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AN ASSESSMENT OF INDICATORS OF THE GLOBAL FOOD SECURITY INDEX UTILIZING POST-COVID-19 DATA AND COMPARING COUNTRIES USING MULTI-CRITERIA DECISION MAKING TECHNIQUES

KÜRESEL GIDA GÜVENCESİ ENDEKSİ GÖSTERGELERİNİN KOVİD-19 SONRASI VERİLERLE DEĞERLENDİRİLMESİ VE ÇOK KRİTERLİ KARAR VERME TEKNİKLERİYLE ÜLKELERİN KARŞILAŞTIRILMASI

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ABSTRACT

The presence of growing disparities, political volatility, and compelled movements of people exert a substantial influence on the collective nutritional well-being of communities. The challenges posed by climate change and the depletion of natural resources present obstacles to achieving the United Nations' Sustainable Development Goals (UN SDGs) by 2030. Based on a study conducted by the United Nations Food and Agriculture Organization (FAO), it is projected that a range of 35 to 122 million individuals will experience a decline in their socioeconomic status, leading to poverty, by the year 2030. The study indicates that climate-related challenges and conflicts will contribute to a reduction in food security. The COVID-19 pandemic is anticipated to exacerbate the food security and nutritional status of the most susceptible areas as a result of its health and socio-economic consequences. The objective of this study is to examine the comparative conditions of several nations, including Turkey, using the CRITIC-based PROMETHEE approach. The analysis was conducted using data from the 2022 post-COVID-19 period in Global Food Security Index, with a specific focus on food security. This study contributes to the existing literature by highlighting the emerging issue of food security after the COVID-19 pandemic period. Based on the multi-criteria decision-making approach data analysis rankings, Finland, Ireland, the Netherlands, France, and the United Kingdom emerge as the top-performing nations. The countries situated in the lowest

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spots of the ranking encompass Indonesia, Thailand, India, South Africa, and Vietnam.

Keywords: *COVID-19, Food Security, PROMETHEE, CRITIC, Sustainable Development Goals*

ÖZ

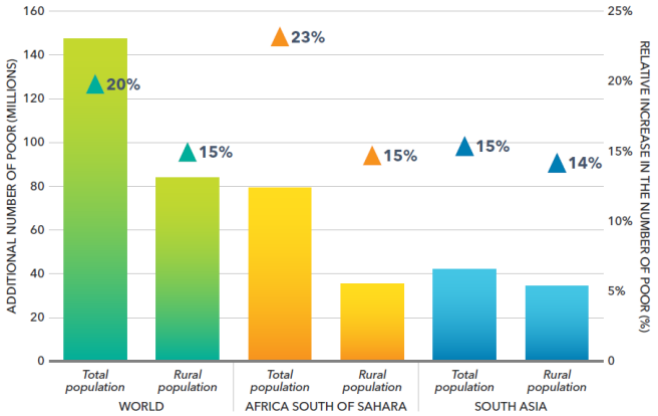
Artan eşitsizlikler, siyasi istikrarsızlıklar ve zorunlu göçler, toplulukların genel beslenme durumu üzerinde önemli bir etkiye sahiptir. İklim değişikliğinin yarattığı zorluklar ve doğal kaynakların tükenmesi, Birleşmiş Milletler'in Sürdürülebilir Kalkınma Hedeflerine (BM Sürdürülebilir Kalkınma Hedefleri) 2030 yılına kadar ulaşılmasının önünde engel teşkil ediyor. Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO) tarafından yürütülen bir araştırmaya göre, 2030 yılına kadar 35 ila 122 milyon kişinin sosyoekonomik statülerinde bir düşüş yaşayacağı ve bu durumun yoksulluğa yol açacağı öngörülüyor. Çalışma, iklimle ilgili zorluklar ve çatışmalar gıda güvencesinin azalmasını tetiklediği görülmektedir. COVID-19 salgınının, sağlık ve sosyo-ekonomik sonuçlarının bir sonucu olarak en duyarlı bölgelerin gıda güvencesini ve beslenme durumunu daha da kötüleştirmesi bekleniyor. Bu çalışmanın amacı, CRITIC temelli PROMETHEE yaklaşımını kullanarak Türkiye'nin de aralarında bulunduğu birçok ülkenin karşılaştırmalı koşullarını incelemektir. Analiz, Küresel Gıda Güvencesi Endeksi'nde yer alan 2022 COVİD-19 sonrası döneme ait veriler kullanılarak ve özellikle gıda güvencesine odaklanılarak gerçekleştirildi. Bu çalışma, COVİD-19 pandemisi dönemi sonrasında ortaya çıkan gıda güvencesi konusuna dikkat çekerek mevcut literatüre katkı sağlamaktadır. Çok kriterli karar verme yaklaşımı veri analizi sıralamasına göre Finlandiya, İrlanda, Hollanda, Fransa ve Birleşik Krallık en iyi performans gösteren ülkeler olarak ortaya çıkıyor. Sıralamanın en alt sıralarında yer alan ülkeler arasında Endonezya, Tayland, Hindistan, Güney Afrika ve Vietnam yer alıyor.

Anahtar Kelimeler: *COVİD-19, Gıda Güvencesi, PROMETHEE, CRITIC, Sürdürülebilir Kalkınma Hedefleri*

1. Introduction

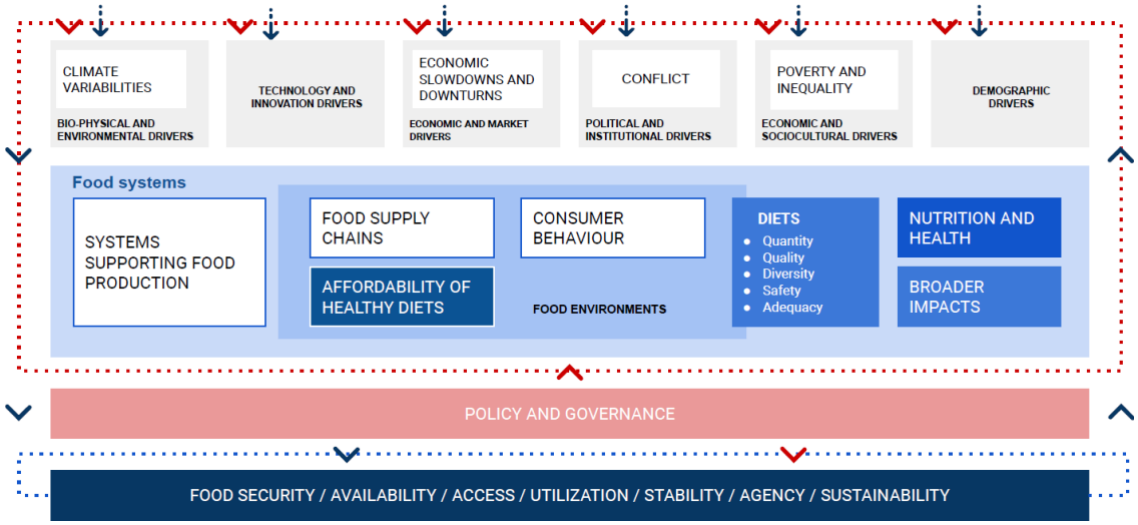
Before the initiation of the COVID-19 pandemic, there was a notable increase in global food insecurity. The present crisis poses a significant risk of exacerbating this reversal, so nullifying the advancements achieved in the worldwide efforts to eradicate hunger and malnutrition. In light of declining incomes and disruptions to supply chains caused by movement restrictions and logistical challenges stemming from the pandemic, the global community is confronted with ongoing difficulties in effectively addressing pre-existing challenges to food security (Singh, Kumar, Panchal, & Tiwari, 2021). The particular concerns are the exacerbating climate and environmental dynamics, such as insufficient precipitation, escalating temperatures, inundations, severe weather events, as well as conflicts and warfare (Scheffran, 2020). The occurrence of frequent shocks is causing overlapping effects that undermine resilience, resulting in the most severe and urgent risk to global food security. The attainment of the second United Nations Sustainable Development Goal (SDG), which aims to eliminate hunger by the year 2030, may face significant challenges unless interventions are implemented to address underlying and entrenched issues (Trends, 2017). Figure 1 depicts the effects of the worldwide economic crisis caused by the COVID-19 pandemic on the prevalence of extreme poverty (Fan, Teng, Chew, Smith, & Copeland, 2021).

Figure 1. Extreme destitution impacts of the COVID-19 global economic crisis



During periods of crisis, the impacts of systemic gaps are experienced with heightened intensity. In light of the global dissemination of the covid-19 pandemic, the presence of economic, social, and environmental disparities has exerted a significant influence on nations' capacity to address the essential requirements of their citizenry, encompassing sustenance, healthcare, and economic stability (Myant, 2020). The global health crisis has brought to light the vulnerabilities that these elements present to food systems and emphasized the significance of investigating not only the present extent of food insecurity, but also the fundamental catalysts and origins. The transmission of impacts from different causes occurs throughout food systems, leading to the undermining of both food security and nutrition. Figure 2 illustrates several significant factors that contribute to the food crisis.

Figure 2. The factors contributing to the food crisis (GFSI, 2020)



Countries and territories experiencing significant food crises mostly attributed to conflict have also been impacted by meteorological extremes, economic shocks, such as the

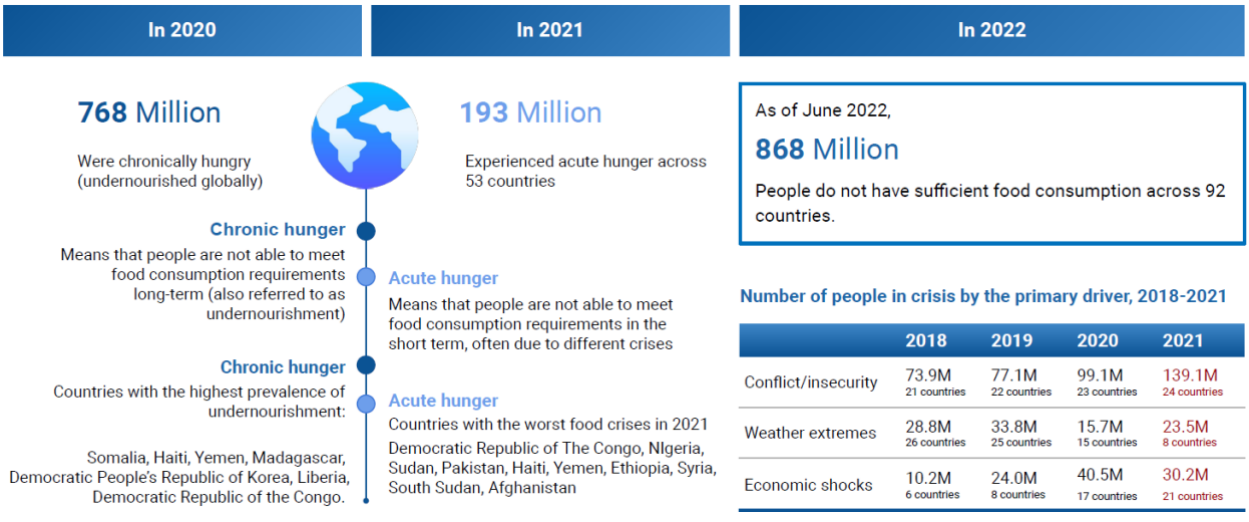
COVID-19 epidemic, or a combination of both (Savary et al., 2020). These two causes frequently contribute to the escalation of tensions and conflicts through the intensification of rivalry over finite natural resources and income-generating prospects. The COVID-19 pandemic has resulted in a worldwide economic recession in the year 2020 (Sułkowski, 2020). Table 1 presents the variations in key economic indicators during the current recession across different areas and economic segments.

