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AGRICULTURAL SECTOR DEVELOPMENT AND ELASTICITY OF ITS LINKS WITH THE FOOD SECURITY LEVEL

Purpose. *The purpose of the article is the assessment of the countries' food security level and its connection with the agricultural sector results.*

Methodology / approach. *The methodology for calculating the food security level is proposed by international organizations, national authorities, and individual researchers. Due to the fact that food security is a complex flexible concept and cannot be limited to the determination of one separate indicator, we propose to calculate a complex general indicator of food security level using the integral taxonomic estimation method and compare its results with those which provided by international organizations, in particular the Global Food Security Index developed by Economist Impact and supported by Corteva Agriscience and Food Security Index developed by Deep Knowledge Analytics.*

Results. *The article proposes the calculation of countries' food security level using the integrated rating evaluation method and comparing its results with the results provided by different international organizations, identification of problematic local components of food security, and improving food security mechanism. Correlation coefficients and multivariate regression of dependence of global food security index on affordability, availability, quality and safety, sustainability and adaptation are presented. Functions of subjects of different levels of the hierarchy during interaction to ensure food security are considered. Components of food security ensuring mechanism, which will lead to innovations in food security, are proposed. The obtained results show that the availability of large fertile land and labor resources in the country, and the presence of favorable natural and climatic conditions for farming are 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 citizens standard of living, ensuring political stability, etc.*

Originality / scientific novelty. *The level of food security is calculated and compared with the results of international organizations, using the maximum set of publicly available indicators, which include systems supporting food production, food distribution and supply chains, and food consumption indicators. The indicators that have the greatest impact on the food security level were identified, which will make it possible to influence these indicators timely to ensure a sufficient and acceptable food security level.*

Practical value / implications. *Timely research of ensuring food security, which depends mainly on agricultural 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 stabilize food security in an emergency, unforeseen circumstances in the future. The results of the 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, timely resource provision, and ensure a stable, accessible, sufficient, safe, and balanced nutrition level of the population.*

Key words: *agriculture, development, integrated assessment, index, interaction, rating, food security, mechanism for ensuring food security.*

Introduction and review of literature. 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.

"The global food system in 2022 has been destabilized by the recent Russian invasion of Ukraine. Levels of hunger and existing acute food insecurity in Sub-Saharan Africa and MENA region, along with higher food insecurity in Latin America and South Asia, are expected to increase even further" (Deep Knowledge Analytics, 2022). At the same time, society needs to feed an estimated population of over 9 billion by 2050 with diminishing natural resources, whilst ensuring the health of people and the planet, that's why the problem of ensuring food security is so urgent (FAOSTAT, 2022).

Researchers from many countries were engaged in the study of food security. Therefore, Dzuričková (2014) based on the data from the Global Food Security Index ranked the current state of food security in Slovakia at an average level in comparison to other examined countries. Ahmadi Dehrashid et al. (2021) examine the peculiarities of Iran's food security and say that, in a systemic approach, the growth of migration from rural to urban areas, pressure on water and soil resources, and the occurrence of environmental hazards are the most significant consequences of food insecurity. In addition, due to the excessive use of underground water for cucurbits, which is the dominant cultivation pattern in this region, the groundwater level has dropped sharply in some villages far from the city, which may cause concern due to the imminent worsening of food insecurity. Dutta & Saikia (2018) described the content, evolutions of food security as a concept, functions, and features of food security.

Skydan & Hrynyshyn (2020) single out three aspects of food security:

– political – the state's ability to maintain its stable, positive international image on agrarian foreign markets, which can provide its citizens with the consumption of whole foods in accordance with accepted international standards and norms;

– economic – the state's ability to mobilize internal resources and the country's agro- and economic potential to organize the production of agricultural products and supply the population with food mainly using its production;

– social – employment of the population in the agricultural sector of the economy with appropriate labor productivity, its payment, with the provision of full provision of infrastructural factors for the functioning of rural areas.

Karan et al. (2022) consider resilience assessment of centralized and distributed food systems and define resilience as the ability of a system to adapt in the presence of a disruptive event, which has been of great interest in food systems for some time. The goal of their research was to build an understanding of resilient food systems that will withstand and recover from disruptions in a way that ensures a sufficient supply

of food for all.

When analyzing food security, many authors consider trends in the development of agriculture. The paper by Izakovicová et al. (2022) is very interesting, the authors evaluate land use changes in Slovakia since the 18th century, identify key periods of land-management practices and prevailing drivers, and specify the socio-economic and environmental impacts of land-use change. The authors say that various socio-economic, technical, or political drivers have caused land use changes, which are linked to many socioeconomic and environmental problems, e.g., different possible land uses competing with each other, changes of landscape character, increasing anthropization of the territory and disruption of spatial ecological stability, threatening the environmental quality and causing overexploitation of natural resources.

In our opinion, understanding the change of agricultural land over time is necessary for the development of effective policies and for ensuring effective protection of the values of the traditional agricultural landscape.

Pawlak & Kołodziejczak (2020) emphasize that the agricultural sector plays a strategic role in improving food availability. Promoting investments in agricultural infrastructure and extension services along with adopting measures aimed at increasing the households' purchasing power, especially those in rural areas, are key drivers for improving both food availability and food access. Their paper focuses not only on identifying the reasons of undernourishment, but also contributes to recognition of the most effective ways to solve the hunger problem under a country's unique conditions.

Cole et al. (2018) described the science of food security. They connect the future global food demand to the role of agriculture and food science in producing and stabilizing foods to meet the global food demand. The authors highlight the challenges facing food and agriculture systems under climate change and global megatrends that are shaping the future world, discuss the opportunities to reduce food loss and waste, and recover products that are currently wasted to make this the new raw ingredient supply for the food industry.

Given that food security comprises availability, access, utilization and stability dimensions, improving practices will involve more effort to incorporate indicators of food access and stability into agricultural systems models (Nicholson et al., 2021). The authors find that agricultural systems models often conflate analysis of food security covariates that have the potential to improve food security (like agricultural yields) with an assessment of food security itself. Agricultural systems modelers should exercise greater caution in referring to analyses of agricultural output and food availability as representing food security more generally.

We agree with this authors' point of view, since the presence of only fertile agricultural land in the country does not guarantee a high level of security. Political stability, the development of food infrastructure, the government's concern for ensuring food security and a decent standard of living in the country are also extremely necessary.

Moreover, "concentrating agricultural production negatively impacts food supply,

food security, and food systems sustainability. The competitiveness of countries and the coherence of their diversification patterns increase per capita food supply and food security but might harm sustainability. So, understanding specialization patterns of countries in food production can provide relevant insights for the evaluation and design of policies seeking to achieve food security and sustainability" (Campi et al., 2021).

The measures and estimation procedures of food security such as principal component analysis, efficiency analysis, corrected ordinary least squares (COLS), data envelopment analysis (DEA), etc. are reviewed by Izraelov & Silber (2019).

The composite index of food security was built by Caccavale & Giuffrida (2020), that measures the multidimensional concept of food security, covering 185 countries between 1990 and 2017. The index weights 21 selected indicators distributed in the four pillars of food security: availability, access, utilization, and stability. Chaudhary et al. (2018) presented twenty-five sustainability indicators across seven domains: nutrition, environment, food affordability and availability, socio-cultural well-being, resilience, food safety, and food waste. The authors show that different countries have widely varying patterns of performance and unique priorities for improvement.

Müller et al. (2021) identified the key pieces of the fragmented landscape of food security modelling. The authors organize achievements and gaps into different contextual domains of food security (production, trade, and consumption) at different spatial scales.

Burchi & Muro (2016) when analyzing food security propose three basic steps: analysis of food entitlements; analysis of nutritional capabilities and analysis of the ability to ensure food security. In this way, we can move beyond income, entitlement or livelihood related frameworks, and identify the root causes of food insecurity. Food insecurity can be the result of a lack of education, health or other basic capabilities that constitute people's wellbeing. This, therefore, allows situating the study within the broader area of wellbeing and development.

Gebeyehu et al. (2022) considered the impact of COVID-19 on food security and the identification of the most compromised aspect of food security to facilitate prioritization of intervention by food safety regulators and stakeholders. Such studies are interdisciplinary and confirm that the level of food security, even if the country has the best potential of land resources and favorable conditions, can change drastically depending on external circumstances (military actions, natural disasters, the spread of pandemics, etc.).

Kolaj et al. (2023) made the assessment of the impact of a number of factors, such as purchasing and psychological behaviour, experience, knowledge and information about food quality and safety, trust in actors and institutions, risk perceptions, safety knowledge and willingness to pay, increased risks in last years and change in consumption, on the food safety of conventional agricultural products (vegetables) in the markets of the city of Tirana, Albania.

The articles devoted to the analysis of the number of publications on the topic of food security in different years are quite informative. The top 10 active countries

from 1980 to 2019 in terms of the number of publications devoted to food security are United States, United Kingdom, China, Australia, India, Germany, Canada, Netherlands, Italy and France (Sweileh, 2020).

Food security research involved agriculture, environmental science and ecology, food science and technology, and business economics. In addition, the climate change, poverty, gender, nutrition, and diet structure have been the focuses of food security research in recent years (Xie et al., 2021).

Taking into account the dynamic, rapidly changing external environment, indicators and factors of ensuring food security must be constantly updated and improved. Given the unresolved issues, this article is devoted to calculating the countries' food security level using the integrated rating evaluation method and comparing its results with those which are provided by different international organizations, identification of problematic local components of food security, and improving food security mechanism.

The purpose of the article is the assessment of the countries' food security level and its connection with the agricultural sector results.

In order to achieve this goal, it is necessary to calculate the countries' food security level using the integrated rating evaluation method, compare its results with those that international organizations provide, and determine the level of diffusion of agricultural sector adaptation mechanism to ensure food security and a sufficient and stable standard of population living.

Methodology. The research is based on the confirmation of the following empirical hypotheses:

Hypothesis 1. The food production and systems supporting food production have the greatest influence on the food security level.

Hypothesis 2. Food security depends on the development of the country's agro-industrial complex, but it is not entirely limited to it. There are a lot of factors that influence food security level.

