Measuring food security in European countries: limitations of the global food security index and its comparison with the DEA approach

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Food security is a current research topic, and most scientific papers in this field focus on its analysis on a global level. The presented paper focuses on the analysis of food security in European countries and its features. It emphasizes the need for objective indicators that will suit the specifics of European countries, which may seem food-secure from a global point of view. The analysis used the definition of food security and its pillars according to Food and Agriculture Organization of the United Nations (FAO) and used available data for 12 variables in 4 pillars of food security over the period of 2012–2020 for all accessible countries to produce composite indicators for European countries. Performance according to this indicator was compared with the ranking produced by the global food security index (GFSI). The comparison showed some limitations of the GFSI for the analysis of food security in European countries. The major problems were the smaller numbers of countries included in the GFSI, its complexity (which may hide some specific food security problems in the region), and weights derived from the subjective opinions of expert panels. However, the GFSI can be very useful for identifying the main issues at the world level, and the presented analysis recommends deriving objective weights for this kind of analysis in European countries by data envelopment analysis with dummy input. Derived weights can also be used as a measure of performance in each food security pillar. Analysis identified weak food security conditions in Eastern and Southeastern Europe. Surprisingly, weak performance compared to other European countries was recorded by France and Slovakia.

Keywords:
food security,
global food security index,
data envelopment analysis,
indicators,
dummy input

Introduction

Food security is a well-known concept in general, however, there are many ways to look at it. Various definitions of food security and its pillars influence its quantification and insight into the current situation in the world. This term was used for the first time at the World Food Conference in 1974. At that time, it was related mostly to price stability and the availability of food. Later, in 1983, the FAO extended the concept of food security by adding pillar connected with physical access to food. On the other hand, there are still various concepts of food security, and some of them are related to food sufficiency (Matkovski et al. 2020). The most widely used food security definition was formulated at the World Food Summit in 1996. According to this definition, food security at the individual, household, state, regional and world level is achieved when all people always have a physical and economic approach with sufficient amounts of safe and adequate food to satisfy their needs and different preferences for an active and healthy life. The World Food Summit of 2009 introduced the concept of food security based on four dimensions: stability, accessibility, access, and use. This approach is still used by the FAO. Currently, more than 200 definitions of food security and its determinants can be found in the literature (Kumar–Sharma 2022).

Current scientific discussion is focused primarily on food security issues in the developing world. According to comparisons at the global level, European regions seem to be food-secure. However, recent years, which have seen the Covid-19 pandemic, war conflict in Ukraine and high inflation, have shown that Europe also has many food security issues. Compared to other world regions, Europe has specific cultural, economic, natural and social conditions. This leads to specific import and export relations, supply chains and ways in which households ensure their food security. To identify specific features and conditions of European food security, this region should be analysed separately from less developed regions, as food security issues in both worlds have different natures. This is the reason why this paper focuses specifically on European countries to identify food security issues in this region and uses benchmarks corresponding to developed countries.

Wide discussion has also been held about the dimensions that should be included in food security indicators. In the scientific literature, different opinions about food security definitions and their content and number of pillars can be found. For example, Wineman (2016) suggests that there should be only three components of food security: the quantity, quality, and stability of food. Barrett (2010) agrees with 3 pillars of food security but suggests availability, access, and utilization. The author sees food security as a hierarchical structure of three suggested dimensions, as availability is essential but not enough to reach access, and this is necessary but not sufficient for utilization. This refers to the effective use of food accessed by households or individuals. Peng–Berry (2018) argue that in addition to the 3 dimensions mentioned above, the stability of the previously mentioned pillars over time should be considered an important part of food security. This approach is also adopted by FAO, which uses these 4 pillars to assess the food security situation in the world. Abdullah et al. (2019) add that food systems are vulnerable when 1 or more pillars of food security are insecure. Rahman et al. (2022) suggests that different indicators may be appropriate for measuring food security at distinct levels, and many modern studies add sustainability as another dimension of food security. Coates (2013) agrees with this opinion and emphasizes the need to focus on the individual and household levels when assessing food security. He adds that food security should include five dimensions: nutrient adequacy, food sufficiency, safety, cultural acceptability, certainty and stability. Different approaches were used by The Economist Intelligence Unit (EIU) in the definition of the GFSI, which is based on four dimensions: affordability, availability, quality and safety, sustainability and adaptation.

Food security indicators

Measuring food security is a complex problem, and it should not be simplified into a dichotomous variable that indicates only security or insecurity. For example, Webb et al. (2006) emphasize the situation in which some households are food insecure but do not experience hunger immediately in comparison with others who are in a desperate situation. Cafiero (2013) explains increasing demand for indicators, which makes a difference between chronic and transitory food insecurity. Carletto et al. (2013) highlight the lack of consensus about food insecurity indicators used by various agencies. For example, the GFSI is only one of several measures of food insecurity introduced in recent decades. It is composed of different pillars and sets of indicators in comparison with the FAO approach. Izraelov–Silber (2019) note that the list of food security indicators used by the FAO and GFSI does not have much in common. On the other hand, instead of using composite indicators, the FAO prefers to use the prevalence of undernourishment as the main food insecurity measure. This way of measuring is common, especially for developing countries. Research in recent years has focused on improving the estimation of prevalence rates, as many agencies measure hunger to inform policy makers (Smith–Meade 2019, Pérez-Escamilla et al. 2017, Barrett 2010).

Some indicators are based on data collected from households or individuals. Poudel–Gopinath (2021) give as examples the food consumption score developed by the World Food Program, which is based on the frequency of consumption of different food groups by households. Another instrument based on the number of unique foods consumed by households is the household dietary diversity score developed by the United States Agency for International Development and the coping strategy index, which evaluates how households cope with shortfalls of food.

The most common food and nutrition security indicators according to Pangaribowo et al. (2013) are the GFSI created by the EIU, the indicator of undernourishment (FAO), the global hunger index developed by the International Food Policy Research Institute (IFPRI), the global poverty index in collaboration with Oxford University, the global hunger index, the hunger reduction commitment index, anthropometric indicators, diet diversity scores and medical and biomarker indicators. Many authors claim that there exists a significant level of variability between different food security indicators (e.g., Poudel–Gopinath 2021, Pérez-Escamilla et al. 2017, Pingali 2016).

The issue of composite indicators is obvious, especially at the national level. Jacobs et al. (2004) stress the importance of composite indicators, especially for delivering information about summary performance and the identification of policy priorities. Nardo et al. (2005) and Saisana et al. (2005) conducted a study of composite indicators, and their results suggest that the weighting scheme for composite indicators should be based on statistical techniques such as data envelopment analysis or principal components, but it is also possible to use a simple scheme with equal weights. Similarly, Endrődi–Kovács–Tankovski (2023) used weights derived by factor analysis to create composite indicators in their study. An alternative way to evaluate performance based on a multivariate approach was used by Tezcan (2023), who applied the TOPSIS method to evaluate the sustainable development performance of Balkan countries. Different methods of normalization weighting and aggregation were compared by Hudrlíková et al. (2013) in their study focused on the sustainable development of regions in the Czech Republic.

