Development of Model Scenarios for Forecasting Food Production and Consumption in Asia in Context of Solving Global Food Problem

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Abstract. The article investigates the prospects of solving the global food problem by using trend, adaptive and integrated autoregressive models (Box-Jenkins and GLM models). The used models meet the criteria of statistical reliability and accuracy, which confirms the objectivity of the obtained estimates. Calculations have been performed world-wide, for Asia, West Asia and Iraq. The obtained results of the calculations show that in Asia, due to domestic resources, the population is provided with opportunities to meet the demand (according to the WHO standards) for cereals, fish and fish products, eggs and sugar plants. The volume of vegetable oils has almost reached parity; there is a slight excess of production, from 2.0% to 7.6%. At the same time, there is a significant shortage of potatoes, meat, milk, and vegetables, provided that the production maintains the trends which have developed in the last ten years. A rather difficult situation with the possibility of providing basic food products by the domestic market at the expense of own resources has developed in the countries of Western Asia. As for the most of basic products according to estimated assessment there has been a significant food deficit of food products. A particularly unfavorable and alarming situation might develop in Iraq. The results of calculations for all food products have shown, that there is no possibility to meet the needs of the population at the expense of own production. It requires the development of modern strategies for solving the global food problem and providing more favorable conditions for access to the world food market by improving the mechanism of regulating international food trade.

1. Introduction.
The globalization processes, unprecedented in scale and dynamics, exerting truly revolutionary influence on all structural subsystems of the world economy in the first quarter of the XXI century and opening qualitatively new resource opportunities for production, scientific and technological, innovative, financial and information progress of almost all countries and regions, have not been able to provide effective solutions to global problems of mankind so far. A special place in their system is occupied by the world food problem, related to providing the population with the food of necessary quantity and quality, as a basic condition for its existence and ensuring national security.

The current scale of the global food problem is evidenced, in particular, by the fact that against the background of 2% annual growth of global food production and 1.14% growth in world population [1], more than 850 million people worldwide are still denied access to the amount of food necessary for an active and healthy life. The total number of starving people in the world includes 25% of children aged under 5 years; 10% of children born in developing countries die from diseases caused by poor nutrition.
[2]; and billions of people suffer from micronutrient and vitamin deficiencies[3]. Moreover, the rapid increase in the global scale of food production at a much lower rate of world population growth is fraught with an immense additional problem of premature disposal of food waste. Suffice to say that globally up to a third of all food produced involved in the food chain is lost or wasted [4].

The global asymmetry in food production and consumption established in recent decades is reflected in the growing gap between the immense surplus of produced food and the enormous volumes of its premature utilization, on the one hand, and the acute shortage of food, on the other. This is evidence of the extremely vulnerable, in terms of food security criteria, state of the global food system, which can be fully understood only on the basis of a deep interdisciplinary synthesis of modern political economy, history and agro-ecology [5]. Only such an approach is able from the modern methodological standpoint of globalism to scale the global process of food reproduction with the identification of its specific features and characteristics, arising primarily from national and regional characteristics of food production and consumption.

2. Analysis of recent research and publications.
The scientific research of modern global problems is characterized by the complexity of consideration and focused on predictive modeling of solution variants. Problems of food supply of population, uneven production and consumption of food in different countries of the world were reflected in the works of foreign and domestic scientists: Malthus (1998), M. Pugachiov (2014), A. Sen (1979), J. Stoliarchuk (2009) and others [6, 7, 8, 9]. At the same time, existing scientific approaches to assessment of the food problem on a global scale that are described in the works of B. Suresh (2014), S. Gajanan (2014), S. Prabuddha (2014) [10] come out of characteristics of food supply security through a defined limiting consumer goods basket and afterwards determine the course of the development of agricultural industry. In the works of A. Satinder (2015), Y. Motarjemi (2014), H. Lelieveld (2014), C. CharisGalanakis (2016), Stein T. Holden (2016), H. Ghebru (2016) [11-15] a system of indicators has been used to evaluate food problem. The indicators are combined into three groups: correspondence between equivalent market food quantity and minimal needs of the public; correspondence between equivalent market price of food ration and income of all social groups, and those which characterize the realization of the two main quantitative criteria of food security situation. At the same time, the existing scientific approaches to the assessment of the food problem on a global scale remain insufficiently researched and need further improvement.