Hypothesis 3. The dominant influence on the level of country food security is formed by a set of different-level factors that depend on the natural and climatic, economic, political, institutional, informational, legal, and technical conditions of operation.

Hypothesis 4. For the successful implementation of the food security ensuring mechanism, it is necessary to ensure the functioning of all interconnected food systems, taking into account the factors affecting the food security level, to ensure government supervision and control over agriculture development, effective interaction of agricultural producers with authorized bodies of state power and local government.

The following methods of scientific research were used in the research process:

– comparative analysis (for comparison the food security level provided by different international organizations);

– integral taxonomic estimation method (for calculation the countries' food security level);

– regression analysis (for finding the influence of individual components on the complex general indicator of the food security).

The methodology for calculating the food security level is proposed by international organizations, national authorities and individual researchers. At the international level we propose to consider the methodologies of Global Food Security Index assessment developed by Economist Impact and supported by Corteva Agriscience and developed by Deep Knowledge Analytics.

In the methodology developed by Economist Impact and supported by Corteva Agriscience, the Global Food Security Index is calculated as follows: "the indicator scores are normalised and then aggregated across pillars to enable a comparison of broader concepts across countries. Normalisation rebases the raw indicator data to a common unit so that it can be aggregated". The indicators for which a higher value indicates a more favorable environment for food security – inequality-adjusted income or food supply adequacy – have been normalised on the basis of:

$$x = (x - Lower\ threshold(x)) : (Upper\ threshold(x) - Lower\ threshold(x)),$$

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:

$$x = (x - Upper\ threshold(x)) : (Upper\ threshold(x) - Lower\ threshold(x)),$$

where *Lower threshold(x) and Upper threshold(x)* are specified for all series.

The normalisation method, by which the underlying data for all series are converted into comparable scores of 0–100, has been updated. Upper and lower threshold values are specified for all series (the data values that correspond to a score of 100 and zero respectively). This has been done to ensure that data outliers do not skew the scores. The same upper and lower thresholds are applied across all years 2012–2022 for each series.

The categories and indicators included in the Global Food Security Index developed by Economist Impact and supported by Corteva Agriscience are presented in Table 1.

Table 1

The categories and indicators included in the Global Food Security Index developed by Economist Impact and supported by Corteva Agriscience

1 AFFORDABILITY	3 QUALITY AND SAFETY
1	2
1.1 Change in average food costs	3.1 Dietary diversity
1.2 Proportion of population under global poverty line	3.1.1 Share of non-starchy foods
1.3 Inequality-adjusted income index	3.1.2 Share of sugar consumption
1.4 Agricultural trade	3.2 Nutritional standards
1.4.1 Agricultural import tariffs	3.2.1 National dietary guidelines
1.4.2 Trade freedom	3.2.2 National nutrition plan or strategy
1.5 Food safety net programmes	3.2.3 Nutrition labelling

Continuation of Table 1

1	2
1.5.1 Presence of food safety-net programmes	3.2.4 Nutrition monitoring and surveillance
1.5.2 Funding for food safety-net programmes	3.3 Micronutrient availability
1.5.3 Coverage of food safety-net programmes	3.3.1 Dietary availability of vitamin A
1.5.4 Operation of food safety-net program	3.3.2 Dietary availability of iron
2 AVAILABILITY	3.3.3 Dietary availability of zinc
2.1 Access to agricultural inputs	3.5.1 Food safety mechanisms
2.1.1 Access to finance and financial products for farmers	3.5.2 Access to drinking water
2.1.2 Access to diversified financial products	3.5.3 Ability to store food safely
2.1.3 Agriculture producer prices	3.4 Protein quality
2.1.4 Access to extension services	3.5 Food safety
2.1.5 Community organisations	3.5.1 Relevant food safety legislation
2.1.6 Empowering women farmers	3.5.2 Food safety mechanisms
2.2 Agricultural research & development	3.5.3 Access to drinking water
2.2.1 Public expenditure on agricultural research and development	3.5.4 Ability to store food safely
2.2.2 Access to agricultural technology, education and resources	4 SUSTAINABILITY AND ADAPTATION
2.2.3 Commitment to innovative technologies	4.1 Exposure
2.3 Farm infrastructure	4.1.1 Temperature rise
2.3.1 Crop storage facilities	4.1.2 Drought
2.3.2 Irrigation infrastructure	4.1.3 Flooding
2.3.3 Access to market data and mobile banking	4.1.4 Sea level rise
2.4 Volatility of agricultural production	4.2 Water
2.5 Food loss	4.2.1 Agricultural water risk – quantity
2.6 Supply chain infrastructure	4.2.2 Agricultural water risk – quality
2.6.1 Planning and logistics	4.3 Land
2.6.2 Road infrastructure	4.3.1 Land degradation
2.6.3 Air, port and rail infrastructure	4.3.2 Grassland
2.7 Sufficiency of supply	4.3.3 Forest change
2.7.1 Food supply adequacy	4.3.4 Soil organic content
2.7.2 Dependency on chronic food aid	4.4 Oceans, rivers and lakes
2.8 Political and social barriers to access	4.4.1 Eutrophication
2.8.1 Armed conflict	4.4.2 Marine biodiversity
2.8.2 Political stability risk	4.5 Political commitment to adaptation
2.8.3 Corruption	4.5.1 Climate finance flows
2.8.4 Gender inequality	4.5.2 Environmental-economic accounting implementation
2.9 Food security and access policy commitments	4.5.3 Early-warning measures / climate smart agriculture
2.9.1 Food security strategy	4.5.4 Commitment to managing exposure
2.9.2 Food security agency	4.5.5 National agricultural adaptation policy
	4.5.6 Sustainable agriculture
	4.6 Disaster risk management
	4.6.1 Pest infestation and disease mitigation
	4.6.2 Risk management coordination

Source: developed by the author on the bases of Economist Impact (2022).

Analyses of the categories and indicators included in the Global Food Security Index (Table 1) show that the level of food security directly affects the development of agriculture and climate change.

There is also the Global Q2 2022 Food Security Index developed by Deep Knowledge Analytics, the methodology of which is presented in Figure 1.

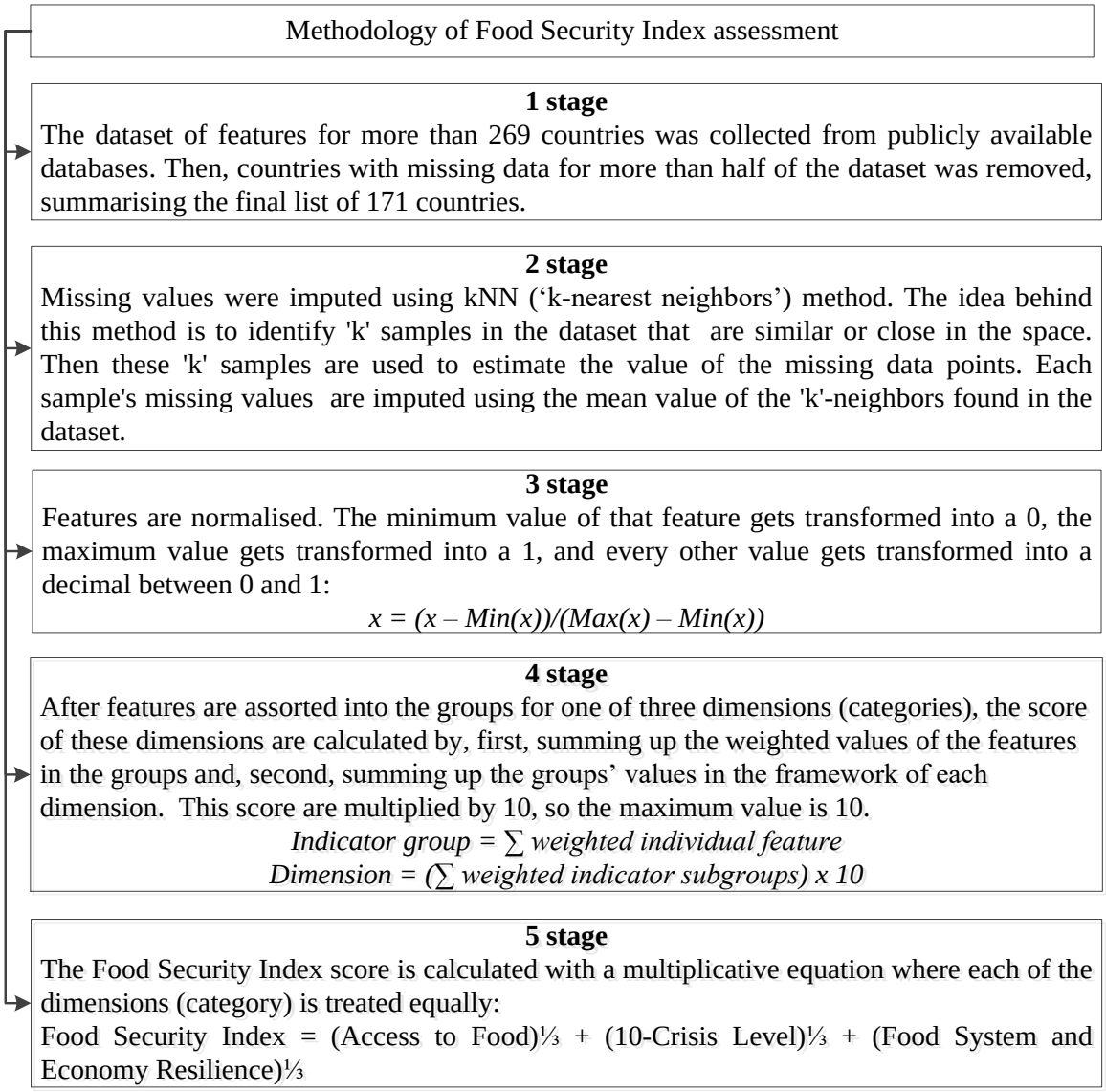

Figure 1. Methodology of Food Security Index assessment

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

According to Deep Knowledge Analytics (2022) Food Security Index includes such categories and indicators: "access to food (measures the ease of access to sufficient and nutritious food that meets people's dietary needs for a healthy and active life); crisis level (assesses a country's vulnerability to the impacts of climate change, sociological or biological hazards); food system and economy resilience (available resources that can mitigate the impact of the global food crisis)" (Table 2).