Table 1. The global economic ramifications of the COVID-19 pandemic in 2020 (GFSI, 2020)

	PERCENTAGE CHANGE FROM BASE YEAR VALUES				
	Real GDP	Household consumption	Export of goods (value in constant dollars)	Agrifood real value added	Agrifood exports (value in constant dollars)
World	−5.0	−1.0	−20.9	−1.8	−24.8
Developed countries	−6.2	−0.1	−23.5	−3.1	−23.8
Developing countries	−3.6	−2.5	−18.0	+0.1	−30.5
Africa south of Sahara	−8.9	−3.2	−35.2	+3.9	−20.6
South Asia	−5.0	−3.7	−27.1	−2.0	−30.7
Southeast Asia	−7.0	−4.2	−27.7	−2.8	−31.9
Latin America	−5.9	−4.4	−30.8	−3.9	−28.5

Figure 3 illustrates the primary factors that influenced food security during the pandemic and the subsequent two years.

Figure 3. Determinants of and outlook for food insecurity throughout the global epidemic and following two years (Organization, 2022)

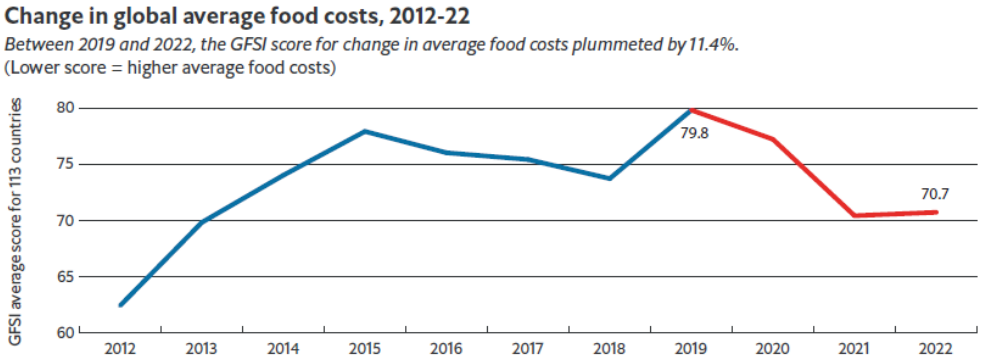


A total of 868 million individuals experience inadequate food consumption. Since the commencement of 2022, there has been a notable surge of 30 percent in the prices of fertilizers. Food export restrictions were implemented in a total of 35 nations. According to available data, a significant proportion of the population in low-income nations,

specifically 88%, lacks access to nutritious food options. There are a total of 25 countries that are classified as 'high risk' and seeing a decline in their overall conditions. In the year 2022, there was a global average increase of 20% in food costs, and this rising trend continues (Organization, 2022).

Food price shocks have a dual role as both a consequence and a factor influencing conflicts. The food prices were seeing an upward trajectory due to a resilient demand, primarily driven by the recuperation from the economic downturn caused by the Covid-19 pandemic. This trend was observed prior to the occurrence of Russia's invasion. The onset of the Ukraine conflict has resulted in significant rises in the expenses of energy, fertilizer, and commodity prices, thus leading to price hikes of up to 30% for essential food items. Certain regions in the United States are currently experiencing a significant surge of 300% in the costs associated with fertilizers (Guenette, Kenworthy, & Wheeler, 2022). The global community is currently confronted with the occurrence of the third global food price crisis within a span of 15 years. Policymakers are determined to prevent a recurrence of the circumstances saw in 2008, when food prices similarly reached unprecedented levels. However, they are confronted with a formidable challenge. The International Panel of Experts on Sustainable Food Systems has observed that the convergence of climate change, pervasive poverty, and conflicts is currently generating pervasive and endemic risks to global food security. Consequently, there is a likelihood that elevated food prices could become the prevailing norm unless measures are implemented to mitigate these threats (Rother et al., 2022). Figure 4 illustrates the fluctuation in worldwide average food costs throughout the period of 2012 to 2022.

Figure 4. Trend in average worldwide food prices from 2012 to 2022 (Organization, 2022)



The importation of food due to necessity results in a situation where countries become reliant on external sources to meet the dietary needs of their populations. Food insecurity is a phenomenon that arises in this context. Presently, a minimum of 34 nations across the globe face the challenge of food insufficiency due to limited access to water and land resources. This phenomenon encompasses a substantial proportion of the worldwide populace who are compelled to depend on imported sustenance for their survival. Food crises have a detrimental impact on all individuals, but they disproportionately afflict impoverished and marginalized communities, exacerbating their vulnerability (Poudel & Gopinath, 2021). There are two explanations for this. One prevalent characteristic observed in the least developed nations is their dependence on imported food.

Additionally, it is worth noting that in economically disadvantaged nations, a significant portion, at least 50%, of household spending is allocated towards food. The prevalence of food-export restrictions has experienced a notable increase of 25%, resulting in a cumulative total of 35 countries implementing such measures over a brief period in 2022. By the conclusion of March 2022, a total of 53 newly implemented policies pertaining to food commerce were recorded. Among these, 31 policies were identified as restrictive measures on exports, while nine policies specifically targeted the curtailment of wheat exports. Several prominent food exporting countries, including Argentina, India, Indonesia, Kazakhstan, and Russia, with minor exporters such as Algeria, Turkey, and Serbia, have implemented measures to restrict food exports (Kowalska, Budzyńska, & Białowąs, 2022).

Table 2 presents a comprehensive overview of significant food export limitations (GFSI, 2022).

Country	Type of food product	Ban end day
Argentina	Soybean oil, soybean meal	31 Dec 2023
Algeria	Pasta, wheat derivatives, oil, sugar	31 Dec 2022
Egypt	Vegetable oils, maize	12 Jun 2022
	Wheat, flour, lentils, pasta, beans	10 Jun 2022
India	Wheat	31 Dec 2022
Indonesia	Palm oil, palm kernel oil	31 Dec 2022
Iran	Potatoes, eggplants, tomatoes, onion	31 Dec 2022
Kazakhstan	Wheat, wheat flour	15 Jun 2022
Kosovo	Wheat, corn, flour, vegetable oil, salt, sugar	31 Dec 2022
Turkey	Beef, goat meat, butter, cooking oils	31 Dec 2022
Ukraine	Wheat, oats, millet, sugar	31 Dec 2022
Russia	Sugar, sunflower seeds	31 Aug 2022

Under specific conditions, the implementation of export limits can lead to a decrease in domestic pricing. Nevertheless, as an increasing number of nations implement limitations, there exists an elevated potential for price instability, frenzied purchasing, scarcities, and stockpiling. Besides to the aforementioned considerations, addressing the formidable task of providing sustainable nourishment for a global population of 10 billion individuals necessitates the implementation of other solutions. In order to mitigate the impact of shocks, it is imperative for governments to allocate resources towards research and development (R&D) endeavors, thereby ensuring the attainment of long-term robustness and stability. Entrepreneurs and innovators worldwide are diligently endeavoring to devise solutions. In order to achieve their objectives, AgTech and New Food innovators engage in the development of services and technologies that prioritize the enhancement of agricultural efficiency and sustainability. Their efforts also revolve around the innovation of food processing techniques, the improvement of food ingredients, and the creation of next-generation food products (Lajoie-O'Malley, Bronson, van der Burg, & Klerkx, 2020; Sodano, 2019). Figure 5 illustrates significant innovations and progressions within the realms of food and agricultural production.

Figure 5. Changes and improvements of great significance in the food and agricultural industries (GFSI, 2022)

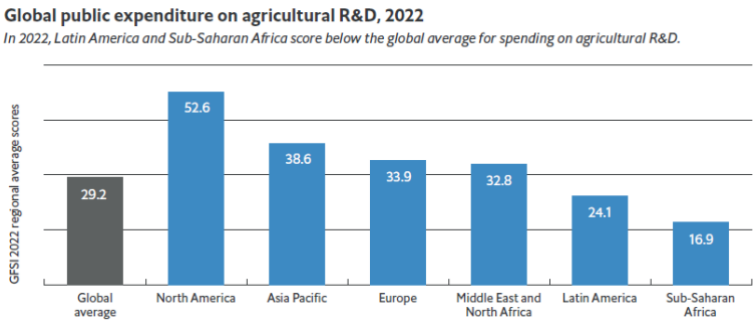
- U-Sync, a Taiwanese enterprise, offers cost-effective Internet of Things (IoT) sensors equipped with an integrated SIM card and solar power supply capabilities, all available at a reasonable monthly subscription rate. Farmers has the capability to readily modify the positioning of sensors in accordance with the specific requirements of their agricultural operations. This enables farmers to actively monitor real-time environmental data pertaining to their fields.

- Unilever employs computerized replicas of their manufacturing facilities, sometimes referred to as digital twins. The Azure Internet of Things (IoT) system facilitates the integration of IoT sensors and smart edge applications with manufacturing facilities and operations. Data is transmitted encompassing a wide range of variables, including but not limited to temperature measurements and production cycle durations, to the digital twin program.

