Aggregate Food Security Measurement Indicators: Current Status and Perspectives

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Abstract

Globally, the situation of the natural resources in terms of continuous and imminent population growth is very concerning. Ensuring food security and food security is increasingly difficult to achieve, and in areas that are becoming more and more extensive. This article presents a general overview of the main aggregate food security measurement indicators according to the classifications established by the most important agri-food institutions. The first section briefly examines food security and food independence on three main areas: food self-sufficiency; food security and environmental sustainability; and the agri-food system. The second section focuses on the aggregate indicators for measuring food security according to Food and Agriculture Organization, International Institute for Food Policy Research, the World Bank or EUROSTAT. The paper also evaluates the current situation of the main indicators and provides examples of actions that helped nations to achieve food self-sufficiency.

Keywords: *agri-food system, food independence, food insecurity, food security, food self-sufficiency.*

JEL classification: Q18
DOI: 10.24818/RMCI.2022.3.408

1. Introduction

Many local, national, regional and global studies, strategies and programs have been introduced in the field of food security and safety. At the same time, global development has generated a series of problems for each nation, as well. Thus, population growth, which will increase the demand for agri-food products (Popescu et al., 2017), continuous soil degradation (Mihalache, Ilie & Marin, 2015), water scarcity (Wang et al., 2017), climate change (Radulescu, Ioan & Nastase, 2016) cause concerns not only to international forums but also to national authorities, in assessing the ability to ensure food security of their peoples.

Global concerns about food security and independence are intense (Drăgoi et al., 2018). Food security is a link in economic security and must help to achieve the following goals: to ensure adequate food production; to modernize and stabilize the flow of agricultural products; to ensure access to the agricultural resources available to those who need them, in order to ensure the health of the population. Food and Agriculture Organization (FAO) is the governing body of countries' efforts to

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achieve these goals. The introduction should provide the reader with enough information so that he gets accustomed with the main ideas and the content of the paper.

2. Research methodology

Previous studies and classifications of agri-food system have led to the questions: *what is the current state of the components of the agri-food system*?; *how can it be developed to ensure the food security and independence of the country*?. The current paper aims to explore the main aggregate food security measurement indicators. The research is mainly based on previously published secondary sources: articles, books and reports. This study is descriptive and conceptual in nature and pursues the following objectives:

- To analyze the current studies on food self-sufficiency and food independence;
- To examine the link between food security and environmental sustainability;
- To explore the challenge of agri-food system and food security;
- To present the main aggregate indicators that reflect food security.

3. Research areas on food security

Current food security research is considered to focus on three main areas:

- *food self-sufficiency* of each state and *food independence*;
- *food security and environmental sustainability*; and
- *agri-food system and food security.*

The following part of this section will present the main information and previous research results regarding each of these main areas.

Food Self-Sufficiency and Food Independence

The FAO defines self-sufficiency in general terms: "*the extent to which a country can meet its food needs*". This definition does not specify whether the food needs are met only from own production or from imports, or if the country is open to international trade or has closed borders (Clapp, 2017).

The measurement of food self-sufficiency is done by the self-sufficiency ratio (SSR), which expresses food production as a ratio of available supply, as represented by the following equation (Santeramo, 2015):

$$SSR = (Production \times 100) / (Production + Imports - Exports).$$

Self-sufficiency can also be measured in terms of total dietary energy production or per capita. A production of less than 2000 kcal per day/inhabitant is considered to be “low”; between 2000-2500 kcal/day/inhabitant is considered as “insufficient” and a production higher than 2500 kcal/day/capita is self-sufficient (Porkka et al., 2013). Food self-sufficiency has become increasingly addressed in

both academic studies and by the governments of various countries, in particular due to the volatility of agricultural prices during the global economic crisis of 2007-2008 (Clapp, 2017; Guo & Tanaka, 2019).