The results of the food security levels using these two methods will be analyzed later in this article.

Table 2

Food Security Index Framework developed by Deep Knowledge Analytics

Indicator groups	Features
Access to food	
Food Expenditure & Consumption	Share of consumer expenditure on food
	Food supply (kcal per capita per day)
	Healthy diet cost (% cannot afford)
	Vulnerability of consumers to price shocks
	Obesity Rate
Undernourishment Levels	People with insufficient food consumption
	The sufficiency of the national food supply
	Prevalence of undernourishment (% of population)
Quality of Diet & Well-being	The nutritional quality of diets, the safety of food
	Prevalence of severe food insecurity in the population
	Mortality rate, infant (per 1,000 live births)
Crisis level	
Natural Hazards	Exposure to the impacts of climate change
	Relative exposure to natural disasters
	Droughts probability and historical impact
Conflict Intensity	Current National Power Conflict Intensity
	Current Subnational Conflict Intensity
	Current Highly Violent Conflict Intensity Score
	Conflict Related Fatalities per 100,000
Vulnerability to Epidemics	Physical vulnerability to epidemics
	COVID-Related Cases per 100,000
	COVID-Related Fatalities per 100,000
Food system and economy resilience	
Economic Development	Country class by income group
	GDP (current USD)
	GDP per capita, PPP (current international USD)
	Unemployment, total (% of total labor force)
Food System Economy	Food dependency ratio
	Food exports (% of merchandise exports)
	Food exports in USD
	Food imports (% of merchandise imports)
	Food imports in USD
Wealth & Equality	Human Development Index (HDI)
	Gini Index
	Poverty headcount ratio at national poverty lines
	Poverty Rate
	Population living in slums (% of urban population)

Source: developed by the author on the bases of Deep Knowledge Analytics (2022).

In addition to the Global Food Security Index developed by international organizations, there are methods of calculating food security developed by different countries. For example, in Ukraine, there are Methodological recommendations for the calculation of the level of economic security of Ukraine, where one of the components of state economic security is food security and such indicators are used

for its calculation (Ministry of Economic Development and Trade of Ukraine, Methodological recommendations for calculation of the level of economic security of Ukraine, 2013):

– "daily caloric content of human nutrition, thousand kcal;

– the ratio of production and consumption of meat and meat products per person, %;

– the ratio of production and consumption of milk and dairy products per person, %;

– the ratio of production and consumption of eggs per person, %;

– the ratio of production and consumption of oil per person, %;

– the ratio of production and consumption of sugar per person, %;

– the ratio of production and consumption of potatoes per person, %;

– the ratio of production and consumption of vegetables and food melon crops per person, %;

– grain production per person per year, tons;

– the level of cereal stocks at the end of the period, % before consumption;

– the share of sales of imported food products through the trade network of enterprises, %".

In addition, methodologies and techniques for calculating food security are developed at the level of individual researchers. Let's consider some of them.

Kurlyak (2016) proposes to assess the food security level by determining: the food security coefficient for a separate main product and integral index of food security.

The food security coefficient for a separate main product (meat, sugar, etc.) was calculated according to the formula:

$$K_{fs} = \frac{C_f}{C_r} - \frac{VI}{VC}, \quad (1)$$

where K_{fs} is the food security coefficient for a separate main product;

Cf is the actual (fact) consumption of a separate product per person per year;

Cr is the rational rate of consumption of a separate product per person per year;

VI is the volume of import of a separate product;

VC is the volume of actual consumption of a separate product.

The integral index of national food security is determined as the average arithmetic value of the security coefficients for a particular type of product according to the formula:

$$IIFS = \frac{K_{fsi}}{n}, \quad (2)$$

where *IIFS* is the integral index of national food security;

K_{fsi} is food security coefficient for the *i*-th product;

n is the number of products.

The scientific problem of the security of any system reflects the implementation of a complex of interrelated interests and goals of open economic systems of different hierarchy levels. This gives reason to consider different economic systems as certain

integrity, which has stable, deep properties and features.

The main factors of the vital activity of complex economic systems are structural connectivity and complexity, dynamic complexity (manageability), stability, adaptability, efficiency, reliability, and self-organization (Casti, 1982).

So, after an annotated literature review on food security, it is undoubtedly clear that the concept of food security is complex and systemic. The food security system is formed as a complex of subsystems, necessary and sufficient to ensure the intended purpose of this system – protection from threats to the basic interest of the state and continuous quantitative and qualitative supply of its population with food. It belongs to the class of economic systems, which are usually called large and complex.

Due to the fact that food security is a complex flexible concept and cannot be limited to the determination of one separate indicator, we propose to calculate a complex general indicator of food security level using the integral taxonomic estimation method and compare its results with those which provided by the Global Food Security Index developed by Economist Impact and supported by Corteva Agriscience and Food Security Index developed by Deep Knowledge Analytics.

The algorithm of the integrated rating evaluation method is presented in Figure 2. The first step is the matrix formation of output data. As the food security indicators are non-uniform, the second step involves standardizing their values using the formula:

$$z_{ij} = \frac{x_{ij} - \overline{x}_j}{s_j}, \quad (3)$$

where j = 1, 2, ..., m; $\bar{x}_j$ – average value of the j-th index;

s_j – standard deviation of the j-th index;

z_{ij} – the standardized value of the j-th index.

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 effect on food security level, are stimulants, others are deterrents. Next steps (4 and 5) provide for the construction of the standard's point and determination of 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:

$$I_i = 1 - \frac{C_{i0}}{C_0}, \quad (4)$$

where $C_0 = \overline{C_0} + 3 \times S_0$; $\quad \overline{C_0} = \frac{1}{w}\sum_{i=1}^{w} C_{i0}$; $\quad S_0 = \sqrt{\frac{1}{w}\sum_{i=1}^{w}\left(C_{i0} - \overline{C_0}\right)^2}$.

The following local components of 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. The choice of

indicators was determined by the openness, general availability and comparability of statistical data. It was also necessary to select indicators that could clearly be classified as stimulators or destimulators. Because indicators such as the prevalence of obesity in the adult population (18 years and older), the percentage of children under 5 years of age who are overweight cannot be clearly assigned to one or another group and they were not included. On the one hand, a high percentage of people with obesity indicate that the country is provided with food and people do not starve, and on the other hand, it indicates an imbalanced diet, lack of adherence to food culture, or even the inability to buy fruits and vegetables in order not to gain excess weight.

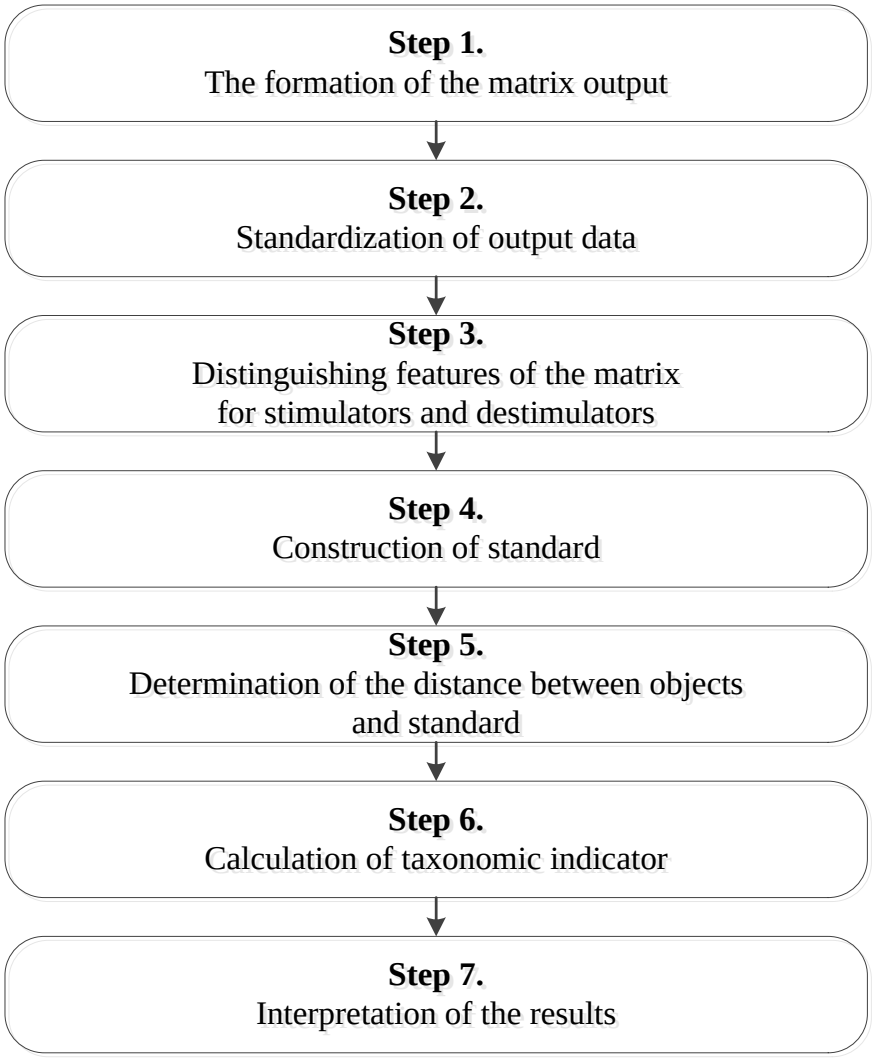

Figure 2. The algorithm of realization of integral taxonomic estimation method

Source: built by the author on the bases of Pluta (1977).

The choice of integral taxonomic estimation method is determined by the following advantages, which are implemented in the paper:

– wide possibilities of usage, especially in conditions of uncertainty and risk;

– convenience in combination with other economic and statistical methods;

– the possibility of taking into account many local indicators affecting the country's food security level, taking into account the complexity of this category;

– dynamic spatial analysis of agricultural complex development;

– the availability of commensurate data on food security indicators in open access.

