

For the *second level* of land use intensity, the districts with the coefficient of ecological stability of the agro-landscape in the range 0.35-0.5 entered. At the same time, the lands of these regions are ecologically stably unstable. The *third level* covers the land districts mostly stably unstable, since they have a high land use intensity. The value of the coefficient of ecological stability of the agro-landscape is less than 0.35; the anthropogenic load factor is over 3.4 points; the rate of plowing of the territory is over 70%; ratio of agricultural land is over 90%; coefficient of agricultural development of the territory is over 80%, recreational capacity is less than 0.25; it characterizes the extremely complex state of land use. The districts with a high land use intensity occupy 43.9% of the area that is fairly large part of the territory of the Cherkasy region. Thus, lands of Cherkasy region have intensive natural and economic use. The most vulnerable were the lands that have a third level.

### **Results of assessment**

Based on the assessment of intensive natural and economic use of lands in the Cherkasy region, indicators for 20 regions were determined. Taking into account the value of the coefficient of ecological stability of the agro-landscape, three levels of intensity of natural and economic land use were identified: moderate, medium and high. The boundaries of indicators values are defined. The lands of Cherkasy, Kaniv and Chyhyryn districts are ecologically medium stable and refer to a moderate level. To the medium level of land use intensity, we defined the lands of 7 regions, which are ecologically stably unstable, to the high we defined the lands of 10 districts, which are environmentally stably unstable. The lowest rates had the lands of Khrystynivka, Zhashkiv and Drabiv districts. At the same time, coefficient of ecological stability of the agro-landscape is less than 0.26. These lands have a complex state of land use. Therefore, special attention should be paid to the land use in these districts.

### **Conclusions**

In order to improve land use, it is necessary to define a strategy for optimizing the land use of districts at certain levels and to develop a balanced land use structure at the regional level. Prospects for further research are to conduct an assessment of the intensity of natural and economic land use at the national level that will allow defining a strategy of rational land use and land protection in Ukraine and form directions for the development of land use in the regions of Ukraine.

## **5.2 MODELLING PROSPECTS OF GLOBAL FOOD PROBLEM SOLUTION WITHIN THE CONTEXT OF ASYMMETRIC WORLD DEVELOPMENT**

### **Introduction**

Solution of the food problem is the most topical issue of the current stage world economic system development. In accordance with the *FAO* estimates, the global famine scale has been decreasing for two previous decades. Malnourished population share has been reduced to a much larger extent than an absolute quantity of the malnourished people, but in the developing countries a substantial share of the population still fails to consume the amount of food products necessary for active and health life.