3. Uninvestigated parts of general matters defining.
Uneven development of the world economic system entities dramatically increases the tendency to aggravation of the global food problem, which has been only deepened by permanent global crisis. Existing mechanisms of formation and distribution of world food resources, international trade therein, and food aid do not create an efficient system to ensure sufficient food support around the world. Therefore, it is important to reason the forecast ratio of deficit (shortage) and domestic production for certain types of food to satisfy the demand under WHO standards.

4. The research objective.
The purpose of the article is to identify the most and least vulnerable countries in terms of food security through the forecast ratio of deficit (shortage) and domestic production for certain types of food to satisfy the demand under WHO standards of the world, Asia, West Asia and Iraq in particular.

5. Presentation of the main material.
Determination and assessment of the possibility of ensuring a balance of supply and demand for certain types of food can be performed on the basis of forecast estimates of production and possible consumption.

Changes in agricultural production volumes are usually presented in the form of time series or dynamic series (1). Levels of series \( Y_z \) are formed under the combined action of plurality of factors, the influence of which can be long or short-term.

When modeling dynamic series, as a rule, the causal mechanism of level formation is not taken into account in the explicit definition, i.e. the dynamic process is defined in general as a function of time, i.e. as \( \bar{Y}_t = f(t) \).

Statistical methods for studying and modeling dynamic series are based on the assumption that series levels can be represented as an additive function of several components reflecting the patterns and randomness of development, in particular, as the sum of the following components:

\[
\bar{Y}_t = f(t) + V_t + S_t + E_t, \quad (1)
\]

where \( \bar{Y}_t \) is a calculated value of the levels;

\( f(t) \) is a long-term development trend determined by time or previous levels. Under these conditions:

\[
f(t) = U_t + Y_{(t-e)}
\]

where \( U_t \) is a trend component, modeling the trend as a function of time;

\( Y_{(t-e)} \) is an autocorrelation component characterizing the dependence of the levels of series on their previous values with the corresponding ending lag \( e_0, e=1,2,3 \);

\( V_t, S_t \) are periodic \( V_t \) and seasonal \( S_t \) components;

\( E_t \) is a random component that characterizes the change in the levels of series under the influence of other factors that are not determined by the above [17].

Identifying the future production volumes and demand for certain types of agricultural products used as food is based on modeling trends and patterns of relevant indicators and their extrapolation to a certain period of bias.

Depending on which component is dominant in the formation of series levels, the following models are used to approximate trends or patterns. For example, in the presence of \( U_t \) trends, analytical series or growth curves are mostly used, in which the change of levels is defined as a function of time \( \bar{Y}_t = f(t) \).

The main analytical forms of growth curves reflecting trends are linear, parabolic, hyperbolic, logarithmic, etc.

If there is an autocorrelation component, autoregressive models are used, paired or multiple and integrated. In most cases, if the random component also has a significant impact, it is advisable to focus on integrated models that combine autocorrelation and random components. The most common are the Box-Jenkins model or the model of autoregressive moving average [ARMA (p, d, q)] and its modification GLM (p, q), where p, d, q are the parameters of model identification, in particular, p is the order of the auto regressions, d is the order of successive differences, q is the order of the moving average.

The general approach to modeling of dynamics is based on the consistent resolving of the following tasks:

- substantive justification of the main components of the formation of time series levels;
- selection of the optimal model for approximation;
- identification of the model, which includes evaluation of parameters, testing of hypotheses according to its statistical reliability and statistical accuracy;
- substantive analysis of the model;
- subject to statistical reliability, the forecast estimates are determined;
- on the basis of extrapolation for a certain period of bias.

The choice of the optimal model of the time series approximation is based on the substantive analysis and on the following combination of formal approximation criteria: \( \min \sum (Y_t - \bar{Y}_t)^2 \) or LSM criterion, max F criterion and min \( E_{relat.} \), where F criterion is the Fisher-Snedekor criterion, provided that the
statistical equation $F_p > F_L$ corresponds to the criterion of statistical reliability with probability $p = 1-2$ and level of reliability $L$; $E_{relat.}$ is a relative approximation error, provided that the $E_{relat.} < 15.0\%$ model meets the requirements of statistical accuracy.

