Criteria Importance Through Inter Criteria Correlation, Statistical Variance Procedure, and Method based on the Removal Effects of Criteria, alongside multiple MCDM techniques including Range of Value, Additive Ratio Assessment, Technique for Order Preference by Similarity to Ideal Solution, Simple Additive Weighting, Weighted Product Method, and Weighted Aggregated Sum Product Assessment, incorporating previously assessed data from Economist Impact. The analysis reveals that the most significant GFSI indicator for these countries are Sustainability, Compliance, and Accessibility. According to the LOPCOW-based DNMA method, the food security performances of the countries are ranked as follows: Canada, Japan, Italy, France, the United States, the United Kingdom, and Germany. Notably, the food security performance values of the United States, the United Kingdom, and Germany are below the average. The findings suggest that G7 countries should prioritize meaningful actions related to Sustainability, Compliance, and Accessibility to enhance their contributions to global food security and the economy. Furthermore, it is essential for Germany, the United Kingdom, and the United States to improve their food security performances to bolster global food security. Methodologically, the LOPCOW-based DNMA method has been observed to align with sensitivity in sensitivity analysis, reliability and validity in comparative analysis, and robustness and stability in simulation analysis. Therefore, it has been evaluated that the LOPCOW-based DNMA method can effectively measure the food security performance of G7 countries within the GFSI framework.

Keywords: Food security, Global Food Security Index, G7, LOPCOW-based DNMA.

G7 Ülkelerinin Gıda Güvenliği Performanslarının Analizi: LOPCOW tabanlı DNMA Yöntemi ile Bir Uygulama

Özet: Büyük ekonomilerin gıda güvenliği performansını analiz etmek, küresel gıda güvenliği politikaları ve daha geniş ekonomi üzerindeki önemli etkisi nedeniyle hayati öneme sahiptir. Bu çalışma, G7 ülkelerinin gıda güvenliği performanslarını Logaritmik Yüzde Değişimine Dayalı Objektif Ağırlıklandırma (LOPCOW) tabanlı Çift Normalizasyon Tabanlı Çoklu Birleştirme (DNMA) Çok Kriterli Karar Verme (MCDM) yöntemi ile değerlendirmek için 2022 yılına ait en güncel Verileri Küresel Gıda Güvenliği Endeksi (GFSI) kullanmaktadır. Ayrıca, bu ülkelerin gıda güvenliği performansını, Economist Impact tarafından daha önce değerlendirilen verilerle birlikte, ENTROPY, Kriterler Arası Korelasyon Üzerinden Kriter Önemlendirme, İstatistiksel Varyans Yöntemi ve Kriterlerin Çıkarma Etkilerine Dayalı Yöntem gibi çeşitli kriter ağırlıklandırma yöntemleri ile Değer Aralığı Yöntemi, Toplam Oran Değerlendirme Yöntemi, İdeal Çözüme Benzerlik ile Tercih Sıralama Tekniği, Basit Toplam Ağırlıklandırma Yöntemi, Ağırlıklı Çarpım Yöntemi ve Ağırlıklı Toplam ve Çarpım Birleştirme Değerlendirme Yöntemi gibi birçok MCDM tekniği ile incelenmektedir. Analiz, bu ülkeler için en önemli GFSI kriterlerinin Sürdürülebilirlik, Uyumluluk ve Erişilebilirlik olduğunu ortaya koymaktadır. LOPCOW tabanlı DNMA yöntemine göre, ülkelerin gıda güvenliği performansları sırasıyla Kanada, Japonya, İtalya, Fransa, ABD, Birleşik Krallık ve Almanya şeklindedir. Özellikle, ABD, Birleşik Krallık ve Almanya 'nın gıda güvenliği performans değerleri ortalamanın altındadır. Bulgular, G7 ülkelerinin küresel gıda güvenliği ve ekonomiye katkılarını artırmak için Sürdürülebilirlik ile Uyumluluk ve Erişilebilirlik ile ilgili anlamlı eylemlere öncelik vermeleri gerektiğini önermektedir. Ayrıca, Almanya, Birleşik Krallık ve ABD'nin küresel gıda güvenliği ve küresel artırmak için söz konusu ülkelerin gıda güvenliği performanslarını artırmaları gereklidir. Metodolojik olarak, LOPCOW tabanlı DNMA yöntemi, duyarlılık analizi ile duyarlılık, karşılaştırmalı analizde güvenilirlik ve geçerlilik, simülasyon analizinde ise sağlamlık ve istikrara uyum sağladığı gözlenmiştir. Bu nedenle, LOPCOW tabanlı DNMA yönteminin, GFSI çerçevesinde G7 ülkelerinin gıda güvenliği performansının ölçülebileceği değerlendirilmiştir.

Anahtar Kelimeler: Gıda güvenliği, Küresel Gıda Güvenliği Endeksi, G7, LOPCOW tabanlı DNMA.

Research Article

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1.Introduction

Food security is a fundamental necessity for healthy and balanced nutrition worldwide (Kerr, 2023). Therefore, sustainable food production and access within the scope of food security are critical for preserving human health and welfare (Martin Ralph & May, 2019). Because food security not only plays a significant role in combating hunger and malnutrition but also supports social stability and economic development (Denning, 2023). Additionally, on a global scale, investment in food security shapes the quality of life for future generations and the sustainability of our planet (Martindale, 2014). Therefore, food security is recognized and supported as a global priority (Zhou, 2020).

The concept of food security arose during World War I as the international community commenced the gathering of national food balance sheet data for the first time. This effort persisted and intensified throughout World War II, with the objective of facilitating the distribution and allocation of food in conflict-affected regions (Shakeel, 2018). Subsequently, food security became more prominent as a right to not suffer from hunger during the 1974 world food crisis. Particularly, the technocratic conceptions of economic growth and free trade influenced this concept as a development goal. By the 1990s, the idea of food security expanded to include not only access to affordable and nutritious foods but also recognized cultural food preferences as a fundamental human right (Bozsik, et al., 2022). However, the concept of food security has become a flexible notion as a result of numerous attempts to define it in research and policy usage (Roetterband & Van Keulen, 2007; Akbari et al., 2022). Consequently, various related definitions of the concept of food security have been formulated (Barrett & Lentz, 2009; Peng & Berry, 2019). The most common and comprehensive definition among these definitions has been provided by the Food and Agriculture Organization (FAO) (Dutta & Saikia, 2018; Ala & Ridwan, 2020; Naz et al., 2023). According to this, food security is described as the physical, social, and economic access of all people at all times to sufficient, safe, and nutritious food, meeting their dietary needs for a healthy life (FAO, 2012).

In general, food security consists of four dimensions: food availability, food access, utilization, and food stability. Food availability is defined as the presence of sufficient quantities of food of adequate quality, supplied through local production or imports (including food aid). Food access refers to individuals' ability to obtain appropriate food and a nutritious diet through sufficient resources. Utilization is defined as the biological use of food through adequate nutrition, drinking water, sanitation, and medical care, to achieve a state of nutritional well-being in which all physiological needs are satisfied, a concept that highlights the importance of non-food inputs in food security. Food stability refers to both the presence and accessibility of reliable food sources for individuals (Gibson, 2012; Ahmad, 2021; García-Díez, et al., 2021).

When examining the relationships between food security and other dimensions in the literature, it is noteworthy that there are more studies explaining the relationship of food security with economic growth. In this context, according to the relevant literature, the relationship between food security and economic growth dimensions has been evaluated in three parts based on data related to countries' food security and economic growth dimensions. Firstly, the mutual impact between food security and the economic dimension is addressed. In this relationship, it has been determined in the literature that firstly, there is a positive and significant relationship between food security and economic (Timmer, 2006; Desta, 2017; Pourreza et al., 2018; Fernandes & Samputra, 2022). Secondly, the mutual interaction between food security and economic growth has been observed to be significant as U-shaped according to temporal and panel data (Kang, 2015) and inverted U-shaped (Chen & Chen, 2023). Thirdly, it has been determined that the food security dimension positively and significantly influences the economic growth dimension (Manap & İsmail, 2019; Ojimadu, 2022), and economic growth also positively affects food security (Gnedeka, 2023). From another perspective in the literature, it has been observed that climate change negatively and significantly affects food security between the dimensions of food security and climate change (FAO, 2008; HLPE Steering, 2012; El Mokhtar et al., 2019). When evaluating the relationship between life data and food security dimensions, it has been found that food security significantly and negatively affects the dimensions of quality of life (Moafi et al., 2018) and life satisfaction (Salahodjaev & Mirziyoyeva, 2021). Again from another perspective, when examining the relationship between food security and sustainable development dimensions, it has been determined that ensuring food security contributes significantly and positively to sustainable development (Bazga, 2015; Berry, 2015). Due to the global nature of food security, countries have recognized the need to be aware of their performance in food security and accordingly require metrics that objectively measure their progress in food security (Economist Impact, 2022). Therefore, the only scale that measures countries' food security performances is the Global Food Security Index (GFSI) developed by the Economist Impact organization. The index primarily consists of four indicator (components), namely affordability, availability, quality and safety, and sustainability and adaptation. Methodologically, countries' performances on GFSI indicator are scored between 0 and 100. The food security performances of countries can be measured by the arithmetic average of these GFSI indicator (Economist Impact, 2022). Accordingly, the explanations of the GFSI indicator are shown in Table 1 below.

Table 1. Explanation of GFSI indicator (Economist impact, 2022).

Tablo 1. GFSI indikatörlerin açıklaması (Economist impact, 2022).

GFSI Indicator	Explanations
Affordability	Assesses consumers' ability to buy food, their susceptibility to price shocks, and the existence of programs and policies to assist consumers during shocks.
Availability	Evaluates agricultural production and on-farm capabilities, the risk of supply disruption, national capacity for food distribution, and research efforts to enhance agricultural output.
Quality and Safety	Assesses the diversity and nutritional value of typical diets, as well as the safety of food.
Sustainability and Adaptation	Evaluates a nation's vulnerability to the effects of climate change, its exposure to risks related to natural resources, and its efforts to adapt to these risks.

In this study, the food security performances of the G7 countries, which are the world's largest economies, were measured for the latest and most current year, 2022, using values from GFSI indicator through the Logarithmic Percentage Change-driven Objective Weighting based (LOPCOW) Double Normalization-Based Multiple Aggregation (DNMA) Multi-Criteria Decision-Making (MCDM) method. Additionally, in this study, the food security performance of G7 countries, previously measured by the Economist Impact institution, is evaluated using different criteria weighting methods (ENTROPY, Criteria Importance Through Inter Criteria Correlation (CRITIC), Statistical

Variance Procedure (SVP), Method based on the Removal Effects of Criteria (MEREC)) and various Multi-MCDM methods (Range of Value (ROV), Additive Ratio Assessment (ARAS), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Simple Additive Weighting (SAW), Weighted Product Method (WPM), and Weighted Aggregated Sum Product Assessment (WASPAS)). The weights of the GFSI indicator and the food security performance of the countries are measured, and the resulting values are compared.