- The laboratory-cultivated chicken products of Eat Just, a United States-based corporation, are manufactured in Singapore, where the company's central operations are located. Additional domestic start-ups, such Umami Meats and Shiok Meats, have emerged in the market, focusing on the production of cell-cultured fish as well as providing cultivated options for seafood and red meat (GFSI, 2022).

The available research indicates that investment in research and development (R&D) yields substantial benefits, not just by enhancing production but also by contributing to broader welfare outcomes, including the elimination of poverty. However, this particular indicator exhibits one of the lowest rankings in the 2022 Global Food Security Index (GFSI), with an average global score of 29.2. This low score is mostly influenced by the regions of Sub-Saharan Africa and, to a lesser extent, Latin America. Moreover, there has been a decline of 10% in public investment in research and development (R&D) since the year 2012. Figure 6 illustrates the worldwide allocation of public funds for research and development activities in the agricultural sector during the year 2022 (GFSI, 2022; Organization, 2022).

Figure 6. The global allocation of public funds towards agricultural research and development in 2022 (GFSI, 2022; Organization, 2022).



The objective of this study was to assess a comprehensive metric for assessing national food systems, with a specific focus on investigating and analyzing the factors influencing food security in countries around the globe. The Global Food Security Index (GFSI) was utilized as the primary tool for this analysis. The index considers the country's ability to adequately fulfill the caloric and nutritional requirements of its population, while also assessing the influence of external factors such as agricultural infrastructure, political stability, and climate hazards, among other variables. Furthermore, this development has presented policymakers with a valuable chance to integrate the influence of climate-related variables into the discourse surrounding food security within their respective nations. The GFSI report integrates the analysis of index trends and outcomes with an assessment of the impact of an unforeseen crisis, namely the covid-19 pandemic, as well as enduring structural factors like climate risk. These factors contribute to the amplification of pre-existing vulnerabilities within the global food system. Conversely, it is worth noting that both immediate and long-term factors also present prospects and room for inventive solutions and innovation.

The following are a few of the most significant highlights from the GFSI 2022 Report (GFSI, 2022):

- Shocks like the covid-19 outbreak, high input costs, and the war in Ukraine have led to increased prices for food around the world, causing affordability scores to plummet. Between 2019 and 2022, the index's affordability score fell by 4%. The covid-19 epidemic and increasing prices for agricultural inputs have had a significant role in this reduction, along with declining trade freedom and the government's incapacity to fund safety nets. Recent events, such as an overall increase in food prices of 7.9 percent, are not reflected in this drastic decline.

- The most volatile and climate-vulnerable regions in the world are also the ones with the lowest levels of food security.

- The state of food security varies considerably from one country to the next.

- To mitigate climate change, we must immediately focus on improving our irrigation and water management practices.

The most significant increases observed in the Global Food Security Index (GFSI) between the years 2019 and 2022 are shown in Table 3.

Table 3. Highest GFSI increases from 2019 to 2022 (GFSI, 2022)

	Pillar or indicator	Percent increase from 2019 to 2022
2.1)	Access to agricultural inputs	4.2%
2.1.1)	Access to finance and financial products for farmers	3.1%
2.1.2)	Access to diversified financial products	6.9%
2.1.3)	Agriculture producer prices	13.4%
2.1.6)	Empowering women farmers	18.5%
2.2)	Agricultural research & development	6.8%
2.2.2)	Access to agricultural technology, education and resources	10.2%
2.2.3)	Commitment to innovative technologies	6.9%
2.9)	Food security and access policy commitments	10.7%
2.9.1)	Food security strategy	13.3%
2.9.2)	Food security agency	5.7%
3.5.2)	Food safety mechanisms	6.1%
	Sustainability and adaptation pillar	3.9%
4.5)	Political commitment to adaptation	10.4%
4.5.1)	Climate finance flows	16.7%
4.5.2)	Environmental- economic accounting implementation	25.7%
4.5.5)	National agricultural adaptation policy	16.1%
4.5.6)	Sustainable agriculture	3.6%
4.6)	Disaster risk management	13.7%
4.6.1)	Pest infestation and disease mitigation	11.3%
4.6.2)	Risk management coordination	18.7%

The subsequent sections of the research are organized in the following manner: The second section provides the literature review. The methods that have been proposed are elucidated in Section 3.The results are provided in Section 4. The conclusion and discussion are presented in sections 5, respectively.

2. Literature Review

This study seeks to contribute to the existing literature by examining the emerging issue of food security, which has been exacerbated by the worldwide COVID-19 epidemic, wars, and long-term structural causes. Additionally, this research employs Multi-Criteria Decision Making methodologies to further analyze this topic. The anticipated utility of the study's findings and methods extends to scholars and policymakers on a global scale. The ranking of the 40 countries was determined by evaluating four dimensions: affordability, availability, quality, and safety. Additionally, the assessment considered natural resources and resilience, encompassing a total of 55 indicators. The CRITIC and PROMETHEE methodologies were employed to carry out the analysis.

Several scholarly articles have been published on this issue in the academic literature. In their study, Leroy, Ruel, Frongillo, Harris, and Ballard (2015) conducted research to identify the most appropriate indicators for assessing the many aspects of access to food security. Additionally, they provided suggestions for future research in this area. Desiere, D'Haese, and Niragira (2015) conducted a study in Burundi to assess the cross-sectional and intertemporal validity of the Household Food Insecurity Access Scale (HFIAS). In a study conducted by Garibaldi et al. (2017) it was shown that agricultural techniques have the potential to enhance biodiversity, livelihoods, and food security. In their study, Pérez-Escamilla, Gubert, Rogers, and Hromi-Fiedler (2017) incorporated considerations on food safety measurement and governance problems while assessing the applicability of several food insecurity indicators for policymakers. Cafiero, Viviani, and Nord (2018) used methodologies grounded in the Rasch model for the purpose of establishing the eight-item Food Insecurity Experience Scale (FIES). This scale is designed to assess worldwide food insecurity by employing a set of criteria. In their study, Smith, Kassa, and Winters (2017) employed the Food and Agriculture Organization's food insecurity experience measure to evaluate the prevalence of food insecurity in Latin America and the Caribbean region. Smith, Rabbitt, and Coleman-Jensen (2017) conducted an extensive review of the scholarly literature pertaining to the various dimensions of food insecurity within prosperous countries. Poulsen, McNab, Clayton, and Neff (2015) undertook a thorough assessment of the impacts of urban agriculture on food security in the least developed countries. In a study conducted by Kansiime et al. (2020), it was found that COVID-19 has adverse effects on both household income and food security in Kenya and Uganda. Pachapur et al. (2020) published a report pertaining to the subject of food security and sustainability.

Numerous investigations have been conducted utilizing the methodology applied in this particular study, encompassing the subsequent: In 2010, a comprehensive investigation of the existing literature on PROMETHEE methodologies and applications was carried out by Behzadian Behzadian, Kazemzadeh, Albadvi, and Aghdasi (2010). Out of the 217 publications evaluated, a total of 195 papers, accounting for 89.9 percent, were considered suitable for the aims of this review. The authors encountered challenges in identifying relevant concerns due to the wide range of applications of PROMETHEE techniques, which exhibited considerable diversity. After conducting a comprehensive analysis of the submissions to identify commonalities and distinctions, a total of 195 papers were categorized into nine distinct groups. The subsequent table presents a summary of the quantity of papers and their respective proportion in relation to the overall total, categorized by field. According to the data presented in Table 4, a considerable proportion of the research publications on PROMETHEE focused on the subject of management (Behzadian et al., 2010).

Table 4. The classification of articles based on their respective fields of application (Behzadian et al., 2010).

Application areas	N	%
Environment Management	47	24.1
Business and Financial Management	25	12.8
Hydrology and Water Management	28	14.4
Chemistry	24	12.3
Logistics and Transportation	19	9.7
Energy Management	17	8.7
Manufacturing and Assembly	19	9.7
Social	7	3.6
Other Topics	9	4.6
Total	195	100

3. Methodology and Data

Figure 7 presents the research framework that was used for the purpose of the study.

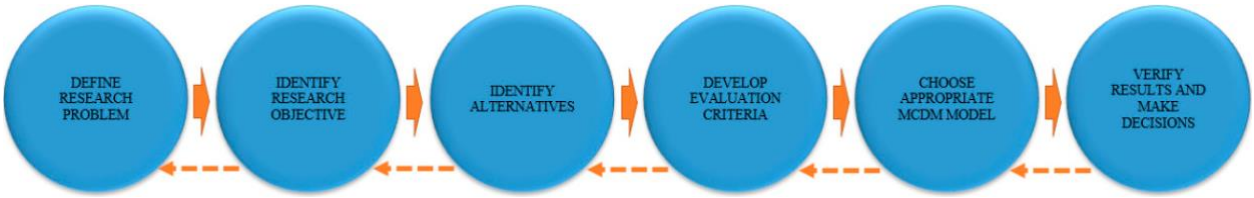


Figure 7. Generalized framework for MCDM process (Wang, Dang, Tibo, & Duong, 2021).

The objective of this study is to evaluate the food security performance of 40 nations worldwide through the application of Multi-Criteria Decision-Making (MCDM) techniques. These countries frequently hold significant importance within their respective regions in terms of both economics and population. The selection of these countries was based on their respective qualities and their representation of the regions in which they are geographically situated. Table 1 presents the nations that were included in the study, along with supplementary descriptive data.

The initial aspect of the study examines the affordability of food through the assessment of many factors, including the purchasing power of households, their resilience to market fluctuations, and the presence of support systems and interventions to aid households during times of crisis. After North America, Europe emerges as the region with the greatest scores in terms of these dimension indicators. This may be attributed to several factors including high incomes, low poverty rates, stable food costs, robust welfare mechanisms, and effective agricultural financing channels.

The second aspect of the research assesses various variables, including the adequacy of the country's food supply, the risk of supply disruption, the capacity for food distribution,

and scientific initiatives aimed at enhancing agricultural output. While European countries exhibit commendable performance in terms of agricultural infrastructures there are significant prospects for further growth, particularly in the domains of transportation networks and harvest volatility. It is imperative for nations to consistently monitor the number of agricultural storage facilities and the state of irrigation infrastructure on a frequent basis to uphold sustained food security, particularly during instances of severe weather events and subpar harvests.