The article presents data that covers the countries occupying the first five places in international food security rankings, as well as V4 countries (Czech Republic, Hungary, Poland, Slovak Republic), Slavic countries (Belarus, Russian Federation, Ukraine), and the country that occupies the last place in the rankings for the period 2020–2022. The data was taken from the official websites of the World Bank, OECD, FAO, NASA, and Statistical Offices of the countries studied.

Results and discussion. The results of the Global Food Security Index assessment developed by Economist Impact, which include 113 countries of the world, are presented in Table 3.

Table 3

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

Country	2020		Country	2021		Country	2022	
	Overall score	Rank		Overall score	Rank		Overall score	Rank
Finland	85.3	1	Ireland	84.0	1	Finland	83.7	1
Ireland	83.8	2	Austria	81.3	2	Ireland	81.7	2
Netherlands	79.9	3	United Kingdom	81.0	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
Russian Federation	73.7	24	Russian Federation	74.8	23	Russian Federation	69.1	43
Belarus	73.8	23	Belarus	70.9	36	Belarus	64.5	55
Ukraine	63.0	54	Ukraine	62.0	58	Ukraine	57.9	71
Yemen	35.7	113	Burundi	34.7	113	Syria	36.3	113

Source: built by the author on the bases of Economist Impact (2022).

There is 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. 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). To find out which categories have changed, let's analyze GFSI in 2022 by food security categories (Table 4).

Table 4

The Global Food Security Index (GFSI) in 2022 by food security categories

Rank	Country	Overall score	Affordability (AF)	Availability (AV)	Quality and safety (QS)	Sustainability and adaptation (SA)
1	Finland	83.7	91.9	70.5	88.4	82.6
2	Ireland	81.7	92.6	70.5	86.1	75.1
3	Norway	80.5	87.2	60.4	86.8	87.4
4	France	80.2	91.3	69.0	87.7	70.3
5	Netherlands	80.1	92.7	70.7	84.7	69.2
16	Czech Republic	77.7	91.3	69.4	76.3	70.3
21	Poland	75.5	87.4	63.8	81.5	66.7
34	Hungary	71.4	86.7	63.3	74.4	57.0
36	Slovak Republic	71.1	89.1	55.3	77.9	57.6
43	Russian Federation	69.1	77.8	61.4	78.7	56.6
55	Belarus	64.5	67.8	61.9	69.0	58.5
71	Ukraine	57.9	66.6	48.1	71.3	43.5
113	Syria	36.3	32.0	26.6	50.8	38.4

Source: built by the author on the bases of Economist Impact (2022).

Correlation coefficients between GFSI and AF, AV, QS, and SA are presented in Table 5.

Table 5

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 author.

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 Table 6.

Table 6

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 ***	-
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 author.

The obtained model is:

$$GFSI = 0.01011 + 0.2998 \cdot AF + 0.2502 \cdot AV + 0.2251 \cdot QS + 0.2248 \cdot SA \quad (5)$$

Determination coefficient $R^2 = 0.9999931$ shows that the correlation is significant; the variables AF, AV, QS, and SA describe 99.9 % of GFSI. The results showed that AF had a greater impact on GFSI.

The results of Global Q2 2022 Food Security Index developed by Deep Knowledge Analytics are presented in Table 7.

Table 7

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
2022 year					
1	United States	7.90	8.76	2.76	7.70
2	Norway	7.89	8.19	1.02	6.50
3	Ireland	7.82	8.49	1.46	6.41
4	Netherlands	7.79	8.24	1.98	7.11
5	Canada	7.79	8.63	1.60	6.34
18	Czech Republic	7.28	8.00	2.05	5.88
9	Poland	7.50	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	5.40
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 author on the bases of Deep Knowledge Analytics, Global Food Security Index (2022).

Despite the fact that the results of the ranking developed by different organizations differ somewhat, there is a general trend that V4 countries in terms of food security are in the following order the Czech Republic, then Poland, then Hungary, then the Slovak Republic.

The formation of food security forms many interconnected chains from systems supporting food production (agricultural land, the number of people employed in agriculture, availability of necessary equipment for land cultivation, etc.) to food consumption and as a result to nutrition and health, and life quality. The main factors that influence food security are presented in Table 8.

Table 8

Factors that influence on food security

Food System	Inputs	Factors
Systems supporting food production (Resource potential formation)	– land; – energy; – water; – minerals; – fertilizers; – equipment; – labour	– climatic conditions in the country; – availability of water; – available resources (agricultural land, arable land, etc.); – the number of rural population and number of people employed in agriculture; – cost of material resources; – potential volumes of food production; – availability of necessary equipment for land cultivation (tractors, combines, etc.); – availability of fertilizers
Food production	– minerals; – machinery; – labour; – buildings; – materials	– volumes of production of agricultural products; – gross domestic product per capita; – production costs (in particular, the cost structure); – economic indicators of agricultural enterprises; – stock levels of strategic types of agricultural products
Food distribution and food supply chains	– infrastruc-ture; – vehicles	– specific weight of consumed food products that were produced in other regions (countries); – the structure of food distribution for sales channels; – export and import volumes; – the presence of a retail network per 10,000 people; – the number of retail outlets in food markets per 10,000 people; – the state of development of wholesale trade in food products; – the density of paved public roads and railways rut
Food consumption	– consumer behaviour; – ration; – diet	– volumes of consumption of food products (in physical units); – volumes of food consumption per person (in physical units of measurement and in terms of proteins, fats and carbohydrates); – energy value of the daily ration – actual and normative indicators; – volumes of food consumption by quintile (20 %) groups depending on the size of total income; – food inflation, indices of the prices of plant and animal products; – the value of the consumer basket; – incomes of the population, average wages

Source: developed by the author.

Comparison of Food Security Level and Systems supporting food production (resource potential formation) in 2020 is presented in Table 9.

Table 9

Comparison of Food Security Level and Systems supporting food production (Resource potential formation) in 2020

Country	Food Security Level (Overall score)	Rank	Agricultu-ral land, thsd ha	Arable land, thsd ha	Land under permanent crops, thsd ha	Land under permanent meadows and pastures, thsd ha	Percentage of the population in rural areas
Finland	85.3	1	2270	2243	5	22	14.62
Ireland	83.8	2	4512	444	1	4067	36.83
Netherlands	79.9	3	1814.45	1004.83	37.21	772.41	8.51
Austria	79.4	4	2646.76	1321.08	66.87	1258.81	41.70
Czech Republic	78.6	5	3523.87	2484.15	50.11	989.61	26.21
United Kingdom	78.5	6	17259.3	5978.5	45.09	11235.7	16.60
Poland	73.5	25	14461	10921	350	3190	39.94
Hungary	70.1	36	4903	4012	158	733	28.65
Slovak Republic	69.2	40	1910	1346	18	519	46.27
Russian Federation	73.7	24	215494	121649	1793	92052	25.57
Belarus	73.8	23	8281	5660	100	2521	21.41
Ukraine	63.0	54	41311	32924	853	7534	30.65
Yemen	35.7	113	23452	1158	294	22000	63.36

Source: developed by the author on the bases of FAOSTAT (2020).

It is clear that the presence of a large amount of agricultural land does not always mean ensuring food security, since food security depends not only on agriculture development, and agriculture depends not only on the amount of land but also on climatic conditions in the country, availability of water, necessary equipment for land cultivation (tractors, combines, etc.), fertilizers, carrying out works on chemical melioration of land, etc. For example, Yemen has much more agricultural land than Slovakia, but at the same time, it ranks 6th place in another ranking "Water stress" and as a result ranks last place on food security. Of the analyzed countries, Slovakia has an almost even distribution of the rural and urban population (46.27 % of the population lives in rural areas). The most uneven distribution is in the Netherlands, where only 8.51 % of the population lives in rural areas. At the same time, this does not prevent the Netherlands from being in 3rd place in the ranking in terms of food security. The visual comparison of production volumes of various types of food products in 2020 is presented in Figure 3a, and Figure 3b.

Before the war, Ukraine provided 46 % of global sunflower oil exports, 9 % of the wheat exports, 17 % of the barley, and 12 % of the maize on global markets (USDA, 2022; NASA, 2022). Therefore, the russian war in Ukraine affects food security of many countries. Such global effects of the russian war in Ukraine are highlighted by (Glauben, et al., 2022; Ben Hassen & El Bilali, 2022):

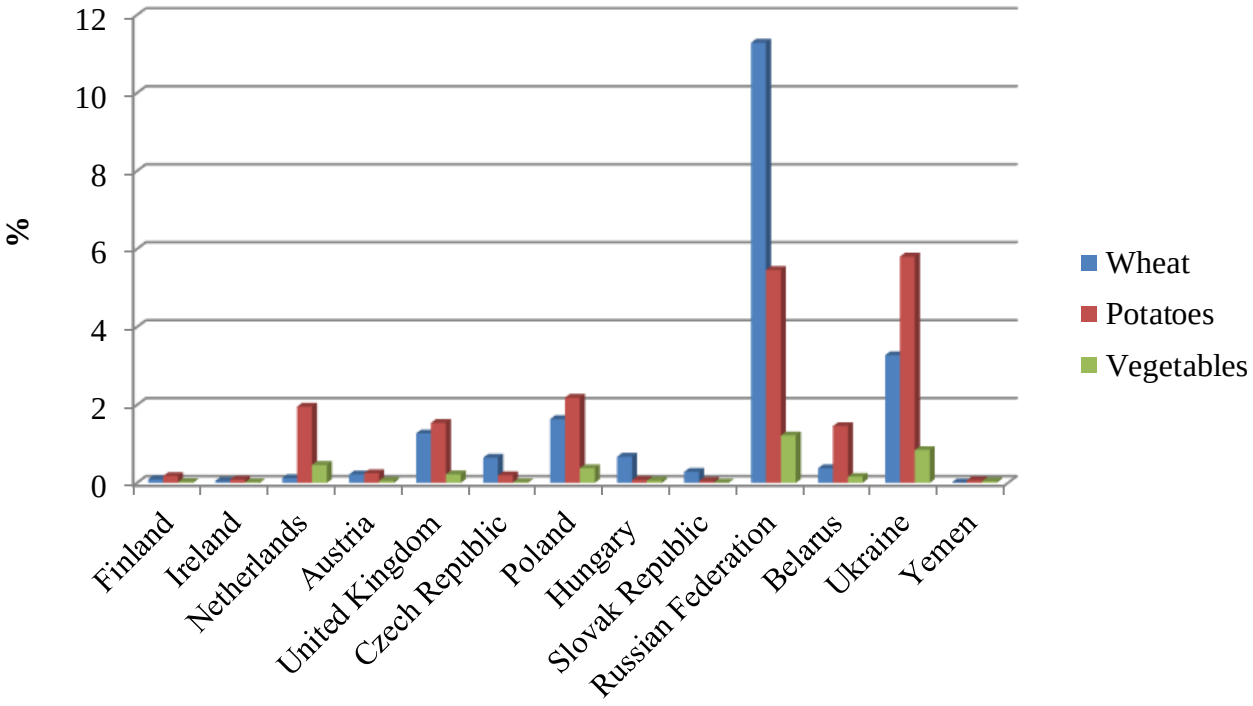

Figure 3a. Food production as a percentage of the world level for wheat, potatoes and vegetables