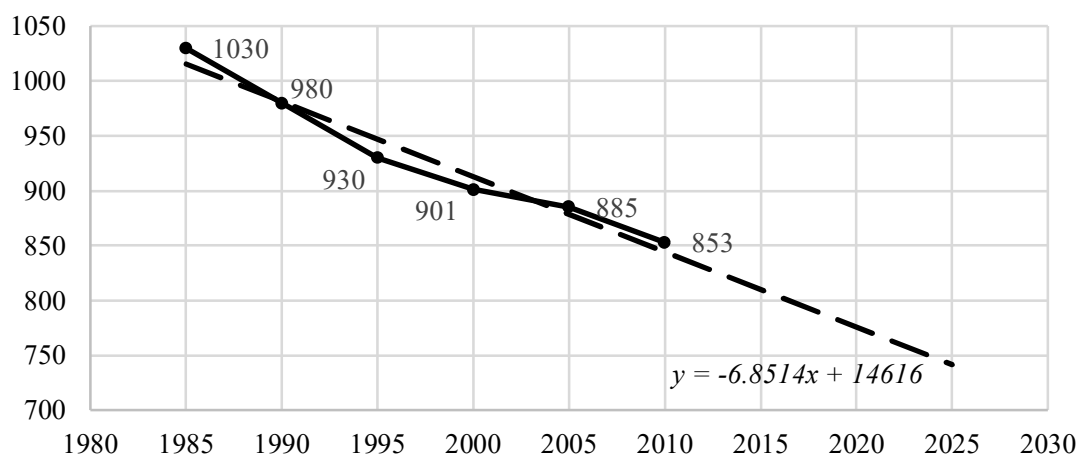
## Literature Review

Considerable attention is paid to the research of the global food problem by national researchers. Fundamental works of the scientists working in this area, viz. Berehovi (2011), Bilorus (2003), Luzan (2011), Paskhaver (2006), Sabluk (2008), Vlasov (2006) et al have developed principal evaluation methods and methodology of registration of various factors' influence forming country's food security and agro development, but the question related to the causes forecasting, mechanisms of the global food issue development, its tendencies by means of mathematical models are covered insufficiently. At the same time, existing scientific approaches to the food problem evaluation on a global scale described in the works of Uusitalo (2015), Lehtikoinen (2015), Helle (2015), Myrberg (2015), Pianosi (2015), Sarrazin (2015), Wagener (2015) practiced Global Sensitivity Analysis (*GSA*), that is increasingly being used in the development and evaluation of environmental models. They have presented Matlab/Octave toolkit for *GSA* application. In the works of Lokers (2016), Knapen (2016), Janssen (2016), Yke van Randen (2016), Jansen (2016) has been suggested to use data processing technologies based on highly productive computations, to create new opportunities for intensive data processing in a diverse agro-ecological sector. In the works of Eerens (2014), Haesen (2014), Rembold (2014), Urbano (2014), Tote (2014), Bydekerke (2014) it is emphasized that monitoring of the global food problem is vital taking into consideration strong year-to-year variability, growing competition for natural resource and effects of climate change on agriculture. They suggest to apply software *SPIRITS* for the global food problem evaluation, but the proposed autonomous toolkit is developed for the environmental monitoring in order to receive accurate and evidence-based information for crop production; so, it is impossible to get a clear understanding of the global food problem by means of the mentioned toolkit. Mason-D'Croz (2016), Vervoort (2016), Palazzo (2016), Islam (2016), Lord (2016), Helfgott (2016), Havlík (2016), Peou (2016), Sassen (2016), Veeger (2016), Arnout van Oesbergen (2016), Arnell (2016), Stuch (2016), Arslan (2016), Lipper (2016) in their works developed methods for the application of scripts that provide alternative futures to inform food policy makers. The implementation process of the proposed regional scripts for South-East Asia is described in their scientific work. Regardless of a great number of scientific works in this area, the issues on prospects for the global food problem solution with the help of mathematical models remain under-researched.

The *aim of the article* is to study the prospects of the global food problem solution by means of mathematical models built on the basis of biological neural networks operation.

*Empirical results and discussion:* Analysis of target indicators of the global food problem solution provided in the Millennium Development Goals inspires optimism and hope for solution of the tasks set. Thus, the malnourished population share is annually reduced by 0.5%. If this tendency persists, then malnourished population share will amount to 12.8%, which is just 1.1% higher than the target indicator of the Millennium Development Goals. Forecasting of indicators of the absolute quantity of malnourished people in the world is of equal importance. If relative future stability

of absolute values of the malnourished people, average level of the series, average absolute increment and average growth rate are assumed, a conclusion can be made that in time this indicator will tend toward zero or that complete solution of the global food problem may be reached (Figure 5.2.1).



**Figure 5.2.1: Forecast of solution of the global food problem on the basis of the regressive model, mln malnourished people**

Source: calculated by author

In general, this forecast for the period  $(n + t)$  can be presented as a function (5.2.1), where  $Y_{n+t}$  is a forecast value of the level of the time series;  $l$  is a period of advance;  $Y_n$  is a level of the series taken as an extrapolation base;  $a_i$  are trend equation parameters.

$$Y_{n+t} = f(Y_n, l, a_i) \quad (5.2.1)$$

The malnourished people shall include the persons, who consume less than 1,700 calories per day. However, application of this approach, when the forecast level is equal to the average value of the series levels in the past provides a predictive point estimate. Exact match of these estimates to the actual data is unlikely. Therefore, this forecast should not be perceived as an authentic one unequivocally in the long term period, although for one or two-year forecast these approaches enable gaining results with a high authenticity level.