In the scope of the LOPCOW method, there is no limitation on the number of criteria when calculating the degrees of importance of criteria relative to decision alternatives. The most significant difference between the LOPCOW method and other objective weighting methods lies in its calculation of the percentage of standard deviations of mean squared values, thereby eliminating the dimensionality-related differences in data (Bektaş, 2022). The DNMA method possesses several advantages within its unique framework in the MCDM literature. Firstly, one of its strengths lies in its flexibility. Flexibility refers to the ability to adjust the weights of different clustering models, decision-making requirements, and goals according to decision makers' risk attitudes. Secondly, the method exhibits a reliability feature. Reliability entails compensating for the advantages and disadvantages of the two normalization methods used in the method, thereby reducing information loss during the normalization process. By utilizing three types of utility functions, a balance can be achieved between overall performance and worst-case scenarios, enabling the ranking of decision alternatives. Lastly, the method is based on simplicity. Consequently, through the integration approach employed in the method, a direct set of alternatives can be derived (Wu & Liao, 2019; Ecer, 2020). Therefore, in accordance with the specified advantages of the methods, the LOPCOW method was utilized to measure the weights (degrees of importance) of GFSI indicator for the countries under study, while the LOPCOW-based DNMA method was employed to assess the food security performances of the countries.

ENTROPY, CRITIC, SVP, and MEREC are objective criteria weighting methods frequently utilized by researchers for weighting criteria in decision-making problems within the MCDM literature (Keleş, 2022; Demir et al., 2021). The ENTROPY method is based on the premise that data groups with higher entropy values exhibit greater uncertainty (Ayçin, 2019). In the CRITIC (Criteria Importance Through Inter Criteria Correlation) method, the correlation values between criteria are taken into account (Diakoulaki et al., 1995). The MEREC (Method based on the Removal Effects of Criteria) method relies on exclusion procedures rather than inclusion steps to derive criterion weights, taking into account the effects of removal or exclusion (Keshavarz-Ghorabaee et al., 2021). In this context, objective criterion weights have been preferred for the comparative analysis. Because objective weighting methods determine the importance level of criteria without relying on personal judgments, instead using values directly calculated from data. These methods ensure consistency by eliminating the influence of personal biases and subjective evaluations, thus reducing the likelihood of human error (Ecer, 2020).

A review of the MCDM literature reveals that methods such as ROV, ARAS, TOPSIS, SAW, WPM, and WASPAS are commonly employed in selection problems or in measuring the performance of decision alternatives (Demir et al., 2021). In this context, In the ROV method, The ROV method is an approach that equally considers both cost and benefit criteria (Ulutaş & Topal, 2020). In the ARAS method, the evaluation and selection of decision alternatives are based on analyzing the benefit levels of each alternative (Uludağ & Doğan, 2021). In the TOPSIS method, the evaluation and ranking of decision alternatives depend on their closeness to the positive ideal solution and their distance from the negative ideal solution (Ciardiello & Genovese, 2023). The WPM method is based on a weighted product approach. The SAW method, on the other hand, is a technique based on weighted averages. The WASPAS method is based on the combined use of the SAW and WPM methods (Demir et al., 2021). These MCDM methods are frequently utilized by researchers in the literature for solving selection problems or measuring the performance of decision alternatives (Ayçin, 2019; Ulutaş & Topal, 2020). Therefore, in the comparative analysis, the ROV, ARAS, TOPSIS, SAW, WPM, and WASPAS MCDM methods have been employed from an MCDM perspective.

It can be considered that countries with particularly large economies play a significant role in global food supply and access. Therefore, changes and fluctuations in food security in large economies can affect the global food market. Additionally, considering the relationship between economic growth and food security dimensions, the strategies and methods of large economies regarding food security can influence the policies of other countries in terms of food security (Economist Impact, 2022). The G7 countries are among the largest economic organizations in the world, holding approximately 30% to 40% of global capital between the years 2000 and 2024 (Dyvik, 2024). When examining the relationship between economic size and food security dimensions, many studies have observed that food security positively and significantly contributes to economic growth (Kavallari et al., 2014; Desta, 2017; Abogahsem et al., 2018; Manap & Ismail, 2019). Therefore, as the G7 countries rank among the largest economies in the world, analyzing their food security performance is critically important for understanding the connections between economic growth and sustainable food access. Economic growth can enhance agricultural productivity and improve food systems. Thus, examining the food security strategies of G7 countries can be considered a valuable contribution to the development of more effective policies at the international level.

The G7 countries, which are home to the world's largest economies, first attempted to unite global efforts on food security and nutrition in 2016. In line with the 2030 Agenda for sustainable development and the COP21 Paris Agreement, the G7 countries proposed an Action Vision for Food Security and Nutrition to advance the global nutrition agenda. They focused on improving nutrition with a people-centered approach and aimed to ensure sustainability and resilience in agriculture and food systems (Ministry of Foreign Affairs of Japan, 2016; Group G7, 2019). In this context, the G7 countries have engaged in collaboration with the World Bank to address potential global food security issues. Furthermore, the efforts and collaborations of G7 countries in the field of food security create synergy, significantly enhancing their contributions to global food security and the global economy. Therefore, the analysis of the food security performance of G7 countries can be considered crucial. (Germany G7, 2022). According to Economist Impact (2022), the average food security performance of 114 countries within the GFSI framework was observed to be 58, while the performance of G7 countries was 78. Thus, the food security performance of G7 countries is 35% higher than the global average. Accordingly, the overall food security performance of G7 countries is significantly above the global average due to their advancements in factors such as sustainable food systems and food accessibility. In this context, the food security performances of G7 countries have been analyzed using the LOPCOW-based DNMA method. In the literature, no studies have been found that measure food security using any numerical or MCDM method in relation to the subject of this research. Therefore, this study contributes to the literature in terms of both its subject and methodology. Therefore, this study holds global significance in terms of analyzing the current food security performance of G7 countries. Methodologically, it has been demonstrated that the LOPCOW-based DNMA method is successful in measuring the performance of decision alternatives. Consequently, within the scope of the research motivation, firstly, it was evaluated which indicator of the GFSI should be prioritized for the G7 countries to contribute to global food security and the economy. Secondly, it was examined which country or countries among the G7 should prioritize increasing their food security performances to contribute to global food security and economic recovery using the LOPCOW-based DNMA method. Thirdly, from a methodological perspective, it was assessed whether countries' food security performances within the scope of the GFSI could be measured using the LOPCOW-based DNMA MCDM method. In this context, in the materials and methods section of the research, the analysis of the study, dataset, LOPCOW, and DNMA methods were explained respectively. In the results and discussion section, insights regarding the quantitative findings identified in the study were provided.

2. Material and Method

2.1. Analysis of the Study and Data Analysis

The dataset for the research consists of GFSI criterion values for the latest and most current year, which is 2022, for the G7 countries. In this study, the food security performance of G7 countries, previously assessed by the Economist Impact organization, is analyzed using various criteria weighting techniques, including ENTROPY, CRITIC, SD, SVP, and MEREC. Additionally, multiple MCDM methods such as ROV, ARAS, TOPSIS, SAW, WPM, and WASPAS are employed. The weights assigned to the GFSI indicator, along with the countries' food security performance metrics, are calculated and compared to derive insightful conclusions. Accordingly, in the study, the food security performances of G7 countries were measured using the LOPCOW based DNMA method with the relevant data. For ease of reference, the abbreviations of the GFSI indicator are provided in Table 2.

Table 2. Abbreviations of the GFSI indicator.
Tablo 2. GFSI indicator kısaltması.

GFSI Indicator	Abbreviations
Affordability	GFSI1
Availability	GFSI2
Quality and Safety	GFSI3
Sustainability and Adaptation	GFSI4

2.2 LOPCOW Method

LOPCOW method is an objective weighting method introduced to the MCDM literature by Ecer & Pamucar (2022). The logic of the method is based on aggregating data from different dimensions to obtain appropriate or ideal weights. Additionally, this method aims to minimize the gaps between the most important and least important indicator. Furthermore, LOPCOW takes into account the mutual relationships between indicator. Moreover, the method is not influenced by negative raw data (Bektaş, 2022; Wu and Liao, 2019; Ecer & Pamucar, 2022; Keleş, 2023). The application steps of the method are explained below (Ecer & Pamucar, 2022; Ecer & Zolfani, 2022).

Step 1: Obtaining of the Decision Matrix (X)

$i: 1, 2, 3 \ldots n,$ where m shows the number of decision alternatives.

$j: 1, 2, 3, \ldots m,$ where n shows the number of criteria

X: Decision matrix

C: Criterion

d_{ij}: The decision matrix is constructed according to Equation 1, where "i_j" explains the $i-th$ decision alternative on the $j-th$ criterion. In this context, the decision matrix is formed according to Equation 1.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Step 2: Normalization of the Decision Matrix $\left(r_{ij}^{x}\right)$

During this stage, the values in the decision matrix are computed for benefit-driven criteria using Equation 2 and for cost-centric criteria employing Equation 3.

For benefit-oriented criteria:

$$r_{ij}^{x} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}} \tag{2}$$

For cost-oriented criteria:

$$r_{ij}^{x} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}} \tag{3}$$

Step 3: Determining the Percentage Value of Each Criterion $\left(PV_{ij}\right)$

In this stage, Equation 4 is employed to represent the squared mean value as a fraction of the standard deviations for each criterion. This method effectively eliminates the impact of data size on variability. Within Equation 4, the symbol σ denotes standard deviation, and In represents the natural logarithm.

$$PV_{ij} = In \left| \frac{\sqrt{\frac{\sum_{i=1}^{m} r_{ij}^{2}}{m}}}{\boldsymbol{\sigma}} \right| \tag{4}$$

Step 4: Measuring Criterion Weights $\left(w_j\right)$

$$w_j = \frac{PV_{ij}}{\sum_{\boldsymbol{k}} PV_{ij}} \tag{5}$$

Although the LOPCOW objective criterion weighting method is relatively new and up-to-date, many researchers have utilized it for measuring the weight values of criteria in the literature. In this regard, research related to LOPCOW is presented in Table 3.

Table 3. LOPCOW literature
Table 3. LOPCOW literatürü.