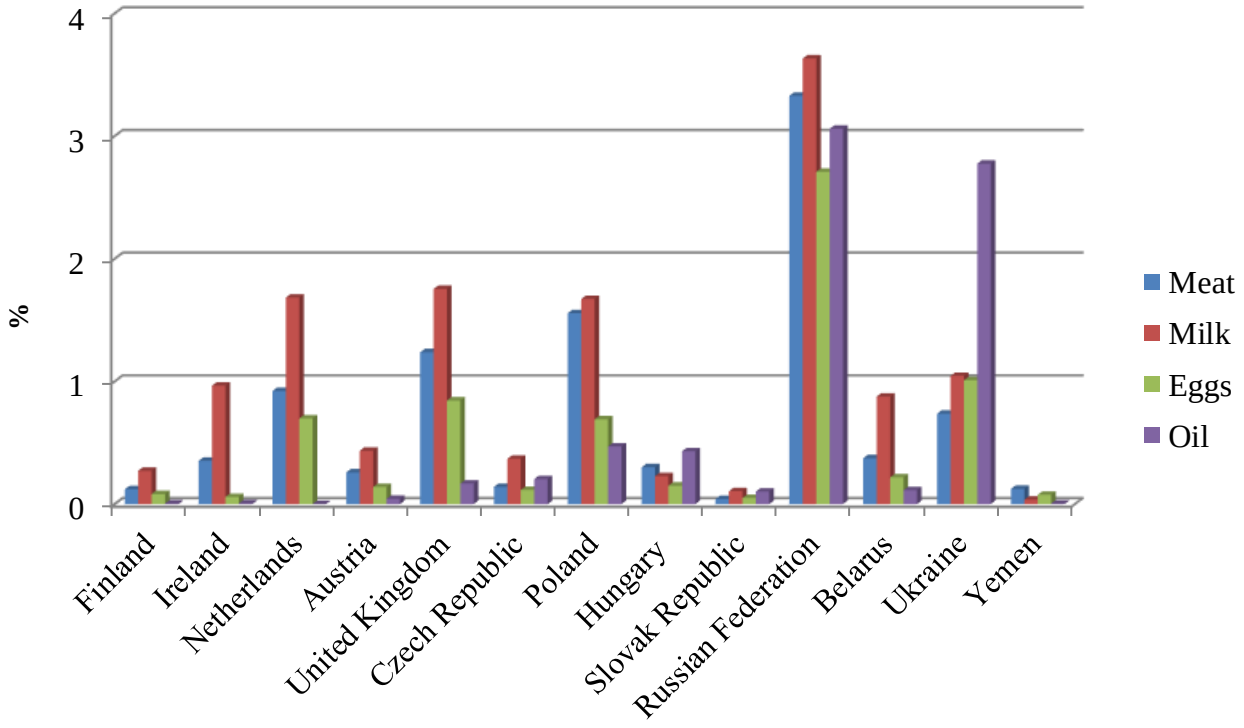

Figure 3b. Food production as a percentage of the world level for meat, milk, eggs and oil

Source: built by the author on the bases of Visual Capitalist. Food Production Around the World (2020).

– "disruptions to global food and energy markets, which have further pushed up already elevated agricultural commodity and fuel prices;

– shipments from Black Sea harbors have been reduced in volume, immediately affecting countries depended on food imports;

– high prices coupled with shortages due to disruptions of exports from the region are likely to reduce fertilizer usage in many countries, which will affect yields of coming harvests and the future availability of agricultural commodities on international markets".

The UN Food and Agriculture Organization (2022) also highlighted the following key areas of influence: "disruption to winter harvesting and spring planting; agricultural labor availability, impacted by displacement; access to and availability of agricultural inputs, particularly fuel, seeds, fertilizers and pesticides; disruption of logistics and all elements of the food supply chains; abandonment and restriction of access to agricultural land; damage to crops due to military activity, especially during vegetative stages in spring; and destruction of agrifood system assets and infrastructure".

It is necessary to analyze not only the total amount of land in the country and the total amount of produced agricultural products, but also the productivity (t/ha of the harvested area) since the productivity indicates the fertility of the land, favorable weather conditions in the country, the level of attitude and land cultivation. The yield of crops in Ukraine is presented in Figure 4. In turn, the yield of crops in Russia is presented in Figure 5.

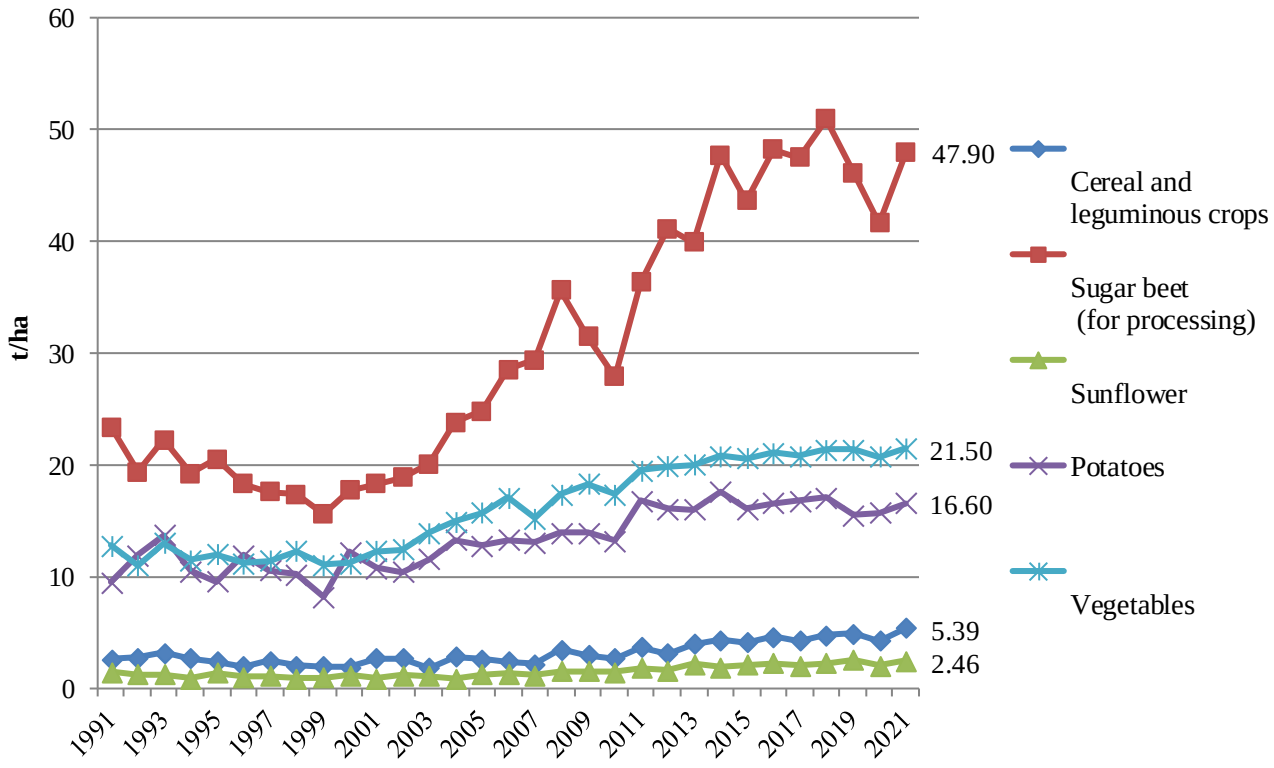

Figure 4. Yield of crops in Ukraine, t/ha of the harvested area

Source: built by the author on the bases of the State Statistics Service of Ukraine (2022).