Forecasting of the process of the food problem solution is rather complicated task, which requires attention of considerable number of factors including asymmetric information. That is why the US Department of Agriculture has involved mathematical modelling tools, which consist of 76 partial equilibrium models in order to assess prospects of solution of the global food problem. These models are mainly focused on assessment of the prospects of the poorest world regions (African and Asian countries). Forecast of food problem solution has been carried out by means of assessment of the food products consumption level by different population groups. For this purpose, the population has been divided into five groups subject to the scope of food consumption (from the lowest to the highest scope) in each country. Herewith, the scope of food consumption has been assessed for three product groups only: cereals, edible roots and other. This complicated modelling procedure required several powerful computers simultaneously.

Naturally, several powerful computers with the cutting-edge mathematical modelling kit cannot be used within the framework of our research. Therefore, the mathematical model of the National Scientific Centre "Institute of Agrarian Economy" based on the neural networks combining autoregressive models with neural components of various complexity levels, has been used to model prospects of the global food problem solution. This combination improves quality of the forecast in the context of the asymmetric information on the present and future of the world economy and its food system. Mathematical models built on the principle of operation of biological neural networks (neural networks) have been widely used in forecasting recently. As opposed to regressive models, they are enable taking into account asymmetry of information, non-linear connections, uncertainty of economic development, unpredictable quick changes in subjective factors.

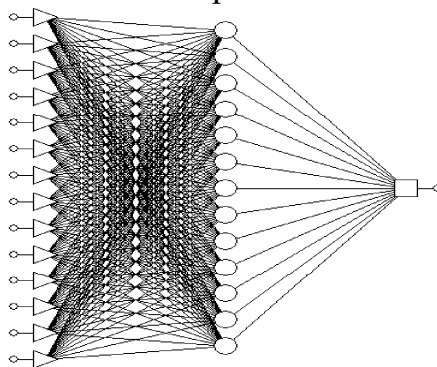
To determine the current neuron status ( $S$ ), the weighted total of indicators at the entry point is calculated by formula (5.2.2), where  $x_i$  and  $w_i$  are the indicators processed by the neuron.

$$S = \sum_{i=0}^n x_i \times w_i \quad (5.2.2)$$

The outgoing result of the neuron is characterized by the functions of its state. It may be presented in different ways. Mainly, it is a non-linear function, which is called the activation function. One of the most common ones is a non-linear function with saturation, so-called logistical function or sigmoid function (i.e. S-shaped function).

Neural networks are used to solve complicated non-formalized tasks without established analytical solution algorithms, incomplete or controversial incoming data, which correspond to the forecast on the global food problem to a certain extent. Principal spheres of neural networks application include recognition of target attributes of the researched objects, dynamic forecasting of numeric values of the object in time and automatic grouping of objects.

When world economy development processes and the food problem are modelled, in particular, neural networks enable determining the most influential ones, which are most likely to define changes in food provision and the global food problem due to group recording of a large number of independent variables. The modelling process is presented in *Figure 5.2.2* in the simplified form.



**Figure 5.2.2: Functional diagram of food problem development modelling on the basis of neural networks**

*Source: adapted by author according to Matviichuk (2011)*

Due to uncertainty increase in economic development, unpredictable changes in the food problem and asymmetry of information, establishment of interconnections among principal macroeconomic indicators by means of mathematical tools is very complicated. Therefore, hybrid models combining regressive and autoregressive components and artificial neural networks have been used in our research. This combination is quite efficient, as it is able to reproduce complicated non-linear processes by means of the econometric tools. In particular, autoregressive neural networks (*AR-NN*) enable exercising behavior of linear oscillations around the average the level of which can change in time on a non-linear basis. More complicated case is smooth transition regressive hybrid models (*ST(A)R*) and smooth transition multi-regime hybrid models in which the behavioral structure not only of the mean value (intersection), but also the rest of beta coefficients are non-linear. By contrast with the regressive models, when preconditions for improvement or deterioration of the global food problem state, which are restricted to the continued development assumption the main past tendencies in the future are formalized and identified, neural networks take into consideration asymmetry of information, growing uncertainty and impact of subjective factors in the context of economic instability and crises, unpredictable changes in tendencies and identify non-linear interconnections.