A frequently used indicator for the assessment of food security at the national level is the GFSI. Since 2012, it has been used to monitor global food security development, covers over 100 countries, and has become the most popular national food security measure. The index was the subject of analysis of many authors who focused on his shortcomings. For example, Thomas et al. (2017) reviewed its conceptual framework and concluded that the GFSI is focused on food security determinants rather than its outcomes and therefore rates the food security environment. Another critical review of GFSI conducted by Maričič et al. (2016) concluded that despite quality methodology and reliable data, its weighting scheme is biased. As the weak spot was identified subjectively assigned weights, the authors in their paper recommended using the I-distance method to obtain an objective unbiased weighting scheme. Despite the subjective weighting scheme, the GFSI was found to be suitable for assessing differences in food security at the national level by Chen et al. (2019), Izraelov–Silber (2019), and Thomas et al. (2017). Several authors have suggested data envelopment analysis to estimate objective weights of composite indicators at the national level. This method was originally designed to measure the performance of decision-making units and their ability to effectively transform inputs into production outputs. The typical use of DEA analysis is in comparison of efficiency in agriculture, e.g., Fusco et al. (2023), who employed it to analyse gender diversity, and Bartová et al. (2018), who investigated the eco-efficiency of agriculture in European member states. A similar analysis of the ecological efficiency of emerging economies was also conducted by Nadeem et al. (2023). However, Lovell–Pastor (1999), Kao (2010), Liu et al. (2011), and Blancas et al. (2013) state that DEA can also be applied to produce a composite index. It is a special type of DEA without explicit inputs or outputs. This method was already applied for reassessment of the GFSI by Chen et al. (2019) to estimate objective weights at the global level. The results of the reassessed performance of countries were not significantly different from the original index.

The main objective of the presented paper was to apply the food security definition according to the FAO based on available data on FAOstat to produce a food security measure that offers insight into the food security situation in Europe and its development over time. As a suitable method, data envelopment analysis was selected, which allowed us to compare European countries with the best performance in the region within every analysed year. The secondary objective was to compare the produced measure with the GFSI and show the advantages and disadvantages of both approaches. The main contribution of the presented paper to the current literature lies from a theoretical point of view in its methodological approach, which is new in the field of food security measures. Practical contributions are its focus specifically on the European region and the analysis of recent developments and the current state of food security in Europe. It identifies weak regions and aspects of food security dimensions in Europe, which may be helpful information for policy makers. However, in the process of research, some issues related to specifics of measuring food security situations in European countries were identified.

The FAO usually describes the food security situation at the national level with indicators measuring the prevalence of undernourishment. FAOstat also includes data about food security-related indicators in four pillars, namely, availability, access, stability, and utilization, but there is no available composite indicator based on these variables. Food security is a concept usually related to the developing world rather than to developed countries. The intention was to use as many variables from FAOstat as possible. However, the first problematic issue was the fact that most records in the database were not available for developed countries or had just ridiculously small variability in this category. As a result, from the large set of food security-related indicators available in the FAOstat database, only a few could be used for the analysis of the situation in European countries, and the most recent available period was 2020. The second issue related to the comparison of indicators based on FAOstat data and the GFSI was the different number of countries in both databases. The GFSI is available for 26 European countries for the period of 2012–2022. Although FAOstat data are available only until 2020, they cover a much longer history, with records for 38 European countries. This had to be considered in the performed analysis. The main objective of the paper was therefore to characterize the food security situation in 38 European countries according to constructed indicators based on available data from FAOstat in the period of 2012–2022. The secondary objective was to compare the performance of the constructed indicator based on data envelopment analysis and data from FAOstat with the GFSI and identify its strengths and weaknesses. This could be performed with data for only 26 countries with results for both indicators.

Material and methods

The first step in the analysis was the determination of variables that could be used to evaluate the actual food security situation in Europe and to construct a composite indicator according to the definition of food security by the FAO in four pillars: availability, access, stability, and utility. The original intention was to use the largest possible number of variables. All variables should have nonzero variability in European countries and should be available at least until 2020. From the list of all available indicators in the food security section that met the previously mentioned requirements, only 10 variables were supplemented by 2 variables from the World Bank database to ensure an equal number of indicators in every pillar. (Food production index in the "availability" pillar and consumer price index in the "access" pillar). A list of analysed variables can be found in Table 1. Every variable characterizes an important aspect of food security within its pillar. However, the selection of input variables could be subject to further research. All variables were obtained for 38 European countries in the period of 2012–2020. The reason for the smaller number of selected indicators was that most variables included in the FAOstat database are actual, especially for developing countries. Some missing values were extrapolated or interpolated to maximize the number of observations used in the analysis. The produced indicator was compared with values of the GFSI obtained from the official website of the EIU.

Table 1

List of analysed variables

Pillar	Variable	Units of measurement
Availability	average dietary energy supply adequacy[a)]	%, 3-year average
	dietary energy supply used in the estimation of prevalence of undernourishment[a)]	kcal/cap/day
	food production index[b)]	index variable 2014–2016=100
Access	gross domestic product per capita[a)]	PPP constant 2017 international $
	prevalence of moderate or severe food insecurity in the total population[a)]	%, 3-year average
	consumer price index[b)]	2010=100
Stability	political stability and absence of violence/terrorism[a)]	Index (–2,5 weak; 2,5 strong)
	per capita food supply variability[a)]	kcal/cap/day
	coefficient of variation in habitual caloric consumption distribution[a)]	real number
Utility	minimum dietary energy requirement[a)]	kcal/cap/day
	incidence of caloric losses at retail distribution level[a)]	%
	percentage of population using safely managed sanitation services[a)]	%

Source: a) FAOstat; b) World Bank.

To obtain composite indicators with consistent rankings, it was necessary to normalize all variables according to the process described by Kao (2010) and Chen et al. (2019). Variables where higher values are better were normalized according to function 1. This was applied to most analysed variables.

$$Y = \frac{y - \min(y)}{\max(y) - \min(y)} \quad (1)$$

Variables where smaller values mean better results, such as the prevalence of moderate or severe food insecurity in the total population, consumer price index, per capita food supply variability, coefficient of variation in habitual caloric consumption and incidence of caloric losses at the retail distribution level, were normalized according to Equation 2.

$$Y = \frac{\max(y) - y}{\max(y) - \min(y)} \quad (2)$$

In both equations, min and max are the smallest and the highest values among 38 countries for each variable.

A composite indicator of food security was created with data envelopment analysis. Standard DEA is a method to measure the efficiency of the transformation of inputs into outputs for every DMU. Lovell–Pastor (1999), Kao (2010), Liu et al.

(2011), and Blancas et al. (2013) and Chen et al. (2019) suggested that DEA can also be applied in situations without explicit inputs or outputs to generate objective weights for composite indicators. The constructed indicator will be given in contrast to the GFSI, where weights are set subjectively by the panel of experts. In the case of composite indicators, it would be suitable to use hierarchical DEA following the structure of individual pillars of food security as proposed by Chen et al. (2019). In this case, it was not possible due to the few available indicators in each pillar. For the construction of the composite food security indicator, basic DEA for aggregating variables was used.

Let y_i (i=1,2...M) be the indicator for each DMU j (j=1,2...N). As proposed by Kao (2010), input-oriented DEA can be used to generate objective weights for the composite indicator for the j-th DMU by assuming an input equal to one (dummy input). Then, the objective function has the form:

$$Max\,\theta_j = \sum_{i=1}^{M} u_{ij}\, y_{ij} \quad i = 1,2, \dots M \;\; j = 1,2, \dots N \tag{3}$$

Subject to

$$\sum_{i=1}^{M} u_{ij}\, y_{ij} \leq 1\,,\; i = 1,2, \dots M \;\; j = 1,2, \dots N \tag{4}$$

where θ is the value of the composite food security index, u is the weight for variable I and country j, and y is the value of variable I and country j.

