COUNTRIES' FOOD SECURITY LEVEL ASSESSMENT

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Abstract

Food security has headed the list of main topics on the international agenda considering political instability, volatility of agricultural product prices, the increasing demand for food, growing populations and malnutrition, and the challenges posed by climate change. The paper is devoted to calculating the countries' food security level using the integrated rating evaluation method and comparing its results with those that international organisations and identification of complex local components of food security provide. The theoretical principles and practical recommendations for assessing the food security level and its connection with the agricultural sector results are proposed. Correlation coefficients and multivariate regression of global food security index dependence on affordability, availability, quality and safety, sustainability and adaptation are presented. The obtained results show that the availability of sizeable fertile land and labour resources in the country and the presence of favourable natural and climatic conditions for farming is insufficient for the high food security level, so it is also necessary to ensure food infrastructure in the country, the concern of the authorities for the citizen's standard of living, and ensuring political stability.

Keywords: agriculture, global challenges, integrated assessment, food security

JEL Code: O11, Q14, Q18

Introduction

In the conditions of modern global challenges, one of the main tasks of every state is to ensure economic security, which consists of production, demographic, energy, foreign-economic, investment and innovation, macroeconomic, food, social, and financial security. Food security is the state of food production in the country, which can fully satisfy the needs of every member of society in food of appropriate quality, provided it is balanced and accessible to every member of society. Timely research of food security providing, which depends mainly on agricultural and livestock products and is implemented through the

possibility of purchasing food, taking into account its price, purchasing power, and availability in the appropriate quantity and quality, will lead to social stability, meeting the food necessity, the country's independence from imports, the development of its food production, the creation of reserves to stabilise food security in an emergency, unforeseen circumstances in the future. The results of our research can be useful both for agricultural enterprises and for the authorities, which must pursue a balanced state agricultural policy, take care of farmers' financing, provide timely resource provision and ensure a stable, accessible, sufficient, safe, and balanced level of nutrition of the population of the country.

1 Methodology and Data

Many scientists are engaged in the study of food security issues (Cole et al., 2018; Dehrashid et al., 2021; Dutta and Saikia, 2018; Gebeyehu et al., 2022; Karan et al., 2022). International organisations, national authorities and individual researchers propose a methodology for calculating the food security level.

According to the methodology of the Global Food Security Index (GFSI) assessment developed by Economist Impact, the indicator scores are normalised and then aggregated across pillars to enable a comparison of broader concepts across countries. Normalisation releases the raw indicator data to a standard unit to be aggregated. The indicators for which a higher value indicates a more favourable environment for food security –inequality-adjusted income or food supply adequacy–have been normalised based on the following:

$$x = (x - \text{lower threshold}(x)) / (\text{upper threshold}(x) - \text{lower threshold}(x)),$$

where: *lower threshold (x) and upper threshold (x)* are specified for all series.

For the indicators for which a high value indicates an unfavourable environment for food security, such as volatility of agricultural production or political stability risk, the normalisation function takes the form of:

$$x = (x - \text{upper threshold}(x)) / (\text{upper threshold}(x) - \text{lower threshold}(x)),$$

where: *lower threshold(x) and upper threshold(x)* are specified for all series.