Food self-sufficiency is a complex concept and there are situations in which countries with food self-sufficiency in certain products may have a high level of hunger. This may be because countries may be self-sufficient in some products but may be deficient in others, or where certain segments of the population are poor and do not have the possibility to buy certain products.

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Self-sufficiency has also become a problem for many economically developed countries. The decline in self-sufficiency in Japan, Switzerland and Korea has been due to the enrichment that has led to a change in consumption patterns and the abandonment of local agriculture (Yoo et al, 2016). Among the measures taken by the Japanese government to increase self-sufficiency by 45% are:

- the initiative promoting local products called "Food Action Nippon", which includes rice flour as a substitute for wheat flour;
- the "Marché Japon" action, which involves the sale of local products directly on the streets of big cities;
- the Chochin movement (green paper lanterns), designed to encourage restaurants to use local ingredients, and of course the introduction of subsidies.

A study published in Switzerland aims to assess sufficient supply capacity if the country is in a “severe shortage” (Koch et al., 2013). The optimization model took into account the achievements of the agrarian reform 1993-2011 (introduction of direct payments, abolition of export subsidies, etc.) and the federal recommendations on ensuring safe and competitive production.

Some essential restrictions of the model are the following:

- maintaining arable land,
- respecting a crop rotation,
- respecting biodiversity,
- the possibility of cultivating land now used as pasture,
- ensuring fodder from own production,
- the risk of low harvests due to climate change.

The model was dynamic in the sense that it took into account the crop rotation, the movement of livestock, population growth, climate change expected in the coming years. The model was solved in two situations: a first objective function to reduce the differences between the current food situation and a crisis situation and a second objective function to maximize the energy of the system and achieve at least 90% of the expected food energy value of the system. In both cases, the model has solved the two functions, revealing Switzerland's ability to cope with a

possible very serious food crisis. The system is up and running and is constantly updated. The model sensitized the federal authorities to limit urbanization on productive land, to stimulate the development of the processing industry, to develop irrigation and to stimulate the use of organic waste.

In China, food self-sufficiency is estimated at 95%, with 19.9% of the world's population and arable land being only 7% of the world's cultivated area (Ghose, 2014). Measures to increase production include: multi-crops, small-scale farming such as gardening, the use of improved seeds, drip irrigation, and the construction of terraces. By promoting harmony in society and reducing social inequities, food self-sufficiency is expected to decrease to 90% in the near future, which will lead to massive food imports. The increase in food demand in China, even if the population is expected to decrease by 2050 (Ghose, 2014), will be caused by urbanization and changing the socio-economic status of a large part of the population.

It is believed that by increasing imports of agri-food products, China is making a significant contribution to world food production and consumption. Experts also found that in China, the report entitled "Prospects for Chinese Agriculture in 2014-2023" aims to get rid of the burden of imports in order to gain food independence. For some countries, the country's food situation is a matter of national security, such as Iran and Egypt which import 40%, Algeria, Japan, South Korea, and Taiwan which import 70%; and Israel and Yemen, which import 90% of their grain needs (Ahmed et al., 2013).

Food security and environmental sustainability

In recent decades, research around the world has aimed to ensure environmental sustainability, in terms of reducing "extreme poverty and hunger", established by the Millennium Development Goals declaration for the period 2000-2015 (Huang et al., 2020). In addition to one-off research on the influence of environmental factors on agricultural production, mathematical models for simulating environmental conditions have been developed at EU level, while simulating the technical and economic aspects of the whole agri-food system. Thus, the CAPRI model was developed at the request of the EU, through a research project and has been operational since 1999. The CAPRI model aims to determine the impact of European Union agricultural policies on the development of 280 regions of the Member States and of Norway, Turkey and the Western Balkans. There are a total of 2450 farm models on the basis of which regional non-linear models are designed for up to 10 farm types. These cover land use for arable crops, pastures and animal production (Espinosa et al., 2016). The model includes 50 agricultural production activities and 50 restrictions on production technologies, markets through physical quantities of products and the evolution of prices in a globalized market. The model allows the simulation of fertilizer levels and yields as well as the introduction of biophysical parameters to determine the influence on the environment. The model analysed the CAP Reforms on the impact of bilateral or multilateral trade liberalization scenarios as well as the environmental impact of