Author(s)	Method(s)	Theme(s)
Biswas et al., 2024	LOPCOW, ERUNS	Firm capacity in energy field
Dhruva et al, 2024	Fermatean Fuzzy Set, LOPCOW, and CoCoSo	Analysis of suitable cloud vendors for health centre
Ecer at al., 2023	q-rung fuzzy LOPCOW-VIKOR	Analysis the role of unmanned aerial vehicles

ARAS: Additive Ratio Assessment, CRITIC: Criteria Importance Through Inter Criteria Correlation, COCOSO: Combined Compromise Solution, CRITIC: Criteria Importance Through Inter Criteria Correlation, ERUNS: Evaluation based on Relative utility and nonlinear standardization, LOPCOW: Logarithmic Percentage Change-Driven Objective Weighting, MARCOS: Measurement Alternatives and Ranking According to Compromise Solution, MEREC: Method Based on the Removal Effects of Criteria, VIKOR: VIse Kriterijumska Optimizacija I Kompromisno Resenje.

Table 3. LOPCOW literature (continue).
Tablo 3. LOPCOW literatürü (devamı).

Author(s)	Method(s)	Theme(s)
Işık et al., 2023	LOPCOW, SWARA II, and MARCOS	Analysis of Turkish non-life insurance companies' financial performance
Öztaş & Öztaş, 2024	LOPCOW and MAIRCA	Assessment of innovation performance analysis of G20 countries
Simic et al., 2023	LOPCOW and ARAS	Neutrosophic LOPCOW ARAS model for prioritizing industry 4.0 based material handling technologies in smart and sustainable warehouse management systems
Yalman et al., 2023	MEREC, LOPCOW and MARCOS	Evaluation of the macroeconomic performance of the Turkish economy in the period 2000-2020
Chatterjee & Chakraborty 2024	MEREC, LOPCOW, IDOCRIW, SPC, CILOS, and PCA	Impact of objective weighting methods on TOPSIS-Based parametric optimization of non-traditional machining processes
Kahreman, 2024	CRITIC, LOPCOW and CoCoSo	Assessment of the economic performance of the D8 countries
Dua et al., 2024	MEREC, LOPCOW, CRITIC, MARA, RAM, and PIV	Material selection

ARAS: Additive Ratio Assessment, CILOS: CRITERION Impact LOSs, COCOSO: Combined Compromise Solution, CRITIC: Criteria Importance Through Inter Criteria Correlation, IDOCRIW: Integrated Determination of Obkective Criteria Weights, LOPCOW: Logarithmic Percentage Change-Driven Objective Weighting, MAIRCA: Multi-Atributive Ideal-Real Comparative Analysis, MARA: Magnitude of the Area for the Ranking of Alternatives, MARCOS: Measurement Alternatives and Ranking According to Compromise Solution, MEREC: Method Based on The Removal Effects Of Criteria, PCA: Principal Component Analysis, PIV: Proximity Index Value, RAM: Root Assessment Method, SPC: Symmetry Point of Criterion.

2.3. DNMA Method

The DNMA (Double Normalization-Based Multiple Aggregation) method is based on the combination of linear and vector normalization techniques. Therefore, in this method, the ideal decision alternative is selected to be closest to the expected solution consisting of the expected values of each criterion or component (Wu & Liao, 2019; Ecer & Zolfani, 2022).

Below are the application steps of the DNMA method (Wu & Liao, 2019; Ecer, 2020).

Step 1: Obtaining the Decision Matrix

$i: 1,2,3 \ldots n, n$: Number of decision alternative

$j: 1,2,3, \ldots m, m$: Number of criteria

D: Decision matrix

d_{ij}: The decision matrix is formed with the Equality 6 for the $i'th$ decision alternative on the $j'th$ criterion.

$$D = [d_{ij}]_{nxm} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{6}$$

Step 2: Calculation of Linear $(\tilde{x}_{ij}^{1N})$ and Vector $(\tilde{x}_{ij}^{2N})$ Normalization Values: $(\tilde{x}_{ij}^{1N})$

Linear Normalization:

$$(\tilde{x}_{ij}^{1N}) = 1 - \frac{|x^{ij} - r_j|}{max\,\{max(x^{ij}, r_j)\} - min\,\{min(x^{ij}, r_j)\}} \tag{7}$$

Vector Normalization:

$$(\tilde{x}_{ij}^{2N}) = 1 - \frac{|x^{ij} - r_j|}{\sqrt{\sum_{i=1}^{m} (x^{ij})^2 + (r_j)^2}} \tag{8}$$

Step 3: Correction of Criterion Weights

In order to establish balance between conflicting components, criterion weights are adjusted. The third step of the method is carried out through three operations.

1st Operation: Calculation of the standard deviation (σ_j) of criterion j.

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m} (\frac{x^{ij}}{mak\ x^{ij}} - \frac{1}{m} \sum_{i=1}^{m} (\frac{x^{ij}}{mak\ x^{ij}}))^2}{m}} \tag{9}$$

2nd Operation: Measurement of normalized values for the standard deviations found in (i) concerning the criteria (ω_j^{σ}):

$$\omega_j^{\sigma} = \frac{\sigma_j}{\sum_{j=1}^{n} \sigma_j} \tag{10}$$

3rd Operation: Correction of weights $(\widetilde{\omega}_j)$:

$$\widetilde{\omega}_j = \frac{\sqrt{\omega_j^{\sigma} . \omega_j}}{\sum_{j=1}^{n} \sqrt{\omega_j^{\sigma} . \omega_j}} \tag{11}$$

Step 4: Measurement of Utility Functions:

In the fourth step, three utility functions are calculated for each decision alternative.

First Function: CCM (Complete Compensatory Model):

Under the CCM, the low performance of a decision alternative under certain criteria can be compensated by its good performances under other criteria.

Second Function: UCM (Uncomplete Compensatory Model): UCM aims to ensure that the selected decision alternative does not perform significantly worse than any other decision alternative or to determine the worst performance of the decision alternative across all criteria.

Third Function: ICM (Incomplete Compensatory Model): This function addresses the need to compromise in selection problems where we prefer an alternative with an average performance instead of one that performs very poorly for some criteria but very well for others.

CCM, UCM, and ICM functions are calculated using the equations specified below.

$$\mathrm{CCM}: u_1(a_i) = \frac{\sum_{j=1}^{n} \widetilde{\omega}_j . \tilde{x}_{ij}^{1N}}{max\tilde{x}_{ij}^{1N}} \tag{12}$$

$$\mathrm{UCM}: u_2(a_i) = max\widetilde{\omega}_j(1 - \tilde{x}_{ij}^{1N})/max\tilde{x}_{ij}^{1N}) \tag{13}$$

$$\mathrm{ICM}: u_3(a_i) = \prod_j (\tilde{x}_{ij}^{2N}/max\tilde{x}_{ij}^{2N})^{\omega_j} \tag{14}$$

Step 5: Integration of Utility Functions and Establishment of Rankings. (DN_i)

$$DN_i = w_1.\sqrt{\varphi.\left(\frac{u_1(a_i)}{maksu_1(a_i)}\right)^2 + (1-\ \varphi).\frac{m - r_1(a_i) + 1}{m}} -$$

$$w_2.\sqrt{\varphi.\left(\frac{u_2(a_i)}{maksu_2(a_i)}\right)^2 + (1-\ \varphi).\frac{m-r_2(a_i)+1}{m}} +$$
$$w_3.\sqrt{\varphi.\left(\frac{u_3(a_i)}{maksu_3(a_i)}\right)^2 + (1-\ \varphi).\frac{m-r_3(a_i)+1}{m}} \qquad (15)$$

The DN_i values of decision alternatives are ranked from highest to lowest value. In Equation 15, $r_1(a_i)$ represents the rank number for the CCM function, and $r_2(a_i)$ represents the rank number for the ICM function, with the highest value being in the first place. $r_3(a_i)$ represents the rank number for the UCM function, with the lowest value being in the first place. (φ) denotes the relative importance of utility functions and ranges between '0' and '1' $(\varphi \in [0,1])$. The method's developers have emphasized that the value of (φ) could be 0.5 w_1, w_2 and w_3 represent the degrees of importance (weights) of the CCM, UCM, and ICM utility functions, respectively, and the sum of criterion weights should be '1' $(w_1 + \ w_2 + w_3 = 1)$. The values of w_1, w_2 and w_3 can be determined by the decision maker depending on the risk situations. These weights can be determined in three scenarios based on the overall performance or worst performance of decision alternatives.

First Scenario: Decision makers may assign the highest weight to the CCM if they prioritize comprehensive performance of decision alternatives or if most decision alternatives perform best across criteria.

Second Scenario: If decision makers prefer to avoid risks or if the selected decision alternatives should not perform poorly across certain criteria, the highest weight can be given to the UCM.

Third Scenario: If decision makers aim to evaluate both comprehensive performance and risks, the highest weight can be assigned to the ICM.

Weights can also be determined using linear and vector normalization techniques. If linear normalization is considered more efficient and effective, larger weights can be assigned to CCM and UCM. Otherwise, the largest weight is allocated to the ICM utility function.

When reviewing the literature on MCDM, it has been observed that many researchers utilize the DNMA method to measure the performance of alternatives or to address selection problems. In line with this, studies related to the DNMA method are shown in Table 4.

Table 4. DNMA literature.
Tablo 4. DNMA literatürü.

Author(s)	Method(s)	Theme(s)
Nie et al., 2019	Hesistant Fuzzy Linguistic DNMA	Utilizing Cardinal Consensus Reaching Process for Selecting Shopping Mall Locations
Liao et al., 2020	SWARA, DNMA, WASPAS, and TOPSIS	Selection of Sustainable Suppliers for Construction

DNMA: Double Normalization-Based Multiple Aggregation, WASPAS: Weighted Aggregated Sum Product Assessment. SWARA: Step-Wise Weight Assessment Ratio Analysis, TOPSIS: Technique for Order Preference by Similarity to Ideal Solution.

Table 4. DNMA literature (continue).
Tablo 4. DNMA literatürü (devamı).

Author(s)	Method(s)	Theme(s)
Zhang et al., 2020	Pythagorean Fuzzy DNMA	Analysis of Internet Financial Investment Products
Demir, 2022	LMAW and DNMA	Evaluation of the Financial Performance of the Deposit Banking Sector During the COVID-19 Period.
Ecer & Zolfani, 2022	MEREC and DNMA	Assessing economic freedom of OPEC countries
Hezam et al., 2022	Fuzzy MEREC, RS and DNMA	Evaluating alternative fuel vehicles from a sustainability perspective
Saha et al., 2022	q-Rung Orthopair Fuzzy FUCOMD, DNMA	Assessing of Healthcare Waste Treatment Methods
Dündar, 2023	LMAW and DNMA	Evaluation of the Performance of Regional Development Agencies
Lai et al., 2020	DNMA and Gini-Coeffcient	Development of a sustainable provider for cloud services.
Mishra et al., 2023	MEREC-SWARA DNMA	Analysis of a sustainable site for the establishment of a lithium-ion battery manufacturing facility.