To determine preconditions of changes in the state of the food problem, correlation and regression analysis has been conducted; comparative analysis of its deliverables with the ones received from application of neural networks both to the internal and external factors has been performed. The conclusion has been made that synthesized feed-forward back propagation (*FFBP*) neural networks are most flexible and efficient when working with economic data. They are the structures, which approximate any continuous multivariable function with sufficient precision. The *FFBP* architecture includes two or three levels: input, hidden and output. The input and output levels perform linear transformations and aggregation of input data; hidden level determines the main attributes of the neural network, which perform logical "switch", i.e. "if..., then..." rather than linear ones. They can be presented mathematically in the form of the logic sigmoid function (5.2.3), where  $\psi(s)$ ,  $\psi(s) \in R$  is a value of the neuron activation function;  $s$ ,  $s \in R$  is a weighted total of input values (artificial neuron entry);  $k$ ,  $k > 0$  is a parameter, which defines curvature of the function, speed of its transition from zero-close values to the values close to one:

$$\psi(s) = \frac{1}{1 + e^{-ks}} \quad (5.2.3)$$

In practice, the most common autoregressive model with the neural feed-forward back propagation component with one output is neural network *AR-NN*( $p$ ,  $q$ ) in the following form (5.2.4), where  $y_t$  is a dependent variable in the current period;  $w_t$  is a vector of order ( $1 \times p$ ) regressors (lag values of dependent variables);  $\beta_0'$  is a vector of linear parameters of the order autoregression ( $1 \times p$ );  $q$  is a hidden layer neuron quantity;  $\beta_j$  is a vector of weight coefficients of the output layer of the neural network of the order ( $1 \times p$ );  $\gamma_j'$  is a weight coefficient vector of the hidden layer of the order ( $1 \times p$ );  $G(\gamma_j' w_t)$  is a hidden neurons activation function;  $\varepsilon_t$  is a vector of independent identically distributed remains.

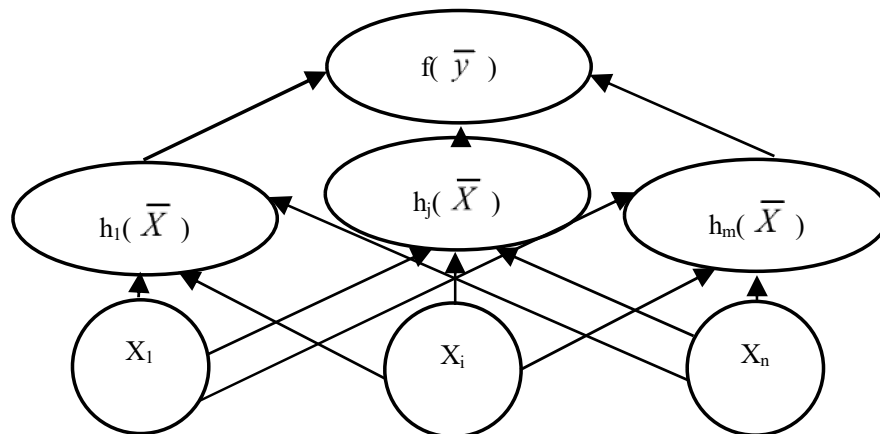
$$y_t = \beta_o' w_t + \sum_{j=1}^q \beta_j G(\gamma_j' w_t) + \varepsilon_t, \quad (5.2.4)$$

In the model the forecasting object is an absolute value of the quantity of malnourished people in the world. This indicator is most representative to assess the state of the global food problem. Modelling has been performed on the basis of assessment of two factor groups, which have internal and external impact on a provisional basis. The data have been taken for the period from 1980 until 2015. The source data on the state of the food problem have been taken from the indicators of socioeconomic development of Oxford Economics, the British analytical service.

This analytical service was founded in 1981 as a commercial enterprise in the business college of Oxford University in order to provide an economic forecasting and modelling for British companies and financial institutions. Throughout the period of its existence, Oxford Economics has turned into one of the leading global independent advisory centers for the development of reports, forecasts and provision of analytical tools for 200 countries, 100 industrial sectors and over 3,000 cities. Global economic and industrial models and analytical tools, which are the best in their class give an unprecedented opportunity to forecast world market tendencies, perform econometric modelling, scenario planning and analysis of economic impact on markets, research into and assess socioeconomic processes and their impact on business. Empiric data for modelling have been gained on the basis of a set of 14 factors, which have been selected from among 238 indicators of the general global socioeconomic development of Oxford Economics, the British Analytical Service. All data available have been collected as to each measurement of the food problem, and changes have been analyzed within the framework of the forecast. The indicators within 4 measurements, which are determined on the scale from 1 to 5 have been aggregated into consolidated indicators for each measurement for 1980-1995 and 2000-2015 by means of weight coefficients calculated on the basis of principal component analysis. The radial basis function (RBF) has been used for this purpose (5.2.5):

$$f(x) = \sum_{j=1}^m w_j h_j(x) \quad (5.2.5)$$

The functional diagram of the radial basis function is presented in *Figure 5.2.3*.