agriculture on the current situation and a 10-year outlook. The model is continuously improved through research projects. The CAPRI model also allows the elaboration of a market model (77 countries with 40 trading blocks) for 47 products. The main beneficiary of the CAPRI model is the EU Commission, in particular its directions for agriculture and the environment, and provides an assessment of the ex-ante impact of the CAP on production, revenues, markets, trade and the environment at regional level on a global scale (Gocht et al., 2017).

Agri-food system and food security

The challenge of food self-sufficiency is an initiative to increase the supply of food to cities in the surrounding agricultural areas. It is interesting to study the implications of the "Urban Food Policy Pact in Milan", in which the mayors of 113 cities signed a commitment involving concrete actions at the local level to deal with global emergencies such as hunger, malnutrition, reduction food waste but also exchanges of experience on these measures.

The study seeks to project increased supply in metropolitan areas for large cities. The analysis part of the model highlighted the possibilities for increasing food self-sufficiency for the metropolitan population as land is under pressure to be used for residential, commercial and industrial purposes, for transport infrastructure, green spaces, for leisure or for reforestation and nature conservation. The model proposes multifunctional, efficient production systems, short production and supply chain alternatives, the use of technological innovations, greenhouse production, organic farming and urban agriculture to increase food production, in conditions of degradation and depletion of resources. The model highlights the need for interactions between the city and its urban and rural peripheries to materialize in the management of food systems in terms of increasing food self-sufficiency, reducing waste and transforming production into organic farming (Zasada et al., 2019).

4. Aggregate indicators for measuring food security

There are several attempts to aggregate indicators that reflect food security. The following are the main aggregate indicators for measuring food security, according to the classifications established by the most important agri-food institutions:

Food Security Indicators (FAO)

An important role in establishing food security indicators is played by the FAO, through the Food Security Committee, which in 2011, together with numerous food and nutrition experts, established the publication of FAO Food Security Indicators. These indicators come from FAO publications and other publications of international bodies. FAOSTAT provides most of the data, more than 1 million records, in time series, and which includes agricultural statistics from 210 countries.

The aggregate indicators that characterize food security are: *availability, access, stability* and *use*. Each of the indicators is composed of simple indicators, which have a certain weight in the final indicator. According to FAO reports, in 2020 there were 768 million of people undernourished, 927.6 million of severely food insecure people and 2,368.2 million of moderately or severely food insecure people (Table 1).

Table 1. Selection of Food Security Indicators, 2020

Food Security Indicators	Unit	Value
Prevalence of undernourishment	%	9.9
Number of people undernourished	millions	768
Prevalence of severe food insecurity in the total population	%	11.9
Prevalence of moderate or severe food insecurity in the total population	%	30.4
Number of severely food insecure people	millions	927.6
Number of moderately or severely food insecure people	millions	2,368.2

Source: FAOSTAT (2020), https://www.fao.org/faostat/en/#data/F

Global Food Security Index

The Global Food Security Index (GFSI) created by the Economist Intelligence Unit, using data provided by FAO, the International Institute for Food Policy Research (IFPRI), the World Bank, EUROSTAT and other agencies, provides a ranking of countries on food security and safety, with the help of aggregate indicators, starting with 2012. A number of states were taken into account (in 2012 there were 105 states; in 2021 there were 113 states). The method consists in assigning points to each state, for each food security indicator, on a scale from 0 to 100. The state that has the maximum value for an indicator will receive 100 points, and the one with the minimum value will receive 0 points. The other countries will receive weighted points on this scale depending on the value of the indicator.

The 26 indicators are grouped into 3 groups: accessibility (6 indicators) and financial access (8 indicators); availability and quality and safety of food (use) (12 indicators).