According to equations 1 and 2, the weights generated objectively without external influence will maximize the value of the indicator for each DMU (country in this case), and the constraint will ensure that the index for all other countries will be less than or equal to one (Ramathan 2006). This formulation also means that the food security index for each country will depend on the performance of all other analysed countries in the current year. For this reason, the calculation of the food security composite index included data for all 38 European countries available at FAOstat (equation 4 means 38 constraints, one for every country).

According to the assumption of a simple additive weighting scheme, the constraint that the sum of weights should be equal to one was also included, formulated in equation 5.

$$\sum_{i=1}^{M} u_{ij} = 1 \quad i = 1,2, \dots M \;\; j = 1,2, \dots N \tag{5}$$

To avoid zero weights for some indicators (especially for small indicator values in the maximization function), it was necessary to add constraints to restrict the maximum and minimum values of the weight. According to some authors, these values could be decided by expert opinion. The goal of this paper was to determine objective weights, so the scheme suggested by Chen et al. (2019) was applied based on the average weight without subjective elements (equations 6 and 7).

$$Lb = \frac{1}{(number\ of\ indicators\ in\ composite\ index)} - 50\% \tag{6}$$

$$Ub = \frac{1}{(number\ of\ indicators\ in\ composite\ index)} + 50\% \tag{7}$$

The constraint for the nonzero weight of the indicator has the form:

$$Lb \leq u_{ij} \leq Ub \quad i = 1,2, \dots M \quad j = 1,2, \dots N \tag{8}$$

where Lb is the lower bound for the indicator weight, Ub is the upper bound for the indicator weight and u_{ij} is the weight of variable i and country j. In the presented case, 12 indicators included in the composite index had a minimum weight equal to 0.0417 and a maximum weight equal to 0.125. This means that the minimum weight of one food security pillar could be 0.125 and the maximum weight 0.375.

Every value of the produced composite index was the solution of the maximization problem with 40 constraints. This was solved for 38 European countries for the period of 2012–2020. The indicator considered the performance only in European countries, so the result of every country in the current year depends on the performance of all other European countries in the analysed period. The indicator can take values between 0 and 1. A value closer to 1 means better food security performance. Despite using DEA, the estimated value of the indicator is not efficient, and no country reached a value equal to 1. This was caused by restrictions for maximum and minimum weights.

The results offer insight into the food security situation in European countries in every analysed period. The principle of the DEA approach is that countries with the highest values of the constructed food security indicator were used as benchmarks, and all other countries were compared with the efficiency frontier based on the best performing results. The value of the indicator therefore shows the ratio between the real and ideal performance of every analysed country in a particular year. The common application of DEA involves the comparison of productivity and ideal productivity, which is calculated as the ratio of cumulative output and cumulative input. In the presented analysis, DEA was used to create an index, which was a very similar application, but the cumulative input was set explicitly to 1, and the analysis compared the cumulative output with its ideal value. Weights used for the cumulation of output were estimated using linear programming, and they are specific for each country. However, as the limitation of DEA analysis could be considered, how real would the results be for every decision making unit achieving performance, which were calculated as ideal in real conditions?

The conclusions were first focused on the comparison of performance according to the constructed index with DEA weights and ranking according to the GFSI. This could be conducted only for 26 European countries that are included in the GFSI results. The results were then used to characterize the food security situation in 38 European countries in the analysed period.

The ranking of countries produced by the DEA index and GFSI was compared graphically, and the similarity of both results was evaluated using Pearson's correlation coefficient. The significance of differences in rankings was verified by the nonparametric Wilcoxon signed rank test for matched samples.

Results

The produced composite indicator was based on the results of DEA applied for all 38 countries to estimate objective weights. Analysis was performed separately for every year in the period of 2012–2020. The obtained evaluation of food security for every country therefore depends on the performance of all 38 countries included in the analysis. If European countries were included in the analysis together with developing countries, their results would probably be homogenous. To identify problematic regions in Europe, it is essential to analyse European countries separately. The composite indicator is the result of the maximization of the mathematical function. This means that the weights were different for each country, with the highest values for the best performing indicators. Estimated weights are therefore not only an indicator of each pillar's importance but also show the performance of every pillar in the period analysed. Table 2 shows estimated mean weights for every pillar over the period analysed. For simplicity of presentation, it was obtained by averaging mean weights for every analysed year. The mode value therefore means weight, which was the most frequent mean value over the analysis period. The best evaluation measured by average weight in European countries was for the "stability" pillar. This can be considered a strength of European food security. The fluctuation of the mean weight for stability over the analysed period was small, from 0.28 to 0.34. The smallest average weight in the analysed period was estimated for the "availability" pillar at 0.21. The average value of this weight in the analysed period was between 0.18 and 0.23. This dimension was evaluated as the weakest. The highest fluctuations were recorded in the "accessibility" pillar; its weight was 0.25, and it varied from 0.21 to 0.29 over the analysed period. The variability of weights measured by the coefficient of variation was equal to 12.12%.

Table 2

Mean weights for the pillars in the composite DEA indicator over the analysed period

Mean weights	Mean	Mode	Median	Min	Max	CV
Availability	0.21	0.19	0.20	0.18	0.23	7.45
Accessibility	0.25	0.28	0.25	0.21	0.29	12.12
Stability	0.32	0.34	0.32	0.28	0.34	6.17
Utility	0.22	0.21	0.22	0.20	0.25	5.77

Source: author´s work based on data from FAOstat.

These weights are not directly comparable to GFSI weights because they use slightly different dimensions: affordability (30%), availability (25%), quality and safety (22.5%) and sustainability (22.5%). These weights are obtained by processing expert opinions. They do not change over time; on the other hand, weights obtained by DEA change every year according to the actual performance of all investigated countries. Availability has a slightly higher weight in the GFSI. If accessibility was compared with affordability in the GFSI, this dimension was slightly higher in the GFSI. Stability and utility are not directly comparable with the other two GFSI pillars (sustainability and quality and safety). Stability has a significantly higher weight than these pillars. On the other hand, the average weight of utility in the analysed period was close to them.

The obtained results could be compared with the GFSI only for 26 European countries that are included in the analysis of the EIU. The values of both indicators are not directly comparable, but it was possible to compare countries' rankings obtained by both indicators.

Table 3 shows the correlations between the rankings of both indicators and their comparison using the Wilcoxon signed rank test for matched samples. According to the results in the table, a significant correlation was found between the constructed DEA indicator and the GFSI. The correlation measured by the Pearson coefficient varies between 0.62 and 0.72, which may be considered a strong relationship. The DEA indicator was based on variables strongly related to food, but the GFSI is based on a wide set of indicators related to more aspects. This suggests that, however, food has an important role in the GFSI, and its final value also depends on other factors considered in this index. The correlation expressed by Spearman coefficients was even smaller (overall value equal to 0.63). However, significant differences in country rankings were not identified. The Wilcoxon signed rank test p value in all periods was higher than 0.05. This means that there is no significant difference in countries ranking according to the GFSI and DEA composite index. Nevertheless, there are some differences that are worth highlighting.

Table 3

Comparison of rankings obtained by GFSI and DEA composite index

Ranking comparison	2012	2013	2014	2015	2016
Pearson correlation	0.64	0.62	0.72	0.71	0.69
p value	0.0004	0.0007	<0.0001	<0.0001	0.0001
Spearman correlation	0.51	0.45	0.54	0.54	0.50
p value	0.0003	0.0012	0.0001	0.0001	0.0003
Wilcoxon signed rank stat	–11	6	–7.5	9	15
p value	0.77	0.87	0.84	0.79	0.66
Ranking comparison	**2017**	**2018**	**2019**	**2020**	**overall**
Pearson correlation	0.69	0.73	0.69	0.72	0.77
p value	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Spearman correlation	0.52	0.54	0.50	0.53	0.63
p value	0.0002	<0.0001	0.0003	0.0001	<0.0001
Wilcoxon signed rank stat	5	–9	3.5	6	132.5
p value	0.87	0.93	0.93	0.87	0.89

Source: author´s work based on data from FAOstat and EIU.