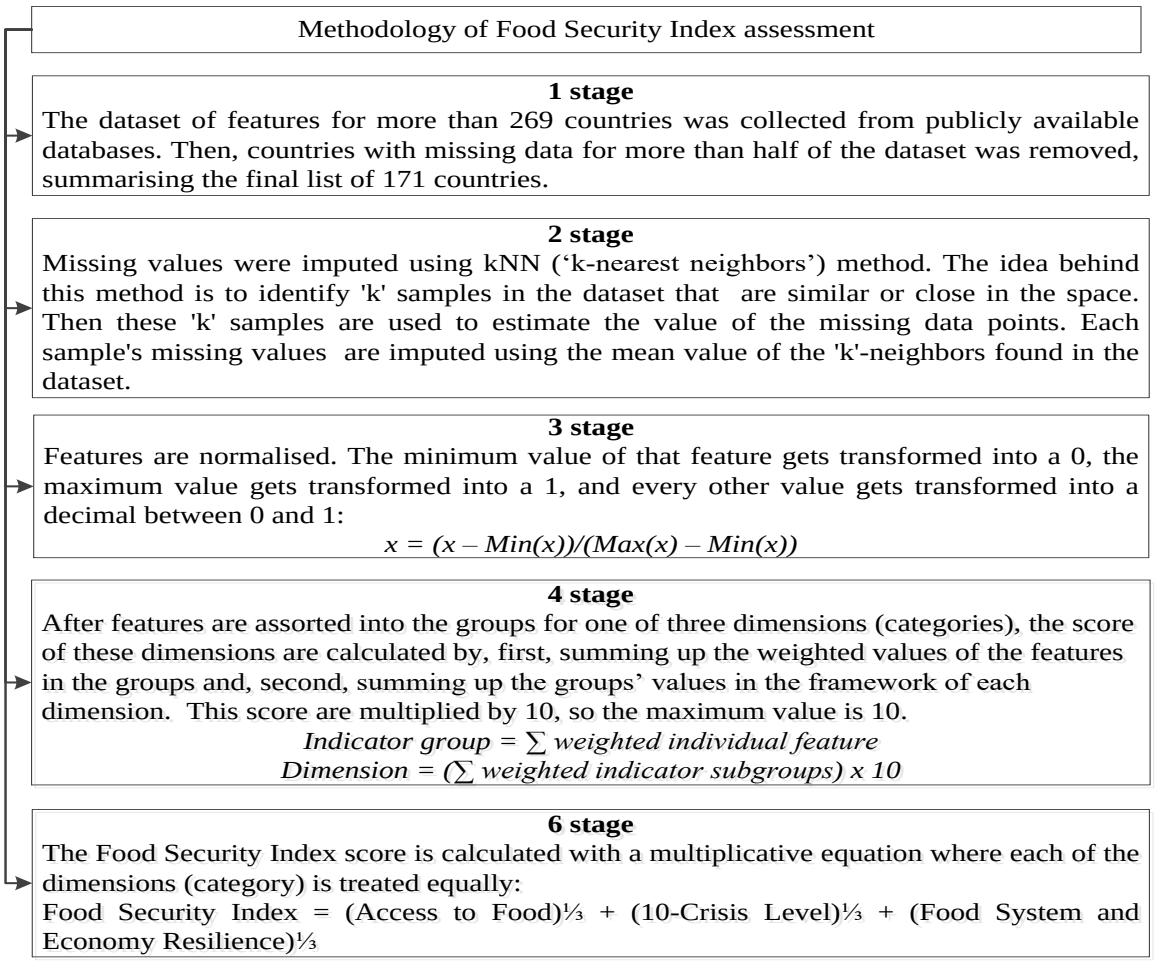
The normalisation method has been updated by converting the underlying data for all series into comparable scores of 0–100. Upper and lower threshold values are specified for all series (the data values corresponding to a score of 100 and zero, respectively).

The categories and indicators included in the GFSI are:

- affordability (AF): change in average food costs, the share of the population under the global poverty line, inequality-adjusted income index, agricultural trade, food safety net programmes;
- availability (AV): access to agricultural inputs, agricultural research & development, farm infrastructure, volatility of agricultural production, food loss, supply chain infrastructure, the sufficiency of supply, political and social barriers to access, food security and access policy commitments;
- quality and safety (QS): dietary diversity, nutritional standards, micronutrient availability, protein quality, food safety;
- sustainability and adaptation (SA): exposure, water, land, oceans, rivers and lakes, political commitment to adaptation, disaster risk management.

Also, there is the Global Q2 2022 Food Security Index developed by Deep Knowledge Analytics, the methodology of which is presented in Fig. 1.

Fig. 1: Methodology of Food Security Index assessment



Source: built by the authors on the bases of (Deep Knowledge Analytics. Global Food Security Index, 2022)

According to this methodology, Food Security Index includes such categories as:

- access to food: measures the ease of access to sufficient and nutritious food that meets people's nutrition needs for a healthy and active life;
- crisis level: assesses a country's exposure to the impacts of a changing climate, sociological or biological hazards;
- food systems and economy resilience: resources available that can alleviate the impact of the global food crisis.

Having studied the methods of food security level calculating, which are used by various international and state organisations, as well as various researchers, it is proposed to calculate the food security level of the studied countries using an integrated rating evaluation method and compare its results with those which international organisations provide.

The first step is the matrix formation of output data. The second step involves standardising their values, as the food security indicators are non-uniform. The third step carried out the differentiation characteristics of the observations matrix on stimulators or destimulators (deterrents). The basis for the characteristics division into two groups is the impact of each indicator on the food security level. Characteristics that have positive, stimulating effects on food security levels are stimulants; others are deterrents. The following steps (4 and 5) provide for constructing the standard's point and determining the Euclidean distance between objects and the standard. Step 6 involves the direct calculation of the integral taxonomic indicator of the food security level by the formula (Plyuta, 1980):

$$I_i = 1 - \frac{C_{i0}}{C_0}. \quad (1)$$

The following local components of the food security level for each of the countries as systems supporting food production ($I_{1_{it}}$), food production ($I_{2_{it}}$), food distribution and supply chains ($I_{3_{it}}$), and food consumption ($I_{4_{it}}$) are calculated. Data's openness, general availability and comparability determined the indicators' choice. It was also necessary to select indicators that could be classified as stimulators or destimulators.