Accessibility and financial access to food purchases refer to: food consumption expenditure as a proportion of total household expenditure, the proportion of the population living below or close to the global poverty line; GDP per capita (at purchasing power parity or PPP, exchange rates); the import of agricultural products, the presence of food security programs; price fluctuations.

Availability is measured in the indicators by: sufficient food supply at national level; public expenditure on agricultural research and development; agricultural infrastructure; volatility of agricultural production and the risk of political stability.

Food quality and safety measures the variety and nutritional quality of average diets through indicators: diet diversification, national nutrition standards programs; availability of micronutrients; protein quality, food safety, malnutrition. GFSI manages to make a comprehensive assessment of the indicators that characterize the security, safety and food policy of each country. The GFSI index is important because it measures the interaction between agricultural policies and food security, which is manifested primarily in the agricultural production of each state, even if food security is ultimately measured at the household and individual level. According to GFSI data released in September, 2021 Ireland was the most performant country based on its food security score with an overall score of 84.0 (Table 2). Austria, United Kingdom, Finland and Switzerland were the following countries that scored more than 80 points.

Table 2. Performance of countries based on their 2021 food security score

Rank	Country	Overall score	Affordability	Availability	Quality and Safety	Natural Resources and Resilience
1	Ireland	84.0	92.9	75.1	94.0	74.1
2	Austria	81.3	90.5	75.2	91.2	65.7
3	United Kingdom	81.0	91.1	72.7	89.6	69.0
4	Finland	80.9	91.7	66.2	93.8	75.1
5	Switzerland	80.4	89.0	76.9	86.4	65.1
6	Netherlands	79.9	89.7	73.7	92.2	61.2
7	Canada	79.8	87.6	77.7	94.5	54.4
8	Japan	79.3	90.0	75.7	83.4	61.9
9	France	79.1	90.3	67.0	92.1	67.5
9	United States	79.1	88.7	71.0	94.3	61.3

Source: GFSI (2021), https://impact.economist.com/sustainability/project/food-security-index/Index

Global Hunger Index (GHI)

The Global Hunger Index (GHI) is a multidimensional statistical tool designed to comprehensively measure and monitor hunger globally, regionally and nationally. Each year, the International Food Policy Research Institute (IFPRI) calculates GHI scores to assess its progress or lack of it in reducing hunger. GHI combines indicators into the following components: the share of malnutrition as a percentage of the population; the share of children under the age of five suffering from anemia; mortality rate of children under the age of five.

The latest dataset presented by IFPRI contains values utilized to compute the GHI for four periods: years 2000, 2005, 2010 and 2019 (IFPRI, 2019). Table 3 shows that the GHI for the 117 countries and 518 observations has a minimum value of 2.5 and a maximum value of 65.1.

Table 3. Global Hunger Index Indicators

Indicator	Min-max number of years	Countries / Obs.	Min / max value
Child Mortality	2000 / 2019 / 4	132 / 517	0.3 / 23.3
Child Stunting	2000 / 2019 / 4	132 / 518	0.7 / 64
Child Wasting	2000 / 2019 / 4	132 / 518	0.3 / 25.4
Global Hunger Index (GHI)	2000 / 2019 / 4	117 / 460	2.5 / 65.1
Undernourishment	2000 / 2019 / 4	117 / 461	1.7 / 71.5

Source: IFPRI (2019), https://www.landportal.org/pt/book/dataset/ifpri-ghi

Household Dietary Diversity Score (HDDS)

HDDS illustrates the number of food groups consumed by a household and allows us to assess the household's ability to access food, as well as its socio-economic status. In middle- and high-income countries, although there is an abundance of food, malnutrition is present through malnutrition and overweight. Systematic integration of nutrition in the evaluation of agricultural and food systems is needed (Nordhagen et al., 2022). Each food group has a score of 1 (if consumed) or 0 (if not consumed). Per household, the score can range from 0 to 12 and is equal to the total number of food groups consumed by the household.