Figure 1a shows the development of both indicator average values compared over time in the period of 2012–2020. The GFSI increased over all analysed periods. On the other hand, the average value of the composite indicator based on DEA analysis decreased between 2014 and 2016. This could be caused by deterioration of the average score for the indicators consumer price index, political stability, food supply variability and minimum dietary energy requirement, which were mostly stable for the rest of the analysed period. Weights in the DEA indicator were estimated separately every year, which may suggest that they are not directly comparable, but a decrease in the indicator suggests a decrease in overall food security performance in European countries. Figure 1b shows a comparison of variability in both indicators measured by the coefficient of variation. In the case of GFSI, the variability did not exceed 10%, on the other hand, the variability of DEA did not decrease under 10%. Higher variability of the DEA indicator is influenced by more countries' data used in his estimation. This shows the advantage of the DEA approach, which helps to identify better differences between countries within the analysed group. On the other hand, the GFSI is produced at the world level, which is also considered in the selection of a large number of input indicators, and in the analysis, which includes only European countries, the results are more homogenous.

Figure 1a

Average DEA and GFSI indicators

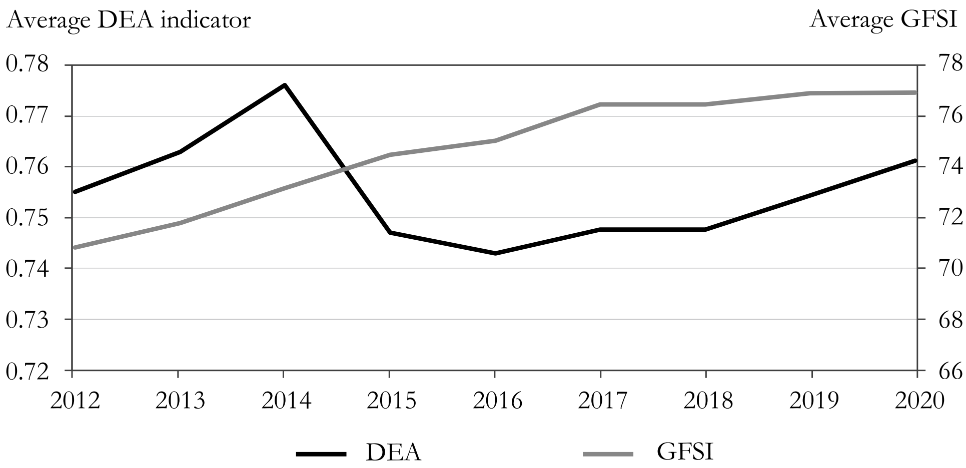
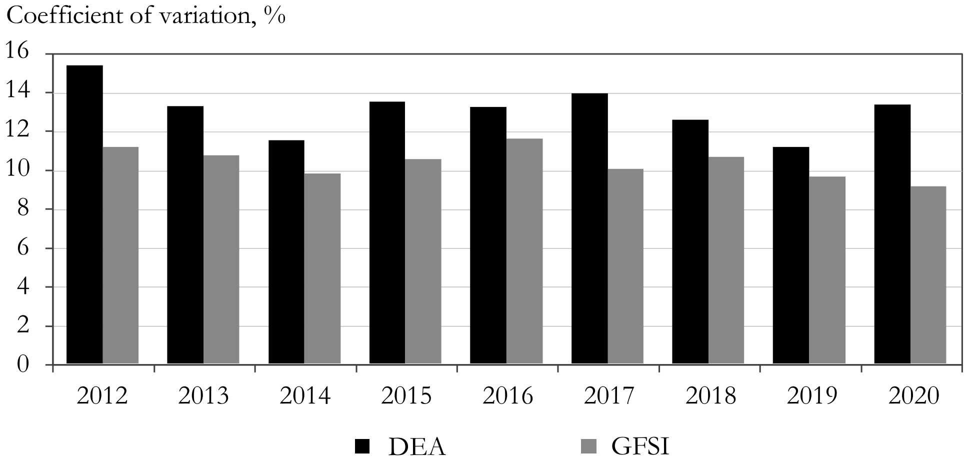


Figure 1b

Variability of DEA and GFSI

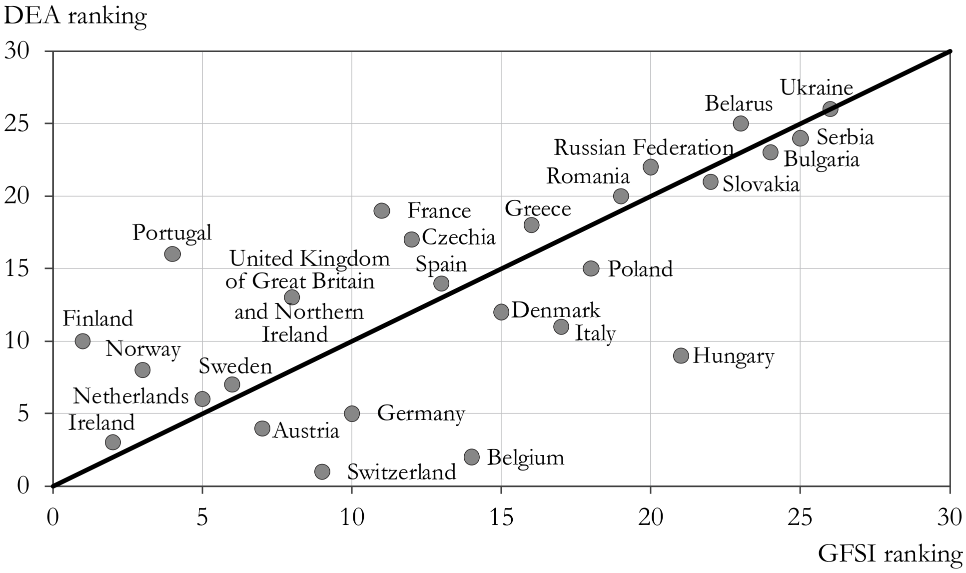


Source: author´s work based on data from FAOstat and EIU.

In addition, different variability contrasts can also be found in its trend. At the beginning of the period analysed, the disparity between countries measured by food security indicators decreased. The change in variability was different in 2016, 2017 and 2018. At the end of the analysed period, the variability of the GFSI decreased, in contrast to the increase in the variability of the composite DEA indicator. Better insight into differences in rankings by both indicators offers Figure 2, which displays a comparison of both rankings in 2020. Countries lying on the orange line have the same ranking according to both indicators. This is the case for Ukraine, in which the food security situation was evaluated as the worst among European countries. Countries below the orange line are evaluated better by the composite DEA indicator, and countries above are better according to the GFSI ranking. Similar conclusions can also be made for other countries at the end of both rankings. The exception is Hungary, which was ranked 21st according to the GFSI, but in the DEA ranking, it is 9th. Much higher variability can be observed between the best evaluated countries.