The general approach to forecast estimates of production, consumption and determination of sufficiency (insufficiency) of certain types of products for 2020-2023 nutrition years is based on the following starting points.

Based on the optimal models of approximation of trends in population change and production of certain products, their forecast values for 2020-2023 are calculated.

Taking into account the share used for food, the corresponding volumes of products that can be consumed by the population are determined.

Consumption standards assess the required need (demand) for certain food products, and the basic norms developed by the WHO are selected as the basic standards. The ratio of production volumes that can be used as food and the calculated in accordance with the required volumes of demand, determines the level of balance of the domestic consumption market for individual regions and, accordingly, the surplus or shortage volume of products for each region being analyzed.

In general, the Table 1 shows all around the world forecast estimates of production volumes of certain types of products and identifies possible volumes that are used for food. All models that were used for the forecast meet the criteria of statistical reliability and accuracy, which confirms the objectivity of the obtained estimates. As can be seen from the above calculations, provided that the trends and patterns developed during 2010-2018 are preserved, the volume of production of certain types of agricultural products for the next four years, from 2020 to 2023, have a slight increasing trend, that includes production of milk, meat, vegetables, eggs, fish and fish products. At the same time, the production volumes of cereals, potatoes may decrease, while the volumes of fruits and sugar plants remain almost unchanged.

**Table 1.** Forecast estimates of population size and production of basic products types for 2020-2023.

| Indicators               | Conventional sign | Statistical equation and model | Statistical reliability criteria | Forecast estimates of production volumes | Including those used for food |
|-------------------------|-------------------|--------------------------------|---------------------------------|-----------------------------------------|-----------------------------|
|                         |                   |                                |                                 | 2020 | 2021 | 2022 | 2023 | 2020 | 2021 | 2022 | 2023 |
| Population size, mil. people | $S_1$   | Box-Jenkins or ARMA model (1,1,1) $E_{relat.}=0,0001\%$ $F_p=280,9$ | $F_p > F_L$                     | 7796,2 | 7879,9 | 7962,8 | 80463 | 2341,7+118,4t-4,981t^2 | $E_{relat.}=1,2\%$ |
| Cereals, mil. tons $^a$ (0,74) | $Y_1$  | $F_p(V_1=2)$ $F_p(V_1=6)$ $58,9$ | $F_p(V_1=2)$ | 3011,3 | 3045,2 | 3039,0 | 3022,9 | 2250,6 | 2253,4 | 2248,9 | 2236,9 |
| Potatoes, mil. tons $^b$ (0,71) | $Y_2$  | GLM or ARMA model (2,1) $E_{relat.}=0,8\%$ $F_p=4,4$ | $F_p(V_1=2)$ | 367,1 | 365,9 | 366,5 | 366,2 | 260,6 | 259,8 | 260,2 | 260,0 |
Continuation of table 1.

| Product                  | Y_i | Model or Parameters | Equation Type | Parameters | Values | Values | Values | Values | Values | Values | Values |
|--------------------------|-----|---------------------|---------------|------------|--------|--------|--------|--------|--------|--------|--------|
| Meat, mil. tons (0.997)  | Y_1 | GLM or ARMA model (2,1) | | E_{rel} = 0.1%, F_y > F_k | 333.3  | 336.9  | 340.2  | 343.3  | 332.3  | 335.8  | 339.2  | 342.3  |
| Milk (without butter), mil. tons (0.887) | Y_4 | GLM or ARMA model (2,1) | | E_{rel} = 0.8%, F_y > F_k | 795.9  | 802.6  | 809.0  | 815.1  | 705.9  | 711.9  | 717.5  | 723.0  |
| Vegetables, mil. tons (0.34) | Y_5 | Box-Jenkins or ARMA model (2,2,1) | | E_{rel} = 0.4%, F_y > F_k | 1108.6 | 1120.9 | 1137.8 | 1147.2 | 376.9  | 381.1  | 385.5  | 390.0  |
| Sugar plants, mil. tons (0.34) | Y_6 | Y_o=2200.88-283.3t + 0.1t^2 | | E_{rel} = 0.6%, F_y > F_k | 2175.1 | 2177.3 | 2179.1 | 2180.6 | 739.5  | 740.3  | 740.9  | 741.4  |
| Eggs, tsd. tons (0.892) | Y_7 | Box-Jenkins or ARMA model (1,1,1) | | E_{rel} = 1.6%, F_y > F_k | 91888.1 | 94591.3 | 97294.1 | 99996.9 | 81964.2 | 84375.4 | 86786.3 | 89197.2 |
| Fish and fish products, mil. tons (0.885) | Y_8 | Box-Jenkins or ARMA model (1,1,1) | | E_{rel} = 0.9%, F_y > F_k | 180.9  | 183.9  | 186.9  | 189.9  | 160.1  | 162.7  | 165.4  | 168.1  |
| Fruits, mil. tons (0.872) | Y_9 | GLM or ARMA model (1,1) | | E_{rel} = 1.2%, F_y > F_k | 2158.4 | 2157.7 | 2158.1 | 2158.1 | 1882.1 | 1881.5 | 1881.9 | 1881.9 |
| Vegetable oil, mil. tons (0.56) | Y_10 | Y_{n}=142.8+8.484t-0.105t^2 | | E_{rel} = 0.1%, F_y > F_k | 208.1  | 215.8  | 223.7  | 231.8  | 116.5  | 120.8  | 125.3  | 129.8  |