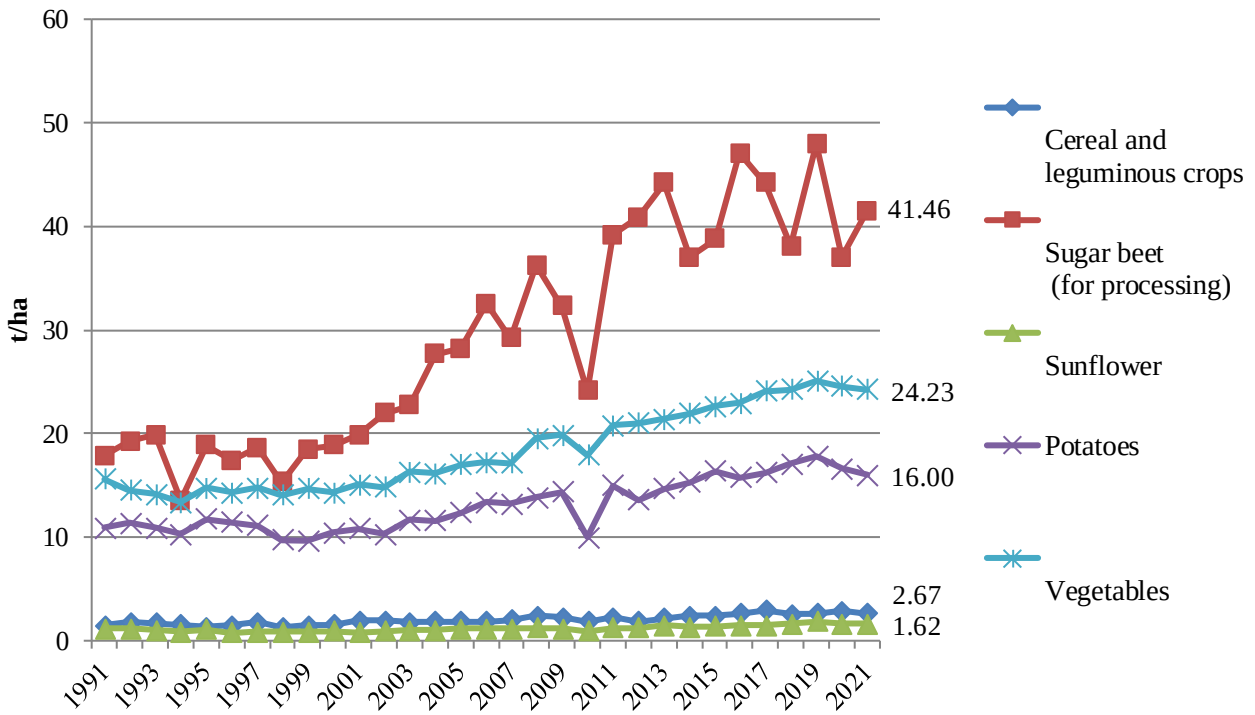

Figure 5. Yield of crops in Russia, t/ha of the harvested area

Source: built by the author on the bases of Federal State Statistics Service (2022).

Despite the fact that Russia has much larger agricultural land and produces more products in absolute terms, productivity in Ukraine is much higher. In 2021, in Ukraine the yield of wheat was 5.39 t/ha of the harvested area, and in Russia it was 2.67. The yield of sugar beat in Ukraine was 47.9 t/ha of the harvested area, in Russia it was 41.5, sunflower in Ukraine was 2.46 t/ha of the harvested area, in Russia it was 1.62 t/ha of the harvested area, potatoes in Ukraine 16.6, in Russia 16.0 t/ha of the harvested area, which means that it is not enough to have large amounts of agricultural land at disposal, it must be cultivated effectively. For a comprehensive analysis, it is worth analyzing not only the total amount of food production but also the provision of it per capita (Figure 6a, and Figure 6b).

The Russian Federation produces in 2020 the largest amount of wheat, potatoes, vegetables, meat, milk, eggs, and oil in natural terms (in tons). However, the availability of these food products per capita in Russia is lower than in other countries. For example, Russia produces 3.63 % of the world's milk, and Finland only 0.27 %, but the milk supply of the population of the Russian Federation is 141.8 kg per capita per year, while in Finland it is 337.09 kg per capita. This is explained by the population amount and the ratio of the volumes of food exports and imports of different countries.

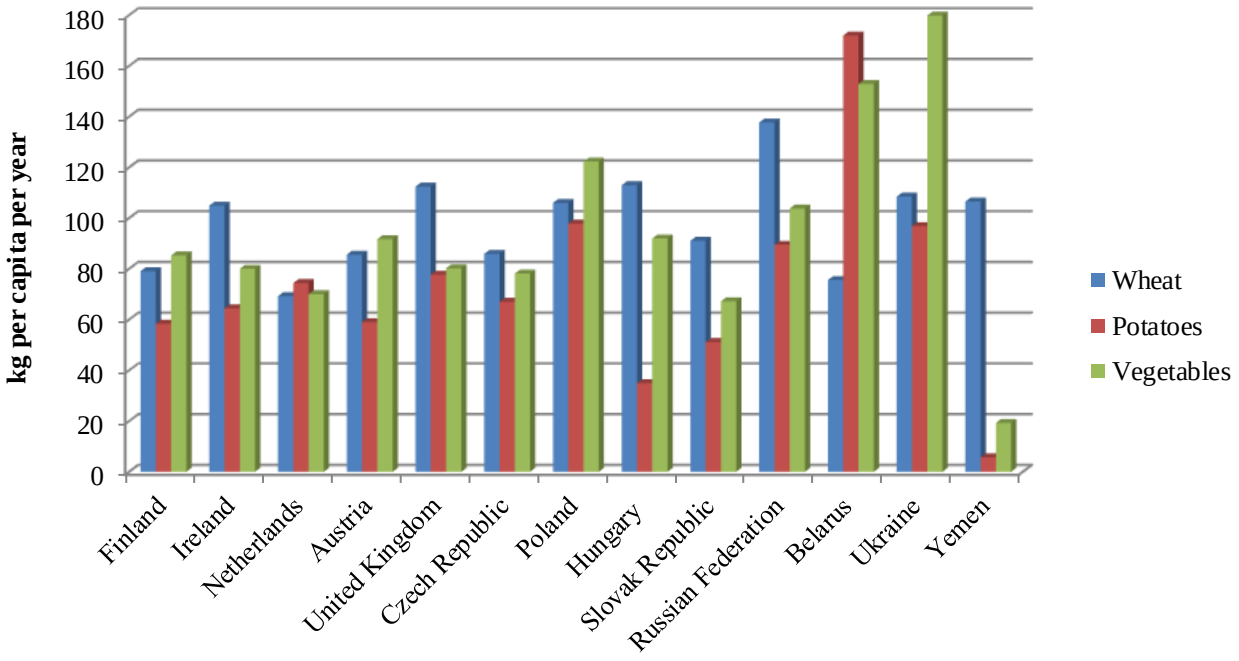

Figure 6a. Food supply (kg per capita per year) for wheat, potatoes and vegetables

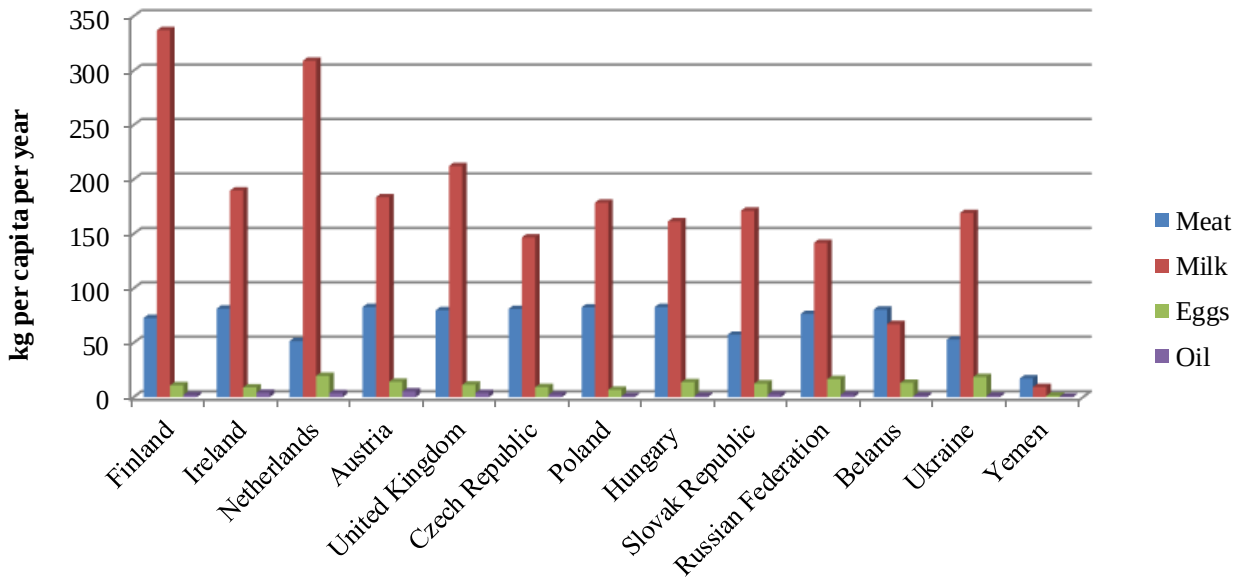

Figure 6b. Food supply (kg per capita per year) for meat, milk, eggs and oil

Source: built by the author on the bases of OECD, WITS (2020).

Having studied the methods of food security level calculating, which do various international and state organizations, as well as various researchers use, 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 are provided by different international organizations. The proposed system of food security indicators is presented in Table 10.

Table 10

The system of food security indicators

Symbol	Indicator
$I_{1_{it}}$ (Systems supporting food production)	
x_{1_1}	Agricultural land, thsd ha
x_{1_2}	Arable land, thsd ha
x_{1_3}	Land under permanent crops, thsd ha
x_{1_4}	Percentage of the population in rural areas
x_{1_5}	Availability of fertilizers
$I_{2_{it}}$ (Food production)	
x_{2_1}	Gross domestic product per capita
x_{2_2}	Cireals production, tones
x_{2_3}	Wheat production, tones
x_{2_4}	Potatoes production, tones
x_{2_5}	Vegetables production, tones
x_{2_6}	Meat production, tones
x_{2_7}	Milk production, tones
x_{2_8}	Eggs production, tones
x_{2_9}	Oil production, tones
$x_{2_{10}}$	Per capita food production variability
$I_{3_{it}}$ (Food distribution and supply chains)	
x_{3_1}	Rail lines density (total route in km per 100 square km of land area)
x_{3_2}	Value of food imports over total merchandise exports (%)
x_{3_3}	Number of supermarkets per million habitants
x_{3_4}	Political stability and absence of violence/terrorism (index)
$I_{4_{it}}$ (Food consumption)	
x_{4_1}	Food inflation (indices of the prices)
x_{4_2}	Average wages, USD/month
x_{4_3}	Wheat supply (kg per capita per year)
x_{4_4}	Potatoes supply (kg per capita per year)
x_{4_5}	Vegetables supply (kg per capita per year)
x_{4_6}	Meat supply (kg per capita per year)
x_{4_7}	Milk supply (kg per capita per year)
x_{4_8}	Eggs supply (kg per capita per year)
x_{4_9}	Oil supply (kg per capita per year)
$x_{4_{10}}$	Average protein supply (g/capita/day) (3-year average)
$x_{4_{11}}$	Average dietary energy supply adequacy (%) (3-year average)
$x_{4_{12}}$	Percentage of children under 5 years of age who are stunted (%)
$x_{4_{13}}$	Prevalence of anemia among women of reproductive age (15–49 years)

Source: developed by the author.