DNMA: Double Normalization-Based Multiple Aggregation, FUCOMD: Full Consistency Method, LMAW: A New Logarithm Methodology of Additive Weights, MEREC: Method Based on the Removal Effects of Criteria, RS: Ranking Sum, SWARA: Step-Wise Weight Assessment Ratio Analysis.

3. Result

3.1. Computational Analysis

In the study, initially, the weights of the GFSI indicator for each country were measured using the LOPCOW method. In this context, in the first step of the LOPCOW method, decision matrix was formed with Equation 1. In the second step of the method, since GFSI is benefit-oriented, the normalized values of the decision matrix were measured with Equation 2. In the third step, the percentage weight value of each criterion was calculated with Equation 4. In the final step, the weights of the GFSI indicator were calculated with Equation 5. The relevant values determined in this regard are shown in Table 5.

Upon examining Table 5, the weights of the GFSI indicator for each country have been ranked as GFSI4 (Sustainability and Adaptation), GFSI1 (Affordability), GFSI3 (Quality and Safety), and GFSI2 (Availability). Additionally, it has been observed that the weight value of GFSI4 criterion significantly differs from the weight values of the other indicator in terms of having a higher weight value. Furthermore, the average weight value of the indicator has been calculated $(w_{Mean} = 0{,}250)$, and it has been determined that the criteria GFSI4 and GFSI2 have weight values higher than the average value. Therefore, based on this result, it can be concluded that the criteria GFSI4 and GFSI2 are more important compared to the other indicator.

Table 5. Decision Matrix, normalized Matrix, PV_{ij} and w values.
Tablo 5. Karar Matrisi, normalize Matriks, PV_{ij} ve w değerleri.

Decision Matrix (D)

G7	GFSI1	GFSI2	GFSI3	GFSI4
Oriented	**Mak.**	**Mak.**	**Mak.**	**Mak.**
Canada	88.3	81.2	89.5	60.1
Germany	91.3	69	87.7	70.3
France	87.9	67	79.9	70.8
Italy	89.5	68.7	75.9	57.3
Japan	89.8	81.2	77.4	66.1
UK	91.5	71.6	77.6	71.1
USA	87.1	65.1	88.8	69.4
Maximum	91.5	81.2	89.5	71.1
Minimum	87.1	65.1	75.9	57.3

Normalized Matrix (r_{ij}^{x})

G7	GFSI1	GFSI2	GFSI3	GFSI4
Canada	0.273	1.000	1.000	0.203
Germany	0.955	0.242	0.868	0.942
France	0.182	0.118	0.294	0.978
Italy	0.545	0.224	0.000	0.000
Japan	0.614	1.000	0.110	0.638
UK	1.000	0.404	0.125	1.000
USA	0.000	0.000	0.949	0.877

PV_{ij}

Indicator	GFSI1	GFSI2	GFSI3	GFSI4
PV_{ij}	48.56	33.10	35.42	62.95

w

Indicator	GFSI1	GFSI2	GFSI3	GFSI4
w	0,270	0,184	0,197	0,350
Rank	2	4	3	1

GFSI1: Affordability, GFSI2: Availability, GFSI3: Quality and Safety, GFSI4: Sustainability and Adaptation.

In the second step of the research, countries' food security performances were measured using the LOPCOW-based DNMA method. In this context, in the first step of the DNMA method, a decision matrix is formed with Equation 6. The said decision matrix has been previously shown in Table 3 with the assistance of Equation 1 within the framework of the LOPCOW method. In the second step of the method, due to the benefit-oriented nature of the GFSI indicator, linear normalization is measured with Equation 7 and vector normalization values are measured with Equation 8. The calculated linear and vector normalization values are explained in Table 6.

Table 6. Lineer and vector values.
Tablo 6. Doğrusal ve vektör değerleri.

Lineer Normalization $(\tilde{x}_{ij}^{1N})$

Countries	GFSI1	GFSI2	GFSI3	GFSI4
Canada	0.273	1	1	0.203
France	0.955	0.242	0.868	0.942
Germany	0.182	0.118	0.294	0.978
Italy	0.545	0.224	0.000	0.000
Japan	0.614	1	0.110	0.638
UK	1	0.404	0.125	1
USA	1	0.000	0.949	0.877

GFSI1: Affordability, GFSI2: Availability, GFSI3: Quality and Safety, GFSI4: Sustainability and Adaptation.

Table 6. Lineer and vector values (continue).
Tablo 6. Doğrusal ve vektör değerleri (devamı).

Vector Normalization $(\tilde{x}_{ij}^{2N})$

Countries	GFSI1	GFSI2	GFSI3	GFSI4
Canada	0.987	1	1	0.942
France	0.999	0.941	0.992	0.996
Germany	0.986	0.932	0.959	0.998
Italy	0.992	0.940	0.942	0.927
Japan	0.993	1	0.949	0.974
UK	1	0.954	0.950	1
USA	0.983	0.922	0.997	0.991

GFSI1: Affordability, GFSI2: Availability, GFSI3: Quality and Safety, GFSI4: Sustainability and Adaptation.

In the third step of the method, adjusted criterion weight values have been calculated. In this regard, firstly, the standard deviation (SD) of the indicator is determined with Equation 9, and the normalized standard deviation (NSD) values are determined with Equation 10. Subsequently, the adjusted criterion (AW) weight values are measured with Equation 11. The relevant measured values are shown in Table 7.

Table 7. SD, NSD and AW values of criteria.
Tablo 7. Kriterlerin SD, NSD ve AW değerleri.

Standard Deviations (SD: σ_j)

SD	GFSI1	GFSI2	GFSI3	GFSI4
σ_j	0.969	0.885	0.917	0.932

Normalized Standard Deviations (NSD: ω_j^{σ})

NSD	GFSI1	GFSI2	GFSI3	GFSI4
ω_j^{σ}	0.262	0.239	0.248	0.252

Adjusted Weights (AW: $\tilde{\omega}_j$)

Indicator	GFSI1	GFSI2	GFSI3	GFSI4
$\tilde{\omega}_j$	0.268	0.211	0.222	0.299

GFSI1: Affordability, GFSI2: Availability, GFSI3: Quality and Safety, GFSI4: Sustainability and Adaptation.

In the fourth step of the method, the utility function values for CCM are measured with Equation 12, for UCM with Equation 13, and for ICM with Equation 14. In order to ensure a comprehensive approach in the study, taking into account both the strengths and weaknesses of the countries (decision alternatives) in terms of performance, the weights assigned were 0.2 for CCM, 0.2 for UCM, and 0.6 for ICM, based on their extensive performance and risks. Consequently, the highest weight was assigned to ICM. The utility function values for the countries are presented in Table 8.

Table 8. CCM, UCM and ICM scores.
Tablo 8. CCM, UCM ve ICM skorları.

Countries	CCM	UCM	ICM
Canada	0.567	0.238	0.9302
France	0.818	0.168	0.9301
Germany	0.441	0.224	0.881
Italy	0.354	0.548	0.821
Japan	0.590	0.198	0.918
UK	0.680	0.195	0.906
USA	0.499	0.282	0.898

CCM: Complete Compensatory Modeli, ICM: Incomplete Compensatory Model, UCM: Uncomplete Compensatory Model.

In the final step of the DNMA method, Equation 15 is used to combine the values of CCM, UCM, and ICM, resulting in the combined values of countries' utility functions (food security performance values) being measured. In this context, the food security performance values of countries and their rankings are indicated in Table 9.

Table 9. DN scores of countries.
Tablo 9. Ülkelerin DN skorları.

Countries	DN	Rank
Canada	1.018	1
France	0.848	4
Germany	0.670	7
Italy	0.851	3
Japan	0.899	2
UK	0.706	6
USA	0.710	5
Mean	0.815	

DN: Integration of Utility Functions and Establishment of Rankings.

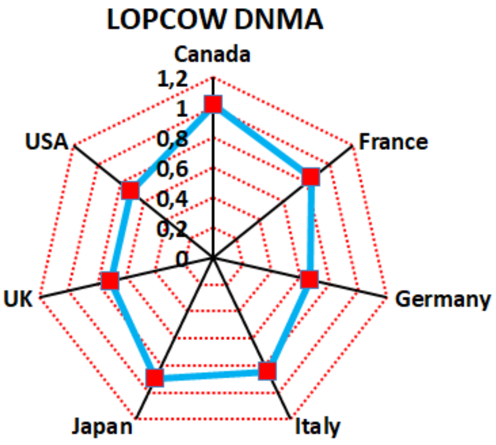

Figure 1. Position of LOPCOW-DNMA method
Şekil 1. LOPCOW-DNMA yönteminin pozisyonu

Upon examining Table 9 and Figure 1, countries' food security performances are ranked as Canada, Japan, Italy, France, USA, UK, and Germany. Additionally, according to Table 8, the average food security performance value of countries has been calculated, and it has been observed that the countries with performance values higher than the calculated average performance value are Canada, Japan, Italy, and France.

3.2. Sensitivity Analysis

One approach to assessing the robustness of MCDM methods is by introducing new alternatives to the original set or eliminating weaker alternatives from it. In such instances, the MCDM method is expected not to exhibit significant shifts in the ranking of alternatives. This issue is known as the 'rank reversal problem' and has received substantial attention in the literature (Demir & Arslan, 2022). In this context, a rank reversal application was conducted for sensitivity analysis, starting with the lowest-performing alternative according to the LOPCOW-based DNMA method. The resulting country rankings are presented in Table 10, while the visual representation of the rankings is shown in Figure 1.

Table 10. Rank reversal.
Tablo 10. Ters Sıralama.

G7	S0	S1	S2	S3	S4	S5
Canada	1	1	1	1	2	1
France	4	4	4	4	---	---
Germany	7	---	---	---	---	---
Italy	3	3	3	3	3	---
Japan	2	2	2	2	1	2
UK	6	6	---	---	---	---
USA	5	5	5	---	---	---

SO: Result, S1: 1. Scenario, S2: 2. Scenario, S3: 3. Scenario, S4: 4. Scenario, S5: 5. Scenario

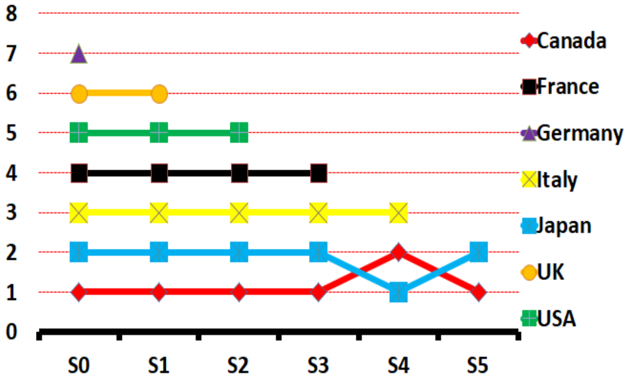

Figure 2. Rank Reversal Visual.
Şekil 2. Sıralama Tersliği Görseli.