Figure 2

Comparison of GFSI ranking and DEA ranking of 26 European countries in 2020

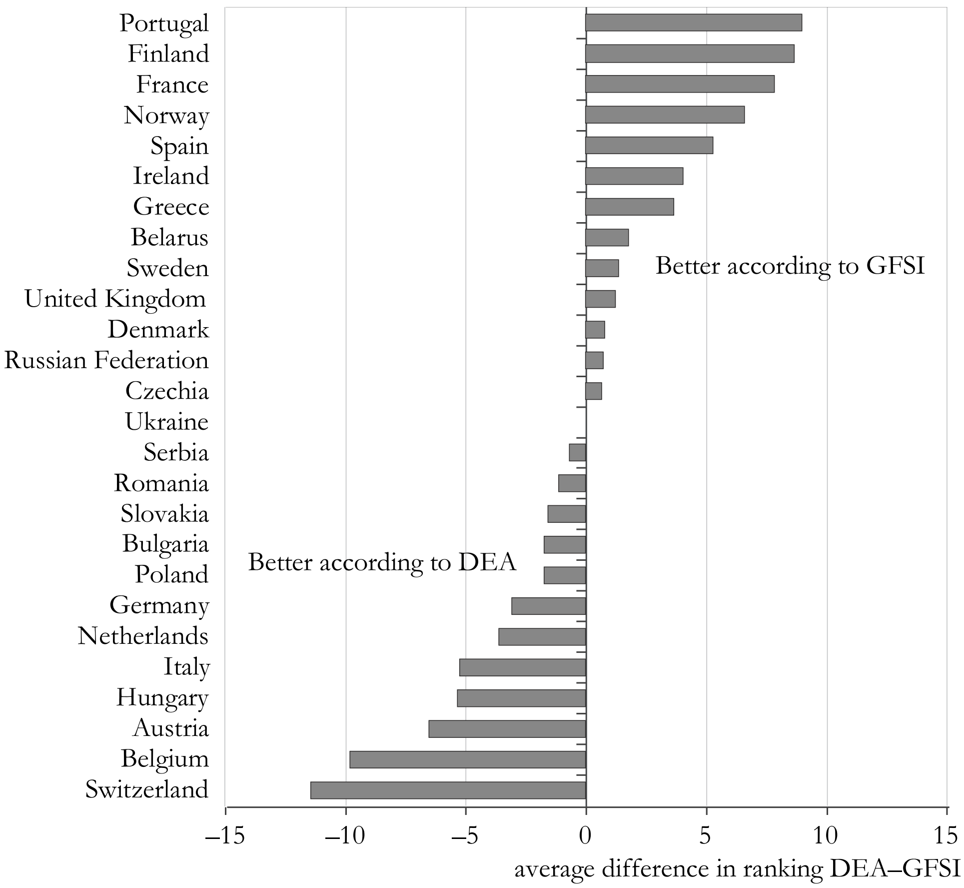


Source: author´s work based on data from FAOstat and EIU.

The best countries according to the GFSI ranking in 2020 were Finland, Ireland, Norway, Portugal, and the Netherlands. However, according to the DEA ranking, Finland placed 10^{th} and Portugal 16^{th}. On the other hand, the best countries according to the DEA indicator were Switzerland, Belgium, Ireland, Austria, and Germany. Except for Ireland, which was not included in any of these countries in the top 5 according to the GFSI, Belgium was not even included in the top 10. Based on both indicator results, it can be concluded that the best food security situation in Europe is in Ireland, the Netherlands, Norway, Switzerland, Finland, Austria, Sweden, and Germany, which were ranked in the top 10. Figure 2 contains only the comparison for the year 2020. There is an obvious difference in ranking between the two food security indicators. Figure 3 can help to identify which difference in evaluation is systematic and which occurred only in the year 2020. The figure shows the average difference between the ranking produced by the DEA indicator and the GFSI ranking for the whole analysed period of 2012–2020. Positive values mean that countries were ranked better according to the GFSI, and negative values mean better assessment of countries according to the DEA indicator.

Figure 3

Average difference between DEA and GFSI rankings for 2012–2020



Source: author´s work based on data from FAOstat and EIU.

Countries that were systematically rated as better by the GFSI were Portugal, Finland, France, Norway, and Spain. The average differences between the GFSI and DEA rankings for these countries over the analysed period were more than 5 places. On the other hand, Switzerland, Belgium, Austria, Hungary and Italy were ranked better by the DEA composite indicator. The average differences in the ratings of other countries between these two indicators over the analysed period of years were smaller than 5.

This is caused by the different nature of the two indicators. The GFSI is a more complex indicator that includes various aspects of the food security environment, such as sustainability, legislation, safety, and adaptability. On the other hand, the DEA indicator was based primarily on variables directly linked to food security and availability, accessibility, utility, and stability of food supply. A poor evaluation according to the DEA indicator can therefore be linked to immediate food security problems. On the other hand, a poor evaluation based on the GFSI may be caused by some aspects of the food security environment that will directly affect the population later, such as legislation, agricultural research, risk management or social barriers. Direct food security or insecurity perceived by the population is therefore hidden in the complexity of the GFSI. We suggest that present food security in countries ranked better by DEA will also be better assessed by population. On the other hand, environmental and legislative conditions in countries better evaluated by the GFSI ensure a better food security perspective in the future.