* The share of products used for food is shown within the brackets

Calculated by the author

Taking into account the consumption norms, the Table 2 shows the possible demand for basic food products and the surplus (+) or shortage (-) of their production, which may occur worldwide, subject to preservation of the agricultural production trends developed over the past decade.

The most significant shortage of production to meet the possible demand of the population according to the WHO standards has developed for basic food products, including meat, milk, potatoes and vegetables. For example, as of 2023, the shortage of meat in the world as a whole could reach 502.6 million tons, which is almost 1.5 more than its possible production for food consumption. The deficit of
milk may amount to 2334.6 million tons, which is more than three times (3.22 times) higher than the forecast estimates of production volumes. These calculations show that every year, starting from 2020, the shortage volumes of these types of food will increase. The largest shortages are revealed in the production of meat (76.3%), potatoes (70.1%), and vegetables (65.1%).

Table 2. Ratio of production and demand for basic food products (forecast estimates) in the world

| Types of products, unit of measurement | Production for food consumption | Demand according to the WHO standards | Ratio of production for food consumption to demand |
|---------------------------------------|---------------------------------|----------------------------------------|-----------------------------------------------|
|                                       | 2020   | 2021   | 2022   | 2023   | 2020   | 2021   | 2022   | 2023   | 2020 % to demand | 2021 % to demand | 2022 % to demand | 2023 % to demand |
| Cereals, mil. tons                    |        |        |        |        |        |        |        |        |                  |                  |                  |                  |
|                                      | 177    | 2334.6 | 2334.6 | 2334.6 | 2334.6 | -1338.4| -1338.4| -1338.4| -1338.4          | -1338.4          | -1338.4          | -1338.4          |
| Potatoes, mil. tons                   |        |        |        |        |        |        |        |        |                  |                  |                  |                  |
|                                      | 105    | 332.3  | 335.8  | 339.2  | 342.3  | -486.3 | -486.3 | -486.3 | -486.3           | -486.3           | -486.3           | -486.3           |
| Milk, mil. tons                       |        |        |        |        |        |        |        |        |                  |                  |                  |                  |
|                                      | 380    | 705.9  | 711.9  | 717.5  | 723    | -2256.7| -2256.7| -2256.7| -2256.7          | -2256.7          | -2256.7          | -2256.7          |
| Vegetables, mil. tons                 |        |        |        |        |        |        |        |        |                  |                  |                  |                  |
|                                      | -4.24  | -34.4  | -36.6  | -38.2  | -39.2  | -609   | -609   | -609   | -609             | -609             | -609             | -609             |
| Eggs, mil. tons                       |        |        |        |        |        |        |        |        |                  |                  |                  |                  |
|                                      | 180.21 | 1882.1 | 1881.5 | 1881.9 | 1881.9 | 770.2  | 788.8  | 796.3  | 804.6            | -1102.5          | -1102.5          | -1102.5          |

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These calculations show that, due to the deficit of production of basic food products (meat, milk, vegetables, potatoes) in the world, a fairly high proportion of malnourished people will remain unchanged; according to forecasts for 2023 their total number may reach 816.4 million of persons or 10.1% of the world's population.