When Table 9 and Figure 2 are evaluated together, it is observed that the countries' food security performance rankings are generally consistent across scenarios in the rank reversal method used for sensitivity analysis. According to Table 10 and Figure 2, only in the fourth scenario, Canada ranks second while Japan is placed first. Therefore, based on these results and referencing the literature, it can be concluded that the LOPCOW-based DNMA method demonstrates reasonable sensitivity in assessing countries' food security performances using GFSI indicator.

3.3. Comparative Analysis

The comparative analysis assesses the relationships and standings of the proposed approach relative to other methodologies used for calculating MCDM methods. The proposed method should demonstrate credibility, reliability, and consistency with other methodologies, while also exhibiting a favorable and statistically significant correlation with various MCDM methodologies (Keshavarz-Ghorabaee et al., 2021). In this context, the food security performance values of countries, computed using the LOPCOW-based DNMA method, were juxtaposed with performance values calculated by LOPCOW-based ROV, ARAS, TOPSIS, SAW, WPM, and WASPAS.

When Tables 9 and 11 are examined together, it becomes apparent that the rankings of countries' food security performance values, as determined by the LOPCOW-based DNMA method, differ from those identified by the ROV, ARAS, TOPSIS, SAW, WPM, and WASPAS methods. Accordingly, the correlation values between the methods are presented in Table 12.

Table 11. Performance score of countries by the other LOPCOW based MCDM models.
Tablo 11. Diğer LOPCOW tabanlı MCDM yöntemlerine göre ülkelerin performans skorları.

Country	LOPCOW ROV		LOPCOW ARAS		LOPCOW TOPSIS	
	Score	R.	Score	R.	Score	R.
Canada	0.049	1	0.779	1	0.823	1
France	0.047	3	0.754	3	0.541	3
Germany	0.045	6	0.721	6	0.209	6
Italy	0.045	7	0.721	7	0.206	7
Japan	0.047	2	0.755	2	0.558	2
UK	0.046	4	0.738	4	0.369	5
USA	0.046	5	0.734	5	0.443	4
Country	**LOPCOW SAW**		**LOPCOW WPM**		**LOPCOW WASPAS**	
	Score	**R.**	**Score**		**Score**	**R.**
Canada	0.642	1	0.990	1	0.779	1
France	0.619	3	0.966	3	0.754	3
Germany	0.587	6	0.934	6	0.721	6
Italy	0.587	7	0.933	7	0.721	7
Japan	0.619	2	0.967	2	0.755	2
UK	0.603	4	0.950	4	0.738	4
USA	0.600	5	0.946	5	0.734	5

ARAS: Additive Ratio Assessment, LOPCOW: Logarithmic Percentage Change-Driven Objective Weighting ROV: Range Of Value, SAW: Simple Additive Weighting, TOPSIS: Technique for Order Preference by Similarity to Ideal Solution, WPM: Weighted Product Method, WASPAS: Weighted Aggregated Sum Product Assessment; R: Rank.

Table 12. Correlation Values Between the LOPCOW-Based DNMA Method and Other LOPCOW-Based MCDM Methods.
Tablo 12. LOPCOW tabanlı DNMA Yönteminin Diğer LOPCOW tabanlı MCDM Yöntemleriyle Olan Korelasyon Değerleri.

Methods	ROV	ARAS	TOPSIS
DNMA	0.795**	0.791**	0.755**
	SAW	**WPM**	**WASPAS**
	0.791**	0.791**	0.791**

ARAS: Additive Ratio Assessment, DNMA: Double Normalization-Based Multiple Aggregation, SAW: Simple Additive Weighting, TOPSIS: Technique for Order Preference by Similarity to Ideal Solution, WPM: Weighted Product Method, WASPAS: Weighted Aggregated Sum Product Assessment. **p<.01

Thus, it has been assessed that the performance of G7 countries in food security, measured using the LOPCOW-based DNMA method and GFSI indicator, is aligned with credible and reliable standards. Since different weight-based DNMA methods provide various MCDM approaches, the health security performances of the countries have been calculated using DNMA methods based on the ENTROPY, CRITIC, SVP, and MEREC objectve weighting techniques. The calculated values have been ranked and presented in Table 13.

Table 13. Weight values of indicator according to weighting methods.
Tablo 13. Ağırlıklandırma yöntemlerine göre kriterlerin ağırlık değerleri.

Methods	S-R	GFSI1	GFSI2	GFSI3	GFSI4
ENTROPY	S	0.017	0.391	0.249	0.343
	R	4	1	3	2
CRITIC	S	0.219	0.254	0.288	0.239
	R	4	2	1	3
SD	S	0.233	0.250	0.269	0.248
	R	4	2	1	3
SVP	S	0.025	0.383	0.316	0.276
	R	4	1	2	3
MEREC	S	0.241	0.302	0.199	0.257
	R	3	1	4	2

CRITIC: GFSI1: Affordability, GFSI2: Availability, GFSI3: Quality and Safety, GFSI4: Sustainability and Adaptation, MEREC: Method Based on the Removal Effects of Criteria, SD: Standart Deviation, SVP: Statistical Variance Procedure; S: Score, R: Rank.

Upon examining Table 13, it is observed that the weight rankings of GFSI indicator differ from each other according to objective weighting methods. Continuing analysis, Table 14 illustrates food securiity performances of countries and their corresponding performance rankings, as calculated using the ENTROPY, CRITIC, SVP, and MEREC-based DNMA method

Table 14. Performance scores of countries using various methodologies.
Tablo 14. Farklı metotlara göre ülkelerin performans skorları.

Country	ENTROPY DNMA		CRITIC DNMA	
	Score	**R.**	**Score**	**R.**
Canada	0.866	3	0.906	2
France	0.867	2	0.928	1
Germany	0.648	6	0.693	7
Italy	1.139	1	0.905	3
Japan	0.683	5	0.838	4
UK	0.604	7	0.806	5
USA	0.697	4	0.719	6

Country	SVP DNMA		MEREC DNMA		LOPCOW DNMA	
	Score	**R.**	**Score**	**R.**	**Score**	**R.**
Canada	0.82	3	0.92	2	1.018	1
France	0.866	2	0.983	1	0.848	4
Germany	0.675	7	0.702	7	0.67	7
Italy	1.183	1	0.894	3	0.851	3
Japan	0.729	4	0.758	4	0.899	2
UK	0.695	5	0.724	6	0.706	6
USA	0.687	6	0.745	5	0.71	5

CRITIC: Criteria Importance Through Inter Criteria Correlation, DNMA: Double Normalization-Based Multiple Aggregation, LOPCOW: Logarithmic Percentage Change-Driven Objective Weighting, MEREC: Method Based on the Removal Effects of Criteria, SVP: Statistical Variance Procedure, R: Rank.

Upon examining Table 14, it has been observed that the rankings of countries' food performance values calculated using the LOPCOW-based DNMA method differ from those calculated using other weight-based LOPCOW methods. Accordingly, the correlation values between the methods are presented in Table 15.

Table 15. Correlation Values Between the LOPCOW-Based DNMA Method and Other weight method-based DNMA Methods.

Tablo 15. LOPCOW Tabanlı DNMA Yöntemi ile diğer ağırlıklandırma tabanlı DNMA yöntemleri arasındaki korelasyon değerleri.

Methods	ENTROPY	CRITIC	SVP
LOPCOW	0.514*	0.795**	0.408*

CRITIC: Criteria Importance Through Inter Criteria Correlation, LOPCOW: Logarithmic Percentage Change-Driven Objective Weighting, SVP: Statistical Variance Procedure. **p<.01, *p<.05.

Upon examining Table 15, it has been observed that all the relationships between the food performance values of countries calculated using the LOPCOW-based DNMA method and the food security performance values calculated using DNMA methods based on other weighting techniques are significant and positive. Therefore, considering all correlation values within the comparative framework, LOPCOW-based DNMA method has been found to be aligned with reliability and credibility in measuring the food performance of G7 countries within the GFSI framework.

3.4. Simulation Analysis

To evaluate the robustness and stability of the proposed method's outcomes, a simulation analysis will be conducted. This analysis will entail generating various scenarios by applying different values to decision matrices. A reliable method should demonstrate increasing divergence in its outcomes compared to other methods as the number of scenarios increases. Subsequently, the average variance of MCDM methods determined by the proposed method across the scenarios should be notably higher than that of at least one other MCDM method. This would indicate the superior ability of the proposed method to differentiate between the relative importance of alternative. Finally, the analysis should establish consistency in the variance of MCDM methods across all methods within each individual scenario (Keshavarz-Ghorabaee et al., 2021). Firstly, performance values ranging from 0 to 100 were assigned randomly to countries according to the GFSI methodology, resulting in the creation of 10 distinct decision matrices (Appendix-A: Decision Matrices). In this context, Table 16 displays the correlation coefficients between the LOPCOW-based DNMA method and other LOPCOW-based MCDM methods, calculated based on the initial 10 scenarios of the simulation analysis.

Table 16. Corrrelation values.

Tablo 16. Korelasyon değerleri.

Scenario	ROV	ARAS	TOPSIS
1. Sce.	0.850**	0.843**	0.812**
2. Sce.	0.870**	0.866**	0.828**
3. Sce.	0.840**	0.834**	0.800**
Scenario	**ROV**	**ARAS**	**TOPSIS**
4. Sce.	0.785**	0.767**	0.743**
5. Sce.	0.743**	0.739**	0.721**
6. Sce.	0.725**	0.719**	0.714**
7. Sce.	0.714**	0.708**	0.704**
8. Sce.	0.711**	0.703**	0.692**
9. Sce.	0.703**	0.700**	0.685**
10. Sce.	0.700**	0.697**	0.685**
Mean	0.764	0.758	0.738

ARAS: Additive Ratio Assessment, ROV: Range of Value, SAW: Simple Additive Weighting, TOPSIS: Technique for Order Preference by Similarity to Ideal Solution, WPM: Weighted Product Method, WASPAS: Weighted Aggregated Sum Product Assessment.

Table 16. Corrrelation values (continue).

Tablo 16. Korelasyon değerleri (devamı).

Scenario	SAW	WPM	WASPAS
1. Sce.	0.844**	0.845**	0.845**
2. Sce.	0.866**	0.866**	0.866**
3. Sce.	0.834**	0.835**	0.835**
4. Sce.	0.768**	0.769**	0.769**
5. Sce.	0.739**	0.739**	0.742**
6. Sce.	0.720**	0.722**	0.724**
7. Sce.	0.708**	0.708**	0.708**
8. Sce.	0.703**	0.703**	0.705**
9. Sce.	0.701**	0.702**	0.703**
10. Sce.	0.696**	0.698**	0.700**
Mean	0.758	0.759	0.760

ARAS: Additive Ratio Assessment, ROV: Range of Value, SAW: Simple Additive Weighting, TOPSIS: Technique for Order Preference by Similarity to Ideal Solution, WPM: Weighted Product Method, WASPAS: Weighted Aggregated Sum Product Assessment.