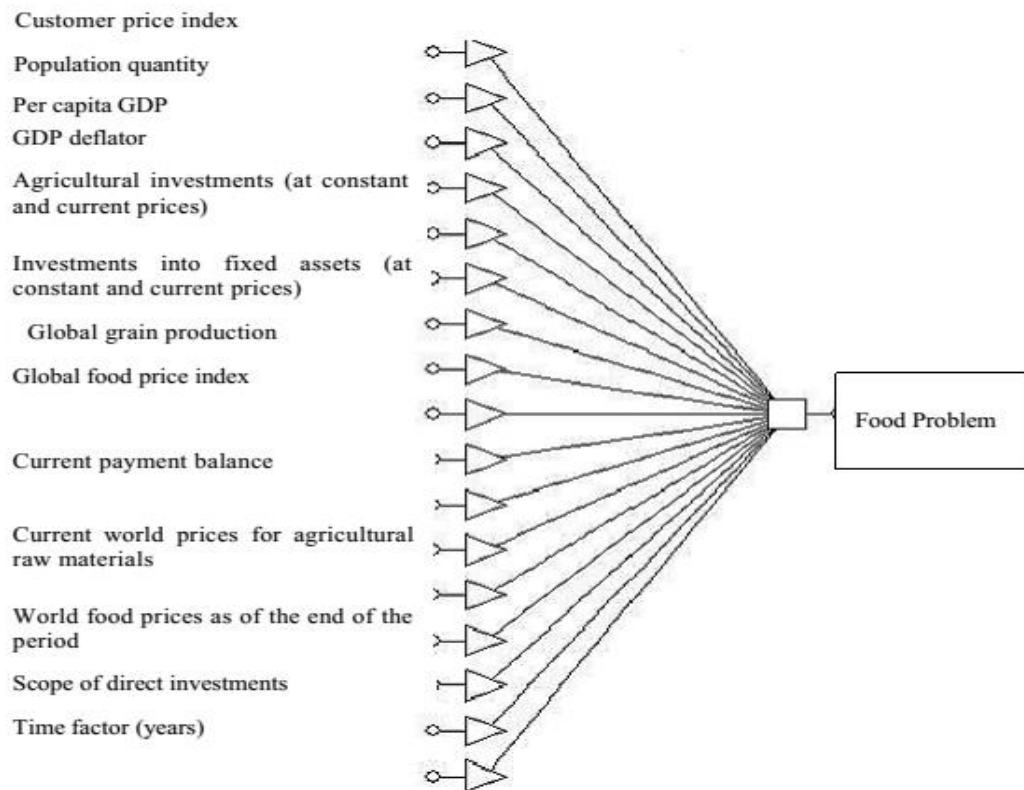
**Figure 5.2.3: Functional diagram of the Radial Basis Function (RBF)**

*Source: created by author according to Matviichuk (2011)*

The process of predictive modelling and analysis of factor impact has been performed and divided into 3 networks: (1) training, (2) verification, (3) modelling for network testing, for the use of 33 quantities of data, 17 of which were used for network training, 8 for verification and 8 for network testing. As a result of self-education by the feed-forward back propagation neural network, the following most significant factors have been selected from modelling of the state of the food problem: (1) customer price index; (2) total world population; (3) reference values of per capita GDP (mln USD) and GDP deflator; (4) amount of agricultural investments and total amount of investments into fixed assets (at constant prices and at the current USD exchange rate); (5) global grain production scope; (6) global food price index; (7) current payment balance; (8) current world prices of agricultural raw materials and world food prices as of the end of the period. These factors have been selected upon identification of the internal impact on the state of the food problem.

