DIGITAL TECHNOLOGIES IN PRODUCING PROGRAMMABLE VEGETABLE CROPS

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ABSTRACT

The aim of the research is to program the harvest of vegetable crops in the arid zone in the context of modern digital changes. The study involved an analysis of the existing definitions of the concept of "programming the crop"; studying the influence of digital technologies on obtaining programmed yields of vegetable crops, identifying trends in the development of the vegetable growing industry in the regional agro-industrial complex. The results of the study confirmed the need for programming the harvest of vegetable crops based on the compilation of economic and mathematical trend models and the widespread use of digital technologies in growing vegetables in the region.

Keywords: *crop programming, digital technologies, vegetable crops, economic and mathematical modelling, a model, food security.*

1. INTRODUCTION

Crop programming as a separate science appeared at late 70s of the last century. But the first steps in potato crop programming were made by L.G. Lorkh in 1930s.

A new direction appearance necessity was due to the crops' product unstable production in some areas with unstable moisture.

Some South Russia regions belong to arid areas. Moisture is the limiting factor of the most crops yield.

To make the crops production more stable in the country and regions scientists developed the range of formulas helping predict the harvest in any year according to weather conditions.

The scientists from Timiryazev Agricultural Academy, Volgograd Agricultural Institute and from other educational establishments of the USSR made a significant contribution to the crops programming development during the Soviet period. Researchers studied the solar radiation influence, territory bioclimatic potential, photosynthesis process intensity, the mineral nutrition level and other factors on the crop productivity genetic level realization.

I.S. Shatilov [12], M.K. Kayumov [6, 7], B.I. Gulyaev [3], V.D. Baranov [2], Kh. G. Tooming [9], A.A. Ziganshin [5], K.P. Afendulov [1] etc. are among those who made a valuable contribution to the basis of crops programming formation.

During the period of the planned economy, crop programming helped agricultural enterprises to obtain the planned harvests of grain, sunflower seed oil, potatoes, fodder, vegetables and other crops in the areas with unstable moisture. Programmed cultivation implied optimization of the level of mineral nutrition, productive moisture reserves in the soil, protective measures against harmful objects integrated system, and other measures.

Strict adherence to the timing and quality of technological methods implementation within the framework of agricultural crops programmed cultivation especially on irrigated lands, provided a significant increase in yield and gross crop production.

At the same time, the crop programming basis, found in the last century during the planned economy period, have not found wide application in the market conditions.

During the years of transition to a market economy, crop programming, as well as agriculture in general, fell into decay. Prices liberalization in 1991 had an adverse effect on the agro-industrial complex development. The disparity in prices turned agriculture into the agro-industrial complex donor. Numerous collective and state farms destruction and the peasant farms development emphasis led to the fact that Russia was on the 42nd place in the world in food security terms. Until the collapse of the USSR in 1990, it was in the top ten countries in terms of nutrition. There was no food problem in the Soviet Union. It manifested itself with particular sharpness during the transition period. More than 30 years after the collapse of the USSR, Russia is trying to reach the parameters of food self-sufficiency. However, there are still problems in the production of milk, beef, greenhouse vegetables and fruit.

Today, the crop programming revival is primarily due to the fact that Russia faces a real threat to agricultural production, it is a negative humus balance manifestation. In 2009, at the agrarian economists third all-Russian congress the academician I.G. Ushachev in his report outlined the problems in the agricultural land use. According to his point of view the arable areas percentage where degradation processes are observed, and a negative humus balance is close to 100.This fact raises serious concerns and the need to take comprehensive measures aimed at improving soil fertility and activating soil-forming processes. The foundations for harvest programming in a market economy were reflected in the papers by V.D. Mukha [8] and others, L.S. Fedotova [10], V.V. Filin [11], G.S. Gusev [4].

The Astrakhan region belongs to an arid zone. Soil and climatic conditions do not allow the sunflower production development and grain production here, there are two the most important directions for the products supply to the world market. In the region, the import substitution strategy is implemented only through the export supplies, mainly to other regions of Russia and some CIC countries, vegetables, melons and potatoes.

The peasant farms average size in the Astrakhan region is not large and it does not exceed 100 hectares. This is many times less compared to the Volgograd, Rostov regions, Stavropol and Krasnodar regions, where chernozem soils prevail and where the average farm size is 2000-5000 hectares.