In Table 16, the 10 scenarios are divided into two categories. The first group comprises the initial 3 scenarios, while the second group consists of the remaining scenarios. Upon examining Table 14, it is noted that as the number of scenarios increases, the correlation values between the LOPCOW-based DNMA method and other methods decrease. This trend is illustrated in Figure 4.

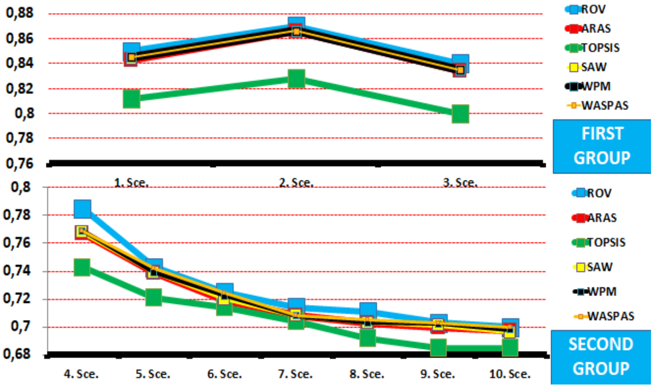

Figure 4. Correlation status between the LOPCOW-based DNMA method and other methods across the scenarios.

Şekil 4. Senaryolara göre LOPCOW tabanlı DNMA ve diğer yöntemlerin arasındaki korelasyon durumları.

Upon examining Figure 4, it is evident that as the scenarios increase, the LOPCOW-based DNMA method diverges, separates, and deviates from other LOPCOW-based MCDM methods. Therefore, based on this observation, it is concluded that as the scenarios increase, the distinctive characteristics of the LOPCOW-based DNMA method become more pronounced. Therefore, based on this observation, it is concluded that as the scenarios increase, the distinctive characteristics of the LOPCOW-based DNMA method become more pronounced. In the continuation of the simulation analysis, the consistency of variances in the criterion weights of the LOPCOW-based DNMA method was examined using ADM (ANOM for variances with Levene) analysis across various scenarios. This analytical approach provides a visual representation for assessing the equality of variances. The graphical representation consists of three components: the overall mean ADM serves as the central line, flanked by the upper decision limits (UDL) and lower decision limits (LDL). If the standard deviation of a group (cluster) exceeds the decision limits, it indicates a significant deviation from the overall mean ADM, suggesting variance heterogeneity. Conversely, if the standard deviations of all clusters fall within the LDL and UDL, it confirms the uniformity of variances (Keshavarz-Ghorabaee et al., 2021). In this context, the variance values of the performance scores of countries measured by the LOPCOW-based DNMA method for each scenario have been computed. Subsequently, the variance values of the LOPCOW based MCDM methods within the scenarios are presented in Table 17.

Table 17. Variance score of methods in scope of scenarios.
Tablo 17. Senaryolar kapsamında yöntemlerin varyans değerleri.

Sce.	DNMA	ROV	ARAS	TOPSIS
1. Sce.	0.014	0.0002	0.0005	0.055
2. Sce.	0.014	0.0003	0.0005	0.062
3. Sce.	0.014	0.0001	0.0004	0.059
4. Sce.	0.014	0.0001	0.0004	0.054
5. Sce.	0.014	0.0001	0.0003	0.051
6. Sce.	0.013	0.0001	0.0003	0.049
7. Sce.	0.013	0	0.0003	0.045
8. Sce.	0.013	0	0.0002	0.041
9. Sce.	0.013	0	0.0001	0.039
10. Sce.	0.012	0	0.0001	0.038
Mean	0.013	0.00009	0.00031	0.0493
Sce.	**SAW**	**WPM**	**WASPAS**	
1. Sce.	0.0005	0.0005	0.0006	
2. Sce.	0.0006	0.0006	0.0008	
3. Sce.	0.0004	0.0005	0.0006	
4. Sce.	0.0003	0.0005	0.0006	
5. Sce.	0.0003	0.0004	0.0005	
6. Sce.	0.0003	0.0003	0.0005	
7. Sce.	0.0002	0.0003	0.0004	
8. Sce.	0.0002	0.0002	0.0003	
9. Sce.	0.0002	0.0002	0.0002	
10. Sce.	0.0001	0.0002	0.0002	
Mean	0.00031	0.00037	0.00047	

ARAS: Additive Ratio Assessment, DNMA:ROV: Range Of Value, SAW: Simple Additive Weighting, TOPSIS: Technique for Order Preference by Similarity to Ideal Solution, WPM: Weighted Product Method, WASPAS: Weighted Aggregated Sum Product Assessment.

Upon examination of Table 17, it is observed that within the scenarios, the LOPCOW-based DNMA method exhibits a higher average variance except LOPCOW-based TOPSIS compared to LOPCOW-based ROV, ARAS, SAW, WPM, and WASPAS methods. Based on these results, it is assessed that the LOPCOW-based DNMA method performs better in discriminating between indicator than the LOPCOW-based ROV, ARAS, SAW, WPM, and WASPAS methods. Additionally, the ADM analysis for the LOPCOW based DNMA method within the scenarios is presented in the corresponding visualization in Figure 5.

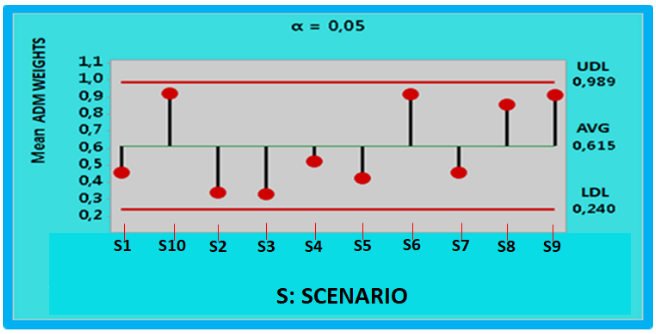

Figure 5. ADM visual.
Şekil 5. ADM görseli.

As shown in Figure 5, the calculated ADM values for each scenario fall within a homogenous range. All values lie between the established UDL (Upper Decision Limit) and LDL (Lower Decision Limit), indicating consistency in the weight variances across scenarios. In addition, Levene's statistic was used to test the homogeneity of the data according to the scenarios. This finding is further supported by the Levene's Test, the key statistics of which are presented in Table 18.

Table 18. Levene test.
Tablo 18. Levene testi.

Levene Statistic	df1	df2	Sig.
0.198	2	10	0.133

p*<.05

Table 18 further supports the homogeneity of variances in criterion weights across scenarios. The p-value of 0.198 exceeds the significance threshold of 0.05, indicating a lack of statistical significance. This reinforces the conclusion that the LOPCOW-based DNMA method demonstrates alignment with robustness and stability, as evidenced by the simulation analysis results.

4. Discussion

The measurement of countries' food security performances is critical for sustainable development and public health (Martin, 2019). Food security is a determining factor not only in terms of nutrition but also regarding economic stability and social justice (Zhou, 2020). Therefore, the systematic evaluation of food security performance contributes to the identification of potential risks and the development of effective policy-making processes (Kumar & Reza, 2011).

When reviewing the literature that explains the relationship between economic size and food security, it is possible to find numerous studies indicating that food security positively contributes to economic growth (Breisinger & Ecker, 2014; Widada et al., 2017). Therefore, considering the positive contribution of food security to economic growth, the economic size of the G7 countries is an important factor in the assessment of their food security performances. These countries have developed robust policies and infrastructures to ensure food security, which in turn supports global economic stability. As a result, the high food security performances among G7 countries are thought to play a critical role in their impact on both domestic markets and global food systems and food security. Through the analysis of the food performances of G7 countries, they can play an effective role in taking global measures and determining strategies through innovation and research and development assistance to cope with future food security challenges within the scope of sustainable development (Ministry of Foreign Affairs of Japan, 2016). This is because changes occurring in major economies can influence global food markets and the food security strategies of other countries. Therefore, the analysis of food security performances in G7 can be considered relavant for enhancing the effectiveness of global food security efforts. Therefore, considering the economic size of the G7 countries as an organization and their initiatives for global food security, the food security performances of the G7 countries can be deemed significant (Group G7, 2019).

A review of the literature indicates that studies aimed at determining the food security performance of countries are exceedingly limited. Consequently, according to the literature, the food security performance of countries has been measured solely by Economist Impact (2022). Moreover, there are no findings of any studies that utilize MCDM methods to assess the food security performance of countries. According to literature, Economist Impact (2022) ranked the food security performance of G7 countries according to the GFSI methodology as France, Japan, Canada, UK, USA, Germany, and Italy. However, in this study, the ranking of countries' food security performances was Canada, Japan, Italy, France, USA, UK, and Germany. Additionally, the study calculated the average food security performance, identifying Canada, Japan, Italy, and France as countries with performances above the average. In the

Economics Impact (2022) study, countries with performances exceeding the average were observed as France, Japan, Canada and UK. Consequently, when considering both studies together, it can be concluded that Canada, France, and Japan exhibit greater superiority in food security compared to other G7 countries.

Moreover, from a methodological perspective, the food security performance of countries was assessed through sensitivity analysis using the ENTROPY, CRITIC, SVP, and MEREC-based DNMA methods. It was observed that the rankings of food security performance values determined by the LOPCOW-based DNMA method differed from those calculated using other weight-based MCDM methods. In the comparative analysis, the food security performance of countries was measured using LOPCOW-based ROV, ARAS, TOPSIS, SWP, WPM, and WASPAS methods. Based on these results, it was found that the rankings of food security performance values identified by the LOPCOW-based DNMA method differed from those calculated by other LOPCOW-based MCDM methods. When all these quantitative findings are taken into account, it can be concluded that both the LOPCOW method and the LOPCOW-based DNMA method possess a unique and distinctive structure.

In the scope of recommendations, firstly, it has been evaluated that methods, strategies, and policies should be developed globally, particularly focusing on the improvement of GFSI4 and GFSI1 indicator, for sustainability of healthy food and contribute to global food security and consequently to global economic growth and development. Additionally, for countries with below-average food security performance, namely USA, UK, and Germany, it has been assessed that they should increase their food security performance to contribute to global food security and consequently to global economic growth and development. From a methodological perspective, besides the DNMA method, other methods such as MARCOS, MAIRCA, PIV, CRADIS, SAW, WASPAS, OPA, SECA, RAFSI, MAUT, ROV, CODAS, OCRA, MOOSRA, MULTI-MOORA, OWA Operator, etc., can be used to measure the food security performances of countries, and the measured values can be compared in terms of methods. Additionally, not only for G7 countries but also for other economic organizations' member countries such as G20, BRICS, OPEC, the food security performances can be measured, and the measured values can be compared on an organizational basis. Lastly, to make the measurement of countries' food performances more effective, comprehensive, and content-rich, either increasing the number of GFSI components or creating country-specific food security components or both can be considered.