Food Insecurity Indicator

In the assessment of food insecurity, a scale is used, Integrated Food Security Phase Classification, initially used for food security analysis in Somalia, and later accepted by international and national bodies. The IPC scale is made up of five phases and is intended to help governments and national and international humanitarian agencies to quickly understand the state of security in order to take appropriate action.

The main criteria that characterize the five phases are:

- *phase 1*, secure food (over 80% of households can meet their basic food needs);
- *phase 2*, unsafe food (in at least 20% of households, food consumption is reduced);
- *phase 3*, acute food crisis (at least 20% of households have significant deficits in food consumption);
- *phase 4*, humanitarian emergency (at least 20% of households face extreme gaps in food consumption; loss of livelihood);
- *phase 5*, humanitarian catastrophe (at least 20% of households face a total lack of food, over 30% of the population suffers from malnutrition, the mortality rate exceeds 2/10,000/day).

Standardized reference tables and evidence-based criteria have been developed to place a country or region in a particular phase of food insecurity, allowing for interoperability of basic results and evidence by comparison and questioning by analysts and decision within the community. Based on these data, global food insecurity situations have been compiled and mapped for overview.

The presentation of aggregate indicators shows a dynamic of them, caused both by the improvement of simple indicators, but especially to respond to the situations created by food insecurity in different geographical areas and special situations.

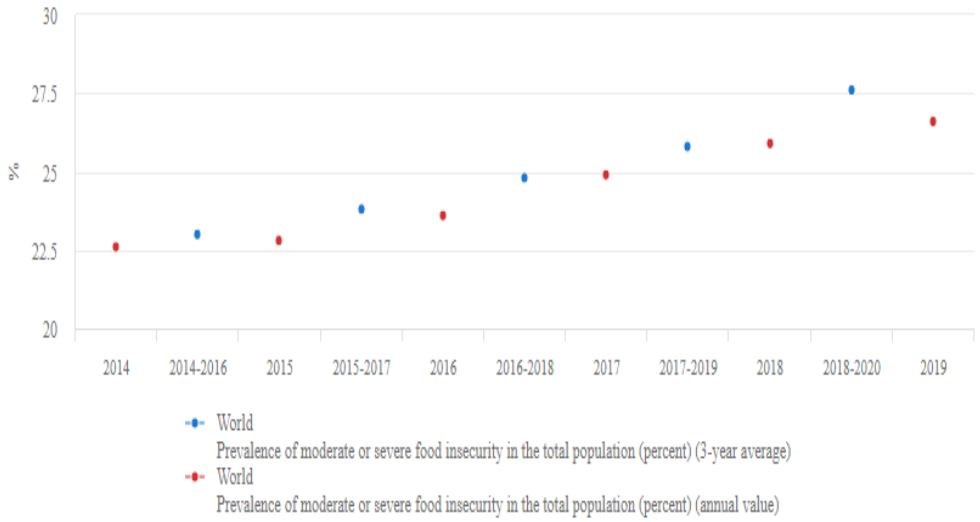

Figure 1. Prevalence of moderate and severe food insecurity in the total population (percent) (annual value)

Source: FAOSTAT (2020), https://www.fao.org/faostat/en/#data/FS

Based on the FAOSTAT values (2020), Figure 1 illustrates the prevalence of moderate and severe food insecurity in the total population. According to the available data, more than 25% of the total world population lives in moderate and severe food insecurity. On a three-year average, more than 27.5% of the total world population experiences moderate and severe food insecurity.

5. Conclusions

Food security plays a very important role when analysing the food independence of a state, the premise established thus being to guarantee the survival of the nation within its territorial limits. Thus, food security, analysed as a component of economic security must help to achieve the following goals: to ensure the production of adequate food; to modernize and stabilize the flow of agricultural products; to ensure access to the agricultural resources available to those who need them, in order to ensure the health of the population.

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