Therefore, the integrated model of food security level estimation is:

$$I_{it} = \begin{cases} I_{1_{it}} = (x_{1_1}, x_{1_2}, x_{1_3}, x_{1_4}, x_{1_5}); \\ I_{2_{it}} = (x_{2_1}, x_{2_2}, x_{2_3}, x_{2_4}, x_{2_5}, x_{2_6}, x_{2_7}, x_{2_8}, x_{2_9}, x_{2_{10}}); \\ I_{3_{it}} = (x_{3_1}, x_{3_2}, x_{3_3}, x_{3_4}); \\ I_{4_{it}} = (x_{4_1}, x_{4_2}, x_{4_3}, x_{4_4}, x_{4_5}, x_{4_6}, x_{4_7}, x_{4_8}, x_{4_9}, x_{4_{10}}, x_{4_{11}}, x_{4_{12}}, x_{4_{13}}), \end{cases} \quad (5)$$

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 period of time *t*;

I_{it} is the complex general indicator of food security for *i*-th country at the appropriate period of time *t.*

Indicators included in the calculation of local components of food security ($I_{1_{it}} - I_{4_{it}}$), were presented in Table 10.

The calculation results of local components and complex general indicator of food security level in 2020 are presented in Table 11.

Table 11

The results of local components of food security level and complex general indicator of food security level

Country	Systems supporting food production ($I_{1_{it}}$)	Food production ($I_{2_{it}}$)	Food distribution and supply chains ($I_{3_{it}}$)	Food consumption ($I_{4_{it}}$)	Complex general indicator of food security (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
Russian Federation	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 author using data from Federal State Statistics Service (2022); Food and Agriculture Organization of the United Nations (2020); Ministry of economic development and trade of Ukraine (2020); Ministry of Agriculture and Rural Development of the Slovak Republic (2020); Ministry of Finance of the Slovak Republic (2020); OECD Data (2020); Statistical Office of the Slovak Republic (2020); State Statistics Service of Ukraine (2020); World Bank (2020).

The obtained integral indicators vary from [0; 1], the closer the value is to 1, the greater the food security level.

For a clearer interpretation and comparison of local components of food security, they are presented in Figure 7.

When comparing our results of the integrated taxonomic assessment and the results of GFSI developed by Economist Impact and Global Food Security developed by Deep Knowledge Analytics, we can conclude that they do not match.

Our research showed that Russia has the highest components "Systems supporting food production" and "Food production" (0.7560 and 0.7301 respectively). At the same time, the countries that, according to the GFSI developed by Economist Impact, are in the first places in the food security rating, have significantly lower values of these local components. If we look at the indicators included in the local components "Systems supporting food production", we can see that this is a bridgehead in the country, a base for agriculture (agricultural land, percentage of the population in rural areas, etc.), and "Food production" (cereals, wheat, potatoes, vegetables, meat, milk, eggs, oil, etc. production), then we can conclude that in Russia this component is the highest (0.7301). In Ukraine it is also at a sufficiently high level (0.5231). But in Finland component "Food production" equals 0.2928, in Ireland – 0.3399, in Poland – 0.4412, and in the United Kingdom – 0.4138, although both according to GFSI developed by Economist Impact and according to Global Food Security developed by Deep Knowledge Analytics, these countries occupy higher positions in the rating than Russia and Ukraine.

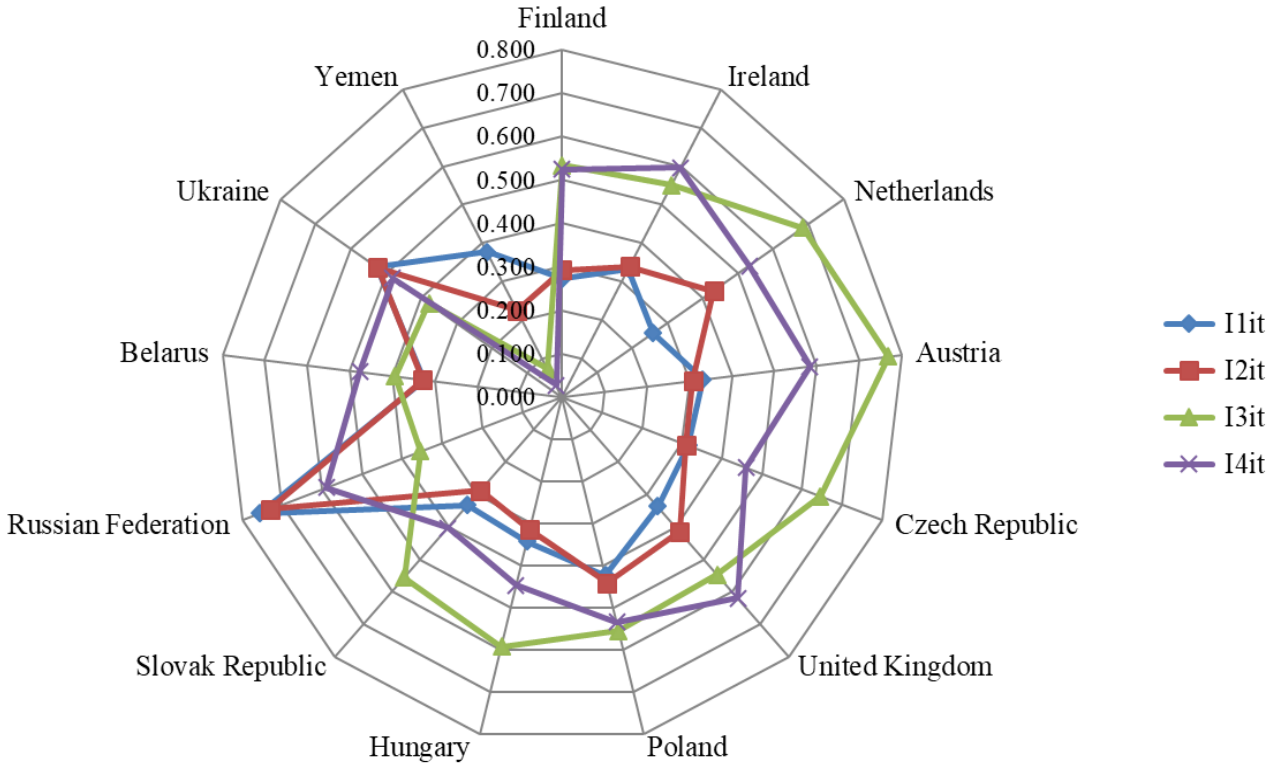

Figure 7. The local components of food security level

Source: built by the author.

However, other local components that ensure the food security level, namely "Food distribution and supply chains" and "Food consumption" in Russia are significantly lower than in other countries (of course, not taking into account Yemen, which occupies the lowest place in the food security rating).

Component "Food distribution and supply chains" include the development of food infrastructure (rail lines density (total route in km per 100 square km of land area), number of supermarkets per million habitants, political stability and absence of violence/terrorism, etc.) and in Russia even before the unjustified war it unleashed in Ukraine, this component is only 0.3941, while in Austria it is 0.7686.

In order to determine the level of influence of each local component on the complex general indicator of food security, the regression model was built and tested using the Shapiro-Wilk test, Jarque-Bera test (normality of residuals testing), Breusch-Pagan test (heteroscedasticity testing), Variance inflation factor (multicollinearity testing), Ramsey Regression Equation Specification Error Test (model specification testing). The resulting model is presented as follows:

$$I_{it} = -0.18 + 0.38 \cdot I_{1_{it}} + 0.49 \cdot I_{2_{it}} + 0.12 \cdot I_{3_{it}} + 0.15 \cdot I_{4_{it}}. \quad (8)$$

As we can see, food production ($I_{2_{it}}$) and systems supporting food production ($I_{1_{it}}$) have the greatest influence on the food security level. Of course, without these local components, achieving a high food security level is difficult. However, an analysis of GFSI shows that countries that do not have a significant amount of agricultural land and do not produce agricultural products in large volumes at the same time occupy higher positions in the rating (for example, Finland compared to Russia). With the beginning of the war, Ukraine fell in GFSI ranking from 58th place in 2021 to 71st place in 2022, and Russia from 23rd place to 43rd place. Therefore, it is necessary to take care of political stability in the country, compliance with the principles of implementation of export-import relations, and establishment of effective cooperation for the provision of high standards of people living.

For example, in Ukraine, unfortunately, there is a situation of exhausting use of land plots by private farmers, who for several years in a row grow sunflower seeds for export and foreign exchange earnings, thus depleting the land and exhausting its natural possibilities. After harvest, some private farmers uncontrollably set land plots on fire to destroy waste and weeds, sometimes burning live plantation trees that are located next to such fields. Some companies extracting mineral resources from land located within or near populated areas carry out such extraction without observing all the necessary norms and sanitary measures, which leads to water resource depletion, a complete absence of water in the wells of residents of villages and towns where similar business entities are located. Therefore, authorized state authorities should interact with business entities to prevent a decrease in the assimilation characteristics of the natural environment and ensure food security in the long term, not just foreign currency export earnings in the short term.

Therefore, it is necessary to ensure government supervision and control over agriculture development, effective interaction of agricultural producers with authorized bodies of state power and local government. At the same time, effective interaction to ensure food security must be achieved at all levels of the hierarchy (Table 12).

