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Forecast of agricultural economic sector using artificial neural networks

The purpose. To substantiate the theoretical and methodical approach of system forecasting of agricultural production on the basis of the application of artificial neural networks, taking into account quantitative and qualitative factors of influence on the development of the agrarian sector of the economy.

Methods. Economic-statistical, calculation-constructive, monographic, comparative, correlation analysis,

artificial neural networks. **Results.** The theoretical and methodical aspects of using the artificial neural

network method in the problems of forecasting the development of the agrarian sector of the economy for

achieving greater objectivity and accuracy are considered. The systematic analysis of the main

production and economic indicators of the agrarian sector of Ukraine for 2000-2017 was carried out. The

quantitative and qualitative factors influencing the development of the agrarian sector of the economy

were determined. A model for forecasting the development of the agrarian sector of the Ukrainian

economy on the basis of an artificial neural network of architectural type multi-layer perceptron is created,

which ensures the minimum deviations of the obtained results from the actual values of these indicators.

Conclusions. The results of research confirm the possibility of practical use of the model of the ANN

developed on the basis of system analysis for adaptive forecasting of the agrarian sector of Ukraine's

economy in the medium and long-term perspective. The proposed model takes into account the factors of

change of sown areas, livestock, crop yields, animal productivity and resource provision of agrarian

production. A methodical approach is developed for the practical use of artificial neural networks for

adaptive forecasting of the agrarian sector of Ukraine's economy in substantiating different strategies and

assessing their impact on the economic, social and ecological state of the industry.

Key words: *development of agrarian sector of economy, forecast, artificial neural networks, model.*

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The Ukrainian agricultural sector development strategy is to ensure its predictability and economic growth and competitiveness of production. The traditional model of agrarian development, which has ensured a quantitative increase in agricultural production during the last 20 years, requires qualitative upgrading and the transition to new principles of sustainable economic activity, innovation and technological modernization. Therefore, we need new approaches to forecasting agrarian development.

A. V. Matviichik, I. V. Parasyuk and other scholars among known today's scientific approaches to solving forecasting problems singled out artificial neural networks, which are used as a universal reproducer of complex nonlinear functional dependencies. The powerful mathematical apparatus of neural networks allows to reveal the main tendencies of changes in the financial and economic indexes according to experimental data of previous periods and in accordance with them to make a forecast for changing this indicator in the future for a certain number of steps forward [1-2].

Actual problems of theoretical, methodological and practical substantiation of ways of using artificial neural networks for forecasting are considered in the works of many foreign and domestic authors. Select separate scientific work. The researcher S. Haykin [3] pays attention to the main directions of the development of artificial neural networks, as well as their role in solving problems of pattern recognition; Lakhmi C. Jain, Anna Maria Fanelli and others study the latest advances in pattern recognition, color induction, classification [4], James M. Keller examines various aspects of the theory's development [5], M. I. Pugacheva explores their use in forecasting GDP Ukraine [6].

In recent years, many scientific papers have been published on the practical application of artificial neural networks in various fields of activity. However, there is not enough work in agriculture. Here are some scientific works in this direction. Raju Prasad Paswan [7] compares the use of statistical methods and neural networks to predict crop production; N. K. Vasiliev [8] to forecast the volumes of production of

various types of agricultural products according to neural networks and econometric models; P. M. Gritsyuk [9] in studies of the study of the possibilities of artificial neural networks for long-term forecasting of grain crop yields; A. I. Solovyov [10] for neural network modeling and forecasting of efficiency indicators of agrarian production management, the use of which allows to create nonlinear systems and models that can provide high reliability of the approximation of complex processes in space and time.

The purpose of the research is to substantiate the theoretical and methodical approach of system forecasting of agricultural production on the basis of the application of artificial neural networks, which takes into account quantitative and qualitative factors of influence on the development of the agrarian sector of the economy.

Research methodology. To realize the set goal in scientific research used economic-statistical, calculation-constructive, monographic, comparative, correlation analysis, artificial neural networks (ANN).