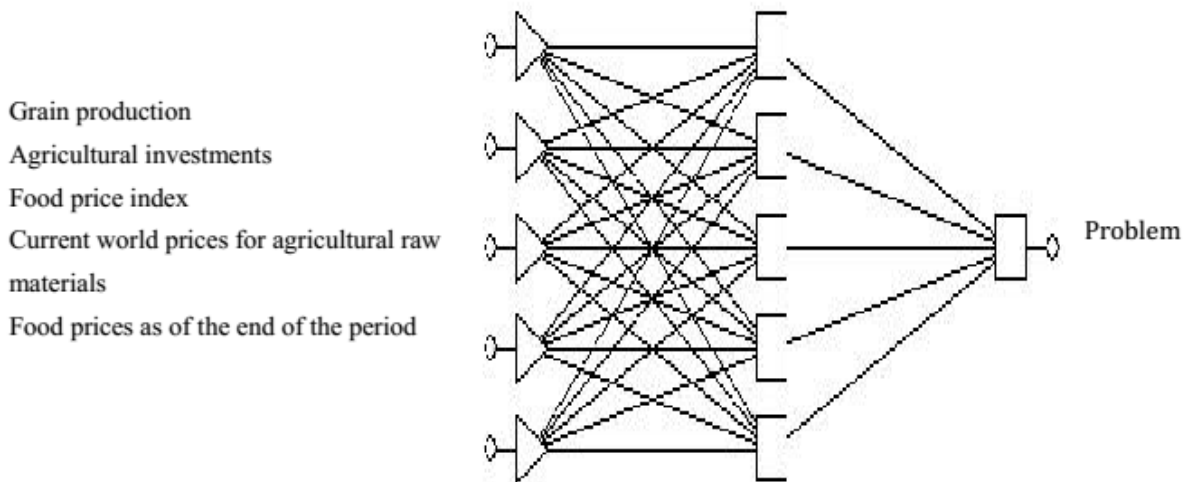
Ten models with the lowest absolute error were selected in the course of analysis. The program tested models and result of their ranging on the basis of the error size. The model without the hidden (internal) layer presented in *Figure 5.2.4* was selected from among them at the initial stage.

The multi-perceptive model with the hidden internal series, which included the following indicators from the internal factors group was selected in the course of modelling of prospects of solution of the global food problem: global grain production scope; agricultural investments; global food price index; current world prices of agricultural raw materials and world food prices as of the end of period (*Figure 5.2.5*).



**Figure 4: Structure of the model with the neural component with one output for modelling of prospects of solution of the global food problem on the basis of the Internal Indicators Group**

*Source: developed by author*



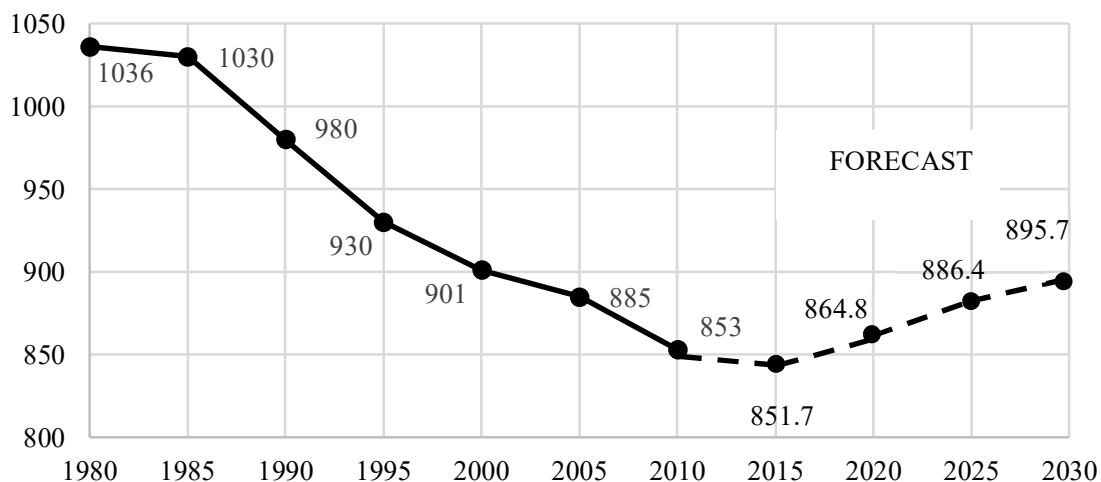
**Figure 5.2.5: Structure of the model with the neural component with one output for modelling of prospects of solution of the global food problem on the basis of the Internal Indicators Group**