Table 12

Functions of subjects of different levels of the hierarchy during interaction to ensure food security

Hierarchical level	The subject that solves the problem	Functions of the subject
Global	"United Nations, EIU, the World Bank Group, the UN Food and Agriculture Organization of the United Nations (FAO), Committee on World Food Security (CFS), the World Health Organization (WHO), the World Trade Organization (WTO), the OECD, Notre Dame Global Adaptation Initiative (ND-GAIN), the World Resources Institute (WRI), the US Department of Agriculture (USDA)"	Promote of stable economic development. Help eliminate hunger, food insecurity and malnutrition by development long-term programs to combat hunger. Make agriculture more productive and sustainable. Reduce rural poverty. Ensure inclusive and efficient agricultural and food systems. Protect livelihoods from disasters. Create of food reserves
Subregional (interstate)	Interregional entities with relevant bodies (for example, the European Union), forums Associations and relevant management bodies	Promotion of stable economic development, improvement of food quality parameters. Solidarity behavior by concluding agreements on trade, prices, standardization
State	Governments, legislative bodies National agriculture and health ministries	Creation of a legislative, regulatory and resource base to ensure food security, formation of appropriate funds and reserves. Determination of directions for improving food quality parameters
Local	Territorial management bodies (district, region)	Creation of conditions for obtaining income in households. Ensuring the supply of products and quality control
Business entities of the agricultural sector	Agricultural cooperatives, etc.	Careful land treatment, prevention of land depletion. Rational usage of existing production facilities. Provision of investment needs for the development of production and replenishment of working capital. Concentration of material, financial and labor resources in the production of final products. Ensuring deep processing of raw materials using by-products and waste. Guaranteed sales of products for food processing and sale. Ensuring high production culture and qualification of personnel. Ensuring an equivalent exchange between the agricultural industry branches
Families (households)	Households by income groups	Obtaining income that ensures rational consumption. Purchase and consumption of food, etc. Effective household farming

Source: developed by the author on the bases of FAO, IFAD, UNICEF, WFP and WHO (2023).

Components of food security ensuring mechanism which will lead to innovations in food security are presented in Figure 8.

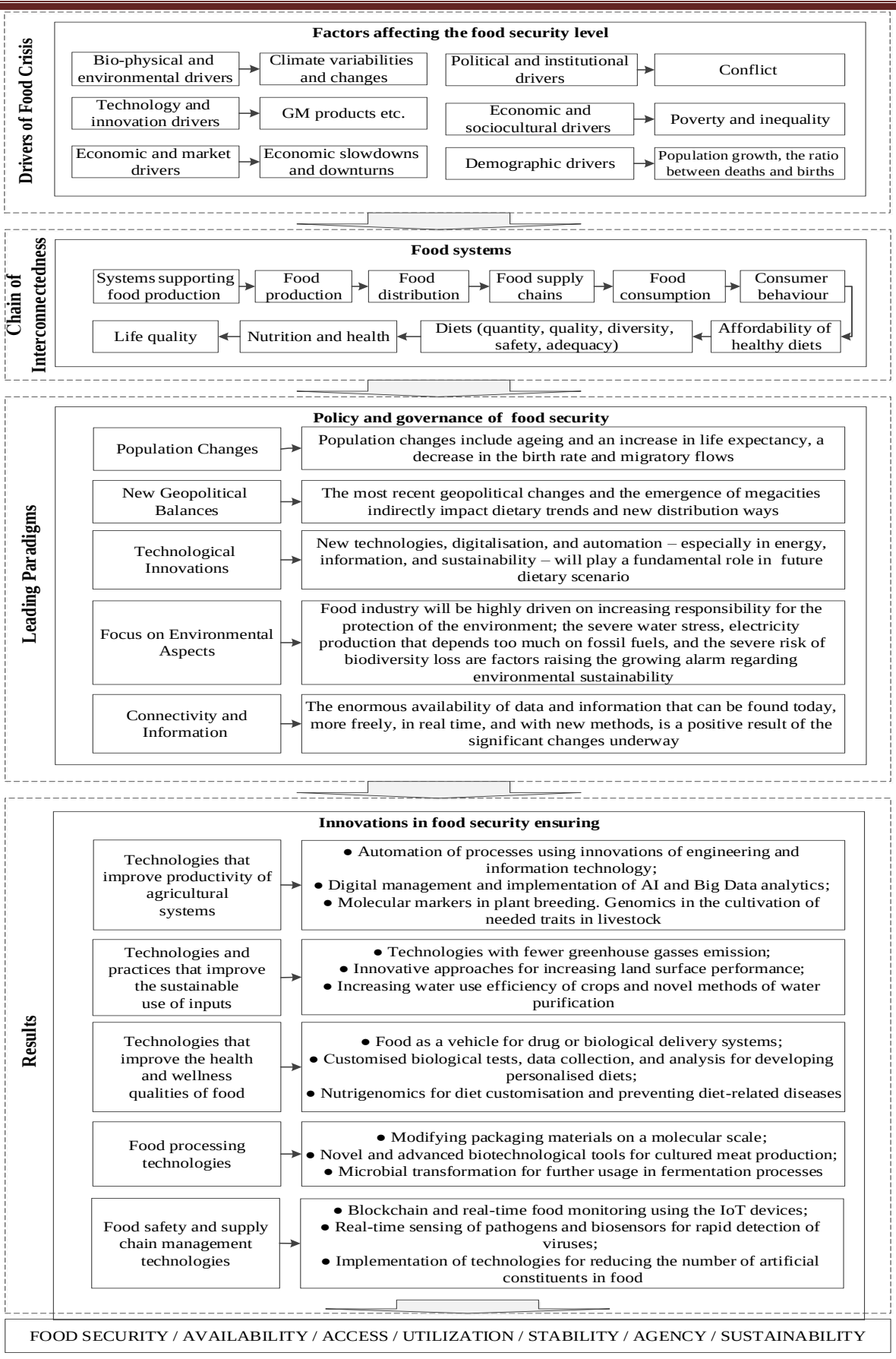

Figure 8. Components of food security ensuring mechanism

Source: developed by the author.

Ensuring food security involves the development and implementation of socio-economic, organizational, legal, scientific and innovative, informational, ecological, and other measures aimed at protecting the vital interests of a person, the community, the region, and the state in terms of ensuring physical, economic and social accessibility, safety and the quality of food products, the stability of the population's food supply and food sovereignty.

Discussion. As a main contribution of the article, the following elements can be singled out:

– improvement of countries' food security level indicators, which maximally covers the entire scope of agrifood systems, starting from supporting systems and ending with nutrition and health and as a result, quality of life;

– identification of problematic local components of food security, which will make it possible to take timely measures to increase their level;

– justification that food security depends on the development of the country's agro-industrial complex, but it is not entirely limited to it; in particular, the study results showed that with an increase in food production by 1, the complex general indicator of food security will increase by 0.49; if the systems supporting food production increases by 1, the complex general indicator of food security will increase by 0.38; an increase in food consumption by 1 will lead to an increase in the complex general indicator of food security by 0.15; an increase in such component as food distribution and supply chains by 1 will lead to an increase of the complex general indicator of food security 0.12;

– characterization of factors that have the dominant influence on the level of country food security and are formed by a set of different-level factors that depend on the natural and climatic, economic, political, institutional, informational, legal, and technical conditions of operation;

– improvement of food security mechanism, the success of which requires the functioning of all interconnected food systems, taking into account the factors affecting the food security level, to ensure government supervision and control over agriculture development, effective interaction of agricultural producers with authorized bodies of state power and local government.

The scientific novelty of the research is revealed in the fact that using the maximum set of publicly available indicators, which include systems supporting food production, food distribution and supply chains, and food consumption indicators, the level of food security is calculated and then compared with the results of international organizations. The indicators that have the greatest impact on the food security level were identified, which will make it possible to influence these indicators timely to ensure a sufficient and acceptable food security level.

At the same time, the issue of not just providing the population with food, but ensuring a high level of food quality, setting limits on the use of pesticides, and ensuring a balanced diet remains debatable.

Conclusions. In general, the obtained results show that the availability of large amounts of fertile land and labor resources in the country, and the presence of

favorable natural and climatic conditions for farming don't always correlate with the high level of food security in the country, since it is not enough to have fertile soil, a favorable climate, and hardworking people, it is also necessary to ensure food infrastructure in the country, the concern of the authorities for the standard of living of the citizens, ensuring political stability in the country, etc.

Recommendations. Therefore, it is necessary to take care of political stability in the country, compliance with the principles of implementation of export-import relations, and establishment of effective cooperation for the provision of high standards of people living.

In order to ensure food security, it is necessary to provide the physical availability of food products for each person; the economic possibility of purchasing food by all social groups of the population, in particular the socially vulnerable segments of population, which is achieved by raising the standard of living or implementing the necessary social protection measures; ensuring the consumption of high-quality products in an amount sufficient for a balanced diet.

For the successful implementation of the proposed 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.

The results will be innovations in food security ensuring namely such as technologies that improve the productivity of agrosystems, the sustainable use of inputs, the health and wellness qualities of food, food processing technologies, food security, and supply chain management technologies.

Limitations and future research. During the research, the following limitations were identified. Firstly, taking into account the complexity of the food security category, the difficult task is the selection of indicators that are included in the country's food security level calculation, as well as ensuring the proportionality of the sample. In this regard, there are methodological limitations, such as the need to develop a valid, universal, and comparative information and analytical research base. In order to eliminate the inclusion of similar indicators, it is necessary to check the correlation of the indicators selected for the study.

Secondly, the use of the method of integral taxonomic assessment involves the determination of indicators that are stimulators, i.e. the increase of which is positive, and destimulators, i.e. the increase of which is negative, which cannot always be determined unambiguously and clearly. In this regard, only those indicators that can be clearly attributed to stimulators or destimulators were included in the sample, ambiguous indicators were excluded from the sample.

Undoubtedly, food security depends on the development of the country's agro-industrial complex, but it is not entirely limited to it. There are a lot of factors that influence food security level. For complex research of food security, it is necessary to

consider the political situation, volatility of agricultural product prices, volatility of energy prices and the mutual influence of changes in energy prices and food prices, characteristics of weather conditions in the country, the impact of climate change, income inequality level, and other global challenges on food security, which will be the focus of our future research.

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