Research results. Agrarian production is a complex dynamic system of social and economic relations based on direct and reciprocal links that are associated with factors of resource, biological, technological, innovation, demographic, ecological, climatic deterministic and stochastic nature of influence in a market environment.

The generalization of the theoretical aspects of the problem under study by the example of the field of agricultural production proves the necessity of its systematic research. This requires the use of fundamentally new methodological approaches to the analysis and assessment of the problem of economic growth in agriculture, which can only be achieved by building adaptive models for forecasting the development of the industry.

«Recently, mathematical models based on the principle of functioning of biological neural networks (neural networks), which, in contrast to regression, allow us to take into account the asymmetry of information, the presence of nonlinear relationships, uncertainty in the development of economic processes, unpredictable rapid change in subjective factors» [6].

Artificial neural networks are a mathematical model with their corresponding program realization with the help of developed special computer algorithms, which operate on the principle of analogous biological structures of a living organism. In a sense, artificial neural networks are a well-developed computing system that consists of many parallel processors and connections that are functioning in parallel.

According to Simon Haykin, neural artificial networks have several advantages and provide the following beneficial properties of systems built on them, namely:

- nonlinearity;
- inputoutput mapping;
- adaptivity;
- evidential response;
- contextual information;
- fault tolerance;
- VLSI Implementability;
- uniformity of analysis and design;
- neurobiological analogy [3, c. 36-37].

Significant spread of the use of ANN in various fields of activity is due to the fact that they under certain simplifications and assumptions demonstrate the capabilities that are inherent in the human brain. It is, first of all, learning based on experience, generalization, extraction of essential data from excessive and varied information.

First and foremost, the adaptive capabilities of the ANN are the ability to change their behavior depending on the state of the environment. After the corresponding analysis of received input signals, a self-tuning and learning procedure is carried out. These aspects are of paramount importance when developing adaptive models of forecasting in agriculture, where there is a complex relationship between exogenous and endogenous factors of influence.

An example of the development of the agrarian sector of the Ukrainian economy is the model of its forecasting using the ANN method in the framework of the analytical platform of the software package Deductor Academic 5.3.0.88 developed by BaseGroup Labs. This program is a freeware version for educational and scientific purposes. In the analytical platform Deductor, the neural network is based on a multilayer perceptron with two learning algorithms - the classic BackProp and its modification of RProp.

For the model, factors were selected that characterize the quantitative (X1-X27) and qualitative (X28-X32) their influence on the development of the agrarian sector of the Ukrainian economy. The productive indicator (Y1-Y4) is the production of gross crop and livestock production in all categories of farms (at constant prices in 2010, million UAH), the number of people employed in agriculture, forestry and fisheries (millions of people), the generation of waste in agriculture, forestry and fisheries (million tons).

In the first stage, the correlation between input and output indicators was investigated and statistical significance was established.

When substantiating the ANN model it is important to study it based on a set of examples: the input state – the initial state by means of an algorithm that provides the minimum deviations of the obtained results of the forecasts from the actual values of these indicators.

The architecture of the model design involves the presence of several inputs and outputs such as a multi-layered perceptron. The input and output parameters are a dynamic range of basic production and economic indicators of the agrarian sector development in Ukraine for 2000-2017 (Table 1-2).

At the second stage of the substantiation of the forecasting model, the approach proposed by P. Grytsyuk, which recommends a sigmoid activation function with initial values in the range from -1 to 1:

$$y = \frac{e^{\lambda v} - 1}{e^{\lambda v} + 1},$$

where, y is the output signal of the neuron; e is the target nonlinear sigmoid activation function. The output signal of the neuron y is determined by passing the level of excitation V through the nonlinear function y .

The coefficient defines the slope of the sigmoid. According to the Tacens theorem, choosing a sufficiently large value of the depth of immersion D can guarantee the uniquely dependence of the future value of a series of its past values D : $X_t = f(\vec{X}_{t-D})$, that is, the prediction of the time series reduces to the task of interpolating the function of many variables. The neural network can be used to restore this unknown function according to the time series data. The value D determines the size of the time window that slides along the time series by specifying the input kits [9].