2 Results

Analyses of the categories and indicators included in the Global Food Security Index show that the level of food security directly affects the development of agriculture and climate change. Results of the Global Food Security Index assessment developed by Economist

Impact, which includes 113 countries of the world, are presented in Tab. 1. For comparison, we show the results of ranking the countries that occupy the first five places in the rating, V4 countries (Czech Republic, Hungary, Poland, Slovak Republic), Slavic countries (Belarus, Russian Federation, Ukraine), and the country that occupies the last 113 places in the rating.

Tab. 1: The Global Food Security Index (GFSI) developed by Economist Impact and supported by Corteva Agriscience

Country	2020 year		Country	2021 year		Country	2022 year	
	Score	Rank		Score	Rank		Score	Rank
Finland	85,3	1	Ireland	84	1	Finland	83,7	1
Ireland	83,8	2	Austria	81,3	2	Ireland	81,7	2
The Netherlands	79,9	3	United Kingdom	81	3	Norway	80,5	3
Austria	79,4	4	Finland	80,9	4	France	80,2	4
Czech Republic	78,6	5	Switzerland	80,4	5	Netherlands	80,1	5
United Kingdom	78,5	6	Czech Republic	77,8	14	Czech Republic	77,7	16
Poland	73,5	25	Poland	74,9	22	Poland	75,5	21
Hungary	70,1	36	Hungary	71,1	31	Hungary	71,4	34
Slovak Republic	69,2	40	Slovak Republic	68,7	42	Slovak Republic	71,1	36
Russia	73,7	24	Russia	74,8	23	Russia	69,1	43
Belarus	73,8	23	Belarus	70,9	36	Belarus	64,5	55
Ukraine	63	54	Ukraine	62	58	Ukraine	57,9	71
Yemen	35,7	113	Burundi	34,7	113	Syria	36,3	113

Source: built by the authors on the bases of (Economist Impact. Global Food Security Index, 2022)

The level of food security decreased significantly in the Russian Federation (from 24th to 43rd place), in Belarus (from 23rd to 55th), and in Ukraine (from 54th to 71st). There is a deterioration in the position of the Czech Republic in the rating, which moved from 5th to 16th place. The Slovak Republic, on the contrary, moved from 40th to 36th place.

Correlation coefficients between GFSI and AF, AV, QS, and SA are presented in Tab. 2.

Tab. 2: Correlation coefficients between GFSI and AF, AV, QS, SA

Indicator	AF	AV	QS	SA	GFSI
AF	1,00	0,75	0,79	0,53	0,94
AV	0,75	1,00	0,70	0,57	0,86
QS	0,79	0,70	1,00	0,61	0,90
SA	0,53	0,57	0,61	1,00	0,73
GFSI	0,94	0,86	0,90	0,73	1,00

Source: calculated by the authors

The highest positive correlation is observed between GFSI and AF (0,94).

Multivariate regression of GFSI dependence on AF, AV, QS, and SA is presented in Tab. 3.

Tab. 3: Multivariate regression of GFSI dependence on AF, AV, QS, SA

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.06832 -0.02537 -0.00176  0.02200  0.07412

Coefficients:
             Estimate Std. Error  t value Pr(>|t|)
(Intercept) 0.0101133  0.0190383    0.531    0.596
AF          0.2997829  0.0002991 1002.285   <2e-16 ***
AV          0.2502155  0.0004551  549.808   <2e-16 ***
QS          0.2250997  0.0004025  559.239   <2e-16 ***
SA          0.2248223  0.0003766  596.990   <2e-16 ***
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.03398 on 108 degrees of freedom
Multiple R-squared:      1,    Adjusted R-squared:      1
F-statistic: 3.887e+06 on 4 and 108 DF, p-value: < 2.2e-16
```

Source: calculated by the authors

The obtained model is:

$$GFSI = 0{,}01011 + 0{,}2998 \times AF + 0{,}2502 \times AV + 0{,}2251 \times QS + 0{,}2248 \times SA. \quad (2)$$

Determination coefficient R^2 = 0,9999931 shows that the correlation is significant, the variables AF, AV, QS, and SA describe 99,9% of GFSI. Durbin-Watson test and Breusch-Godfrey serial correlation LM-test showed no autocorrelation of residuals (Tab. 4).

Tab. 4: Durbin-Watson test and Breusch-Godfrey serial correlation LM-test