Figure 4a

DEA indicator result, 2020

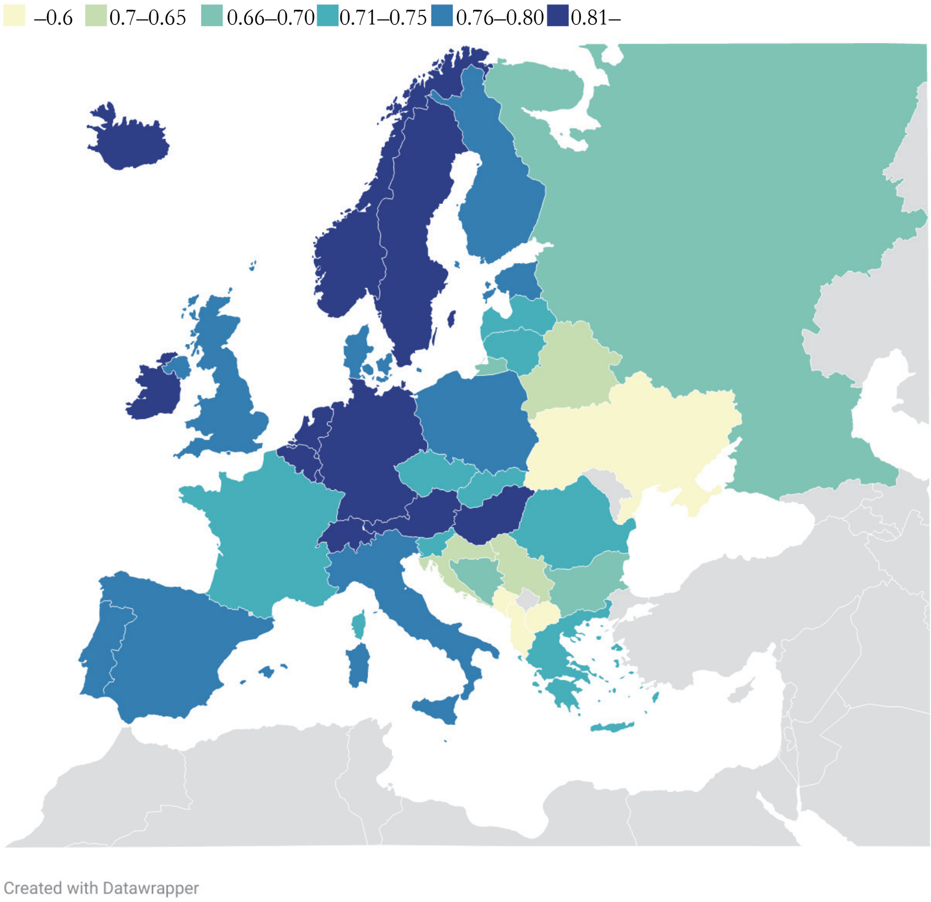
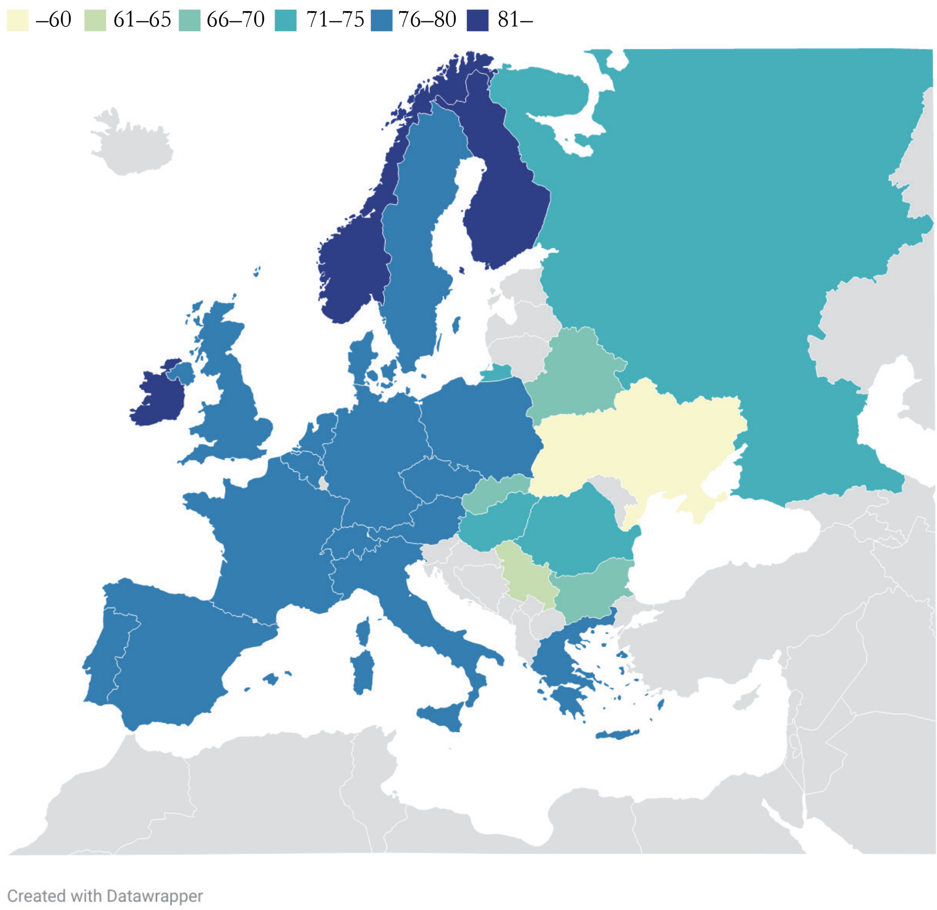


Figure 4b

GFSI result, 2020



Source: author´s work based on data from FAOstat and EIU.

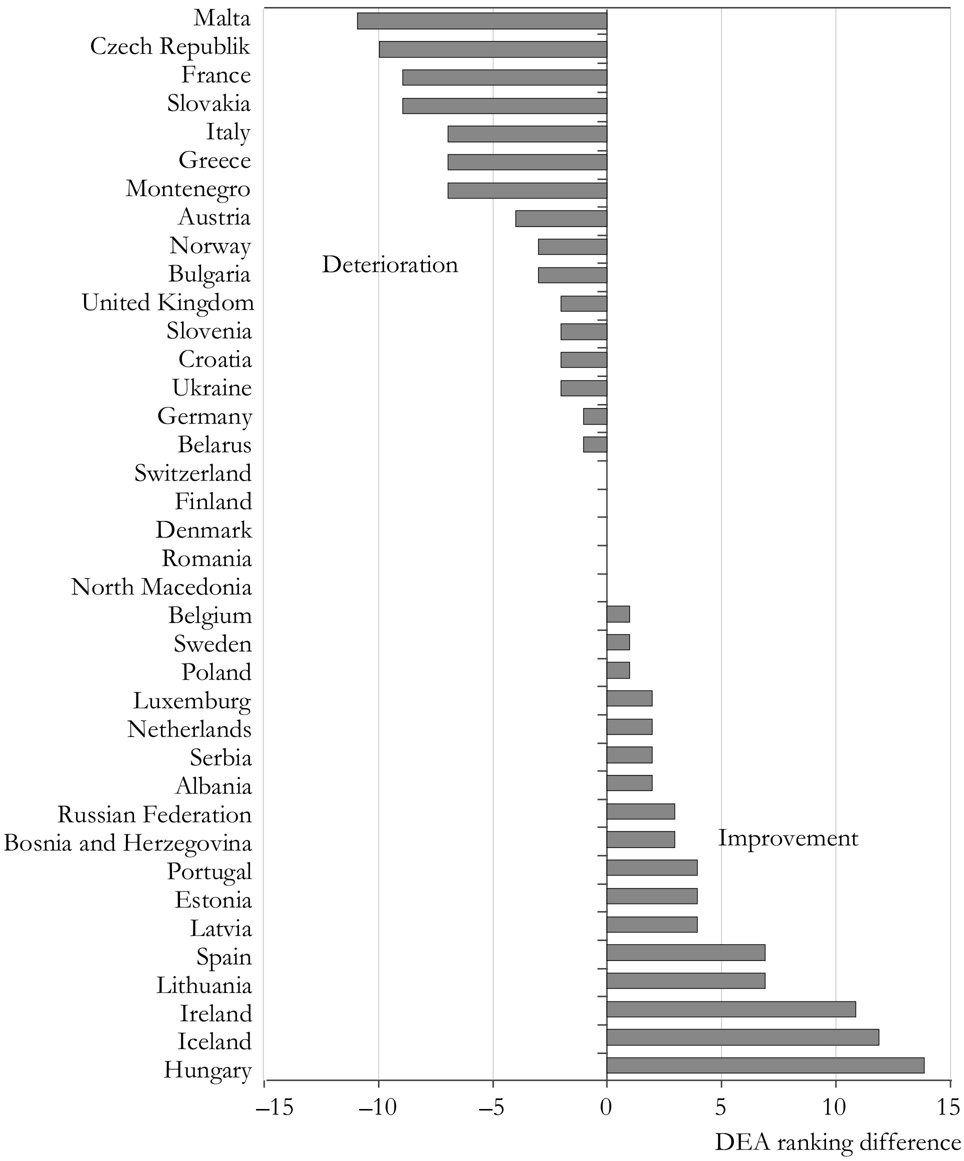
From the methodological point of view, in situations when it is important to assess the food security situation in Europe and identify weak spots, there can be important differences between the GFSI and DEA approaches and the number of analysed countries. Obvious differences can be identified in Figures 4a and 4b. Figure 4b shows a choropleth map with values of the GFSI indicator where the map of Europe includes few grey countries (these countries were not assessed). In contrast, Figure 4a on the left side shows the results according to the produced DEA indicators of almost all European countries. The DEA analysis included 38 countries in contrast with 26 European countries included in the GFSI results. Previous comparisons included results only for countries included in both indicators. Countries that were not included in the GFSI analysis are Albania, Bosnia and Herzegovina, Croatia, Estonia, Iceland, Latvia, Lithuania, Luxemburg, Malta, Montenegro, North Macedonia and Slovenia. The only questionable feature might be the inclusion of Luxemburg, which is usually omitted from analysis because it is an outlier. In this case, it was included to improve the estimated efficiency frontier to make the assessment stricter. Another 11 countries missing in the GFSI are in Eastern and Southern Europe and have food security situations that should be monitored.