The design of the model took into account the choice of one hidden layer with two neurons. We used the backpropagation method with the default settings. This teaching method is an iterative gradient algorithm used to minimize the mistake of working a multilayered perceptron and obtaining the desired output. Its main idea is to spread the error signals from the outputs of the network to its inputs, in the direction of the reverse direct propagation of signals in the normal mode of operation.

1. The main indicators of the dynamics of the agrarian sector of Ukraine's economy in the period 2000-2017.

Indexes	Xn	2000 y.	2005 y.	2010 y.	2011 y.	2012 y.	2013 y.	2014 y.	2015 y.	2016 y.	2017 y.
Sown area (thousand hectares) and livestock (thousand heads) in all categories of farms											
cereal crops	X1	13646,5	15004,8	15090	15723,8	15449	16209,9	14800,8	14738,4	14401,2	14623,6
sugar beet (factory)	X2	855,6	652,2	500,9	532,4	458,4	279,8	331	237,4	292,4	316,1
sunflower	X3	2942,9	3742,9	4572,5	4739,2	5194,1	5051,3	5256,5	5104,6	6073,4	6033,7
soy	X4	64,8	438,5	1076	1134,2	1476,4	1369,9	1805,8	2158,1	1869,4	1999,8
rape	X5	214,3	207,4	907,4	870,0	566,0	1017,4	881,6	682,4	455,1	788,5
potato	X6	1629,3	1513,9	1408,4	1439,2	1439,8	1388,1	1348,2	1291,2	1312,2	1323,2
vegetable crops	X7	538,1	464,7	461,8	497,7	494,4	483,4	463,3	440,4	441,5	439,2
fruits and berries	X8	424,9	299,2	255,3	254,9	254,9	253,2	239,2	234,8	224,4	225,5
forage crops	X9	7063,1	3737,8	2599,1	2477,3	2474,9	2288,7	2101,2	1990,2	1931,9	1858,1
cattle (without cows)	X10	5195,5	2976,9	2090,2	1863,2	1843,6	2091,6	2025,2	1621,3	1583,7	1573,4
cows	X11	5431,0	3926,0	2736,5	2631,2	2582,2	2554,3	2508,8	2262,7	2166,6	2108,9
pigs	X12	10072,9	6466,1	7576,6	7960,4	7373,2	7576,7	7922,2	7350,7	7079,0	6669,1
sheep and goat	X13	1884,7	1754,5	1832,5	1731,7	1739,4	1738,2	1735,2	1371,1	1325,3	1314,8
bird of all kinds	X14	126079,8	152783,2	191446,4	203839,8	200760,6	214070,6	230289,8	213335,7	203986,2	201668,0
Average crop yield and livestock productivity in all categories of farms (t / ha, kg / head)											
cereal crops	X15	1,94	2,60	2,69	3,70	3,12	3,99	4,37	4,11	4,61	4,25
sugar beet (factory)	X16	17,67	24,82	27,95	36,33	41,08	39,89	47,65	43,58	48,15	47,49
sunflower	X17	1,22	1,28	1,5	1,84	1,65	2,17	1,94	2,16	2,24	2,02
soy	X18	1,06	1,62	1,62	2,04	1,71	2,05	2,16	1,84	2,3	1,97
rape	X19	0,84	1,46	1,7	1,73	2,2	2,36	2,54	2,59	2,57	2,79
potato	X20	12,16	12,84	13,25	16,8	16,1	15,97	17,64	16,14	16,58	16,78
vegetable crops	X21	11,23	15,71	17,36	19,5	19,92	19,99	20,78	20,61	21,05	20,79
fruits and berries	X22	3,84	6,37	7,82	8,49	8,99	10,35	9,52	10,45	10,19	10,31
cattle (without cows)	X23	209,8	291,8	312,8	343,9	364	322,3	284,6	371,7	382,1	361,4
cows	X24	2359	3487	4082	4174	4361	4446	4508	4644	4735	4820
pigs	X25	83,6	112,5	120,8	117,3	132,4	138,3	128,4	139,3	142,4	147,8
sheep and goat	X26	20,7	18,4	22,2	23,1	22,2	22,4	15,8	20,6	22,7	20,8
bird of all kinds	X27	2,1	4,4	6,7	6,5	7,0	7,3	6,7	7,1	7,5	7,9