```
        Durbin-Watson test
data:  model1
DW = 1.7172, p-value = 0.04798
alternative hypothesis: true autocorrelation is greater than 0
        Breusch-Godfrey test for serial correlation of orders up to 2
data:  model1
LM test = 8.6185, df = 2, p-value = 0.01344
```

Source: calculated by the authors

The results of the Global Q2 2022 Food Security Index developed by Deep Knowledge Analytics are presented in Tab. 5.

Tab. 5: Global Food Security Q2 2022 Food Security Index developed by Deep Knowledge Analytics

Rank	Country	Food Security Index (Overall Score)	Access to Food	Crises Level	Food System and Economy Resilience
1	United States	7,9	8,76	2,76	7,7

2	Norway	7,89	8,19	1,02	6,5
3	Ireland	7,82	8,49	1,46	6,41
4	The Netherlands	7,79	8,24	1,98	7,11
5	Canada	7,79	8,63	1,6	6,34
18	Czech Republic	7,28	8	2,05	5,88
9	Poland	7,5	8,02	1,91	6,38
32	Hungary	6,93	7,81	3,03	6,02
46	Slovak Republic	6,72	7,58	2,55	5,13
31	Russian Federation	6,93	7,92	2,52	5,4
15	Belarus	7,35	7,84	1,56	5,78
81	Ukraine	6,03	7,03	4,48	5,54
171	Somalia	2,97	2,04	5,27	2,16

Source: built by the authors on the bases of (Deep Knowledge Analytics. Global Food Security Index, 2022)

The proposed integrated model of food security level estimation using an integrated rating evaluation method is:

$$\mathrm{I_{it}} = \begin{cases} \mathrm{I_{1_{it}}} = \left(\mathrm{x_{1_1}}, \mathrm{x_{1_2}}, \mathrm{x_{1_3}}, \mathrm{x_{1_4}}, \mathrm{x_{1_5}}\right); \\ \mathrm{I_{2_{it}}} = \left(\mathrm{x_{2_1}}, \mathrm{x_{2_2}}, \mathrm{x_{2_3}}, \mathrm{x_{2_4}}, \mathrm{x_{2_5}}, \mathrm{x_{2_6}}, \mathrm{x_{2_7}}, \mathrm{x_{2_8}}, \mathrm{x_{2_9}}, \mathrm{x_{2_{10}}}\right); \\ \mathrm{I_{3_{it}}} = \left(\mathrm{x_{3_1}}, \mathrm{x_{3_2}}, \mathrm{x_{3_3}}, \mathrm{x_{3_4}}\right); \\ \mathrm{I_{4_{it}}} = \left(\mathrm{x_{4_1}}, \mathrm{x_{4_2}}, \mathrm{x_{4_3}}, \mathrm{x_{4_4}}, \mathrm{x_{4_5}}, \mathrm{x_{4_6}}, \mathrm{x_{4_7}}, \mathrm{x_{4_8}}, \mathrm{x_{4_9}}, \mathrm{x_{4_{10}}}, \mathrm{x_{4_{11}}}, \mathrm{x_{4_{12}}}, \mathrm{x_{4_{13}}}\right), \end{cases} \quad (3)$$

where: x_{i_j} is the first level indicators of evaluation system of food security local components; $I_{1_{it}} - I_{4_{it}}$ is local components of food security for *i*-th country at the appropriate time period *t*; I_{it} is the complex general indicator of food security for *i*-th country at the time period *t*.

Systems supporting food production ($I_{1_{it}}$) include such indicators as agricultural land (x_{1_1}), arable land (x_{1_2}), land under permanent crops (x_{1_3}), and percentage of the population in rural areas (x_{1_4}), availability of fertilisers (x_{1_5}). Food production ($I_{2_{it}}$) includes gross domestic product per capita (x_{2_1}), production of cereals (x_{2_2}), wheat (x_{2_3}), potato (x_{2_4}), vegetable (x_{2_5}), meat (x_{2_6}), milk (x_{2_7}), eggs (x_{2_8}), oil (x_{2_9}), and per capita food production variability ($x_{2_{10}}$). Food distribution and supply chains ($I_{3_{it}}$) include such indicators as rail lines density (x_{3_1}), the value of food imports over total merchandise exports (x_{3_2}), the number of supermarkets per million habitants (x_{3_3}), political stability and the absence of violence/terrorism (x_{3_4}). Food consumption ($I_{4_{it}}$) includes such indicators as food inflation (x_{4_1}), average wages (x_{4_2}), supply of wheat (x_{4_3}), potatoes (x_{4_4}), vegetables (x_{4_5}), meat (x_{4_6}), milk (x_{4_7}), eggs (x_{4_8}), oil (x_{4_9}), average protein supply ($x_{4_{10}}$), average dietary energy

supply adequacy ($x_{4_{11}}$), percentage of children under 5 years of age who are stunted ($x_{4_{12}}$), and the prevalence of anaemia among women in reproductive age (15–49 years) ($x_{4_{13}}$).

The calculation results of local components and complex general indicators of food security level in 2020 are presented in Tab. 6. The obtained integral indicators vary from [0; 1]; the closer the value to 1, the greater the food security level (Plyuta, 1980).

Tab. 6: The results of local components and complex general indicator of food security