According to A.A. Aitpayeva [13], A.S. Bisalieva [14], A.A. Aitpaeva, A. Bisaliev, A. Bisaliev [15], today new requirements are imposed on the programming of crops. The Strict environmental conditions, high competition, and an unstable situation on the world food markets are forcing many countries, including Russia, to look for ways out of the crisis and to increase agricultural production through domestic potential, without relying on imports. One of the ways to solve this problem is the revival of agricultural crops harvest programming, economic and mathematical modelling widespread use in programming, the introduction of digital technologies into the production process.

2. MATERIALS AND METHODS

The methodological basis of the research will be formed by the fundamental provisions of systems theory and economic and mathematical modelling. It is assumed that the following methodological principles will be applied in the study: the principle of complex analysis, the principle of systems analysis and the principle of the structural-functional approach. In order to solve the problem posed in this study, it is proposed to apply the method of economic and mathematical modelling, which will allow identifying trends in the development of the vegetable growing industry in a particular region.

3. RESULTS

The Astrakhan region is one of the regions in the South of Russia. There are 11 rural areas on its territory.

In general conditions the Astrakhan region enterprises maintain external economic relations with firms from 64 countries, products are exported to 37 countries, imported from 55.

Open field vegetable growing is rapidly developing in the region. Currently the Astrakhan region has a status of all-Russian vegetable garden, annually producing more than 1 million tons of vegetable products. A significant part of vegetables gross harvest (over 80%) is accounted for by peasant farms. This farm group mostly specializes in the production of tomatoes, sweet pepper, eggplant, onion, and potato. According to the rational consumption standards recommended by the Institute of Nutrition of the Russian Academy of Sciences, the Astrakhan adult annual demand in vegetables is 139 kg, or about 140 thousand tons for the entire region population. The analysis showed that the Astrakhan region produces vegetable products 9.7 times more than the rational consumption rates and, according to this indicator, it supplies food independence for its own population.

However, the further increase in acreage under vegetable crops is not desirable as it can lead in the medium term to adverse consequences for soil fertility.

If we take the year 1980 as the beginning of the investigated period, it is necessary to state that in comparison with 2020 the area occupied by grain crops decreased from 217.2 thousand hectares to 15.1 thousand hectares, or it is 14.4 times, the area under vegetable crops increased slightly from 24.6 thousand hectares in 1980 to 25.1 thousand hectares in 2020, it is 1.02 times, the area occupied by potatoes during the observed period increased 5.2 times from 2.2 thousand hectares (1980) to 11.4 thousand hectares (2020).

In modern conditions, the productivity of agricultural crops in the region can be expressed as a derivative function of three variables, among which are soil and climatic conditions, the technology used, the genetic potential of the productivity of the variety:

$$Y = f\,[PK, T, C], \tag{1}$$

where PC - soil and climatic conditions,

T - applied technology,

C - genetic potential of the productivity of the variety.

Humanity cannot change the soil and climatic conditions. However, the technology used and the characteristics of the variety can be adapted to the specific conditions of the region. The share of soil and climatic conditions in the formation of the yield reaches 50%, while the technology accounts for 30%, and the variety 20%. You should also not ignore the observance of two important conditions defined by V.S. Shevelukhoi: correspondence of genotype and environment, variety and technology. The changes analysis in the area occupied by the main crops during the transition period to a market economy revealed a number of problems in the region land use. A detailed confirmation of this fact is the developed economic and mathematical trend models based on polynomial growth curves showed in Tables 1-4.

The investigation involves the 10th year period of 2011-2020 years. The arable land area for the investigated period in the Astrakhan region increased 1.05 times. The regression parameters estimation is the following:

a1=64,6/82,5=0,78;

a0=78,12–0,78·5,5=73,83.

The increase in the area occupied by vegetable crops in the region during the research period occurred faster compared to the increase in arable land as a whole and it amounted to 1.2 times. The regression parameters estimation is the following: a1=35,4/82,5=0,43; a0=23,5-0,43x5,5=21,14.

In modern conditions, the level of vegetable yield in the Astrakhan region is determined by soil and climatic conditions, traditional cultivation technology and the genetic potential of the productivity of the standard variety included in the State Register for the Astrakhan region. Productivity of vegetables in the Astrakhan region in the period from 2011 to 2020 increased by 1.58 times. Estimation of the regression parameters:

a1=207.1/82.5=2.51; a0=43.28–2.51·5.5=29.5.

At the same time, a further increase in the area under vegetable crops in the region is not desirable. It is possible to achieve an increase in gross harvests from the available areas through the introduction of innovative technologies that involve the use of digital tools and promising varieties that have a set of economically valuable traits and high adaptive characteristics, which make it possible to realize the genetic potential of productivity to the maximum extent possible. A prerequisite is the development of technology for a specific variety. Compliance with these conditions will ensure a 2-fold increase in the yield of vegetable crops, compared with today's values.