Source. Own calculations of the author according to the data of the system analysis of the information of the State Statistics Service

2. The main indicators of the dynamics of the agrarian sector of Ukraine's economy in the period 2000-2017.

Indexes	X _n , Y _n	2000 y.	2005 y.	2010 y.	2011 y.	2012 y.	2013 y.	2014 y.	2015 y.	2016 y.	2017 y.
Incorporation of mineral fertilizers by agricultural enterprises in terms of 100% of nutrients, ths. tons											
fertilizers in crop production	X28	281,9	560,5	1064,2	1266,9	1346,6	1493,8	1471,7	1415,0	1728,9	2028,0
Introduction of organic fertilizers by agricultural enterprises, ths. tons											
fertilizers in crop production	X29	28964,1	13387,3	9963,6	9954,2	9685,2	9652,9	9898,4	9662,7	9162,9	9273,9
Expenditures of feed of all kinds for feeding farm animals in all categories of farms, thousand tons of feed units											
feed in animal husbandry	X30	42513	37481	33874	33659	34093	34644	32515	30987	30439	29738
Share of capital investments in agriculture, forestry and fisheries development as a percentage of the total result for all types of economic activity, %											
investment	X31	5,1	5,4	6,1	6,8	6,9	7,4	8,6	11,0	14,1	14,3
Share of households in the structure of total agricultural output, %											
production structure	X32	61,6	59,5	51,7	48,2	49,3	46,0	44,7	44,9	43,0	43,6
Gross agricultural output in all categories of farms, UAH million											
crop production	Y1	92838,9	114479,9	124554,1	162436,4	149233,4	175895,2	177707,9	168439	185052,1	179474,6
livestock products	Y2	58183,3	65125,9	70332,4	71259,9	74021,4	76963,8	73730,7	71028,3	69588,4	69682,4
Number of people employed in agriculture, forestry and fisheries, million people											
employment	Y3	4,37	4,01	3,12	3,41	3,51	3,39	3,09	2,87	2,87	2,86
Waste generation in agriculture, forestry and fisheries, million tons											
ecological state	Y4	1,25	2,59	8,30	12,2	10,03	10,08	8,45	8,74	8,72	6,19

Source. Own calculations of the author according to the data of the system analysis of the information of the State Statistics Service

In the Deductor Academic 5.3.0.88, the input sample selection was divided into 2 sets: educational (95% data) and test (5% data). As an activation function, a sigmoid with steepness was used. The training of the ANN was conducted prior to the onset of 100,000 epochs. The number of neurons in the input and output layers, respectively, was 32 and 4, and in the hidden one - 1. Dependence was found using 100% of the sample for maximum and average errors in the training - 0,5 and testing - 0,5. Received graph of the neural network copy of the program window is shown in Fig. 1.