Country	$I_{1_{it}}$	$I_{2_{it}}$	$I_{3_{it}}$	$I_{4_{it}}$	I_{it}
Finland	0,2719	0,2928	0,5336	0,5248	0,3431
Ireland	0,3339	0,3399	0,5508	0,5959	0,4224
Netherlands	0,2589	0,4304	0,6846	0,5319	0,4314
Austria	0,3313	0,3085	0,7686	0,5836	0,4210
Czech Republic	0,3151	0,3107	0,6461	0,4604	0,3929
United Kingdom	0,3375	0,4138	0,5467	0,6194	0,4682
Poland	0,4233	0,4412	0,5548	0,5349	0,5425
Hungary	0,3424	0,3153	0,5926	0,4474	0,4051
Slovak Republic	0,3330	0,2876	0,5568	0,4031	0,3670
Russia	0,7560	0,7301	0,3538	0,5894	0,7007
Belarus	0,3261	0,3285	0,3941	0,4765	0,3613
Ukraine	0,5259	0,5231	0,3785	0,4811	0,5763
Yemen	0,3773	0,2246	0,0734	0,0298	0,0668

Source: calculated by the authors using data from (Federal State Statistics Service, 2020, FAO, 2020, Ministry of Agriculture and Rural Development of the Slovak Republic, 2020, OECD Data, 2020, World Bank, 2020).

Conclusion

When comparing our integrated taxonomic assessment results and GFSI results developed by Economist Impact, we can conclude that they do not match. Our research showed that the Russian Federation and Ukraine have the highest components, "Systems supporting food production" (0,7560 Russia and 0,5259 Ukraine) and "Food production" (0,7301 Russia and 0,5231 Ukraine). At the same time, according to the GFSI developed by Economist Impact, the countries in first place in the food security rating have significantly lower values of these local components. Let us look at the indicators included in the local components "Systems supporting food production". We can see that this is a bridgehead available in the country, a base for agriculture (agricultural land and the percentage of the population in rural areas), and "Food production". Then we can conclude that in Russia, this component is the highest (0,7301), and in Ukraine, it is also at a sufficiently high level (0,5231). However, in Finland, the component "Food production" equals 0,2928, in Ireland: 0,3399, in Poland: 0,4412, and in the United Kingdom: 0,4138. However, according to GFSI,

these countries occupy higher positions in the rating than Russia and Ukraine. However, other local components that ensure the food security level, namely "Food distribution and supply chains" and "Food consumption" in Russia and Ukraine, are significantly lower than in other countries. To determine the level of influence of each local component on the complex general indicator of food security, the adequate regression model was built according to the Fisher, Student, and Durbin-Watson criteria. The resulting model is presented as follows:

$$I_{it} = -0{,}18 + 0{,}38 \times I_{1_{it}} + 0{,}49 \times I_{2_{it}} + 0{,}12 \times I_{3_{it}} + 0{,}15 \times I_{4_{it}}, \quad (4)$$

As we can see, food production (I_{2it}) and systems supporting food production (I_{1it}) significantly influence food security. In general, the results show that the availability of large amounts of fertile land and labour resources in the country and the presence of favourable natural and climatic conditions for farming do not always correlate with a high level of food security since it is not enough to have fertile soil, a favourable climate, and a working people, it is necessary to take care of political stability in the country, compliance with the principles of implementation of export-import relations, to ensure food infrastructure in the country, the establishment of effective cooperation for the provision of high standards of people living, the concern of the authorities for the standard of living of the citizens. For the successful implementation of the food security mechanism, it is necessary to ensure the functioning of all interconnected food systems, taking into account the factors affecting the food security level (bio-physical and environmental, technology and innovation, economic and market, political and institutional, economic and sociocultural, demographic drivers). The main paradigms should be population changes, new geopolitical balance, technological innovations, focus on environmental aspects, connectivity and information.

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