Figures 4a and 4b show food security in Europe according to the DEA indicator (Figure 4a) and GFSI (Figure 4b). Figure 4b shows that the GFSI result is the best result recorded in Northern European countries (Finland and Norway) and Ireland. Some problems with food security can be found only in eastern and southeastern countries. The rest of Europe seems to be food-secure and without any significant differences. Figure 4a on the left side is more heterogeneous. The top category includes more countries, not only in Northern Europe but also in Central Europe. On the other hand, there were more food security categories in the rest of Europe. Less food-secure are France, the Czech Republic, the Slovak Republic, Romania and Greece, Lithuania and Latvia. Even worse was the situation in Russia, Bosnia and Herzegovina and Bulgaria. The worst food security situation in Europe according to the DEA indicator in 2020 was recorded in Croatia, Serbia, Belarus, Montenegro, Albania, North Macedonia and Ukraine. This result shows that several countries with food security issues can also be found in Europe, and this problem should not be linked only with developing countries.

Figures 5 and 6 show the difference in food security ranking according to both indicators over time between 2012 and 2020. The comparison in Figure 5 shows 38 countries that were included in the DEA analysis. Positive values of ranking difference indicate improvement in the food security situation, and negative values indicate deterioration of the ranking. Countries with the best improvement in ranking according to DEA analysis since 2012 were Hungary, Iceland, Ireland, Lithuania and Spain. On the other hand, the food security situation worsened significantly in Malta, the Czech Republic, France, Slovakia, Italy, Greece and Montenegro.

Figure 5

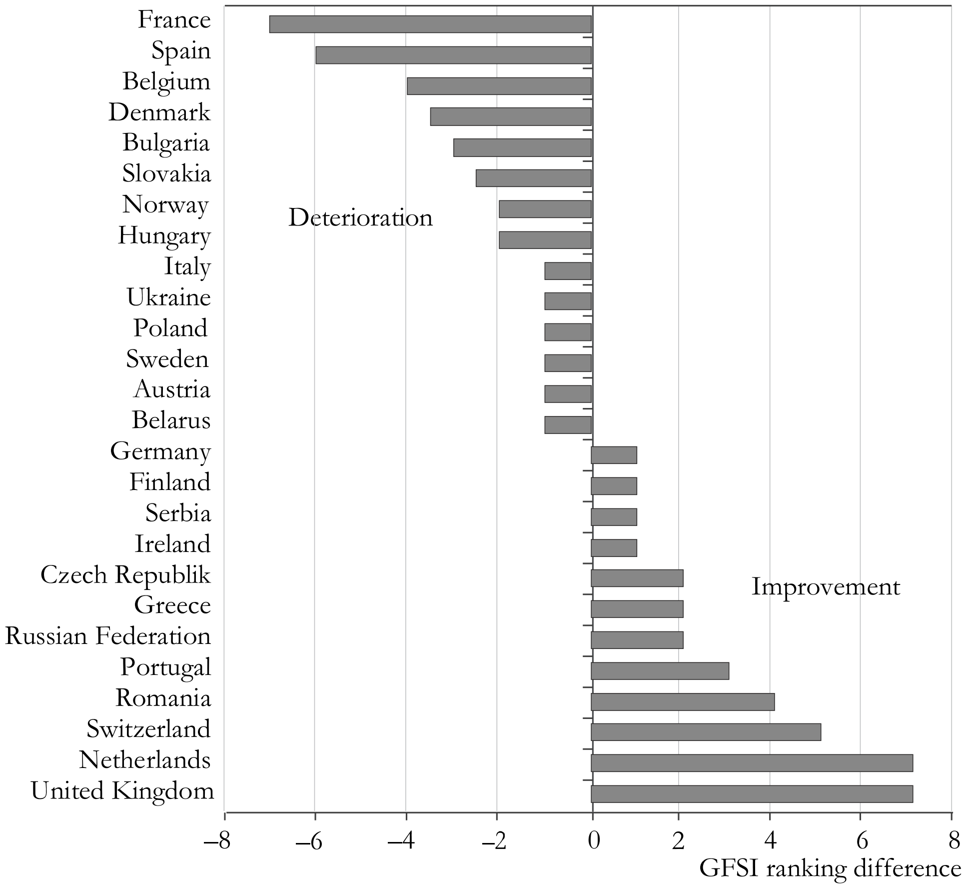
Change in food security ranking between 2012 and 2020 measured by DEA



Source: author´s work based on data from FAOstat.

Figure 6

Change in food security ranking between 2012 and 2020 measured by the GFSI



Source: author´s work based on data from EIU.

The GFSI ranking included only 26 European countries, and the best improvement in ranking was recorded by the United Kingdom, Netherlands and Switzerland, and the largest negative change in ranking was recorded by France, Spain, and Belgium (Figure 6). Ranking by the GFSI indicator can be considered more stable. According to both comparisons, significant deterioration of food security in France can be concluded, which decreased by 7 places in the GFSI ranking and by 9 places in the DEA ranking. This country recorded surprisingly bad results compared to other European countries. The values of the food production index and per capita food supply variability in France made it one of the 5 worst countries in Europe. Food supply variability was worse only in Montenegro, the Czech Republic, Slovakia, and Poland. Both composite food security indicators also confirmed a negative trend in food security in Slovakia and Italy. The large improvement for Switzerland in the

GFSI ranking confirmed its long-term good position according to the DEA ranking. Controversial results were found in the case of Spain, which recorded a substantial positive change in the DEA ranking but a very negative change in the GFSI ranking between 2012 and 2020. The result is that in 2020, Spain was ranked the same according to both indicators. A similar situation was also found in the case of Hungary, when it recorded a slight deterioration in the GFSI ranking, but according to the DEA results, it recorded the highest positive change.

Based on the findings mentioned above, it can be concluded that the composite indicator produced by DEA is related more directly to food and assesses the actual situation of food security as it can be perceived by the population. On the other hand, the GFSI is a more complex indicator, and factors related directly to food are just one of its dimensions. Therefore, it can take longer to record direct change in the food situation as it is perceived by the population, as it expresses complex dimensions of the food security environment.

Discussion

The results of the presented paper agree with Borch–Kjærnes (2016), who concluded that there is an alarming lack of knowledge about European food insecurity. Cooper et al. (2020), in their text mining study, concluded that most of the papers in the field of food security were focused on economic policy and global issues, which highlights the added value of analysis in the presented paper. The methodology applied in this paper to produce composite indicators was based on DEA analysis, which considered four basic pillars of food security as defined by the FAO. In contrast with the view of Clapp et al. (2022), who suggested the extension of food security to the definition of 6 dimensions, the results presented in this paper and its comparison with the GFSI showed that the current four dimensions are sufficient. Producing even more complex indicators with 6 dimensions could cause a smaller weight of availability and quality of food in such measures. The presented comparison with the GFSI indicator was inspired by Chen et al. (2019), who applied methodology to create the composite index suggested by Kao (2010). The objective of his work was reassessment of GFSI based on DEA analysis, which was applied at the world level and included the same countries, pillars, and variables as GFSI. Our analysis applied the same DEA approach, but with pillars and variables according to the FAO definition only for European countries. Both works concluded that there were no significant differences between ranking according to constructed indicators and GFSI. However, our work emphasized some significant differences in the long-term evaluation of some countries. The results and conclusions presented are in accordance with recommendations by Chen et al. (2019), which highlights the food availability dimension. A similar assessment of the GFSI was also published by Izraelov–Silber (2019). They also concluded that the GFSI gives a reasonable ranking of countries.