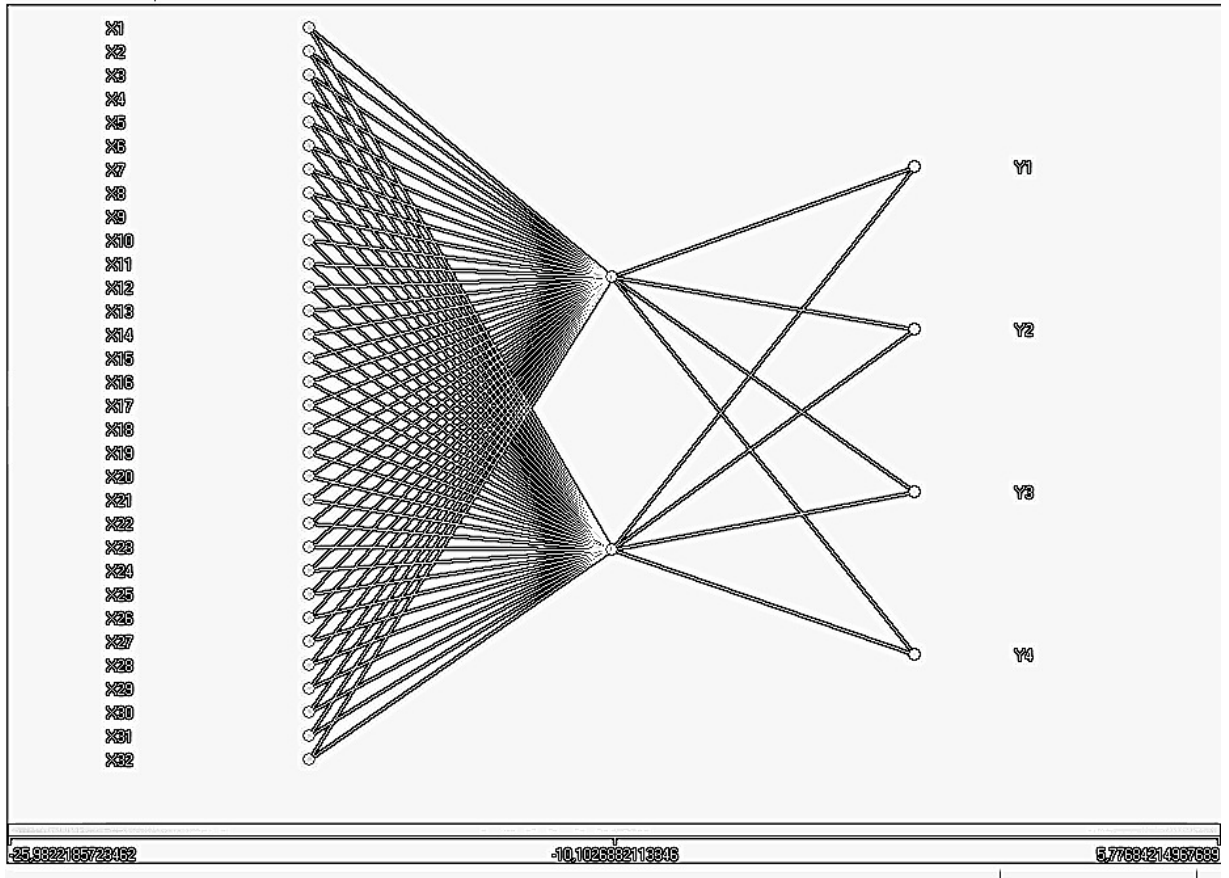


Fig. 1. A graph of the neural network model of the forecast of the agrarian sector of Ukraine's economy

Source: developed by the author independently on the basis of methodological approaches [1,2,3,9]

Compare the results of the forecast. The analysis of the estimated error rate (ERR) of the developed ANN in comparison with the real statistical data shows their high accuracy (Fig. 2).