The analytical calculations have been performed for individual regions, Asia (Table 3), West Asia (Table 4) and Iraq (Table 5).

The ratios presented in the Table 3 of the demand for basic food products and domestic production volumes in Asia as a whole show that due to domestic resources the population is provided with opportunities to meet demand (according to the WHO standards) for cereals, fish and fish products, eggs and sugar plants.

Table 3. Forecast estimates of production volume and demand (according to the WHO standards) for certain types of products in Asia in 2020-2023
In terms of volumes of vegetable oils, there occurred almost parity with a slight excess of production, from 2.0% to 7.6%. At the same time, there is a significant shortage of potatoes, meat, milk, and vegetables, provided that the production trends of the last ten years are maintained. For example, the shortage for potatoes as of 2020 - 2023 may reach about 74.0% of total demand, for meat - up to 68.9%, for milk - about 82%, and for vegetables - more than half of the demand (54.0 %).

The situation that may occur in the domestic food market in Asia as a whole is quite unbalanced, especially for basic products. In this regard, scenarios should be developed in order to compensate for the shortage of certain types of products. If the situation remains the same as forecasted, the share of malnourished people may reach, for example, 402.7 million people as of 2023. Almost 8.5% of the total population of Asia or almost every 11-12 person can get into the contingent of malnourished people.

A rather difficult situation with the possibility of providing basic food products at the expense of the domestic resources developed in the countries of Western Asia. According to forecast estimates for most of the basic products, a significant shortage of food, which can be met at the expense of the domestic market, occurred (Table 4). For example, the shortage of potatoes to meet demand at the level of the WHO standards reaches on average 79%, for meat and vegetables - about 68.5-68.0%, for milk - 71%.

There is a shortage by one third for sugar plants and consumption of fish and fish products. Only the production of cereals and vegetable oil can meet the needs of the population through the domestic production, and much of it can even be export-oriented. Due to food shortages, the share of malnourished people is forecasted to reach 11.3%, which will be about 33.1 million people as of 2023.

Table 4. Forecast estimates of production volumes and demand (according to the WHO standards) for certain types of products in Western Asia in 2020-2023

| Types of products, unit of measurement | 2020 | 2021 | 2022 | 2023 | 2020 | 2021 | 2022 | 2023 | Surplus (+) or shortage (-) |
|---------------------------------------|------|------|------|------|------|------|------|------|-----------------------------|
| Population size, mil. people          | 279.64| 284.04| 288.53| 293.07|      |      |      |      | 11.32 | 11.43 | 11.43 | 11.43 |
| Of whom malnourished, %               | 11.32| 11.43| 11.43| 11.43|      |      |      |      | 11.32 | 11.43 | 11.43 | 11.43 |
| Cereals, mil. tons                    | 32.2 | 32.3 | 32.3 | 32.3 | 12.32 | 12.32 | 12.32 | 12.32 | 14.25 |
| Meat, mil. tons                       | 29.36| 29.80| 30.30| 30.80| -19.80| -20.20| -20.60| -21.10| -21.10|
| Milk, mil. tons                       | 106.26| 107.90| 109.64| 111.37| -75.70| -76.50| -77.60| -78.80| -78.80|
| Vegetables, mil. tons                 | 38.86| 39.50| 40.10| 40.70| -4.80| -4.30| -4.10| -3.70| -3.70 |
| Eggs, mil. tons                       | 25.83| 26.24| 26.64| 27.05| -4.80| -4.30| -4.10| -3.70| -3.70 |
| Sugar plants, mil. tons               | 10.63| 10.80| 10.96| 11.14| -3.63| -3.54| -3.45| -3.35| -3.35 |
| Vegetable oil, mil. tons              | 3.64| 3.69| 3.75| 3.81| -0.40| -0.40| -0.40| -0.40| -0.40 |
| Fish and fish products, mil. tons     | 4.78| 4.97| 5.17| 5.17| -0.78| -0.98| -1.18| -1.38| -1.38 |
| Fruits, mil. tons                     | -6.8 | -6.8 | -6.8 | -6.8 | -6.8 | -6.8 | -6.8 | -6.8 | -6.8 |

A particularly unfavorable and alarming situation might develop in Iraq. As the calculations (Table 5) for all food products show that there is no possibility to meet the needs of the population through the
domestic production. According to the forecast estimates for 2020-2023, there will be a shortage of cereals by 94-96.7%, milk - by 95-97%, meat - almost completely (by 99.2%), sugar plants and fruits - by 98.2 %.