The third aspect involved the evaluation of the diversity and nutritional features, as well as the safety, of the traditional dietary. The result list indicates that a majority of the top ten performing nations, namely six out of ten, are located in Europe. This observation suggests that the region as a whole possesses a notable proficiency in ensuring food quality and safety. The region exhibits a notable degree of dietary diversity, owing to its elevated income levels and abundant access to a wide range of food sources. Additionally, the region boasts a commendable availability of minerals, vitamins, and protein-rich meals. Government entities prioritize nutritional needs and the majority of these nations have implemented nutritional dietary standards to promote the consumption of a wholesome diet. In conjunction with the establishment of a food safety agency, it is imperative for any nation to possess a dependable energy infrastructure that facilitates the secure preservation and utilization of perishable commodities, including fruits and vegetables.

The final component of this study investigates the impact of global climatic hazards, specifically those connected to the weather, earth, water, and seas, on the entire food security condition of a nation. European countries tend to exhibit higher values in this dimension, with the Czech Republic, Finland, and Denmark being particularly notable for their favorable indicator scores in this category. Europe is at the forefront of addressing issues related to natural resources and resilience in the agriculture sector. Numerous countries within the region are currently exploring innovative strategies to effectively handle these obstacles. Dutch floating agricultural activities are being launched in response to the increasing sea levels.

Table 1 presents the nations that were included in the study, along with relevant descriptive data pertaining to each country. Table 5 was **c**reated by authors using the Global Innovation Index 2020 values.

Table 5. A concise overview of each country that was incorporated in the research (Dutta, Lanvin, & Wunsch-Vincent, 2020)

No	Country	Income	Region	Population (mn)	GDP PPP$	GDP per capita, PPP$
1	Australia	High	South East Asia, East Asia, and Oceania	24,8	1.386,60	52.375,50
2	Austria	High	Europe	8,8	464	52.137,40
3	Belgium	High	Europe	11,5	549,7	48.244,70
4	Brazil	Upper middle	Latın America and the Caribbean	210,9	3.370,60	16.154,30
5	Canada	High	Northern America	37	1.852,50	49.651,20
6	China	Upper middle	South East Asia, East Asia, and Oceania	1.415,00	25.313,30	18.109,80
7	Czech Republic	High	Europe	10,6	396,4	37.371,00
8	Denmark	High	Europe	5,8	300,3	52.120,50
9	Finland	High	Europe	5,5	257,2	46.429,50
10	France	High	Europe	65,2	2.968,50	45.775,10
11	Germany	High	Europe	82,3	4.379,10	52.558,70
12	Greece	High	Europe	11,1	312,5	29.123,00
13	Hungary	High	Europe	9,7	308,2	31.902,70
14	India	Lower middle	Central and Southern Asia	1.354,10	10.401,40	7.873,70
15	Indonesia	Lower middle	South East Asia, East Asia, and Oceania	266,8	3.495,90	13.229,50
16	Ireland	High	Europe	4,8	378,5	78.784,80
17	Israel	High	Northern Africa and Western Asia	8,5	336,1	37.972,00
18	Italy	High	Europe	59,3	2.398,20	39.637,00
19	Japan	High	South East Asia, East Asia, and Oceania	127,2	5.632,50	44.227,20
20	Malaysia	Upper middle	South East Asia, East Asia, and Oceania	32	999,8	30.859,90
21	Mexico	Upper middle	Latin America and The Caribbean	130,8	2.575,20	20.601,70
22	Netherlands	High	Europe	17,1	972,5	56.383,20
23	Norway	High	Europe	5,4	398,3	74.356,10
24	Poland	High	Europe	38,1	1.201,90	31.938,70
25	Portugal	High	Europe	10,3	328,8	32.006,40
26	Qatar	High	Northern Africa and Western Asia	2,7	356,7	130.475,10
27	Russian Federation	Upper middle	Europe	144	4.179,60	29.266,90
28	Singapore	High	South East Asia, East Asia, and Oceania	5,8	556,2	100.344,70
29	Slovakia	High	Europe	5,4	191,1	35.129,80
30	South Africa	Upper middle	Sub-Saharan Africa	57,4	790,9	13.675,30
31	South Korea	High	South East Asia, East Asia, and Oceania	51,2	2.139,70	41.350,60
32	Spain	High	Europe	46,4	1.867,90	40.138,80
33	Sweden	High	Europe	10	542,8	52.984,10
34	Switzerland	High	Europe	8,5	551,4	64.649,10
35	Thailand	Upper middle	South East Asia, East Asia, and Oceania	69,2	1.323,20	19.476,50
36	Turkey	Upper middle	Europe	82,9	2.314,40	27.956,10
37	United Arab Emirates	High	Northern Africa and Western Asia	9,5	732,9	69.381,70
38	United Kingdom	High	Europe	66,6	3.033,70	45.704,60
39	United States	High	Northern America	326,8	20.513,00	62.605,60
40	Vietnam	Lower middle	Southeast Asia	97,47	5.710,76	14.285,00

The objective of this study was to assess a comprehensive metric of global food systems, with a specific focus on investigating and assessing the factors influencing food security across various countries. The Global Food Security Index (GFSI) was utilized as the primary tool for this analysis. The primary sources utilized in the Global Food Security Index (GFSI) encompass a range of reputable organizations, including the Economist Intelligence Unit (EIU), the World Bank Group, the United Nations Food and Agriculture Organization (FAO), the World Health Organization (WHO), the World Trade Organization (WTO), the Organization for Economic Co-operation and Development (OECD), the Notre Dame Global Adaptation Initiative (ND-GAIN), the World Resources Institute (WRI), the Yale Environmental Performance Index (EPI), the United States Department of Agriculture (USDA), and various national agriculture and health ministries. Figure 8 illustrates the categories and indicators that are encompassed within the 2022 Global Food Security Index (GFSI).

Figure 8. The categories and indicators that are encompassed within the 2022 (GFSI, 2022)

The categories and indicators included in the 2022 index are:

1)	**AFFORDABILITY**
1.1)	**Change in average food costs**
1.2)	**Proportion of population under global poverty line**
1.3)	**Inequality-adjusted income index**
1.4)	**Agricultural import tariffs**
1.5)	**Food safety-net programmes**
1.5.1)	Presence of food safety-net programmes
1.5.2)	Funding for food safety-net programmes
1.5.3)	Coverage of food safety-net programmes
1.5.4)	Operation of food safety-net programmes
1.6)	**Market access and agricultural financial services**
1.6.1)	Access to finance and financial products for farmers
1.6.2)	Access to diversified financial products
1.6.3)	Access to market data and mobile banking

2)	**AVAILABILITY**
2.1)	**Sufficiency of supply**
2.1.1)	Food supply adequacy
2.1.2)	Dependency on chronic food aid
2.2)	**Agricultural research and development**
2.2.1)	Public expenditure on agricultural research and development
2.2.2)	Access to agricultural technology, education and resources
2.3)	**Agricultural infrastructure**
2.3.1)	Crop storage facilities
2.3.2)	Road infrastructure
2.3.3)	Air, port and rail infrastructure
2.3.4)	Irrigation infrastructure
2.4)	**Volatility of agricultural production**
2.5)	**Political and social barriers to access**
2.5.1)	Armed conflict
2.5.2)	Political stability risk
2.5.3)	Corruption
2.5.4)	Gender inequality
2.6)	**Food loss**
2.7)	**Food security and access policy commitments**
2.7.1)	Food security strategy
2.7.2)	Food security agency

3)	**QUALITY AND SAFETY**
3.1)	**Dietary diversity**
3.2)	**Nutritional standards**
3.2.1)	National dietary guidelines
3.2.2)	National nutrition plan or strategy
3.2.3)	Nutrition labelling
3.2.4)	Nutrition monitoring and surveillance
3.3)	**Micronutrient availability**
3.3.1)	Dietary availability of vitamin A
3.3.2)	Dietary availability of iron
3.3.3)	Dietary availability of zinc
3.4)	**Protein quality**
3.5)	**Food safety**
3.5.1)	Food safety mechanisms
3.5.2)	Access to drinking water
3.5.3)	Ability to store food safely

4)	**SUSTAINABILITY AND ADAPTATION**
4.1)	**Exposure**
4.1.1)	Temperature rise
4.1.2)	Drought
4.1.3)	Flooding
4.1.4)	Storm severity (annual average loss)
4.1.5)	Sea level rise
4.2)	**Water**
4.2.1)	Agricultural water risk—quantity
4.2.2)	Agricultural water risk—quality
4.3)	**Land**
4.3.1)	Land degradation
4.3.2)	Grassland
4.3.3)	Forest change
4.4)	**Oceans, rivers and lakes**
4.4.1)	Eutrophication
4.4.2)	Marine biodiversity
4.5)	**Sensitivity**
4.5.1)	Food import dependency
4.5.2)	Dependence on natural capital
4.6)	**Political commitment to adaptation**
4.6.1)	Early-warning measures/climate-smart agriculture
4.6.2)	Commitment to managing exposure
4.6.3)	National agricultural adaptation policy
4.6.4)	Disaster risk management
4.7)	**Demographic stress**
4.7.1)	Projected population growth
4.7.2)	Urban absorption capacity

3.1. CRITIC (Criteria Importance through Strategic Correlation) Method

The CRITIC approach, which was first proposed in the scientific literature by Diakoulaki, Mavrotas, and Papayannakis (1995), is a weighting method used to estimate the objective weights of criteria. The procedure of weighting the criteria incorporates the inclusion of the standard deviation of the criterion and the correlation between them. The method's application process comprises five distinct steps, as outlined by (Diakoulaki et al., 1995).

Step 1: The X matrix is generated to illustrate the performance of many alternatives, encompassing diverse criteria and options. Equation 1 displays a matrix X as an illustrative example.