	Y1_OUT	Y2_OUT	Y3_OUT	Y4_OUT	Y1_ERR	Y2_ERR	Y3_ERR	Y4_ERR
	92602,3874612355	59910,766634839	4,31687549927559	1,28854755195966	5,96967168463948E-6	0,00846067543157746	0,00123775824622513	1,23926837395591E-5
	100171,947592526	62178,7077966969	4,16876598809396	1,53298806772967	0,00180249232459119	3,25975409977115E-6	0,000154450378993262	2,71083623877431E-5
	106651,845877149	64177,247204884	4,16984605625138	2,0879689876294	0,00161102203027436	0,00620985451506593	0,000390678949941064	5,29636695127781E-7
	94306,2811081746	60188,8486536449	4,14315957560314	1,30347765683702	0,0039126201923571	0,00601667503225533	0,000482240890390922	0,00327374530541421
	106129,59978133	63655,7839578407	4,01316766090543	1,8971765589034	0,0137269944926005	0,00819650321618392	7,60437233983095E-5	0,00293104507673831
	111641,361428025	65186,5386357632	4,02030299963419	2,54990177162084	0,000859867841987787	1,04252035487912E-5	4,65557657392332E-5	1,3409794784492E-5
	118840,937988136	66382,367250194	3,68606467607813	3,3033360836508	0,0005370229041056	0,00352944209445138	0,000570440270435561	4,48546207563444E-5
	115096,466177393	65241,0013950106	3,53326520081496	2,56503210794471	0,00887039162580654	0,00234370647835625	0,00124432332698482	0,00285388073422668
	123748,531321154	66819,3321166919	3,28669800912251	3,6293712358385	0,0167511652539694	0,00665806743884337	0,00048639208648934	0,00168415594002644
	125359,475044479	66781,2833834313	3,11996957486642	3,58775706794846	0,00220821093876439	0,00440395091371336	0,000395520562126129	0,0057144910534696
	141516,905043057	70273,8904454364	3,18361208003408	7,46465376705555	0,0307070041971512	9,70597755565743E-6	0,00177470142812233	0,00581975629277525
	163998,641310158	74411,430915607	3,42272930689916	11,6178059085808	0,000260458384331844	0,0281597530988369	7,10649770330317E-5	0,00282687984056592
	171542,989553106	74923,6110538982	2,9342724362238	11,8413903347471	0,0531159884261007	0,00230782028650271	0,145371794084326	0,0273650252898418
	164728,865612049	74457,6198816549	3,35257322572581	11,6404422899463	0,0133064855058727	0,0178077996062812	0,000614342981698686	0,0203080014199263
	181137,058486336	71960,8049308107	2,86000000034949	9,16600523920888	0,00125492341296126	0,00888138583887147	0,0232007367392813	0,0042756698365302
	170736,367105079	71860,3208652296	2,86002794297884	9,25948914073759	0,00056325220897614	0,00196270095688628	4,36129648845566E-5	0,00225073678484005
	180977,167534862	71417,0905998741	2,86000000016532	8,45868204819276	0,00177207842433033	0,00948126235393753	4,38577240882654E-5	0,000569521669162268
	179123,700649267	69790,4743299059	2,86000000021533	6,32944801640244	1,31403591751938E-5	3,31154607522757E-5	2,03351754715207E-20	0,000162179681646131

Fig. 2. Graphical representation of the interface of the Deductor Academic 5.3.0.88 program and the results of the estimation of the forecast and its errors.

Source: developed by the author alone

The maximum error estimating the accuracy of the forecast for Y1 did not exceed 5.9%; for Y2 – 9.7%; for Y3 – 7.6%; for Y4 – 5.3%. The generated forecasting model based on ANN is simulated and allows to determine in the future different variants of the basic parameters of the agrarian sector development – the value of gross production of crop and livestock, the number of employed population and the volume of waste generation.

Conclusions.

The results of the conducted research confirm the possibility of practical application of the model of the ANN developed on the basis of system analysis for adaptive forecasting of the agrarian sector of Ukraine's economy in the medium and long-term perspective. The proposed model takes into account the factors of change of sown areas, livestock, crop yields, animal productivity and resource provision of agrarian production. The use of the model is possible in substantiating different agrarian sector development strategies and the forecast of their impact on the economic, social and ecological state of the industry.

The methodical approach developed by the practical application of ANN for adaptive forecasting of the agrarian sector of Ukraine's economy allows taking into account the dependence on the influence of various factors and ensuring less error and higher accuracy.

Prospects for further scientific research are the development of the direction of developing new models of artificial neural networks for forecasting the state of the agrarian sector of the economy at the regional level.

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