Source: developed by author

As a result of predictive modelling of the global food problem solution prospects by means of the feed-forward back propagation neural network, the following most significant factors have been selected from the group of external impact factors: world oil demand, mln tones (annualized, i.e. estimated on a year-to-year basis); cost expression of the world oil demand (annualized); world oil supply, mln tones (annualized); cost expression of the world oil supply (annualized). Absence of the forecast on the grain production both in general and its estimate per capita has preconditioned its modified exponent (5.2.6), where:  $A = -4,129.307306$ ;  $B = 5,684.033942$ ;  $C = 1.004832$ .

$$Y = A + B \times C^n \quad (5.2.6)$$

The forecast data gained by means of the neural network has enabled modelling prospects of the global food problem. Modelling deliverables are shown in *Figure 5.2.6*.



**Figure 5.2.6: Forecast of the global food problem solution by means of the neural network, mln malnourished people (consuming less than 1,700 calories per day)**

Source: calculated by author

## Conclusions

Modelling deliverables demonstrate that the world economy is at the critical stage of the global food problem solution. If the relative indicator of the share of the malnourished planet population is stabilized at the level of 12-13%, in the short term there may be an increase in the number of people, who have been consuming less than 1,700 calories per day. According to our forecast, the malnourished people quantity in the world may increase by 12-13 mln by 2020 as opposed to the current state, and it may increase by 34-35 mln by 2025. The important forecasting deliverable is that if no effective measures are taken to solve the food problem, the situation with the malnourished people will deteriorate, and their quantity will keep growing. The example given is a neural forecasting model, which has been developed and assessed on the actual information and takes into account impact of internal and external changes on solution of the global food problem, confirms capabilities for their application for systemic analysis, forecasting and quantitative assessment of influence on principal macroeconomic indicators in the context of uncertainty, asymmetric information and possible changes in economic development tendencies.

The existing mathematical models built on the basis of neural networks enable forecasting with the high authenticity level. In forecasting of the malnourished people quantity in the world, the absolute average error is 7.31. It has been defined on the basis of *MAE* (mean absolute error) criteria (5.2.7). The correlation index is 0.96.

$$MAE = \frac{1}{n} \sum_{k=1}^n |Y_{t+k} - F_{t+k}| \quad (5.2.7)$$

Solution of the global food problem is mainly decelerated by low rates of world economy development and resulting potential reduction in the scope of agricultural investments. For instance, according to the forecast, reduction in agricultural investments scope by USD 10 bln during three years brings decrease in agricultural production by USD 2.1 bln. It will mostly affect animal industries, fodder and vegetable production. Approximately 0.5 mln employees will be fired from the agricultural industry. Having no respective qualifications, most of them will stay unemployed.

The model takes into consideration effect of the existing economic indicators and makes a forecast thereon in the future, also it takes into account the risks caused by deterioration of the socioeconomic situation in the world. Therefore, stabilization of the political situation in the most problematic regions of the planet and engagement of the population into efficient labor for economy development and human well-being are getting currently central. Involvement of economically developed countries into assistance provision to develop economies of the poorest world countries is equally important. This assistance must be first and foremost associated with development of agriculture and rural areas.

Impact of the oil market on the global food problem solution is ambiguous. On the one hand, decrease in the world oil prices promotes reduction of expenses for production and carriage of agricultural products, thus, increasing the supply level of agricultural products. On the other hand, decrease in the oil prices in the context of the persistently low demand for these commodities hinder development of the world

economy and growth of the population's well-being and have negative impact on the consumer demand. A fall in the oil prices brings about impoverishment of population in the oil countries of Latin America and deteriorates the food problem in this region.

The following factors promote the food problem solution: international economic integration and foreign trade development; foreign trade liberalization in agricultural products; activation of scientific research in the agricultural area, viz. plant breeding and protection, distribution of highly-efficient seeds and animals. Taking into consideration high potential of the national agriculture and agrarian science, Ukraine's important task is to take up a decent position on the world agricultural markets.

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