5. Conclusion

Measuring the food security performance of major economies is an important step in understanding the relationship between food security and economic growth. Food security is a critical factor that influences the health, stability, and welfare of an economy. High performance in food security is essential for a healthy population, labor productivity, and sustainable economic recovery and growth. Conversely, food insecurity can lead to illnesses, productivity losses, and economic fluctuations. Therefore, measuring the food security performance of major economies is of fundamental importance for global economic recovery and growth, providing policymakers with guiding information. Additionally, this measurement can serve as a critical tool for strategic decision-making in policy development and implementation processes. Thus, examining the food security performance of G7 countries can be considered significant. In this study, the food security performances of the G7 countries, which are the world's largest economies, were measured using the LOPCOW-based DNMA method. Furthermore, this study evaluates the food security performance of G7 nations, which was earlier analyzed by the Economist Impact organization, utilizing a variety of criteria weighting methods, including ENTROPY, CRITIC, SVP, and MEREC. Additionally, several MCDM techniques such as ROV, ARAS, SWP, WPM, and WASPAS are employed in this analysis. The weights for the GFSI indicator, along with the food security performance metrics of the countries, are computed and compared, leading to meaningful insights and conclusions. Initially, the importance degrees (weights) of the GFSI indicator were determined for each country using the LOPCOW method. According to the findings, the weights of the GFSI indicator were ranked as GFSI4, GFSI1, GFSI3, and GFSI2, with GFSI4 and GFSI1 indicactor being identified as more important. Secondly, the countries' food security performances were measured using the LOPCOW-based DNMA method. Accordingly, the food security performances of countries were ranked as Canada, Japan, Italy, France, USA, UK, and Germany. Additionally, the average food security performance was calculated, and it was observed that Canada, Japan, Italy, and France had performances higher than the average value. Therefore, it was evaluated that these countries have a significant food security capacity compared to other countries. Thirdly, sensitivity, comparative, and simulation analyses were conducted in terms of methodology. According to the results, it has been concluded that the LOPCOW-based DNMA method is aligned with sensitivity and accuracy in sensitivity analysis, reliability in comparative analysis, and robustness and stability in simulation analysis

6. Conflicts of Interest

The authors declare no conflict of interest

7. References

Abogahsem, P., Sara, G., Mohsen, P. (2018). Food Security and Economic Growth. *Journal of Nutrition and Food Security*, *3*(3), 113–115.

Ahmad, N. (2021). Food insecurity: Concept, causes, effects and possible solutions. *IAR Journal of Humanities and Social Science, 2*(1), 105-113. https://doi.org/10.47310/jiarjhss.v02i01.016

Akbari, M., Foroudi, P., Shahmoradi, M., Padash, H., Shahabaldini Parizi, Z., Khosravani, A., Cuomo, M. T. (2022). The evolution of food security: Where are we now, Where should we go next? *Sustainability*, *14*, 1-17. https://doi.org/10.3390/su14063634

Ala, A., Ridwan, I. (2020). Food security and sustainable agriculture. *Earth and Environmental Science*, *486*, 1-6. https://doi.org/ 10.1088/1755-1315/486/1/012110

Ayçin, E. (2019). *Çok kriterli karar verme*. Ankara: Nobel Yayın.

Barrett, C. B., Lentz, E. C. (2009). *Food Insecurity*, Wiley-Blackwell Publishing, London.

Bazga, B. (2015). Food security component of sustainable development-prospects and challenges in the next decade. *Procedia Economics and Finance*, 32, 1075–1082. https://doi.org/10.1016/S2212-5671(15)01570-1

Bektaş, S. (2022). Türk sigorta sektörünün 2002-2021 dönemi için MEREC, LOPCOW, COCOSO, EDAS ÇKKV yöntemleri ile performansının değerlendirilmesi. *BDDK Bankacılık ve Finansal Piyasalar Dergisi*, *16*(2), 247-283. https://doi.org/10.46520/bddkdergisi.1178359

Berry, E. M., Dernini, S., Burlingame, B., Meybeck, A., Conforti, P. (2015). Food security and sustainability: can one exist without the other? *Public Health Nutrition*, 1-10. https://doi.org/10.1017/S136898001500021X.

Biswas, S., Pamucar, D., Dawn, S., Simic, V. (2024). Evaluation based on Relative utility and nonlinear standardization (eruns) method for comparing firm performance in energy sector. *Decision Making Advances*, *2*(1), 1-21. https://doi.org/10.31181/dma21202419

Bozsik, N., Cubillos, J. P., Stalbek, B., Vasa, L., Magda, R. (2022). Food security management in developing countries: Influence of economic factors on their food availability and access. *PLOS ONE*, *17*(7), 1-24. https://doi.org/10.1371/journal.pone.0271696

Breisinger, C., Ecker, O. (2014). Simulating economic growth effects on food and nutrition security in Yemen: A new macro–micro modeling approach. *Economic Modelling*, *43*,100–113. https://doi.org/10.1016/j.econmod.2014.07.029

Ciardiello, F., Genovese, A. (2023). A comparison between TOPSIS and SAW methods. *Annals of Operations Research,* *325*, 967–994. https://doi.org/10.1007/s10479-023-05339-w.

Chatterjee, S., Chakraborty, S. (2024). A study on the effects of objective weighting methods on TOPSIS-based parametric optimization of non-traditional machining processes. *Decision Analytics Journal*, *11*, 1-16. https://doi.org/10.1016/j.dajour.2024.100451

Chen, Y. Q., Chen, Y. H. (2023). Economic growth, income inequality and food safety risk. *Foods*, *12*, 1-17. https://doi.org/10.3390/foods12163066

Demir, G., Özyalçın, A. T., Bircan, H. (2021). *Çok kriterli karar verme yöntemleri ve ÇKKV yazılımı ile problem çözümü*. Ankara: Nobel.

Demir, G. (2022). Analysis of the financial performance of the deposit banking sector in the covid-19 period with LMAW-DNMA methods. *International Journal of Insurance and Finance*, 17-36. https://doi.org/10.52898/ijif.2022.7

Demir, G., Arslan, R. (2022). Sensitivity Analysis in Multi-Criteria Decision-Making Problems. *Ankara Hacı Bayram Veli Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 24*(3), 1025-1056.

Denning, G. (2023). *Universal Food Security*, New York: Colombia University Press.

Desta, A. (2017). Linkages between economic growth and food security: An eclectic perspective. *Review of Business Research,* *17*(1), 31-40. https://doi.org/10.18374/RBR-17-1.4

Dhruva, S., Krishankumar, R., Zavadskas, E. K., Ravichandran, K. S., Gandomi, A. H. (2024). Selection of Suitable Cloud Vendors for health centre: A personalized decision framework with fermatean fuzzy set, LOPCOW, and CoCoSo. *Informatica*, *35*(1), 65–98. https://doi.org/10.15388/23-INFOR537

Diakoulaki, D., Mavrotas, G., & Papayannakis, L. (1995). Determining Objective Weights in Multiple Criteria Problems: The Critic Method. *Computers & Operations Research*, *22*(7), 763-770.

Dua, T., Duc, D. V., Bao, N. C., Trung, D. D. (2024). Integration of objective weighting methods for criteria and mcdm methods: Application in material *selection. EUREKA: Physics and Engineering* (2), 131-148. https://doi.org/10.21303/2461-4262.2024.003171

Dutta, H., Saikia, A. A. (2018). Food security: A review on its definition, levels and evolution. *Trans Asian Research Journals*, *7*(7), 111-122.

Dündar, S. (2023). Performance analysis of regional development agencies by LMAW-DNMA methods. *Osmangazi Üniversitesi İİBF Dergisi*, *18*(2), 354–380. https://doi.org/10.17153/oguiibf.1234630

Dyvik, E. H. (2024). Gross domestic product growth rate forecast of G7 countries 2023-2029. Retrived from https://www.statista.com/statistics/1370777/g7-country-gdp-growth-forecast/.

Ecer, F. (2020). *Çok Kriterli Karar Verme*, Seçkin Yayıncılık, Ankara.

Ecer, F., Pamucar, D. (2022). A novel LOPCOW-DOBI multi-criteria sustainability performance assessment methodology: An application in developing country banking sector. *Omega*, *112*, 1-17. https://doi.org/10.1016/j.omega.2022.102690

Ecer, F., Zolfani, S. H. (2022). Evaluating Economic Freedom Via A Multi-Criteria MEREC-DNMA Model-Based Composite System: Case of OPEC Countries. *Technological and Economic Development of Economy*, *28*(4), 1158–1181. https://doi.org/10.3846/tede.2022.17152

Ecer, F., Yaran Ögel, İ., Krishankumar, R., Tirkolaee, E. B. (2023). The q rung fuzzy LOPCOW VIKOR model to assess the role of unmanned aerial vehicles for precision agriculture realization in the Agri Food 4.0 era. *Artificial Intelligence Review*, *56*, 13373–13406. https://doi.org/10.1007/s10462-023-10476-6

Economist Impact. (2022). *Global Food Security Index 2022*, London: The Economist Group.

El Mokhtar, M., Boutaj, H., Anli, M., Draoui, A., Laouane, R. B., Zarik, L., Fakhech, A. (2019). Global Environmental Changes and Human Health. In Food security and climate change, IGI Global, Hershey, pp 53-73.

FAO. (2008). *Climate change, water and food security*, Rome: Food Agriculture Organization Publication.

FAO. (2012). *Global Strategic Framework for Food Security and Nutrition*. Rome: Food and Agriculture Organization of the United States.

Fernandes, M., Samputra, P. L. (2022). Exploring linkages between food security and economic growth: A systematic mapping literature review. *Potravinarstvo Slovak Journal of Food Sciences*, *16*, 206-218. https://doi.org/10.5219/1734

García-Díez, J., Gonçalves, C., Grispoldi, L., Cenci-Goga, B., Saraiva, C. (2021). Determining food stability to achieve food security. *Sustainability*, *13*, 1-13. https://doi.org/10.3390/su13137222

Germany G7. (2022). G7 Statement on Global Food Security. Retrieved from: www.reliefweb.int/report/world/g7-statement-global-food-security-elmau-28-june-2022.

Gibson, M. (2012). Food security—a commentary: What is it and Why is it so complicated? *Foods, 1*, 18-27.