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}; i = 1, \dots \dots m \ ve \ j = 1, \dots n$$

(1)

Step 2: The normalization of the decision matrix is contingent upon its orientation towards either benefits or costs. The utilization of Equation 2 is employed for the purpose of normalizing the choice matrix in accordance with the benefits. Equation 3 is employed for the purpose of normalizing the decision matrix in accordance with cost considerations.

$$r_{ij} = \frac{X_{ij} - min\, X_{ij}}{maxX_{ij} - min\, X_{ij}}$$

(2)

$$r_{ij} = \frac{maxX_{ij} - X_{ij}}{maxX_{ij} - min\, X_{ij}}$$

(3)

Step 3: In this stage, equation 4 is employed to calculate the correlation coefficients using the data obtained from the normalized decision matrix.

$$p_{jk} = \frac{\sum_{i=1}^{m}(r_{ij} - r_j) * (r_{ik} - r_k)}{\sqrt{\sum_{i=1}^{m}(x_{ij} - \overline{x}_j)^2 * \sum_{i=1}^{m}(x_{ik} - \overline{x}_k)^2}}; j, k = 1, \dots, n$$

(4)

Step 4: The numerical values of "1 - Pjk" are derived by deducting the correlation coefficients from 1. The resultant amount is subjected to cumulative summation, and the resulting sum is then multiplied by the standard deviation values denoted as "σj" to get the value denoted as "Cj". Equation 5 is employed to calculate the value of Cj, while equation 6 is utilized to determine the magnitude of σj.

$$c_j = \sigma_j \sum_{k=1}^{n}(1 - p_{jk}); \quad j = 1, \dots, n$$

(5)

$$\sigma_j = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(x_{ij} - \overline{x}_j)^2}; \ i = 1, \dots, m$$

(6)

Step 5: The acquired "Cj" values are then divided by the sum of the "Cj" results to get the "Wj" values, which represent the weights assigned to the criteria. The calculation of Wj values is determined by equation 7.

$$w_j = \frac{c_j}{\sum_{i=1}^{n} c_j};\ j = 1, \dots, n$$

(7)

3.2. PROMETHEE Method

The PROMETHEE approach is a multi-criterion decision making (MCDM) technique that facilitates the assessment of options by the application of preference functions based on predetermined criteria. The assessment of alternatives is conducted through the process of pairwise comparisons, as outlined by (Tolga, 2013). Mareschal, Brans, and Vincke (1984) proposed the PROMETHEE I approach, which is designed for partial ranking. On the other hand, the PROMETHEE II method is specifically designed for full ranking. Furthermore, Mareschal and Brans (1988) introduced the GAIA approach in 1988, which complements the PROMETHEE method and offers visual representations. The PROMETHEE method is comprised of five distinct processes, as outlined by (Brans & Vincke, 1985; Dağdeviren & Erarslan, 2008; Ishizaka & Nemery, 2011). In Figure 9, the procedural stages involved in the computation of the PROMETHEE technique are illustrated.

Figure 9. The computational stages of the PROMETHEE approach

Step 1. Determination of deviations based on pair-wise comparisons

$$d_j(a,b) = g_j(a) - g_j(b) \qquad (1)$$

Where $d_j(a,b)$ denotes the difference between the evaluations of a and b on each criterion.

Step 2: Application of the preference function

$$P_j(a,b) = F_j[d_j(a,b)] \qquad j=1,\dots,k \qquad (2)$$

Where $P_j(a,b)$ denotes the preference of alternative a with regard to alternative b on each criterion, as a function of $d_j(a,b)$.

Step 3: Calculation of an overall or global preference index

$$\forall a,b \in A, \qquad \pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j \qquad (3)$$

Where $\pi(a,b)$ of a over b (from 0 to 1) is defined as the weighted sum $p(a,b)$ of for each criterion, and w_j is the weight associated with jth criterion.

Step 4: Calculation of outranking flows/ The PROMETHEE I partial ranking

$$\phi^+(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a,x) \qquad (4) \qquad \text{and} \qquad \phi^-(a) = \frac{1}{n-1} \sum_{x \in A} \pi(x,a) \qquad (5)$$

Where $\phi^+(a)$ and $\phi^-(a)$ denote the positive outranking flow and negative outranking flow for each alternative, respectively.

Step 5: Calculation of net outranking flow/ The PROMETHEE II complete ranking

$$\phi(a) = \phi^+(a) - \phi^-(a) \qquad (6)$$

Where $\phi(a)$ denotes the net outranking flow for each alternative.

Determining whether to accept or reject incomparability is an essential component in resolving a given choice dilemma. The decision maker employs PROMETHEE I if they approve it; otherwise, PROMETHEE II is utilized.

PROMETHEE I typically results in an action ranking based on a partial pre-order due to its acceptance of the incomparability. PROMETHEE II ranks the options in a predetermined order, rejecting the notion of incomparability; each alternative is ranked from most favorable to least favorable.

φi, in fact, has the potential to be both positive and negative. As the value of φi increases, xi's outranking of the other choices decreases. Thus:

- x_i outranks x_j if and only if $\phi_i > \phi_j$
- x_i is indifferent to x_j if and only if $\phi_i = \phi_j$.

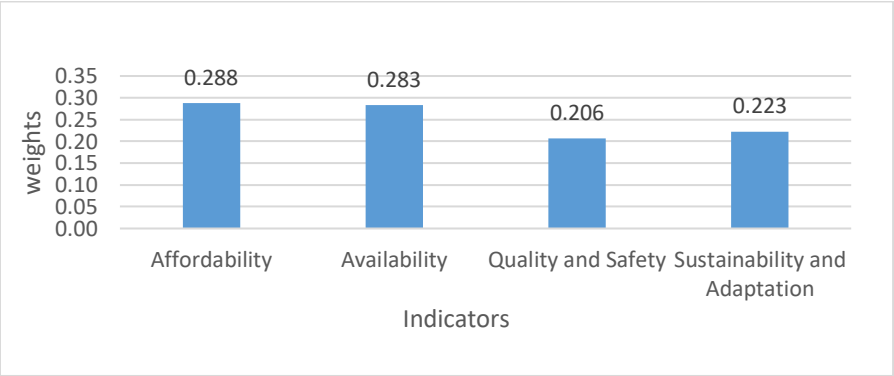
Φ+ (a) > Φ+ (b) and Φ-(a) < Φ-(b)
In order to get the complete rank order of the options using the PROMETHEE II method, it is necessary to consider the net outranking flow, denoted as φ(i). The option with the highest φ(i) is considered to be the most favourable choice.

4. Results

The initial step in the CRITIC technique involved determining the weights of the dimensions, as described in the methodology section. The decision matrix of the CRITIC technique is presented in Appendix A. The applied approach utilized an objective methodology, devoid of subjective evaluations, to determine the weights. These weights were determined by taking into account the values of the indicators.

Figure 10 depicts the weights assigned to the dimensions of food security as determined through the utilization of the CRITIC approach.

Figure 10. The weights of the indicators were obtained using the CRITIC technique



While the affordability is the most significant dimension according to the CRITIC method weights, the indicators with the closest weight to this indicator are the availability, quality and safety, and sustainability and adaptation.

The decision matrix utilized in the PROMETHEE investigation was the transformed normalized decision matrix, as outlined in Appendix B. The indicator values underwent normalization and were thereafter transformed to a scale ranging from 0 to 1. The

transformation was executed using the approach outlined in the second step of the PROMETHEE methodology. Additionally, it should be noted that these values are designated as the upper limits. The research was carried out with Visual PROMETHEE, a tool known for its user-friendly interface. The program represents a notable multi-criteria decision support system that was specifically designed to facilitate the implementation of the PROMETHEE strategy.

The study examined the data from several nations in 2022 to establish a comparative analysis between the times before and after the epidemic. The study findings are juxtaposed with the impacts observed during the COVID-19 pandemic in 2020.

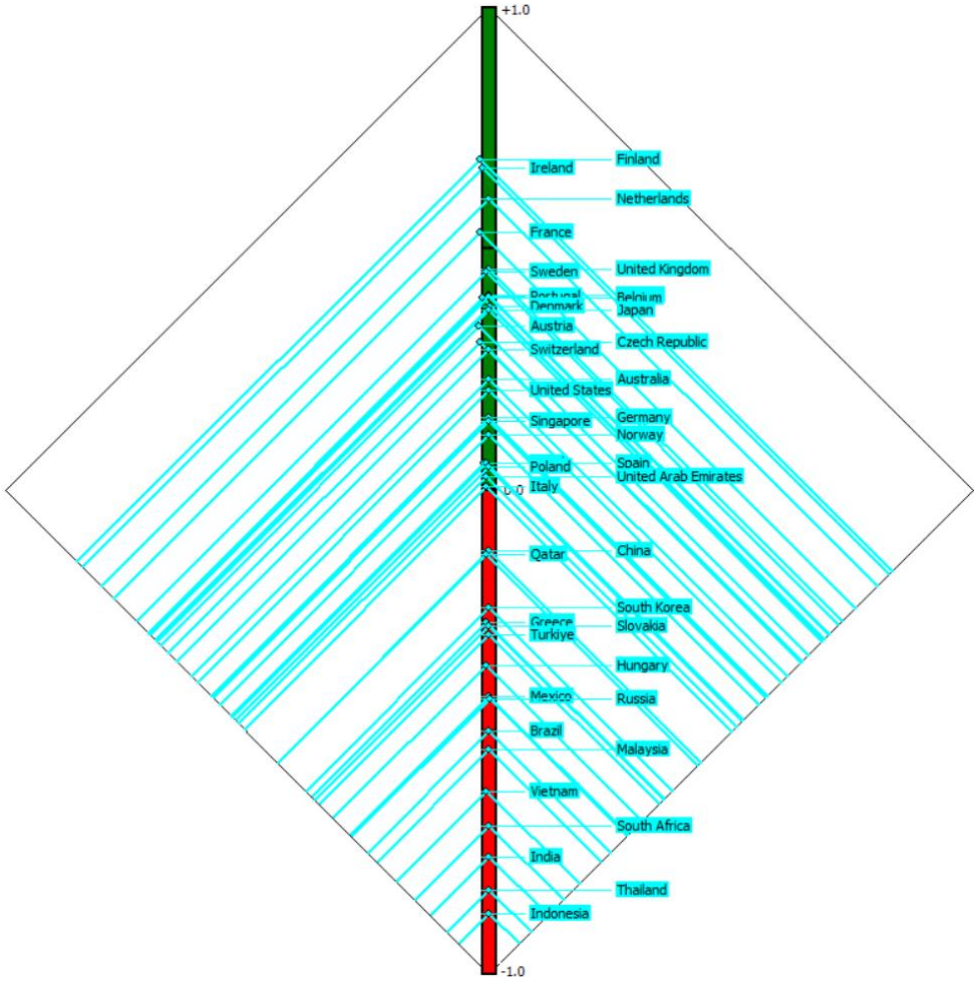
The weights utilized in the analysis were acquired from the CRITIC analysis. The PROMETHEE technique encompasses a range of preference functions that delineate the configuration and interconnectedness of the evaluation criteria. Hence, the preference function was established as the initial type (common) function for all criteria. This decision was made to ensure that the evaluation process relies solely on the predetermined CRITIC weights, without favoring specific value ranges for any criterion, irrespective of subjective assessments. The parameters utilized in the PROMETHEE study are presented in Table 6.