Vegetable production in the Astrakhan region from 2011 to 2020 increased 1.8 times. This fact indicates that the vegetable growing industry is developing through the intensification of production processes. At the same time, the industry digitalization insufficient level determines the shortfall in receiving of a certain profit part taken from the region vegetable-growing farms. The regression parameters estimation is the following:

a1=6029,55/82,5=73,08;

a0=1011,49–73,08·5,5=609,55.

The carried-out calculations made it possible to identify some trends in the vegetable growing industry development in the region (Table 5).

The vegetable growing industry development trend equations analysis in the Astrakhan region showed that during the investigated period from 2011 to 2020, the used arable land in the region increased from 78.5 to 82.8 thousand hectares, the area occupied by vegetables changed from 21.5 thousand hectares to 25.1 thousand hectares, and the vegetables gross harvest increased from 778 thousand tons up to 1363 thousand tons. All investigated parameters show as sustainable growth. At the same time, only one third of arable land is used in the Astrakhan region. Two-thirds of the areas previously occupied by grain and fodder crops are abandoned and often irreversible degradation processes are observed on these areas.

The abandoned arable land involvement into circulation could significantly improve the agricultural production state in the region. The forage grasses expansion in the irrigated forage crop rotations structure would have a favourable effect on the creation of a full-fledged forage base for farm animals and the livestock industries effective development. However, we should not forget about the vegetable growing further development in the Astrakhan region as a main industry for plant growing in general.

In the short term period the vegetable growing development in the region should be given an innovative focus. It is necessary to increase the vegetable crops yield without the sown area expanding. One of the mechanisms for programmed vegetable yields obtaining is an accelerated transition to digital technologies.

In modern conditions some Russian regions, for example, Belgorod and Lipetsk regions, are actively introducing digital tools in agricultural production. With the UAS implementation we monitor agricultural land, assess the cultivated areas structure, the arable lands state, etc. Robotic sets, computer vision systems allow agricultural producers to optimize technological processes, to perform technological operations related to soil cultivation timely and efficiently, mineral fertilizers introduction, and to carry out the protective measures on crops.

We need to consider the prospects for vegetable growing digitalization using the robotics use example. Carrying out the research we compared the Russian-made robot tractor Agrobotprice, which costs to 90 thousand euros or 8,172,000 rubles. The purchasing cost for an autonomous Robotti robot from Agrointelli, Denmark, performing the tractor functions is 100 thousand euros or 9,080,000 rubles. Robotics test is planned for tomato planting on an area of 50 hectares. An assessment of the economic efficiency of a robotic tractor and of an autonomous robot replacing a tractor is shown in Table 6.

The table 6 analysis showed that the predicted economic efficiency may turn out to be higher when using the Agrobot Russian tractor in comparison with the Danish analogue. The tomato production profitability predicted level at this experiment variant can be 103%, and when using the Danish analogue it is 95%.To substantiate the acquiring digital technology feasibility, we will calculate the net present value for the A project (the Russian-made robot Agrobot tractor purchase) and for the B project (the Denmark-made autonomous robot purchase):

NPVA=-8172000+21328000/1,1+29500000/1,21=

=-8172000+19389091+24380165=35597256rubles,

NPVB=-9080000+20420000/1,1+29500000/1,21=

=-9080000+18563636+24380165=33863801rubles.

The net present value for both A project and B project has a positive value, therefore, the digital equipment acquisition is profitable. At the same time, it is preferable for farms to purchase a domestic-made Agrobottractor, since the predicted profitability from its implementation is at 1,733,455 rubles higher than its Danish counterpart. Thus, the carried out research has shown the need for programming the vegetable crops yield based on the compilation of economic and mathematical trend models and the widespread use of digital technologies.

4. FIGURES AND TABLES

Table 1. Intermediate indicators calculation for the regression parameters assessment (arable land used in the region)

Year, t	Уt (used arable land), th. h	t-tср	(t-tср) x(t-tср)	Уt - Утср	(t-tср)х (Уt - Утср)
1	78,5	-4,5	20,25	0,38	-1,71
2	78,7	-3,5	12,25	0,58	-2,03
3	72,2	-2,5	6,25	-5,92	14,8
4	73,4	-1,5	2,25	-4,72	7,08
5	76,6	-0,5	0,25	-1,52	0,76
6	76,1	0,5	0,25	-2,02	-1,01
7	78,3	1,5	2,25	0,18	0,27
8	82	2,5	6,25	3,88	9,7
9	82,6	3,5	12,25	4,48	15,68
10	82,8	4,5	20,25	4,68	21,06
General amount 55	781,2		82,5		64,6
Average 5,5	78,12				