Gnedeka, K. T. (2023). New evidence in the relationship between trade openness and food security in Sub Saharan Africa. *Agriculture Food Security*, *12*(31), 1-17. https://doi.org/10.1186/s40066-023-00439-z

Group G7. (2019). *Financial Report on Food Security and Nutrition*. Retrieved from: www.diplomatie.gouv.fr.

Hezam, I. M., Mishra, A. R., Rani, P., Cavallaro, F., Saha, A., Ali, J., Štreimikiene, D. (2022). A hybrid intuitionistic Fuzzy-MEREC-RS-DNMA method for assessing the alternative fuel vehicles with sustainability perspectives. *Sustainability*, *14*, 1-32. https://doi.org/10.3390/su14095463

HLPE Steering. (2012). Food security and climate change, High Level Panel of Experts on Food Security and Nutrition Rome: (HLPE) Steering Committee.

Işık, Ö., Shabir, M., Belke, M. (2023). Is there a causal relationship between financial performance and premium production? evidence from Turkish insurance industry. *Mehmet Akif Ersoy İktisadi ve İdari Bilimler Fakültesi Dergisi*, *10*(2), 1388-1412. https://doi.org/10.30798/makuiibf.1220299

Kahreman, Y. (2024). D8 ülkelerinin ekonomik performanslarının CRITIC/LOPCOW-CoCoSo modeli ile değerlendirilmesi. *Anadolu Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *25*(1), 534-559. https://doi.org/10.30798/makuiibf.1220299

Kang, H. (2015). A study on the relationship between international trade and food security: Evidence from less developed countries (LDCs). *Agricultural Economics*, *61*(10), 475-483. https://doi.org/10.17221/246/2014-AGRICECON

Kavallari, A., Fellmann, T., Gay, S. H. (2014). Shocks in economic growth: Shocking effects for food security? *In Food Security Springer Science and Business Media LLC*. *6*(4), 567–583. https://doi.org/10.1007/s12571-014-0368-y

Keleş, N. (2023). *Uygulamalarla Klasik ve Güncel Karar Verme Yöntemleri*, Ankara: Nobel Bilimsel.

Kerr, W. A. (2023). *Food Security, Availability, Income and Productivity*, Cheltenham: Edward Elgar Publishing,

Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E. K., Turskis, Z., Antucheviciene, J. (2021). Determination of Objective Weights Using a New Method Based on the Removal Effects of Criteria (MEREC). *Symmetry*, *13*, 1-20. https://doi.org/10.3390/sym13040525

Kumar, D., Raza, A. (2011). *Agriculture and Food Security*. Delhi: Deep & Deep Publications.

Lai, H., Liao, H., Šaparauskas, J., Banaitis, A., Ferreira, F. A., Al-Barakati, A. (2020). Sustainable cloud service provider development by a Z-Number-Based DNMA method with gini-coeffcient-basedweight determination. *Sustainability*, *12*, 1-17. https://doi.org/10.3390/su12083410

Liao, H., Ren, R., Antucheviciene, J., Šaparauskas, J., Al-Barakati, A. (2020). Sustainable construction supplier selection by a multiple criteria decision-making method with hesitant linguistic information. *EM Economics and Management*, *23*(4), 119–136. https://doi.org/10.15240/tul/001/2020-4-008

Manap, N. M., Ismail, N. W. (2019). Food security and economic growth. *International Journal of Modern Trends in Social Sciences*, *2*(8), 108--118.

Martin Ralph, C., May, E. (2019). *Food Security: From Excess to Enough*. Toronto: A.J. Patrick Boyer Book.

Martindale, W. (2014). *Global Food Security and Supply*, Malden: Wiley Blackwell.

Ministry of Foreign Affairs of Japan. (2016). *G7 Vision for Action on Food Security and Nutrition*. Retrieved from: www.mofa.go.jp.

Mishra, A. R., Rani, P., Saha, A., Hezam, I., Cavallaro, F., Chakrabortty, R. K. (2023). An extended DNMA-based multi-criteria decision-making method and its application in the assessment of sustainable location for a lithium-ion batteries' manufacturing plant, *Heliyon*, *9*, 1-24. https://doi.org/10.1016/j.heliyon.2023.e14244

Moafi, F., Kazemi, F., Siboni, F. S., Zainab, A. (2018). The relationship between food security and quality of life among pregnant women. *BMC Pregnancy and Childbirth*, *18*(319), 1-9. https://doi.org/10.1186/s12884-018-1947-2

Naz, S., Amin, H., Khan, J., Nawaz, F. (2023). Determinants of food security among the rural households of the developing countries: A systematic literature review. *Journal of Asian Development Studies*, *12*(3), 811-826.

Nie, S., Liao, H., Wu, X., Tang, M., Al-Barakati, A. (2019). Hesitant fuzzy linguistic DNMA method with cardinal consensus reaching process for shopping mall location selection. *International Journal of Strategic Property Management*, *23*(6), 420–434. https://doi.org/10.3846/ijspm.2019.10851

Ojimadu, P. K. (2022). Food security and economic development in Nigeria. *Global Journal of Applied, Management and Social Sciences (GOJAMSS)*, *24*, 90-101.

Öztaş, T., Öztaş, G. Z. (2024). Innovation performance analysis of G20 countries: A novel integrated LOPCOW-MAIRCA MCDM approach including the COVID-19 period. *Verimlilik Dergisi*, *Special Issue*, 1-20. https://doi.org/10.51551/verimlilik.1320794

Peng, W., Berry, E. M. (2019). The concept of food security. *Encyclopedia of food security and sustainability*, 2, 1-7.

Pourreza, A., Geravandi, S., Pakdaman, M. (2018). Food security and economic growth. *Journal of Nutrition and Food Security (JNFS)*, *3*(3), 113-115.

Roetter, R. P., Van Keulen, H. (2007). Food Security. In Science for Agriculture and Rural Development in Low-Income Countries, Edited: R. P. Roetter, H. Van Keulen, M. Kuiper, J. Verhagen, H. H. Van Laar, Springer, Dordrecht, pp. 27-56.

Saha, A., Mishra, A. R., Rani, P., Hezam, I. M., Cavallaro, F. (2022). Q-rung orthopair fuzzy FUCOM double normalization-based multi-aggregation method for healthcarewaste treatment method selection. *Sustainability*, *14*, 1-28. https://doi.org/10.3390/su14074171

Salahodjaev, R., Mirziyoyeva, Z. (2021). The link between food security and life satisfaction: Panel DATA ANALYSIS. *Sustainability*, *13*, 1-9. https://doi.org/10.3390/su13052918

Shakeel, A. (2018). Food security: Theorizing the evolution and involution of the concept. *The Arab World Geographer/Le Géographe du monde arabe*, *21*(1), 58-82.

Simic, V., Miletic, S. D., Tirkolaee, E. B., Stević, Ž., Ala, A., Amirteimoori, A. (2023). Neutrosophic LOPCOW ARAS model for prioritizing industry 4.0 based material handling technologies in smart and sustainable warehouse management systems. Applied Soft Computing, 143, 1-10.

Timmer, P. C. (2005). Food security and economic growth: An Asian perspective. *Asian Pasific Economic Literature*, *19*(1), 1-17.

Uludağ, A. S., & Doğan, H. (2021). *Üretim yönetiminde çok kriterli karar verme yöntemleri*. Ankara: Nobel Yayıncılık.

Ulutaş, A., & Topal, A. (2020). *Bütünleştirilmiş çok kriterli karar verme yöntemlerinin üretim sektörü uygulamaları*. Ankara: Akademisyen Kitapevi.

Widada, A. W., Masyhuri, M., & Mulyo, J. H. (2017). Determinant Factors of Food Security in Indonesia. Agro Ekonomi, 28(2), 205-218. https://doi.org/10.22146/jae.26245

Wu, X., Liao, H. (2019). Comparison Analysis between DNMA Method and Other MCDM Methods. *ICSES Transaction on Neural and Fuzzy Computing*, *2*(1), 4-10.

Yalman, İ. N., Koşaroğlu, Ş. M., Işık, Ö. (2023). 2000-2020 döneminde Türkiye ekonomisinin makroekonomik performansının MEREC-LOPCOW-MARCOS modeliyle değerlendirilmesi. *Finans Politik Ekonomik Yorumlar*, *664*, 57-86.

Zhang, H., Liao, H., Wu, X., Zavadskas, E. K., Al-Barakati, A. (2020). Internet financial investment product selection with pythagorean fuzzy DNMA method. *Inzinerine Ekonomika-Engineering Economics*, *31*(1), 61–71.

Zhou, Z. Y. (2020). *Global Food Security (What Matters?)*, New York: Routledge

Appendix-A: SCENARIOS

1. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	76	92	81	59
France	53	88	65	75
Germany	67	71	58	91
Italy	83	60	94	85
Japan	99	66	77	90
UK	57	78	69	72
USA	61	84	96	80
2. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	68	90	72	57
France	64	58	96	82
Germany	74	65	81	61
Italy	92	78	99	68
Japan	55	71	88	77
UK	84	85	66	94
USA	73	60	95	80
3. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	93	62	69	58
France	57	94	75	88
Germany	82	77	61	70
Italy	63	99	92	64
Japan	91	85	67	59
UK	71	74	83	87
USA	65	96	72	54
4. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	61	68	90	53
France	76	99	81	84
Germany	62	93	55	71
Italy	85	88	97	67
Japan	69	72	94	79
UK	78	56	89	86
USA	92	64	66	74
5. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	95	81	77	88
France	63	60	98	72
Germany	57	85	74	91

Italy	89	66	92	68
Japan	78	94	83	75
UK	64	73	56	87
USA	59	62	95	66
6. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	88	92	66	58
France	97	61	90	82
Germany	63	99	75	72
Italy	80	77	84	96
Japan	58	69	91	63
UK	73	85	57	88
USA	96	72	65	54
7. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	72	79	63	84
France	95	93	87	57
Germany	68	81	92	65
Italy	59	60	97	77
Japan	94	86	74	80
UK	76	68	89	91
USA	83	70	58	99
8. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	85	66	88	95
France	73	94	69	57
Germany	92	78	96	70
Italy	66	81	74	91
Japan	87	62	55	82
UK	59	97	85	64
USA	78	73	99	58
9. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	65	75	60	96
France	98	87	81	73
Germany	79	94	91	58
Italy	61	63	84	99
Japan	72	66	95	83
UK	84	57	89	69
USA	55	92	64	88
10. Scenario	**GFSI1**	**GFSI2**	**GFSI3**	**GFSI4**
Canada	91	98	70	66
France	77	59	94	89
Germany	68	64	80	93
Italy	56	71	92	73
Japan	85	96	83	61
UK	97	78	58	84
USA	63	87	99	74