Table 6. The parameters of PROMETHEE analysis for 2022.

	C1	**C2**	**C3**	**C4**
Direction of preference	max	max	max	max
Weight coefficient	0,288	0,283	0,223	0,206
Preference function	Usual	Usual	Usual	Usual

The subsequent part provides a description of the outcomes generated by the analysis and their corresponding interpretations. In the PROMETHEE Diamond, every action is depicted as a point located within the (Phi+, Phi-) plane. In order to align the vertical dimension (green-red axis) with the Phi net flow, the plane is tilted at an angle of 45 degrees. Phi+ scores increase as one moves from the left to the top corner, while Phi- scores increase from the bottom to the top corner. The diagram seen in Figure 11 illustrates the PROMETHEE Diamond.

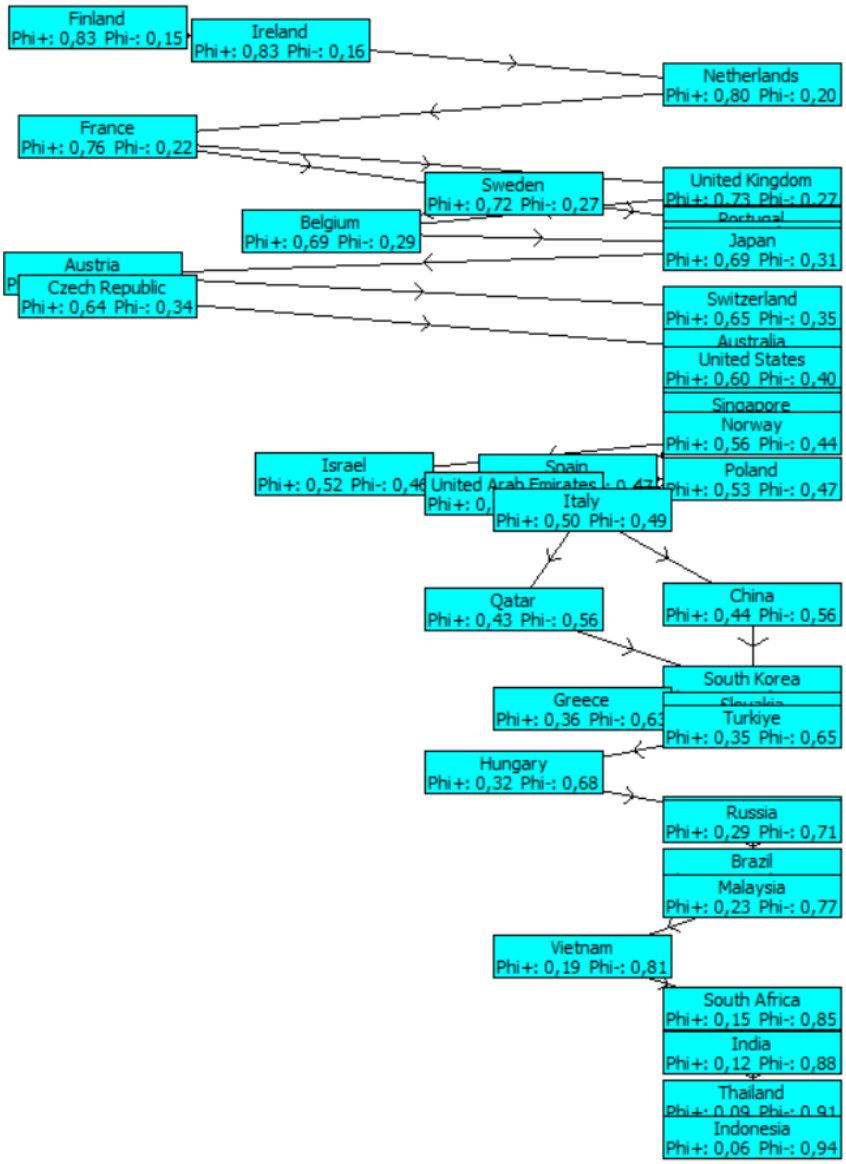
Figure 11. PROMETHEE Diamond



Each activity is symbolized by a cone. In the context of PROMETHEE I Partial Ranking, the presence of overlapping cones signifies the preference of one action over another. Converging cones symbolize actions that are inherently incomparable. By utilizing the vertical dimension, which represents the Phi value, it becomes feasible to simultaneously observe the PROMETHEE ranks. The statistics indicate that Finland is much preferred above all other nations, but the United Kingdom and Sweden cannot be compared.

The PROMETHEE I method offers a partial evaluation of countries by considering food security-related indicators. This study examines three potential results when comparing nations, namely through pairwise comparisons of countries using computed positive and negative superiority values. In conclusion, the potential outcomes encompass the establishment of one country's supremacy over another, the lack of concern exhibited by one country towards another, and the inability to make meaningful comparisons between two countries. The partial ranking of the PROMETHEE I approach is seen in Figure 6, represented as the PROMETHEE Network. In the PROMETHEE Network display, nodes are used to depict each activity, and arrows are employed to show preferences. The positioning of the nodes is determined in relation to the PROMETHEE Diamond, which serves to emphasize the closeness of flow values. The diagram presented in Figure 12 illustrates the PROMETHEE Network.

Figure 12. PROMETHEE Network



Within the PROMETHEE Network, it is evident that Finland exhibits a distinct preference over all other countries, whilst the United Kingdom and Sweden are deemed incomparable, however exhibit a close proximity to one another. Sweden is succeeded in terms of power over other nations by Switzerland and Norway. In cases where the comparative results are inconclusive, it is necessary to employ the PROMETHEE II methodology in order to obtain a comprehensive rating. The results of PROMETHEE II offer a thorough assessment of nations, encompassing a ranking system that include the net advantage value derived from negative and positive superiority values. The attainment of the complete rank value (Phi) is achieved through the subtraction of the negative superiority (Phi-) value from the positive superiority (Phi+) value. The results of PROMETHEE II, as presented in Table 7, display the positive advantage value, negative advantage value, net advantage value, and ranking of the countries. According to the

findings of this study, Finland emerges as the leading nation in terms of net Phi values for the 2022 GFSI data when compared to other countries. According to the ranking, Finland, Ireland, Netherlands, France, and the United Kingdom are the leading countries. The nations occupying the lower positions in the ranking include Indonesia, Thailand, India, South Africa, and Vietnam.

Table 7. Positive, Negative, Net Advantage Values Obtained by PROMETHEE II in terms of Multi-Criteria Evaluation and Full Ranking of Countries

Rank	Action	Phi	Phi+	Phi-	Rank	Action	Phi	Phi+	Phi-
1	Finland	0,6865	0,8331	0,1466	**21**	Spain	0,057	0,5256	0,4686
2	Ireland	0,6688	0,8271	0,1583	**22**	Poland	0,0511	0,5255	0,4745
3	Netherlands	0,6053	0,8027	0,1973	**23**	United Arab Emirates	0,0297	0,5112	0,4814
4	France	0,5338	0,7569	0,2231	**24**	Italy	0,0079	0,5013	0,4934
5	United Kingdom	0,4596	0,7298	0,2702	**25**	China	-0,1248	0,4376	0,5624
6	Sweden	0,4527	0,7226	0,27	**26**	Qatar	-0,1316	0,4305	0,5621
7	Canada	0,406	0,703	0,297	**27**	South Korea	-0,2426	0,3787	0,6213
8	Portugal	0,4035	0,7017	0,2983	**28**	Greece	-0,2711	0,3618	0,6329
9	Belgium	0,3988	0,6929	0,294	**29**	Slovakia	-0,2793	0,3604	0,6396
10	Denmark	0,3829	0,6914	0,3086	**30**	Türkiye	-0,2974	0,3513	0,6487
11	Japan	0,3742	0,6871	0,3129	**31**	Hungary	-0,3608	0,3159	0,6767
12	Austria	0,3399	0,6597	0,3198	**32**	Mexico	-0,4253	0,2874	0,7126
13	Czech Republic	0,3082	0,6441	0,3359	**33**	Russia	-0,4297	0,2852	0,7148
14	Switzerland	0,2928	0,6464	0,3536	**34**	Brazil	-0,498	0,251	0,749
15	Australia	0,2315	0,6157	0,3843	**35**	Malaysia	-0,5357	0,2322	0,7678
16	United States	0,2081	0,604	0,396	**36**	Vietnam	-0,6212	0,1868	0,8079
17	Germany	0,1512	0,5756	0,4244	**37**	South Africa	-0,693	0,1535	0,8465
18	Singapore	0,1439	0,572	0,428	**38**	India	-0,7565	0,1217	0,8783
19	Norway	0,1156	0,5578	0,4422	**39**	Thailand	-0,8251	0,0875	0,9125
20	Israel	0,0575	0,5224	0,4649	**40**	Indonesia	-0,8746	0,0627	0,9373

The performance scores that were determined from the PROMETHEE II research are summarized in Table 8.