However, both Chen et al. (2019) and Izraelov–Silber (2019) reviewed GFSI performance at the world level. Our paper focused on its performance in specific conditions of European countries. The results confirmed the conclusion presented by Thomas et al. (2017) that the complex nature of the GFSI evaluates the food security environment rather than the real level of food security. On the other hand, the results do not agree with Poudel–Gopinath (2021), who explored the disparity between global food security indicators and concluded that there was large variability between them. However, his work also emphasizes the importance of objective indicators with desired properties that could be used to measure food security at any level. Our conclusions agree with the results of most research publications (e.g., Nardo et al. 2005, Saisana et al. 2005) that composite indicators should be based on objective weighting schemes.

Conclusion

Food security in Europe may seem to be a less important issue compared with the rest of the world, especially for poor and developing countries on other continents. In the case of the assessment of global food security, Europe may look homogenous with developed, food-secure countries. The truth is that measuring European food security has some specifics that need to be considered. Europe also has its own problems in the field of food security that may be addressed and solved only with the use of suitable indicators. In the case of using the GFSI for evaluating food security in Europe together with other world regions, no significant differences may be identified. The solution is to investigate food security in Europe separately to identify problematic regions. Another fact that should be considered is that weights in the GFSI are not derived on an objective basis but according to expert opinions. An appropriate method to produce composite indicators with objective weights could be DEA, which would be applied only to European countries. Alternative methods could be indexing with objective weights based on different variabilities or correlations between chosen food security indicators or principal component analysis. For analysis with a large set of input indicators, it could also be an alternative to use a hierarchical approach or factor analysis. In the case of DEA, European countries are benchmarked only to the best performing countries, which will set an efficiency frontier for comparison with other countries. This would allow us to identify weak European regions and compare them at the level corresponding to developed countries.

The main difference in results obtained by the DEA index and GFSI could be explained by the different focus of both methods. As previously mentioned, the GFSI includes more variables and is focused more on the food security environment, which also considers its sustainability, legislation, and adaptability. That is why countries such as Finland, Norway, Portugal, and France were evaluated as better by the GFSI.

On the other hand, the food security index produced by DEA is focused primarily on variables directly related to actual perceptions of food security in dimensions according to the definition by the FAO. Better results according to this approach were recorded, for example, in Hungary, Belgium, Switzerland, Austria, and Germany. A comparison of these two approaches shows that the GFSI is more complex and evaluates the sustainability of food security in the long term according to current conditions, but including a large number of variables related to the environment and adaptability causes a smaller weight of variables related to the instant perception of food security. This implies that the presented DEA index is better for the identification of actual food security problems, as they can be perceived by the population.

Another important task in this kind of analysis is proper selection of input indicators. The analysis presented in this paper used 12 food security variables available for European countries selected according to pillars and definitions applied by the FAO. By contrast, the GFSI is based on a wide range of indicators. This makes it a complex measure focused primarily on food security but also including sustainability, economic and social development. Variables directly connected with the availability, accessibility and quality of food are just part of indicators with smaller weights. When using such an index, it is possible for a country to exist in situation in which people suffer from poor food security conditions but that this country is evaluated as good if it achieves better sustainability, environmental or legislative conditions. Nevertheless, it is necessary to respect the multivariate nature of the food security topic because its evaluation based on only one indicator, such as the prevalence of undernourishment, can provide biased information about the real situation in a country. The optimal solution would be to use a composite indicator with objective weights based on multiple input variables. These variables should be directly related to food. Variables included in the analysis in the presented paper can be used as an example of this approach. The selection of variables to produce composite food security indicators specifically focused on monitoring the situation in European countries could be subject to further discussion. Another discrepancy between the DEA and GFSI indicators was in the development of European food security in past years, when the GFSI concluded its improvement over the whole period, but DEA detected its decrease in 2014–2016. This is due to the different natures and properties of both indicators.

The availability of suitable data also plays an important role. The disadvantage of applying the GFSI in the analysis of food security in Europe is that the data were available for only 26 countries but also that the data was through the year 2022. The DEA analysis, which used data available at FAOstat, included 38 countries, but data were available only until 2020. The solution could be to use data that is available in European databases, with objective selection of variables respecting multivariate food security nature and its pillars. European food security should be monitored, especially in smaller countries that are not included in the GFSI, to identify the most vulnerable regions. Monitoring food security at the aggregated level also has disadvantages. Vulnerable regions could be identified better if they were monitored at the regional or household level.

Current papers published in the field of food security focus on developing countries in Asia and Africa. Most of these papers focused on measuring food security with available indicators or analysing its factors. Only a small number of papers are focused on the problem of its measurement. The major asset of the presented paper is demonstration of specifics of measurement of food security in European countries and identification of main disadvantages of GFSI when applied to Europe. On the other hand, the limitation of the presented study was the availability of data only until 2020. The results thus do not show the influence of the Covid-19 pandemic and Russian invasion of Ukraine. Analysis showed that food security problems can be identified in the eastern and southeastern parts of Europe. Both the GFSI and composite DEA indicators also showed deterioration of food security positions between European countries in France and Slovakia in the period of 2012–2020. These results were recorded before events in recent years. It may be expected that this negatively influenced the food security situation in Europe, and the most endangered regions would be countries that did not perform very well in our analysis. This could also be a suggestion for further research, which could be conducted with a sufficient amount of relevant data. There is still plenty of space for further analysis in the field of European food security and its evaluation. The research presented in this paper could be used as a basis for the further development of food security indicators based on DEA analysis. Research could look for an optimal number of input variables to create an index, select these variables and find an optimal variant of DEA that could be more suitable, such as a hierarchical approach.

Current food security conditions are significantly influenced by high inflation, expensive energy, and war conflicts in Ukraine and Near East, which induce further migration inflows into Europe. Together with global warming and changing environmental conditions, these are the main challenges for food security in the future. Analysis showed that over the last 20 years, evaluations of accessibility and availability of food security in Europe have worsened. This was caused by the disruption of some supply chains in recent years caused by the Covid-19 crisis and war conflicts. This led to a significant increase in food prices in addition to the deterioration of the job market situation caused by the Covid-19 crisis. Recovery was complicated by the spread of conflict in Ukraine, which influenced the prices of specific agricultural commodities, such as oil or wheat. As was shown in the analysis, this endangered especially small countries in Central and Southeastern Europe. Policy makers should therefore focus on the common approach of the European Union to protect countries, especially small countries, from deteriorating food security positions by ensuring stability and continuing to remove trade barriers, which will prevent local increases in food prices. Essential factors will also include decreasing energy and commodity dependence on a single source by increasing the diversification of sources and ensuring that countries possess enough supplies and resources. A focus on the most endangered segments of the population will also play an important role, including in countries that are generally evaluated as food-secure at the national level. To address help to vulnerable groups in the population, further analysis of data collected at the household or individual level will be necessary. Another challenge for ensuring food security in upcoming years will be adaptation to climate change and extreme weather phenomena. Future research should focus on its impact on food security in the region, but actual policy should focus on mitigating its extent and influence as soon as possible. This may be achieved most effectively by educating the population about its negative impacts on everyday life.

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