Table 2. Intermediate indicators calculation for the regression parameters assessment (arable land area occupied by vegetables in the Astrakhan region)

Year, t	Уt (arable land occupied by vegetable crops), th.h	t-tcp	(t-tcp) x(t-tcp)	Уt - Уtcp	(t-tcp)x (Уt - Уtcp)
1	21,5	-4,5	20,25	-2	9
2	22,1	-3,5	12,25	-1,4	4,9
3	22,1	-2,5	6,25	-1,4	3,5
4	22,5	-1,5	2,25	-1	1,5
5	23	-0,5	0,25	-0,5	0,25
6	24,4	0,5	0,25	0,9	0,45
7	25,6	1,5	2,25	2,1	3,15
8	24	2,5	6,25	0,5	1,25
9	24,7	3,5	12,25	1,2	4,2
10	25,1	4,5	20,25	1,6	7,2
General amount 55	235		82,5		35,4
Average 5,5	23,5				

Table 3. Intermediate indicators calculation for assessing the regression parameters (vegetable yield in the Astrakhan region, t / ha; traditional technology, varieties included in the State Register)

Year, t	Уt (vegetable yield), t / ha	t-tcp	(t-tcp) x(t-tcp)	Уt - Уtcp	(t-tcp)x (Уt - Уtcp)
1	**36,0**	-4,5	20,25	-7,28	32,76
2	36,9	-3,5	12,25	-6,38	22,33
3	37,7	-2,5	6,25	-5,58	13,95
4	37,3	-1,5	2,25	-5,98	8,97
5	38,5	-0,5	0,25	-4,78	2,39
6	37,8	0,5	0,25	-5,48	-2,74
7	41,7	1,5	2,25	-1,58	-2,37
8	54,9	2,5	6,25	11,62	29,05
9	55,0	3,5	12,25	11,72	41,02
10	57,0	4,5	20,25	13,72	61,74
General amount 55	432,8		82,5		207,1
Average 5,5	43,28				

Table 4. Intermediate indicators calculation for the regression parameters assessment (vegetables production in the Astrakhan region)

Year, t	Уt (vegetables gross harvest), th.t	t-tcp	(t-tcp) x(t-tcp)	Уt - Уtcp	(t-tcp)x (Уt - Уtcp)
1	778	-4,5	20,25	-233,5	1050,75
2	811	-3,5	12,25	-200,5	701,75
3	832	-2,5	6,25	-179,5	448,75
4	833	-1,5	2,25	-178,5	267,75
5	884	-0,5	0,25	-127,5	63,75
6	906	0,5	0,25	-105,5	-52,75
7	1067	1,5	2,25	55,5	83,25
8	1289,6	2,5	6,25	278,1	695,25
9	1351,3	3,5	12,25	339,8	1189,3
10	1363	4,5	20,25	351,5	1581,75
General amount 55	10114,9		82,5		6029,55
Average 5,5	1011,49				

Table 5. Trends in the vegetable growing industry development in the Astrakhan region(traditional technology, varieties included in the State Register)

Extrapolated exponent	Trend equation
The Astrakhan regionarable and area, general value, th.h	Уt=73,83+0,78t
The area of arable land under vegetable crops in the region, thousand hectares	Уt=21,14+0,43t
Yield of vegetable crops in the Astrakhan region, t / ha	Уt=29,5+2,51t
Gross harvest of vegetables in the region, thousand tons	Уt=609,55+73,08t

Table 6. Robotics using predicted efficiency in tomato planting

Indicators	Robotractor	Autonomous robot
Serviced area, h	50	50
Digital technology cost, rubles	8172 000	9 080 000
Working capital (digital technology cost + working capital) per 50 hectares, rub	12 500 000	12 500 000
Total costs for 50 h, rub	20 672 000	21 580 000
Revenue for 50 h	42 000 000	42 000 000
Profit	21 328 000	20 420 000
Economic efficiency, rubles of	1,03	0,95

profit for 1 ruble of costs		
Production profitability, %	103	95
Tomato sales profitability, %	51	49

AUTHORS’ CONTRIBUTION

Aitpaeva Aigul’ Aldungarovna - the paper text preparation, research results description, economic indicators calculation, economic and mathematical models development.

Arslanova Rumiya Ahtyamovna - literature data review on vegetable cropsharvest programming.

Babakova Anna Sergeevna - the vegetable cultivation state analysis in the region, final editing and text formatting.

Dubin Rinat Ismailovich - data collection and analysis on arable land and vegetables gross yield in the region.

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