Table 8. Scores and rankings using the PROMETHEE II technique

Countries	Score	Countries	Score
Finland	100	Spain	20,83
Ireland	93,66	Poland	20,59
Netherlands	75,61	United Arab	19,73
France	61,16	Italy	18,89
United Kingdom	50,20	China	14,46
Sweden	49,33	Qatar	14,26
Canada	44	South Korea	11,33
Portugal	43,73	Greece	10,66
Belgium	43,25	Slovakia	10,47
Denmark	41,65	Türkiye	10,07
Japan	40,82	Hungary	8,73
Austria	37,73	Mexico	7,50
Czech Republic	35,15	Russian Federation	7,41
Switzerland	33,98	Brazil	6,23
Australia	29,79	Malaysia	5,62
United States	28,35	Vietnam	4,34
Germany	25,21	South Africa	3,37
Singapore	24,84	India	2,58
Norway	23,45	Thailand	1,78
Israel	20,86	Indonesia	1,24

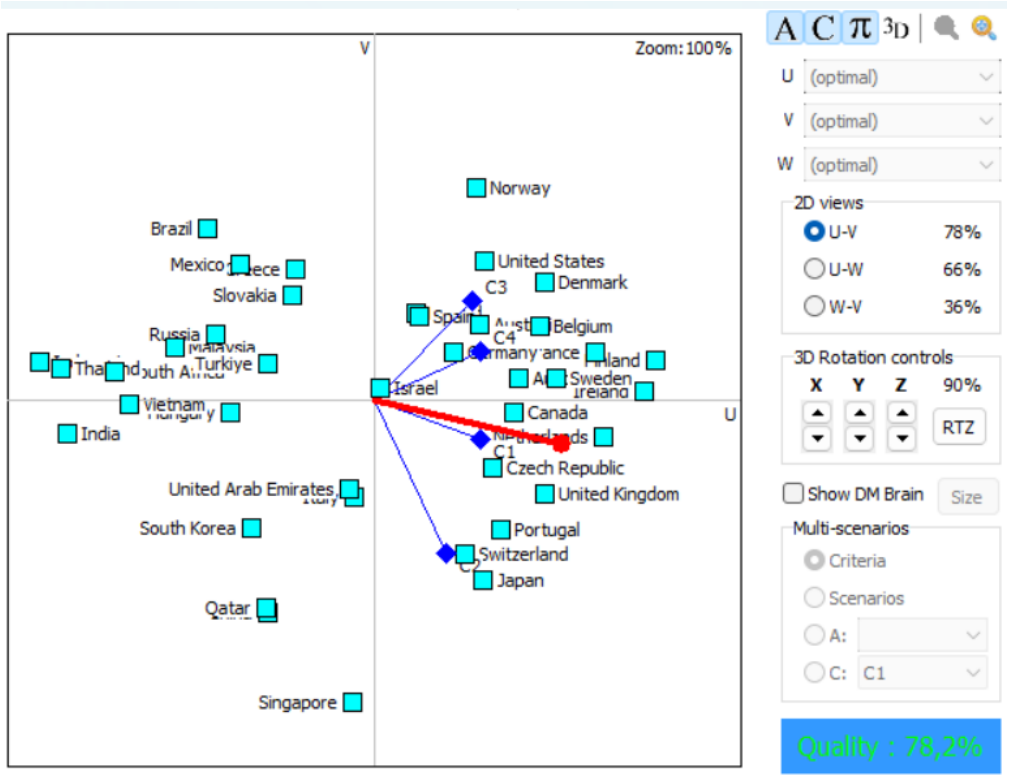
Figure 7 depicts the PROMETHEE II evaluation of the GAIA plane. This diagram was created with PROMETHEE IV. There are actually two potential outcomes:

1. Since the Decision Axis is always pointing in the same direction when the Brain is entirely contained within one side of the GAIA plane, this suggests that PROMETHEE rankings should be consistent. It is simple to pinpoint the most sought-after nations.

2. The Decision Axis can be oriented in any direction when the Brain overlaps the geometrical center of the GAIA plane. Accordingly, the PROMETHEE rankings may vary greatly based on the values of the weights employed within the constraints imposed by the decision maker.

In Figure 13, the GAIA graphic is presented.

Figure 13. GAIA graphic



Let us examine dimension C1, which is depicted in Figure 7 and pertains to the concept of affordability. The orientation of the corresponding axis plays a crucial role in this case, where the C1 axis is oriented towards the right. This implies that nations located towards the right side of the GAIA plane exhibit higher proficiency in fulfilling dimension C1. Based on the C1 criterion axis orientation, the right side is associated with the 'best' results, while the left side is associated with the 'worst' values. The projection of each country is performed orthogonally with respect to the criteria direction. The forecasts illustrate the comparative performance of the countries based on the chosen parameters. The magnitude of the deviation from the established standards is of considerable importance. The expected position of a country on the criteria holds significant importance. According to Figure 7, it is evident that Finland ranks highest among the countries assessed in terms of the C1 Affordability factor.

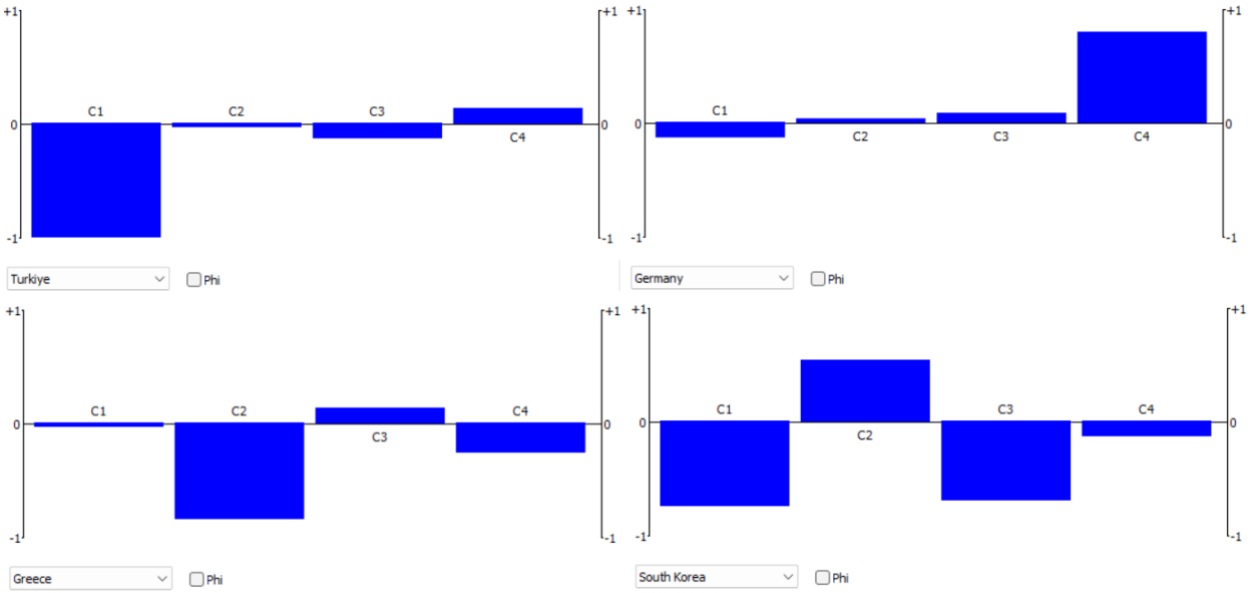
Sweden, Denmark, and Ireland rank second in terms of their C1 dimension and exhibit remarkably similar values. On the other hand, India demonstrates the least favourable value for the C1 dimension.

Naturally, the accuracy of this data is constrained by the capabilities of the GAIA plane. It's easy to see that neighbouring countries on the GAIA plane share extremely similar profile graphs of their positive and negative indicators.

The Figure 8 illustrates the action profile of several countries. The presented graphic provides an overview of the dimensions in which countries demonstrate strong performance, as well as those in which their performance is comparatively weak. Several

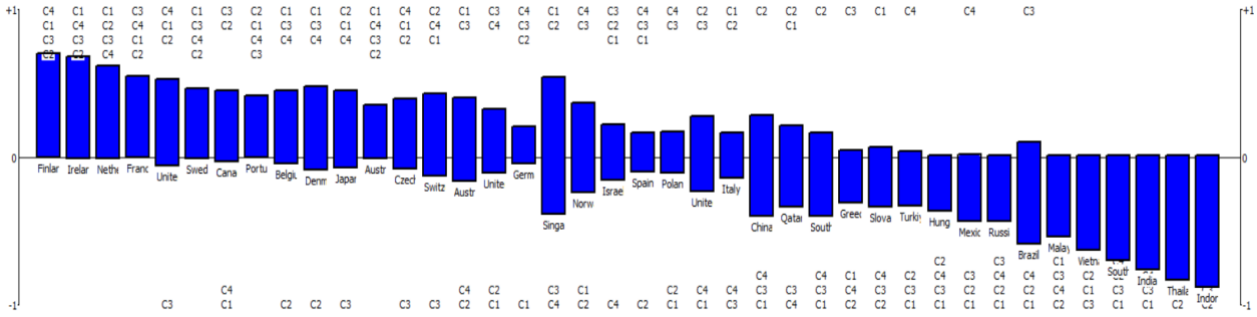
countries, notably Turkey, are mentioned as illustrative instances. Indicators located within the negative region of the axis are indicative of subpar performance, whereas those situated within the positive region imply favourable performance.

Figure 14. Action profile of countries



The Visual PROMETHEE software is utilized for the generation of informative graphical representations. One of the diagrams included in this study is the Rainbow diagram (refer to Figure 9). This visual representation provides utility since it succinctly outlines the merits and drawbacks associated with each alternative (namely, countries) under consideration. The benefits are presented above the histograms, while the drawbacks are exhibited below. According to the data presented in Figure 15, it is evident that the top four rated nations possess a higher number of advantages in comparison to drawbacks. This advantages significantly contributes to their favourable positioning in the final rankings.

Figure 15. Rainbow diagram for 2022



5. Conclusion and discussion

The scores in the 2022 GFSI show a vulnerable global food system that is under great pressure and facing some of its worst results ever. The escalation of food costs and the prevalence of hunger have reached unprecedented levels, coinciding with a significant decline in affordability. This situation is exacerbated by other factors such as the global COVID-19 pandemic, violent conflicts, and the impacts of climate change, which all intensify existing systemic pressures. The aforementioned stressors and shocks present potential concerns that may be exacerbated if challenges to food security increasingly become the prevailing norm. Collaborative efforts among stakeholders across several sectors of a multifaceted and interdependent food system are necessary for effectively addressing these risks and attaining the dual objectives of resilience and sustainability.

The involvement of various stakeholders, including governments, international organizations, and non-governmental organizations (NGOs), is crucial in driving this momentum. Various instruments, such as humanitarian aid, trade policies, economic measures, and social protection mechanisms, can be employed to mitigate the adverse effects of transient disruptions. However, the current Global Food Security Index (GFSI) also presents a discernible trajectory for additional stakeholders, such as enterprises, agricultural practitioners, and community organizations. Collaborative efforts between governmental bodies and non-governmental organizations (NGOs) have yielded significant progress in the realms of adaptation policy, innovation, and finance.

The significance of technology in attaining global food security is increasingly paramount. The utilization of Big Data analytics, artificial intelligence (AI), and real-time monitoring has promise in addressing food security concerns. These technologies can empower firms to devise effective food management systems that optimize production processes and enhance supply chain operations.