**Table 5.** Forecast estimates of production volumes and demand (according to the WHO standards for certain types of products in Iraq in 2020-2023

| Types of products | Unit of measurement | 2020 | 2021 | 2022 | 2023 | 2020 | 2021 | 2022 | 2023 | Surplus (+) or shortage (-) |
|-------------------|---------------------|------|------|------|------|------|------|------|------|----------------------------|
| Population size, mil. people | | 40,24 | 41,05 | 41,82 | 42,54 | -811,9 | 17,2 | -1202,4 | 25,0 | -1404,8 | 28,7 | -1416,7 | 28,5 |
| Of whom malnourished, % | | 23,5 | 23,77 | 24,0 | 24,24 | -3498,0 | 82,8 | -3587,0 | 83,2 | -3634,3 | 82,8 | -3697,2 | 84,2 |
| Cereals, mil. tons | | 3896,2 | 3600,5 | 3486,0 | 3560,5 | -14359,4 | 93,9 | -14941,6 | 95,8 | -15273,5 | 96,1 | -15377,8 | 96,2 |
| Potatoes, mil. tons | | 227 | 228,8 | 228,2 | 227,2 | -4119,0 | 94,8 | -4204,6 | 94,8 | -4288,4 | 94,9 | -4367,1 | 96,7 |
| Meat, mil. tons | | 727,2 | 723,3 | 756,8 | 769,5 | -3498,0 | 82,8 | -3587,0 | 83,2 | -3634,3 | 82,8 | -3697,2 | 84,2 |
| Milk, mil. tons | | 931,8 | 657,4 | 618,1 | 787,4 | -14359,4 | 93,9 | -14941,6 | 95,8 | -15273,5 | 96,1 | -15377,8 | 96,2 |
| Vegetables, mil. tons | | 297,2 | 288,9 | 275,9 | 268,8 | -5296,1 | 94,7 | -5417,1 | 94,9 | -5537,1 | 95,3 | -5644,3 | 97,1 |
| Eggs, mil. tons | | 300,9 | 304,7 | 307,4 | 310,3 | -70,9 | 19,1 | -74,6 | 19,7 | -79,0 | 20,4 | -82,8 | 21,0 |
| Sugar plants, mil. tons | | 13,3 | 13,4 | 13,4 | 13,4 | -1515,8 | 99,1 | -1546,6 | 99,1 | -1575,8 | 99,1 | -1603,0 | 99,2 |
| Vegetable oil, mil. tons | | 461,5 | 429,7 | 447,2 | 473,3 | -61,6 | 11,8 | -104,0 | 19,5 | -96,5 | 17,8 | -79,7 | 14,4 |
| Fish and fish products, mil. tons | | 91,2 | 96,2 | 101 | 98,7 | -633,1 | 87,4 | -642,7 | 87,0 | -651,8 | 86,6 | -667,0 | 87,1 |
| Fruits, mil. tons | | 60,1 | 63,9 | 67 | 70,2 | -3963,9 | 98,5 | -4041,1 | 98,4 | -4115,0 | 98,4 | -4183,8 | 98,3 |

As a result of such processes, about 24.2% of the population may fall into the contingent of malnourished. As can be seen from the above forecast estimates, the main opportunities to supply the population of the country are primarily related to food imports. But at the same time programs should be worked out in order to develop domestic production and increase its efficiency.

### 6. Conclusions.

The above calculations show that as for basic food, there is no possibility of providing the population with a balanced nutrition through domestic production in Asia. The situation in Iraq is particularly worrying, requiring the development of modern strategies to address the global food problem.

Solving the food problem remains the most pressing issue of the current stage of world economic system development. According to FAO estimates, a declining trend of starvation in world has been observed over the past two decades. The share of the starving population has declined much more than the absolute number of starving people, but in developing countries a significant part of population still does not consume the necessary amount of food to ensure an active and healthy life.

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