Due to the subjective nature of assessments employed in MCDM techniques like the Analytic Network Process (ANP) and Analytic Hierarchy Process (AHP), it is possible to find disparate outcomes for same indicators across various analyses. When the weights of the criteria are decided through subjective evaluations, it might lead to variations in the results produced from the same procedures used to the same indications. This study employed Multi-Criteria Decision Making (MCDM) procedures, wherein the criteria were objectively weighted and did not necessitate any subjective evaluation. The focus was solely on processing and assessing the values of the criterion. The evaluations were conducted within a wholly objective context, in other terms. Future studies may provide varying rankings due to the computational disparities among different Multiple Criteria Decision Making (MCDM) approaches. Upon evaluating the findings of the study in a broader context, it is evident that the results align with the rankings observed in other scholarly works within the existing body of knowledge.

This study highlights the significance of determining appropriate objective weights and identifying key indicators for comparing nations in terms of food security. The analysis

considers the values of the countries under examination. This paper presents an analysis of the strengths, shortcomings, and relative comparisons of the countries under consideration in their present circumstances. According to the analysis conducted using the CRITIC approach in the study, the dimension that exhibits the highest weight is referred to as "C1 Affordability". This study use objective assessment approaches, namely CRITIC and PROMETHEE, to compare the top-performing countries across all continents. Additionally, it examines the findings of this study in relation to the existing literature review. Instead of focusing on a particular country or region, as is commonly observed in numerous research projects, the objective was to conduct a comprehensive evaluation on a global level to the greatest extent feasible.

The PROMETHEE approach exhibits a modest advantage over other methods when it comes to visually assessing the similarities of countries and the similarities and differences within country groupings based on indicator values. Furthermore, as highlighted in the literature review section pertaining to the methodology, the rationale for using this particular method in the present study stems from its prevalence and preference in analogous research endeavors.

Based on the findings of the CRITIC evaluation, the parameters have been assigned the following weights: The affordability of C1 is measured at (0,288), while the availability of C2 is measured at (0,283). The sustainability and adaptation of C4 are measured at (0,223), while the quality and safety of C3 are measured at (0,206). Based on the PROMETHEE method rankings, Finland emerges as the leading nation in terms of net Phi values for the 2022 Global Food Security Index (GFSI) data. According to the ranking, the top five nations are Finland, Ireland, the Netherlands, France, and the United Kingdom. The nations occupying the lower positions in the ranking are Indonesia, Thailand, India, South Africa, and Vietnam. It is noteworthy that all five of these nations ranked highest are European nations. At the bottom of the list, there is no particular union or territory that can be evaluated in this fashion. Indonesia, Thailand, India, South Africa, Vietnam, China, Brazil, and Russia, countries characterized by their substantial population sizes relative to many other nations, are positioned towards the lower end of the ranking. This result illustrates the presence of a significant food security issue affecting a substantial population.

The comparison of the 2020 COVID-19 data MCDM analysis results given by Özkaya and Uçak Özkaya (2022)with the findings of this study based on 2022 data reveals significant alterations in the ranks. Although Singapore is ranked second in terms of pandemic statistics, it does not feature among the top ten in this particular research study. Significant progress has been achieved by France, the United States, and the United Kingdom. Significant development has been demonstrated by Slovakia and China toward the conclusion of the list. Regarding the remaining countries situated at the lower end of the list, there has been minimal alteration observed throughout this two-year period.

The analysis reveals that affluent nations with established food security are unlikely to experience famine. However, they may face challenges such as shortages of certain food items and increased levels of inflation. It is imperative for governments across the globe to give precedence to the adoption of a comprehensive food security strategy in order to effectively tackle the enduring issue of domestic food insecurity, especially in times of instability and global crises.

In the field of nutrition, notable advancements have been achieved in the reduction of child stunting and low birthweight, as well as the promotion of exclusive breastfeeding throughout the initial six months of an infant's life. Nevertheless, it is worth noting that the prevalence of wasting exceeds the established targets, while the occurrence of both childhood overweight and adult obesity is on the rise in nearly all regions. This alarming pattern is expected to contribute to the overall burden of disease worldwide and escalate the expenses associated with public health services and healthcare. It is imperative to address and reverse the prevailing patterns of hunger, food insecurity, and malnutrition. The presence of epidemic hazards such as COVID-19, along with inter-country conflicts and wars, is anticipated to exacerbate the prevailing circumstances, hence heightening the vulnerability of marginalized populations. Immediate action plans are necessary to achieve the targets set for 2030, despite the global anticipation of the repercussions arising from conflicts and pandemics.

The deterioration of individuals' dietary patterns is observed as their availability of food becomes more limited, resulting in an elevated susceptibility to both undernutrition and overweight/obesity. In addition to various other considerations, the cost of food plays a vital role in determining individuals' ability to obtain it. The introductory section of this study provides insight into the role of food prices and the affordability of diets in the context of food insecurity and disparities in diet quality. Additionally, it demonstrates many activities and recommendations that are necessary to reform food systems in order to provide widespread availability of sufficient nutritious foods that promote the consumption of healthy diets. The ongoing years of the UN Decade of Action on Nutrition 2016–2025 provide a favourable occasion for governments, civil society, and the commercial sector to collaborate and expedite their endeavours. There remains a sufficient timeframe within which to realign efforts towards the attainment of the goal of eradicating all manifestations of hunger and addressing all kinds of malnutrition by the year 2030. Regrettably, the persistent conflicts undermine these aspirations.

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Contributions of the authors

Gökhan ÖZKAYA contributed to the planning of the study, literature review, writing the manuscript, applying the statistical and MCDM methods, and interpretation of the results.

Gülsüm UÇAK ÖZKAYA contributed to the planning of the study, literature review, writing the manuscript, applying the statistical methods, and interpretation of the results.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics

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Appendix A. CRITIC Method Decision Matrix

Countries\Criteria	C1	C2	C3	C4
Australia	93,30	61,10	84,00	58,80
Austria	91,30	67,10	81,20	69,70
Belgium	92,60	64,60	88,40	61,00
Brazil	63,00	58,60	83,90	56,30
Canada	88,30	75,70	89,50	60,10
China	86,40	79,20	72,00	54,50
Czech Republic	91,30	69,40	76,30	70,30
Denmark	92,10	63,20	89,10	63,80
Finland	91,90	70,50	88,40	82,60
France	91,30	69,00	87,70	70,30
Germany	87,90	67,00	79,90	70,80
Greece	88,50	58,30	80,80	57,30
Hungary	86,70	63,30	74,40	57,00
India	59,30	62,30	62,10	51,20
Indonesia	81,40	50,90	56,20	46,30
Ireland	92,60	70,50	86,10	75,10
Israel	88,60	67,20	87,40	52,20
Italy	89,50	68,70	75,90	57,30
Japan	89,80	81,20	77,40	66,10
Malaysia	87,00	59,50	74,70	53,70
Mexico	76,00	60,00	78,90	60,20
Netherlands	92,70	70,70	84,70	69,20
Norway	87,20	60,40	86,80	87,40
Poland	87,40	63,80	81,50	66,70
Portugal	90,00	77,00	79,80	64,50
Qatar	88,60	72,90	71,70	51,00
Russia	77,80	61,40	78,70	56,60
Singapore	93,20	77,80	69,70	44,30
Slovakia	89,10	55,30	77,90	57,60
South Africa	63,40	60,10	66,10	56,90
South Korea	76,80	71,50	71,50	58,50
Spain	89,00	63,10	81,20	66,40
Sweden	91,90	68,30	85,00	68,30
Switzerland	89,20	76,80	73,50	69,50
Thailand	83,70	52,90	45,30	51,60
Turkey	58,40	65,30	78,50	61,20
United Arab Emirates	86,70	73,80	81,30	55,20
United Kingdom	91,50	71,60	77,60	71,10
United States	87,10	65,10	88,80	69,40
Vietnam	84,00	60,70	70,20	52,20

Appendix B. PROMETHEE Method Decision Matrix

Ti	C1	C2	C3	C4
Countries/ Indicator Preference	MAX	MAX	MAX	MAX
Australia	1	0,336633663	0,875565611	0,33642691
Austria	0,94269341	0,534653465	0,812217195	0,58932715
Belgium	0,979942693	0,452145215	0,975113122	0,387471
Brazil	0,131805158	0,254125413	0,873303167	0,27842227
Canada	0,856733524	0,818481848	1	0,36658933
China	0,802292264	0,933993399	0,604072398	0,23665893
Czech Republic	0,94269341	0,610561056	0,701357466	0,60324826
Denmark	0,965616046	0,405940594	0,990950226	0,45243619
Finland	0,959885387	0,646864686	0,975113122	0,88863109
France	0,94269341	0,597359736	0,959276018	0,60324826
Germany	0,845272206	0,531353135	0,78280543	0,61484919
Greece	0,862464183	0,244224422	0,803167421	0,30162413
Hungary	0,810888252	0,409240924	0,658371041	0,29466357
India	0,025787966	0,376237624	0,380090498	0,16009281
Indonesia	0,659025788	0	0,246606335	0,04640371
Ireland	0,979942693	0,646864686	0,923076923	0,71461717
Israel	0,865329513	0,537953795	0,952488688	0,18329466
Italy	0,891117479	0,587458746	0,692307692	0,30162413
Japan	0,899713467	1	0,726244344	0,50580046
Malaysia	0,819484241	0,283828383	0,665158371	0,21809745
Mexico	0,504297994	0,300330033	0,760180995	0,36890951
Netherlands	0,982808023	0,653465347	0,891402715	0,57772622
Norway	0,8252149	0,313531353	0,938914027	1
Poland	0,830945559	0,425742574	0,819004525	0,51972158
Portugal	0,905444126	0,861386139	0,780542986	0,46867749
Qatar	0,865329513	0,726072607	0,597285068	0,15545244
Russia	0,555873926	0,346534653	0,755656109	0,28538283
Singapore	0,99713467	0,887788779	0,552036199	0
Slovakia	0,87965616	0,145214521	0,737556561	0,30858469
South Africa	0,143266476	0,303630363	0,470588235	0,29234339
South Korea	0,52722063	0,679867987	0,592760181	0,32946636
Spain	0,876790831	0,402640264	0,812217195	0,51276102
Sweden	0,959885387	0,574257426	0,898190045	0,55684455
Switzerland	0,88252149	0,854785479	0,63800905	0,58468677
Thailand	0,724928367	0,066006601	0	0,16937355
Turkey	0	0,475247525	0,751131222	0,39211137
United Arab Emirates	0,810888252	0,755775578	0,814479638	0,25290023
United Kingdom	0,948424069	0,683168317	0,730769231	0,62180974
United States	0,82234957	0,468646865	0,984162896	0,58236659
Vietnam	0,733524355	0,323432343	0,563348416	0,18329466